Resilient software design applied

A hands-on course for the undaunted developer

Uwe Friedrichsen & Ansgar Fitz (codecentric AG) – JAX – Mainz, 22. April 2016

@ufried

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Agenda

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2. Complete parameter checking	50′
3. Timeout	50′
4. Retry	30′
5. Graceful degradation	30′
6. Failover	30′
7. Circuit breaker	50′
Outlook & wrap-up	30′

Breaks based on wall clock

Why resilience?


It’s all about production!

Business

Production

Availability

$$\text{Availability} := \frac{\text{MTTF}}{\text{MTTF} + \text{MTTR}}$$

MTTF: Mean Time To Failure

MTTR: Mean Time To Recovery

Traditional stability approach

$$\text{Availability} := \frac{\text{MTTF}}{\text{MTTF} + \text{MTTR}}$$

Maximize MTTF

(Almost) every system is a distributed system

Chas Emerick

The Eight Fallacies of Distributed Computing

1. The network is reliable
2. Latency is zero
3. Bandwidth is infinite
4. The network is secure
5. Topology doesn't change
6. There is one administrator
7. Transport cost is zero
8. The network is homogeneous

Peter Deutsch

https://blogs.oracle.com/jag/resource/Fallacies.html

A distributed system is one in which the failure of a computer you didn't even know existed can render your own computer unusable.

Leslie Lamport

Failures in todays complex, distributed and interconnected systems are not the exception.

- *They are the normal case*
- *They are not predictable*
- *They are not avoidable*

Do not try to avoid failures. Embrace them.

Resilience approach

$$\text{Availability} := \frac{\text{MTTF}}{\text{MTTF} + \text{MTTR}}$$

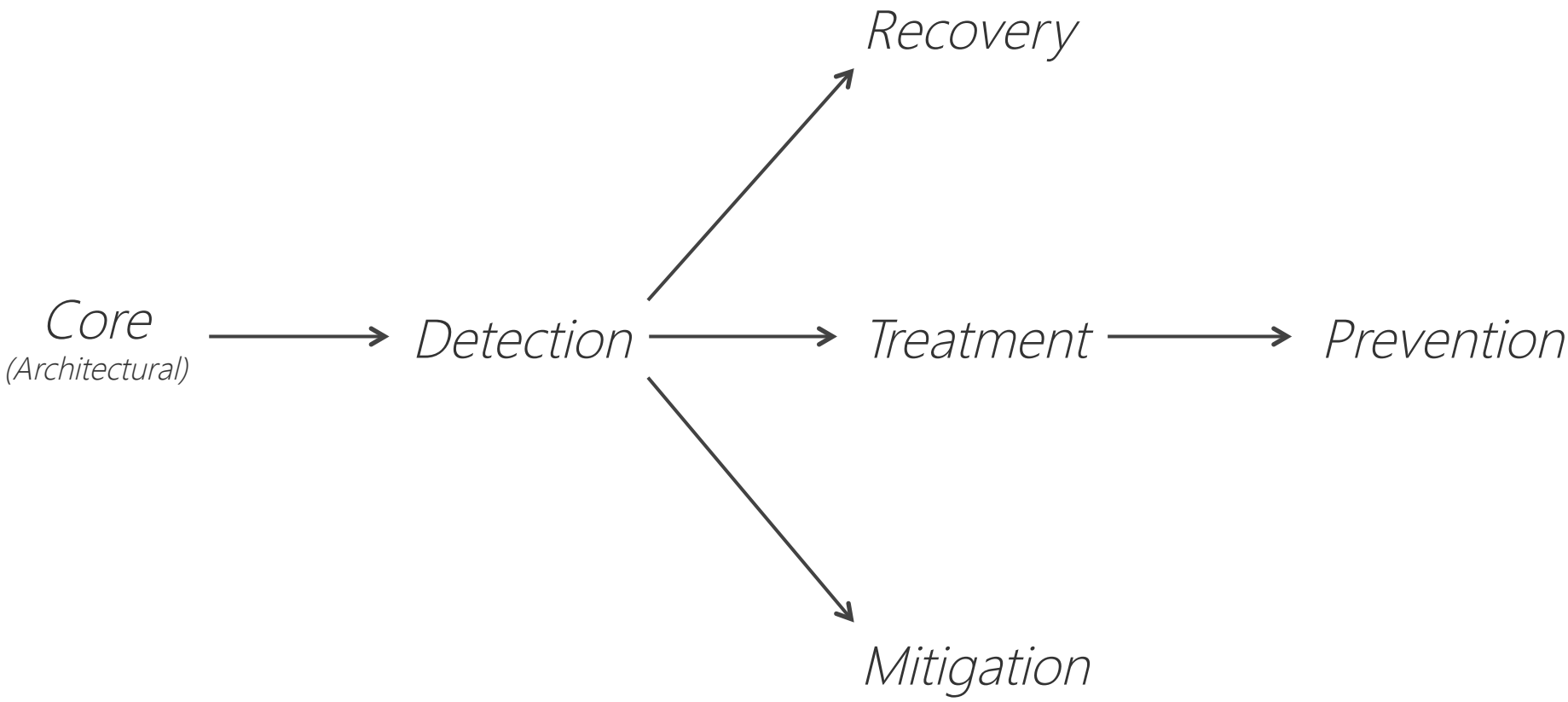
Minimize MTTR

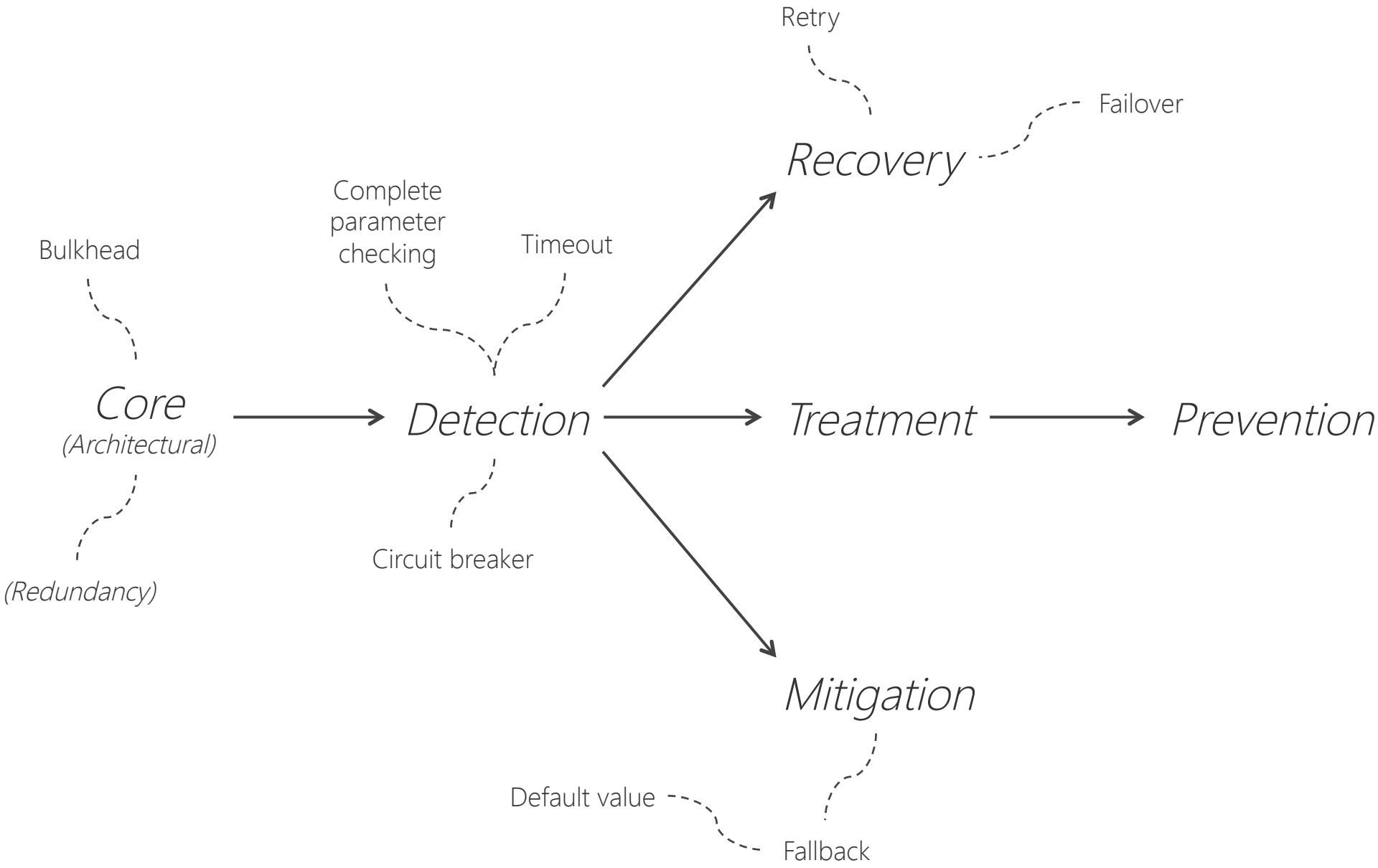
resilience (IT)

the ability of a system to handle unexpected situations

- without the user noticing it (best case)
- with a graceful degradation of service (worst case)

A little taxonomy on resilience …


Recovery
Core
(Architectural)
Detection
Treatment
Prevention
Mitigation


Retry
Failover
Recovery
Complete parameter checking
Timeout
Bulkhead
Core
(Architectural)
(Redundancy)
Detection
Circuit breaker
Treatment
Prevention
Mitigation
Default value
Fallback

Case Study: Awesome, Inc!

