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TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

SSA 07 –Architecture Styles and Pattern

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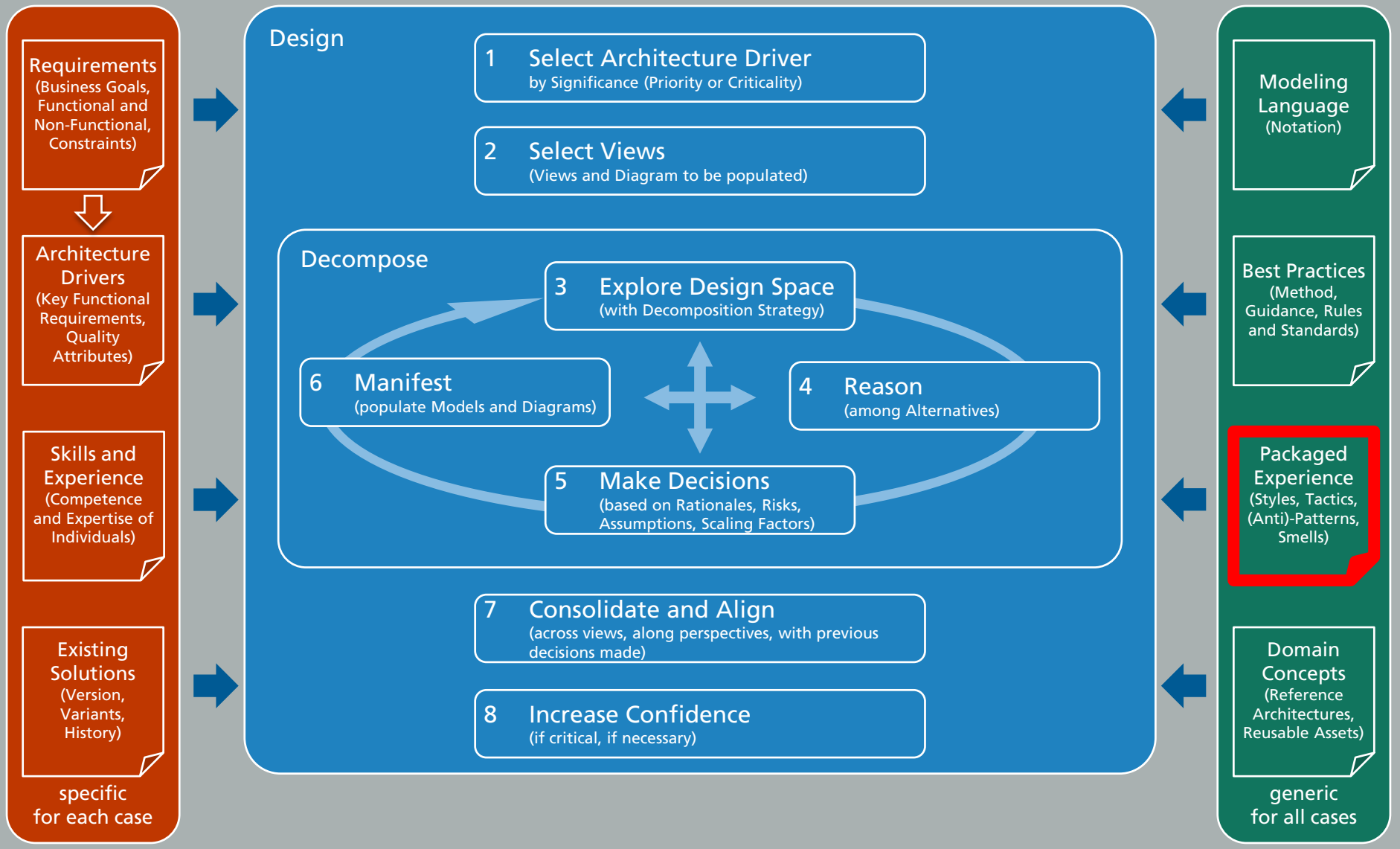
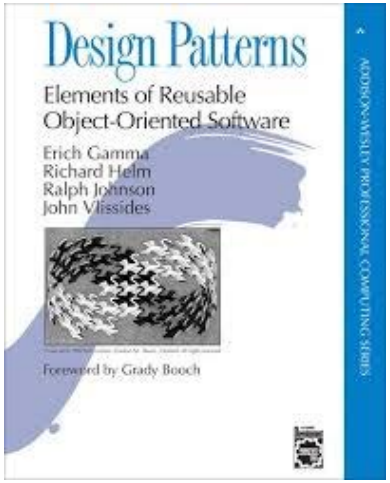
TU Kaiserslautern, SS2018
Lecture "Software and System Architecture (SSA)"

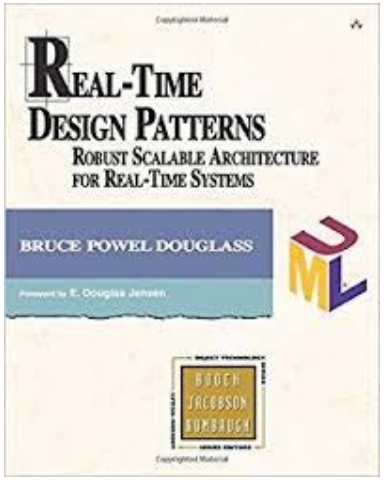
Architecture Design Iteration



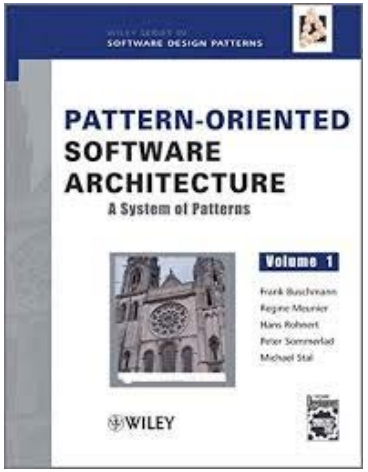
Literature for Software Architecture Pattern, Styles and Tactics



every developer



embedded developer



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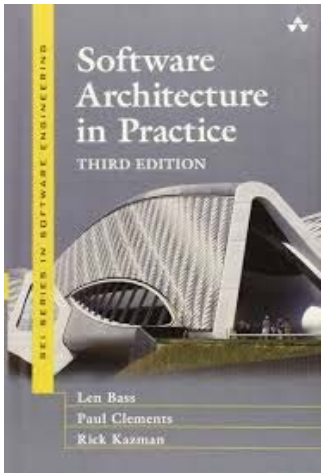
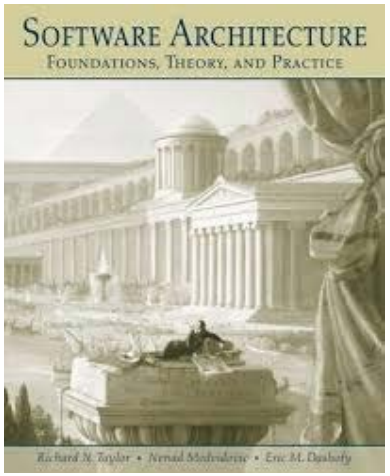
interested Software Architect



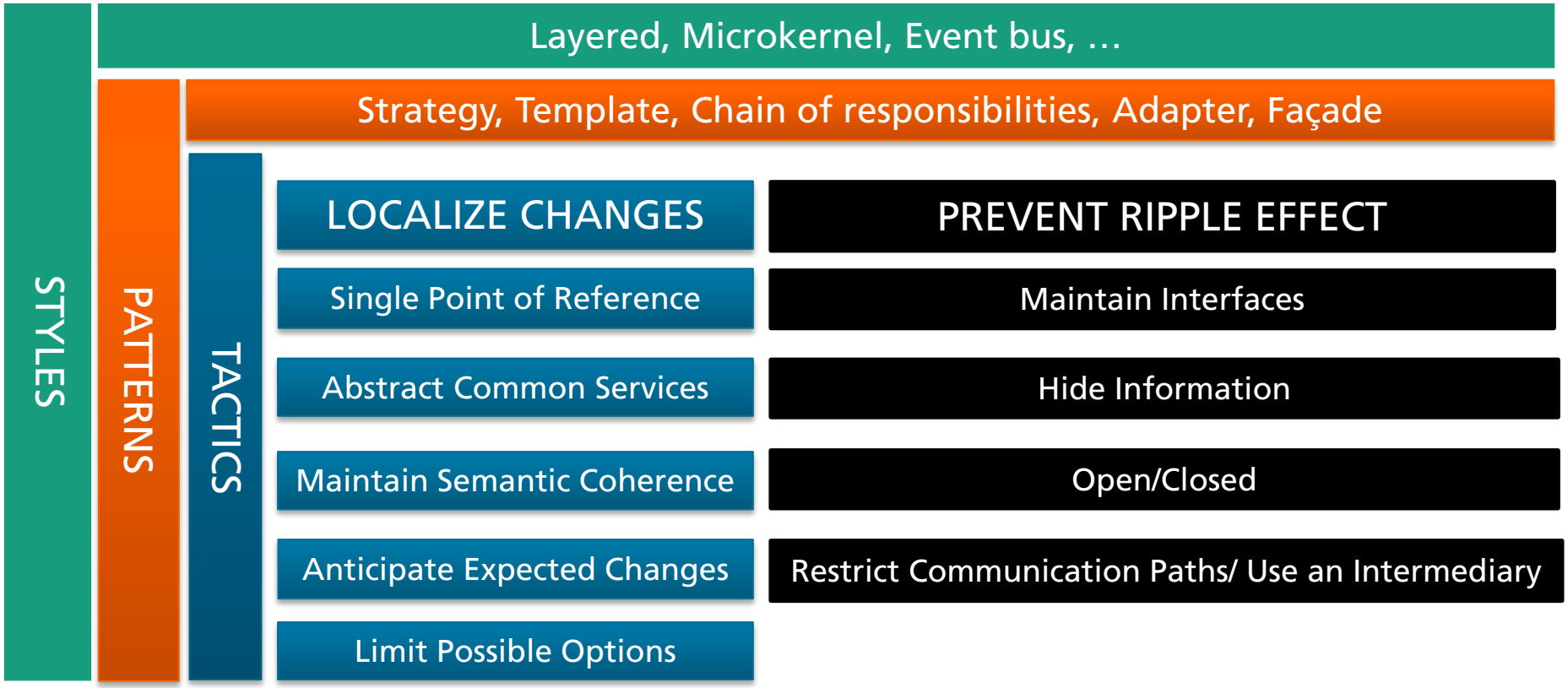
every software Architect



interested Software Architect

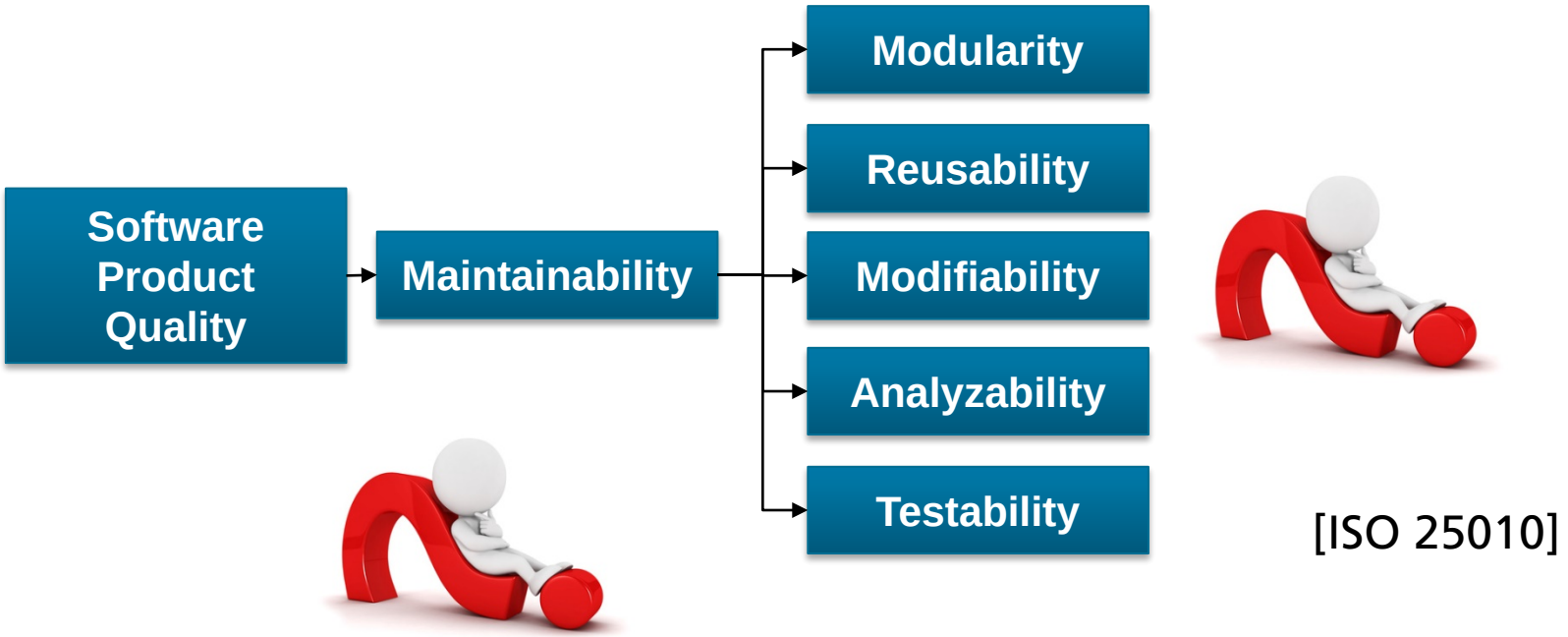
Maintainability

Architecture Tactics, Styles and Patterns: Maintainability



Goal Definition

- Maintainability= „Quality attribute relating to degree of effectiveness to which a software product can be modified by the maintainers.“



[ISO 25010]

Develop a system that is **well-structured**, **easy to change** & **analyze**.

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Legend: Quality Attribute — Refinement

Maintainability Strategies

Strategies / Principles	Requ.	Arch.	Design	Impl.	Compil.	V & V	Depl.	Exec.
Localize Changes		☒						
Prevent Ripple Effects		☒						

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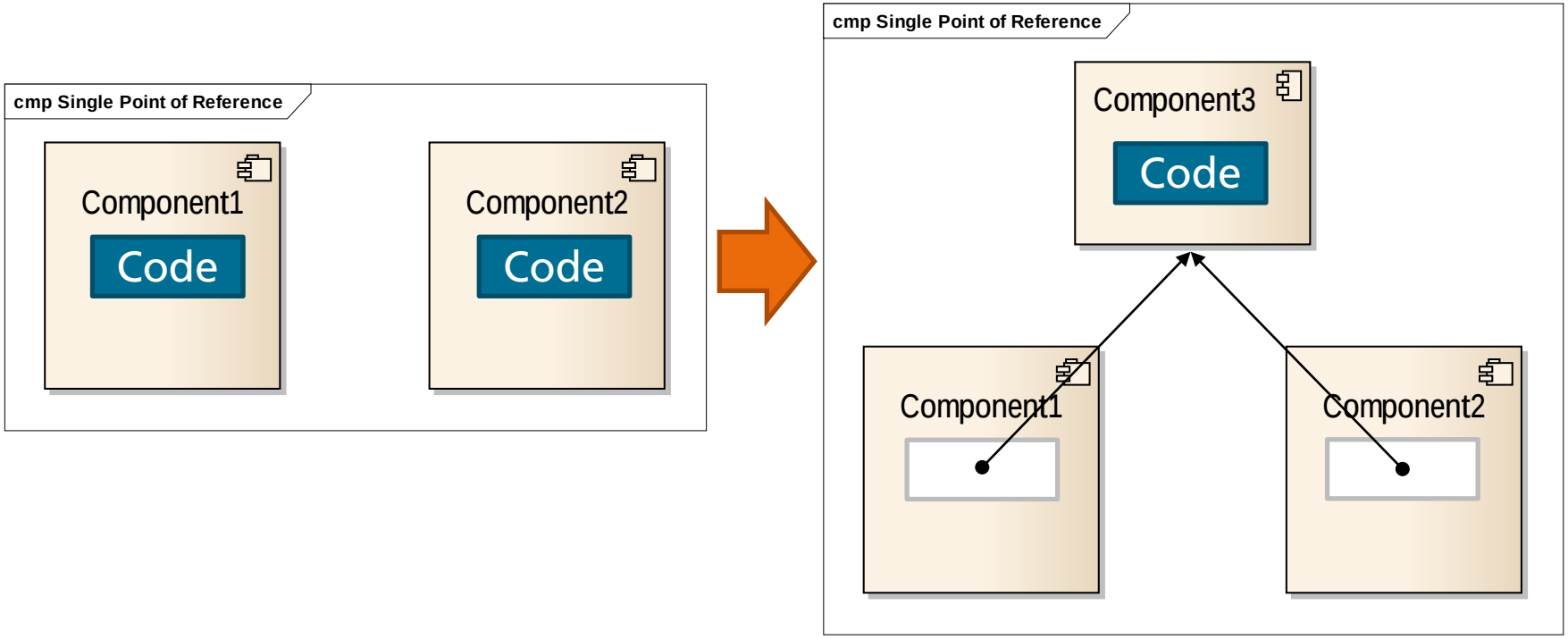
Legend: ☒ Application of Strategy/Pattern
☑ Resolution of Strategy/Pattern

