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# Terminology Issues in Dependable Computing

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# Prologue: my fortuitous encounter with the dependability problem

- 1960: I complete the Ph.D. on computer arithmetic at the University of Illinois and move to the Jet Propulsion Laboratory that Caltech operates for NASA
- JPL is assigned the mission to explore the planets of our solar system by the means of unmanned interplanetary spacecraft
- I am asked to investigate the design of an on-board computer that can survive during a journey of several years and then deliver a specified performance at planetary encounters
- No such unique requirement had existed anywhere in the world until the JPL mission was established by NASA

# Prologue: continued

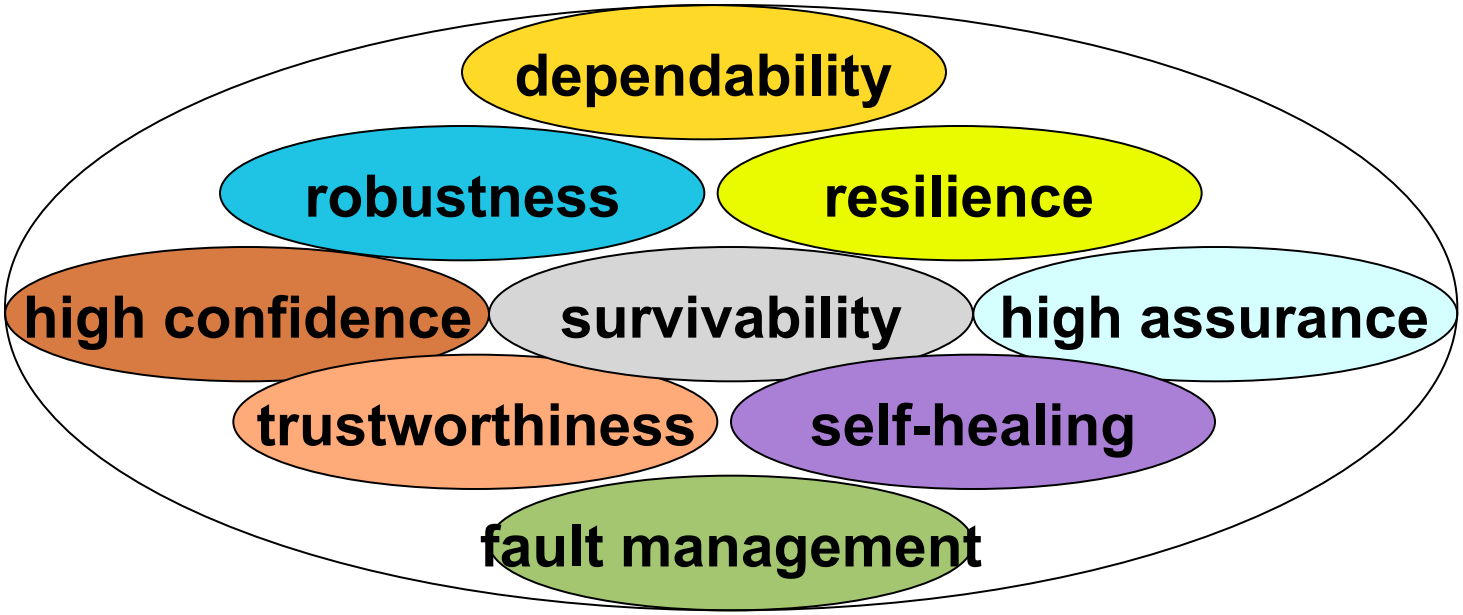
- **1967:** The paper "Design of fault-tolerant computers" by A. Avizienis at the Fall Joint Computer Conference introduces the concept of fault tolerance and describes the JPL-STAR (Self-Testing-And-Repairing) computer design.
- **1970:** Lab model of JPL-STAR is demonstrated, a U.S. patent is granted, and the STAR design is chosen for the 15-year "Grand Tour" mission to four planets.
- IEEE Computer Society Technical Committee on Fault-Tolerant Computing (TC-FTC) is founded, I serve as first Chair.

# Prologue: concluded

- **1971**: First IEEE International Symposium on Fault-Tolerant Computing (FTCS-1) takes place in Pasadena, CA, USA, with JPL support. (The 42nd,now "DSN" is in Boston this June)
- *Bad news*: NASA budget is affected by the war in Vietnam and the Grand Tour mission is cancelled, JPL-STAR is an orphan.
- **1972**: *Good news:* the NSF awards a five-year grant to transfer fault tolerance research to UCLA, where the "Dependable Computing and FT Systems Laboratory" continues work until 1994. About 10 faculty, 20 foreign scholars, and 50 graduate students take part in its research.

# Our Field's Goal: deliver expected service under adverse conditions

## Our Field's Top Concepts:




## How are they related?

# The Concepts of Dependability: a Quest for Structure and Clarity

- **1981:** First meeting of IFIP Working Group 10.4 in Portland, Maine, USA, includes a workshop on the concepts and terminology. A.Avizienis is the founding Chair of the WG.
- **1982:** FTCS-12 in Santa Monica, CA, USA, has a session on the concepts of dependability.
- **1992:** Joint work by members of WG 10.4 appears in the book "Dependability: Basic Concepts and Terminology", J.-C. Laprie, A.Avizienis and H.Kopetz, editors (850 citations in Google Scholar)
- **2001:** Report "Fundamental Concepts of Dependability" by A.Avizienis, J.-C.Laprie and B.Randell (600 citations in Google Scholar)

# 2004: The "Taxonomy" Milestone

*"Basic concepts and taxonomy of dependable and secure computing"* by Algirdas Avižienis, Jean-Claude Laprie, Brian Randell and Carl Landwehr appears in:

*IEEE Transactions on Dependable and Secure Computing, vol. 1, no. 1, January-March 2004, pp. 11-33.*

**This paper summarizes and extends the long-term efforts of the authors and of their colleagues in IFIP WG 10.4 and IEEE CS TC-FTC, as presented next.**

*Currently Google Scholar lists nearly 2000 citations*.

Download Technical Report: http://drum.lib.umd.edu/bitstream/1903/6459/1/TR_2004-47.pdf

# The Basic Concepts

- **Service** delivered by a system (the **provider**): its behavior as it is perceived by its user(s)
- **User:** another system that receives service from the provider
- **Function** of a system: what the system is intended to do
- **Specification** (functional): description of the system function
- **Correct service**: when the delivered service implements the system function

# The Basic Concepts (cont.)

- **Service failure**: event that occurs when the delivered service deviates from correct service, either because the system does not comply with the specification, or because the specification did not adequately describe its function
- **Failure modes**: the ways in which a system can fail, ranked according to failure severities
- **Error**: part of system state that may cause a subsequent service failure; errors are *latent* or *detected*
- **Fault:** known or hypothesized cause of an error; faults are *dormant (vulnerabilities)* or *active*