Bulkhead

Bulkhead

- Core isolation pattern (a.k.a. “failure units” or “units of mitigation”)
- Shaping good bulkheads is hard (pure design issue)
- Diverse implementation choices available, e.g., µservice, actor, scs, …
- Implementation choice impacts system and resilience design a lot

Exercise 1: Bulkhead

Case Study: Recommendation service

Complete parameter checking

Complete Parameter Checking

- As obvious as it sounds, yet often neglected
- Protection from broken/malicious calls (and return values)
- Pay attention to Postel's law
- Consider specific data types

Exercise 2: Complete parameter checking

Timeout

Timeout

- Preserve responsiveness independent of downstream latency
- Measure response time of downstream calls
- Stop waiting after a pre-determined timeout
- Take alternate action if timeout was reached

Timeout with standard library means

```
// Wrap blocking action in a Callable
Callable<MyActionResult> myAction = <My Blocking Action>

// Use a simple ExecutorService to run the action in its own thread
ExecutorService executor = Executors.newSingleThreadExecutor();
Future<MyActionResult> future = executor.submit(myAction);
MyActionResult result = null;

// Use Future.get() method to limit time to wait for completion
try {
  result = future.get(TIMEOUT, TIMEUNIT);
  // Action completed in a timely manner – process results
} catch (TimeoutException e) {
    // Handle timeout (e.g., schedule retry, escalate, alternate action, …)
} catch (...) {
    // Handle other exceptions that can be thrown by Future.get()
} finally {
    // Make sure the callable is stopped even in case of a timeout
    future.cancel(true);
}
```

Exercise 3: Timeout

Retry

Retry

- Very basic recovery pattern
- Recover from omission errors
- Limit retries to minimize extra load on an already loaded resource
- Limit retries to avoid recurring errors

Retry example

```
// doAction returns true if successful, false otherwise
boolean doAction(...) {
    ...
}


// General pattern
boolean success = false
int tries = 0;
while (!success && (tries < MAX_TRIES)) {
    success = doAction(...);
    tries++;
}


// Alternative one-retry-only variant
success = doAction(...) || doAction(...);
```

Exercise 4: Retry

Fallback

(Graceful degradation of service)

Fallback

- Execute an alternative action if the original action fails
- Basis for most mitigation patterns
- Fail silently – silently ignore the error and continue processing
- Default value – return a predefined default value if an error occurs

Exercise 5: Graceful degradation

Failover

Failover

- Used as escalation if other measures failed or would take too long
- Requires redundancy – trades resources for availability
- Many implementation variants available, incl. out-of-the-box solutions
- Usually implemented as a monitor-dynamic router combination

Exercise 6: Failover

Circuit breaker

Circuit Breaker

- Probably most often cited resilience pattern
- Extension of the timeout pattern
- Takes downstream unit offline if calls fail multiple times
- Specific variant of the fail fast pattern

Home

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What is Hystrix?

In a distributed environment, failure of any given service is inevitable. Hystrix is a library designed to control the interactions between these distributed services providing greater latency and fault tolerance. Hystrix does this by isolating points of access between the services, stopping cascading failures across them, and providing fallback options, all of which improve the system's overall resiliency.

Hystrix evolved out of resilience engineering work that the Netflix API team began in 2011. Over the course of 2012, Hystrix continued to evolve and mature, eventually leading to adoption

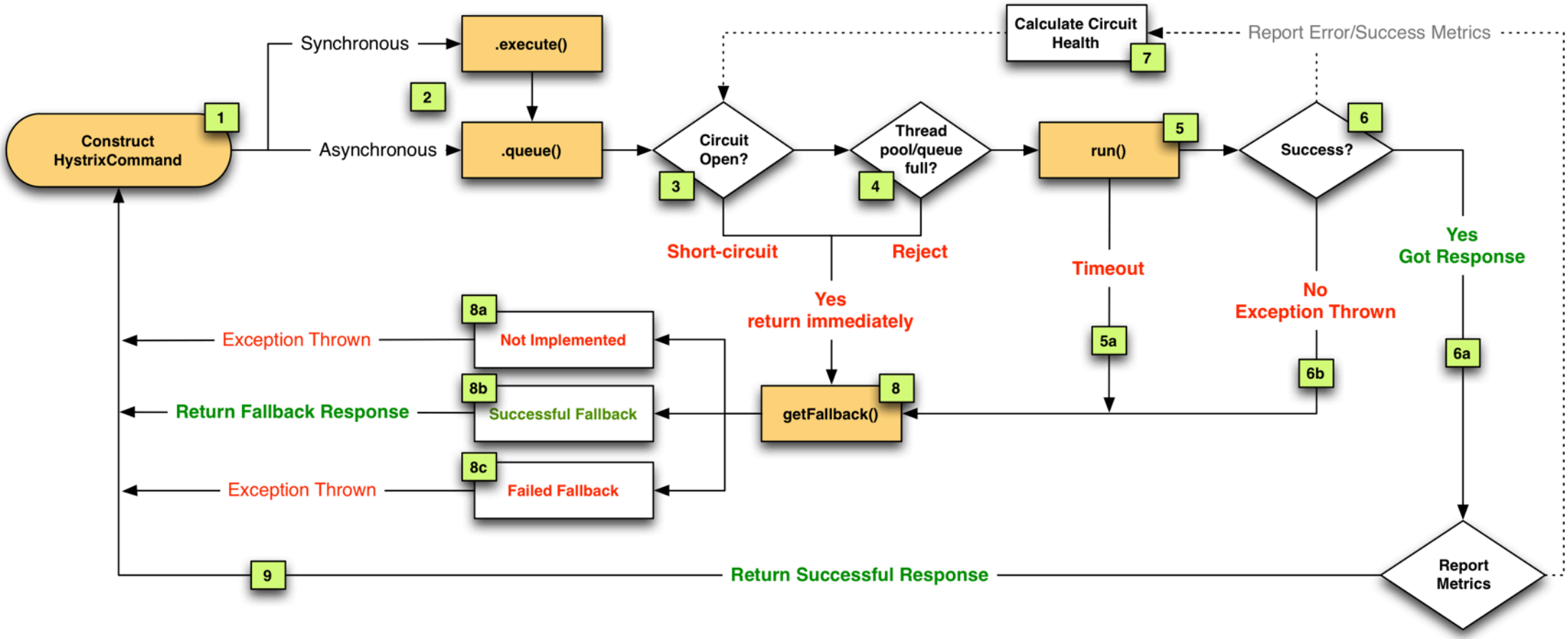
```
// Hystrix “Hello world”

public class HelloCommand extends HystrixCommand<String> {
    private static final String COMMAND_GROUP = ”Hello”; // Not important here
    private final String name;

    // Request parameters are passed in as constructor parameters
    public HelloCommand(String name) {
        super(HystrixCommandGroupKey.Factory.asKey(COMMAND_GROUP));
        this.name = name;
    }

    @Override
    protected String run() throws Exception {
        // Usually here would be the resource call that needs to be guarded
        return "Hello, " + name;
    }
}


// Usage of a Hystrix command - synchronous variant
@Test
public void shouldGreetWorld() {
    String result = new HelloCommand("World").execute();
    assertEquals("Hello, World", result);
}
```



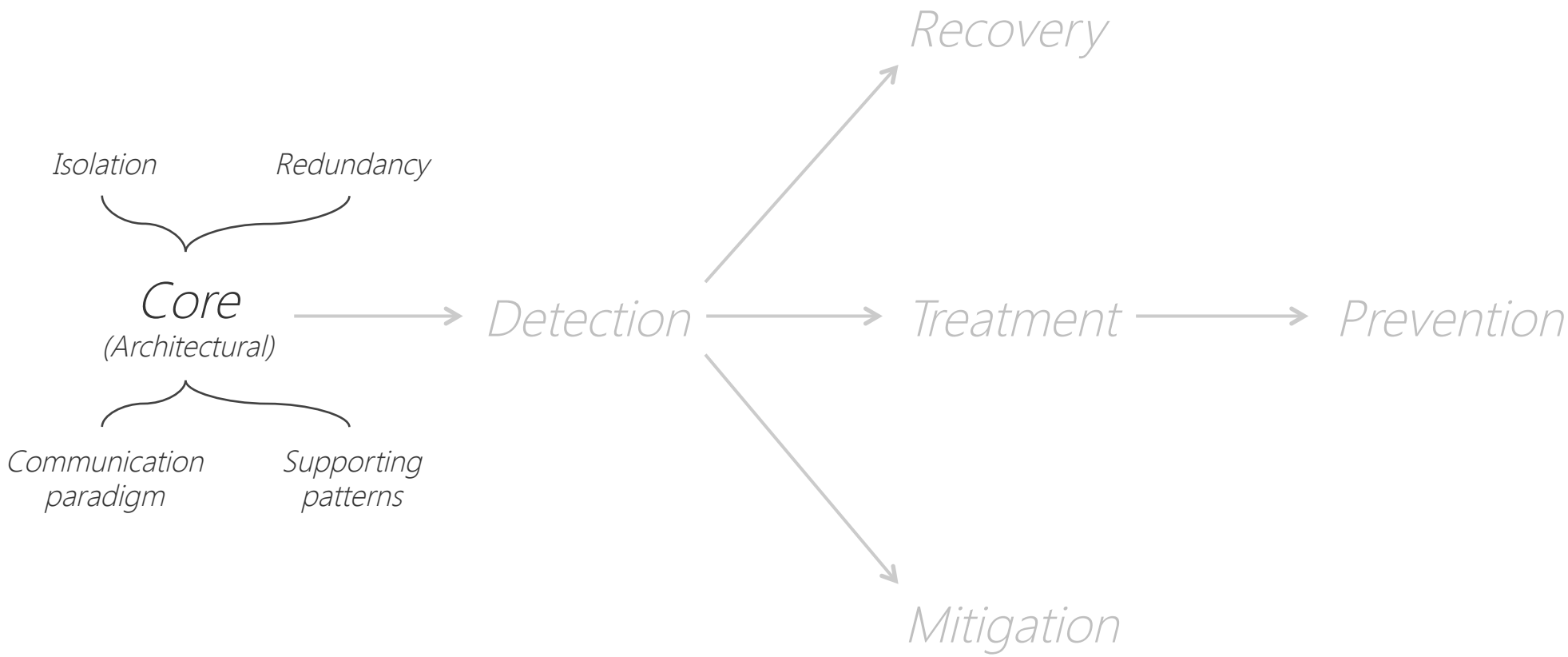
Source: https://github.com/Netflix/Hystrix/wiki/How-it-Works

Exercise 7: Circuit breaker

```
// Required super class constructor call for this exercise

super(HystrixCommand.Setter
    .withGroupKey(HystrixCommandGroupKey.Factory.asKey("AnalysisService"))
    .andCommandPropertiesDefaults(HystrixCommandProperties.Setter()
        .withExecutionTimeoutInMilliseconds(200)
        .withCircuitBreakerRequestVolumeThreshold(1)
        .withMetricsRollingStatisticalWindowInMilliseconds(1000)
        .withMetricsRollingStatisticalWindowBuckets(1)
        .withMetricsRollingPercentileEnabled(false)));
```

