CISTER - Research Center in
Real-Time & Embedded Computing Systems

How Realistic is the Mixed-Criticality Real-Time System Model?

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INESCTEC

Introduction

Current status

MC model gradually gaining sophistication

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Issue

Safety-related standards not freely accessible
→many academic works are building on top of previous models and claims

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Contribution

Elaborate on misinterpretations and discuss motivating arguments for future work

System Design and Development Assurance Process

Safety-critical Systems

Aeronautics

Railway

Automotive

Space

Industry

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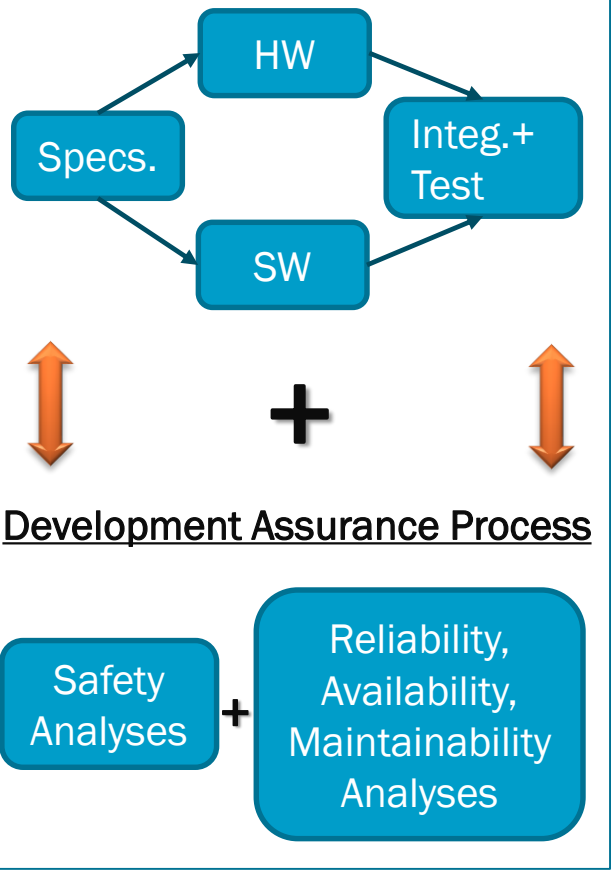
Safety-critical Systems Development Process



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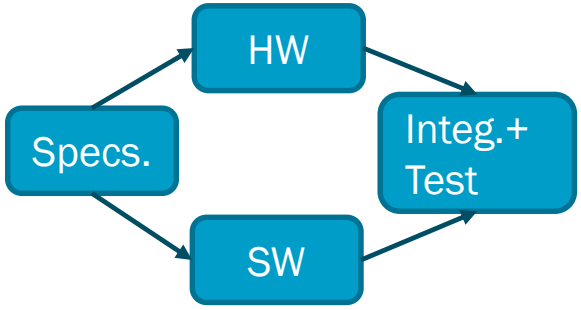
System Development Process



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Development Assurance Process

Safety Analyses + Reliability, Availability, Maintainability Analyses

System Operation

Certification Process

Certification Authority

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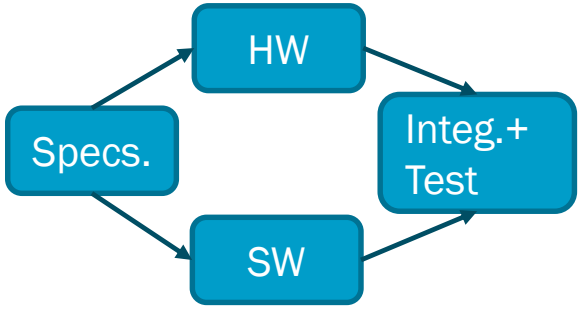

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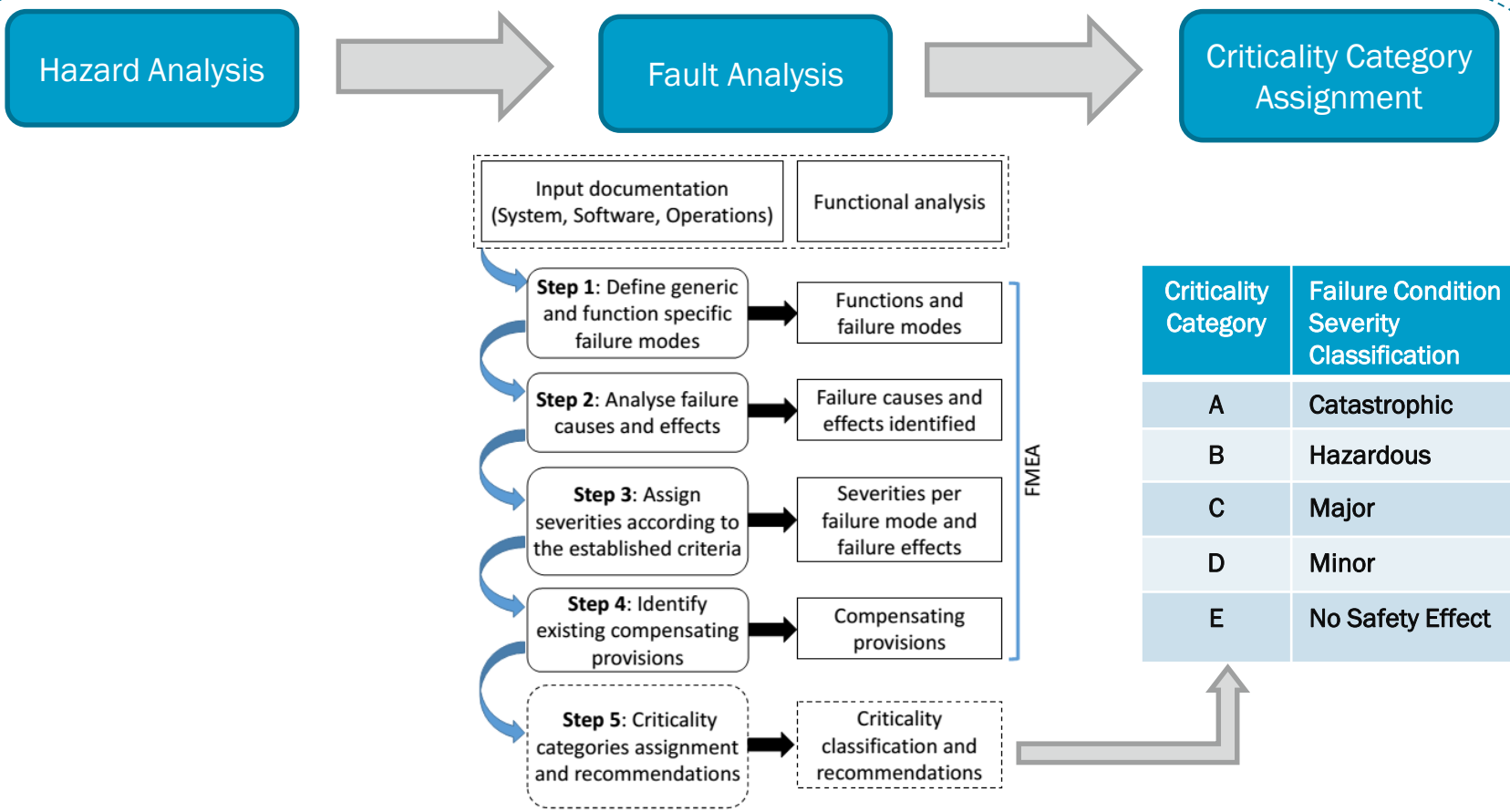
Redesign

The Notion of Mixed-Criticality Systems

System Safety Assessment Process



Criticality Category	Failure Condition Severity Classification
A	Catastrophic
B	Hazardous
C	Major
D	Minor
E	No Safety Effect

