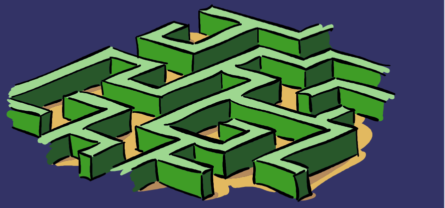
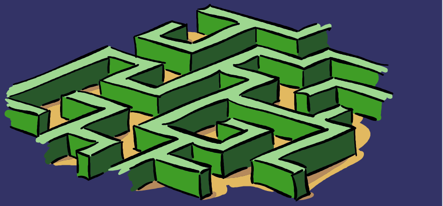
Basic Concepts and Taxonomy of Dependable and Secure Computing

Algirdas Avizienis, Jean-Claude Laprie
Brian Randell, and Carl Landwehr



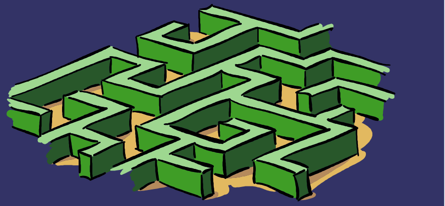
Overview

- Motivation
- Concepts in Our Taxonomy
- Dependability and Security
- Threats to Dependability and Security
- Means to Dependability and Security
- Conclusion
- Questions



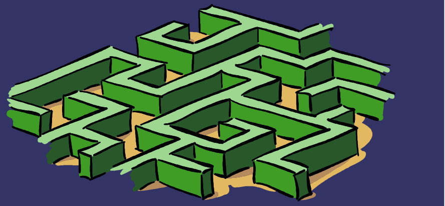
Motivation

- Communication and cooperation among communities are difficult
  - Especially when system failures
- Explicit and clear concepts are necessary
- But, there are uncertainties and complexity in systems



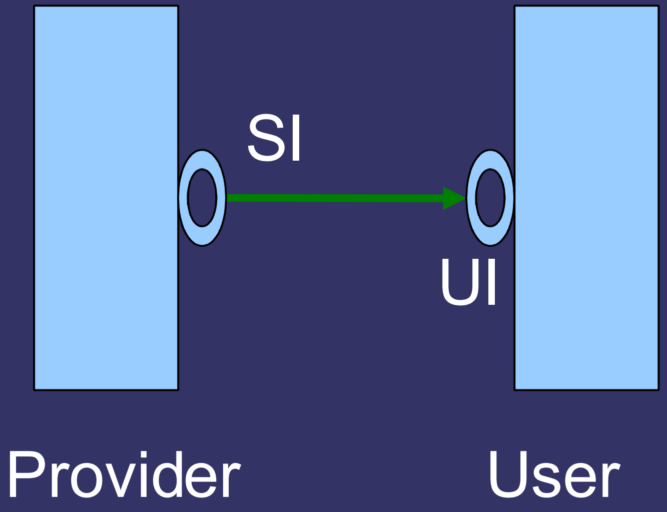
Concepts of Our Taxonomy

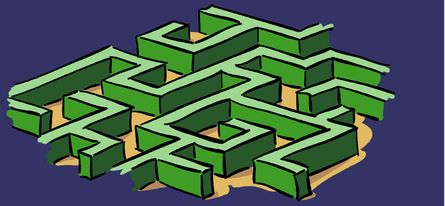
- System
  - A system is an entity that interacts with other entities, i.e., other systems, including hardware, software, humans, etc.
- Function
  - The function of a system is what the system is intended to do and is described by the functional specification in terms of functionality and performance
- Behavior
  - The behavior of a system is what the system does to implement its function and is described by a sequence of states
- Structure
  - The structure of a system is what enables it to generate the behavior.



Concepts Continued.