… and that’s just the beginning

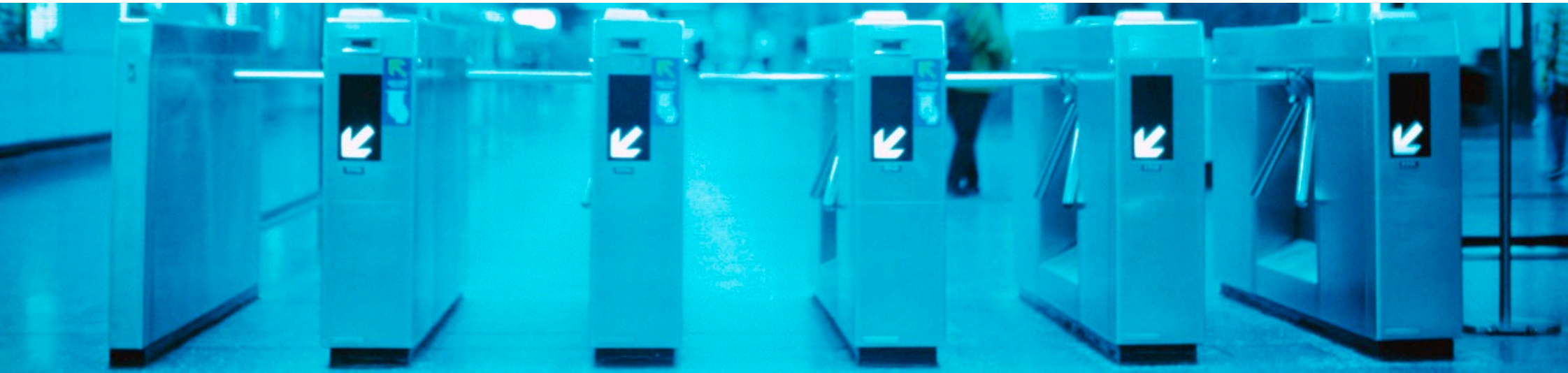

Isolation
Redundancy
Core
(Architectural)
Communication paradigm
Supporting patterns
Detection
Recovery
Treatment
Prevention
Mitigation

Communication paradigm

- Request-response <-> messaging <-> events
- Not a pattern, but heavily influences resilience patterns to be used
- Also heavily influences functional bulkhead design
- Very fundamental decision which is often underestimated

Redundancy

- Core resilience concept
- Applicable to all failure types
- Basis for many recovery and mitigation patterns
- Often different variants implemented in a system



Failure types

- Crash failure
- Omission failure
- Timing failure
- Response failure
- Byzantine failure

Usage of redundancy

- Patterns
  - Failover
- Schemes
  - Active/Passive
  - Active/Active
  - N+M Redundancy
- Implementation examples
  - Load balancer + health check (e.g., HAProxy)
  - Dynamic routing + health check (e.g., Consul, ZooKeeper)
  - Cluster manager with shared IP (e.g., Pacemaker & Corosync)

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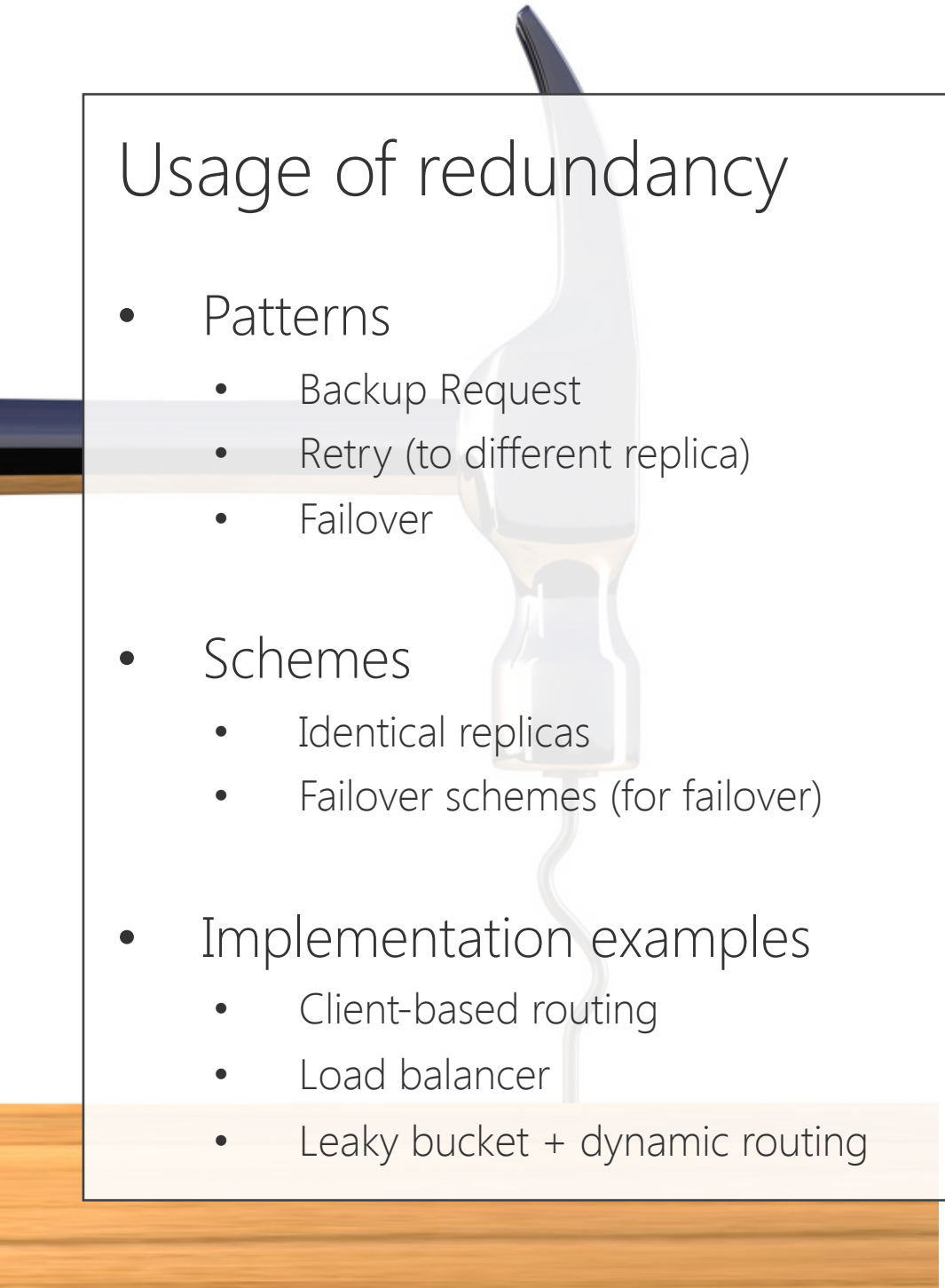

Usage of redundancy

- Patterns
  - Backup Request
  - Retry (to different replica)
  - Failover
- Schemes
  - Identical replicas
  - Failover schemes (for failover)
- Implementation examples
  - Client-based routing
  - Load balancer
  - Leaky bucket + dynamic routing

Failure types

- Crash failure
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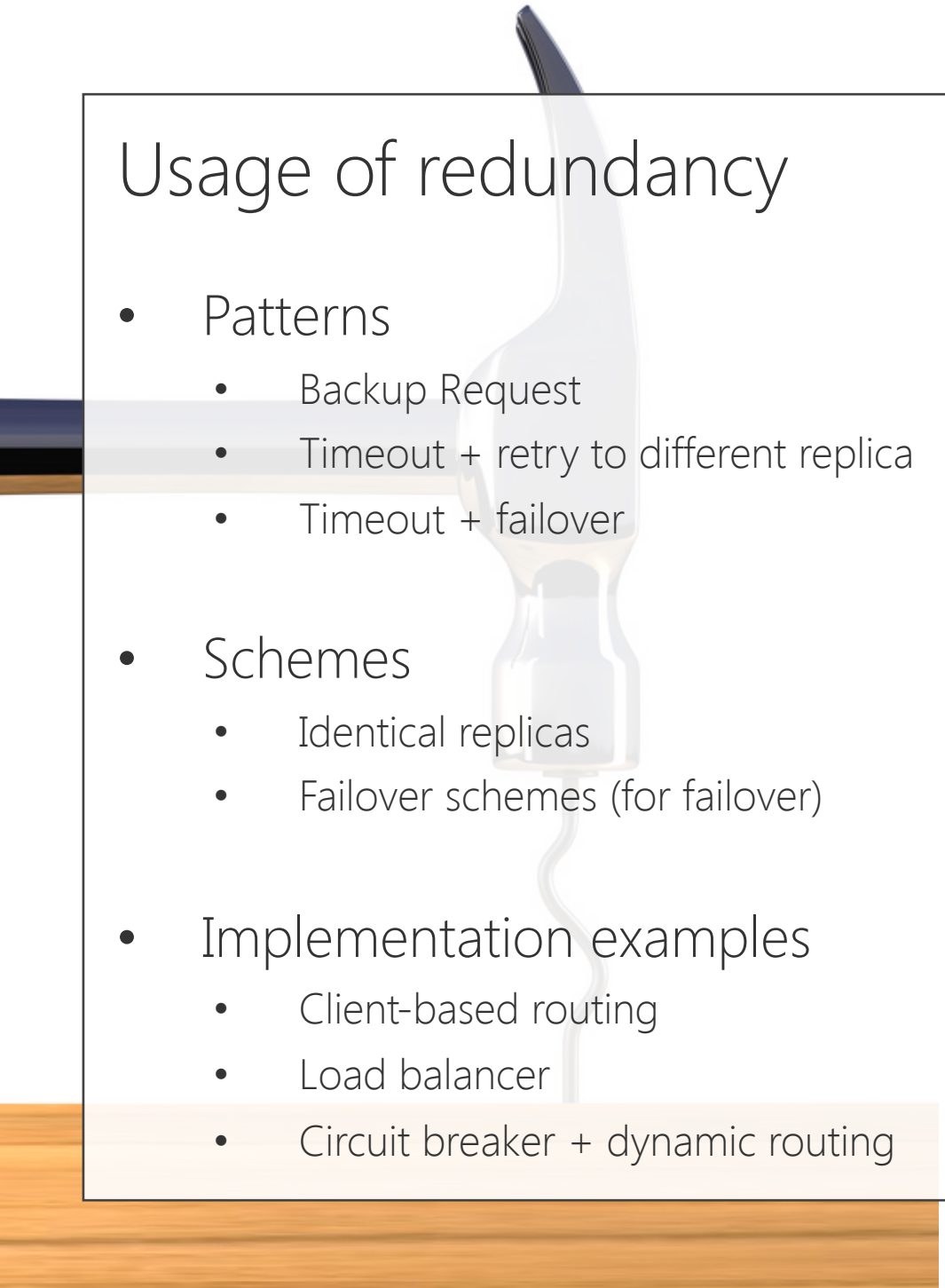