The Notion of Mixed-Criticality Systems

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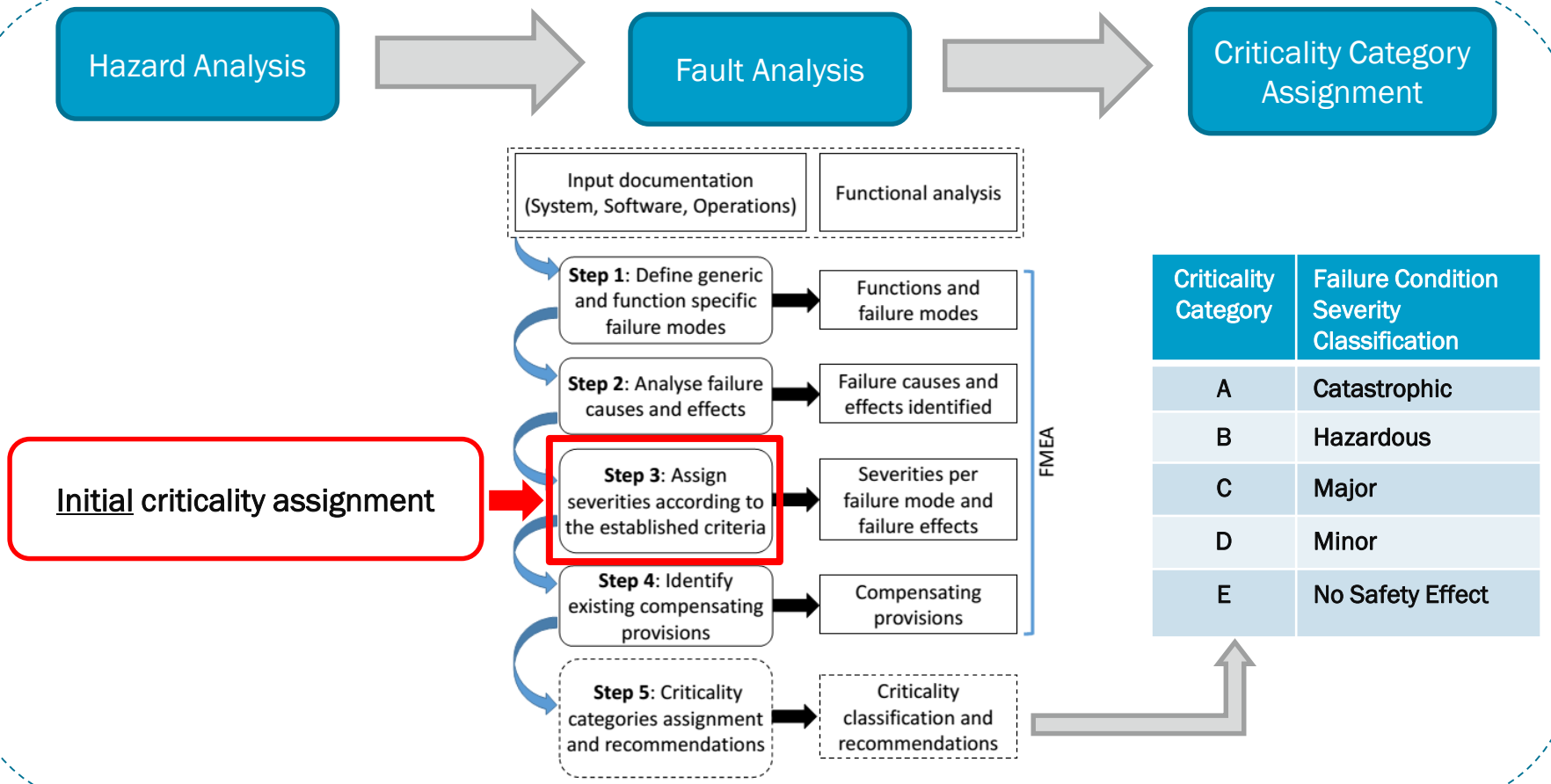

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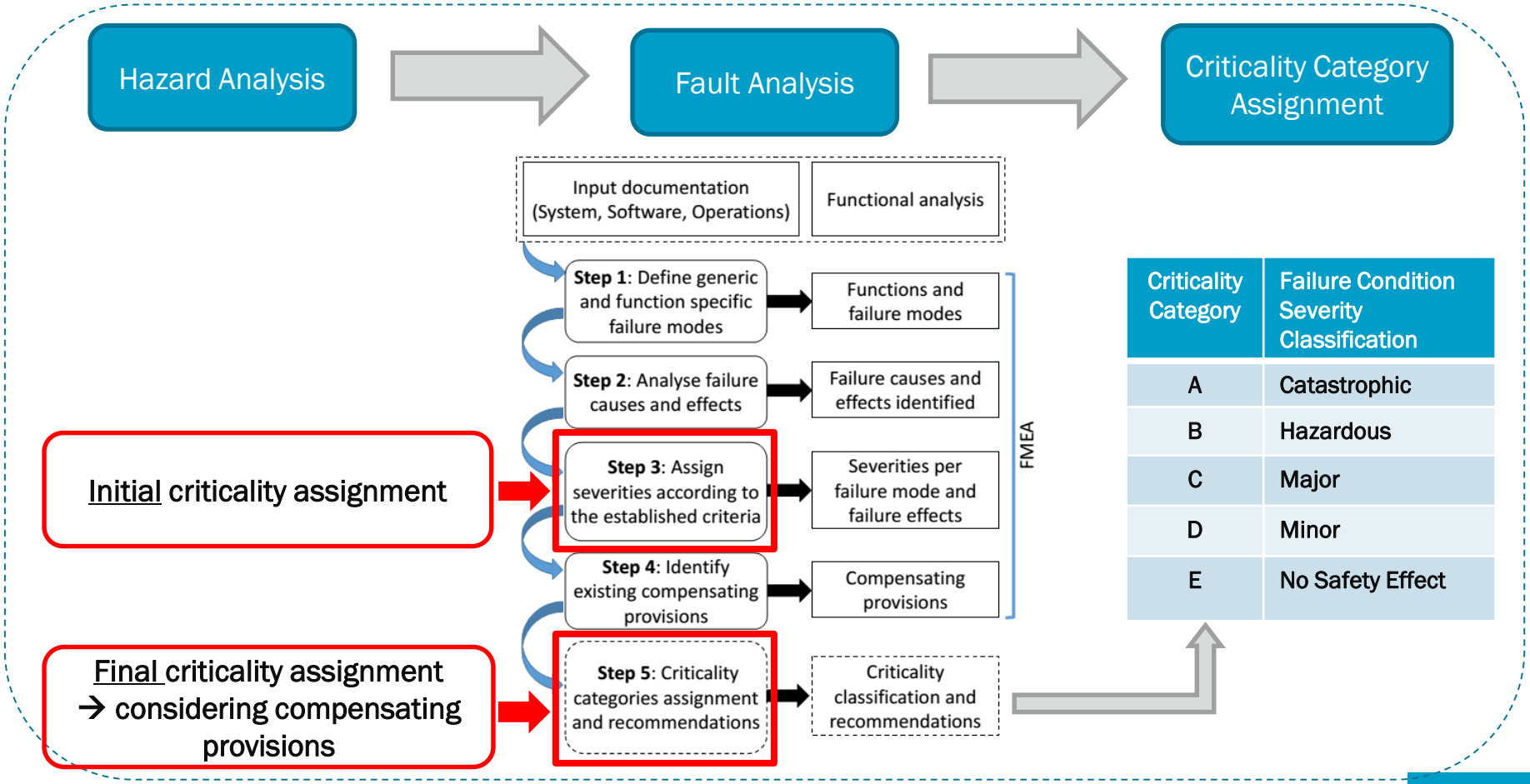

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Safety-related Industrial Standards

Industry

IEC 61508
Functional safety of E/E/PE safety-related systems

IEC 61511
Functional safety – Safety instrumented systems for the process industry sector

IEC 62061
Safety of machinery – Functional safety of electrical, electronic and programmable electronic control systems

Automotive

ISO 26262
Road vehicles – Functional safety

Aeronautics

ARP 4761
Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

DO-178B/C
Software Considerations in Airborne Systems and Equipment Certification

ARP 4754
Certification Considerations for Highly-Integrated or Complex Aircraft Systems

DO-254
Design Assurance Guidance for Airborne Electronic Hardware

Development Assurance – Safety Standards

Railway

EN 50126
Railway applications – Specification and demonstration of reliability, availability, maintainability and safety