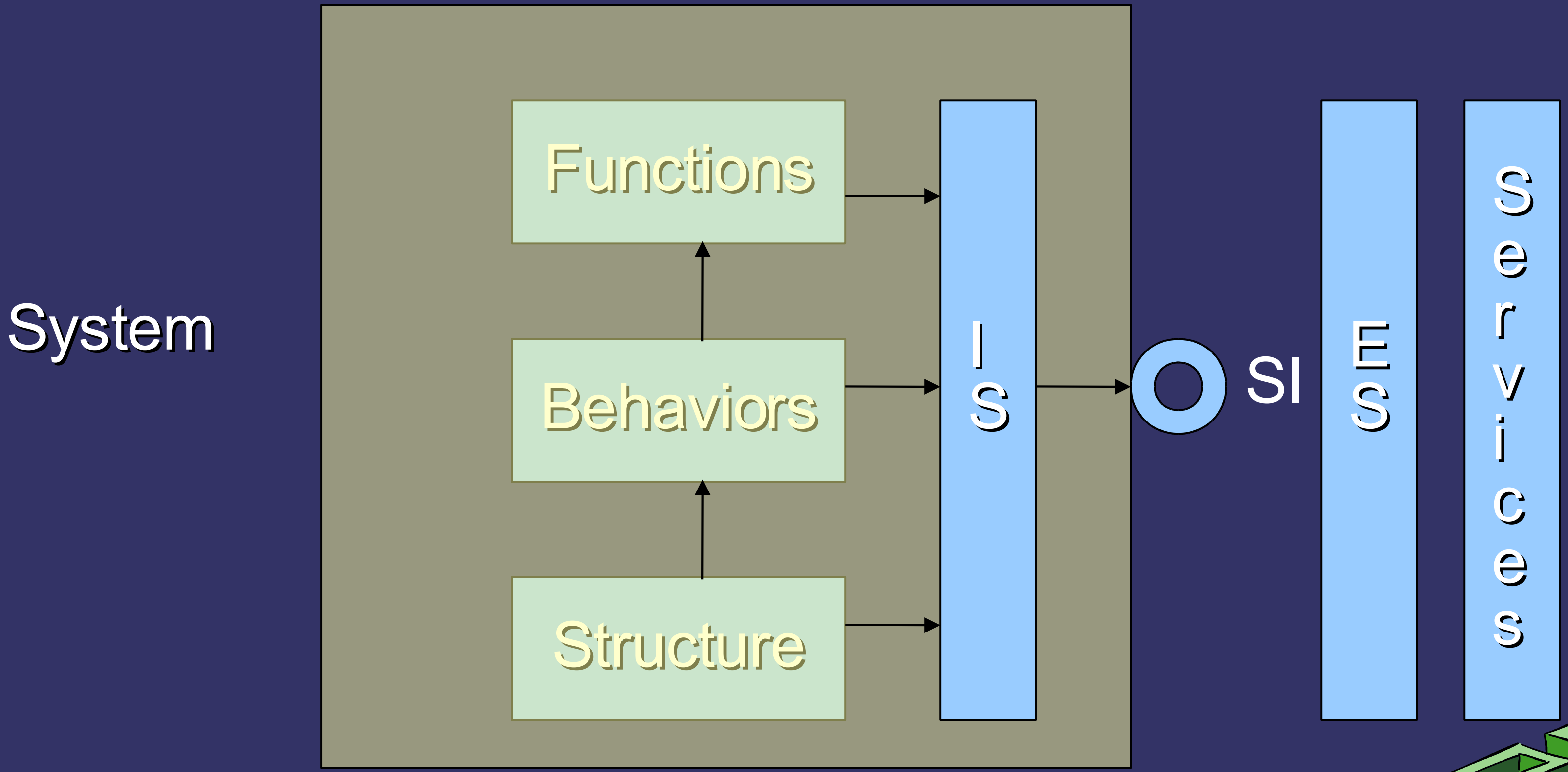
- Service
  - The service delivered by a system is its behavior as it is perceived by its user(s)
- Roles
  - Provider
  - User
- Interfaces
  - Service Interface
  - Use Interface
- States
  - External State
    - Global varibles
  - Internal State
    - Local variables





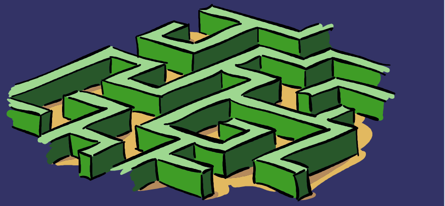
Relationship

- Overview of a system
  - A service is a sequence of the system's external states



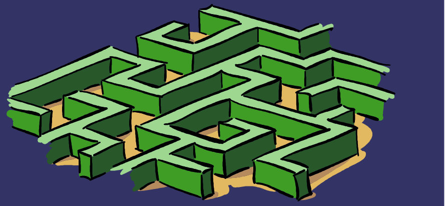
Dependability and Security

- Definition of Dependability
- Definition of Security
- Their Attributes
- Their Relationship



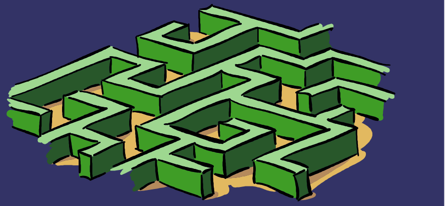
Definitions of Dependability

- Definition 1
  - The ability to deliver service that can justifiably be trusted
    - Stress the need for justification of trust
- Definition 2
  - The ability to avoid service failures that are more frequent and more severe than is acceptable
    - Stress the avoidance of failures



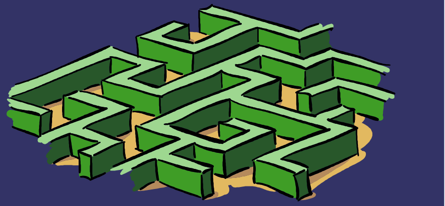
Attributes of Dependability

- Availability
  - Readiness for correct service
- Reliability
  - Continuity of correct service
- 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