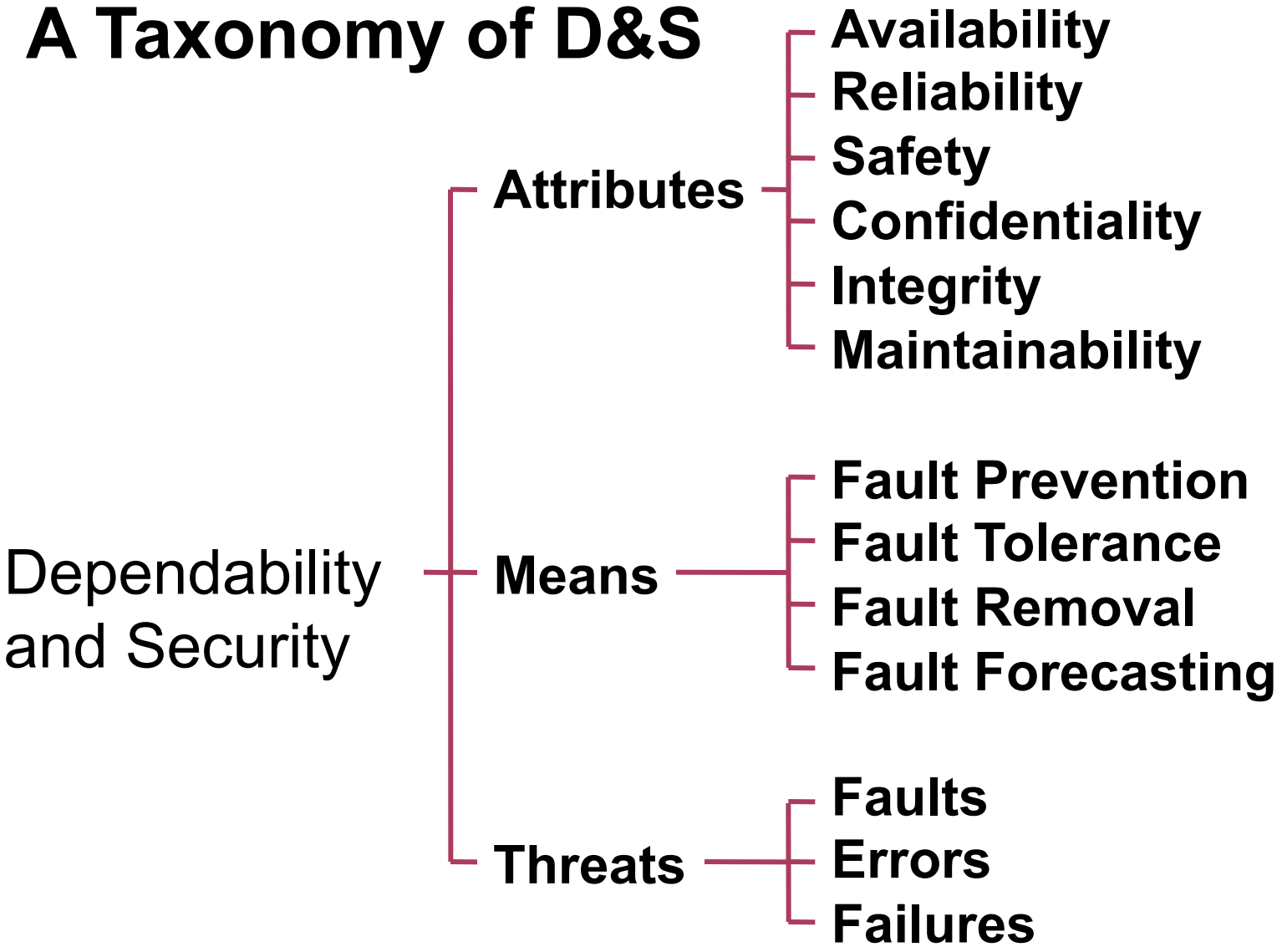
# Two Definitions of Dependability

**Dependability**: ability to deliver service that can justifiably be trusted (*qualitative*)

**Dependability**: ability to avoid service failures that are more frequent or more severe than is acceptable (*quantitative*)

When service failures are more frequent or more severe than acceptable, we have a **dependability failure**

# A Taxonomy of D&S



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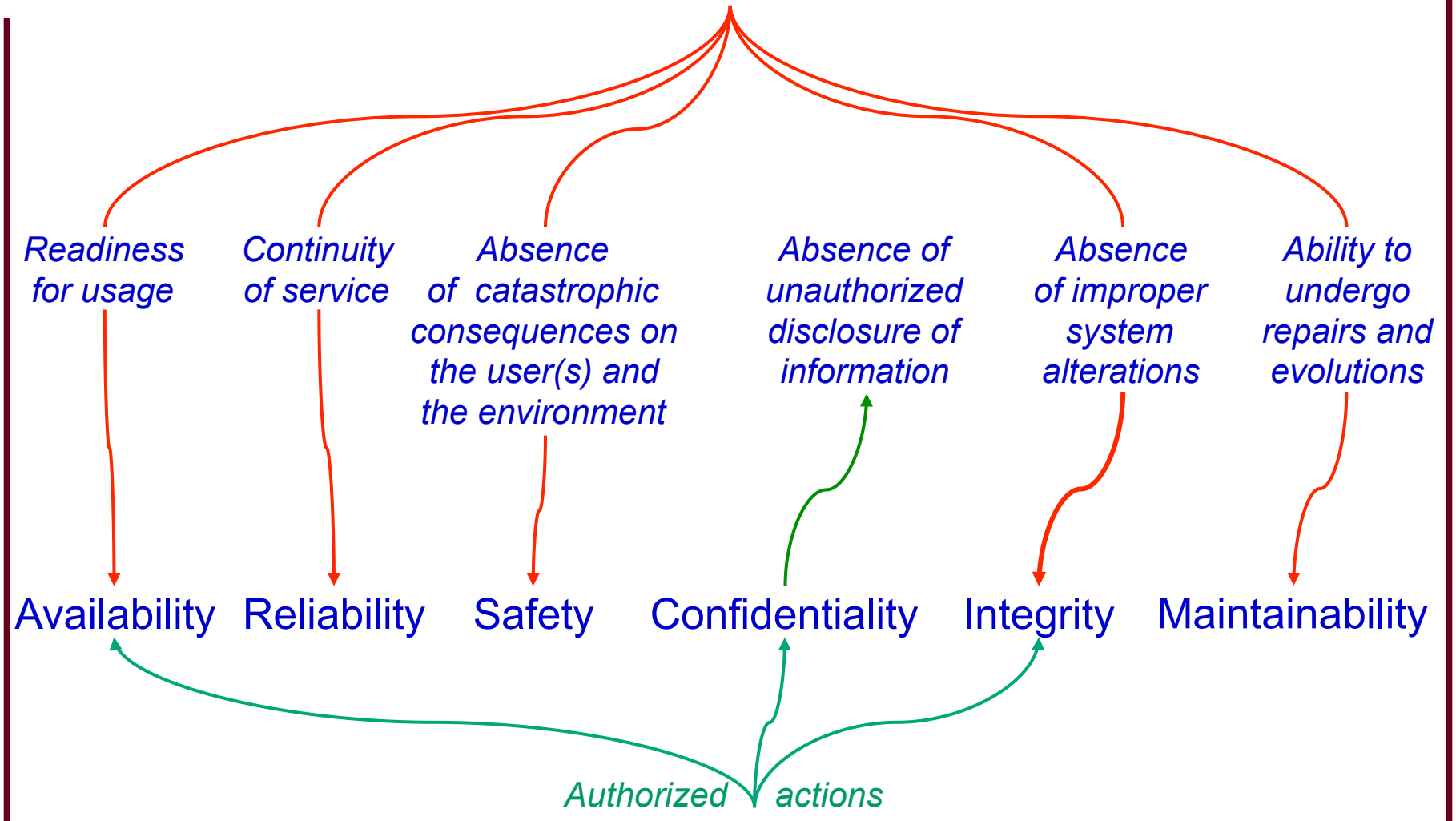
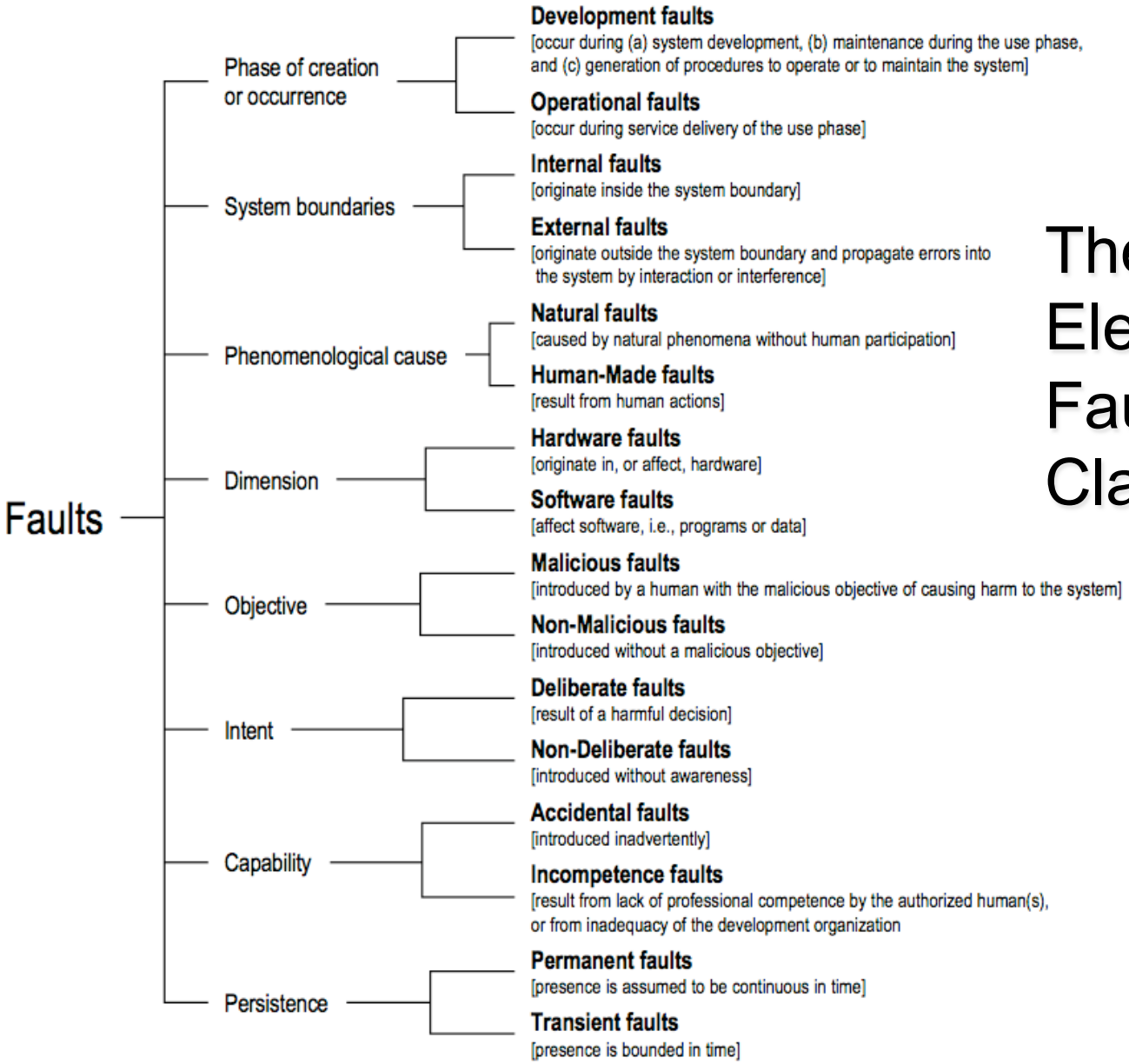
# Dependability



