

**AuRE '06 (Int'l Workshop on
Automotive Requirements Engineering)**



AoREAS: Aspect-Oriented Requirements Engineering for Automotive Software Systems

Mikio Aoyama and Atsuko Yoshino (Higashi)

Nanzan University

mikio.aoyama@nifty.com

<http://www.nise.org/>

We are *NISE*: Network Information and Software Engineering

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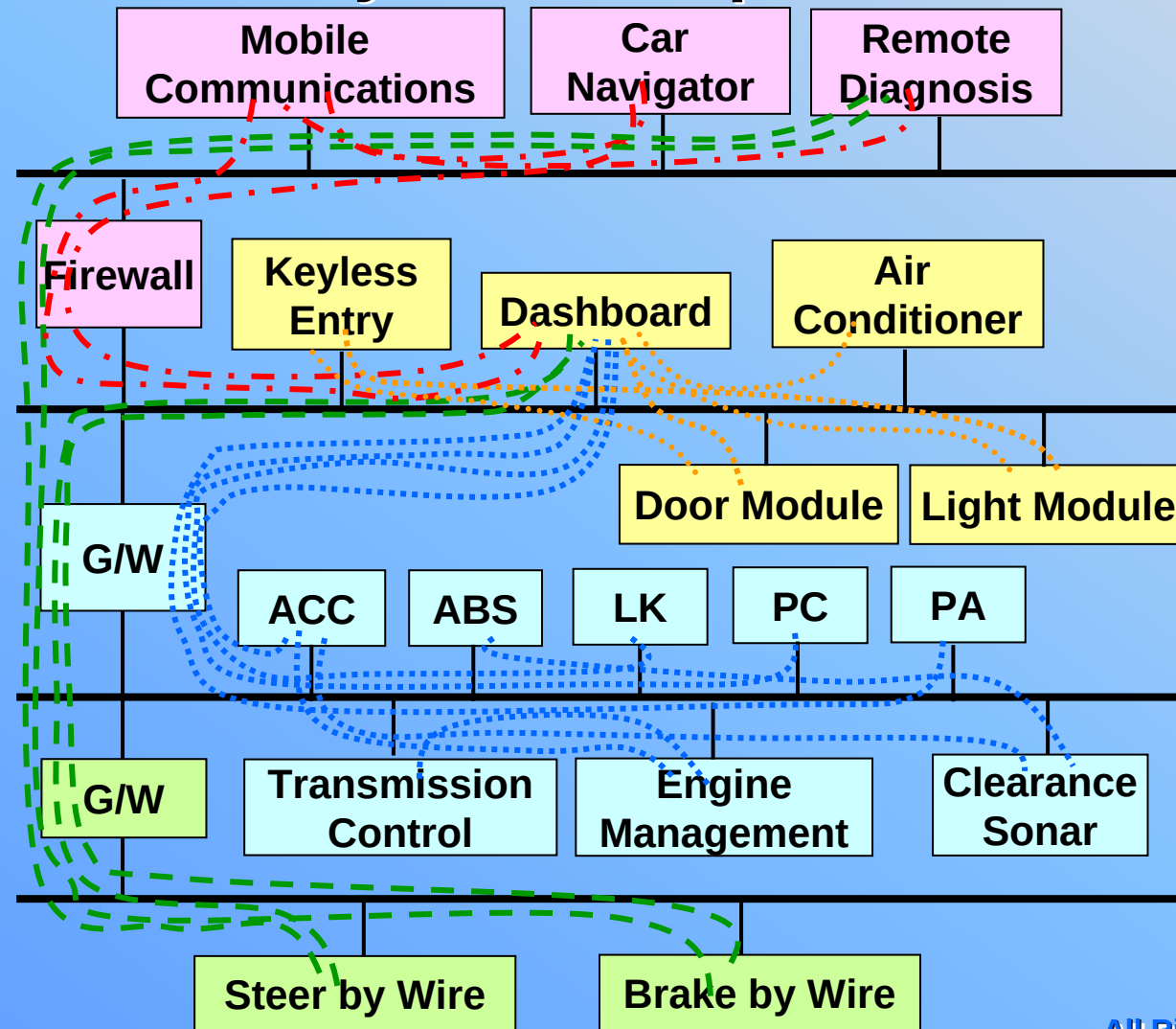
Scenario

- ➡ **Motivating Example**
- ➡ **Conventional Approaches and their Issues**
- ➡ **Our Approach**
- ➡ **AuREAS: Aspect-oriented Requirements Engineering for Automotive Software**
- ➡ **Application to An Example Automotive System**
- ➡ **Evaluation and Future Work**
- ➡ **Conclusion**

1. Motivating Example: Integrated Automotive Software System

➡ Integration of Multiple Heterogeneous ECUs & Networks

➡ Functionality and Multiple Inter-related Aspects



G/W: Gateway
LK: Lane-Keeping
ACC: Adaptive
Cruise
Control
PC: Pre-clash
Control
PA: Parking
Assistance

2. Conventional Approaches and their Issues

☞ Requirements Engineering

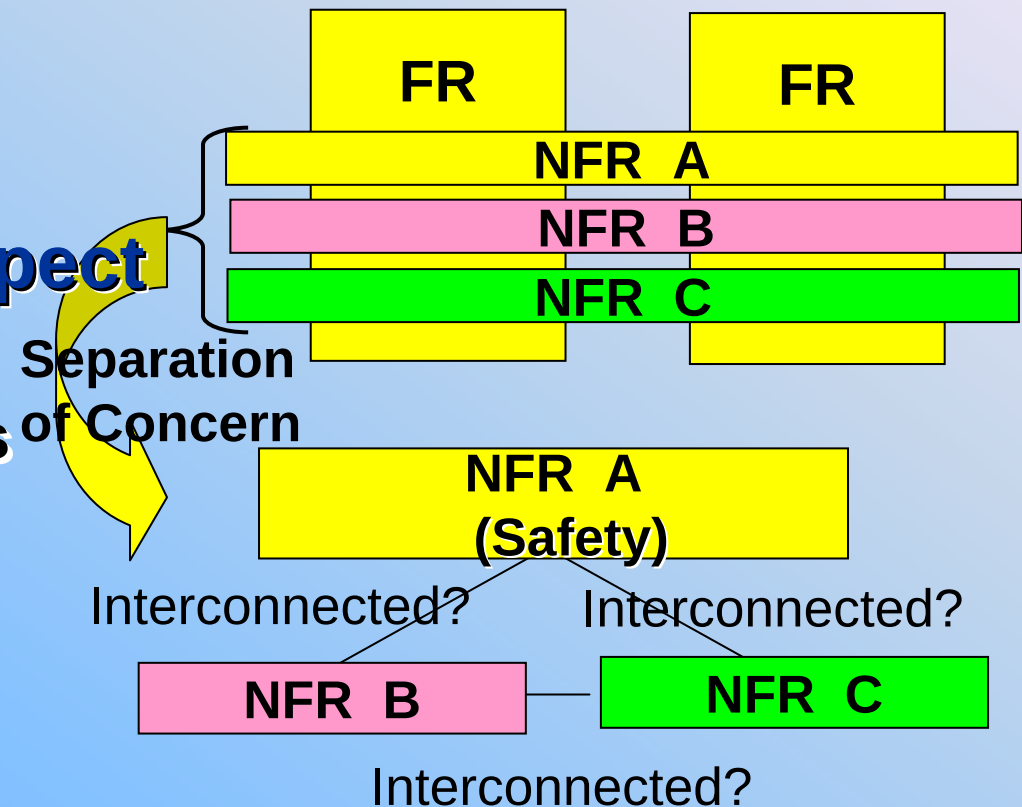
- ☞ Limitation in modeling relationships between NFRs