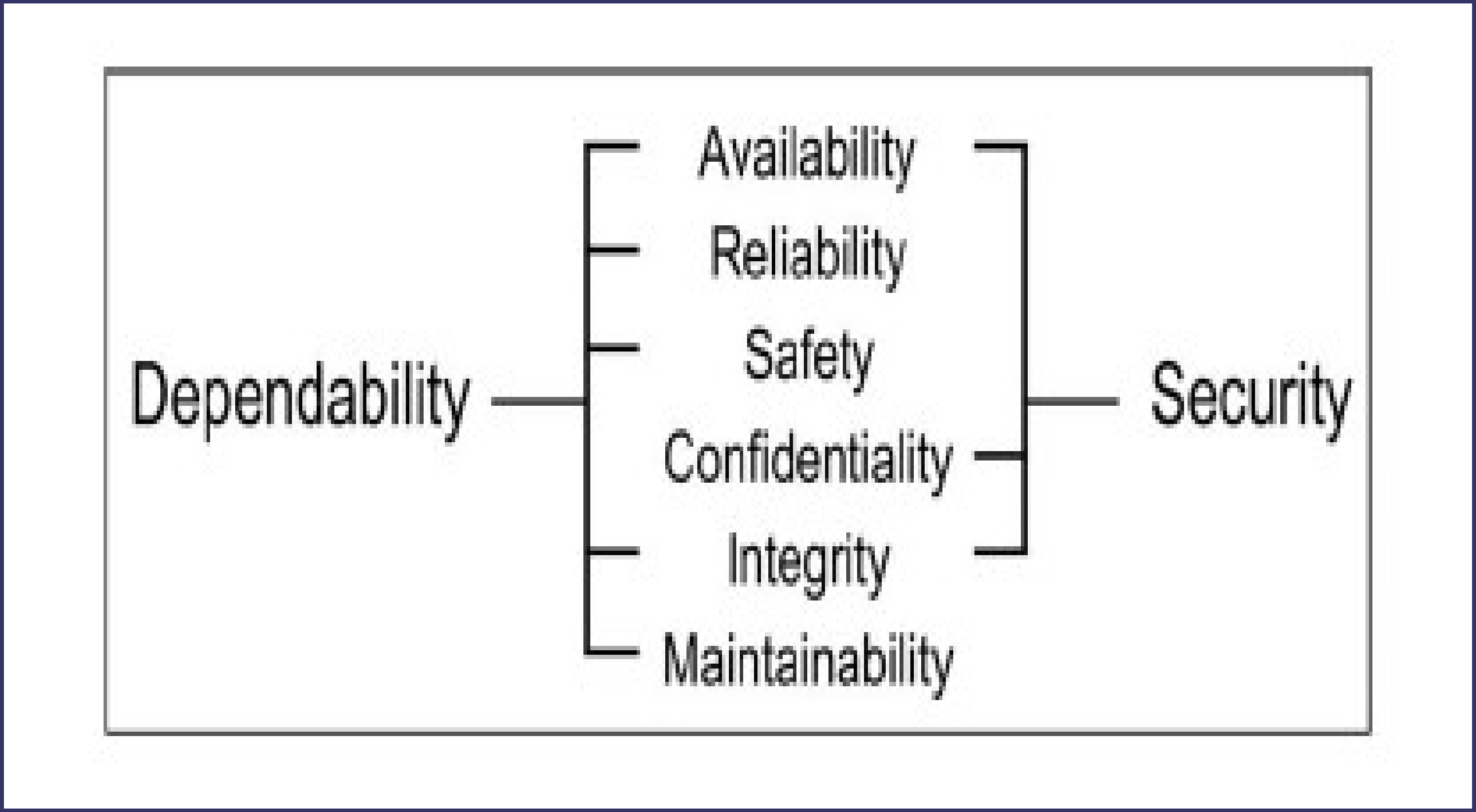


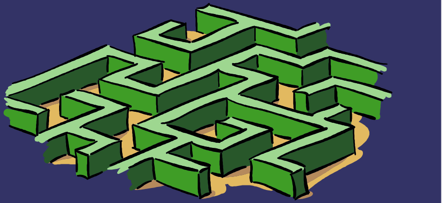
Security

- Definition of Security
  - Security is a composite of the attributes of confidentiality, integrity, and availability, requiring the concurrent existence of
    - Availability for authorized action only
    - Confidentiality
    - Integrity with “improper” meaning “unauthorized”
- Confidentiality
  - The absence of unauthorized disclosure of information
  - With great prominence



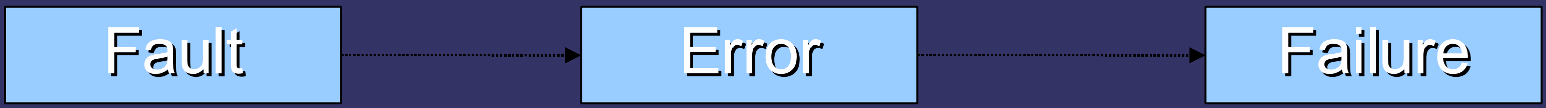
Relationship between Dependability and Security