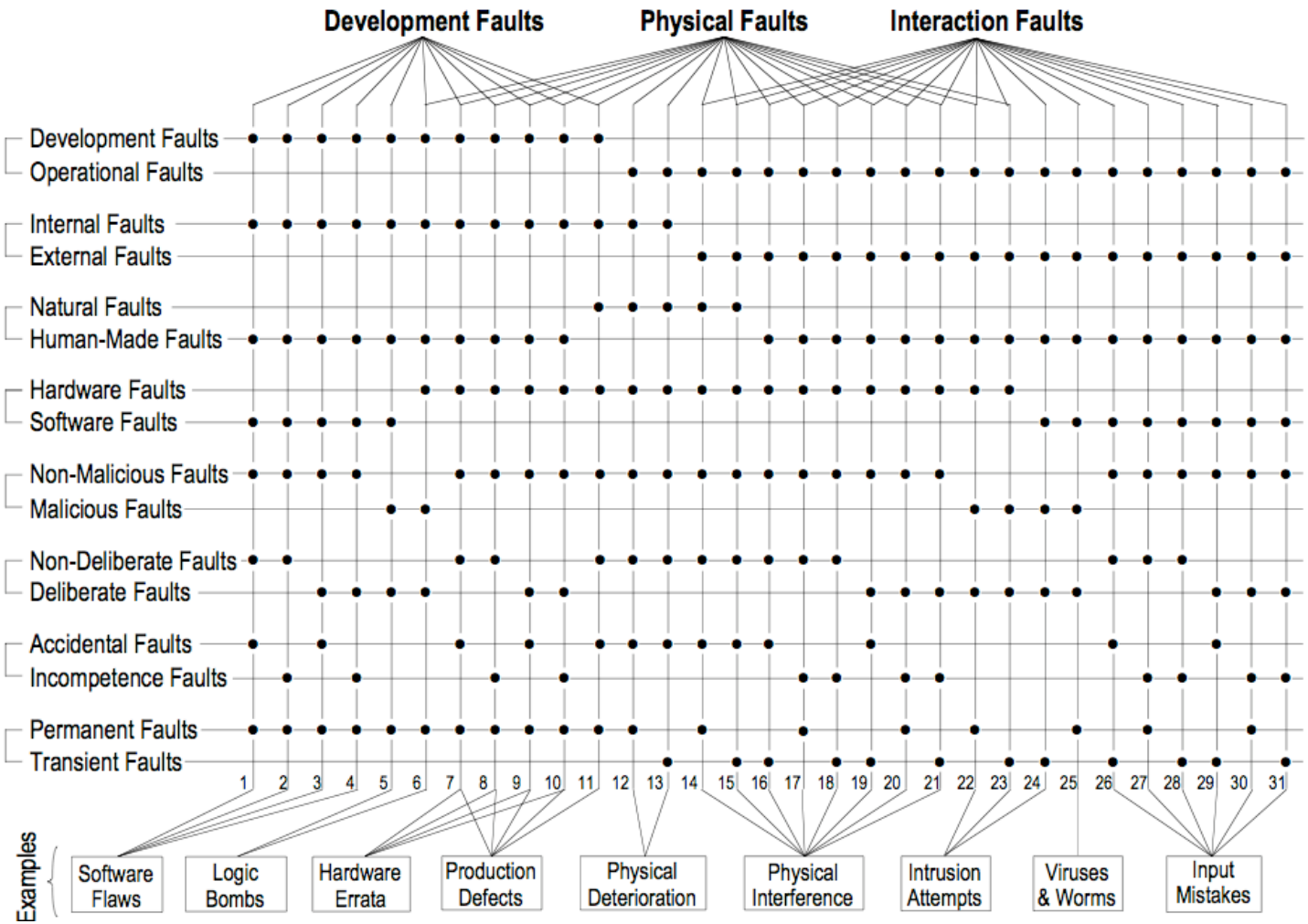

## Security

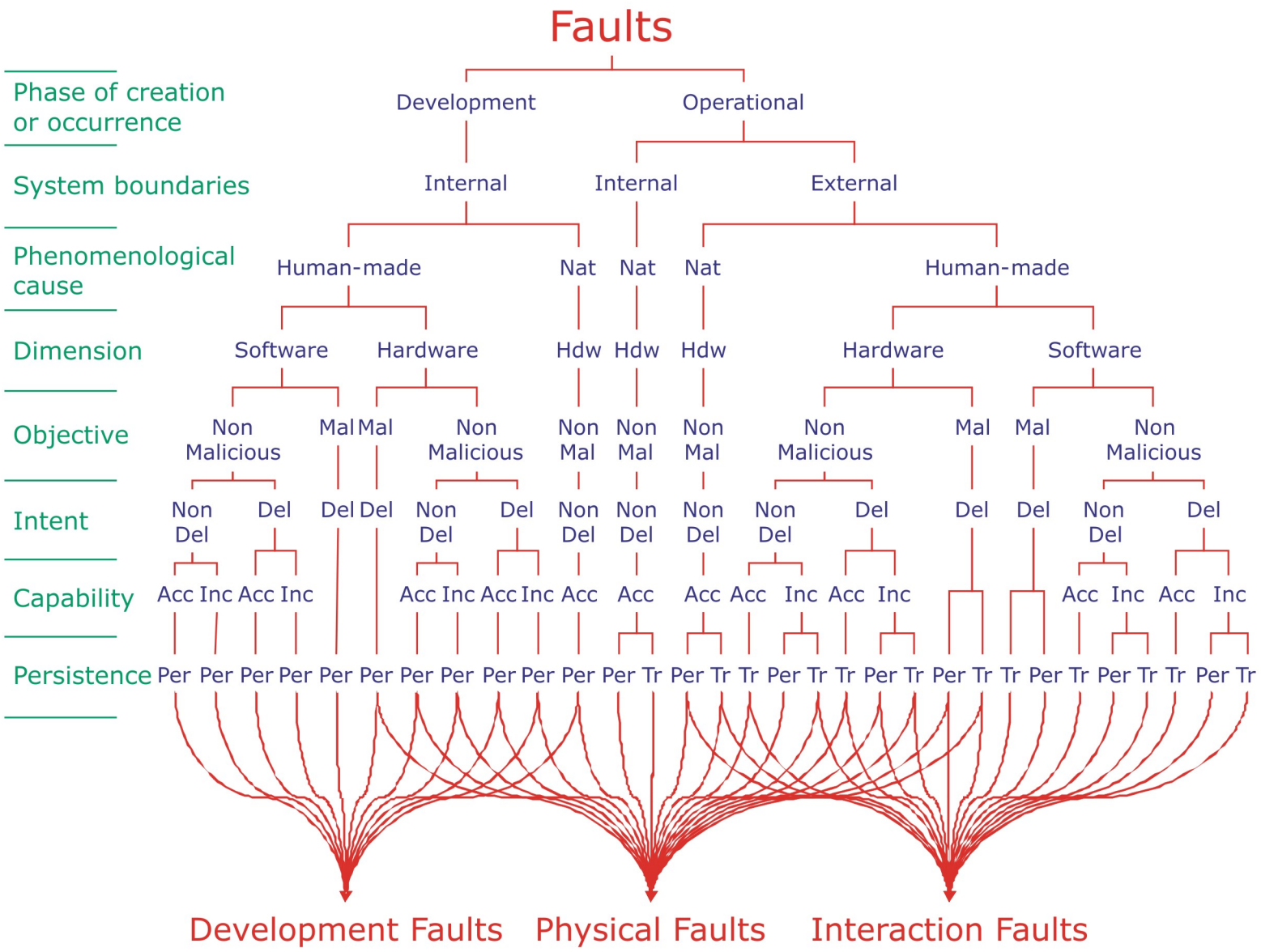
Absence of unauthorized access to, or handling of, system state