Usage of redundancy

- Patterns
  - Backup Request
  - Timeout + retry to different replica
  - Timeout + failover
- Schemes
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Failure types

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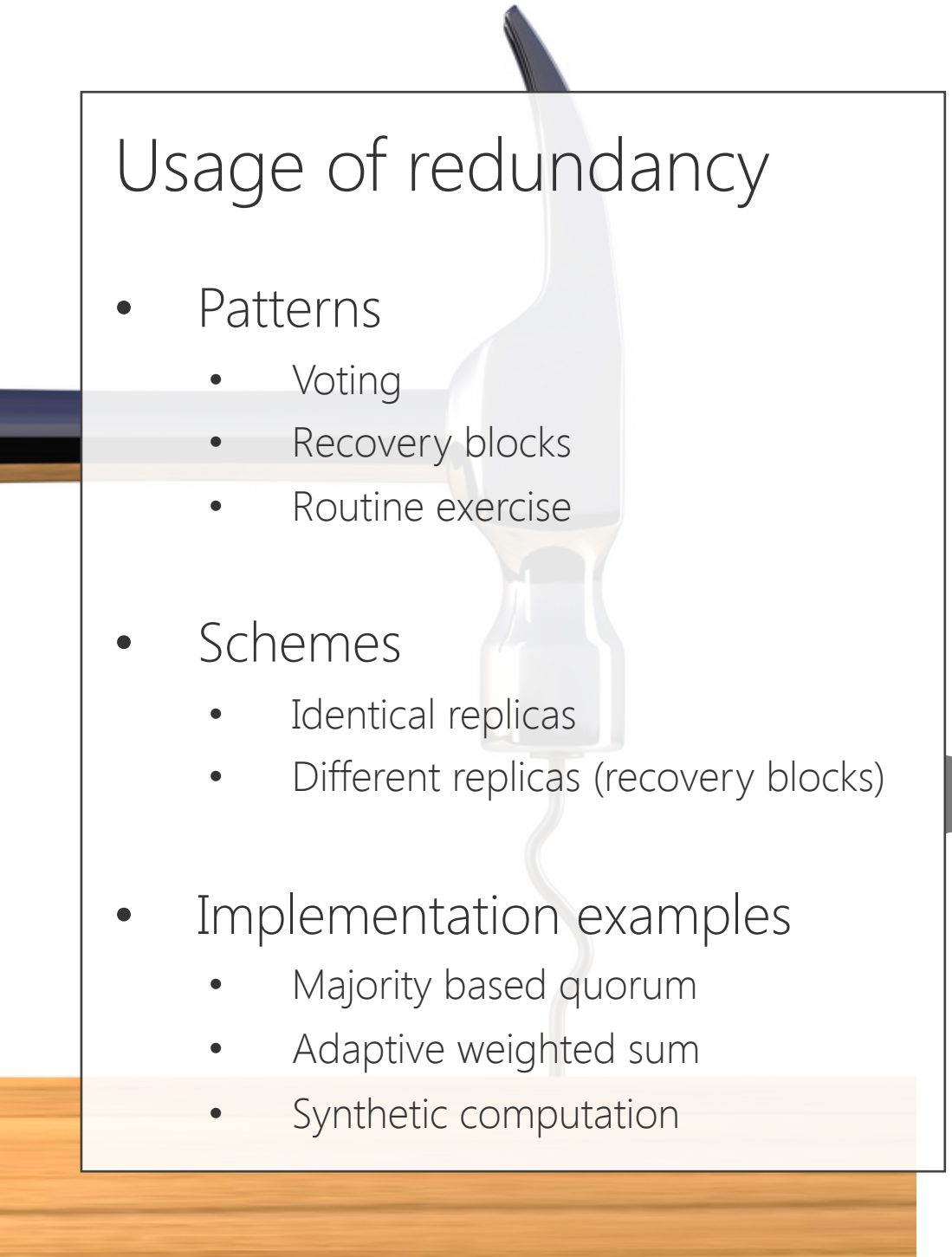

Usage of redundancy

- Patterns
  - Voting
  - Recovery blocks
  - Routine exercise
- Schemes
  - Identical replicas
  - Different replicas (recovery blocks)
- Implementation examples
  - Majority based quorum
  - Adaptive weighted sum
  - Synthetic computation

Failure types

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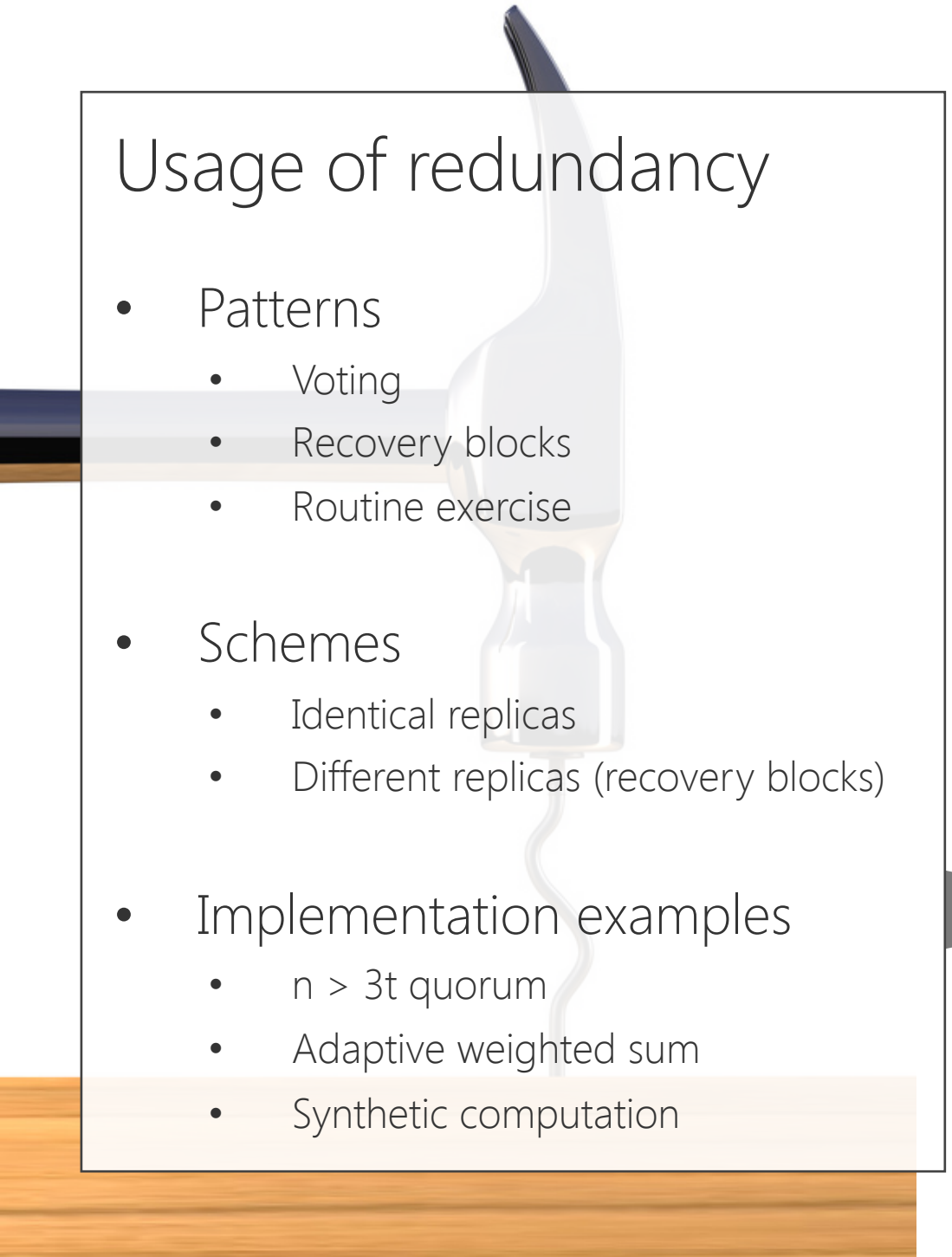
- Response failure
- Byzantine failure