The Localize Changes Strategy

- **Purpose**
  - Reduce number of modules directly affected by changes
- **Tactic: Single Point of Reference**



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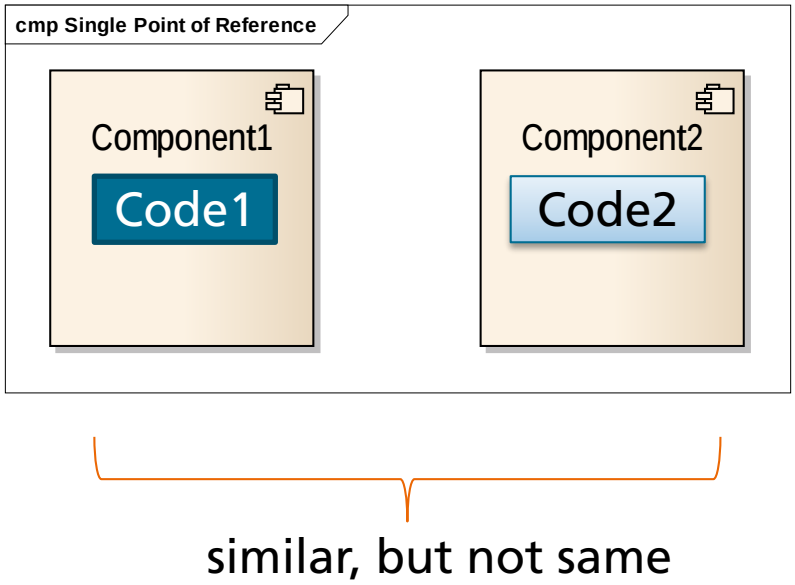
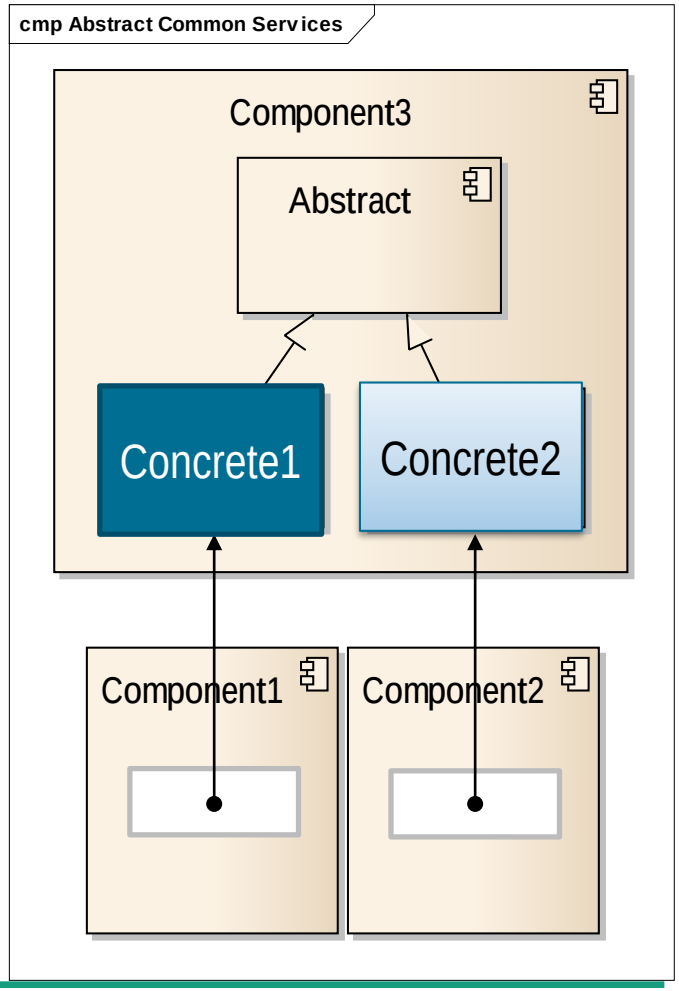
The Localize Changes Strategy

- **Purpose**
  - Reduce number of modules directly affected by changes
- **Tactic: Abstract Common Services**





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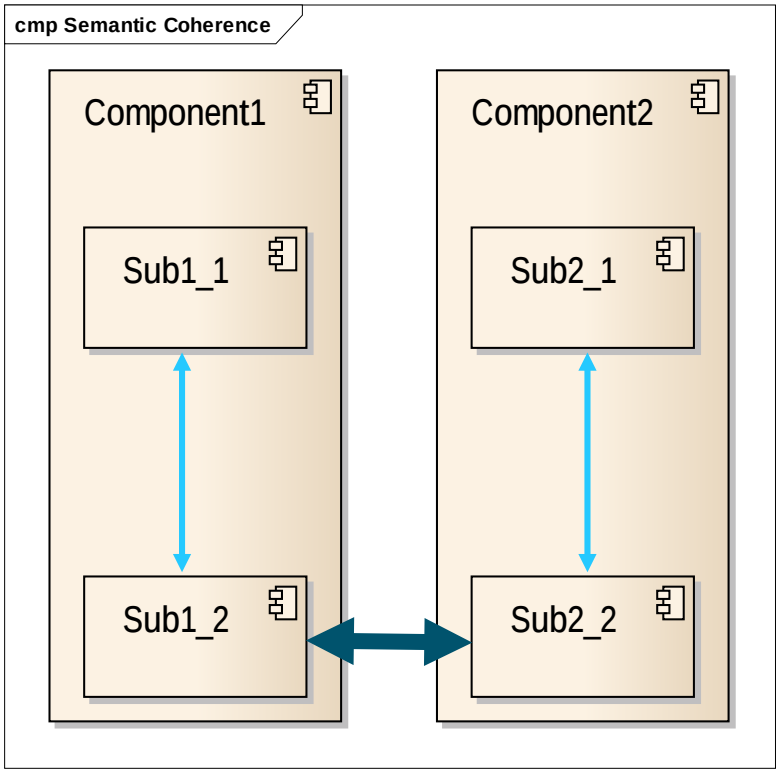
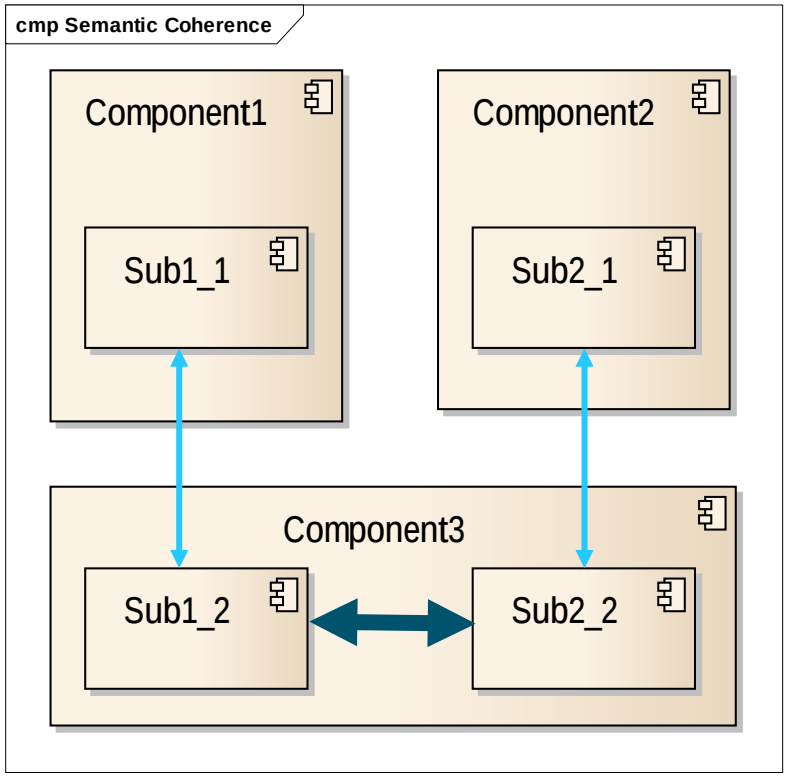
The Localize Changes Strategy

- **Purpose**
  - Reduce number of modules directly affected by changes
- **Tactic: Maintain Semantic Coherence**





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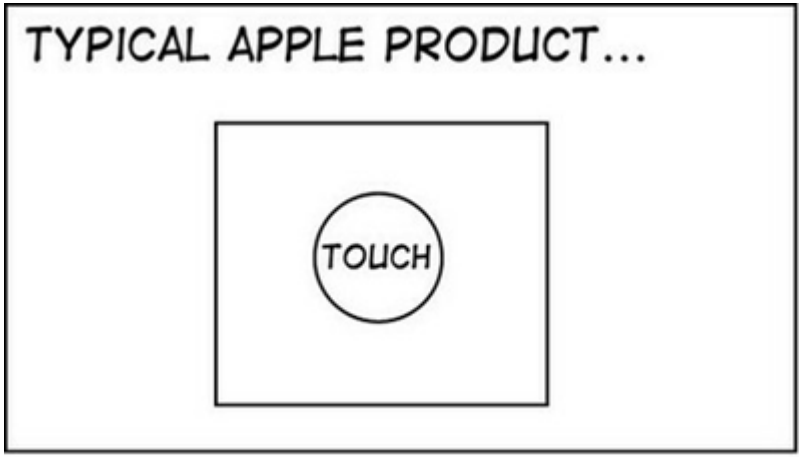
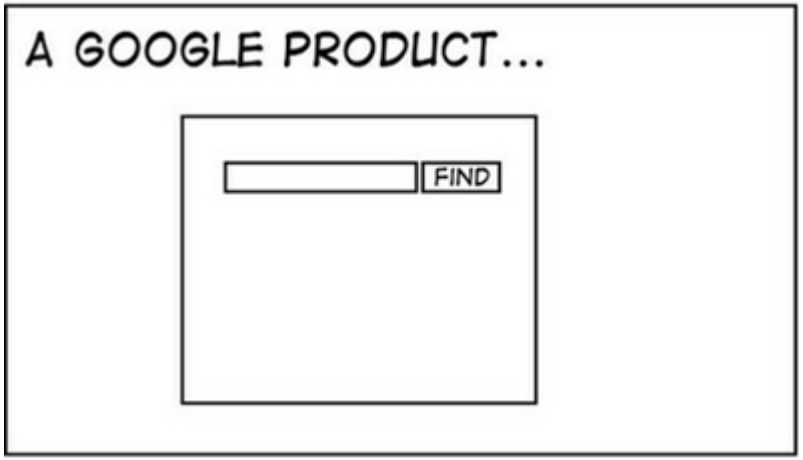
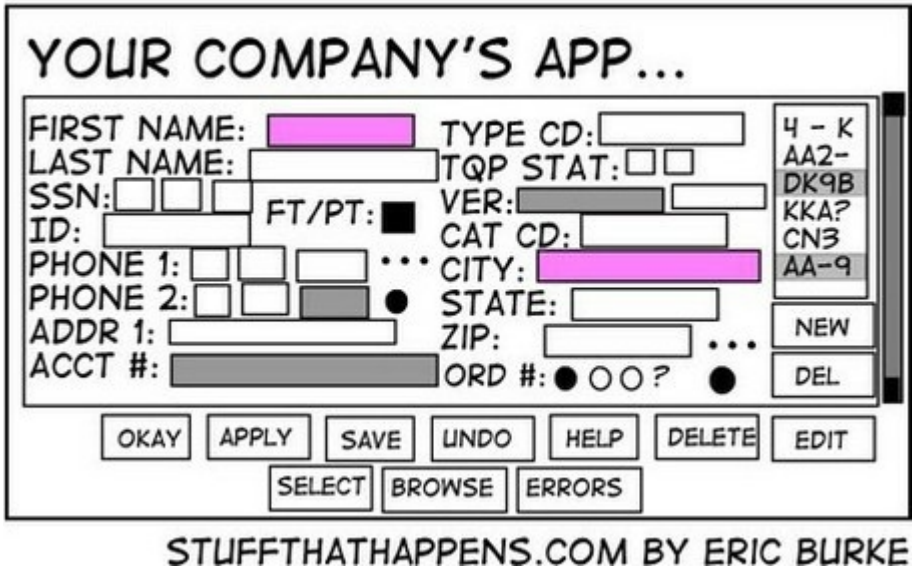
Weak coupling Strong coupling

The Localize Changes Strategy

- **Purpose**
  - Reduce number of modules directly affected by changes
- **Tactic: Limit Possible Options**







STUFFTHATHAPPENS.COM BY ERIC BURKE

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The Localize Changes Strategy

Strategy ID	Localize Changes

Purpose	▪ Reduce number of modules directly affected by changes
	▪ Tactics to implement the strategy
	  ▪ Single point of reference
	  ▪ Abstract common services
	  ▪ Maintain semantic coherence
	  ▪ Limit possible options
	  ▪ Anticipate expected changes (especially in product lines)

Advantages	▪ Cost reduction for implementing changes ▪ System is more understandable
Drawbacks	▪ Difficulty for determining “right” place of components for semantic coherence

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The Prevent Ripple Effects Strategy

Strategy ID	Prevent Ripple Effects

Purpose	▪ Reduce number of modules indirectly affected by changes
	▪ Tactics to implement the strategy
	  ▪ Maintain Interfaces
	  ▪ Hide Information
	  ▪ Open/Closed
	  ▪ Restrict Communication Paths
	  ▪ Use an Intermediary

Advantages	▪ Separation of interface and implementation ▪ More structured system ▪ More stable system
Drawbacks	▪ Difficulty of defining interfaces in advance

… more about strategies and tactics in Software Architecture in Practice

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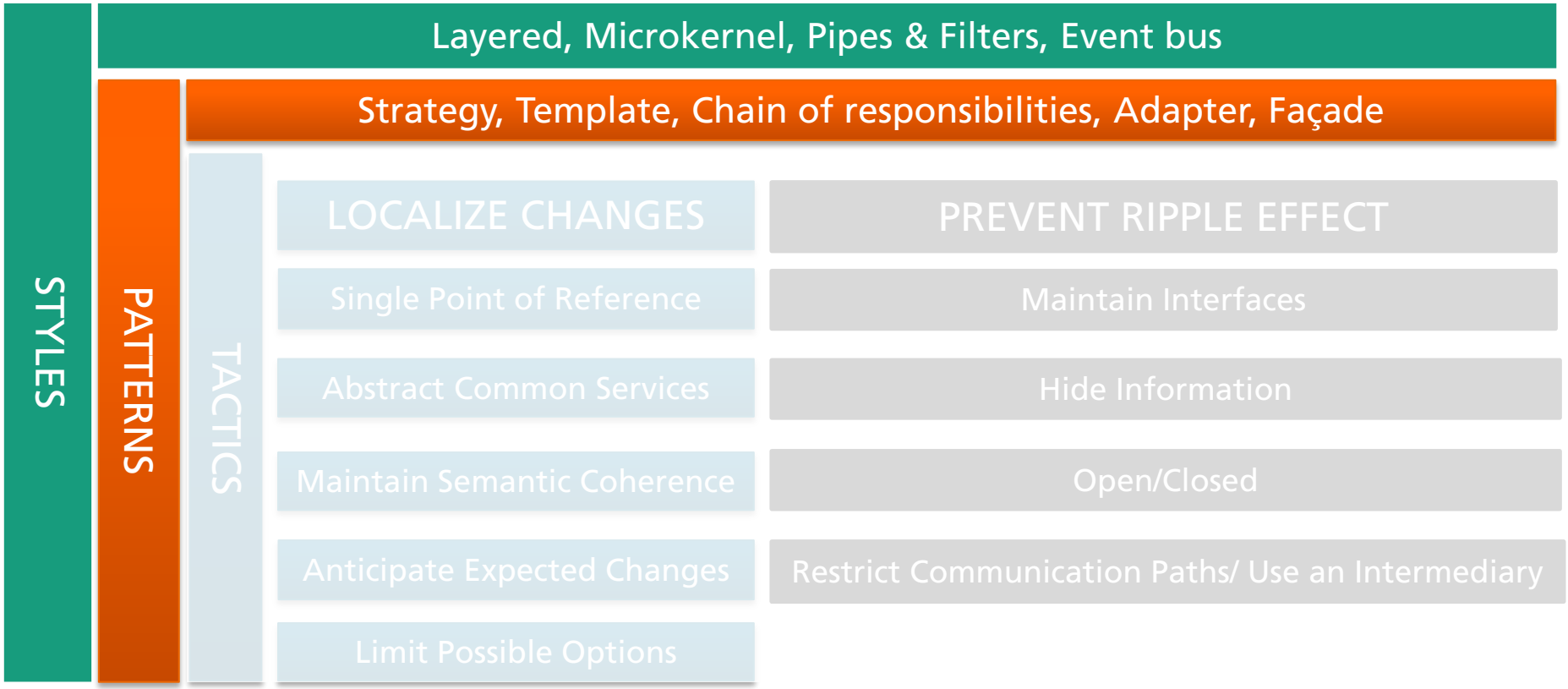
Maintainability Styles and patterns