☞ Aspect-Orientation/Early Aspect

- ☞ Limitation in modeling relationships between aspects

☞ Dependability and Fault-Tolerance

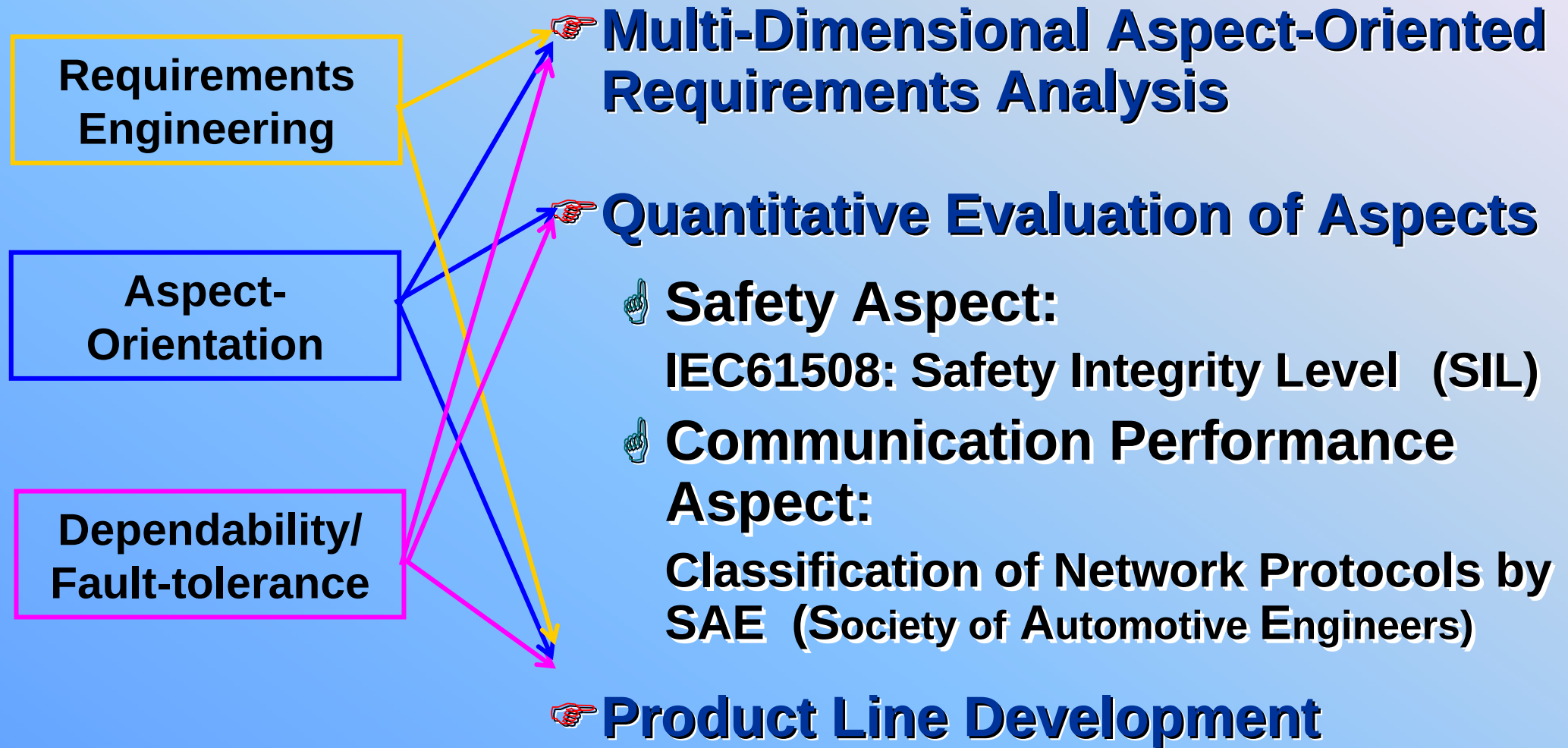
- ☞ Limitation in considering the relationship of dependability with other aspects



FR: Functional Requirements
NFR: Non-Functional Requirements

Difficulty of Modeling and Quantitative Evaluation of Multiple Non-Functional Requirements