Usage of redundancy

- Patterns
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Failure types

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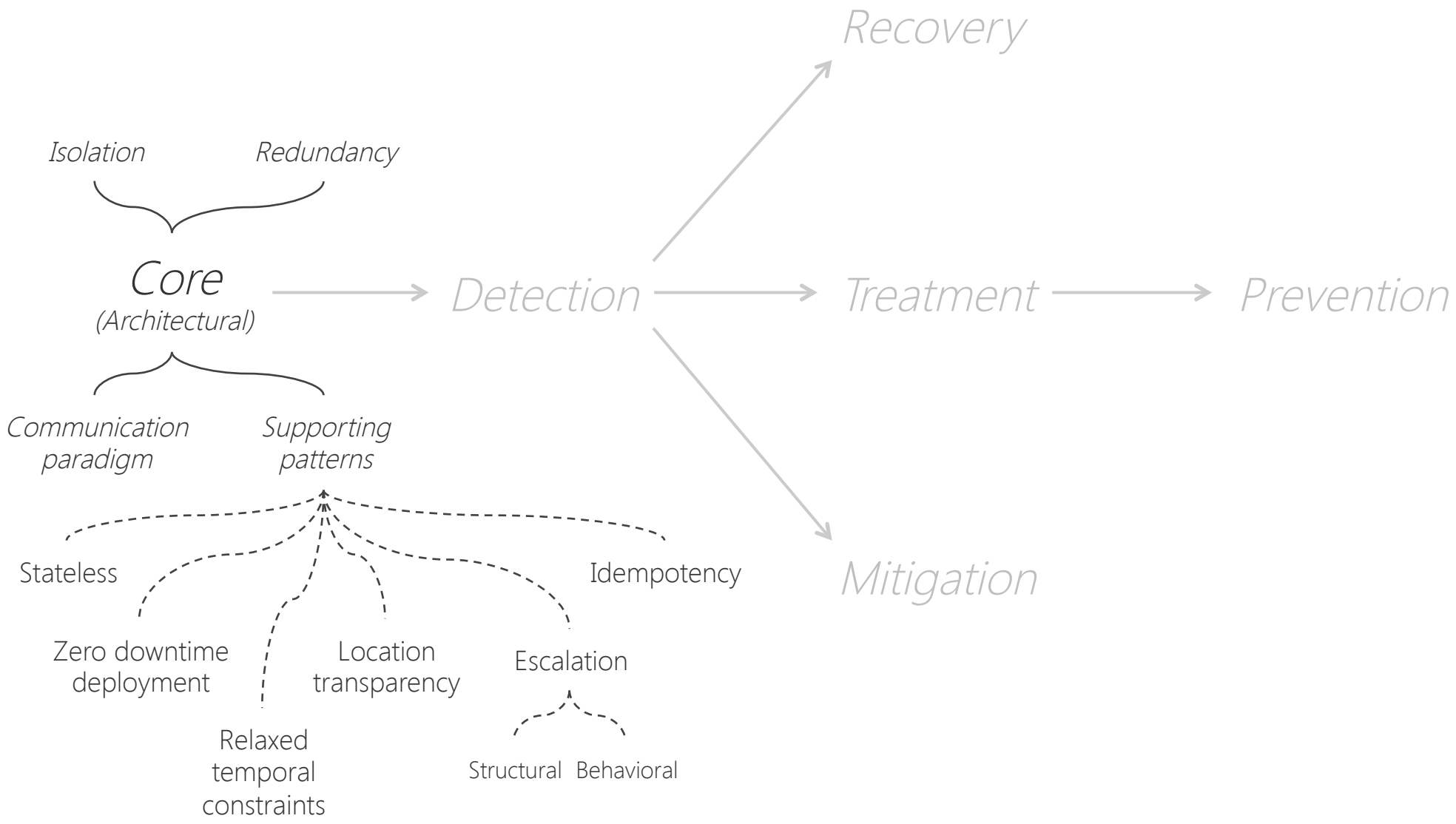
