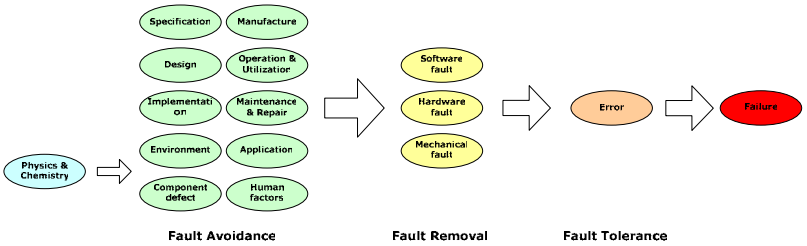
Concepts for Dependable and Secure Computing

References

- Algirdas Avizienis, Fellow, IEEE, Jean-Claude Laprie, Brian Randell, and Carl Landwehr. *Basic Concepts and Taxonomy of Dependable and Secure Computing*, in IEEE TRANSACTIONS ON DEPENDABLE AND SECURE COMPUTING, VOL. 1, NO. 1, JANUARY-MARCH 2004

Fault, Error and Failures



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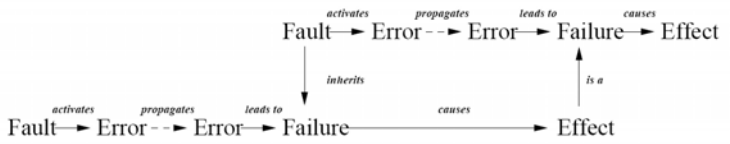
Threads to Dependability



- Fault.
  - The cause of a failure is a fault that ranges from specification and design defects to physical or human factors.
- Error.
  - An error is a design flaw or a deviation from the desired or intended state of a system.
- Failure.
  - A failure is defined as the manner in which a component, subsystem, or system could potentially fail to meet or deliver the intended function.
- Effect.
  - The effect is the actual consequence of a system behavior in the presence of a failure.

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Dependability Attributes

- Availability
  - readiness for correct service.
    mean time to failure /
    mean time to failure + mean time to repair
- Reliability
  - continuity of correct service.
    mean time to failure
- Safety
  - absence of catastrophic consequences on the user(s) and the environment.
- Integrity
  - absence of improper system alterations.
- Maintainability
  - ability to undergo modifications and repairs.

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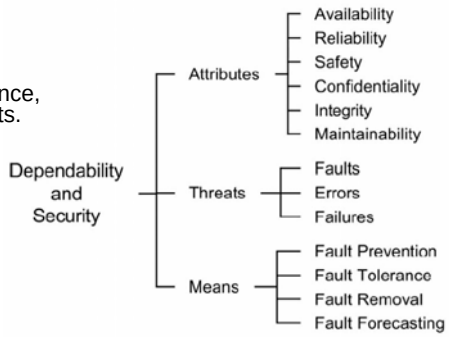
Means to attain Dependability

- Fault projecting
  - projecting failure modes in software development is used to establish a fault hypothesis and estimate the presence of faults, the future incidence, and the likely consequences of faults.
- Fault prevention / avoidance
  - means to prevent the occurrence or introduction of faults.
- Fault removal
  - means to reduce the number and severity of faults.
- Fault forecasting / prediction
  - tries to identify complex structures that are likely to become a source of faults.
- Fault tolerance
  - means to avoid service failures in the presence of faults.



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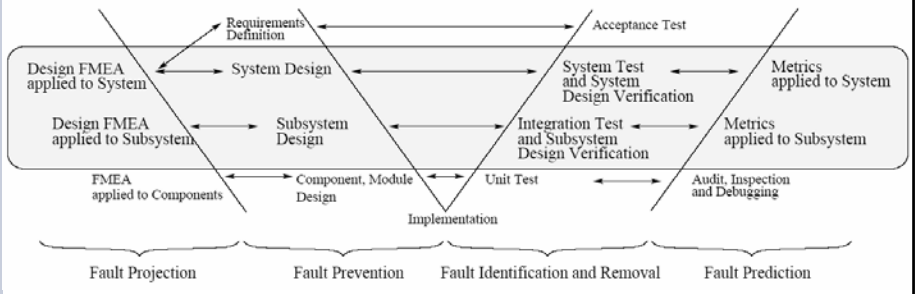
Analysis and Testing Lifecycle