# The Elementary Fault Classes



# Fault Classification




Faults
Phase of creation or occurrence
System boundaries
Phenomenological cause
Dimension
Objective
Intent
Capability
Persistence
Development
Operational
Internal
Internal
External
Human-made
Nat
Nat
Nat
Human-made
Software
Hardware
Hdw
Hdw
Hdw
Hardware
Software
Non Malicious
Mal
Mal
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Acc Inc Acc Inc
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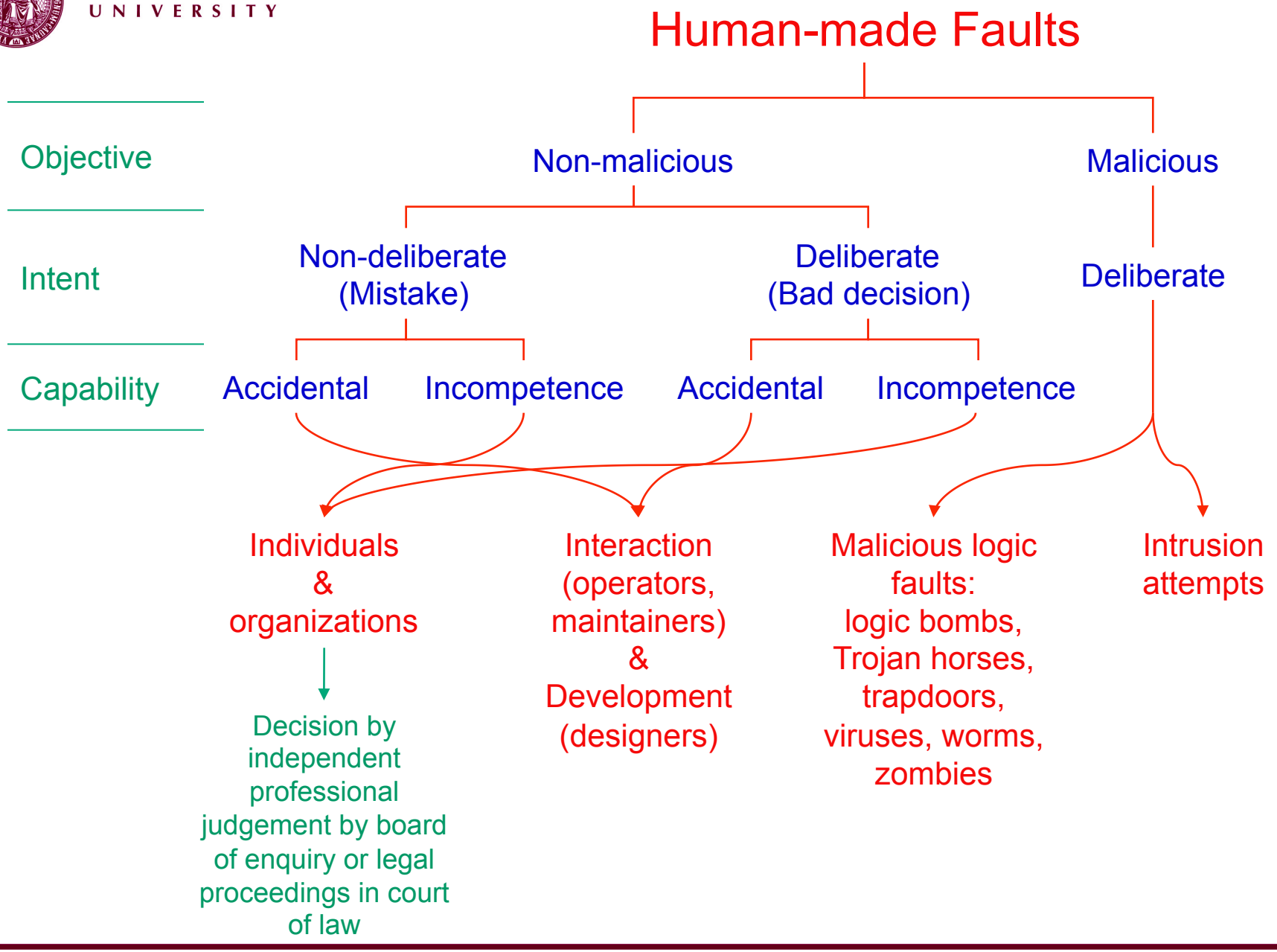
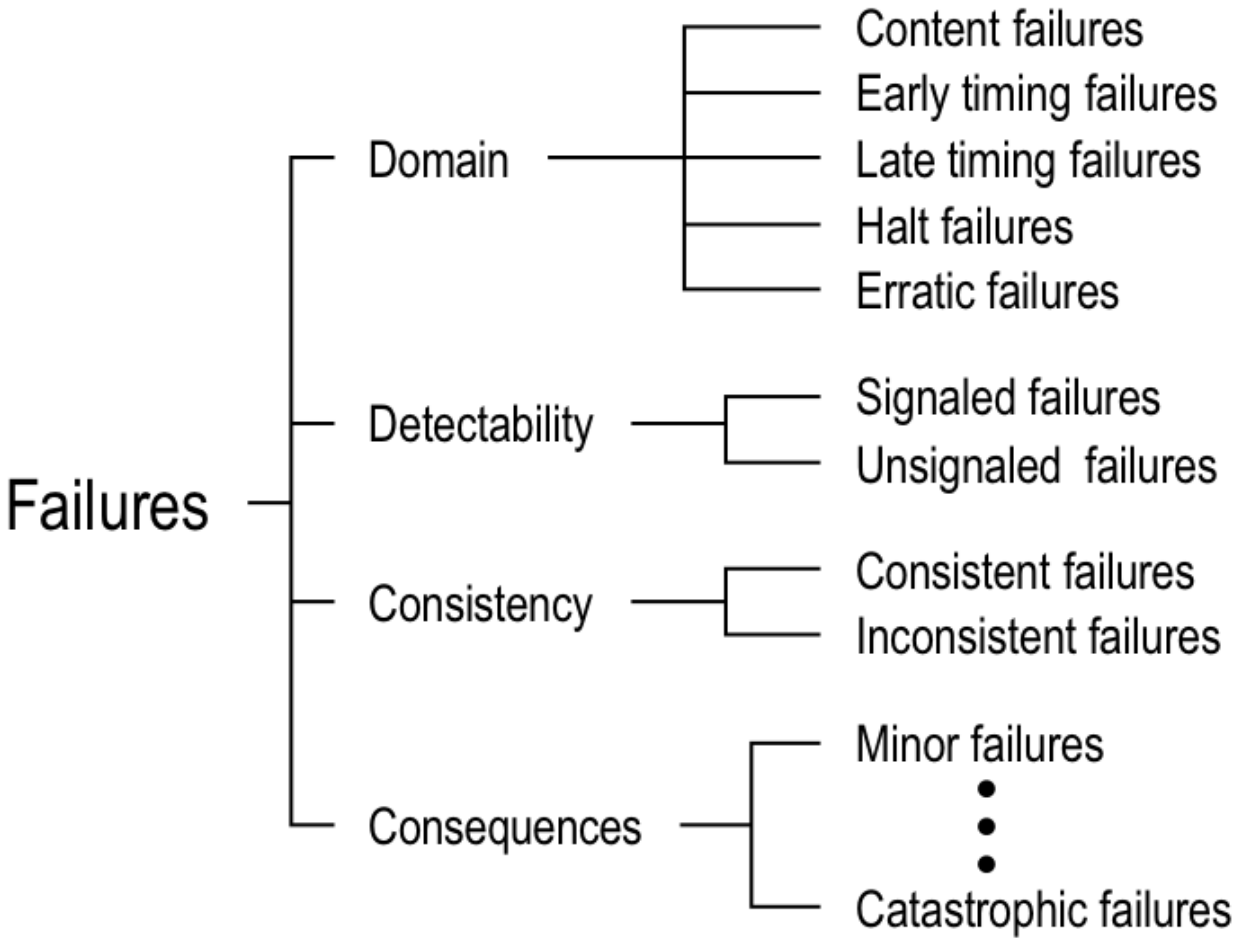
Development Faults
Physical Faults
Interaction Faults


Human-made Faults
Objective
Intent
Capability
Non-malicious
Malicious
Non-deliberate
(Mistake)
Deliberate
(Bad decision)
Deliberate
Accidental
Incompetence
Accidental
Incompetence
Individuals
&
organizations
Interaction
(operators,
maintainers)
&
Development
(designers)
Malicious logic
faults:
logic bombs,
Trojan horses,
trapdoors,
viruses, worms,
zombies
Intrusion
attempts
Decision by
independent
professional
judgement by board
of enquiry or legal
proceedings in court
of law

# Service Failure Modes



# Faults, Errors and Service Failures

The fault causes an *error* – it is the part of the total system state that may lead to a service failure.

The error can be propagated inside the system – that is, it causes more errors during computation.

When an error reaches the service interface, it causes a service failure – it is a transition from correct to incorrect service. The service failure is an event that initiates a service outage.

The return to correct service is a service restoration.

# Recommendations for the Handbook

Introduce the concept **error:** part of the system state that was caused by a fault and may lead to a (service) failure.

Define (service) **failure** as an event: “the transition of delivered service (at the service interface) from correct to incorrect service.

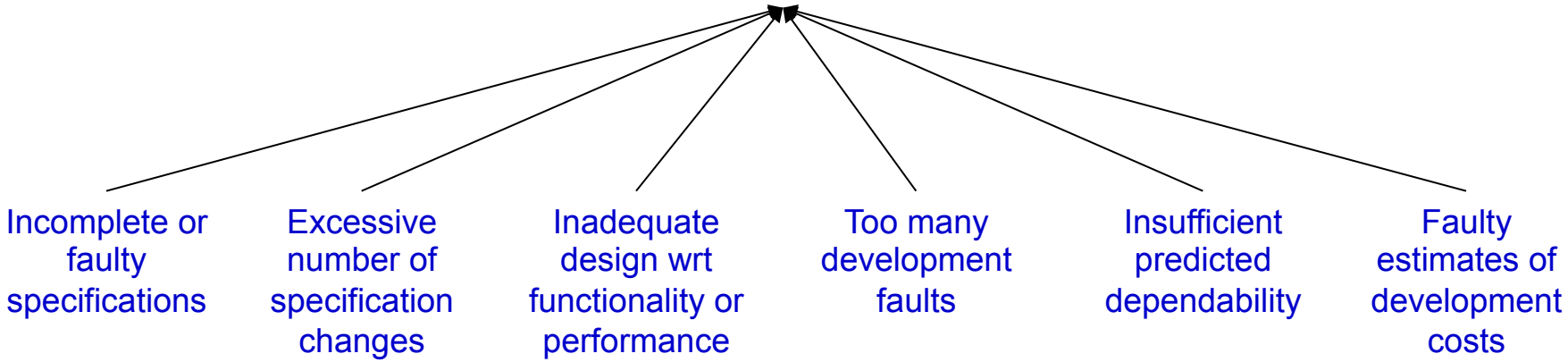
Eliminate the concept “failure tolerance”.

Introduce the concepts of **service outage** and **service restoration.**

Define **fault tolerance** as “the means to avoid service failures in or after the presence of faults”.