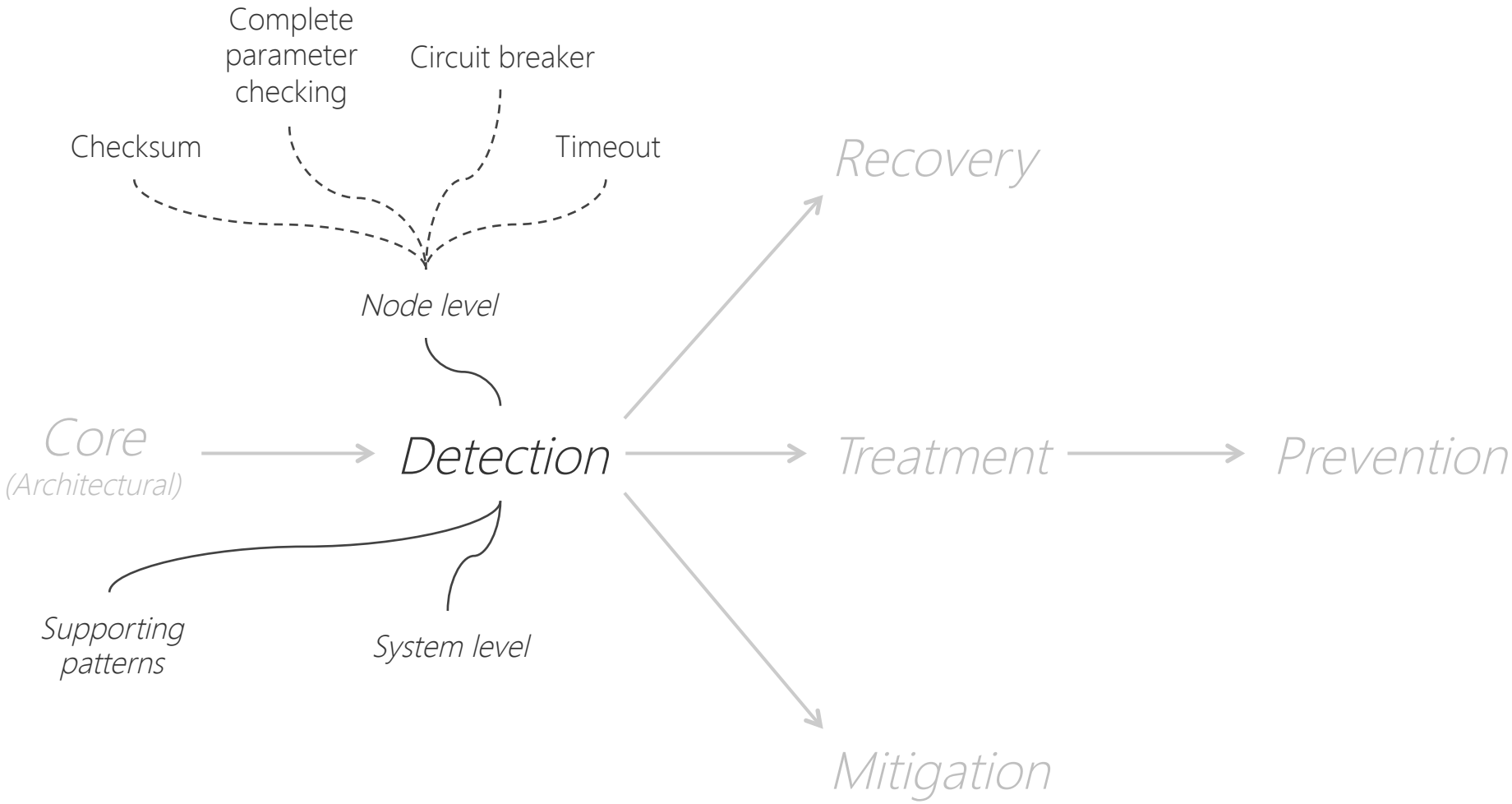
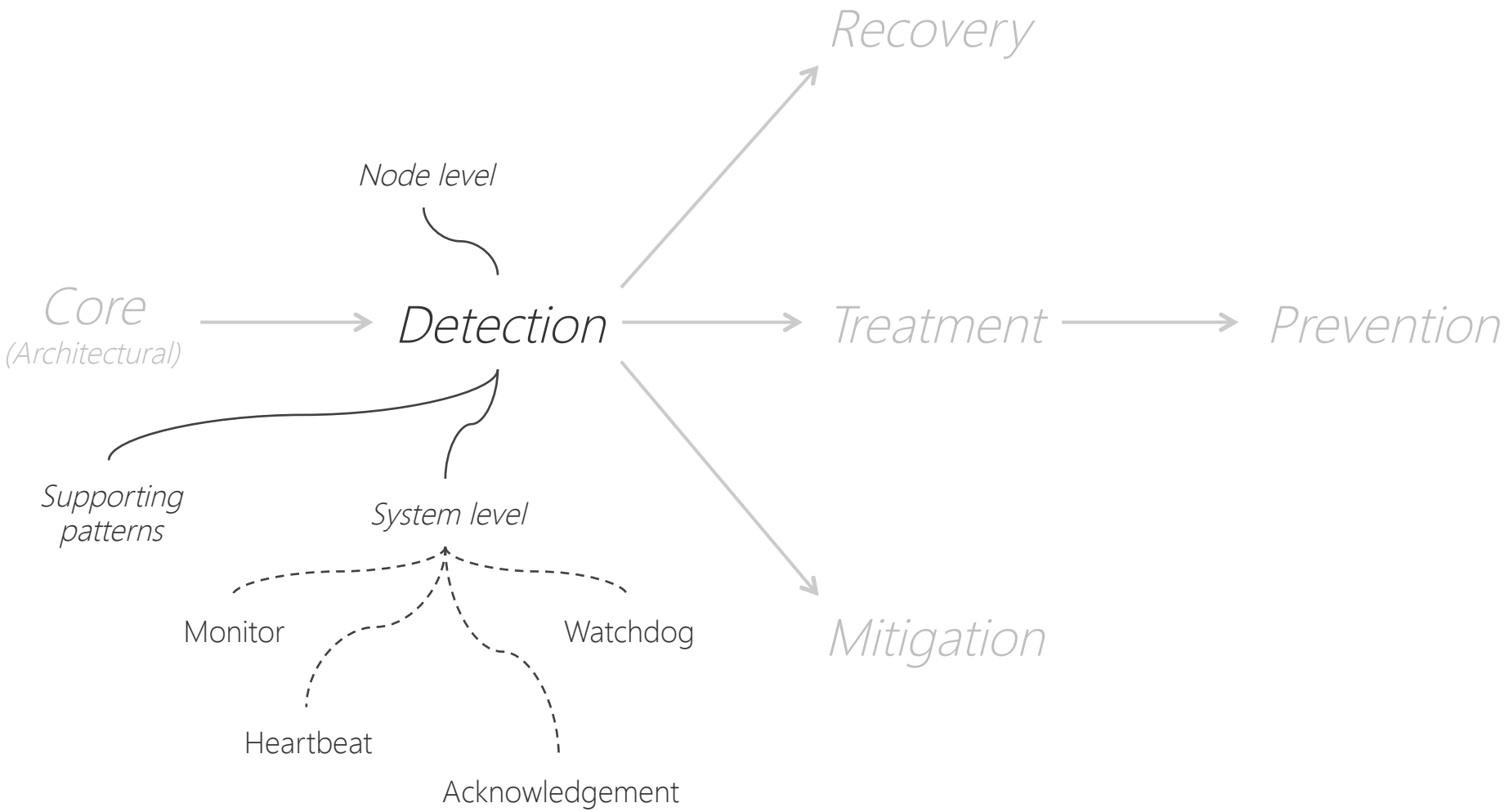
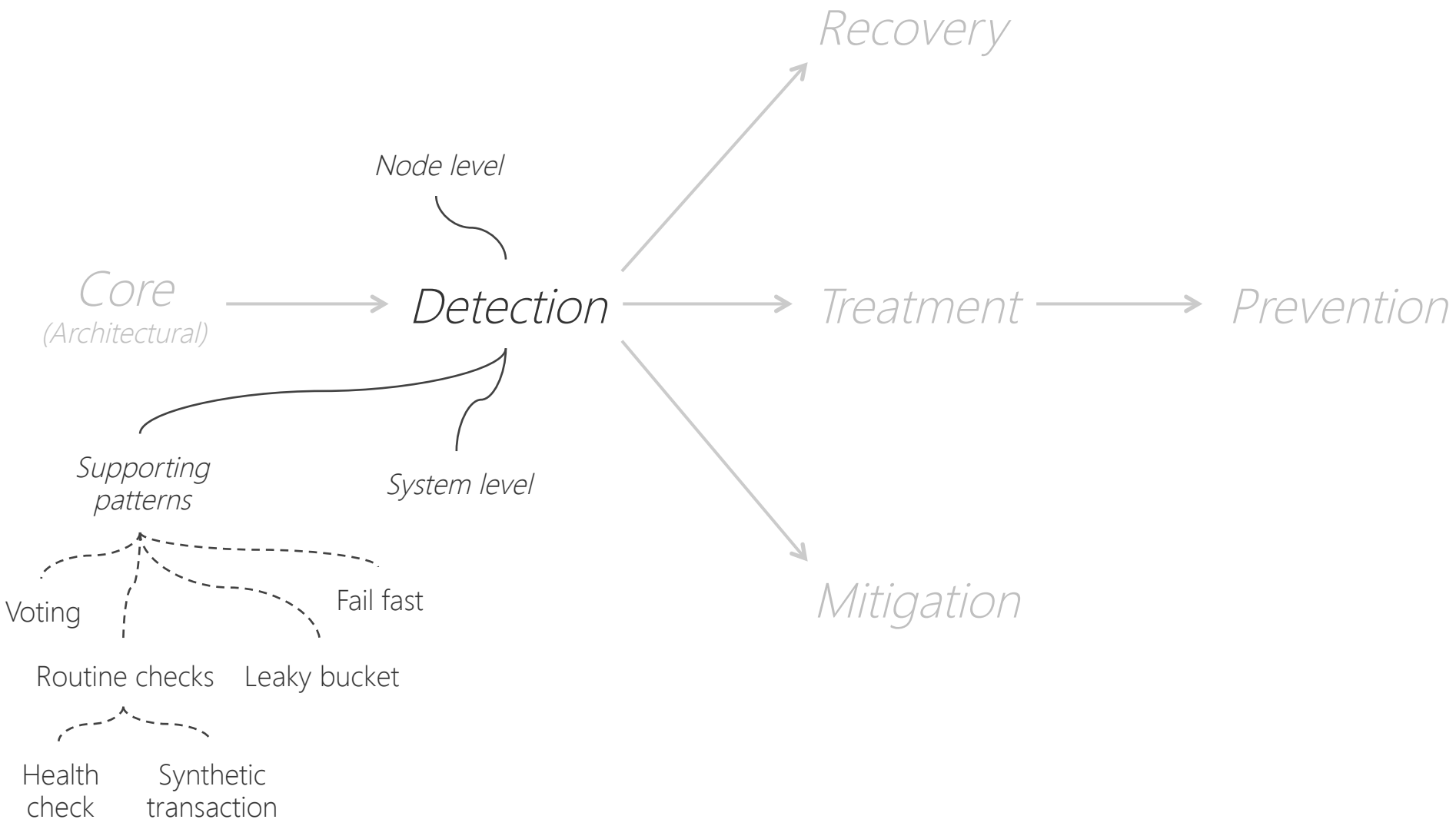
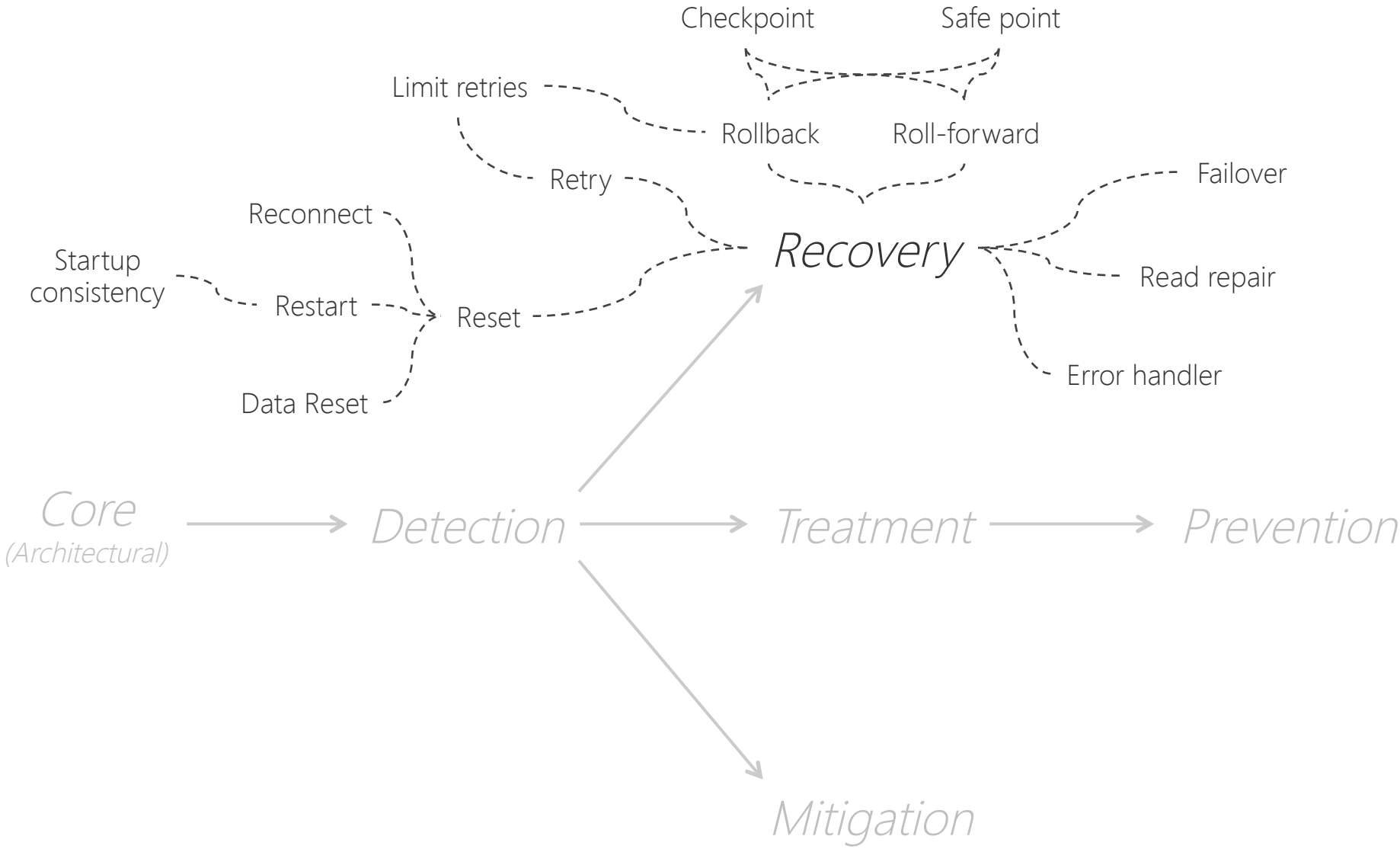
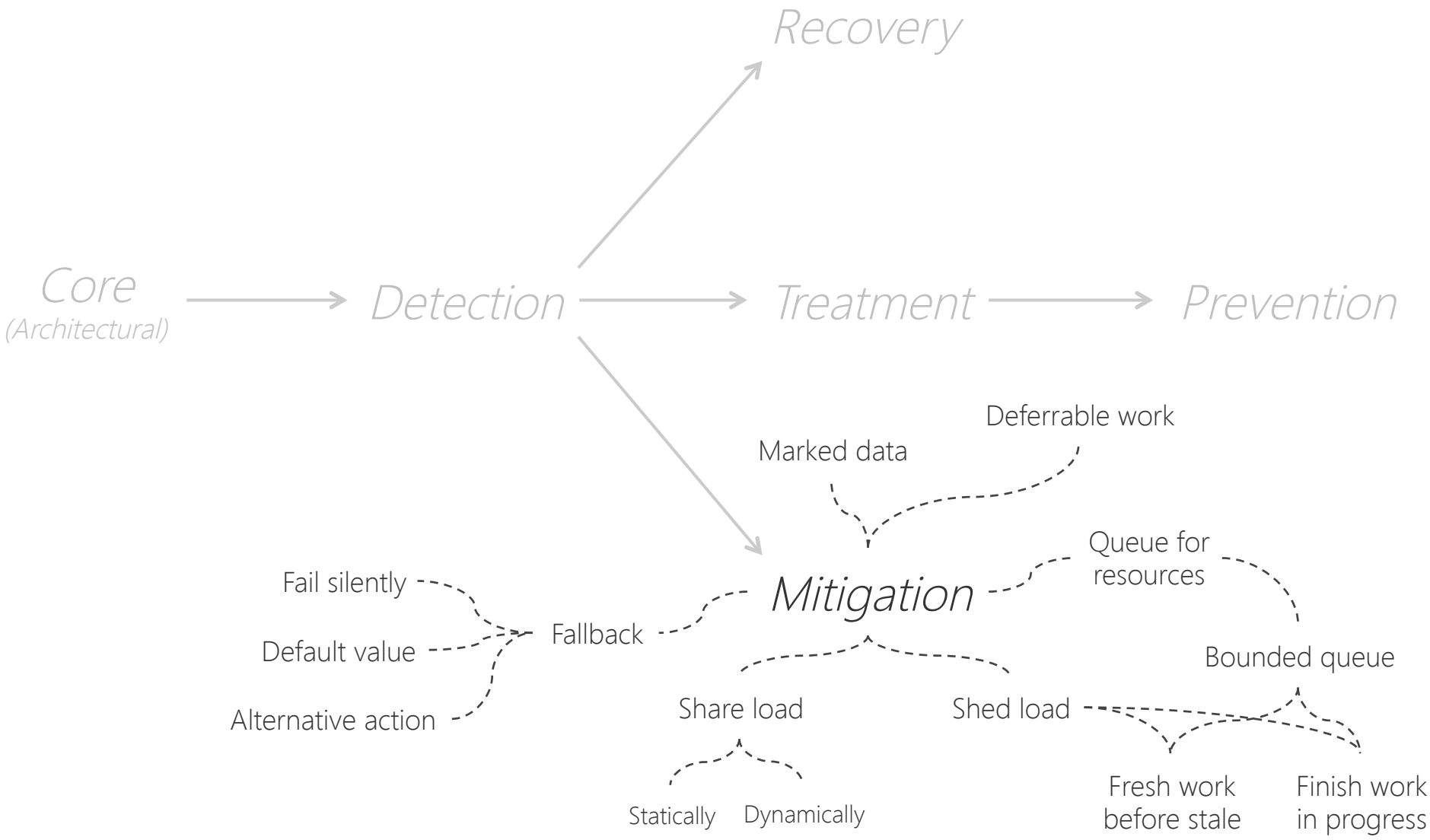