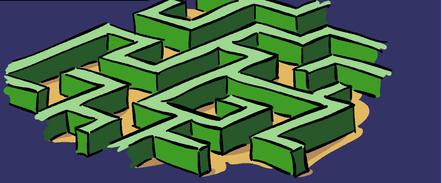




Threats to Dependability and Security

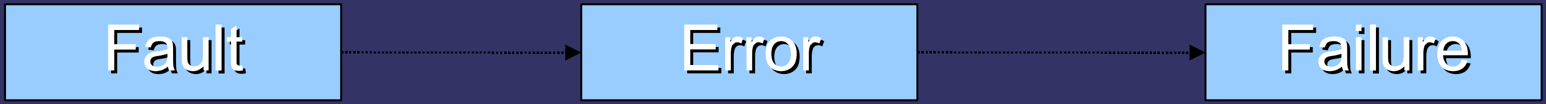
- Faults
  - ⑤ A fault is the adjudged or hypothesized cause of an error
- Errors
  - An error is the part of total state of the system that may lead to its subsequent service failure
    - Active
    - Latent

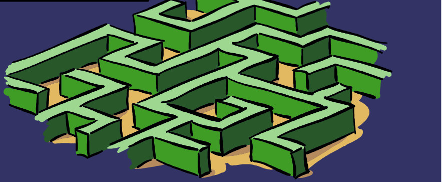




Threats continued

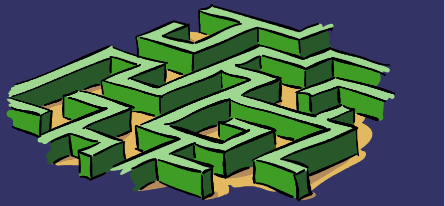
- Failures (or Service Failures)
  - A failure is an event that occurs when the delivered service deviates from correct service
  - At least one external state of the system deviates from the correct service state





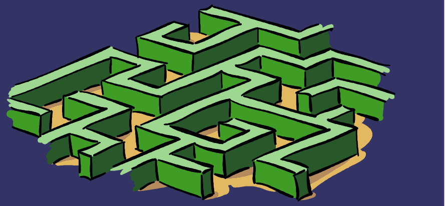
Taxonomy of Faults

- Development Faults
  - All fault classes occurs during the development
- Physical Faults
  - All fault classes that affect hardware
- Interaction Faults
  - All external faults
    - e.g. Interface mismatch between components



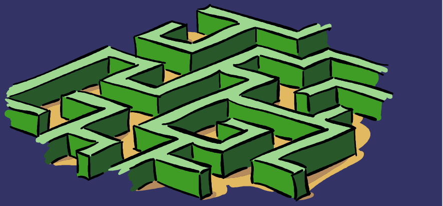
Taxonomy of Faults

- Natural Faults
  - Caused by natural phenomena without human participation
    - Physical faults
    - Production defects originating from development
    - Internal/External
- Human-Made Faults
  - Result from human actions
    - Omission/Commission faults
      - e.g. Absence/Wrong action
    - Malicious/Nonmalicious faults
      - Virus/Flaw