EN 50128
Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems

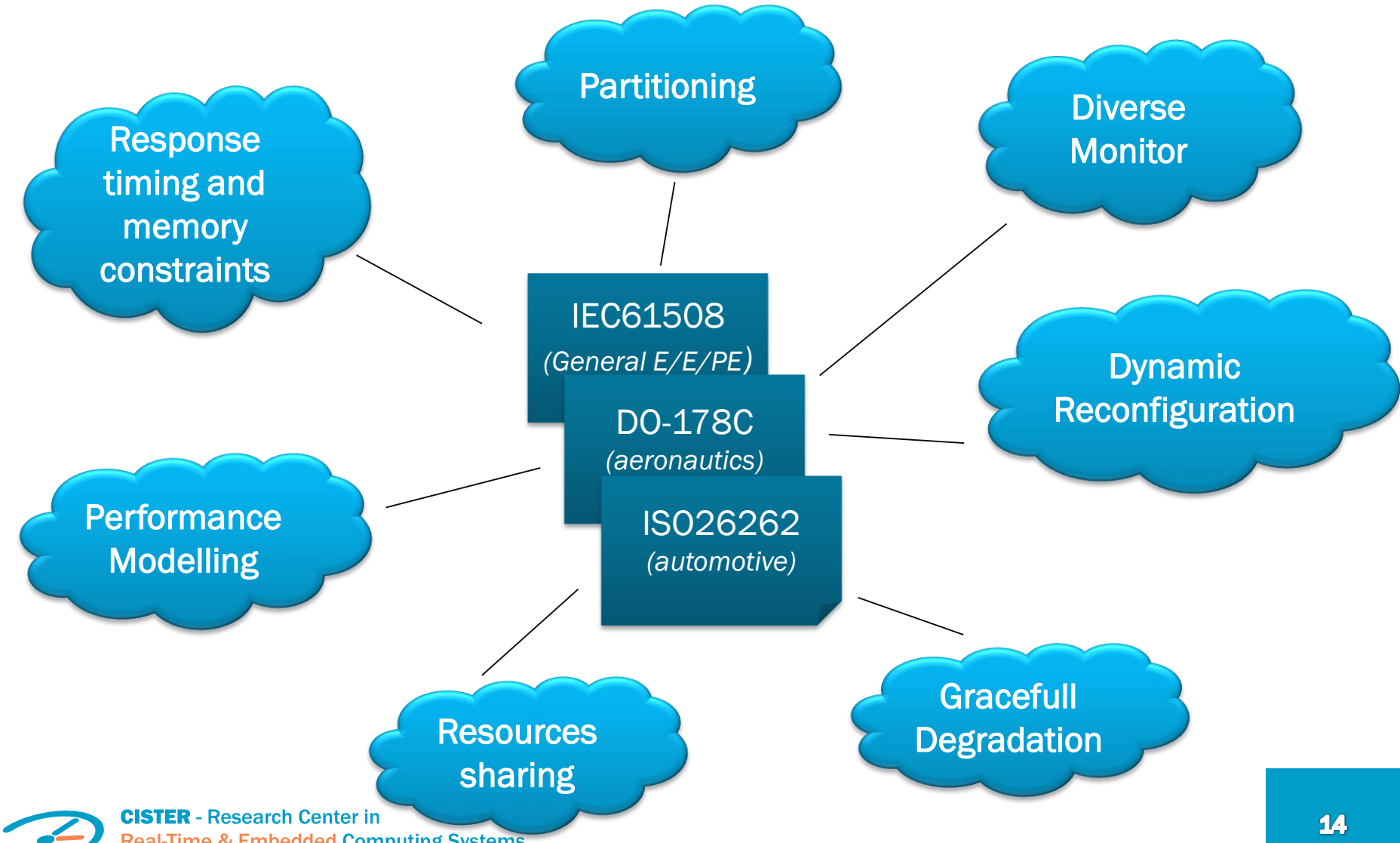
EN 50129
Railway applications – Communication, signalling and processing systems – Safety related electronic systems for signalling

Space

ECSS series
Processes for project management, engineering and product assurance in space projects and applications

NASA-STD-8719.13B
Software Safety Standard – NASA Technical Standard

Requirements of Safety-Related Industrial Standards



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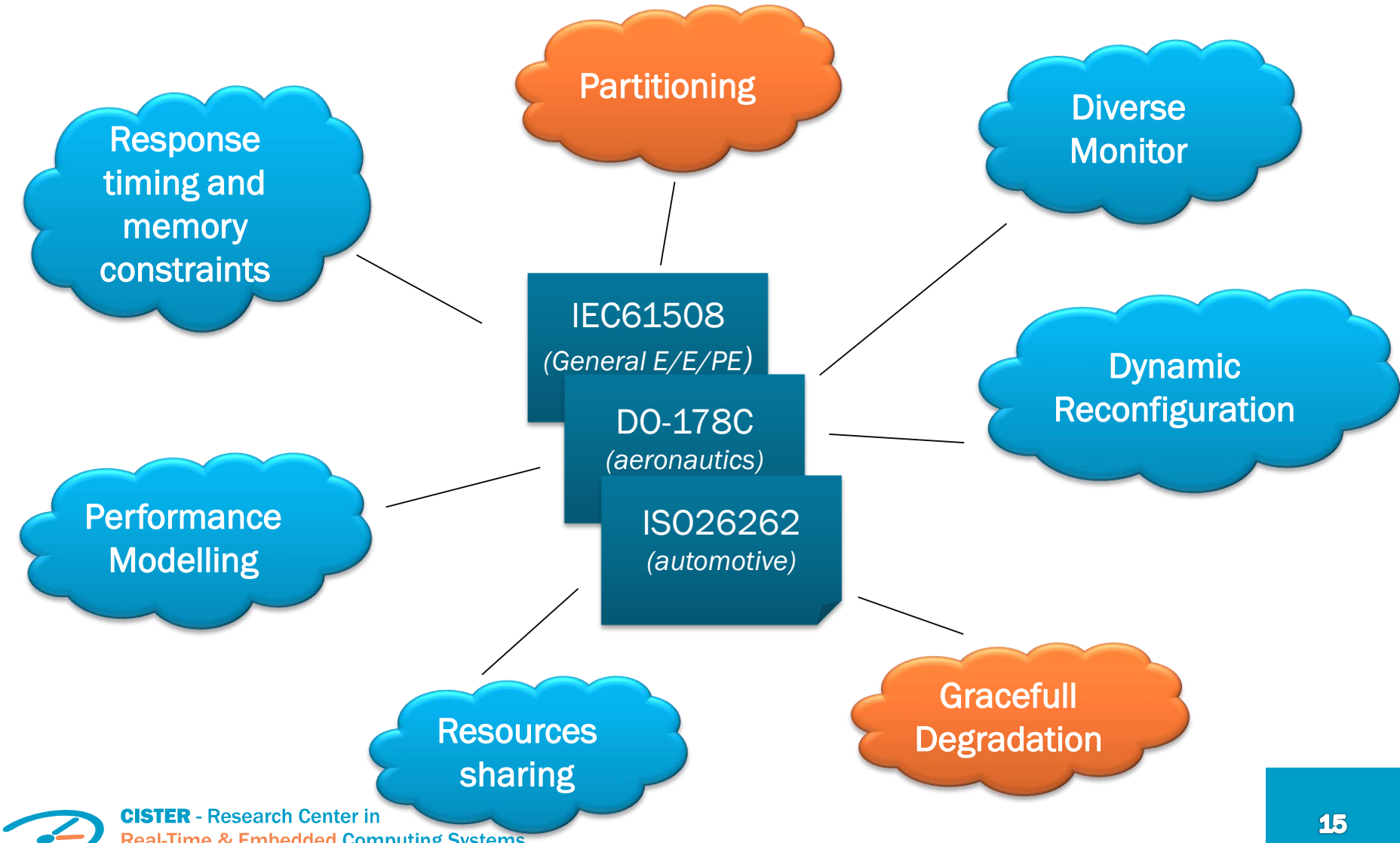
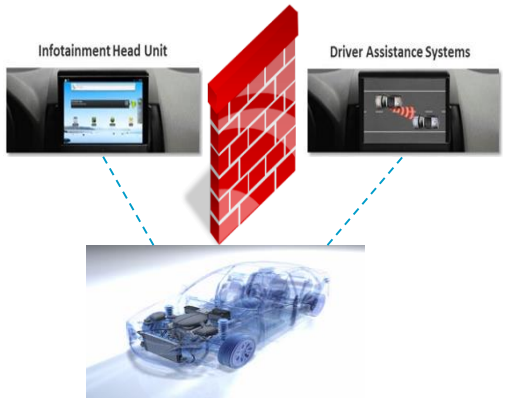


MCS and the Challenge of Compliance to Safety-related Standards

Safety-related Industrial Standards

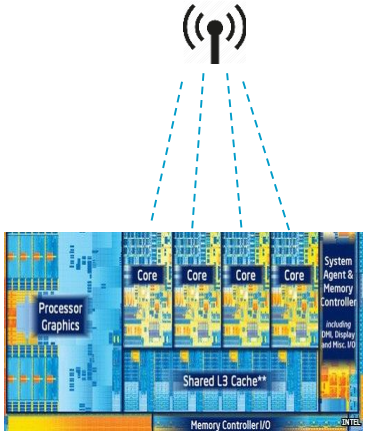
No explicit MCS requirements

...but specify stringent safety requirements



→ *isolation* and *independence* between applications.