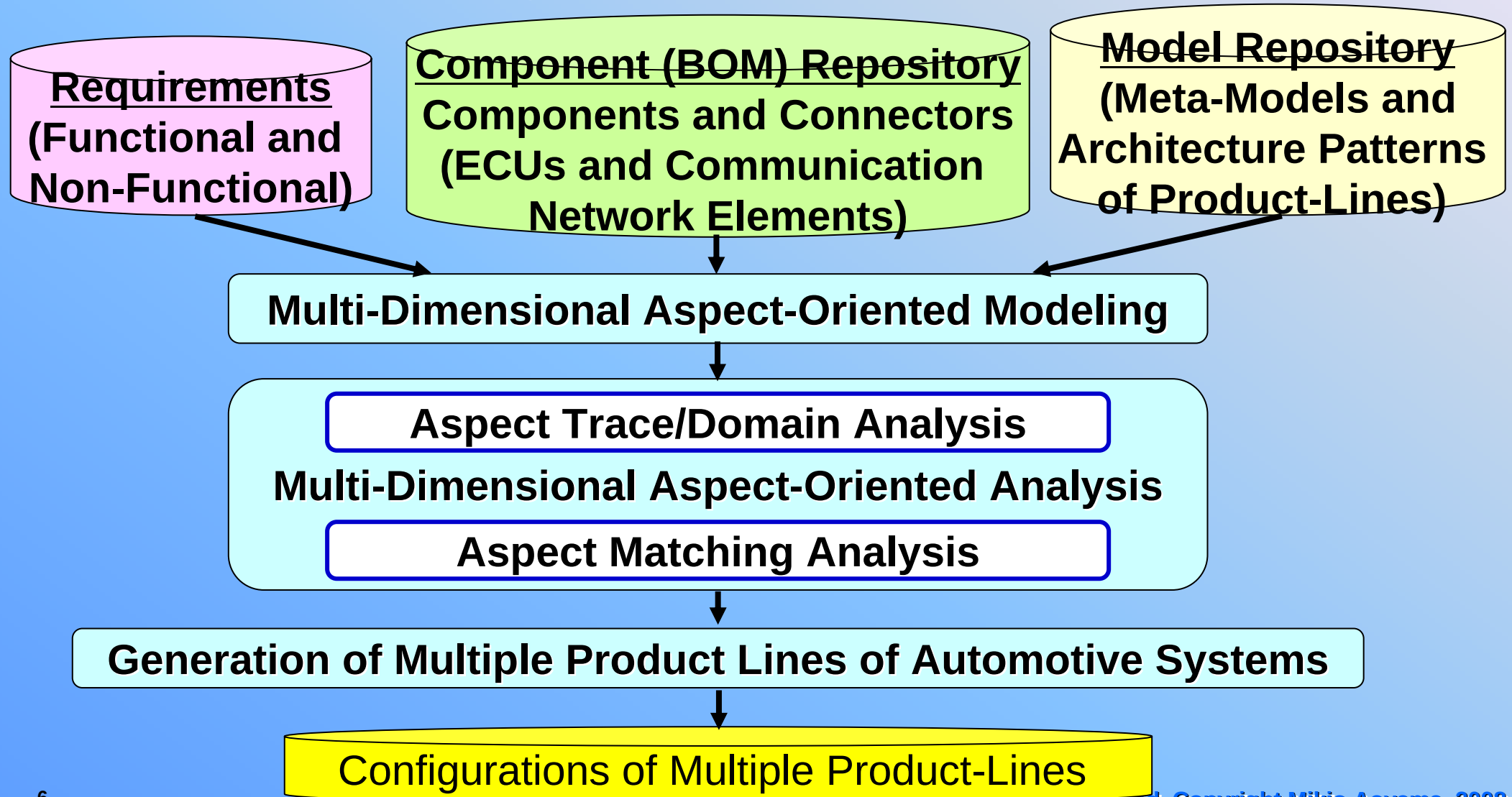
3. Our Approach



Propose a Design Methodology to Satisfy Multiple NFRs

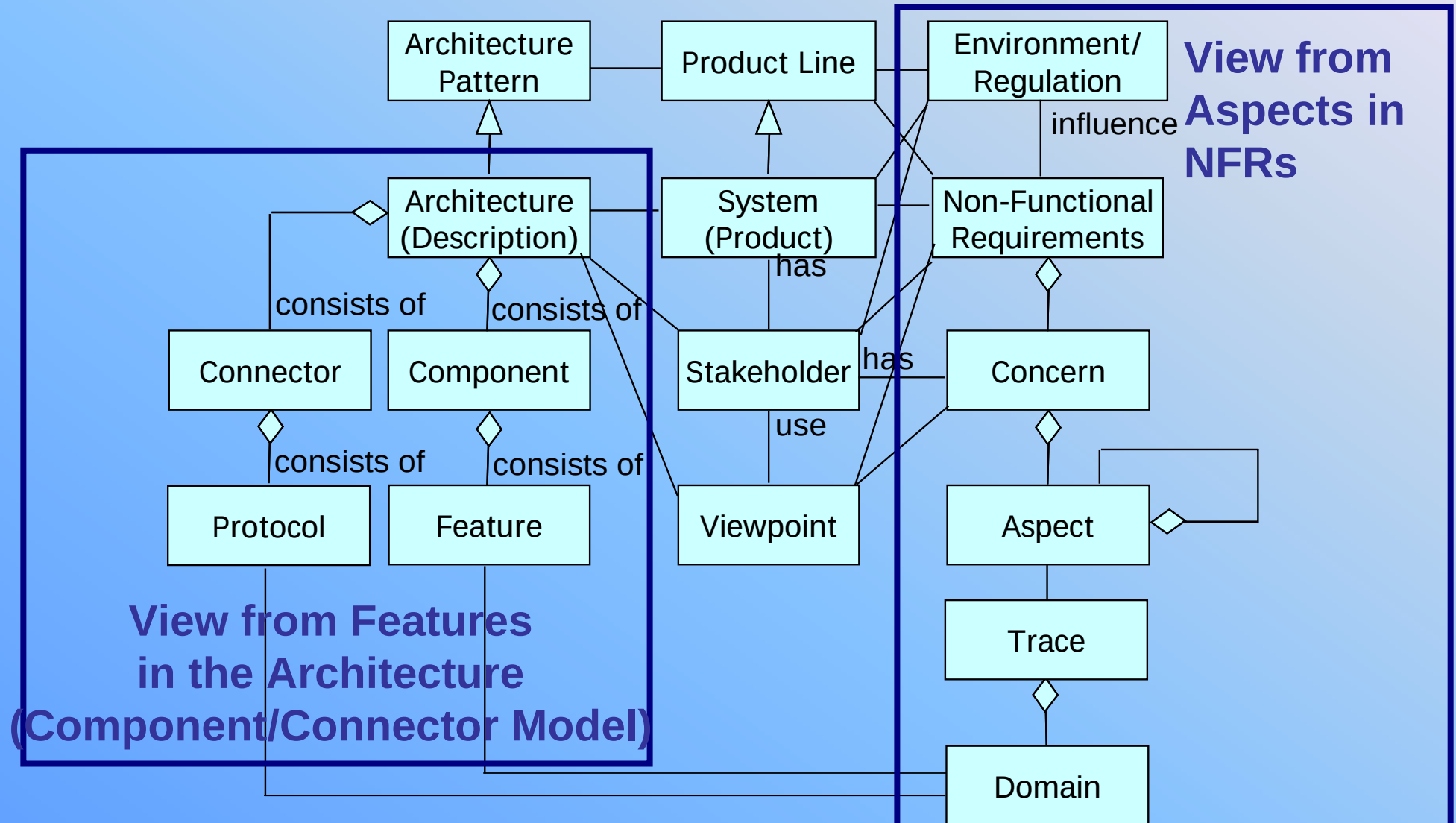
4. AoREAS: Aspect-oriented Requirements Engineering for Automotive Software System

👉 Modeling and Analysis of Multiple-Interrelated Non-Functional Requirements through Aspect-Orientation



4.1 Aspect-Oriented Product Line Architecture Meta Model

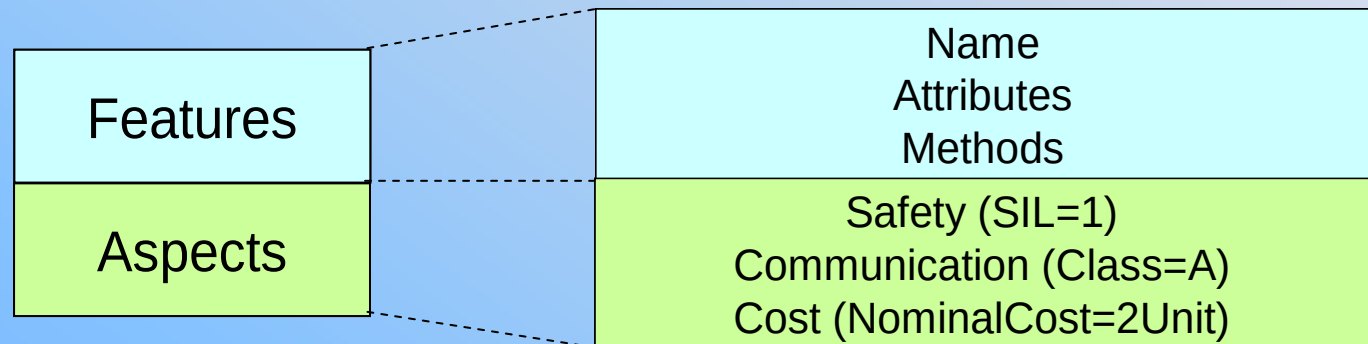
👉 Meta Model with Two Views



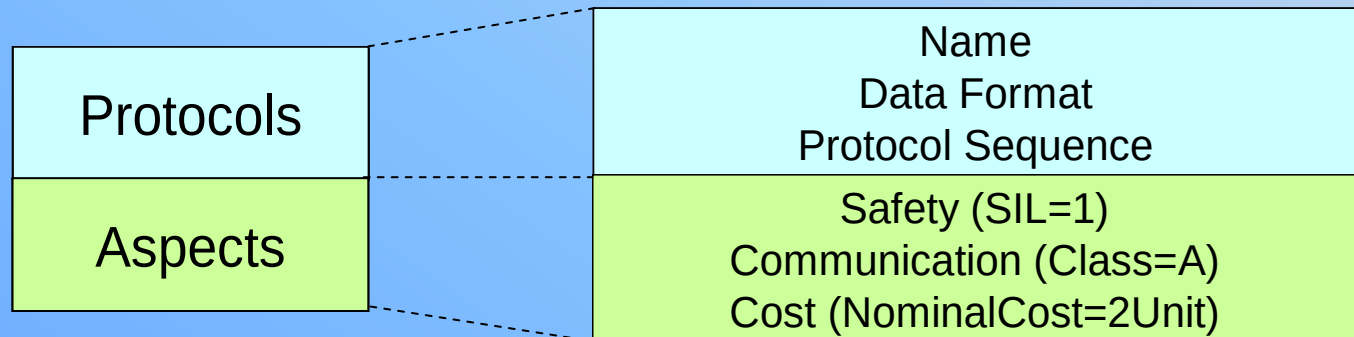
4.2 Notation of Aspects

☞ Formal Representation by Extending Class Notation in UML

Component = F (Features, Aspects)