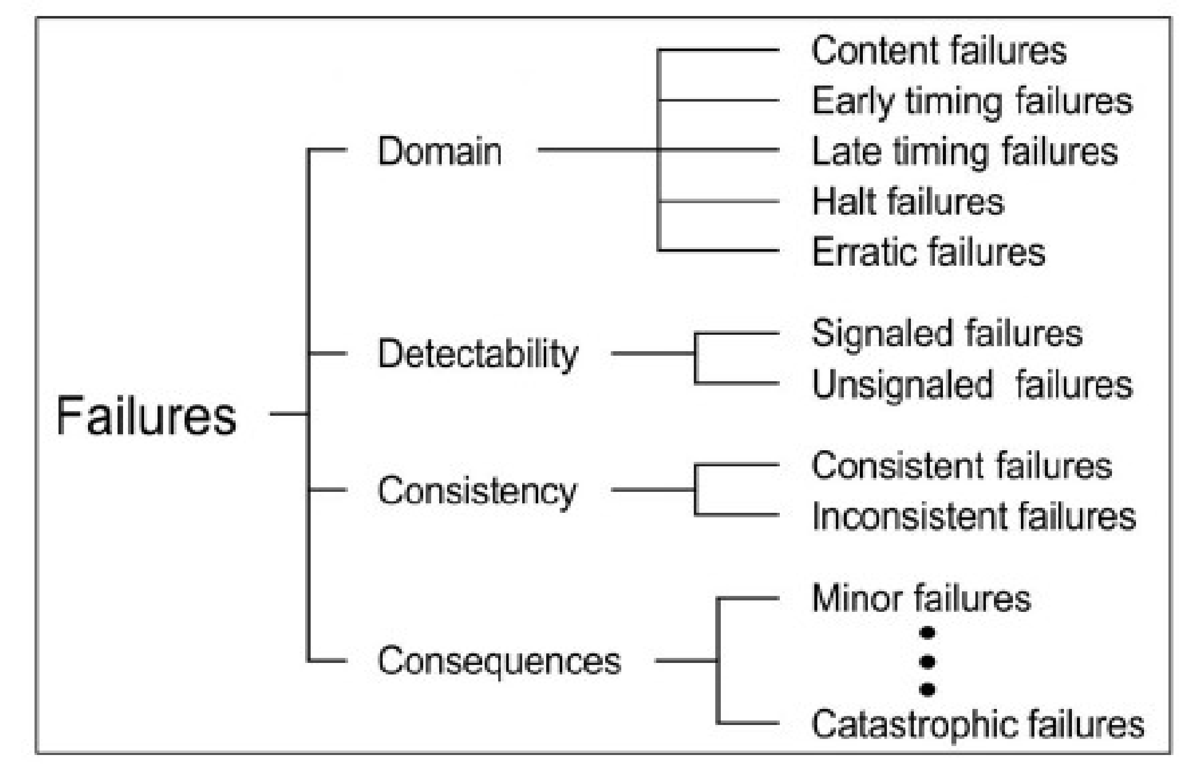
Taxonomy of Errors

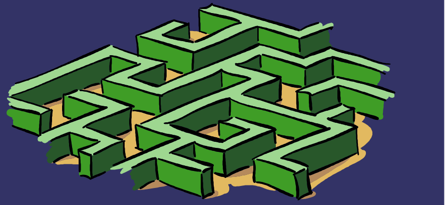
- Errors
  - An error is the part of total state of the system that may lead to its subsequent service failure
    - Detected/Latent
    - Content/Timing
    - Consistent/Inconsistent
- Does an error cause a service failure?
  - It depends on the structure of the system
    - Redundancy
  - It also depends on the behavior of the system
    - What if the part of the state that contains the error never be needed for service?



Taxonomy of Failures

- Service Failures
  - A service failure is defined as an event the occurs when the delivered service deviates from correct service
  - 4 Viewpionts