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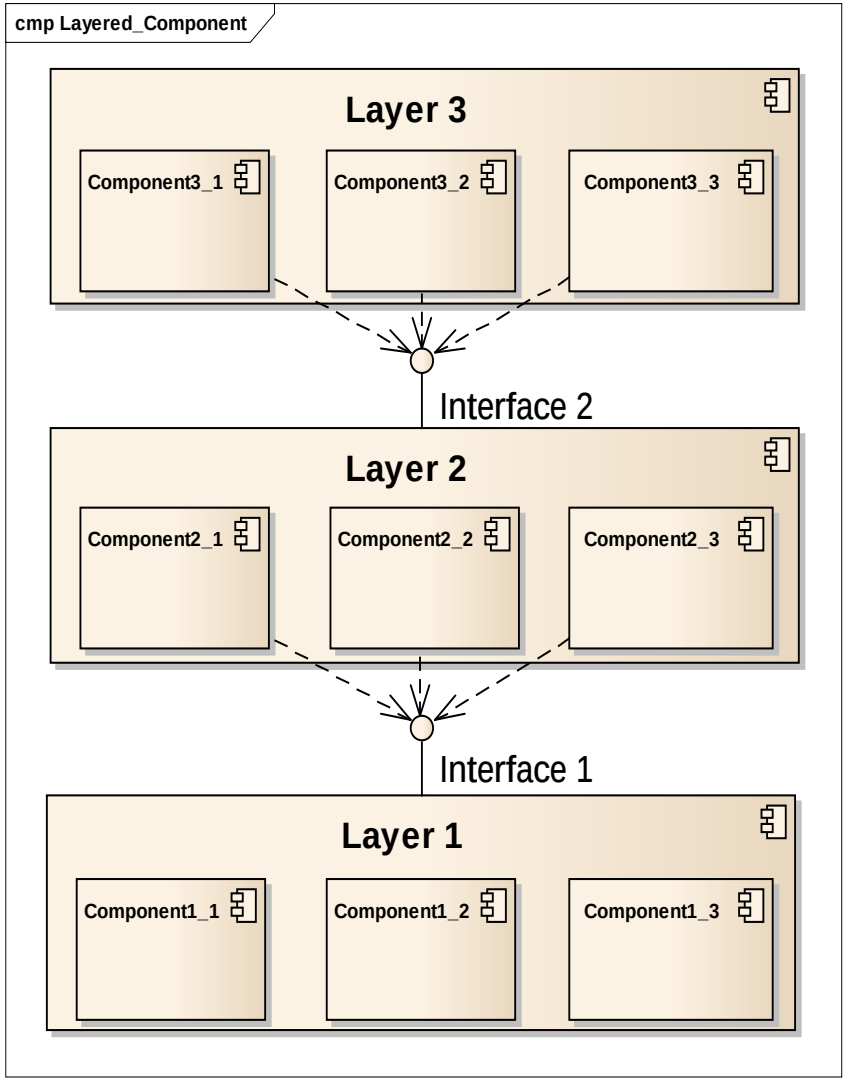
The Layered Style

- **Problem/Context**
  - System is decomposed into components
  - Components are defined at different abstraction levels
  - Components depend on each other
- **Solution**
  - Group components into ordered layers
  - Components in a layer may only use services from the layer below it
  - Communication over fixed interfaces



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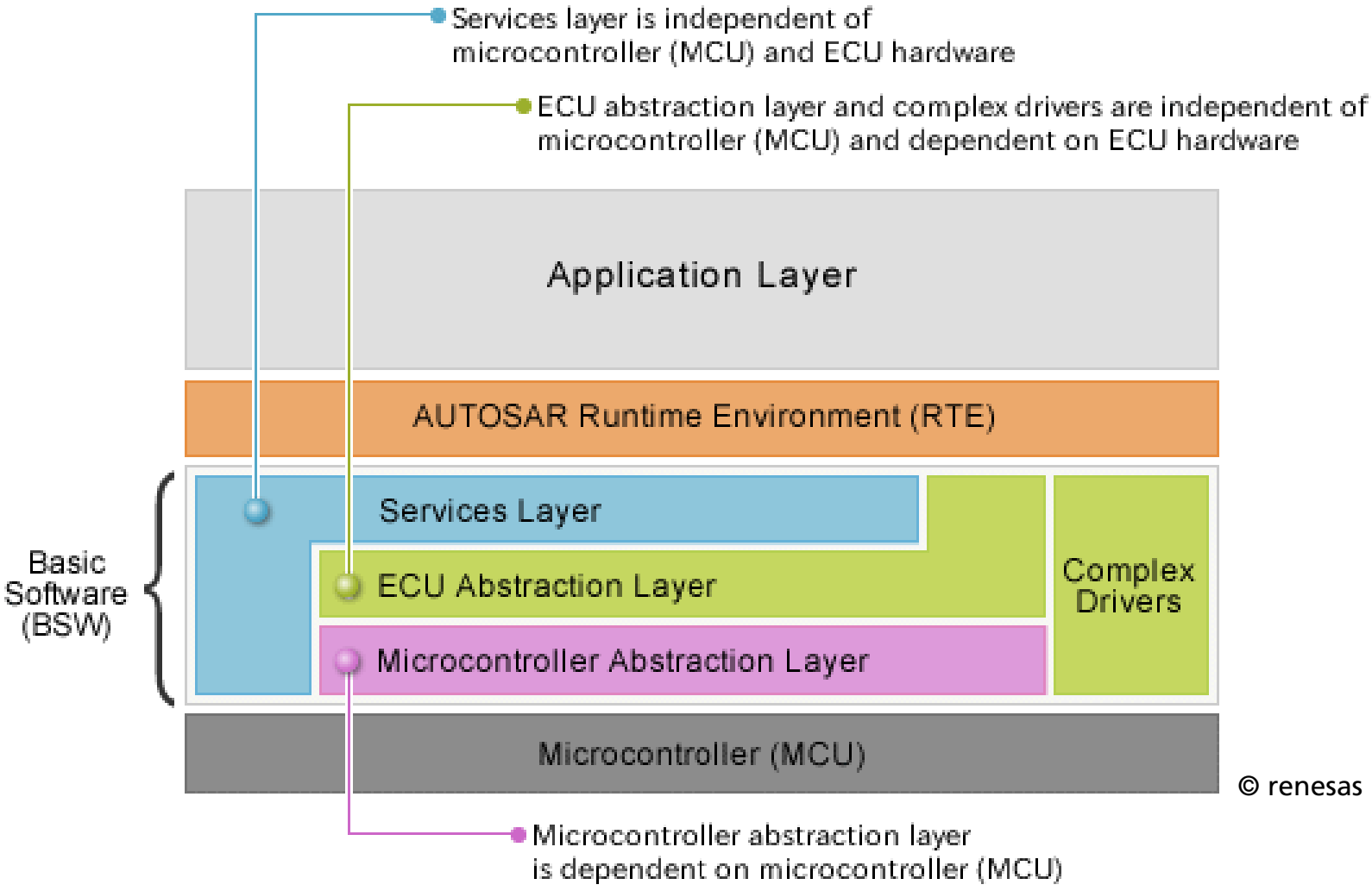
The Layered Style: Example AUTOSAR



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The Layered Style

- **Advantages**
  - Reuse of layers
  - Dependencies are kept local
  - Exchangeability of layer implementation
    (but external behavior must be the same, otherwise potential cascade of changing behavior)

- **Drawbacks**
  - Communication overhead
  - Difficulty to decide on granularity of a layer

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The Layered Style

Pattern ID	Layered
Problem/ Context	▪ System is decomposed into subtasks ▪ Subtasks are defined at different abstraction levels ▪ Subtasks depend on each other
Solution	▪ Group subtasks into ordered layers ▪ Subtasks in a layer may only use services from the layer below it ▪ Communication over fixed interfaces
Advantages	▪ Reuse of layers ▪ Dependencies are kept local ▪ Exchangeability of layer implementation
Drawbacks	▪ Cascade of changing behavior ▪ Communication overhead ▪ Difficulty to decide on granularity of a layer
Impact on Safety	▪ Improvement of safety in a layer trickles through it dependents. ▪ Difficulty handling mixed criticality when there is a high degree of dependencies in a layer. ▪ Safety mechanisms, e.g. failure detection/management, tend to crosscut across the functional layers. ▪ Layering overhead increase latencies and timing uncertainties.
Example	AUTOSAR, TCP/IP

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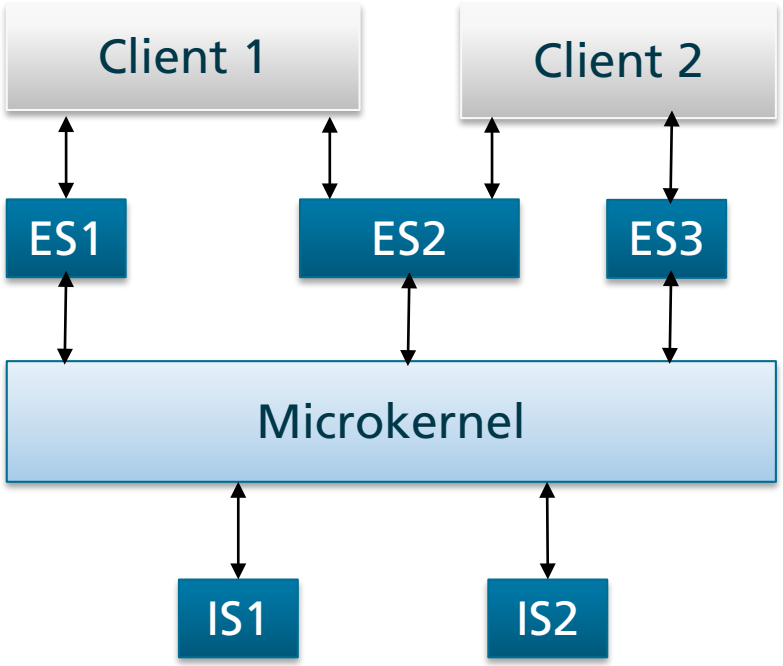
The Microkernel Style

- **Problem/Context**
  - Several applications use same core functionality
  - Core functionality implementation should be safe and maintainable
  - Core functionality is expected to remain stable
  - System should be still modifiable
- **Solution**
  - Separate a minimal functional core from extended services
  - Microkernel (stable, maintainable)
  - External services (application specific)
  - Internal services (platform specific)



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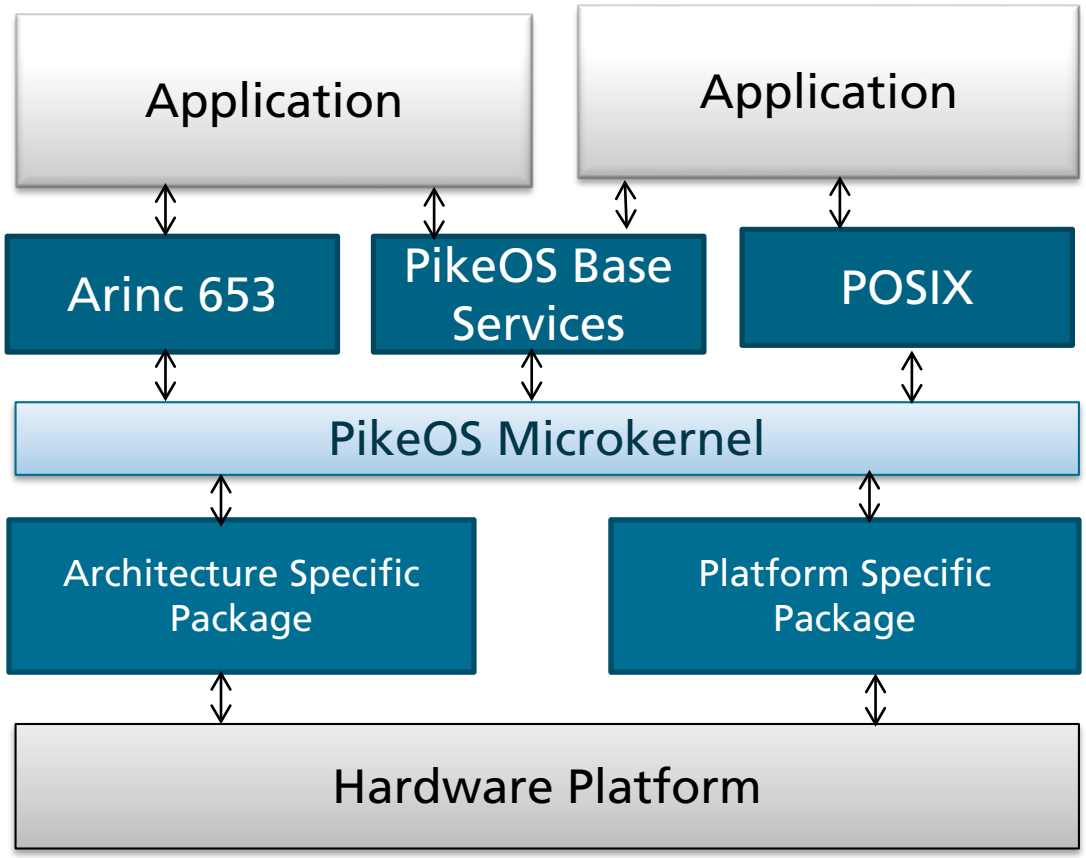
The Microkernel Style Example: PikeOS



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The Microkernel Style

- **Advantages**
  - Maintainable / modular
  - Ease of adding / removing services
  - Separation of policy and mechanisms
- **Drawbacks**
  - Performance decreases (compared to monolithic system)
  - Complexity of design and implementation increase

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The Microkernel Style

Pattern ID	Microkernel
Problem/ Context	▪ Several applications use same core functionality ▪ Core functionality implementation: safe and maintainable ▪ Core functionality is expected to remain stable ▪ System should be still modifiable
Solution	Separate a minimal functional core from extended functionality and customer-specific parts
Advantages	▪ Maintainable / modular ▪ Ease of adding / removing services ▪ Separation of policy and mechanisms
Drawbacks	▪ Performance decreases (compared to monolithic system) ▪ Complexity of design and implementation increase
Impact on Safety	▪ Minimum code base eases qualification. ▪ Reuse of certified kernels. ▪ Expand upon infrastructural safety mechanisms (e.g. safety kernel). ▪ Common cause of failures / single point of failure of kernel.
Example	PikeOS, EB tresos Safety OS, Linux Kernel,…

