Adapting Fault Resilience Granularity to Overcome Varying Failure rates in CPS

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Motivation

- ✓ Most CPS applications are mission critical, hence higher reliability is demanded.
- ✓ More processing nodes in CPS, due to increasing demand of more complex functionality and higher performance, imply more resources that may fail.
- ✓ Strict system requirements that CPS usually have, such as severe energy and performance constraints, and distributed control, urge for adaptive and efficient fault resilience solutions.
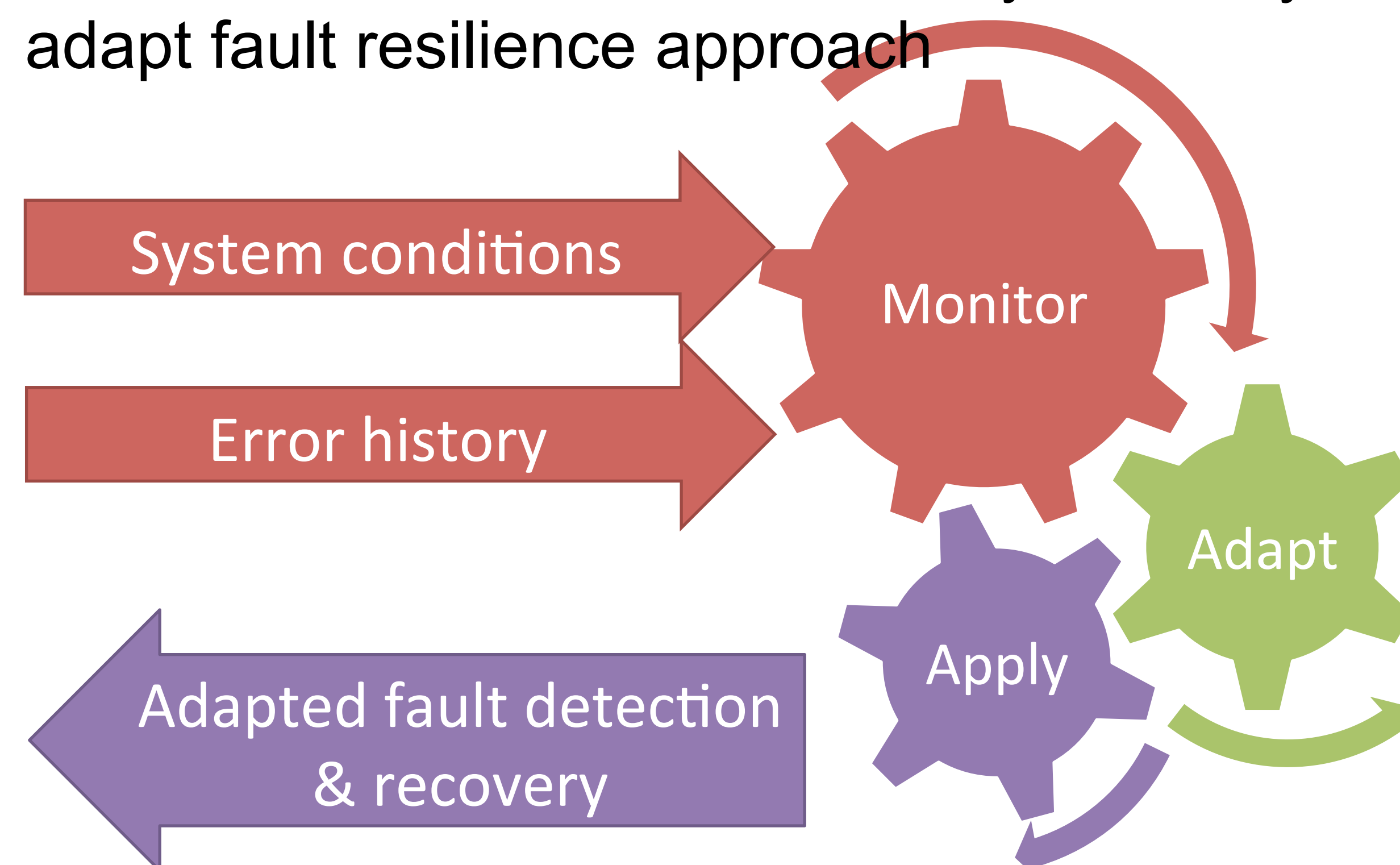
Fault classification