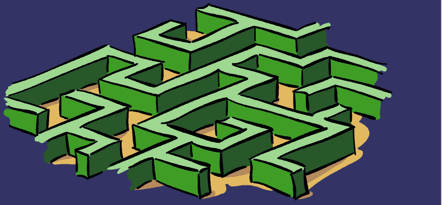




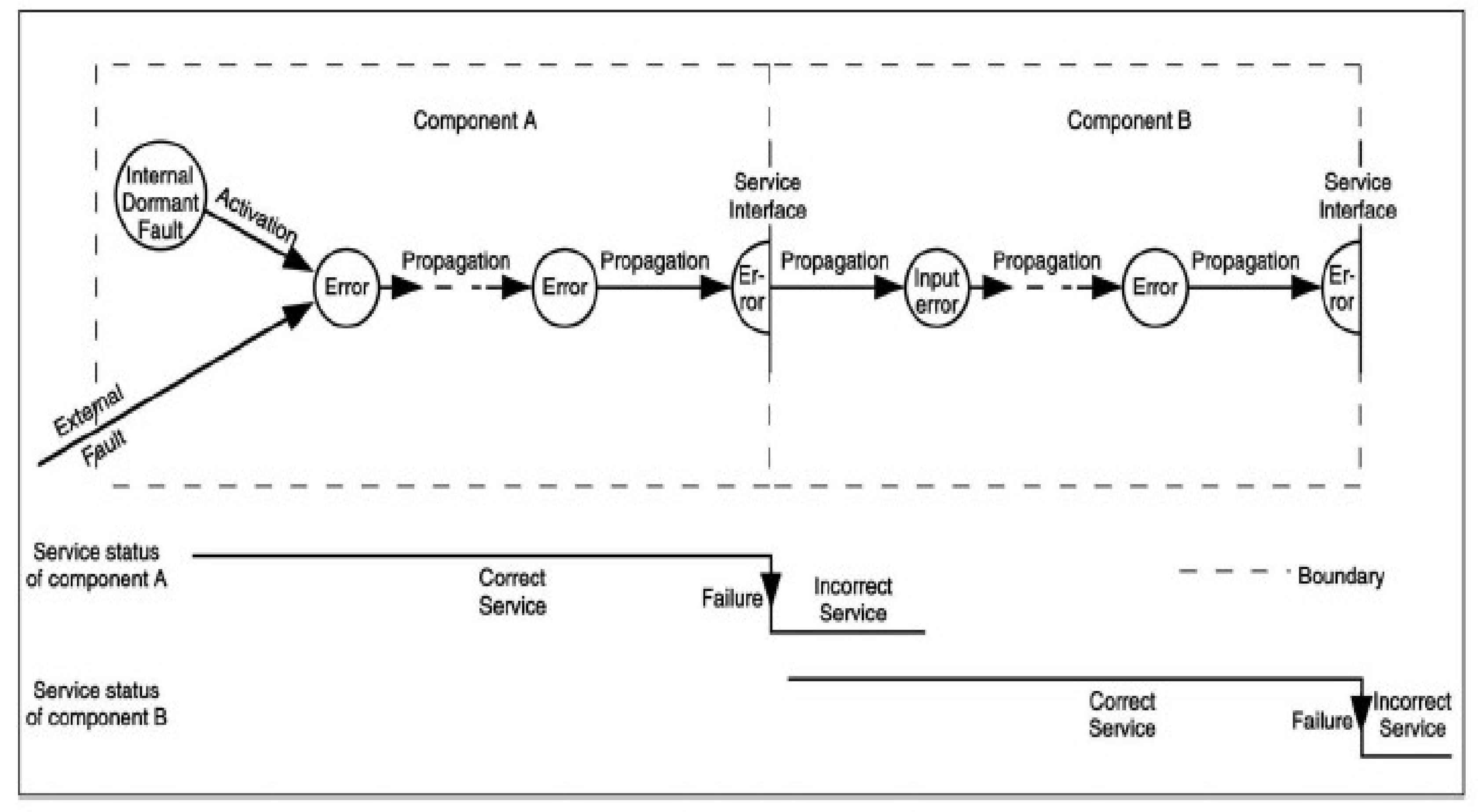
Development Failures

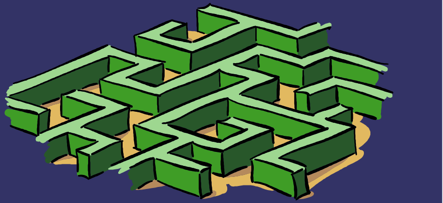
- Development Failures
  - Development faults introduced into the system by its environment, especially by human, may contribute to partial or complete development failures
    - Budget failure
    - Schedule failure

- Development failures have a very negative impact on the user community
    - Complete development failure of the AAS system resulted in the waste of $1.5 billion!!!

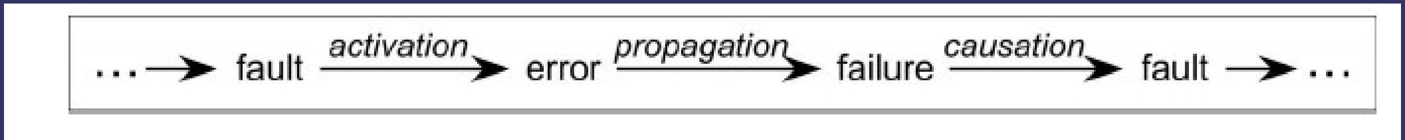


Pathology of Failure

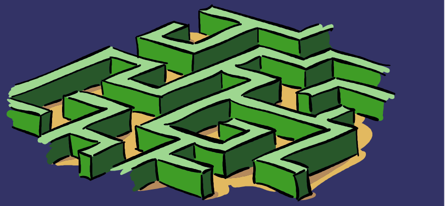




Chain of dependability and security threats

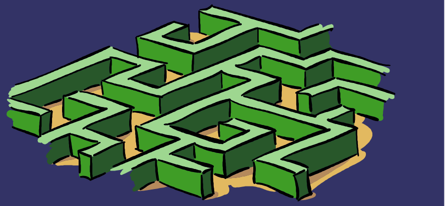


$$\cdots \rightarrow \text{fault} \xrightarrow{\textit{activation}} \text{error} \xrightarrow{\textit{propagation}} \text{failure} \xrightarrow{\textit{causation}} \text{fault} \rightarrow \cdots$$



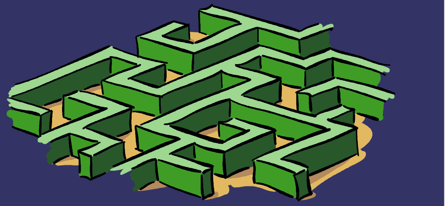
Means to Attain Dependability and Security