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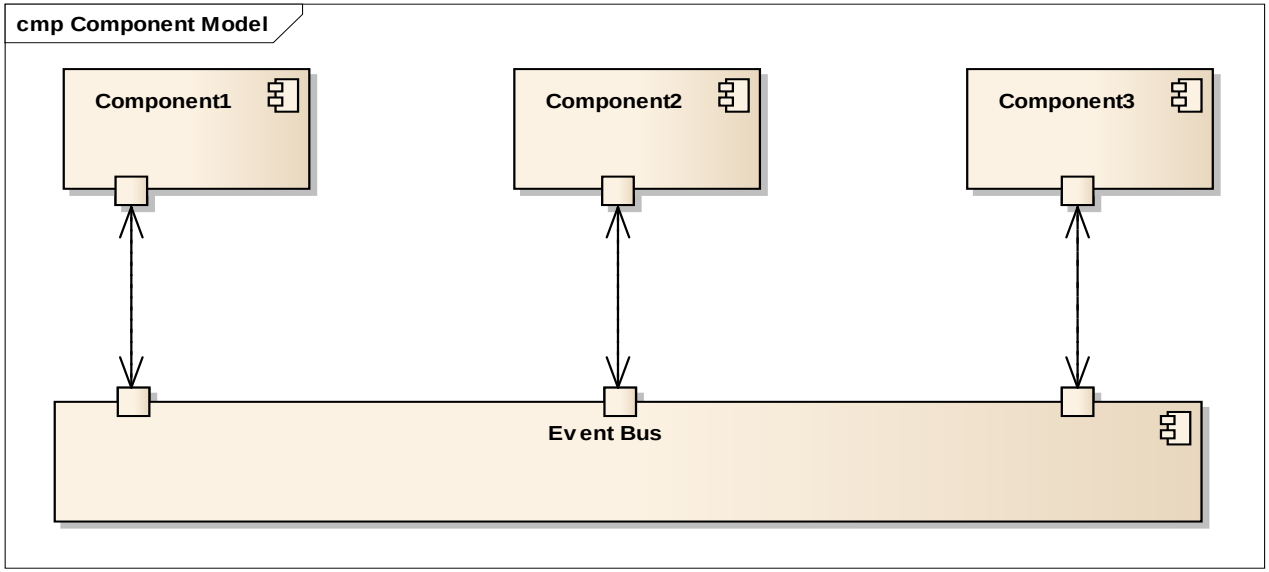
The Event-Bus Style

- **Problem/Context**
  - Distributed system where many components communicate
  - Connections between each communicating component not feasible/ desirable

- **Solution**
  - Components asynchronously emit and receive events over event busses
  - Components communicate with the event-bus, not directly with each other



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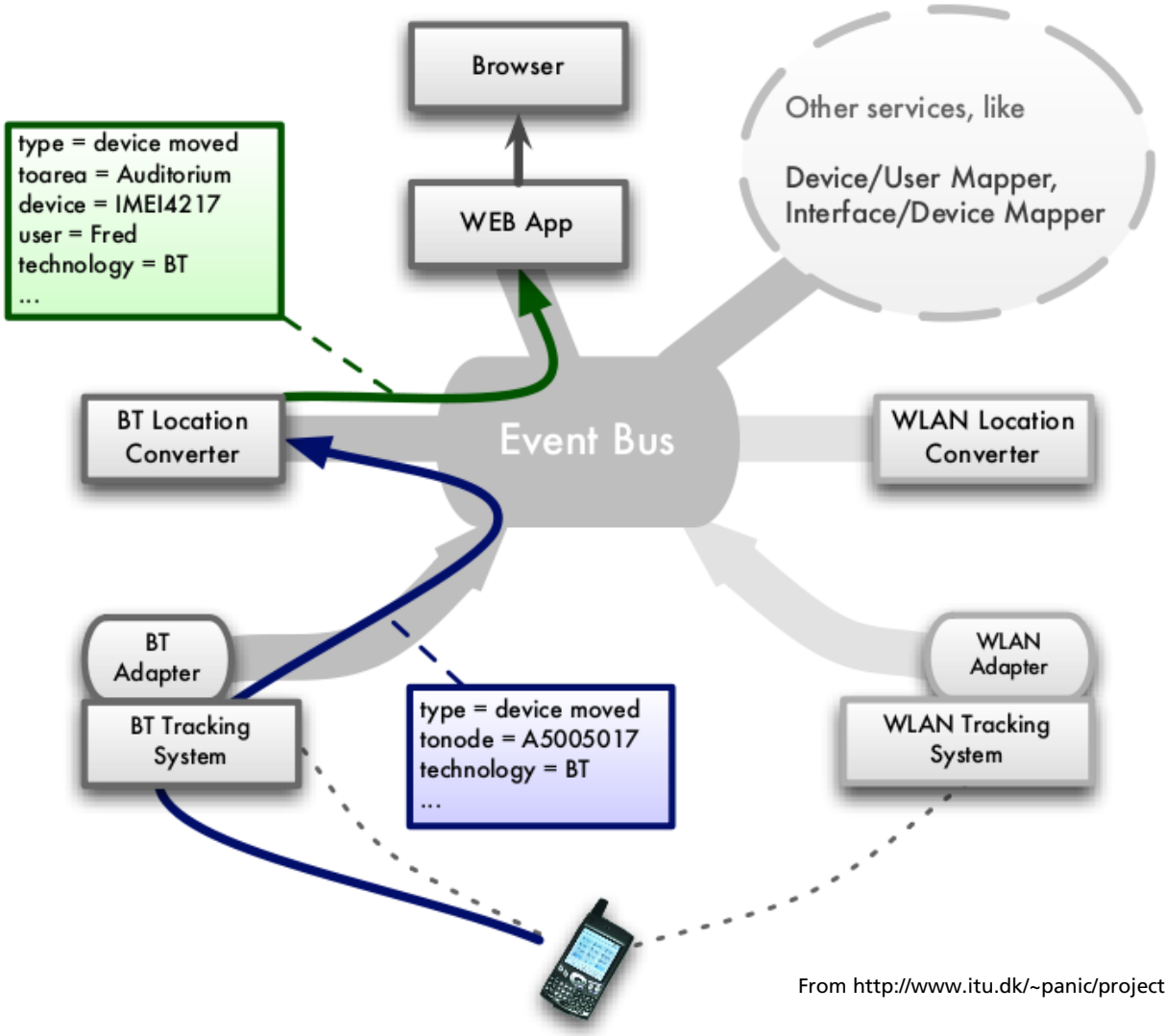
The Event-Bus Style Example: Android



From http://www.itu.dk/~panic/projects/SeamlessTracking.html

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The Event-Bus Style

- **Advantages**
  - Easy to add new components to the system
- **Drawbacks**
  - No guarantee that a message arrives at the destination
  - Message delay possible

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The Event-Bus Style

Pattern ID	Event-Bus
Problem	▪ Distributed system where many components communicate ▪ Connections between each communicating component not feasible
Solution	▪ Components asynchronously emit and receive events over event busses ▪ Components communicate with the event-bus, not with each other
Advantages	▪ Easy to add new components to the system
Drawbacks	▪ No guarantee that a message arrives at the destination ▪ Message delay possible
Impact on Safety	▪ Entry point for hooking safety mechanisms to failure events ▪ Separates failure detection from failure recovery. ▪ Manage redundancies using activation/deactivation events. ▪ Dynamic execution complicates analysis. ▪ CCF/SPF of the bus.
Example	Satellite constellation communication, Event Bus in android

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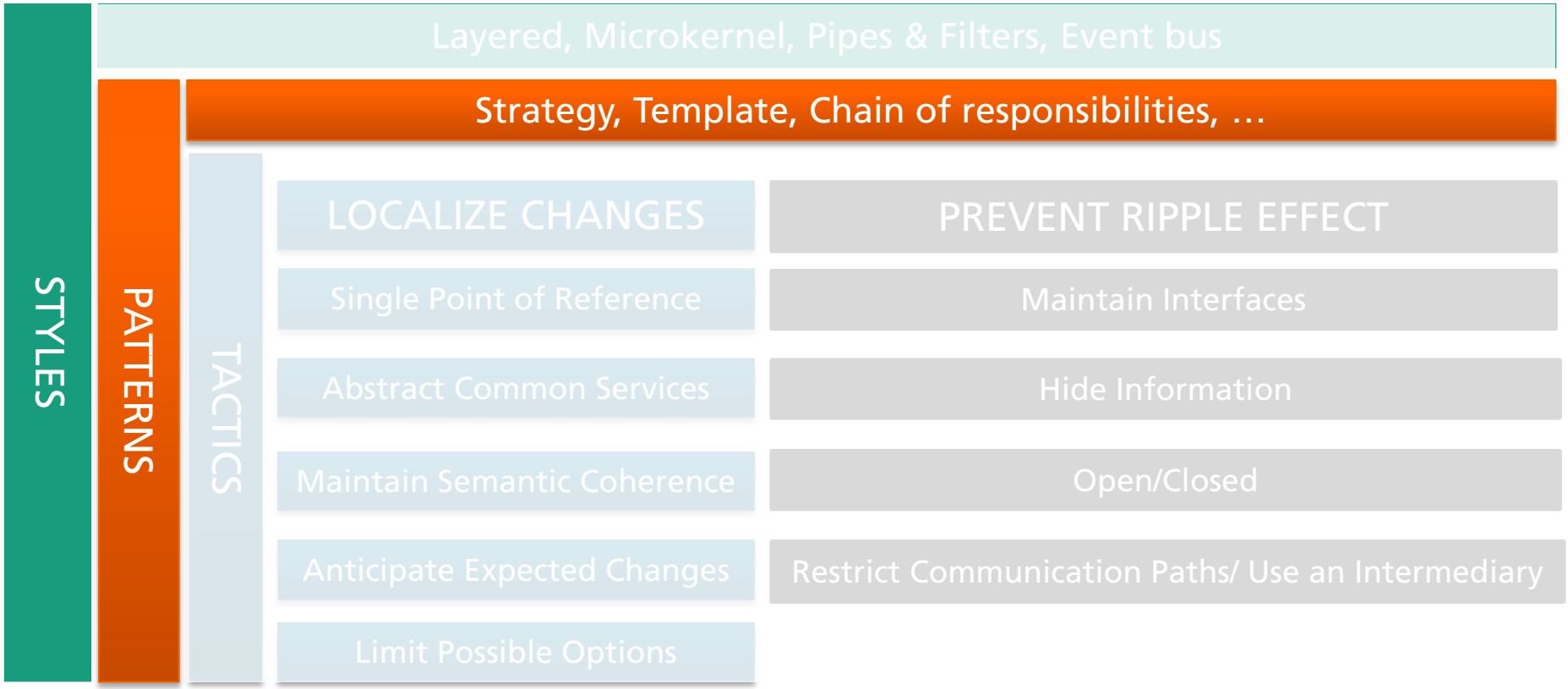
Styles and patterns



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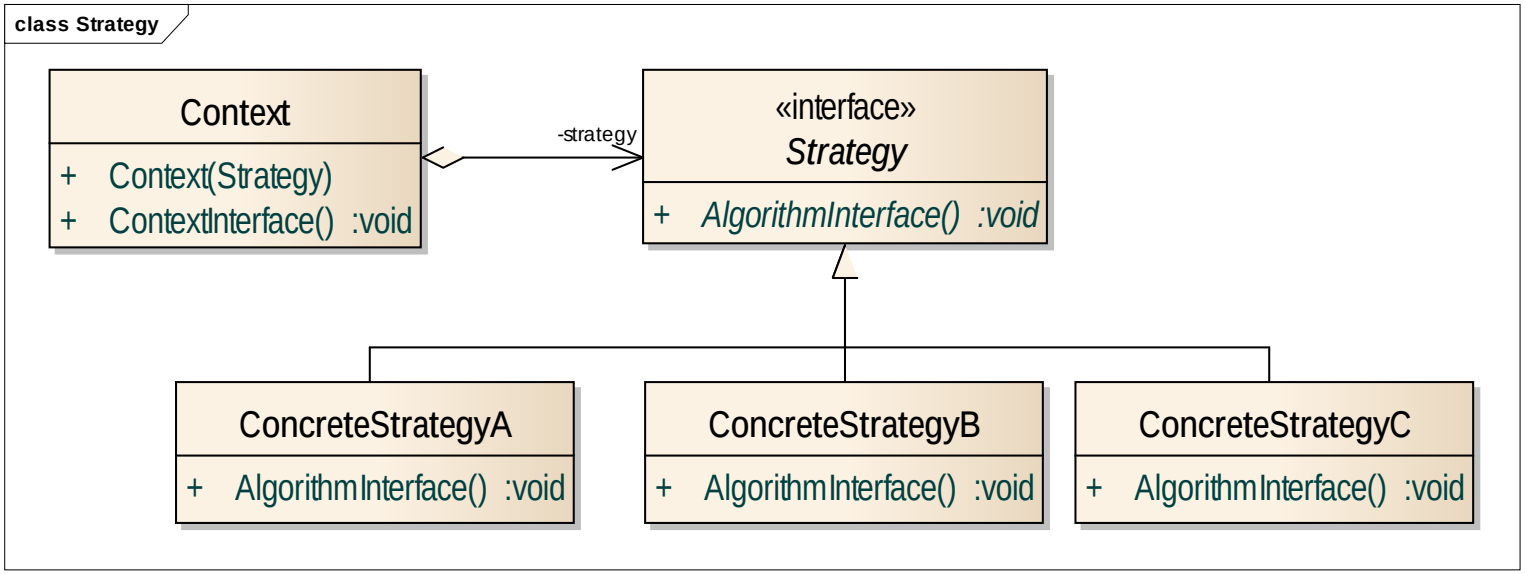
The Strategy Pattern

- **Problem**
  - Different variants of an algorithm are needed
  - Selection of variant depends on the context
- **Solution**
  - Define an interface for a family of algorithms to make them interchangeable



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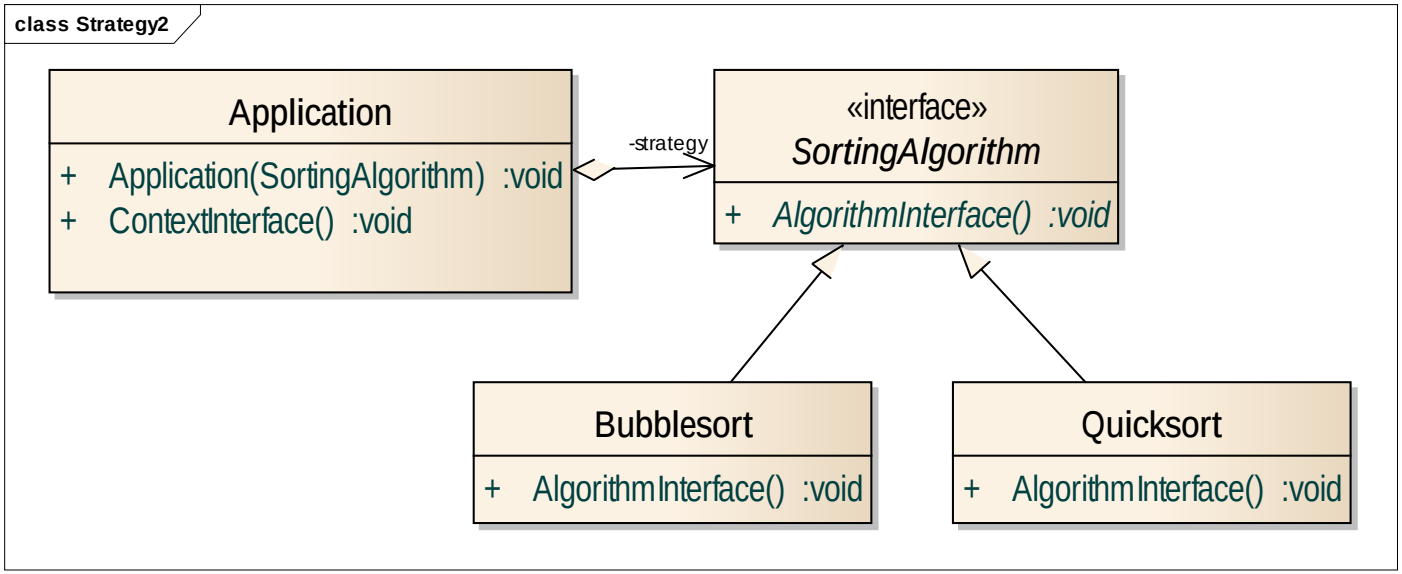
The Strategy Pattern Example: Sorting Algorithm



- Bubble Sort: (-) slower (+) no additional memory
- Quick Sort : (+) faster (–) additional memory
- Compile time instantiation: depending on system properties
- Runtime instantiation: depending on currently available memory

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The Strategy Pattern

- **Advantages**
  - Strategies can provide different implementations of the same behavior with a clean interface
  - Client can choose among implementations with different time and space trade-offs
  - Strategy eliminates conditional statements that are hard to maintain
  - Strategies can be selected at runtime

- **Drawbacks**
  - Client code must be aware of different strategies
  - Strategies should implement **same** behavior, otherwise functional outcome depends on instantiation and the overall behavior is hard to predict
  - Communication overhead