# Development failures

Development process terminates before the system is accepted for use and placed into service




# Partial development failures

- Budget or schedule overruns
- Downgrading to less functionality, performance, dependability

# The Varieties of Maintenance

**Repairs** of the system:

- **Corrective M**: removal of reported faults
- **Preventive M:** discovery & removal of dormant faults

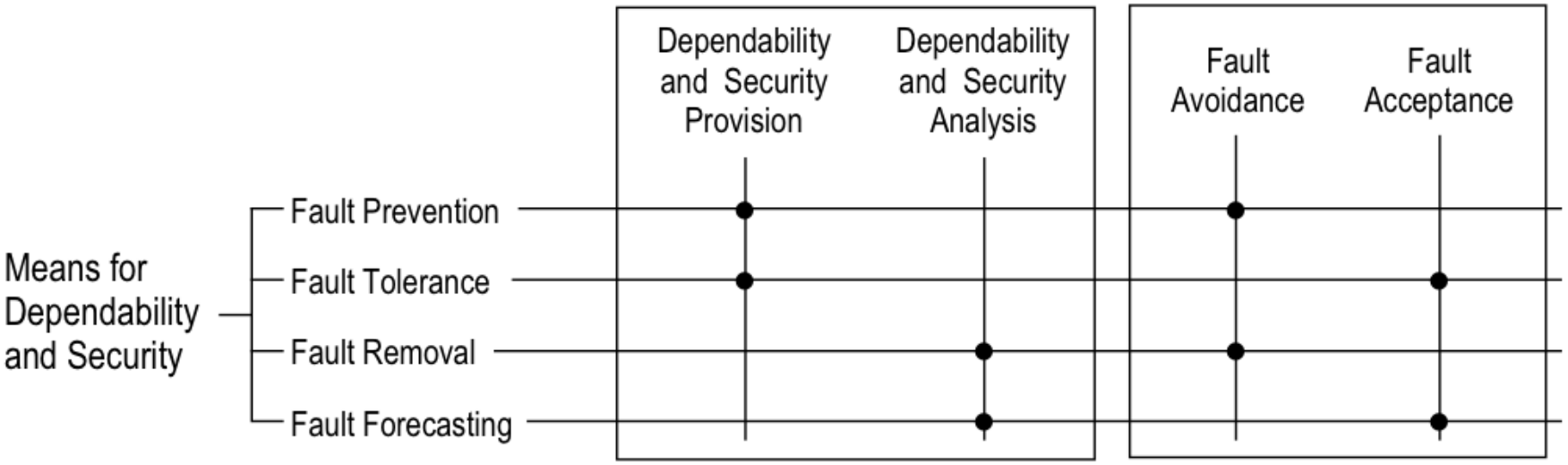
**Modifications** of the:system:

- **Adaptive M**: adjustment to environment changes
- **Augmentive M:** augmentation of system function

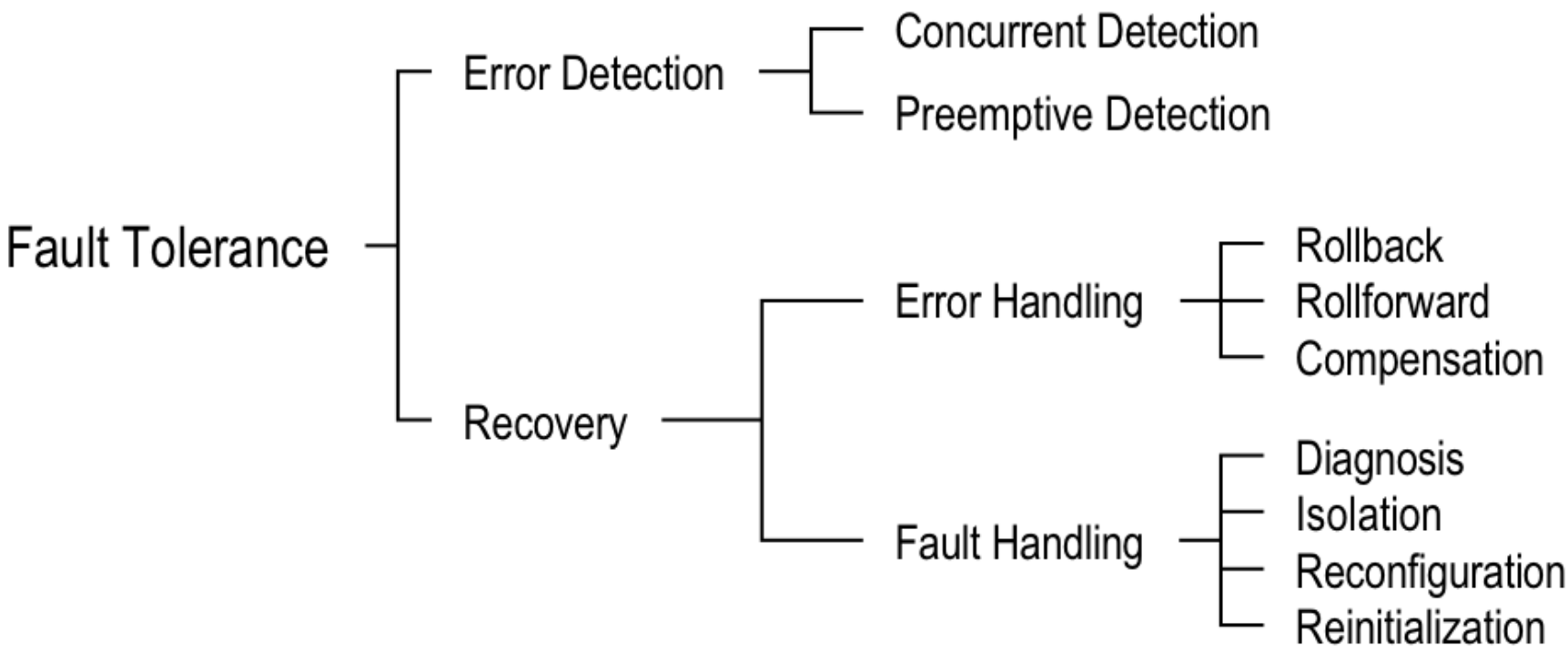
# The Means of Achieving Dependability and Security

- **fault tolerance:** means to avoid service failures in the presence of faults;
- **fault prevention:** means to prevent the occurrence or introduction of faults;
- **fault removal:** means to reduce the number and severity of faults;
- **fault forecasting:** means to estimate the present number, the future incidence, and the likely consequences of faults.

# Groupings of the Means for Dependability and Security



# Fault Tolerance Techniques



# Fault Removal

- **During Development**:
  - Verification
    - Deterministic testing
    - Statistical (random) testing
    - Fault injection
- **During use**:
  - Preventive maintenance
  - Corrective maintenance

# Fault Forecasting

- **Qualitative** (ordinal) evaluation:
  Identify, classify and rank failure modes

- **Quantitative** (probabilistic) evaluation:
  Modeling
  Operational testing
  Benchmarking