Connector = P (Protocols, Aspects)



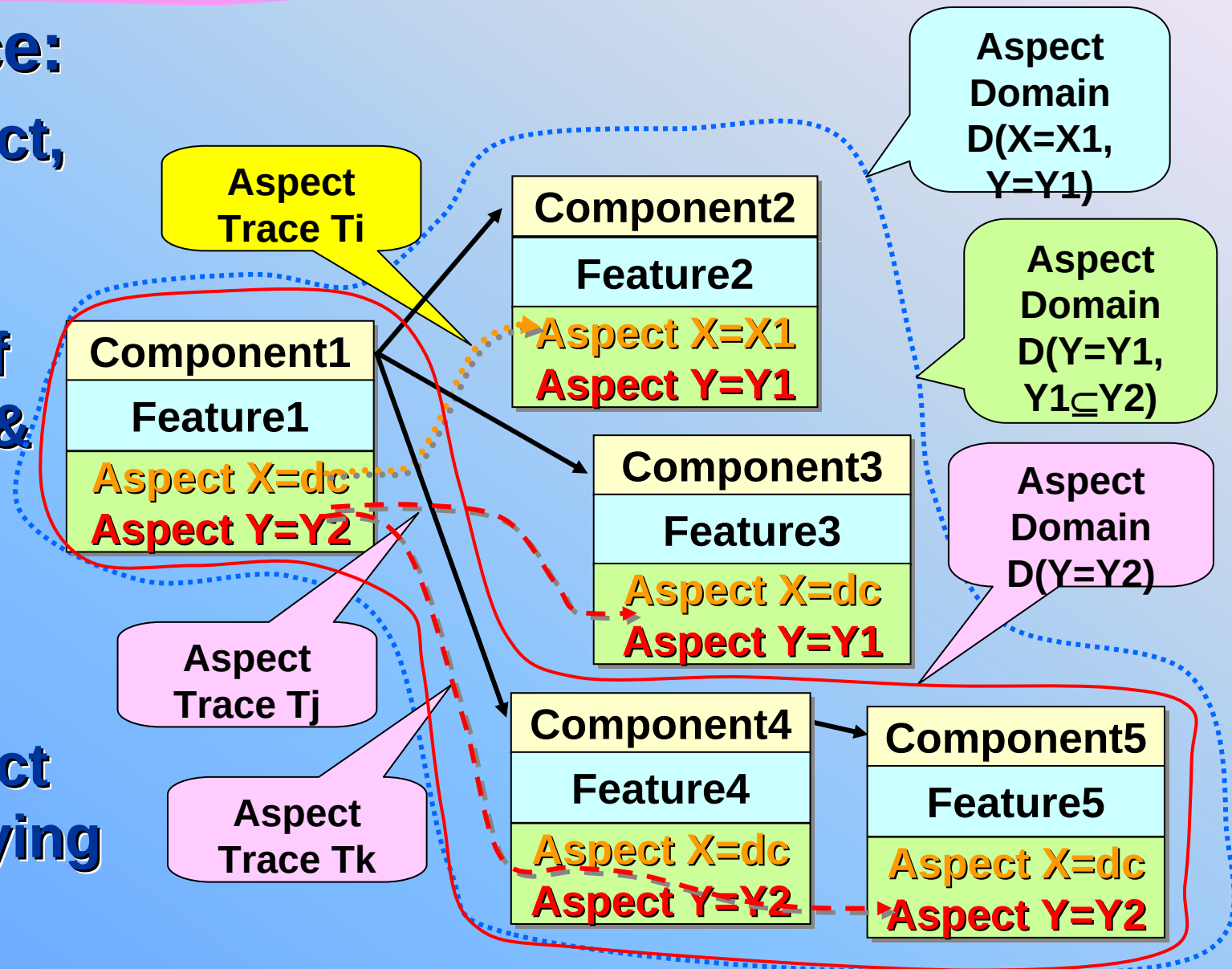
4.3 Multi-Dimensional Aspect Analysis (1/2)

Aspect Trace:

A Set of Aspect, along with an Ordered Connection of Components & Connectors

Aspect Domain:

A Set of Aspect Traces Satisfying Aspect Requirements

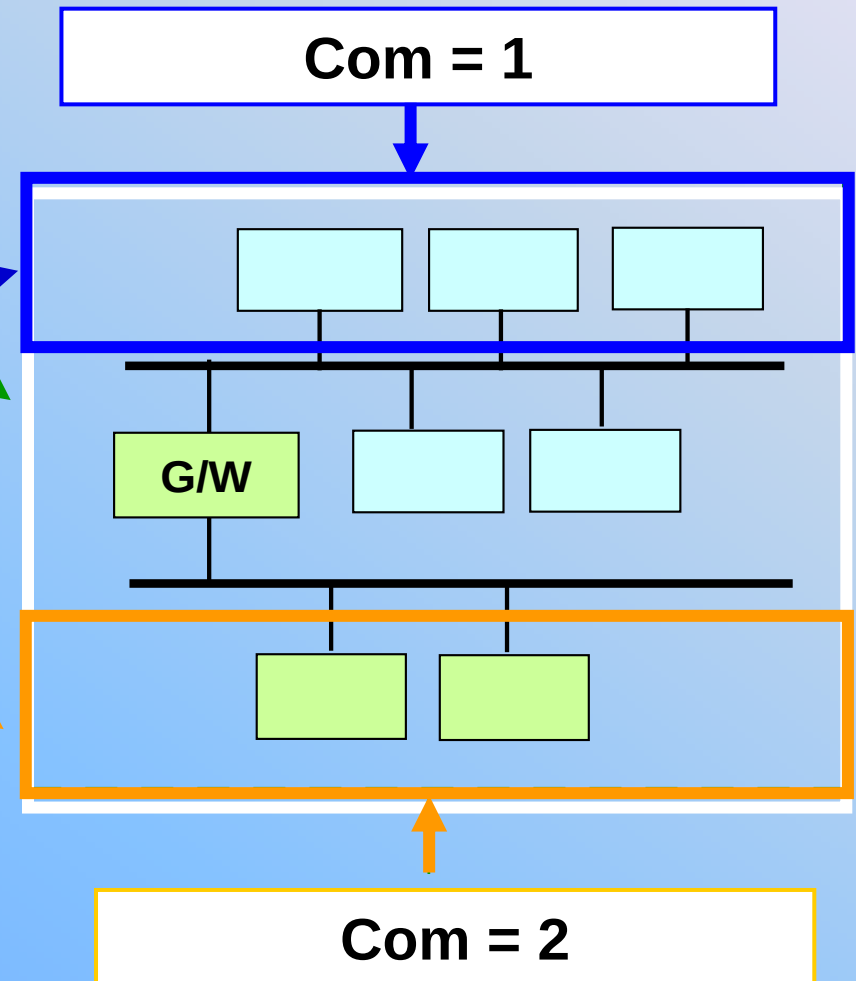


4.3 Multi-Dimensional Aspect Analysis (2/2)

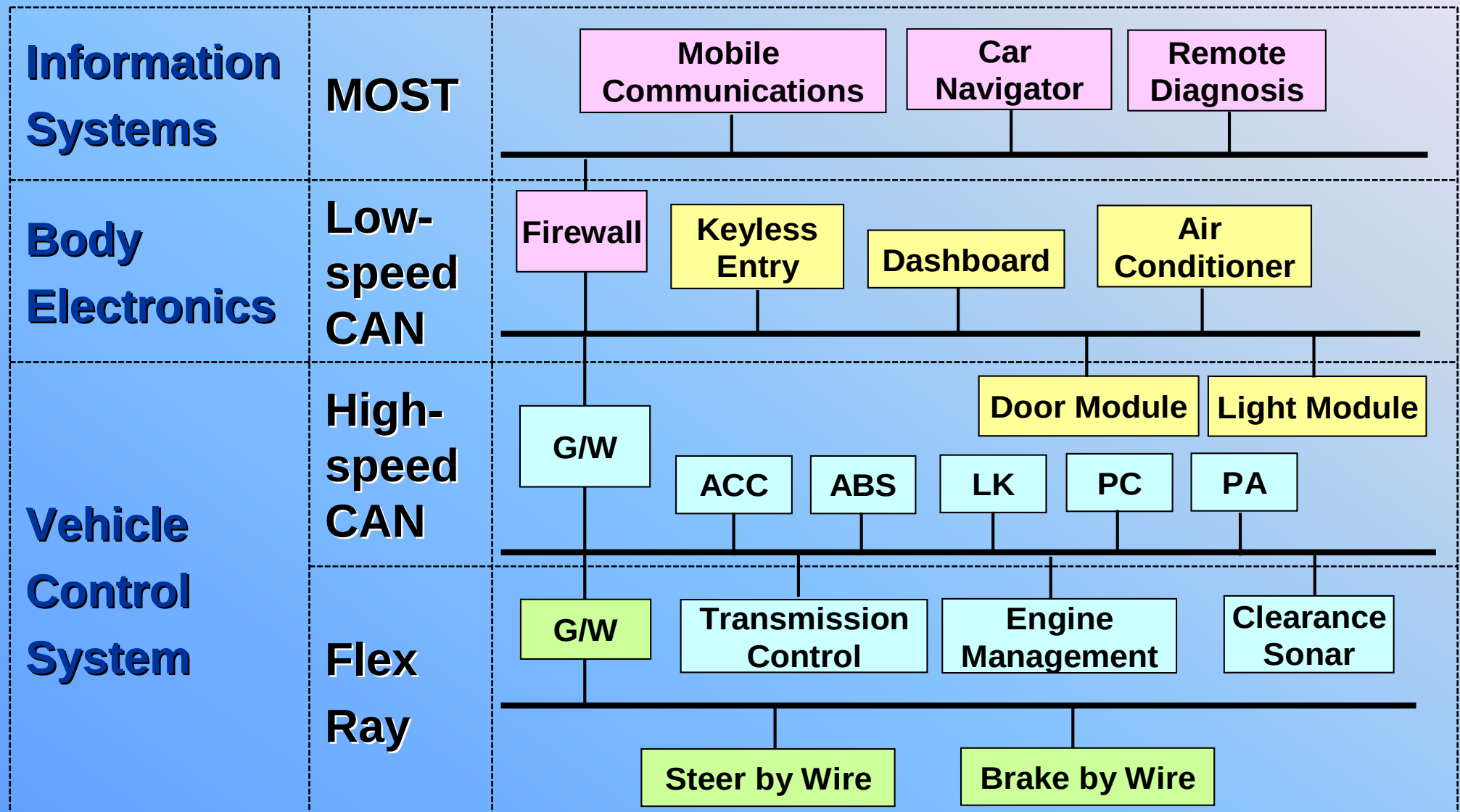
☞ **Aspect Matching: Grantee the Consistency of Aspects on a System**

☞ **Strong Matching:**
All aspects meet given conditions **across the system**

☞ **Weak Matching:**
A part of aspects meet given conditions **in a certain part of the system**