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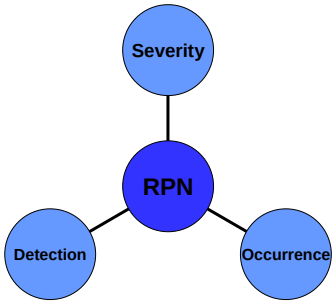
Fault projection

- Anticipate potential scenarios of failure as soon as possible
- Focus on high-risk components
  - Identification of Failure Modes, Effects, Causes, Design Controls
  - Assessment with Risk Priority Number (RPN)



Effects → **Severity**

Causes → **Occurrence**

Error → **Detection**

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Fault avoidance

- Fault avoidance
  - use of formal methods, semi-formal methods, structured methods and object-oriented methods.
- Impose discipline and restrictions on the designers of a system.
  - Hinder the designers from making too complex designs and
  - provide means to model and predict the behavior of their designs.

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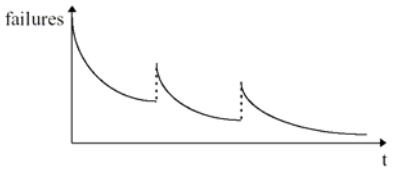
Fault Removal

- Software does not wear out over time. It is therefore reasonable to assume that as long as errors are uncovered reliability increases for each error that is eliminated.
- *The failure rate of software decreases when errors are removed.*
  However, new errors are introduced when the software is changed.



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Fault Tolerance: Phases

1. error detection
   - presence of fault is detected
2. damage confinement
   - damage due to a failure must be delimited
3. error recovery
   - correction of error
4. fault treatment and continued service
   - fault or fault component has to be identified and remove the component or use it differently

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Error detection: Timing check

- Timing checks typically set a timer with a value presenting the timing constraints of the component.
- If the timer times out, it means that the timing constraints are violated.
- a timing violation often implies that the component behaves incorrectly

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Error detection: Structural and Coding checks

- **Semantic checks**
  - ensure that the value is consistent with the rest of the system
- **Structural check**
  - internal data structure is as it should be
- **Coding checks**
  - E.g. with checksums

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Damage confinement

- **Error detected**
  - Prevent error from propagating through the system
- **Firewalls**
  - Design firewalls into the system to ensure that no information flow takes place across the walls.

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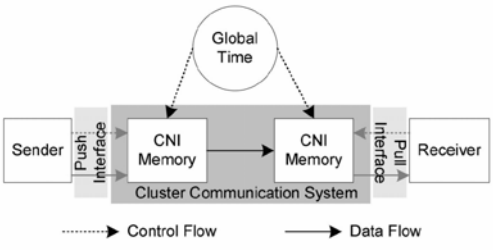
Communication Network Interface (CNI)

- A receiver that is working on a time-critical task is never interrupted by a control signal from the communication system.
- Since no control signals cross the CNI, propagation of control errors is prohibited by design.



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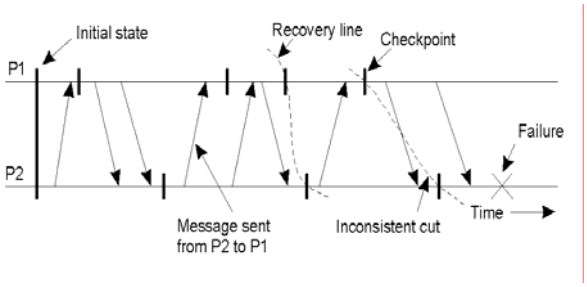
Error recovery

- **Backward recovery**
  - system state is restored to an earlier state, hoping that the earlier state is error-free.