Recovery
Isolation
Redundancy
Core
(Architectural)
Detection
Treatment
Prevention
Communication paradigm
Supporting patterns
Stateless
Idempotency
Mitigation
Zero downtime deployment
Location transparency
Escalation
Relaxed temporal constraints
Structural
Behavioral

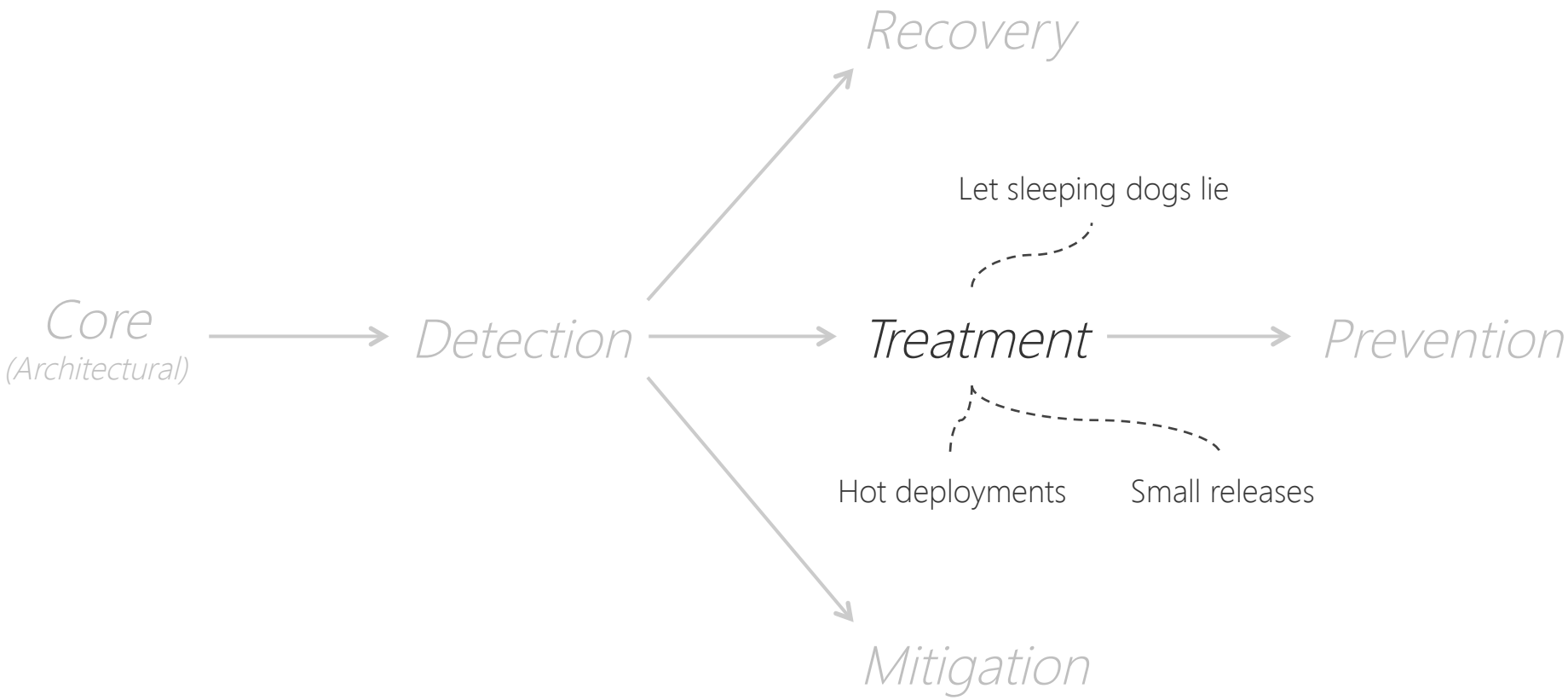

Complete parameter checking
Circuit breaker
Checksum
Timeout
Recovery
Node level
Core
(Architectural)
Detection
Treatment
Prevention
Supporting patterns
System level
Mitigation

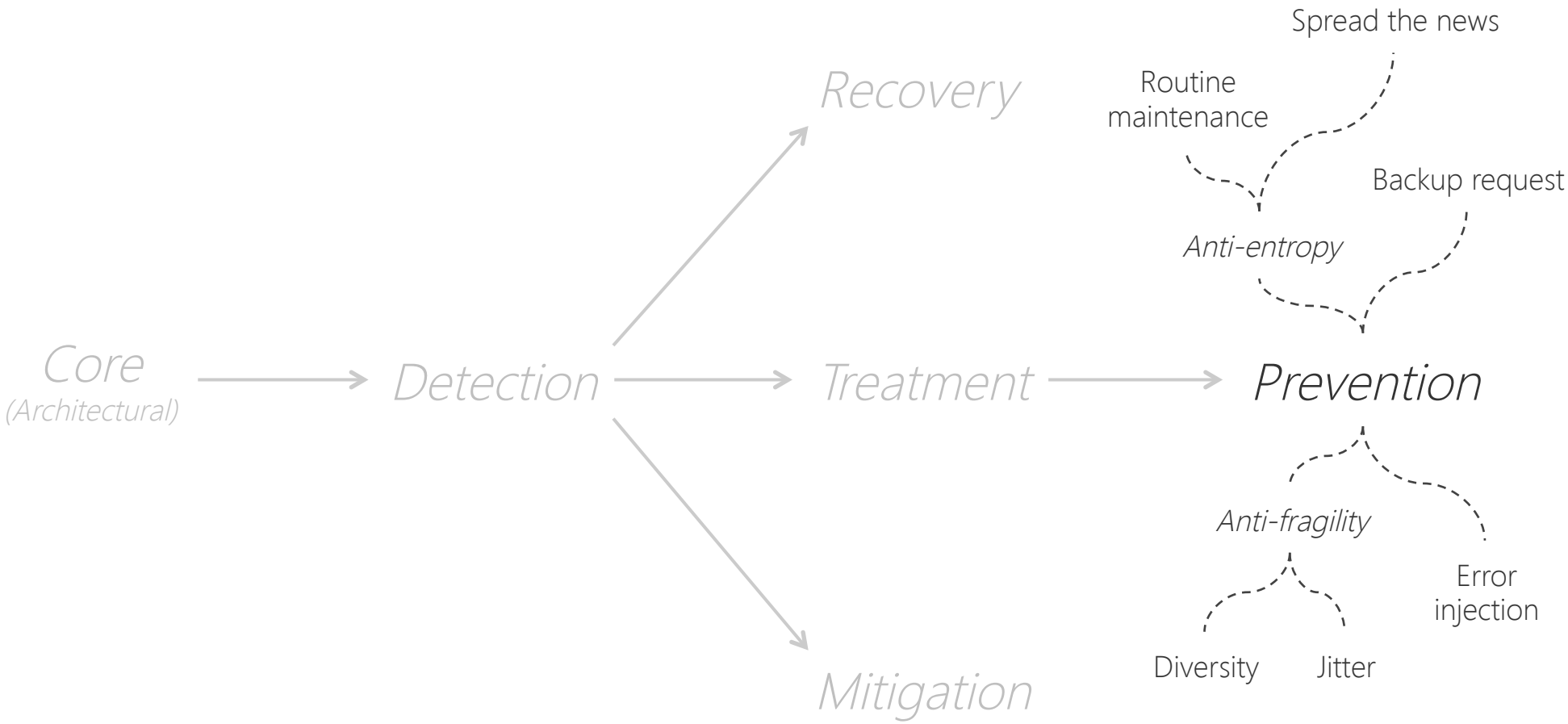

Recovery
Node level
Core
(Architectural)
Detection
Treatment
Prevention
Supporting
patterns
System level
Monitor
Watchdog
Mitigation
Heartbeat
Acknowledgement


Recovery
Node level
Core
(Architectural)
Detection
Treatment
Prevention
Supporting
patterns
System level
Mitigation
Voting
Fail fast
Routine checks
Leaky bucket
Health
check
Synthetic
transaction


Checkpoint
Safe point
Limit retries
Rollback
Roll-forward
Retry
Failover
Reconnect
Recovery
Startup consistency
Restart
Reset
Read repair
Error handler
Data Reset
Core
(Architectural)
Detection
Treatment
Prevention
Mitigation


Recovery
Core
(Architectural)
Detection
Treatment
Prevention
Deferrable work
Marked data
Queue for
resources
Fail silently
Mitigation
Default value
Fallback
Bounded queue
Alternative action
Share load
Shed load
Statically
Dynamically
Fresh work
before stale
Finish work
in progress