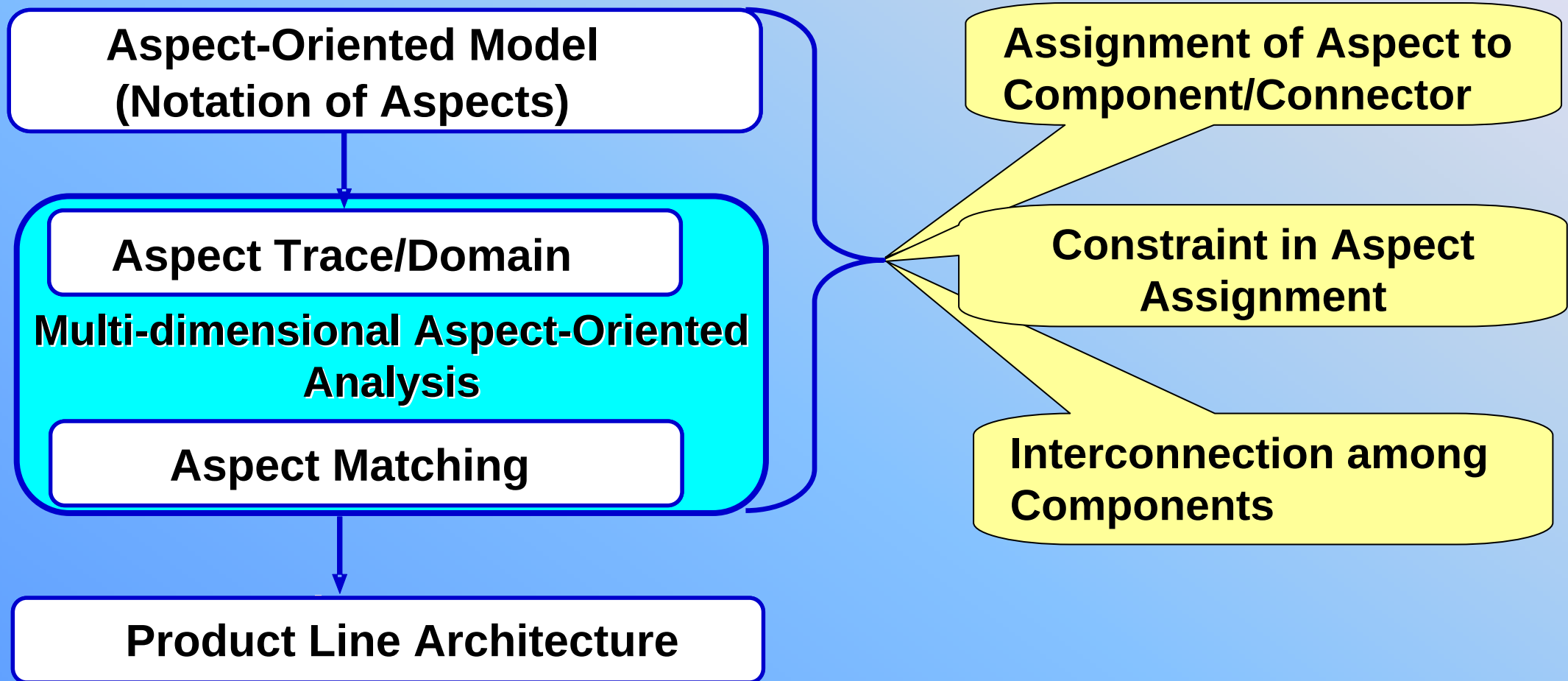


5. Application to Example of Automotive Embedded System



5.0 Product Line Architecture based on Aspect-Oriented Analysis

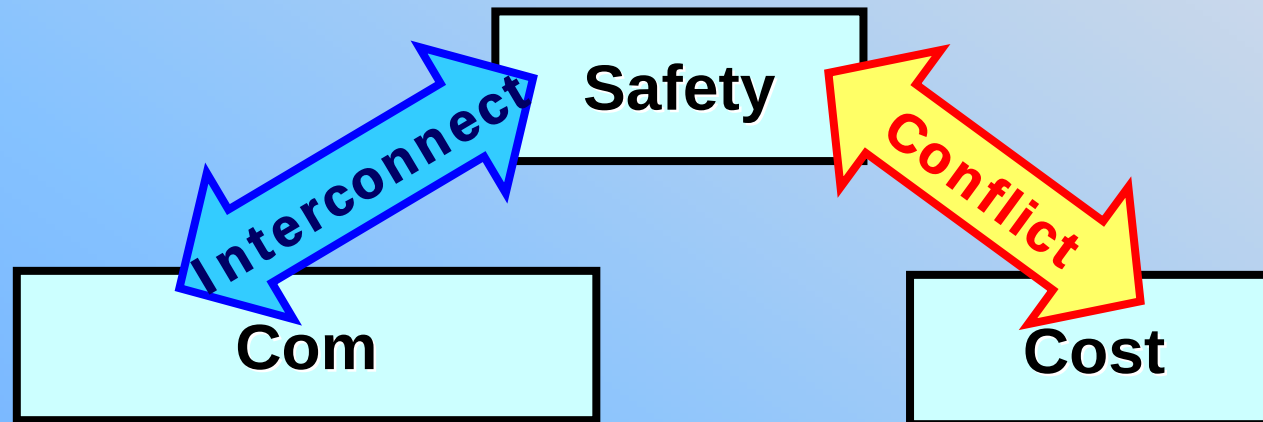
☞ Multi-Dimensional Aspect-Oriented Modeling and Analysis to Product Line Architecture



5.1 Aspects Across the System

☞ Select Aspects and Define their Relationships

☞ Safety, Communication Performance (Com), Cost

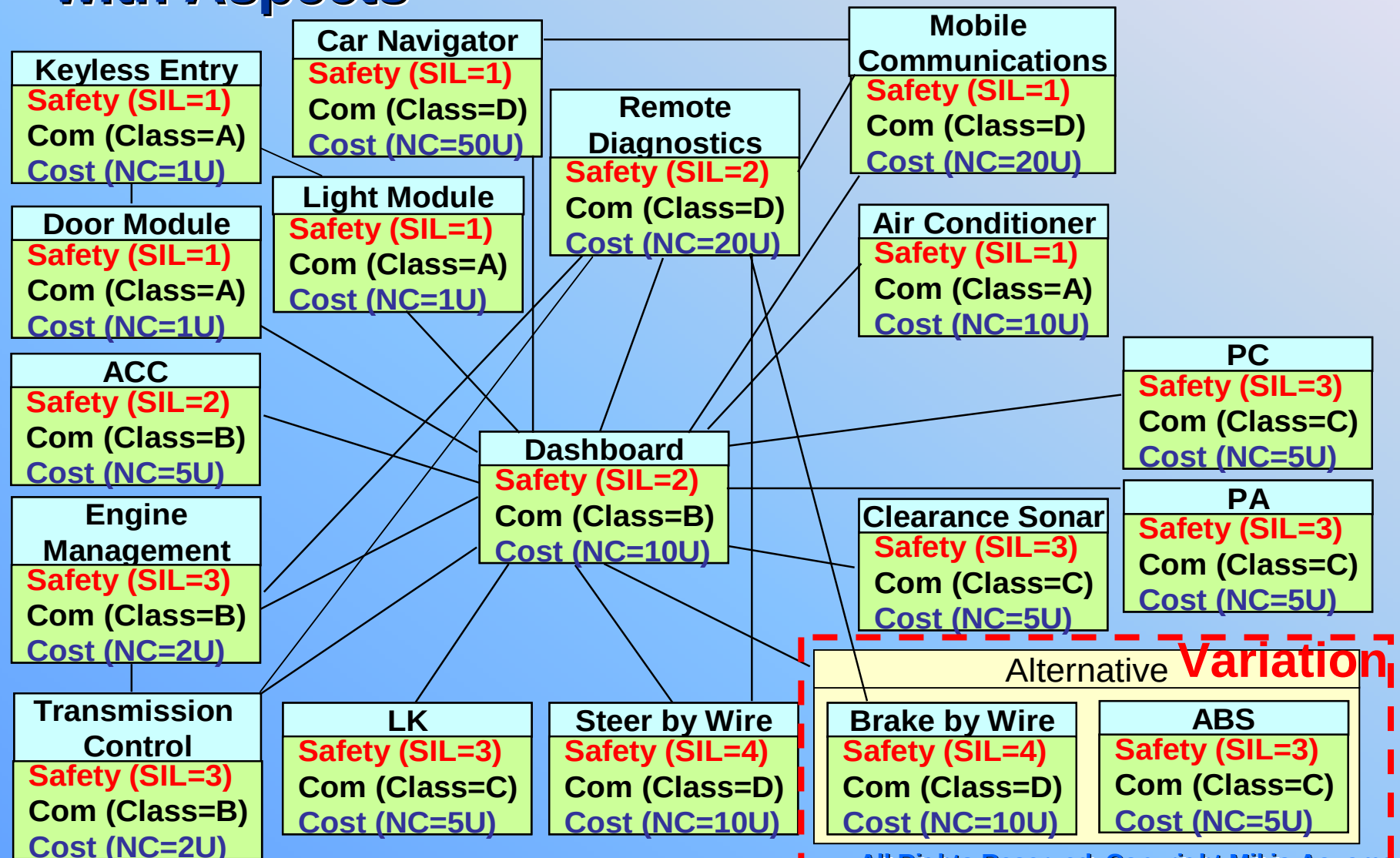


☞ Measure and Criteria to Evaluate Aspects

Aspect	Measure	Criteria
Safety	IEC 61508 SIL	1(Low) - 4(High)
Com	SAE Class	A(Low) - D (High)
Cost	Unit Cost	1, 5, 10, > 50

5.2 Aspect-Oriented Component Model

👉 Interconnection among Components assigned with Aspects



5.3 Aspect Trace and Aspect Domain

☞ Analysis: Verification of Aspect Trace and Aspect Domain (Brake-by-Wire and ABS)

☞ Dashboard → Brake-by-Wire

☞ $T_{\text{Dashboard, BrakeByWire}}$

☞ **Safety** → $SIL2 \subseteq SIL4$

☞ **Com** → $\text{Class B} \subseteq \text{Class D}$

☞ $D_{\text{Dashboard, BrakeByWire}}$

☞ **Safety = SIL4, Com = Class D, Cost = 10U**

Dashboard
Safety (SIL=2)
Com (Class=B)
Cost (NC=10U)

☞ Dashboard → ABS

☞ $T_{\text{Dashboard, ABS}}$

☞ **Safety** → $SIL2 \subseteq SIL3$

☞ **Com** → $\text{Class B} \subseteq \text{Class C}$

☞ $D_{\text{Dashboard, ABS}}$

☞ **Safety = SIL3, Com = Class C, Cost = 10U**

Alternative	
Brake by Wire	ABS
Safety (SIL=4)	Safety (SIL=3)
Com (Class=D)	Com (Class=C)
Cost (NC=10U)	Cost (NC=5U)