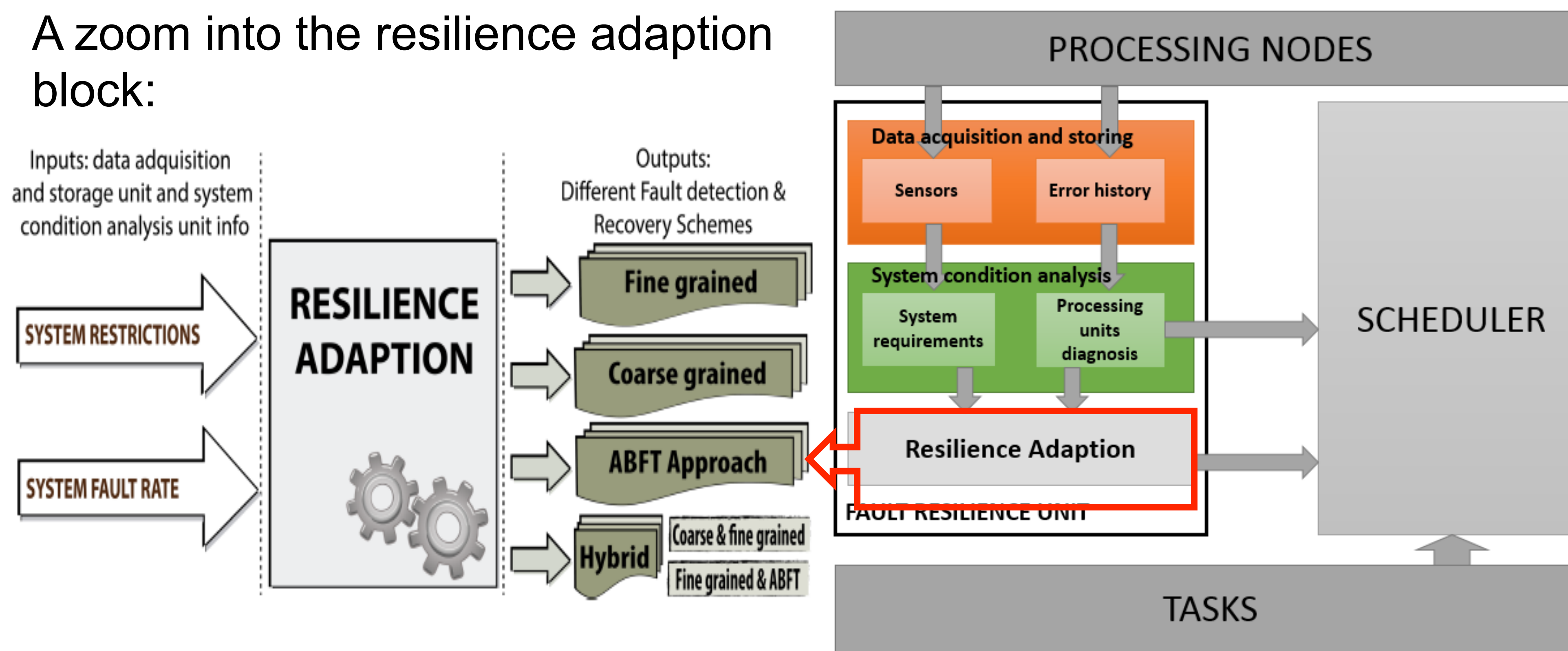| Category	Behavior
Permanent	The resource can not be used anymore.
Intermittent	A warning for what could be a permanent fault.
Transient	Environmental effects that cause temporal faults.