- Fault Prevention
- Fault Tolerance
- Fault Removal
- Fault Forecasting



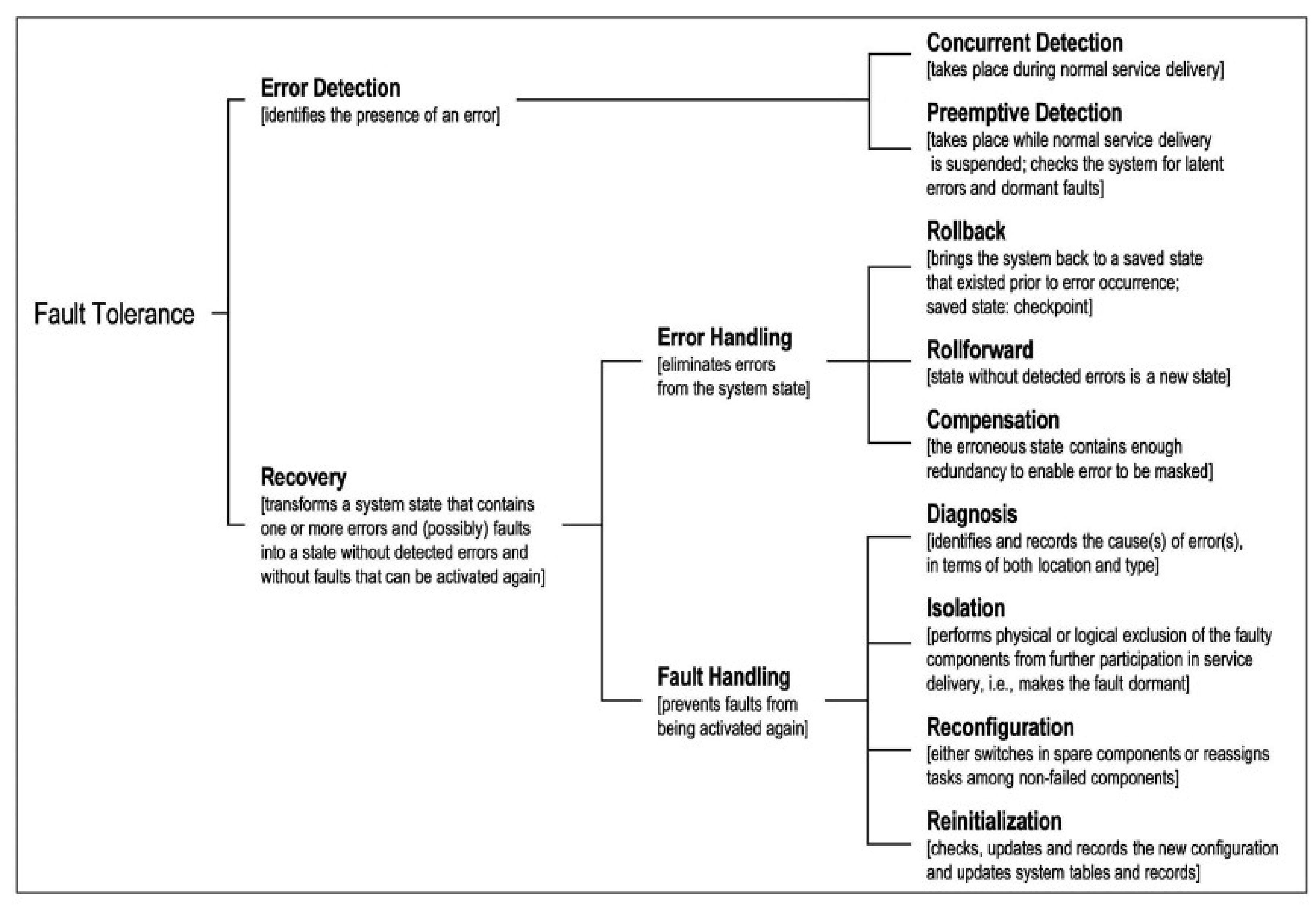
Fault Prevention

- Part of general engineering
- Prevention of development faults is mentioned
  - Software & hardware
    - e.g. C or Java
  - Improvement of development processes
    - e.g. Recording faults in product