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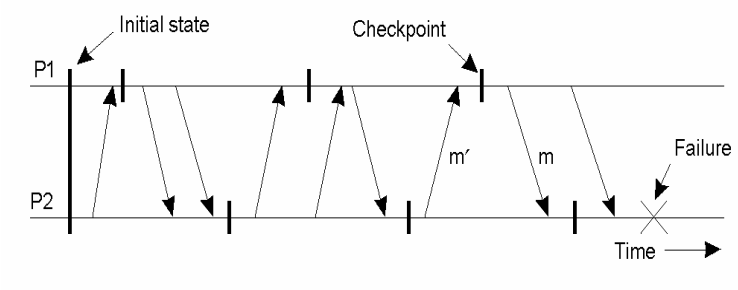
Error recovery

- **Independent checkpointing**
  - Domino effect



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Error recovery

- **Forward recovery**
  - no previous state is available. Instead the system attempts to go forward trying to make the system error-free by taking corrective actions

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Fault tolerance design principles

- **Fault tolerant designs can be divided into two categories**
  - robust designs
    - Robust systems are designed to cope with unexpected inputs, changed environmental conditions and errors in the model of the external system. A robust design can for example, be a servo feedback loop in a control system.
  - redundant designs

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Redundant design

- **Information Redundancy:**
  - For example, checksums or double-linked lists are/make use of redundant *information*. Data structures that make use of redundant information are usually referred to as robust data structures. If, for example, a double linked list is used – and one link is corrupted, the list can be regenerated using the other link.
- **Time Redundancy**
  - Redundancy in *time* can be realized for example, by allowing a function to execute again if a previous execution failed.
- **Physical Redundancy**
  - *Redundancy* in space is called *replication*. The concept is founded on the assumption that parts that are replicated fail independently. A common use of replication is for example, to use several sensors, networks or computers in parallel.
- **Model Redundancy**
  - *Model-based* redundancy uses properties of a known model, e.g., physical laws. If for example, a revolution counter for a wheel, in a four wheel drive vehicle fails, it is possible to estimate the revolution speed based on the other wheels' speeds.

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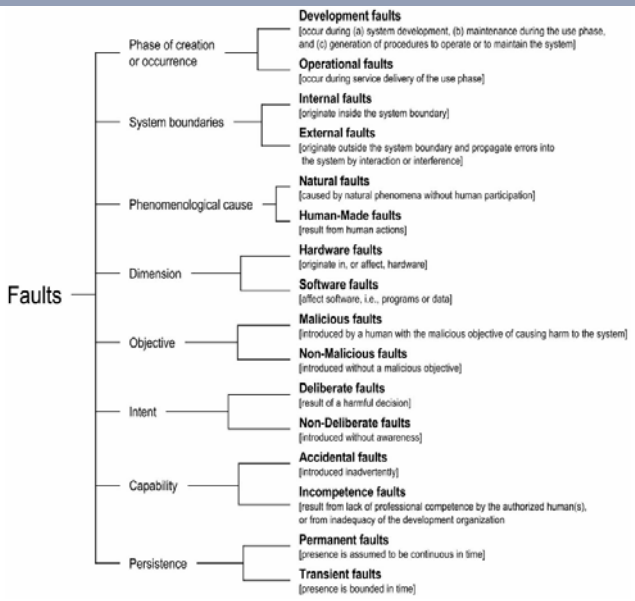
Faults



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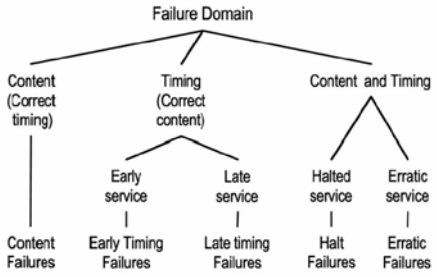
Failures

- Content failures
  - The content of the information delivered at the service interface (i.e., the service content) deviates from implementing the system function.
- Timing failures
  - The time of arrival or the duration of the information delivered at the service interface (i.e., the timing of service delivery) deviates from implementing the system function.



- Halt failure
  - or simply halt when the service is halted (the external state becomes constant, i.e., system activity, if there is any, is no longer perceptible to the users)
- Erratic failures
  - i.e., when a service is delivered (not halted), but is erratic (e.g., babbling).

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Failure Consistency

- consistent failures
  - The incorrect service is perceived identically by all system users.
- inconsistent failures
  - Some or all system users perceive differently incorrect service (some users may actually perceive correct service); inconsistent failures are usually called, after, Byzantine failures.