*To tackle these challenges, **efficient fault resilient techniques** are needed, to allow the system to keep working autonomously in the presence of faults.*
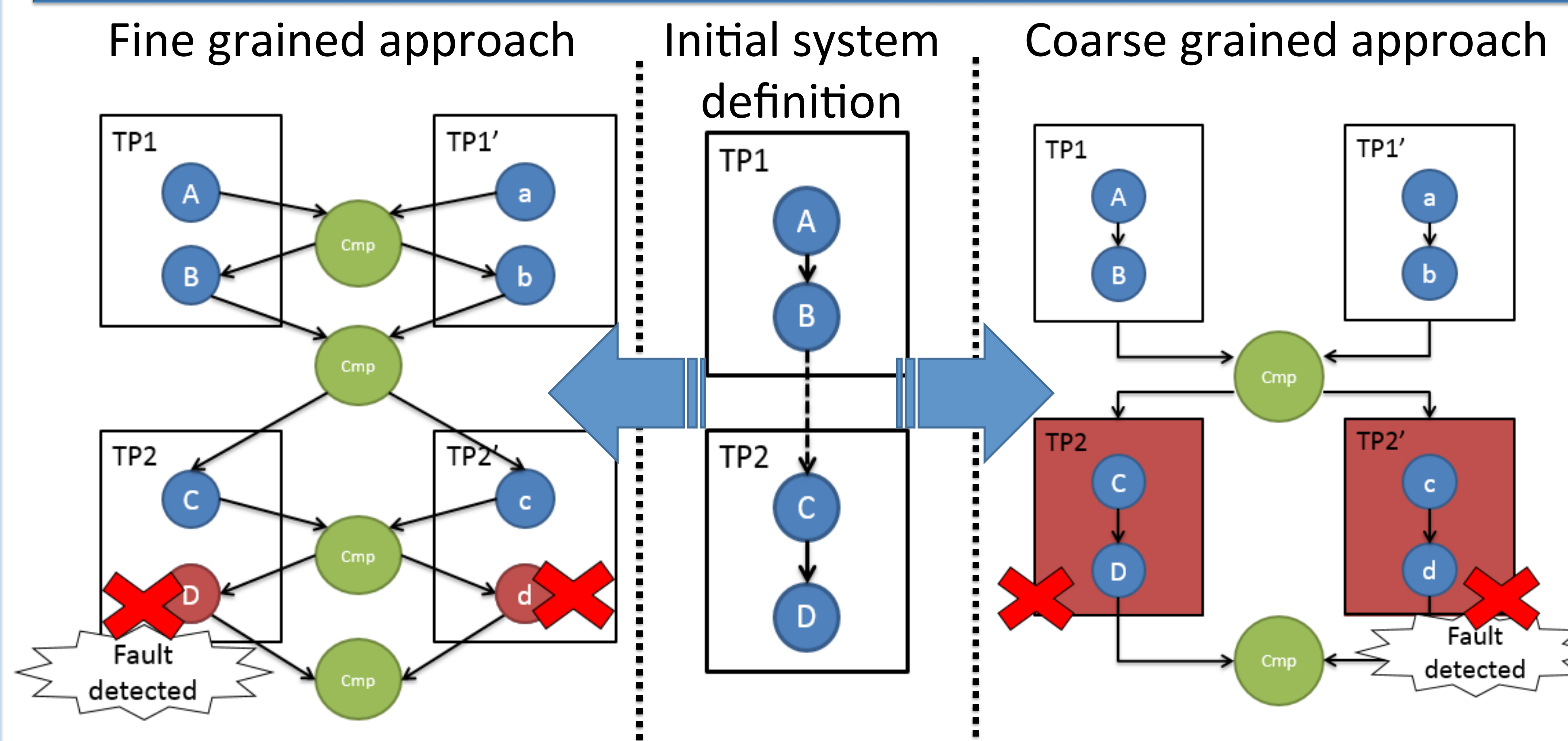
Prevent these faults from affect the system

Use online feed-back control to dynamically adapt fault resilience approach

System conditions
Error history
Monitor
Adapt
Apply
Adapted fault detection & recovery

Proposed framework

A zoom into the resilience adaption block:

Inputs: data adquisition and storage unit and system condition analysis unit info

SYSTEM RESTRICTIONS
SYSTEM FAULT RATE

RESILIENCE ADAPTION

Outputs: Different Fault detection & Recovery Schemes
Fine grained
Coarse grained
ABFT Approach
Hybrid — Coarse & fine grained / Fine grained & ABFT

PROCESSING NODES
Data acquisition and storing — Sensors — Error history
System condition analysis — System requirements — Processing units diagnosis
Resilience Adaption
FAULT RESILIENCE UNIT
SCHEDULER
TASKS

Different fault resilience granularities: Fine grained vs. Coarse grained

Fine grained approach   Initial system definition   Coarse grained approach

Fault detected

	Fine grained	Coarse grained
Fault detection Overhead (*Fault rate **independent***)	High	Low
Recovery Overhead (*Fault rate **dependent***)	Low	High

- ✓ Overhead of each approach has its own behavior in terms of fault rate.
- ✓ It is necessary to find the "cross point" that makes one approach more efficient than the other. This motivates us to monitor the system fault rate.
- ✓ Decision making process needs to be fast, so the fault resilience scheme is applied at the precise time where conditions required it.