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The Strategy Pattern

Pattern ID	Strategy
Problem	▪ Different variants of an algorithm are needed ▪ Selection of variant depends on the context
Solution	▪ Define an interface for a family of algorithms to make them interchangeable
Advantages	▪ Strategies can provide different implementations of the same behavior with a clean interface ▪ Client can choose among implementations with different time and space trade-offs ▪ Strategy eliminates conditional statements that are hard to maintain ▪ Strategies can be selected at runtime
Drawbacks	▪ Client code must be aware of different strategies ▪ Strategies should implement same behavior, otherwise functional outcome depends on instantiation ▪ Communication overhead
Impact on Safety	▪ Entry point for expressing (safe) mode-dependent algorithms as different strategies. ▪ Eases qualification by facilitating a per-strategy (e.g. per-mode) safety analysis. ▪ Dynamic execution binding complicates analysis.
Example	Selecting sorting functions based on free memory availability

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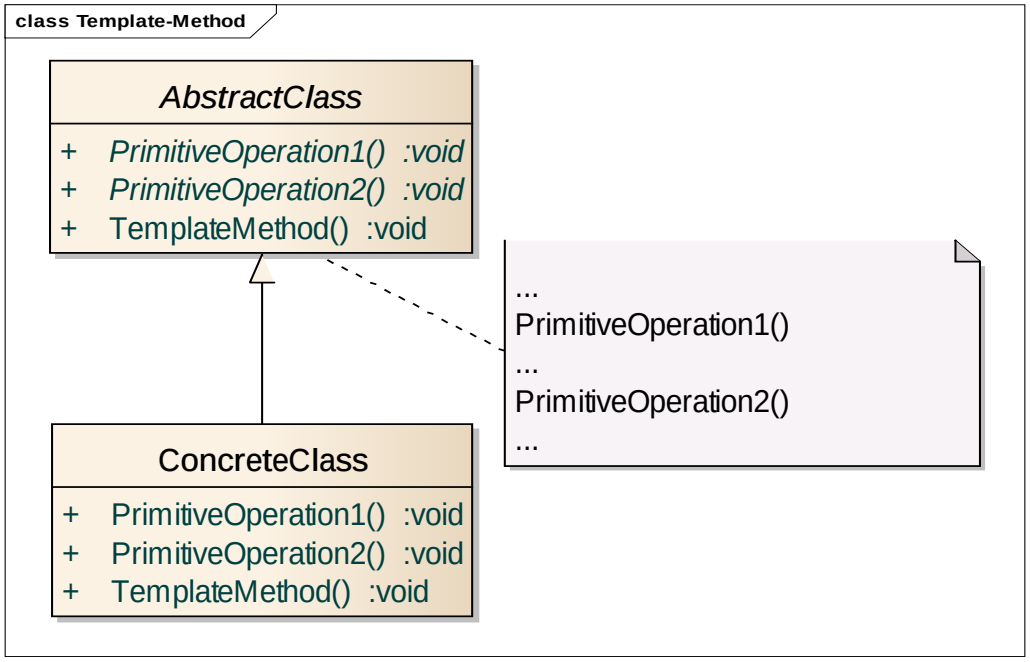
The Template Method Pattern

- **Problem**
  - Different variants of an algorithm are needed
  - Variants differ only in small steps
- **Solution**
  - Define a skeleton of an algorithm in a function, deferring some steps to other functions that may vary



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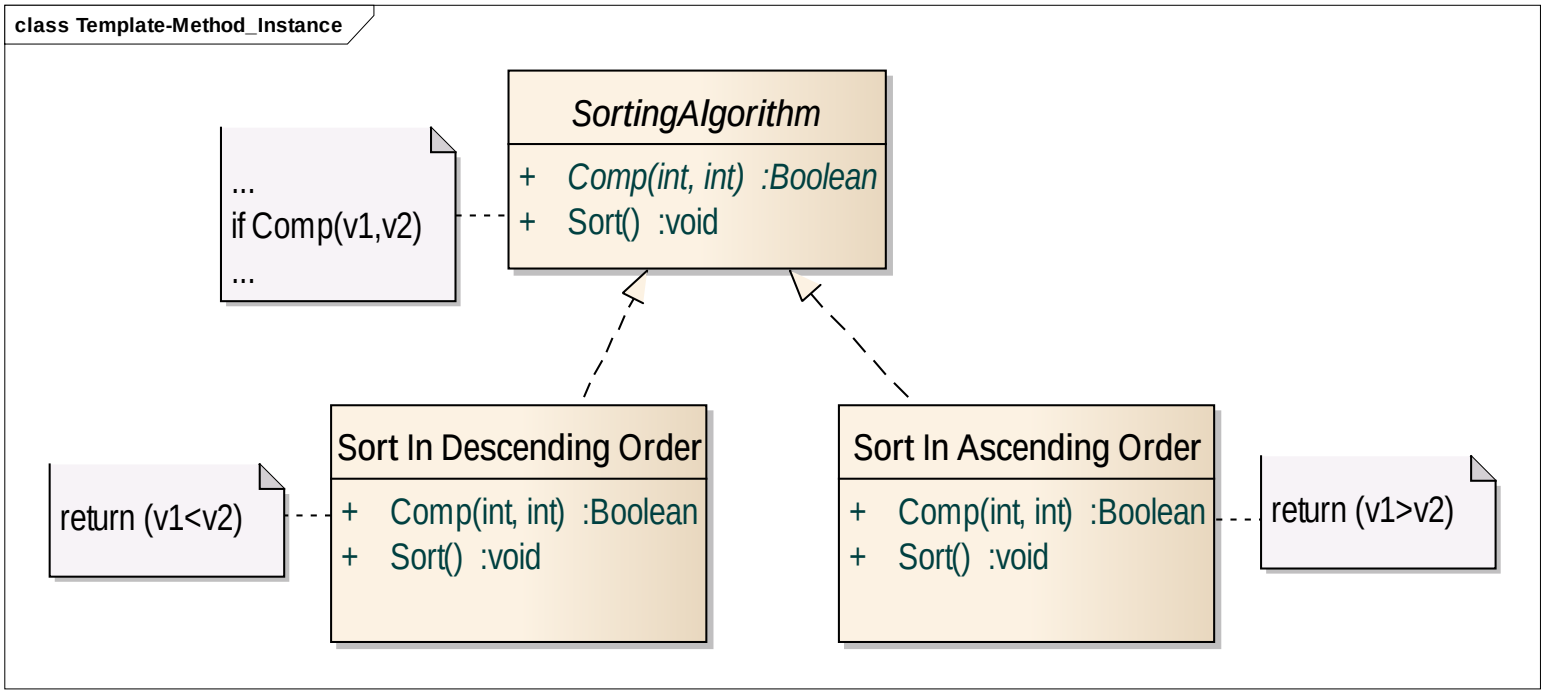
The Template Method Pattern Example: Sorting



- Difference to Strategy
  - in scope: strategy replaces whole algorithm, template-method only parts
  - intention: strategy intended to select algorithm, template-method to build
- Concrete strategies may be implemented using template-method !

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The Template Method Pattern

- **Advantages**
  - Template Method eliminates conditional statements that are hard to maintain
  - Supports Code Reuse
- **Drawbacks**
  - Must be well documented, otherwise hard to understand

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The Template Method Pattern

Pattern ID	Template Method
Problem	▪ Different variants of an algorithm are needed ▪ Variants differ only in small steps
Solution	Define a skeleton of an algorithm in a function, deferring some steps to other functions that may vary
Advantages	▪ Template method eliminates conditional statements that are hard to maintain ▪ Supports code reuse
Drawbacks	Must be well documented, otherwise hard to understand
Impact on Safety	n.a.
Example	Sorting in descending/ascending order

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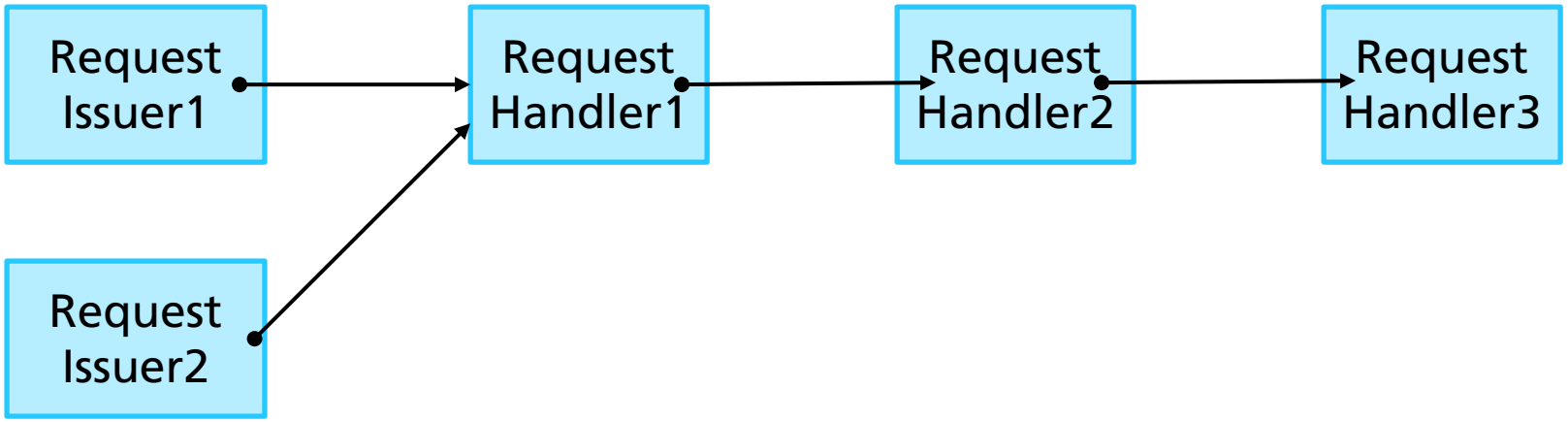
The Chain of Responsibility Pattern

- **Problem**
  - A request (like error handling) is issued but it is unclear at which part of the system the request should be handled
- **Solution**
  - Request are passed along a chain of possible handlers until one handles it



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Request Communication Path

The Chain of Responsibility Pattern Example: Satellite Fault Management

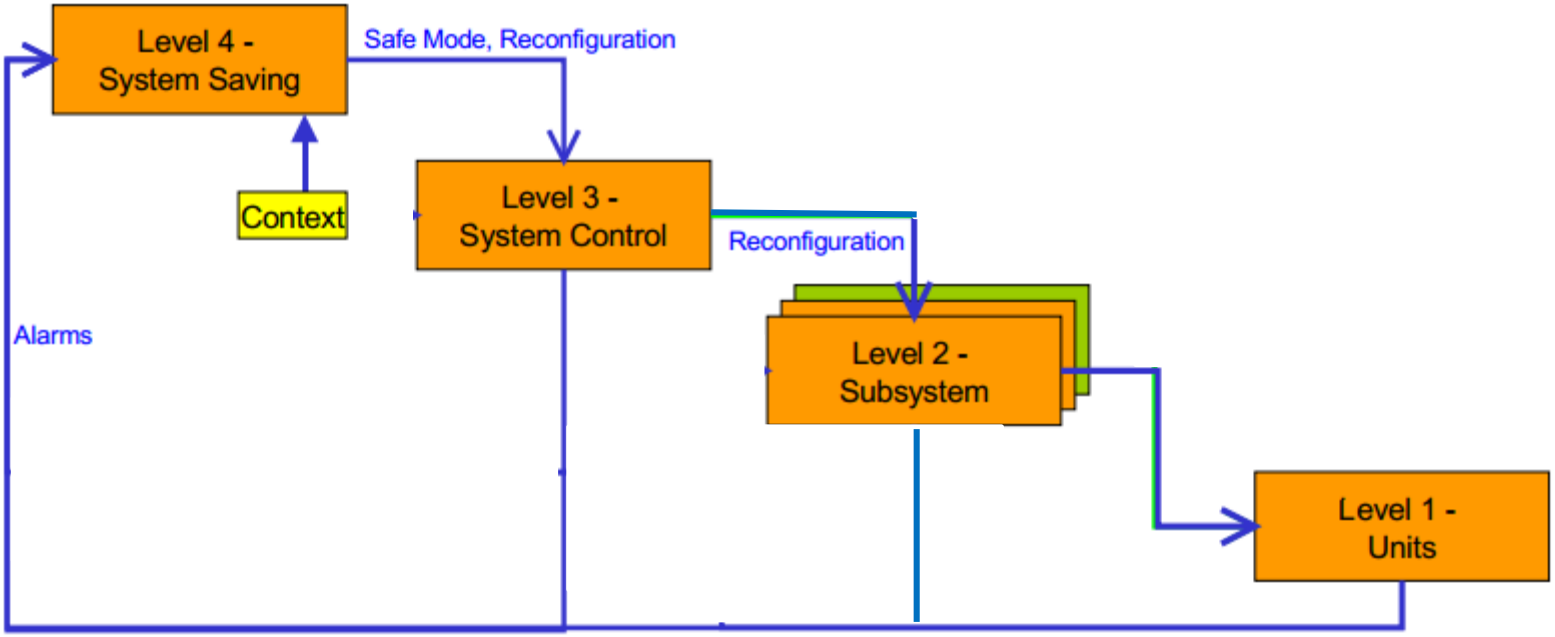

Figure 4: FDIR Hierarchical Breakdown

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The Chain of Responsibility Pattern

- **Advantages**
  - Reduced coupling
  - Added flexibility for handling requests
- **Drawbacks**
  - No guarantee that request is handled if not pre-planned

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The Chain of Responsibility Pattern

Pattern ID	Chain of Responsibility
Problem	A request (like error handling) is issued but it is unclear at which part of the system the request should be handled
Solution	Request are passed along a chain of possible handlers until one handles it
Advantages	▪ Reduced coupling ▪ Added flexibility for handling requests
Drawbacks	No guarantee that request is handled if not pre-planned
Impact on Safety	▪ Organizational scheme for managing failures across crosscutting abstractions or levels, i.e. classical way for implementing fault management. ▪ Dynamic execution binding complicates analysis.
Example	Satellite fault management

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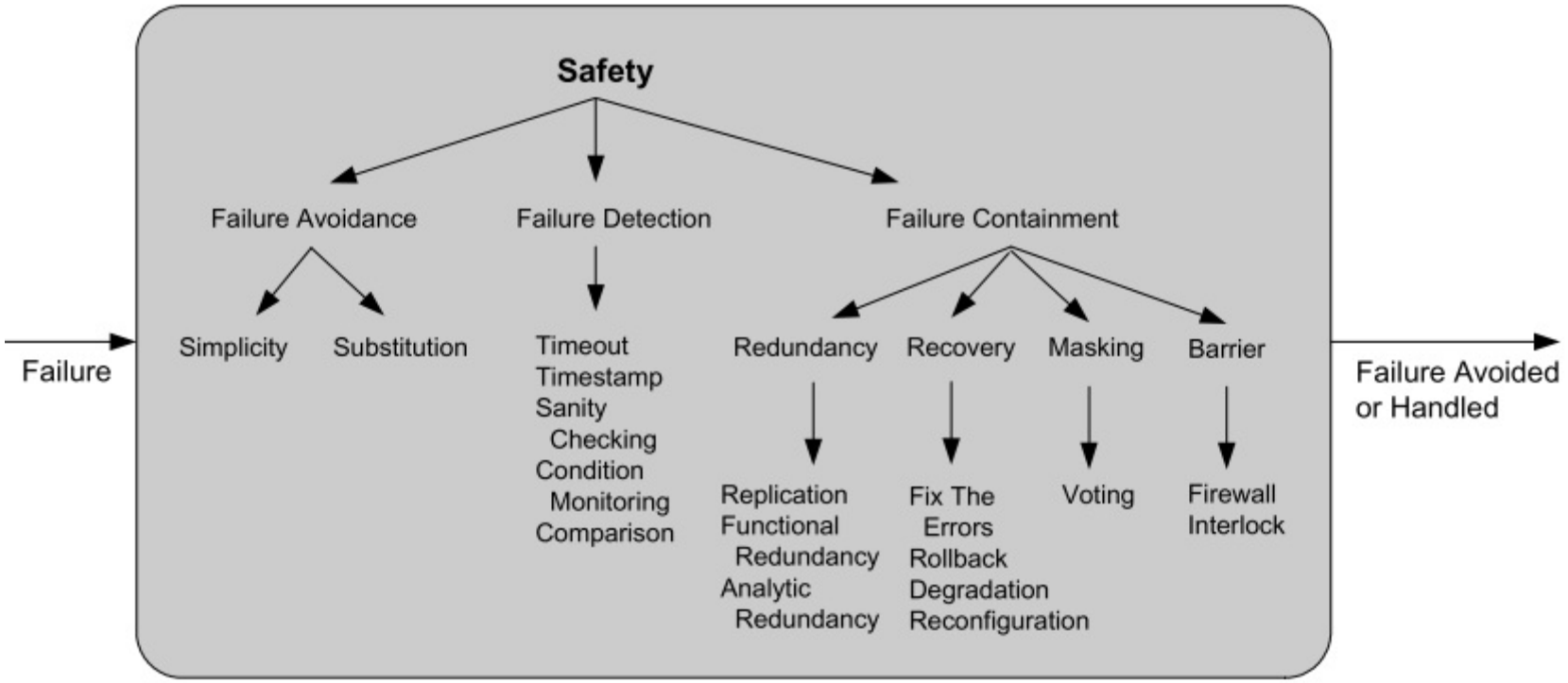
Safety