Additional challenges

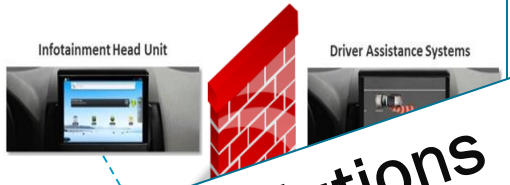


Multicore + Shared Resources

MCS and the Challenge of Compliance to Safety-related Standards

Safety-related Industrial Standards

...but specify stringent **safety requirements**



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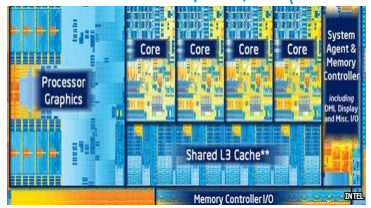


Multicore + Shared Resources

Industrial Solutions
ARINC-653 & AUTOSAR

The Theoretical MC Model and its Common Misconceptions

Most MCS work are based on Vestal model:

- Several modes of execution (1, 2, . . . , L)
- tasks → period, deadline, WCET and an assurance level
- System running in mode k
- Budget of a task is overshot
- System switches to mode k + 1
- All the tasks of criticality not greater than k are suspended (potentially reactivated)

The Use of the Word “Function”

Safety-related Industrial Standards

- Used at system level
- System functionality (HW + SW)

“Function” ≠

Academic Publications

- Used like a pure SW function
- E.g.: C function or real-time task

Mismatch of Interpretation of the Concept of "System Criticality"

Safety-related Industrial Standards

- Level of assurance (e.g. DAL, SIL,...)
- Safety functions

"System Criticality" ≠

Academic Publications

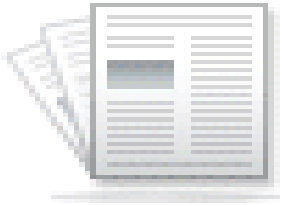
- Based on Vestal
- Modes of execution
- E.g. high and low criticality

The Misalignment of Terminology

Safety-related Industrial Standards

≠

Academic Publications



Although **not fundamentally wrong**, it creates confusion in the context of industrial MCS

→ leads the two communities to **misunderstand** each others' work

Confusion between the Notions of Criticality and Importance

Function 1

Severity:
Car unusable
Probability:
Probable
Controllability:
Driver can keep the car on the road

Function 2

Severity:
Car unusable
Probability:
Probable
Controllability:
Uncontrollable

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Both are important!

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But ...
ASIL = Severity + Probability + Controllability

Severity class	Probability class	Controllability class		
		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

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ASIL C

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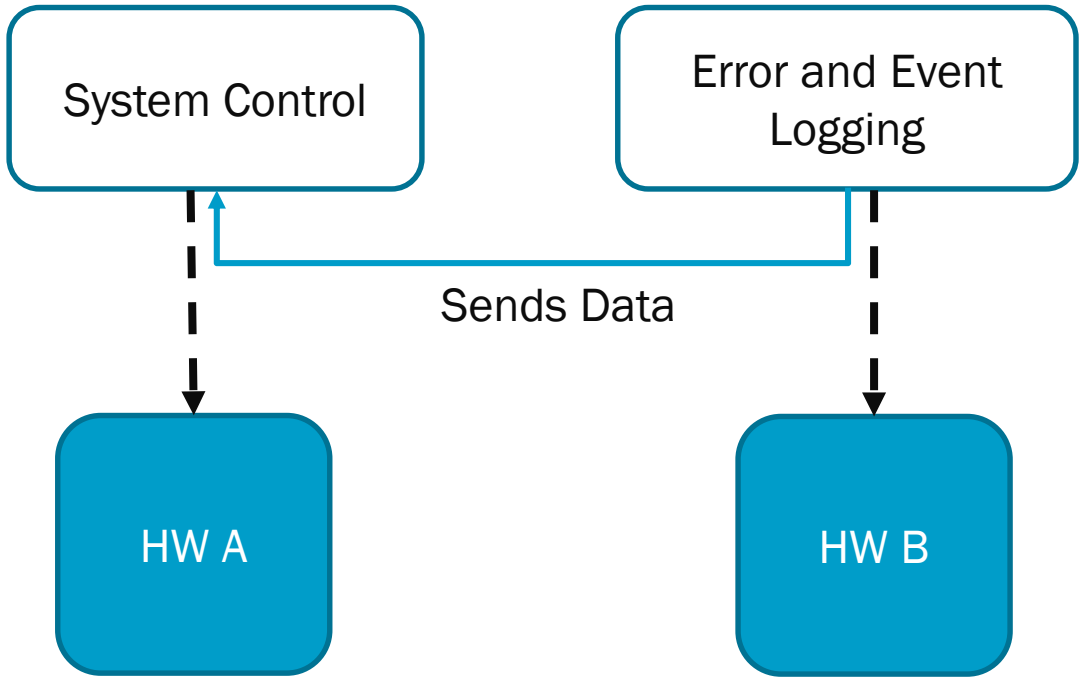
Function 2 — ASIL D

Severity:
[illegible]

We cannot always stop lower criticality tasks in favour of higher criticality ones

Confusion between the Notions of Criticality and Importance

Example from IEC61508



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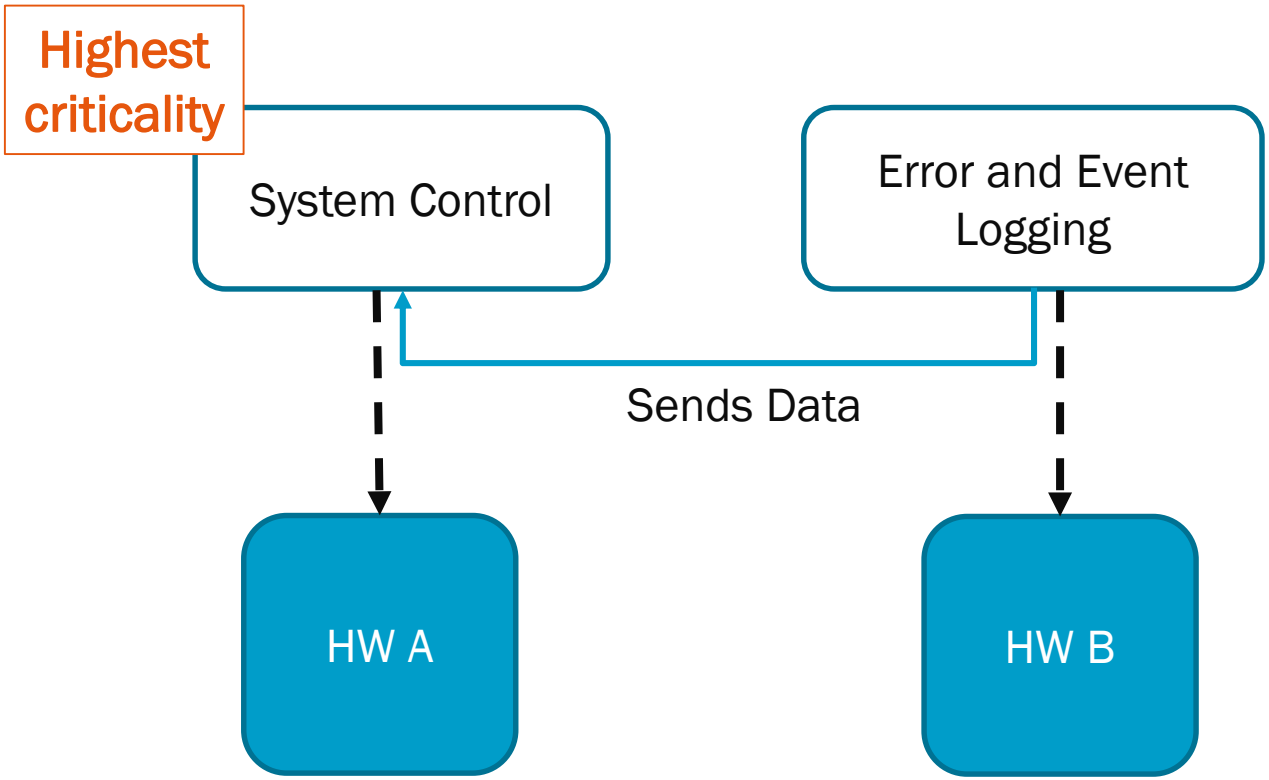