Fault rate threshold

Time overhead

Fault rate

Fine grained — Coarse grained
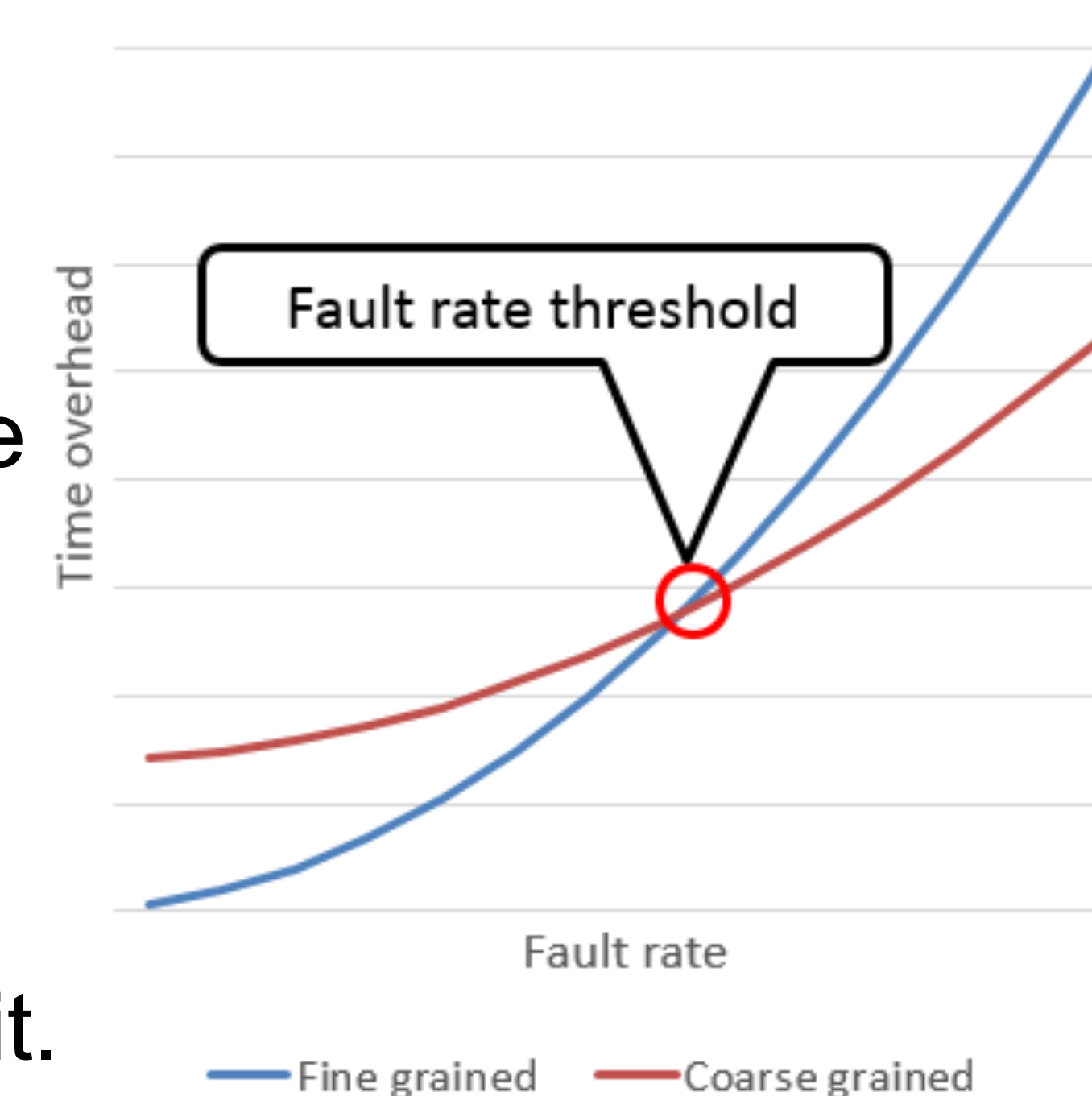
Fault injection

Simulate different fault rates and fault types that are:
- ✓ Independent of each other;
- ✓ Independent of the resilience implementation.

RUNTIME
CODELET ABSTRACT MACHINE

RUNTIME

Cluster		Cluster		FAULT UNIT
TP Scheduler Socket=0 PU=1	µ Scheduler Socket=0 PU=2	TP Scheduler Socket=0 PU=3	µ Scheduler Socket=0 PU=4	Fault Injection Socket=0 PU=0
Thread 0	Thread 1	Thread 2	Thread 3	Thread 2

THREAD AFFINITY

Num of TP = 2   Num of µ = 2   Fault Rates= [10,10,10,10]

Affinity Mask

TP Schedulers mask		µ Schedulers mask		Fault mask
Socket=0 PU=1	Socket=0 PU=3	Socket=0 PU=2	Socket=0 PU=4	Socket=0 PU=0

MACHINE

Socket #0

L2 Cache		L2 Cache		L2 Cache	
L1 Cache	L1 Cache	L1 Cache	L1 Cache	L1 Cache	L1 Cache
Core #0	Core #1	Core #2	Core #3	Core #4	Core #5
PU - 0	PU - 1	PU - 2	PU - 3	PU - 4	PU - 5

A new independent thread is dedicated for the fault injection module, that allows the user to set additional information to configure it.