Safety Tactics



Safety Tactics for Software Architecture Design
W. Wu and T. Kelly

Safety Pattern

Redundancy

- Homogeneous Redundancy
- Triple Modular Redundancy

Pattern for Error Detection

- Monitor-Actuator Pattern
- Watchdog

Achieving Quality Attributes

Redundancy

- Homogeneous Redundancy
- Triple Modular Redundancy

Pattern for Error Detection

- Monitor-Actuator Pattern
- Watchdog

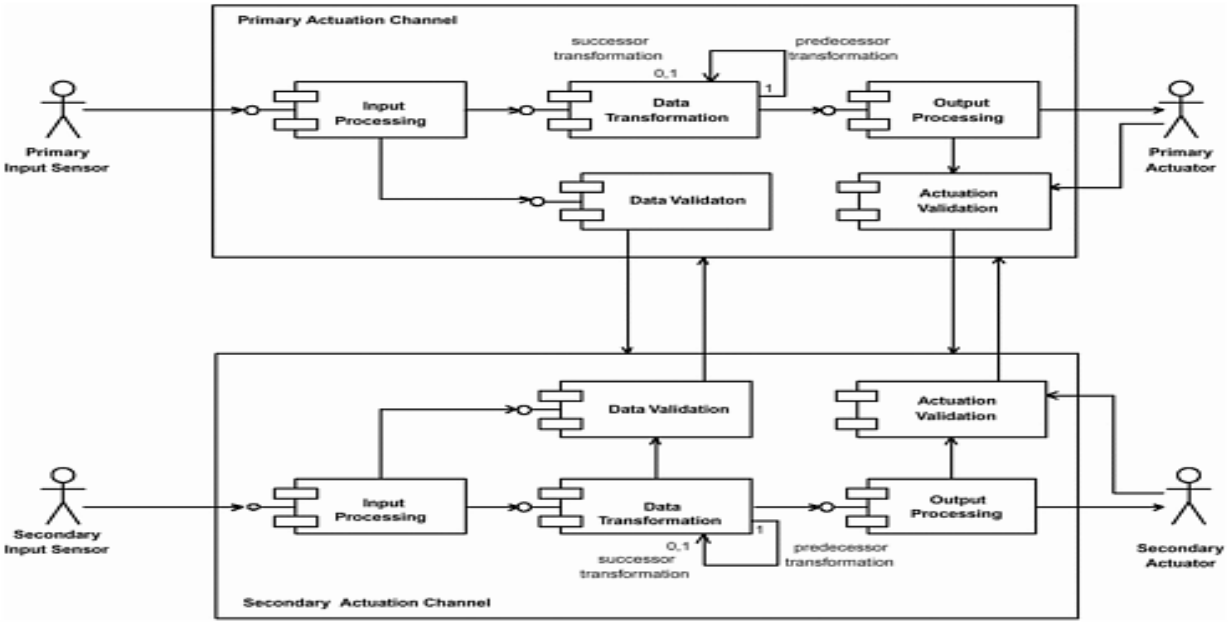
Homogeneous Redundancy Pattern (1/3)

"An obvious approach to solving the problem of things breaking is to provide multiple copies of that thing." B.P. Douglass

Pattern goal

- Improve reliability by offering multiple channels that can operate in sequence or in parallel.

Homogeneous Redundancy Pattern (2/3)



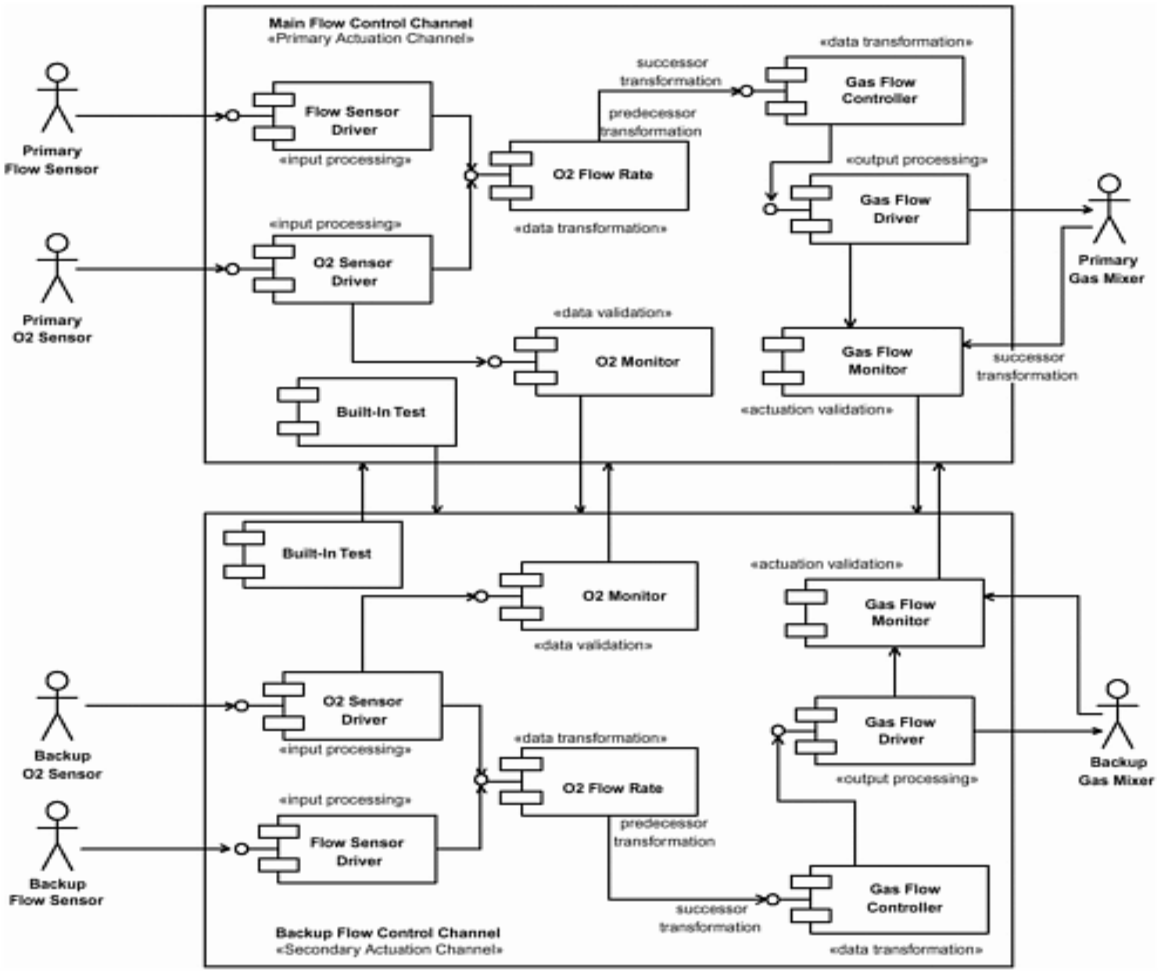
Solution

- Improves reliability by addressing random faults (failures) in the system execution.

Drawback

- Any systematic fault in one copy of the system is replicated in its clones, thus, not proving, protection against systematic faults (errors).

Homogeneous Redundancy Pattern (3/3)



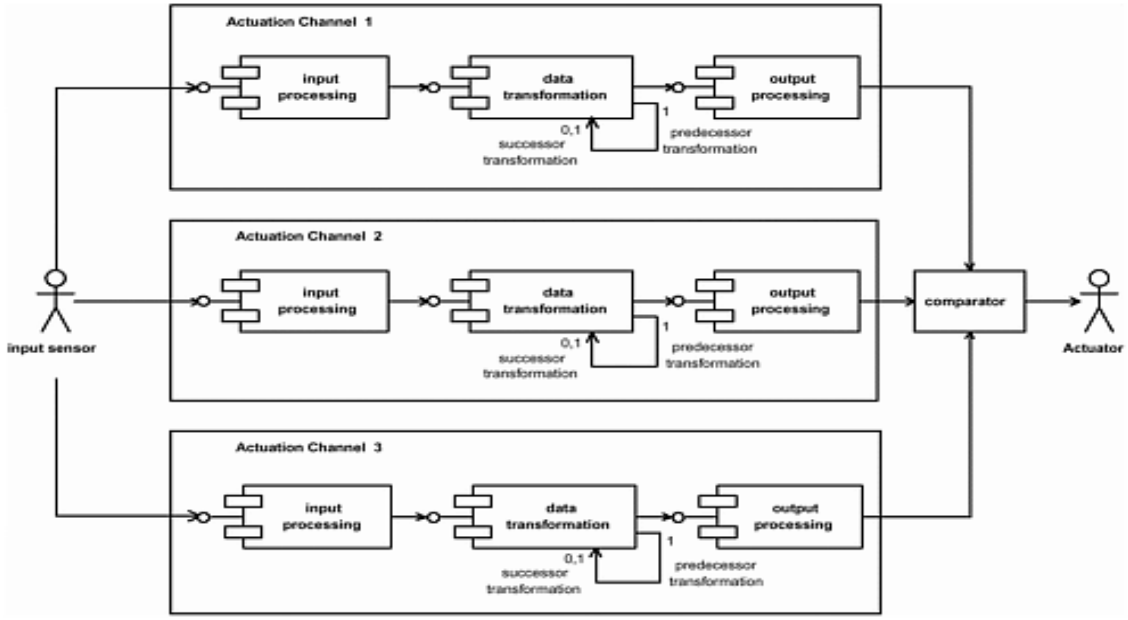
Triple Modular Redundancy (1/2)

Pattern goal

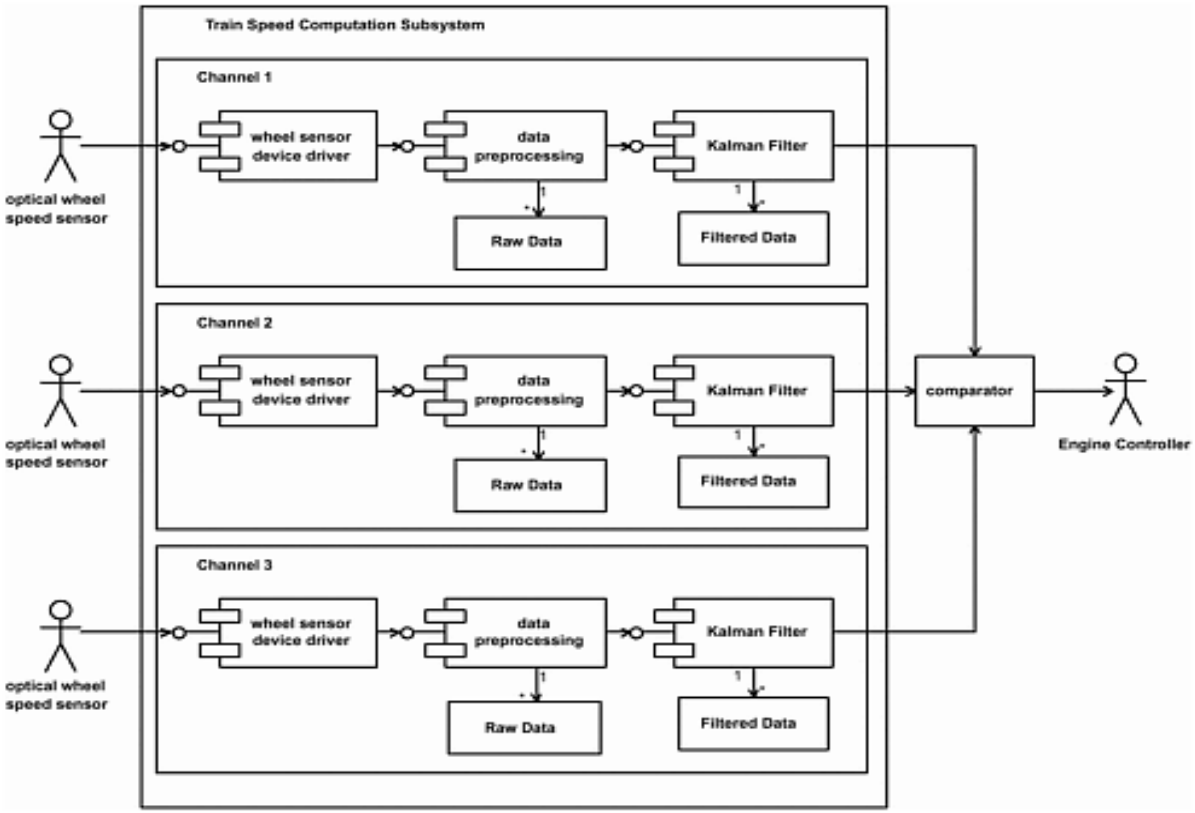
- Enhance reliability and safety in situations where there is no **fail-safe state**.

Solution

- Odd number of channels operating in parallel, each in effect checking the results of all the others.
- The computational results or resulting actuation signals are compared, and if there is a disagreement, then a *"two-out-of-three majority wins"* policy is invoked.



Triple Modular Redundancy (2/2)



Drawbacks

- High recurring cost because the hardware and software in the channels must be replicated.

Achieving Quality Attributes

Redundancy

- Homogeneous Redundancy
- Triple Modular Redundancy

Tactics for Error Detection

- Monitor-Actuator Pattern
- Watchdog

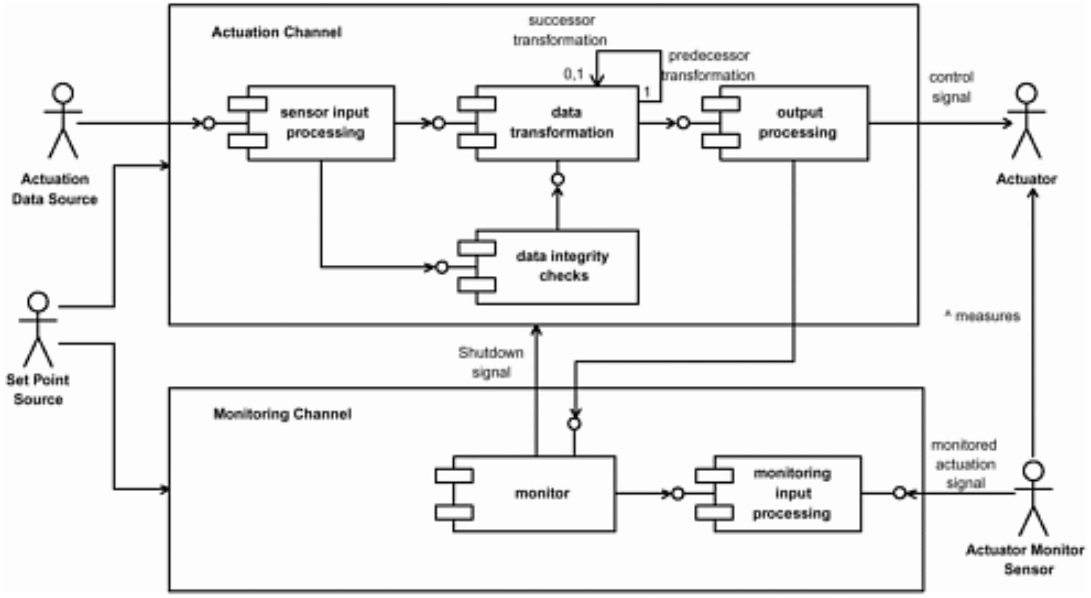
Monitor-Actuator (1/2)