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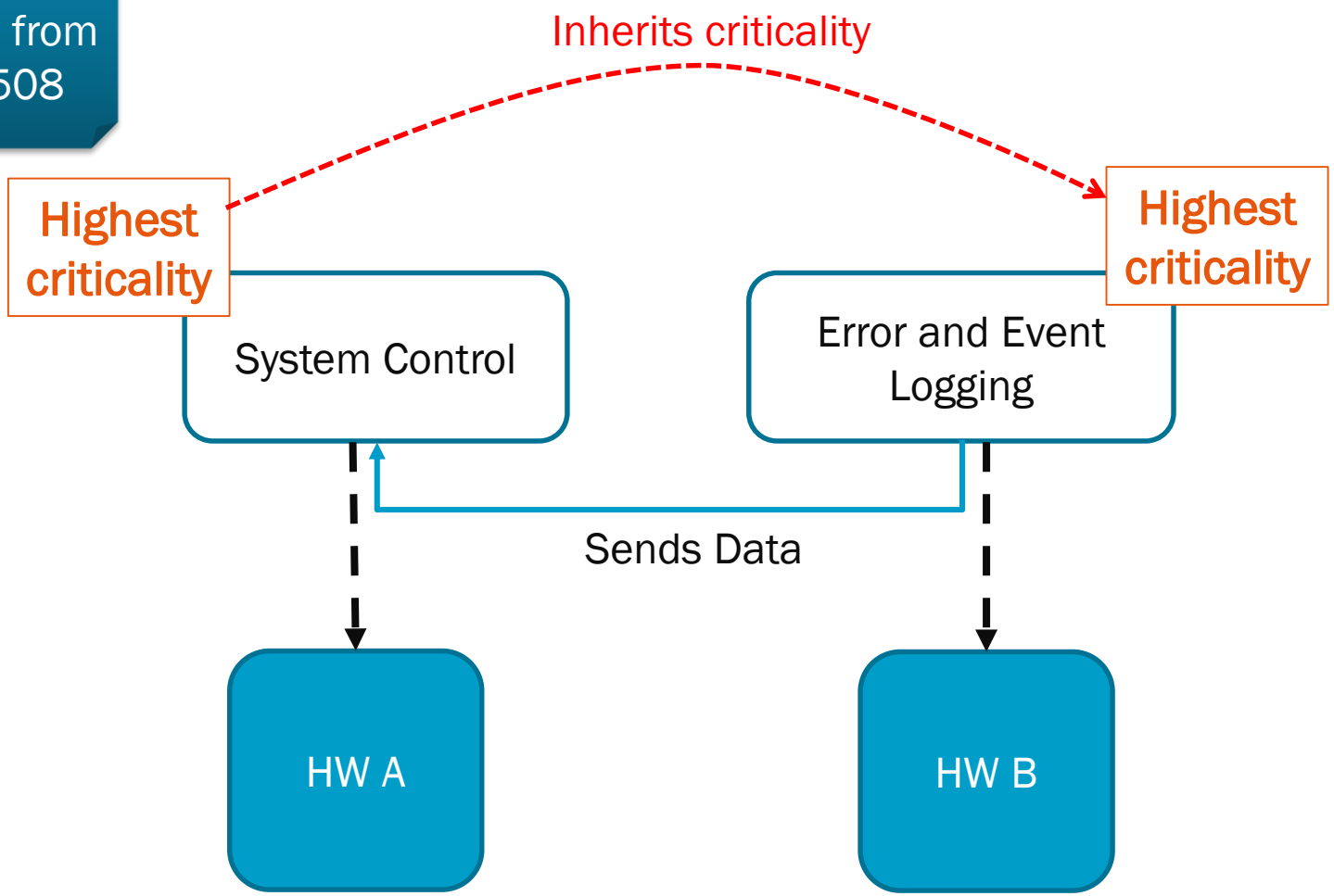

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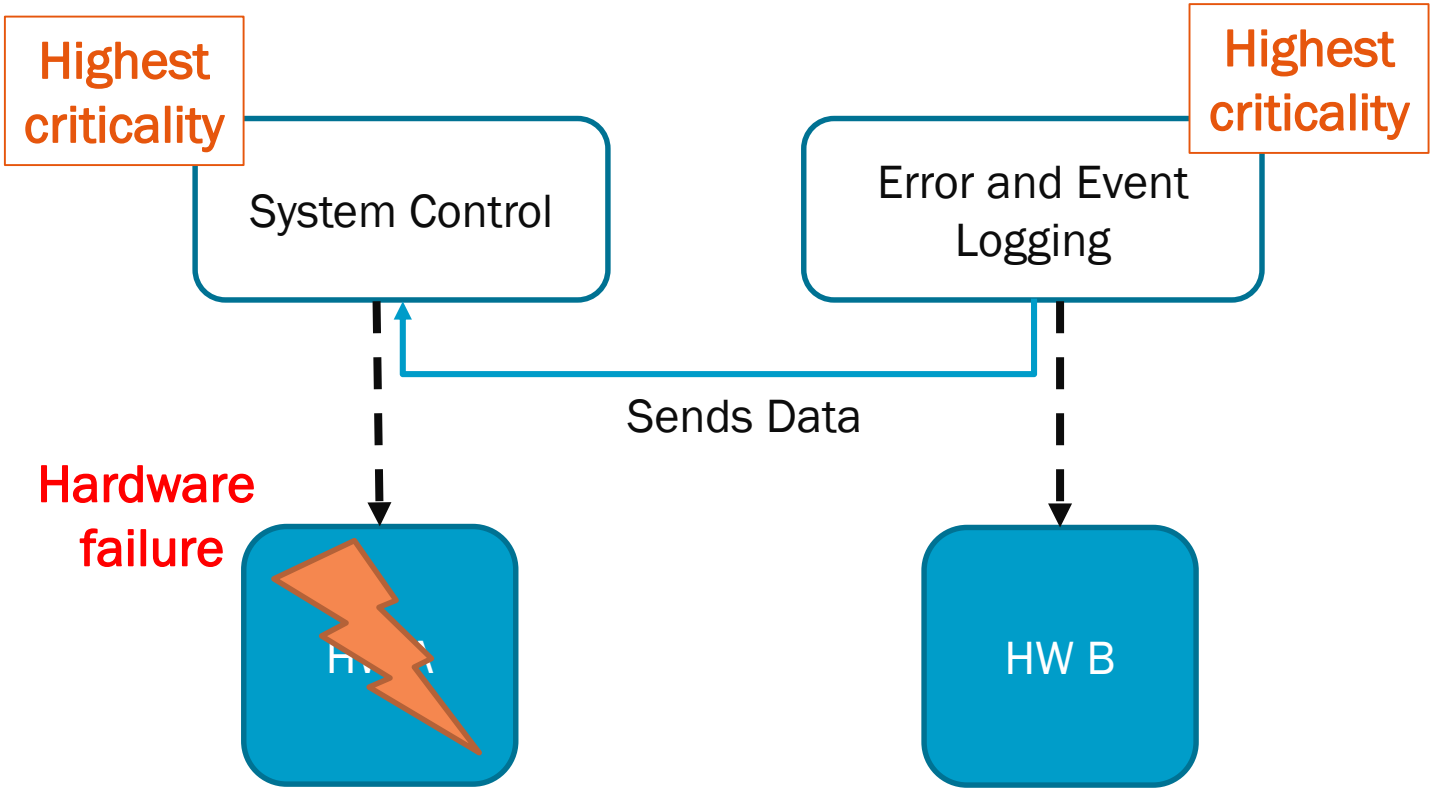