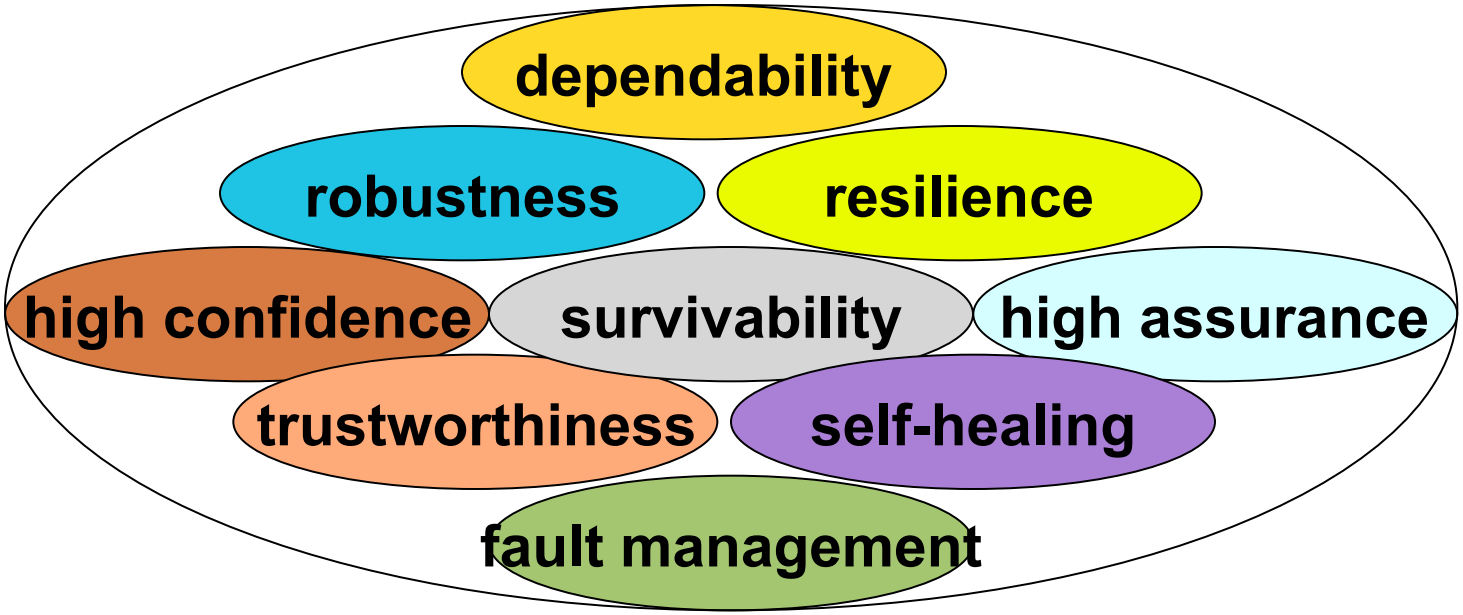
# Fault Prevention

- **Qualitative** (ordinal) evaluation:
  Identify, classify and rank failure modes

- **Quantitative** (probabilistic) evaluation:
  Modeling
  Operational testing
  Benchmarking

# Our Field's Goal: deliver expected service under adverse conditions

## Our Field's Top Concepts:




## How are they related?

# Four Essentially Equivalent Concepts

| Concept | Dependability | High Confidence | Survivability | Trustworthiness |
|---|---|---|---|---|
| Goal | 1) ability to deliver service that can justifiably be trusted<br>2) ability of a system to avoid service failures that are more frequent or more severe than is acceptable | consequences of the system behavior are well understood and predictable | capability of a system to fulfill its mission in a timely manner | assurance that a system will perform as expected |
| Threats present | 1) development faults (e.g., software flaws, hardware errata, malicious logic)<br>2) physical faults (e.g., production defects, physical deterioration)<br>3) interaction faults (e.g., physical