Pattern goal

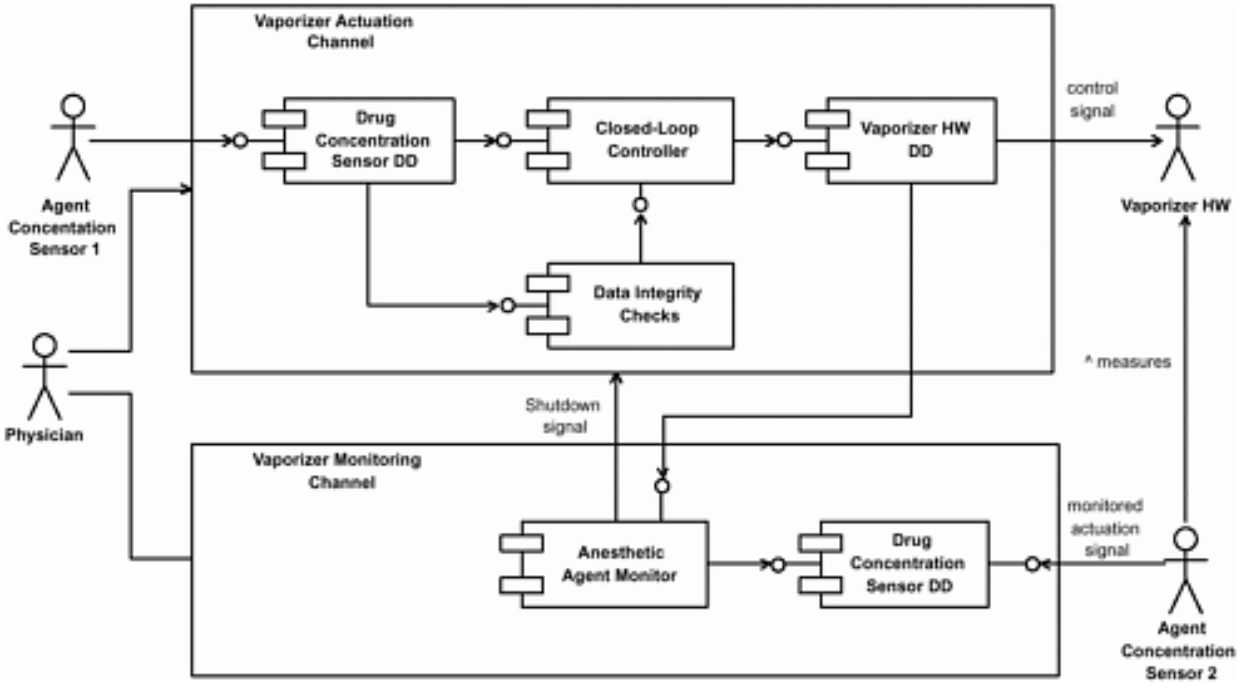
- Improve safety in a system with moderate to low availability requirements at a low cost.

Solution

- Redundant channel differs from the primary actuation channel by providing monitoring.
- *Monitor* maintains a watch on the actuation channel looking for an indication that the system should be commanded into its fail-safe state.



Monitor-Actuator (2/2)



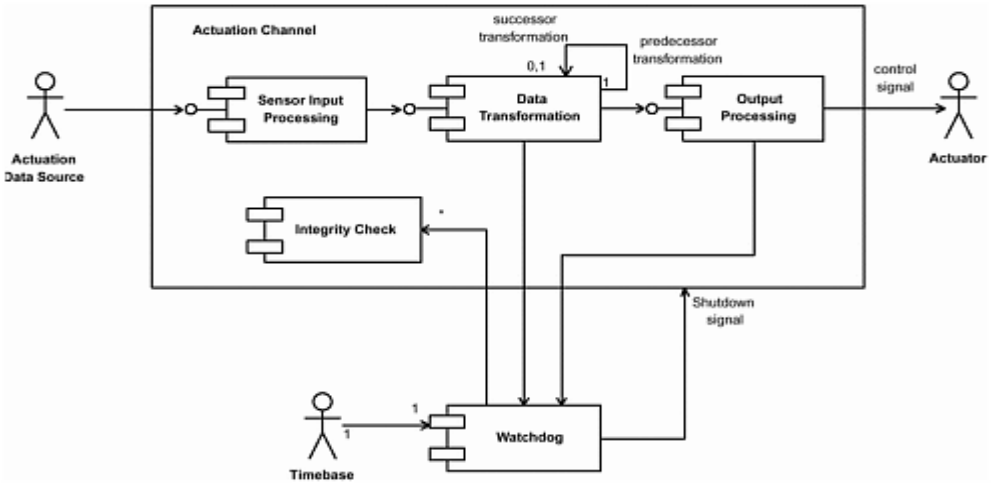
Drawback

- Because there is minimal redundancy, the system cannot continue to function when a fault is identified.

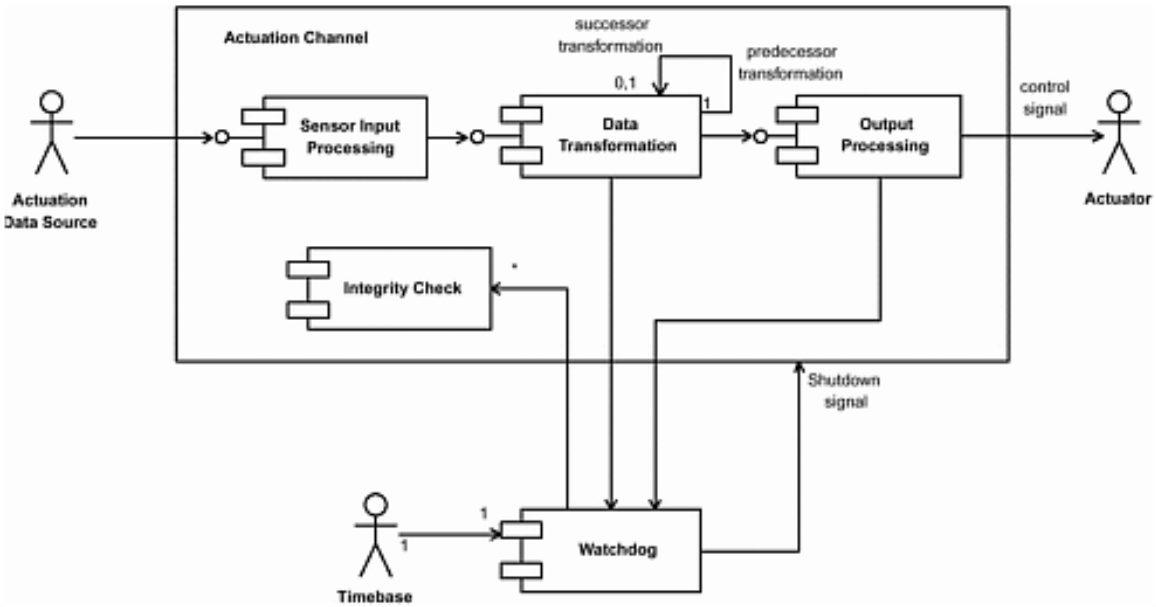
Watchdog (1/3)

Pattern goal

- Checks that the internal computational processing is proceeding as expected.
  - Check a computation timebase;
  - Ensure that computation steps are proceeding in a predefined order.



Watchdog (2/3)



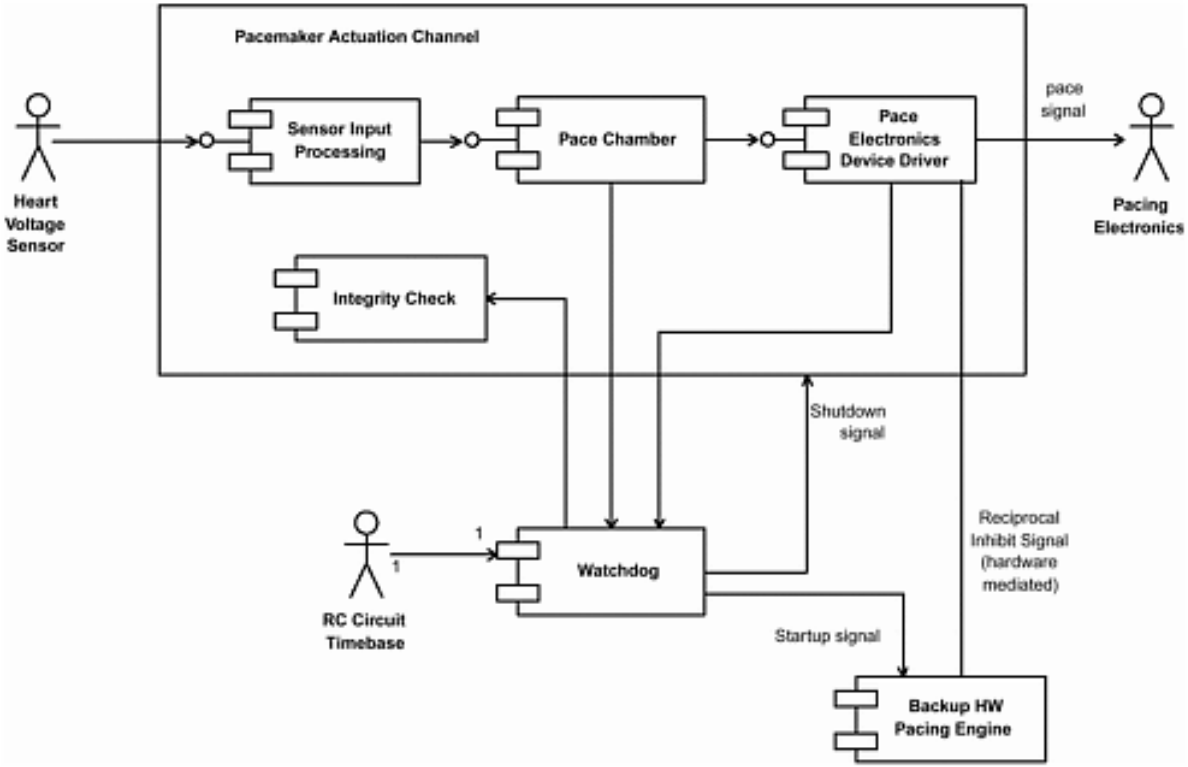
Solutions

- Watches out over processing of another component, ensuring that nothing is *obviously* wrong.
- The *Actuator Channel* operates independently of the watchdog, often sending a *liveness* message to the watchdog.

Drawback

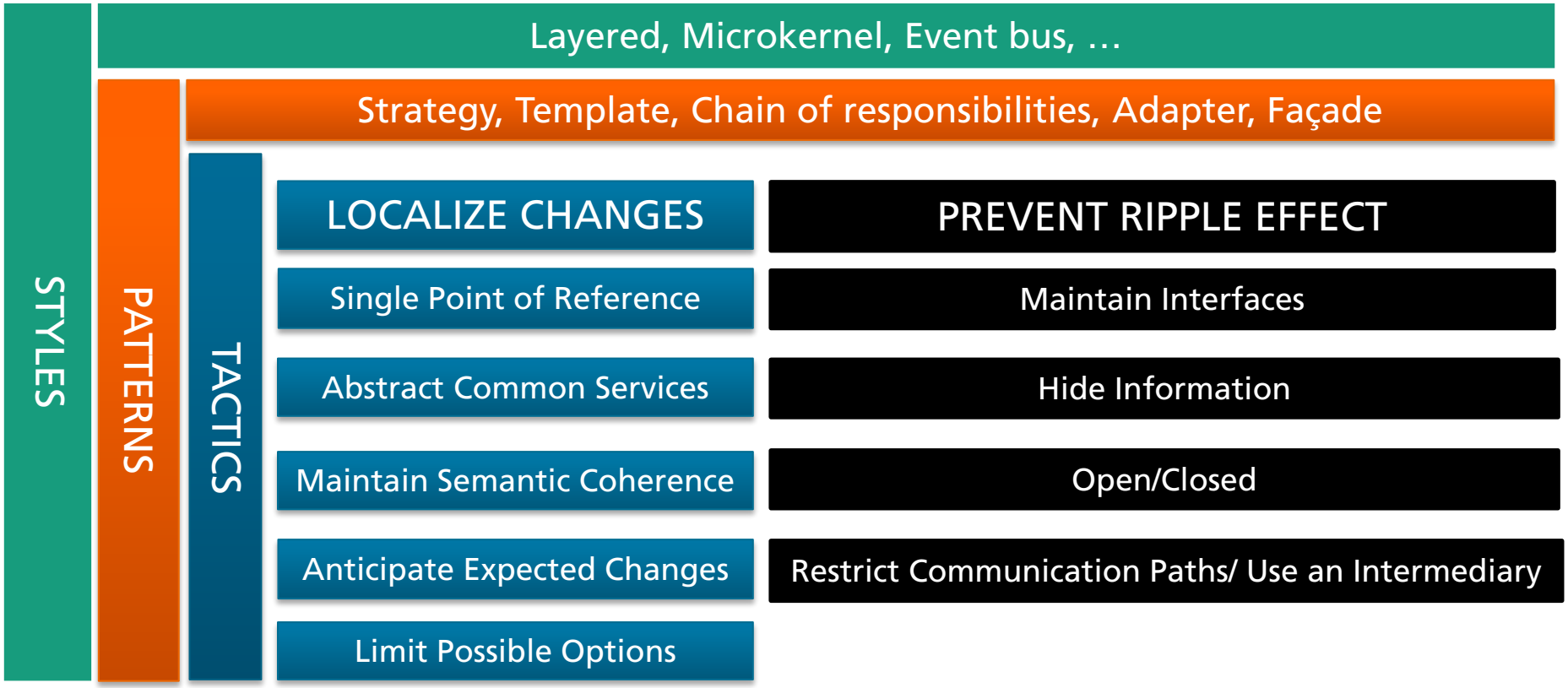
- Because of the minimal coverage of the Watchdog Pattern, it is rarely used alone, but combined with other tactics.

Watchdog (3/3)

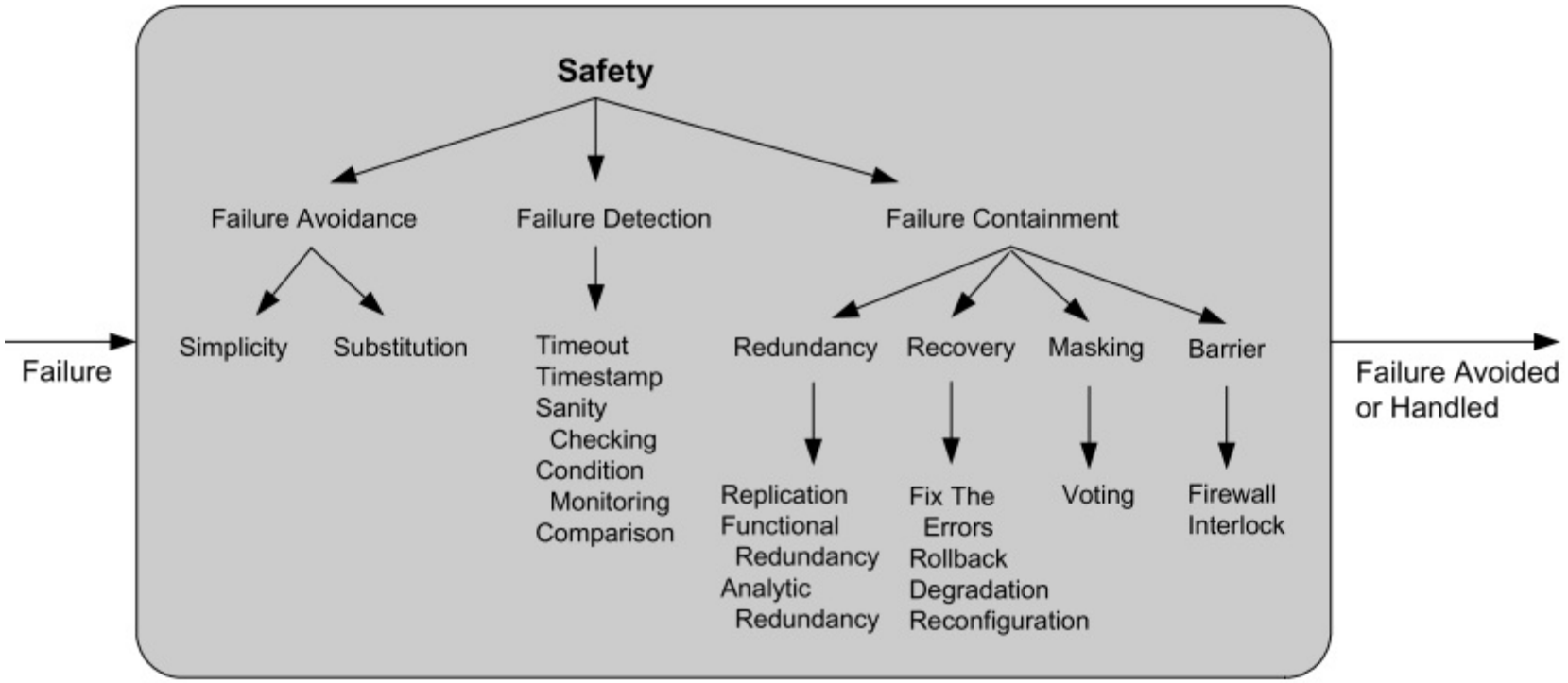

Pacemaker Actuation Channel
Heart Voltage Sensor
Sensor Input Processing
Pace Chamber
Pace Electronics Device Driver
pace signal
Pacing Electronics
Integrity Check
Shutdown signal
RC Circuit Timebase
1
1
Watchdog
Reciprocal Inhibit Signal (hardware mediated)
Startup signal
Backup HW Pacing Engine