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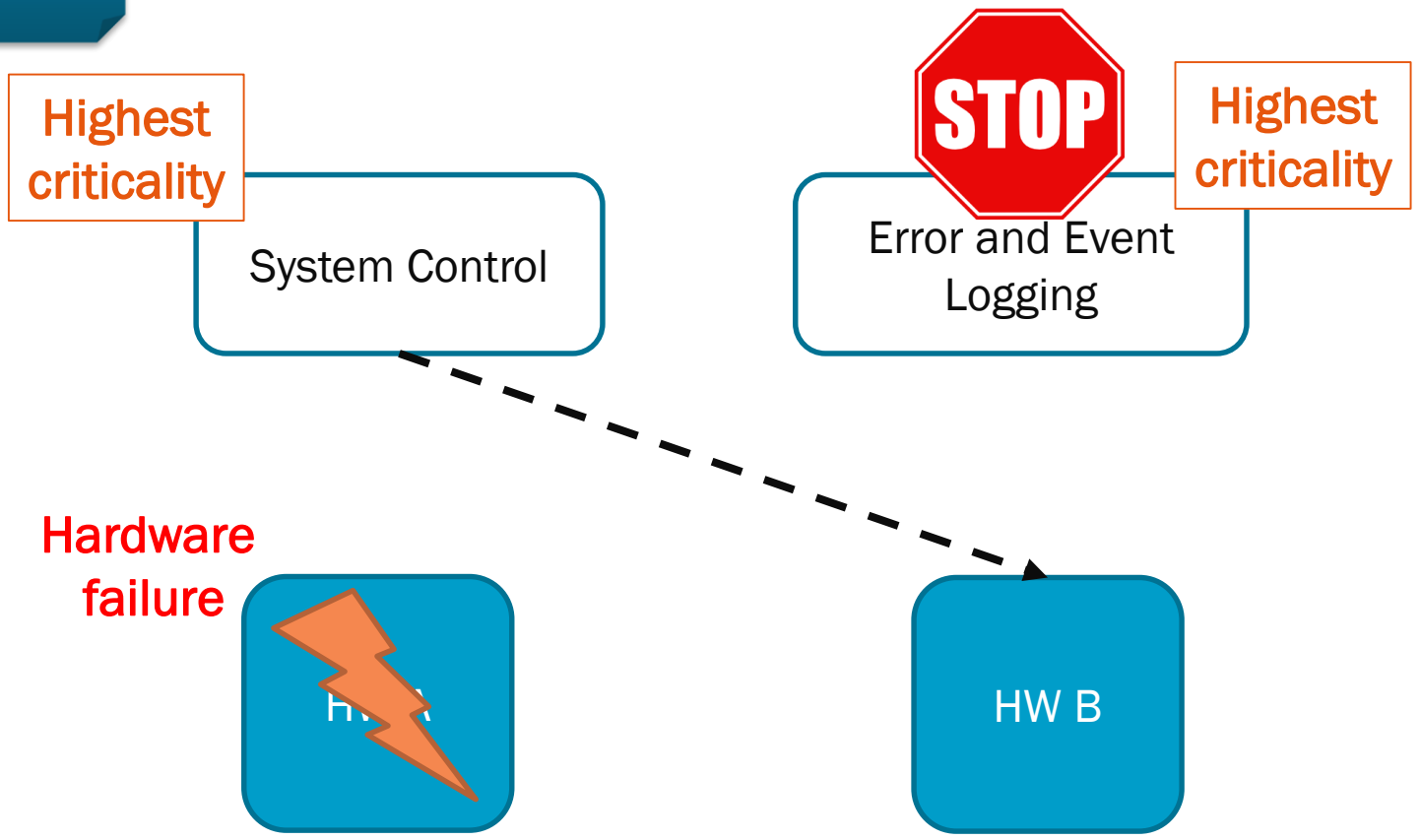

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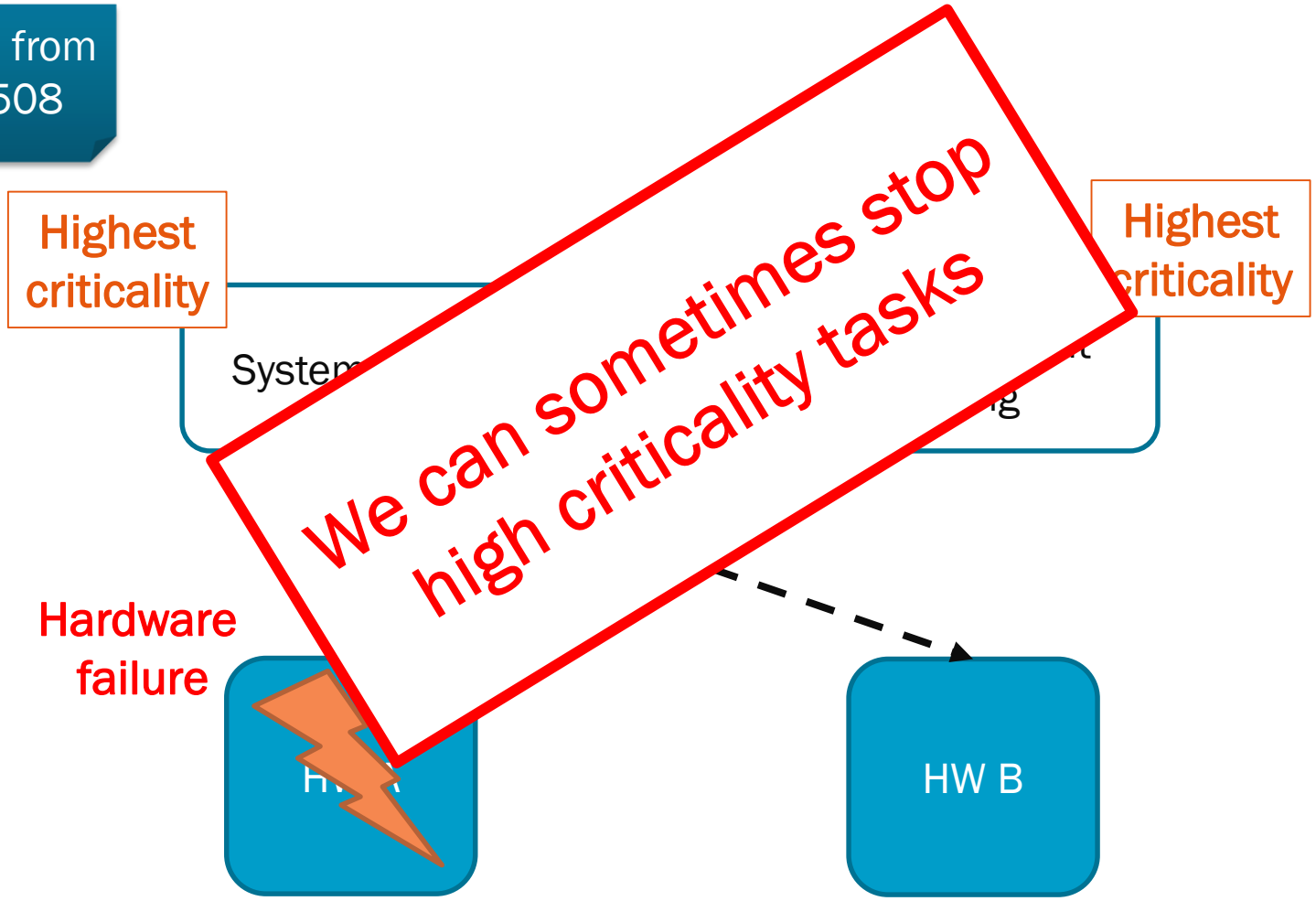
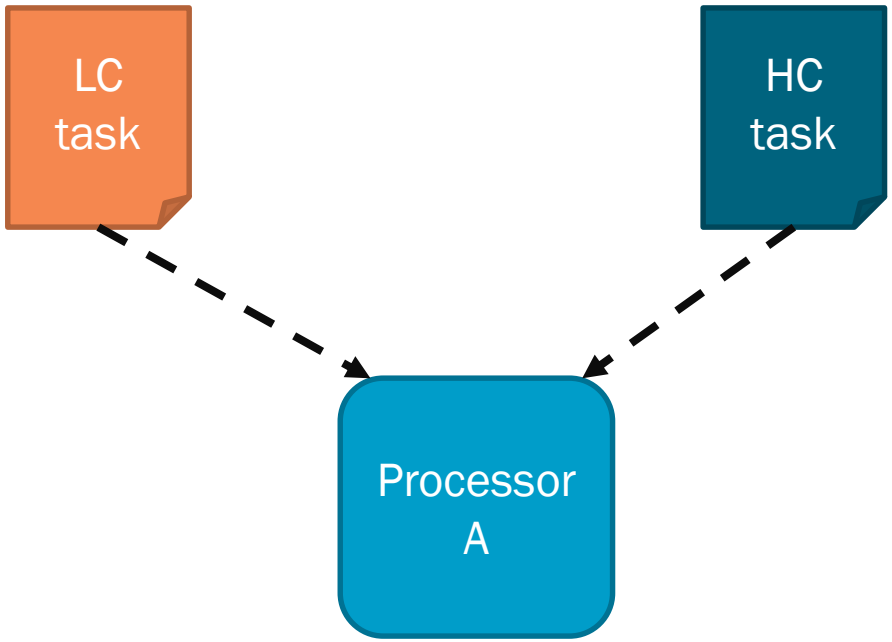


Vestal's Model and Isolation

Vestal's model:
High and Low criticality tasks run on the same processor and scheduler



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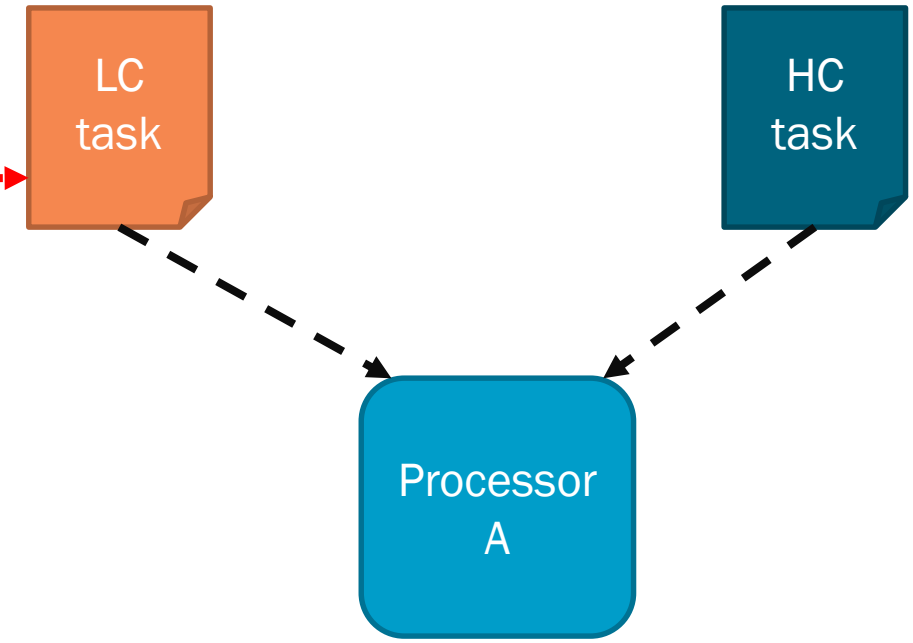
Industrial perspective