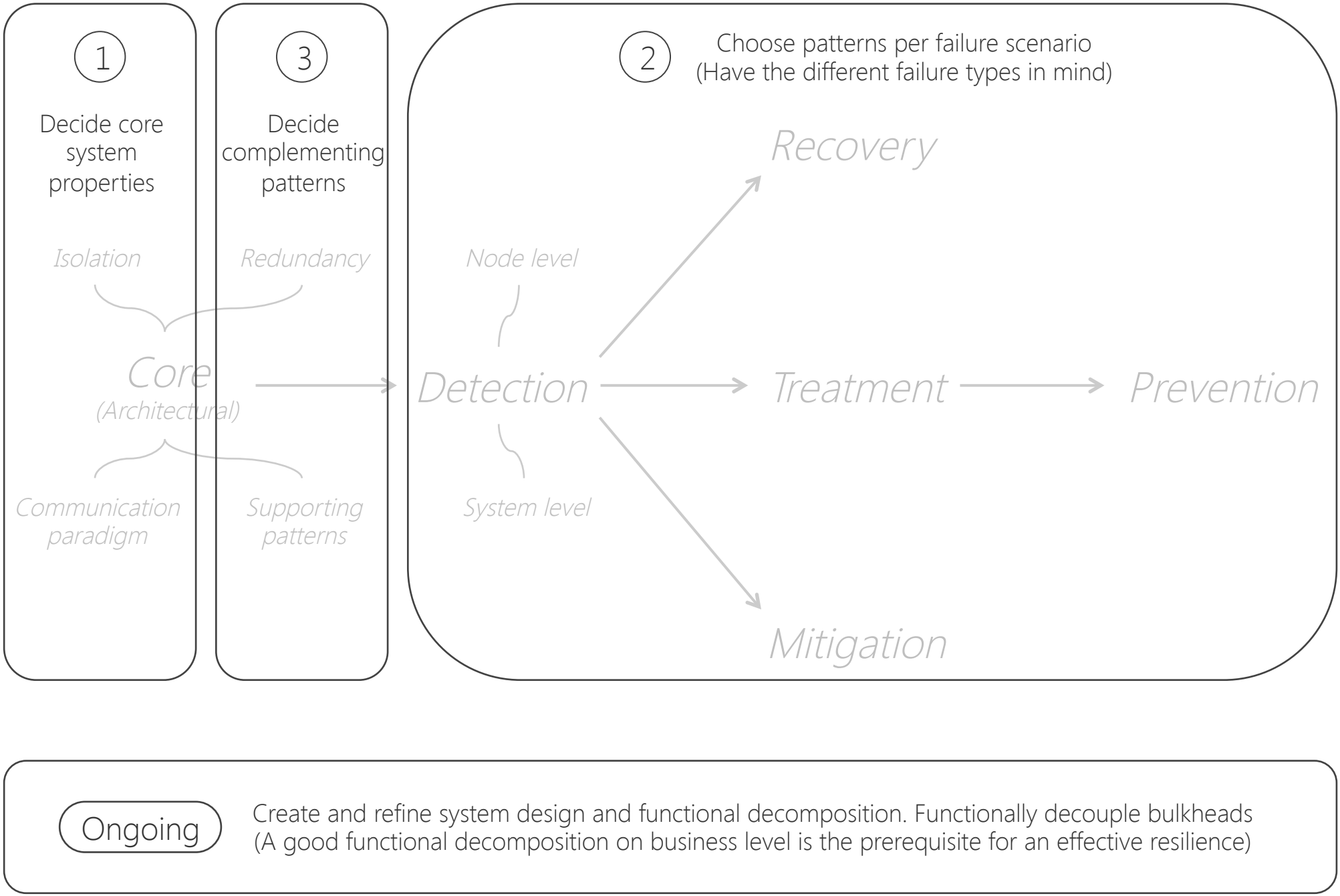

Recovery
Let sleeping dogs lie
Core
(Architectural)
Detection
Treatment
Prevention
Hot deployments
Small releases
Mitigation

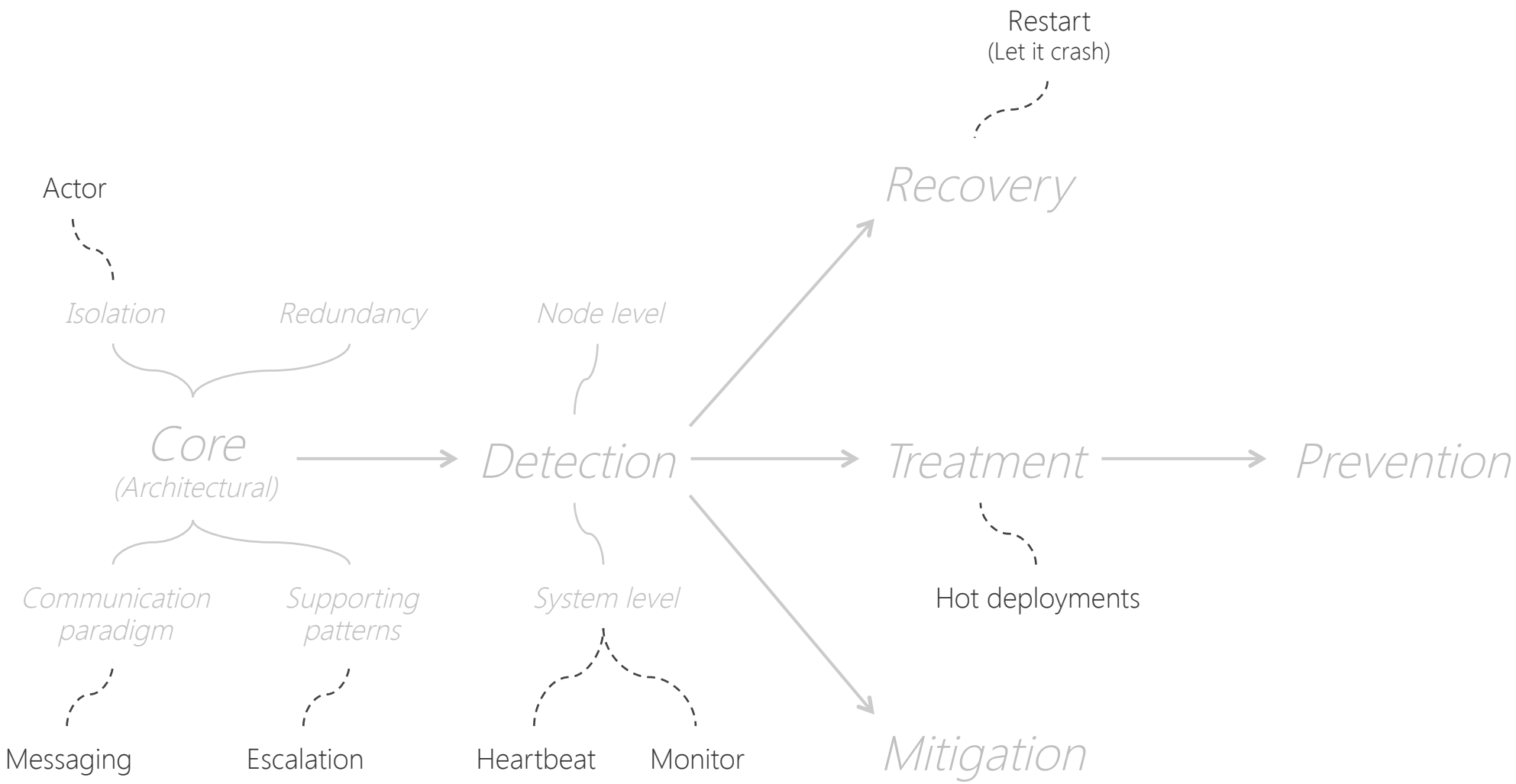

Core
(Architectural)
Detection
Recovery
Treatment
Mitigation
Prevention
Spread the news
Routine maintenance
Backup request
Anti-entropy
Anti-fragility
Error injection
Diversity
Jitter

Towards a pattern language …

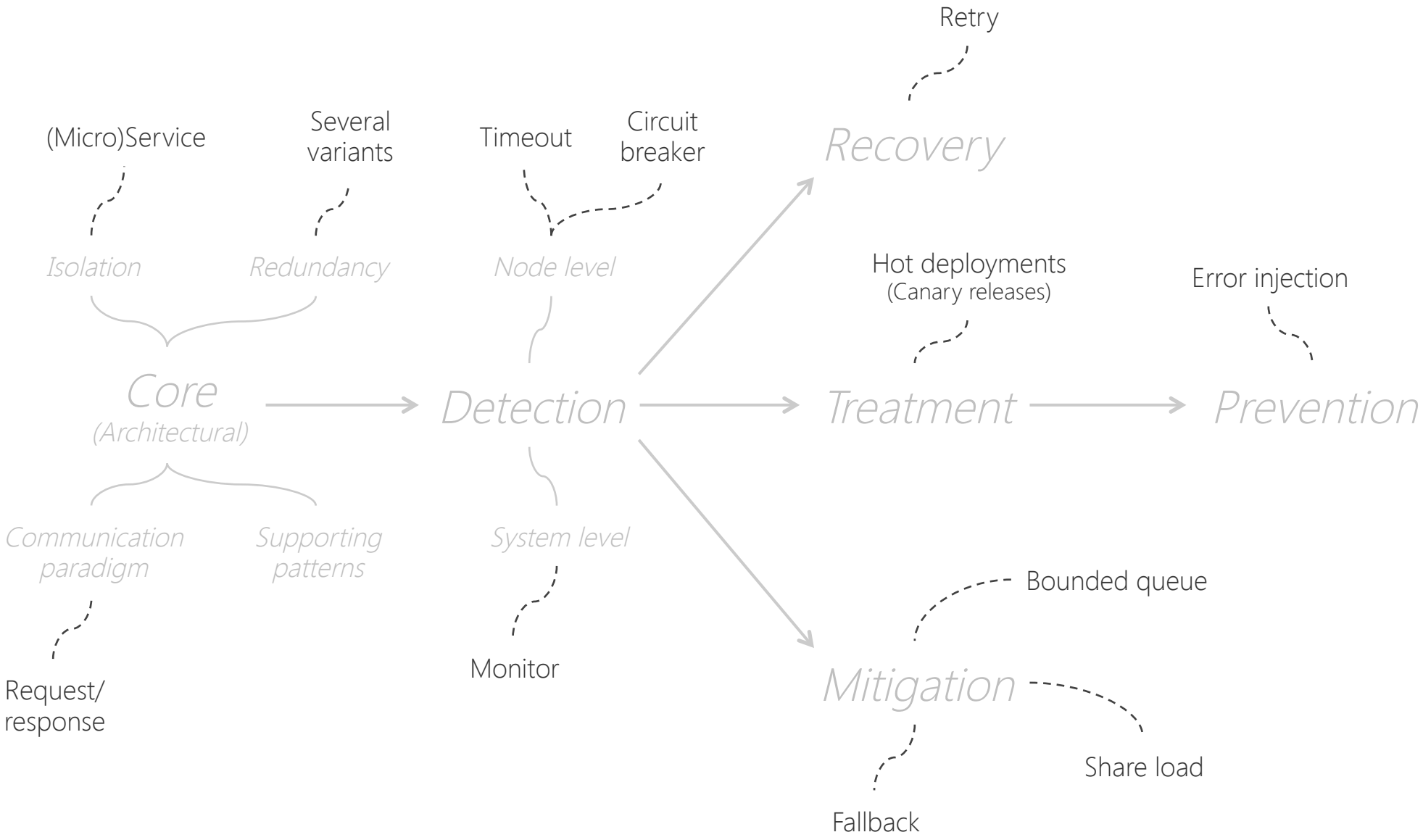
Decisions to make

- General decisions
  - Bulkhead type
  - Communication paradigm
- Decisions per failure scenario (repeat)
  - Error detection on node & system level
  - Recovery/mitigation mechanism
  - Supporting treatment mechanism
  - Supporting prevention mechanism
- Complementing decisions
  - Complementing redundancy mechanism(s)
  - Complementing architectural patterns


1
Decide core system properties
Isolation
Redundancy
Core
(Architectural)
Communication paradigm
Supporting patterns
3
Decide complementing patterns
2
Choose patterns per failure scenario
(Have the different failure types in mind)
Node level
Detection
System level
Recovery
Treatment
Prevention
Mitigation
Ongoing
Create and refine system design and functional decomposition. Functionally decouple bulkheads
(A good functional decomposition on business level is the prerequisite for an effective resilience)



Example: Erlang (Akka)



Example: Netflix

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