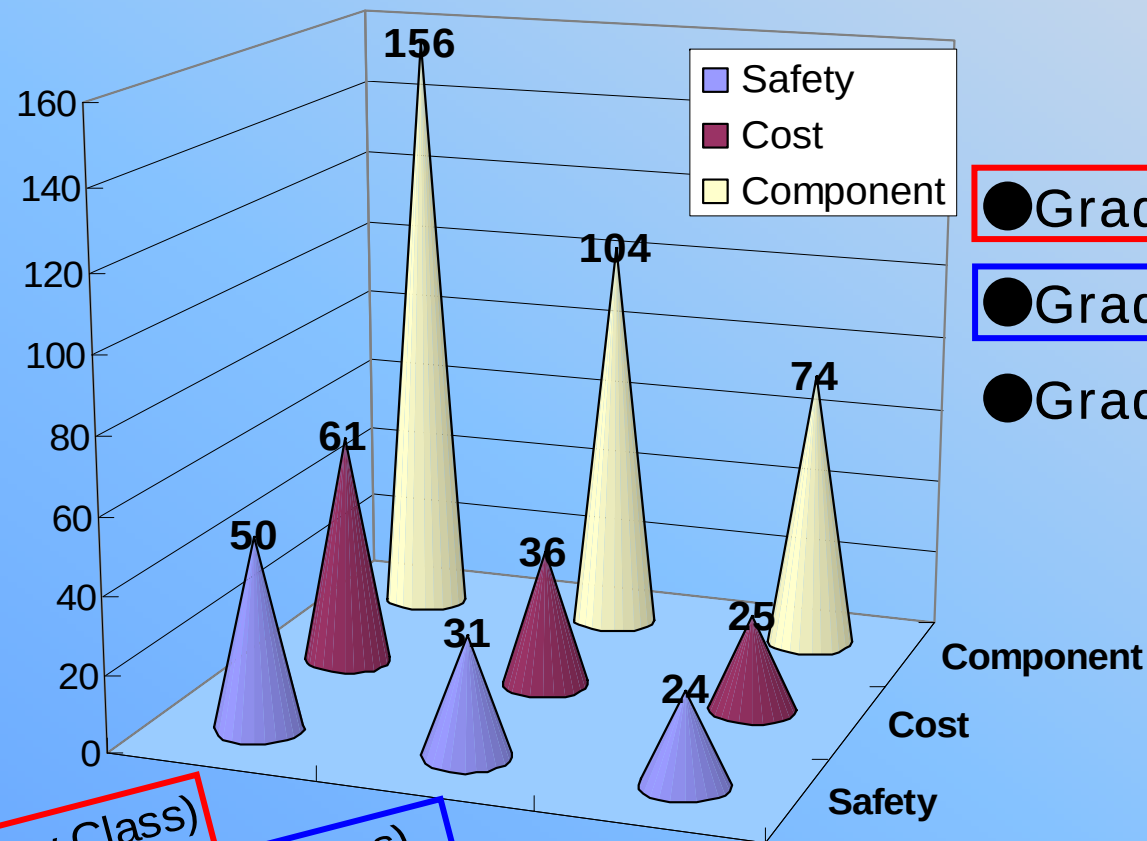
5.4 Relationship between Components/Connectors and Aspects

☞ Relationship between All Components/Connectors and Aspects on System

Safety-Criticality: High ● 4 3 2 Low ● 1 Throughput: High ● 4 3 2 Low ● 1 NFR			Component																					
			Information Systems				Body Electronics							Vehicle Control Systems										
														A									B	
			Mobile Communications	Car Navigator	Remote Diagnosis	MOST	Air Conditioner	Keyless Entry	Dashboard	Door Module	Light Module	Low-Speed CAN	ACC (Adaptive Cruise Control)	ABS	LK (Lane Keep)	PC (Pre-crash)	PA (Parking Assist)	Transmission Control	Engine Management	Clearance Sonar	High-Speed CAN	Steer by Wire	Brake by Wire	FlexRay
Safety-criticality		Time-Driven	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	4	4	4
		Event-Driven	2	2	3	2	1	1	2	1	1	1	3	3	3	4	1	-	-	2	3	-	-	-
Perform- ance	Time Behavior	Response Time (ms)	D C	D C	D C	D C	D C	D C	D C	D C	D C	D C	D C	D C	D C	D C	DC	D C	D C	D C	D C	40 ms	20 ms	5 ms
		Throughput	4	4	3	4	1	1	1	1	1	1	2	2	3	4	3	2	2	2	2	3	3	3
Trigger Condition	Time-Driven		X	X	X	X	X	X	X	X	X	X	X	○	X	X	X	○	○	X	○	○	○	○
	Event-Driven		○	○	○	○	○	○	○	○	○	○	○	X	○	○	○	X	X	○	X	X	X	X
Cost			4	4	4	4	1	1	2	1	1	1	2	2	3	3	3	3	3	2	2	4	4	4

5.5 Aspect Range

➡ Aspect Range: Constraints of Aspects to Construct Product Line Architectures



● Grade A (Luxury class)

● Grade B (Mid class)

● Grade C (Compact class)

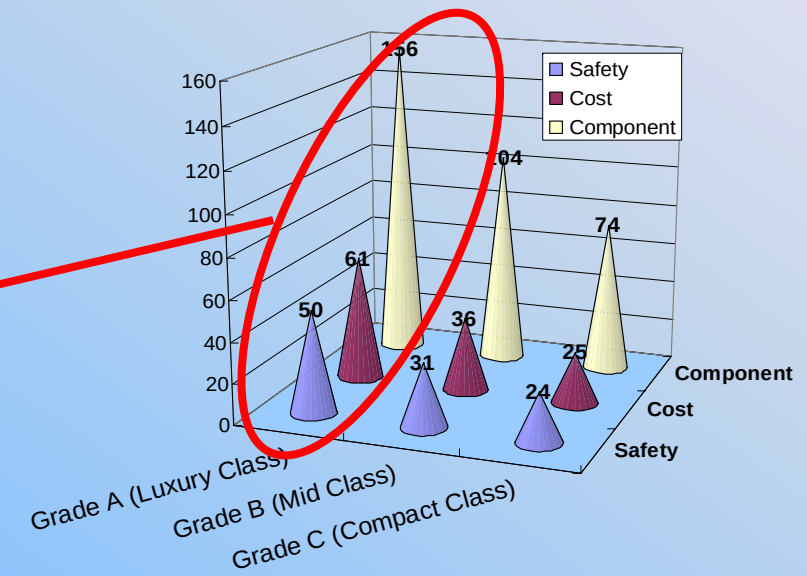
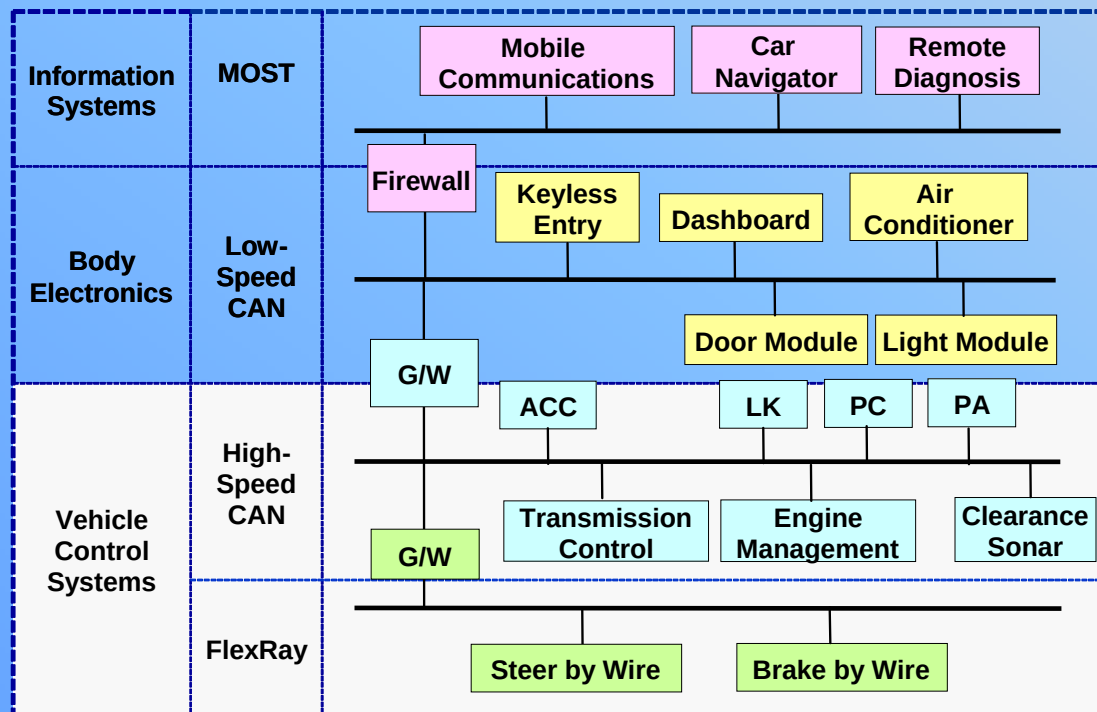
Grade A (Luxury Class)