Wrap Up

Architecture Tactics, Styles and Patterns: Maintainability



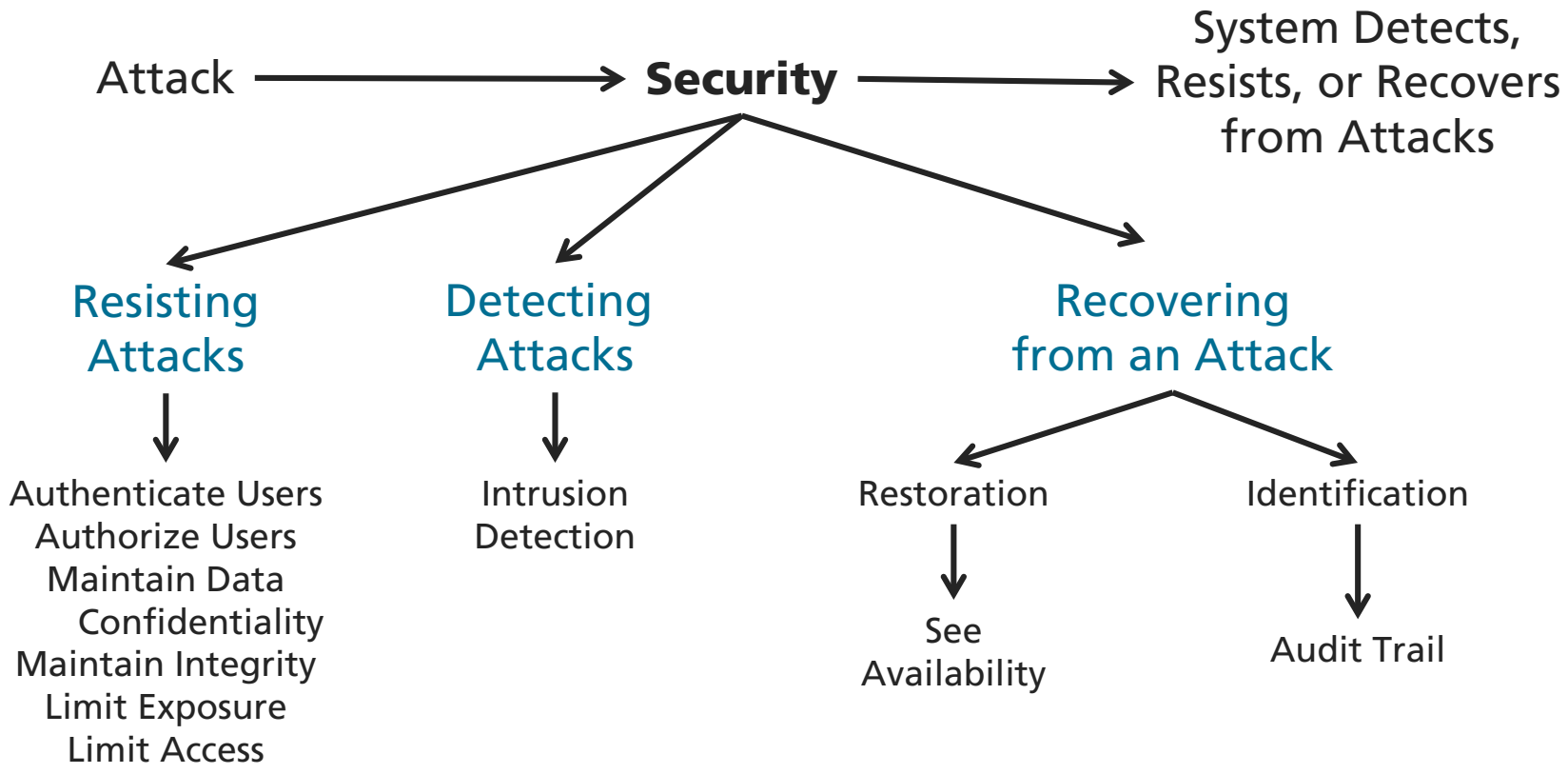
Safety Tactics



Safety Tactics for Software Architecture Design
W. Wu and T. Kelly

Tactics for other Quality Attributes

Security Tactics



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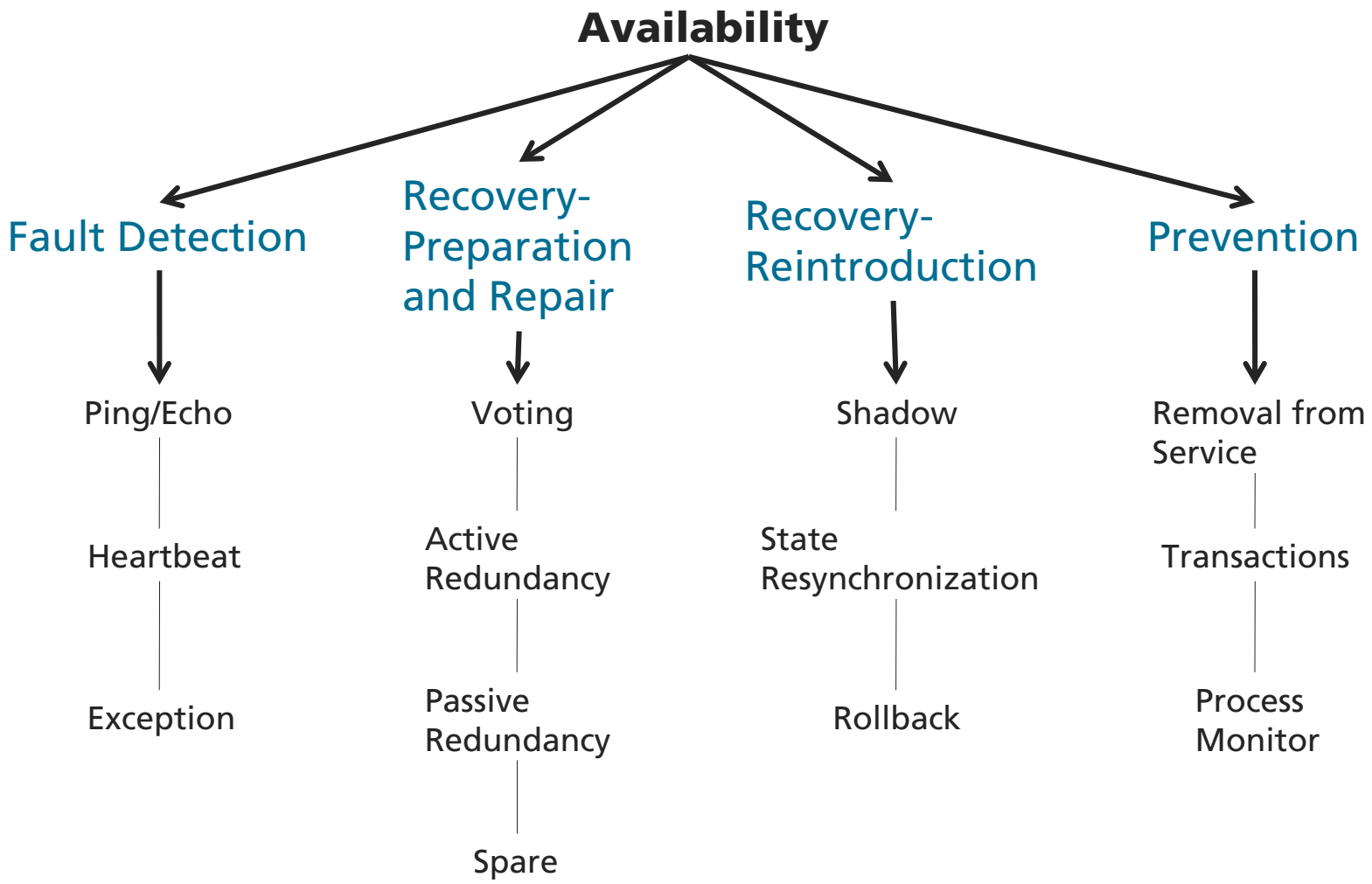
Availability Tactics



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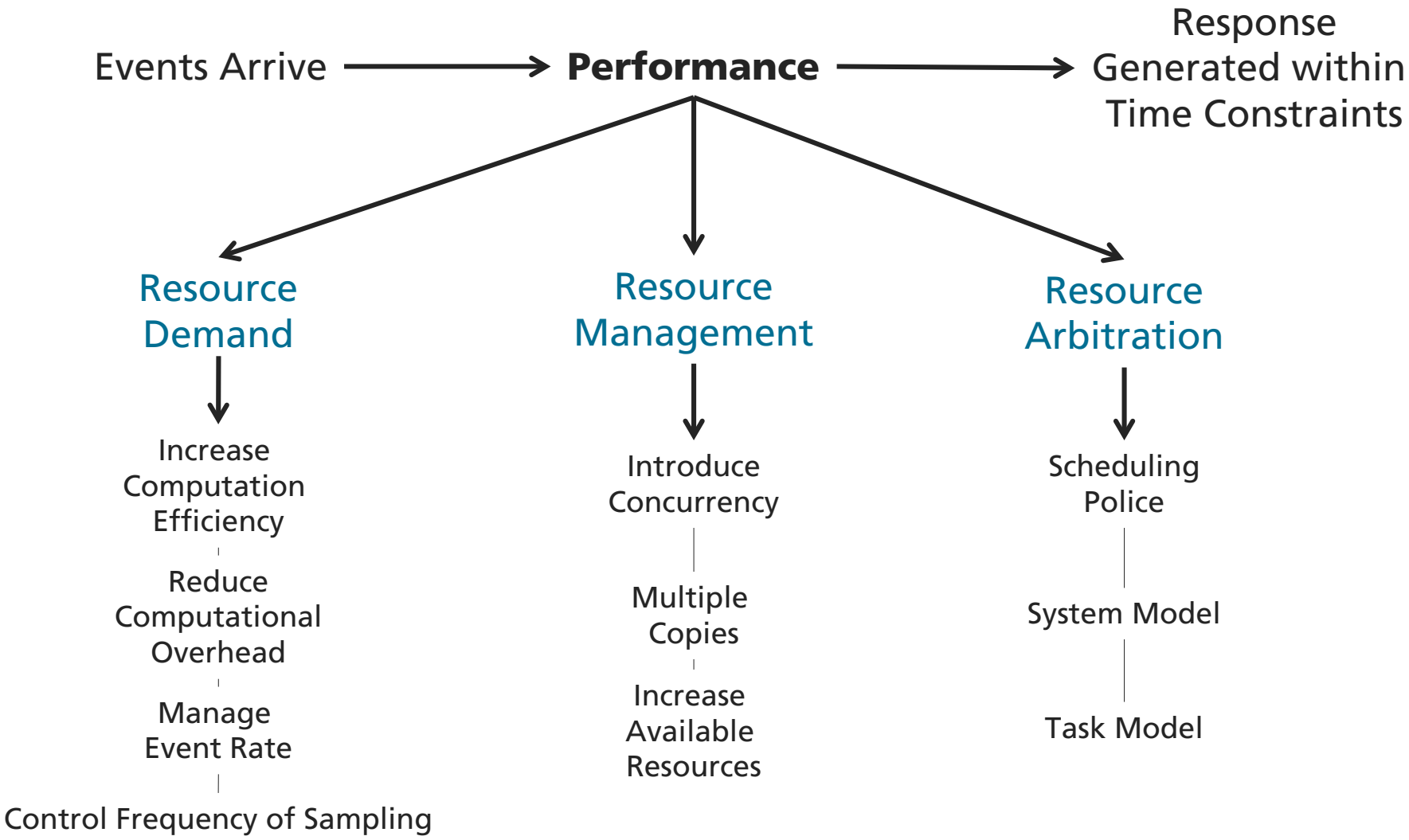
Performance Tactics



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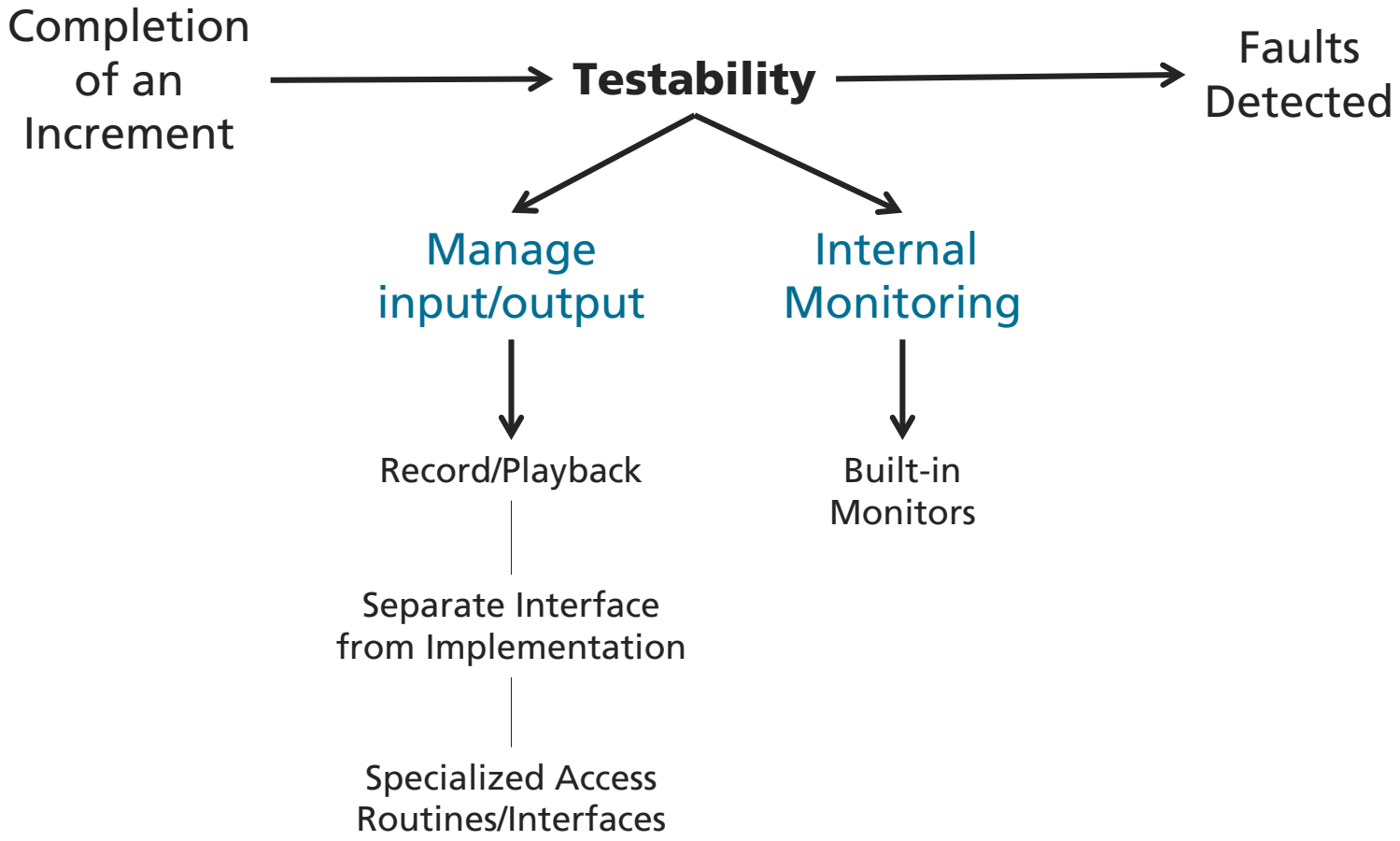
Testability Tactics



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