Impact
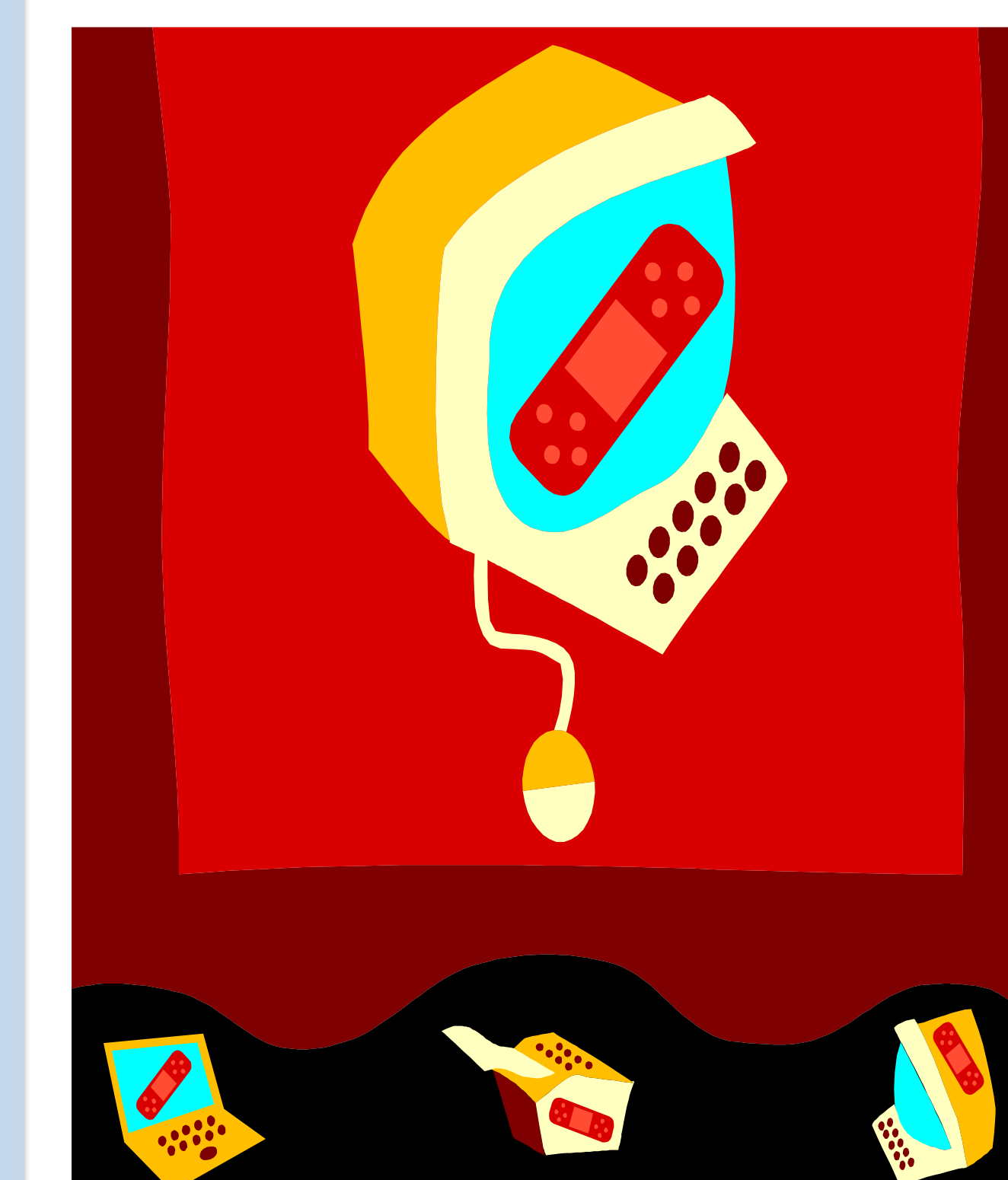
- ✓ The presented fault resilience solution reduces overhead, while allowing the system to tolerate a diverse range of fault rates.
- ✓ These techniques relax the requirement of 100% correctness for devices and interconnects, thus dramatically reducing costs of manufacturing, verification and testing for CPS systems.