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Development Failure

- Budget failure.
  - The allocated funds are exhausted before the system passes acceptance testing.
- Schedule failure
  - The projected delivery schedule slips to a point in the future where the system would be technologically obsolete or functionally inadequate for the user's needs.
- Partial Development Failures
  - Overruns
    - Budget or schedule overruns occur when the development is completed, but the funds or time needed to complete the effort exceed the original estimates.
  - Downgrading
    - The developed system is delivered with less functionality, lower performance, or is predicted to have lower dependability or security than was required in the original system specification.

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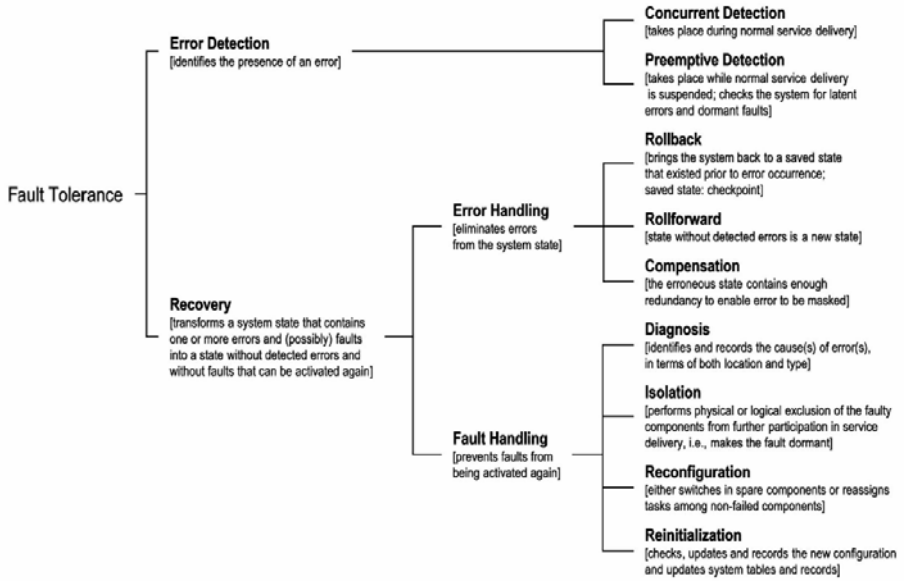
Means to attain Dependability



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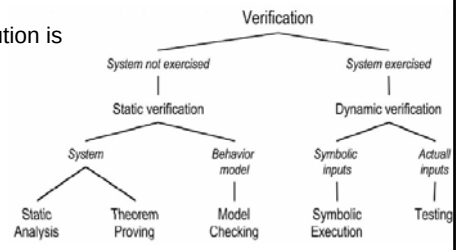
Fault Removal and Verification

- Verifying a system without actual execution is static verification.
  Such verification can be conducted:
  - static analysis
    - (e.g., inspections or walk-through, data flow analysis, complexity analysis, abstract interpretation, compiler checks, vulnerability search, etc.)
  - theorem proving;
    - on a model of the system behavior, where the model is usually a state-transition model (Petri nets, finite or infinite state automata), leading to model checking.



- Verifying a system through exercising it constitutes dynamic verification
  - Testing
    - Idea: Assumption that there exist a piecewise continuous relationships between the input and the output of a system. Only a few tests, for each continuous piece, needs to be performed. The behavior of the system intermediate to the samples can be interpolated.

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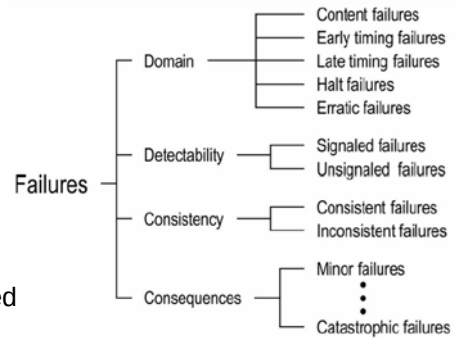
Failure severity

- for availability
  - the outage duration
- for safety
  - the possibility of human lives being endangered;
- for confidentiality
  - the type of information that may be unduly disclosed
- for integrity
  - the extent of the corruption of data and the ability to recover from these corruptions.



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