FMEA analysis

Failure mode:
Period change of external event



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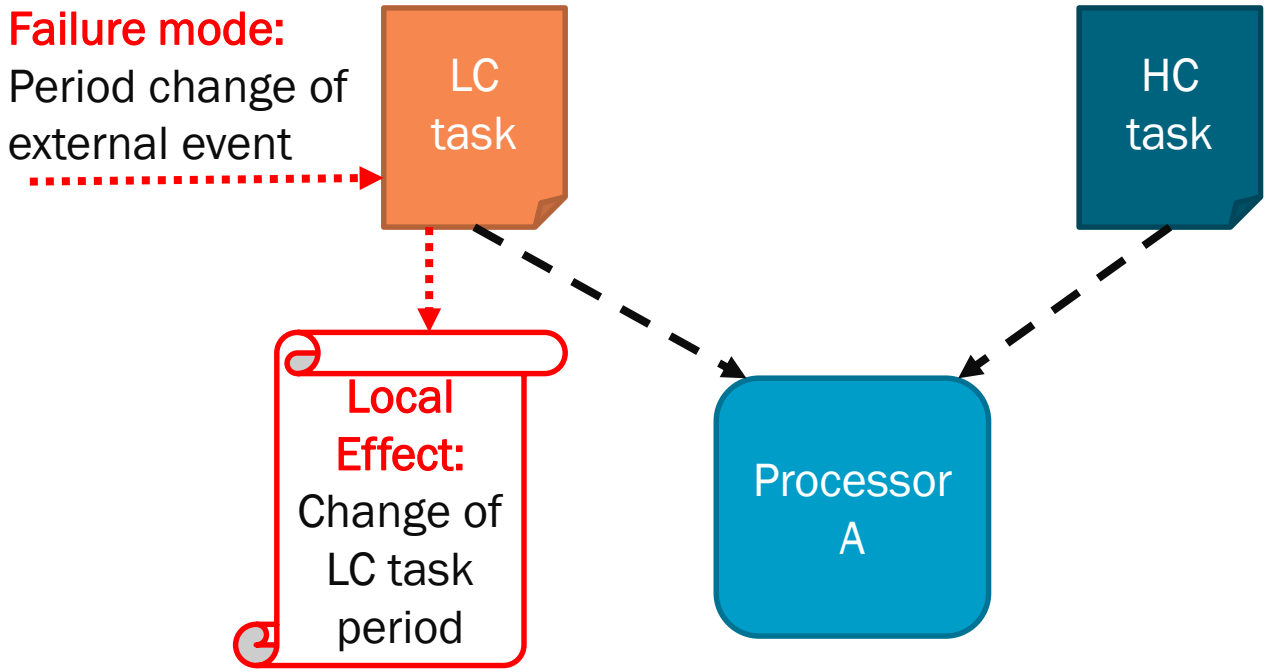

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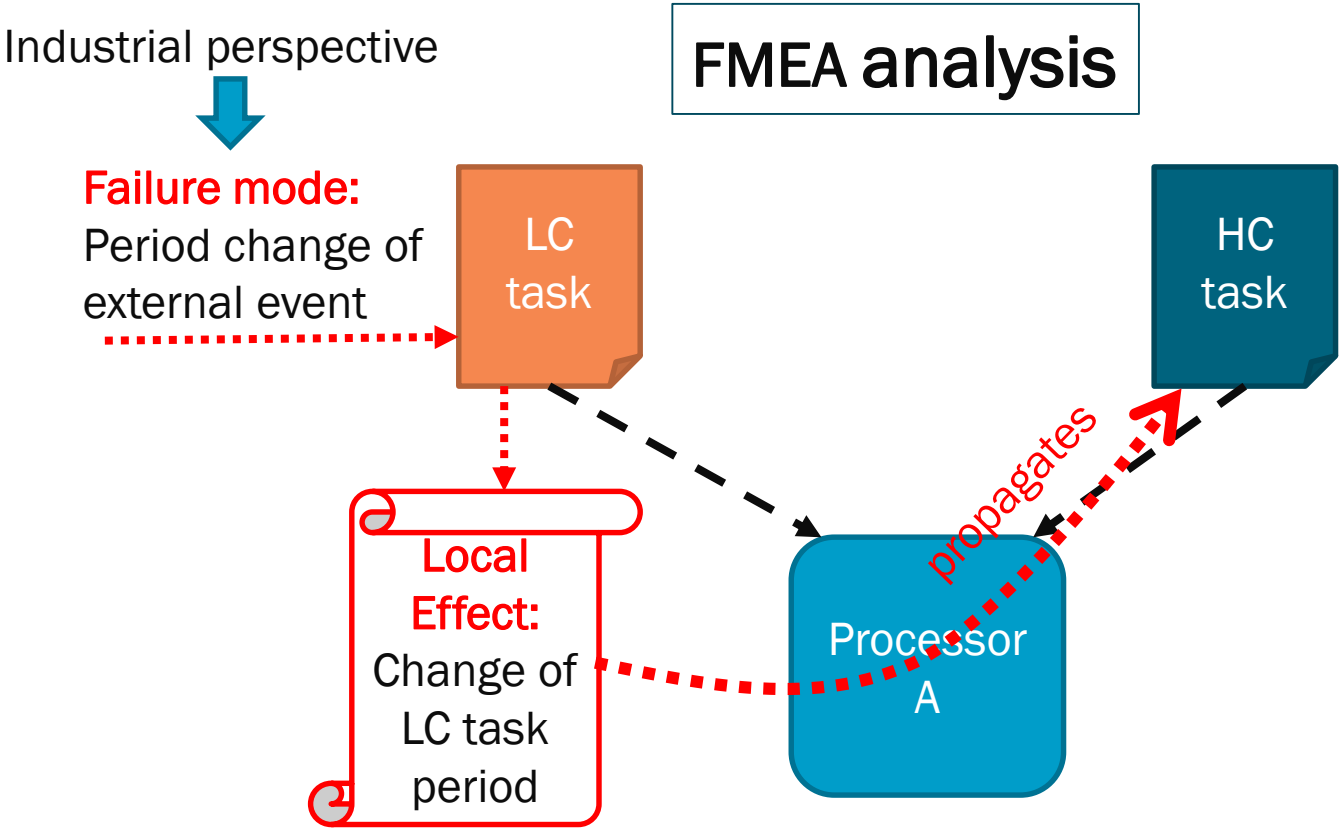