interference, input mistakes, attacks, including viruses, worms, intrusions) | • internal and external threats<br>• naturally occurring hazards and malicious attacks from a sophisticated and well-funded adversary | 1) attacks (e.g., intrusions, probes, denials of service)<br>2) failures (internally generated events due to, e.g., software design errors, hardware degradation, human errors, corrupted data)<br>3) accidents (externally generated events such as natural disasters) | 1) hostile attacks (from hackers or insiders)<br>2) environmental disruptions (accidental disruptions, either man-made or natural)<br>3) human and operator errors (e.g., software flaws, mistakes by human operators) |
| Reference | This paper | "Information Technology Frontiers for a New Millennium (Blue Book 2000)" [NSTC 2000]] | "Survivable network systems" [Ellison *et al.* 1999] | "Trust in cyberspace" [Schneider 1999] |

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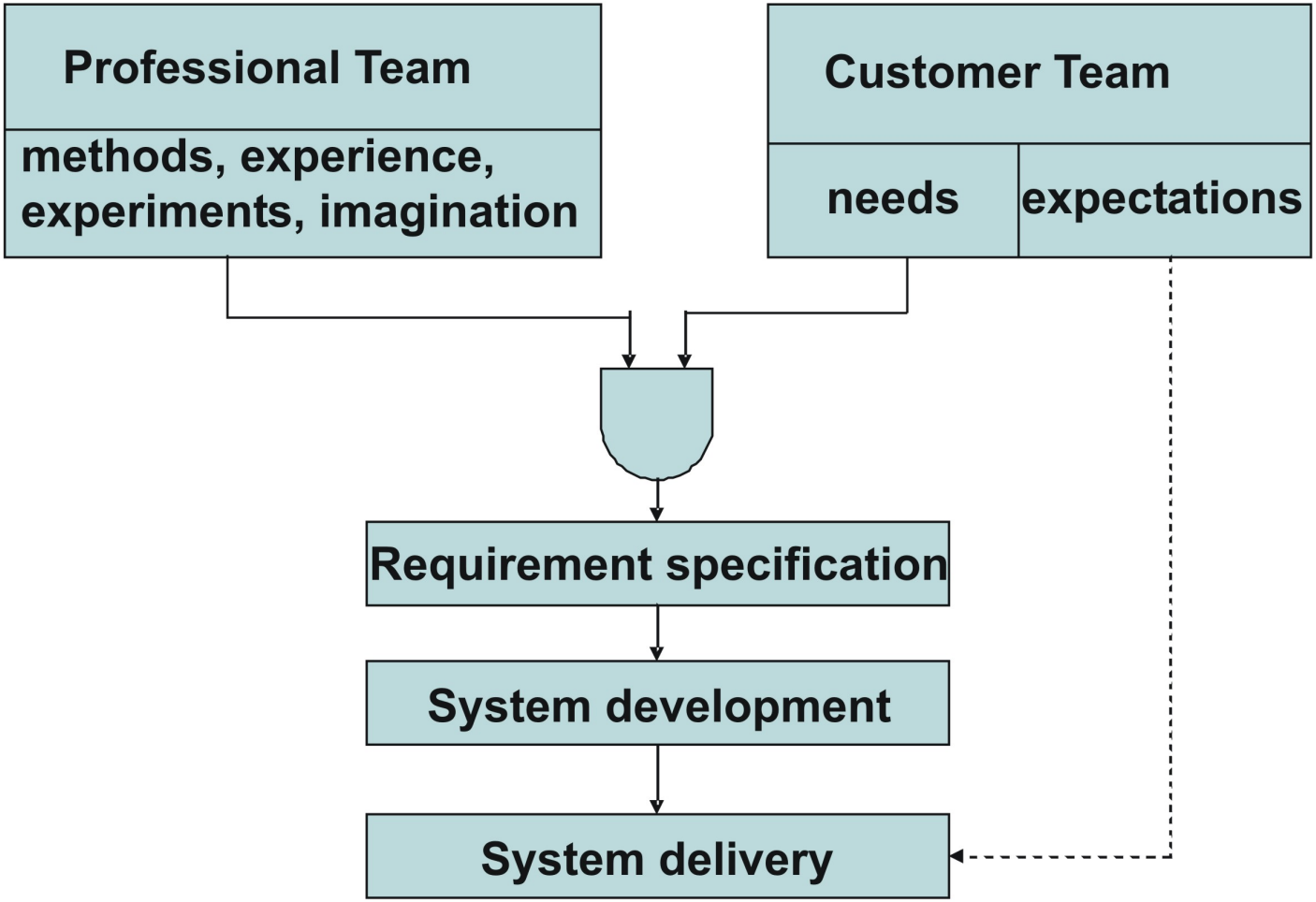
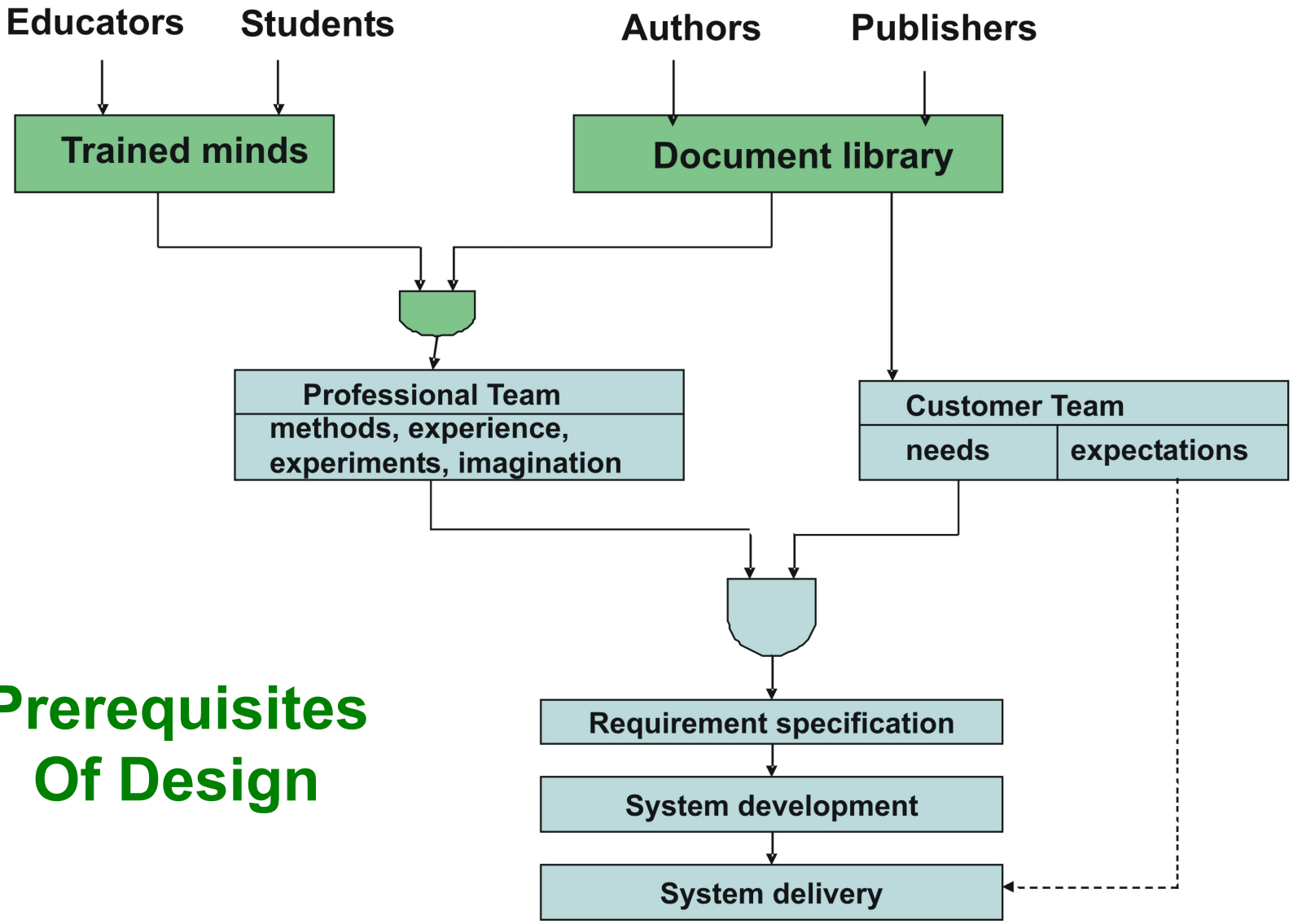
# On the Dependability of Scientific and Technical Texts