Fault Tolerance

Failure avoidance by error detection and system recovery

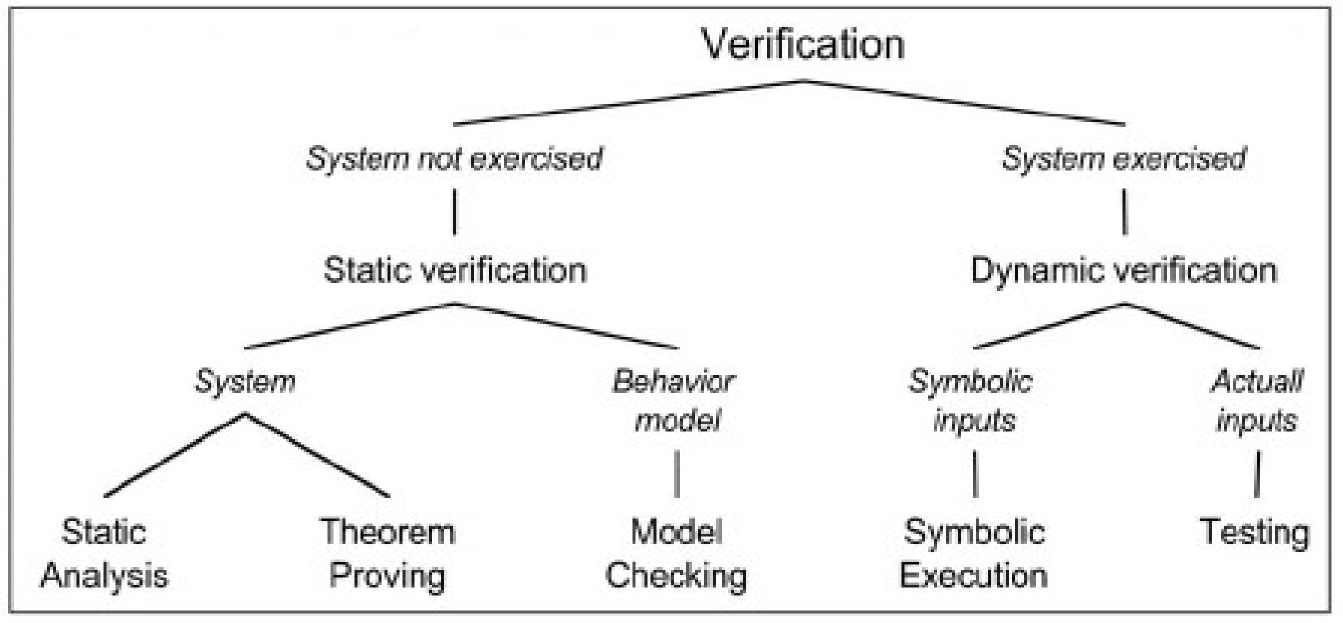


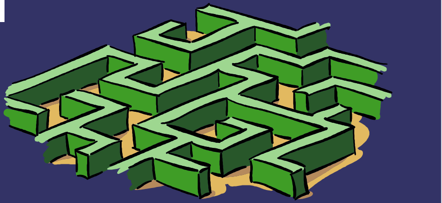
Fault Tolerance

- **Error Detection** [identifies the presence of an error]
  - **Concurrent Detection** [takes place during normal service delivery]
  - **Preemptive Detection** [takes place while normal service delivery is suspended; checks the system for latent errors and dormant faults]
- **Recovery** [transforms a system state that contains one or more errors and (possibly) faults into a state without detected errors and without faults that can be activated again]
  - **Error Handling** [eliminates errors from the system state]
    - **Rollback** [brings the system back to a saved state that existed prior to error occurrence; saved state: checkpoint]
    - **Rollforward** [state without detected errors is a new state]
    - **Compensation** [the erroneous state contains enough redundancy to enable error to be masked]
  - **Fault Handling** [prevents faults from being activated again]
    - **Diagnosis** [identifies and records the cause(s) of error(s), in terms of both location and type]
    - **Isolation** [performs physical or logical exclusion of the faulty components from further participation in service delivery, i.e., makes the fault dormant]
    - **Reconfiguration** [either switches in spare components or reassigns tasks among non-failed components]
    - **Reinitialization** [checks, updates and records the new configuration and updates system tables and records]

Fault Removal

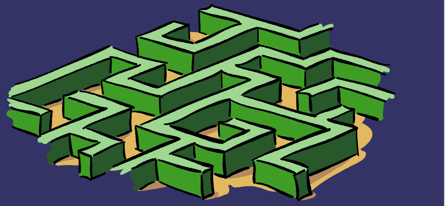
- System development phase
  - 3 steps: Verification,Diagnosis, Correction
  - Verification approaches
- System use phase
  - Corrective or preventive maintenance





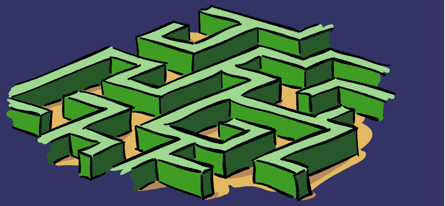
Fault Forecasting

- Fault forecasting is conducted by performing an evaluation of the system behavior with respect to fault occurrence of activation
  - Qualitative evaluation
    - Identify, classify, and rank the failure modes
  - Quantitative evaluation
    - Evaluate in terms of probabilities the extent to which some of the attributes are then viewed as measure



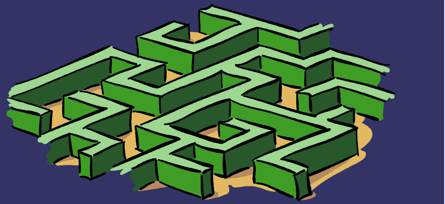
Relationship between the 4 means

- Fault Prevention vs Fault Removal
  - Faults may occur after prevention, we need fault removal
- Fault Removal vs Fault Forecasting
  - Fault removal may generates faults, we need fault forecasting
- Fault Tolerance is required even more
  - Increasing dependence on computing systems
  - Fault Tolerance needs fault removal & forecasting
- Nothing is perfect, we need the combined utilization of all 4 means



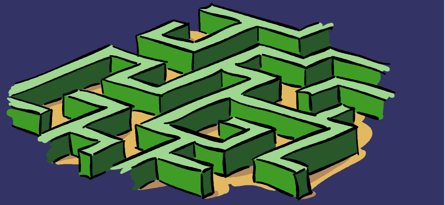
Conclusion

- We need trust various computing systems
  - Airplane, nuclear plant, etc
- A single conceptual framework among various systems
  - Availability
  - Reliability
  - Safety
  - Confidentiality
  - Integrity
  - Maintainability
- We need a system with an appropriate balance of these properties



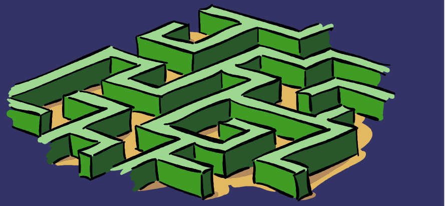
Question 1

- In fault tolerance, error handling includes rollforward, can you give me an example of rollforward? Is it easy to do a rollforward?



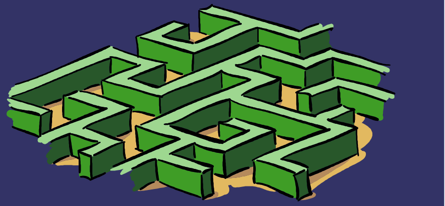
Question 2

- What is symbolic execution? (in section 5.3.1)



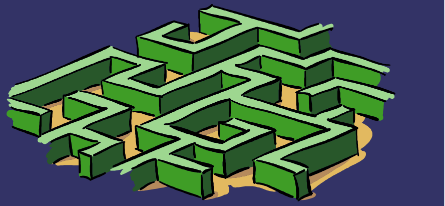
Question 3

- What’s the difference between protective redundancy and unintentional redundancy?



Question 4

- Are there any computing systems, each phase of which actually uses all 4 approaches presented in the paper? (Fault prevention, fault removal, fault tolerance, fault forecasting)



More Questions?