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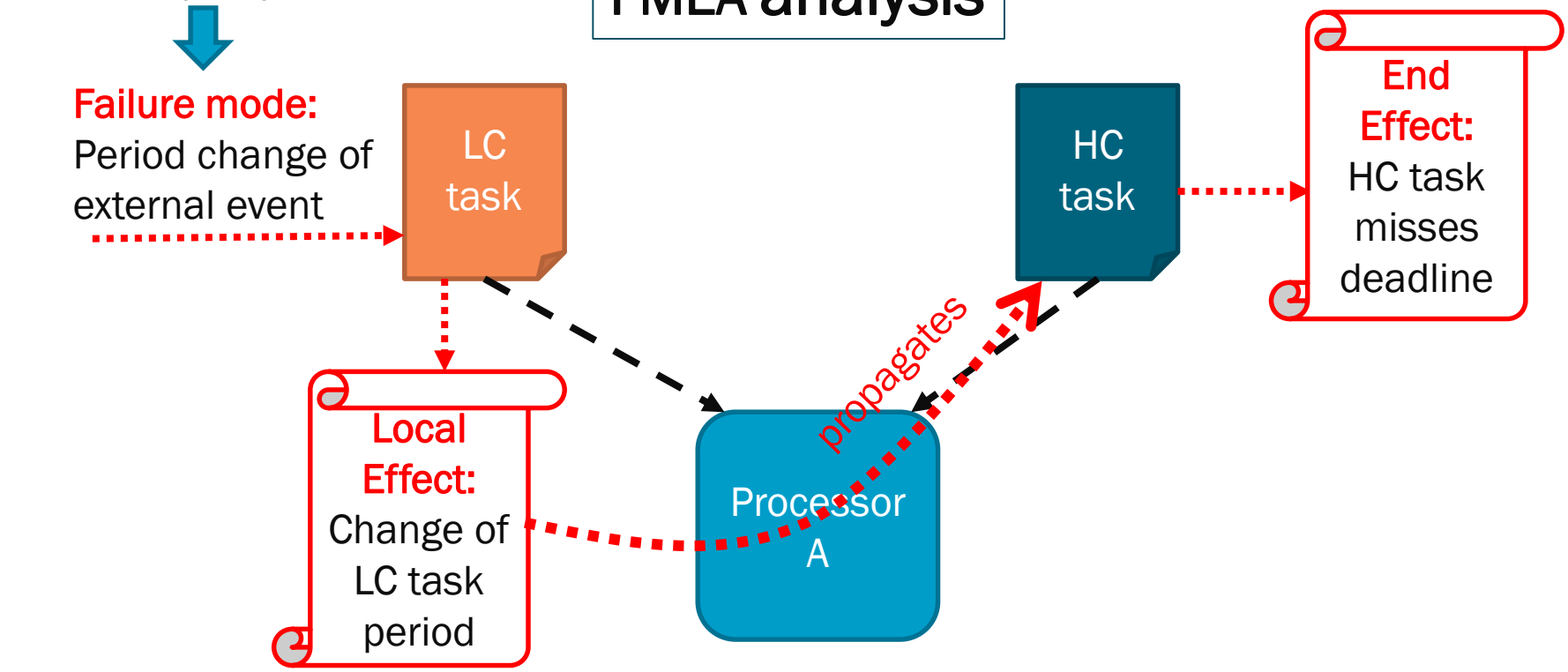

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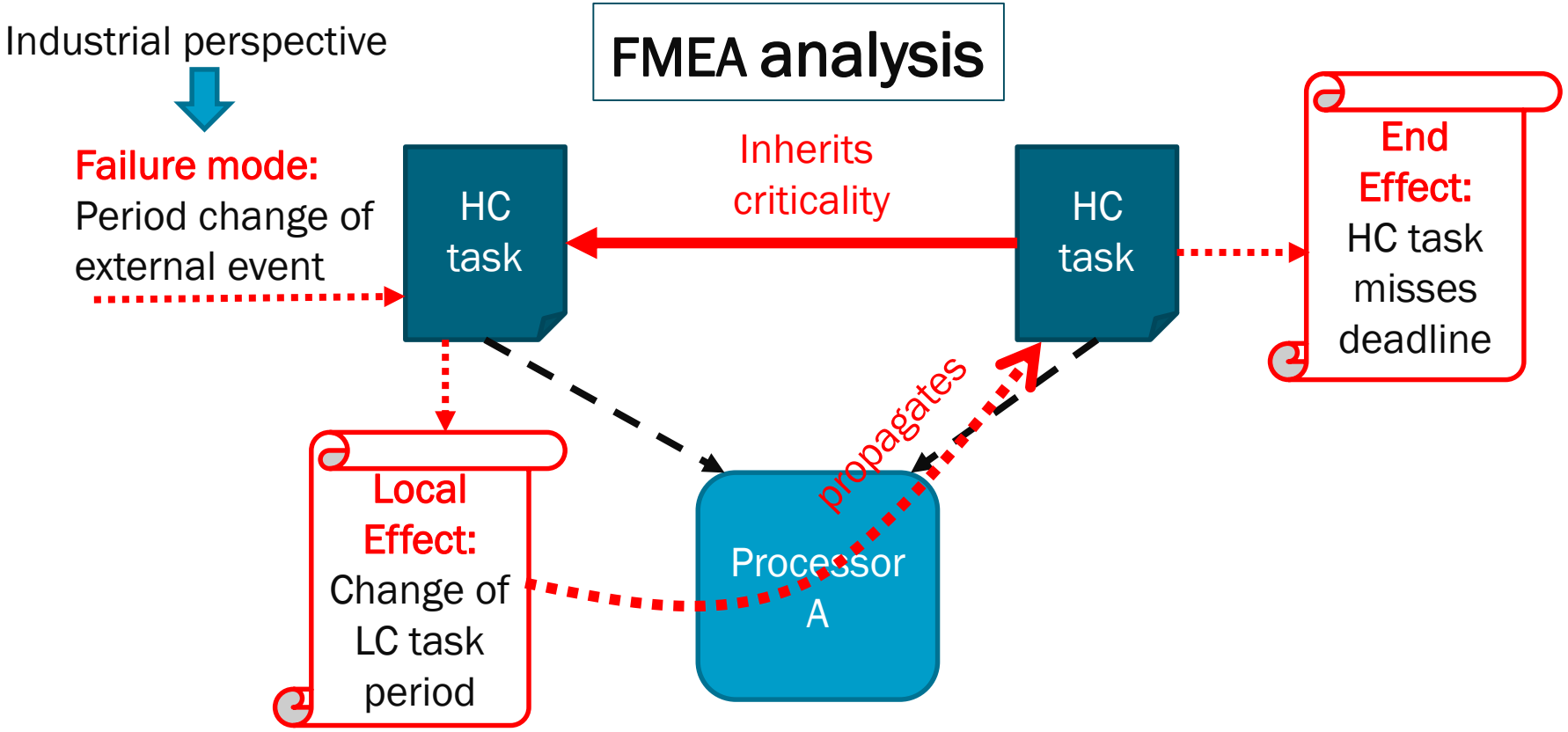

Vestal's Model and Isolation

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Industrial perspective

Failure mode:
Period change of external event

FMEA a…

HC t…

HC and LC tasks not isolated in time → all tasks will have to be certified at HC level

End Effect:
HC task misses deadline

Local Effect:
Change of LC task period

…rocessor A

Vestal's Model and Isolation

Vestal's model:
High and Low criticality tasks run on the same processor and scheduler

- Will never be able to convice a certification authority that the tasks are isolated in time
  - The cost of the system would increase exponentially…
    - We miss the initial goal of integrating a mixed-criticality system in the same platform to decrease costs

WCET Estimation

Vestal's model & Derivatives:
Assumption: Higher degree of assurance of a task → more pessimistic WCET estimation

- WCET upperbound → necessary but not sufficient condition to ensure the safety

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Safety-Standards

- Requires mechanisms to ensure that safety is not compromised in case of timing violation
  - E.g. time partitioning

Probabilistic WCET vs. Software Reliability

Probabilistic WCET

- Provides a probabilistic upper-bound on the execution time
- Aims at building a reliability model of the software

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- Confidence cannot be placed in such models

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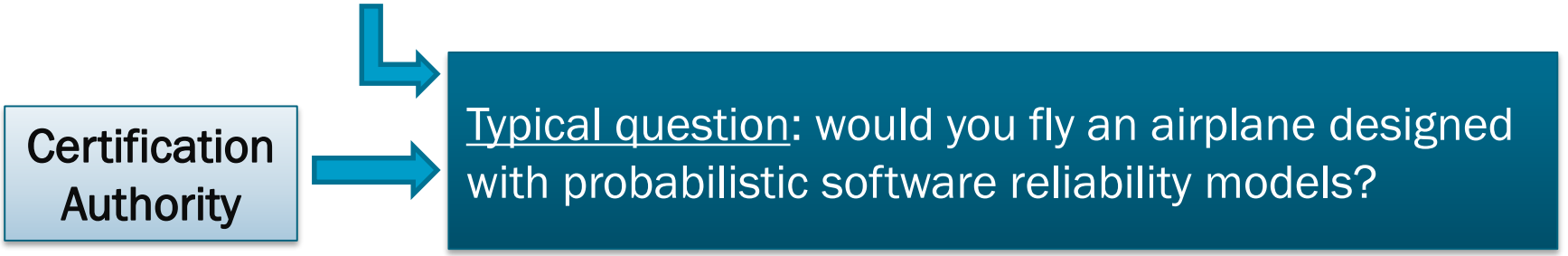

Probabilistic WCET vs. Software Reliability

Probabilistic WCET
- Provides a probabilistic upper-bound on the execution time
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Certification Authority

Typical question: would you fly an airplane designed with probabilistic software reliability models?

Conclusion

- Clear gap between some of the guidelines provided in safety-related standards and their interpretation by the academic community
  - Misalignment of terminology leads to misunderstanding of each other's work
  - Confusion between the notions of criticality and importance
  - Ensuring safety in terms of timing isolation goes beyond accurate WCET estimates
  - Probabilistic WCET estimates: in case that direction is followed → need to work on the argumentation

Question & Answers