Grade B (Mid Class)

Grade C (Compact Class)

5.6 Construction of Product Line Architectures (1/2)

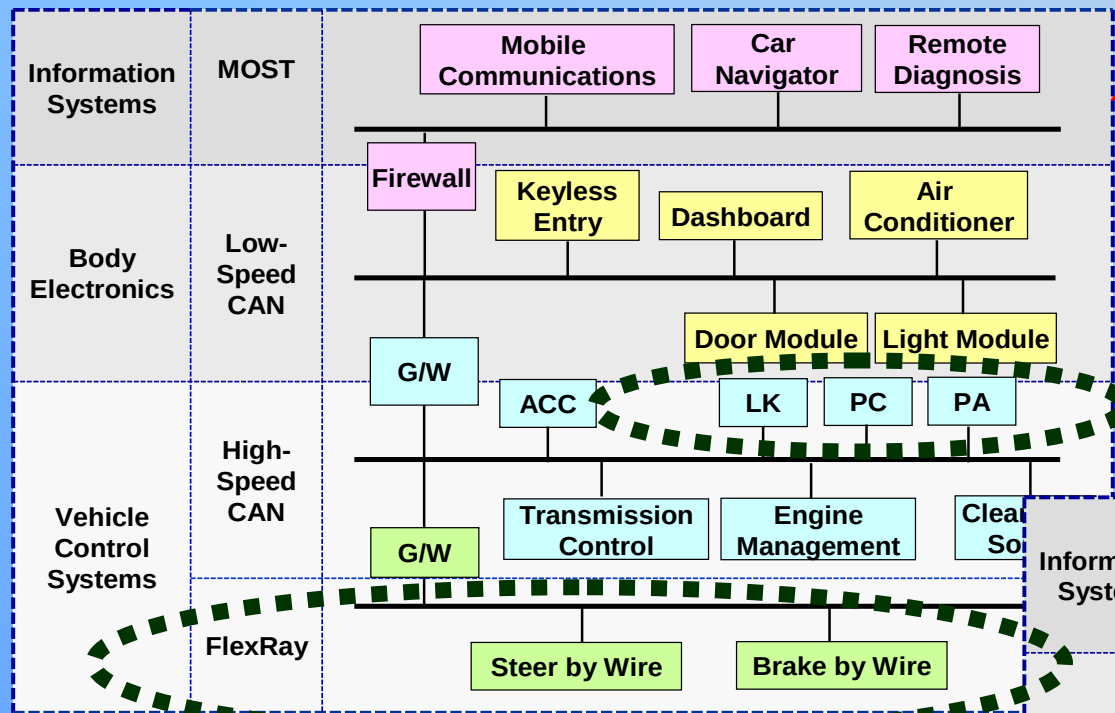
👉 Product Line Architectures Satisfying Both Functional Requirements and Aspect Range



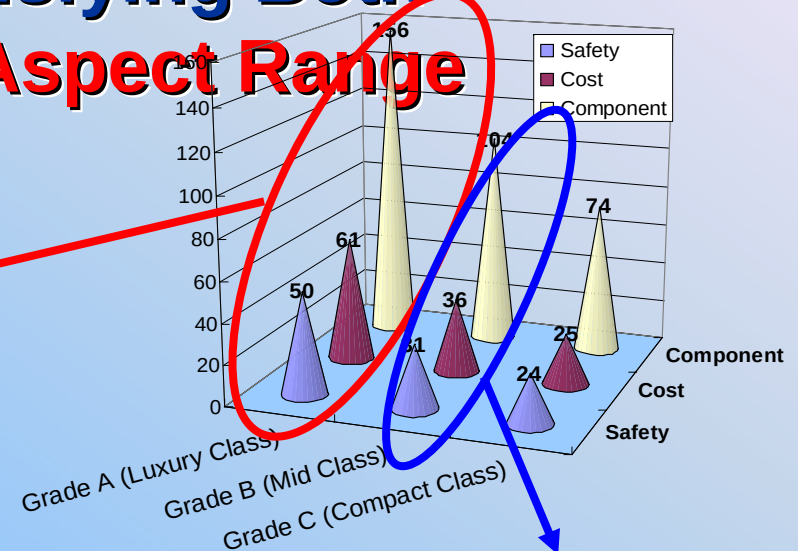
↑ Grade A (Luxury Class)

5.6 Construction of Product Line Architectures (2/2)

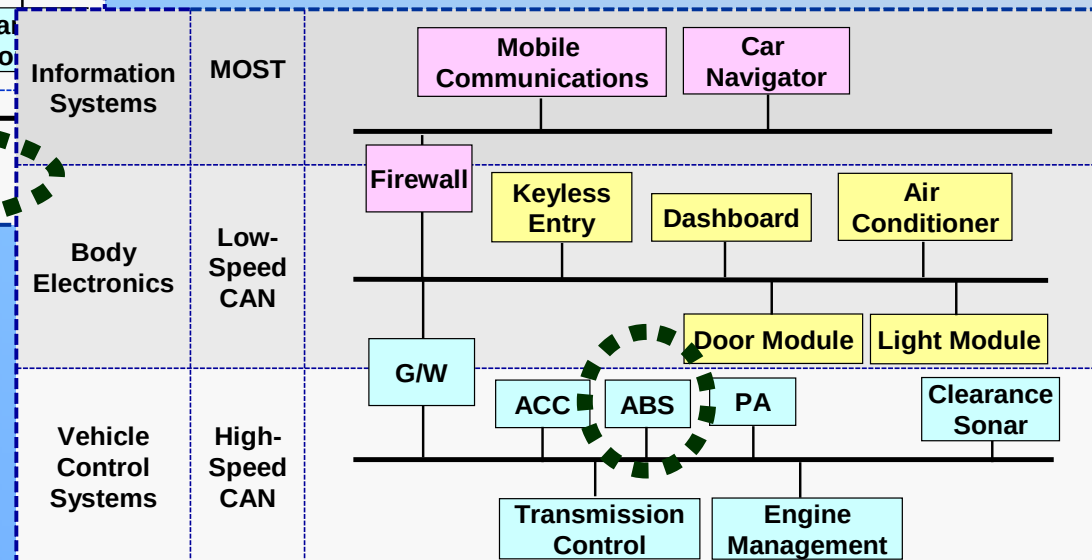
Product Line Architectures Satisfying Both Functional Requirements and Aspect Range



↑ Grade A (Luxury Class)



↓ Grade B (Mid Class)



6. Evaluation and Future Work

Evaluation:

-  Derived **Multiple Product Line Architectures of Automotive Embedded System** by Applying Proposed Aspect-Oriented Modeling Methodology

Future Work:

-  Increasing Number of Combination of Aspects Caused by Connection of a Large Number of ECUs
-  Simulation Methods to Support Design Activity

7. Conclusion

- ❏ **Complexity in Design of Automotive Embedded Systems Caused by Tangling Functional Requirements and Non-Functional Requirements**
- ❏ **AoREAS: Analysis of Multi-Dimensional Aspects by Multi-Dimensional Aspect-Oriented Modeling and Analysis Methodology**
- ❏ **Derivation of Multiple Product Line Architectures by Definition of Aspect Range**