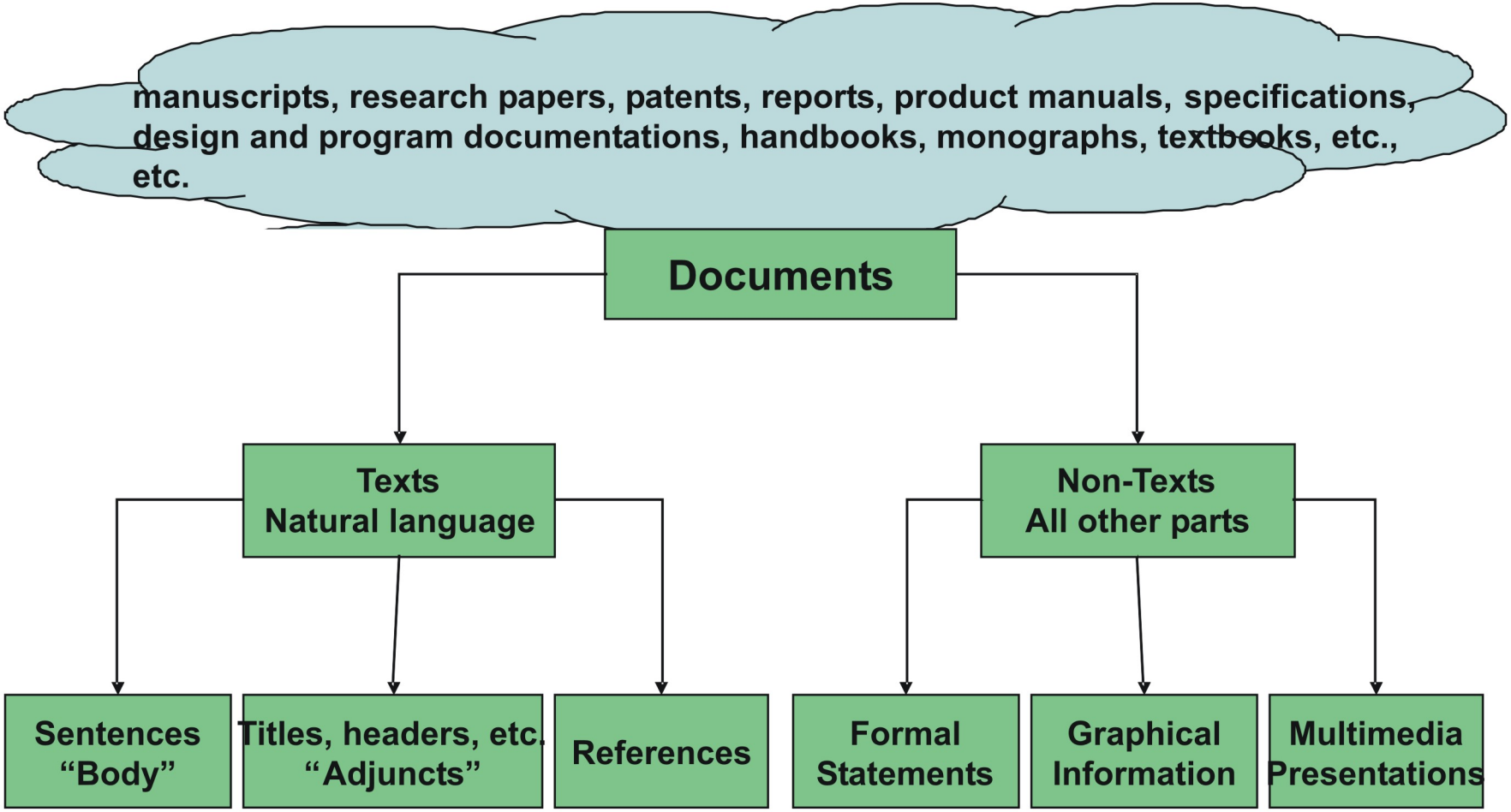
**The Goal: to treat the content of the texts of documents as a part of the development process of information processing systems**

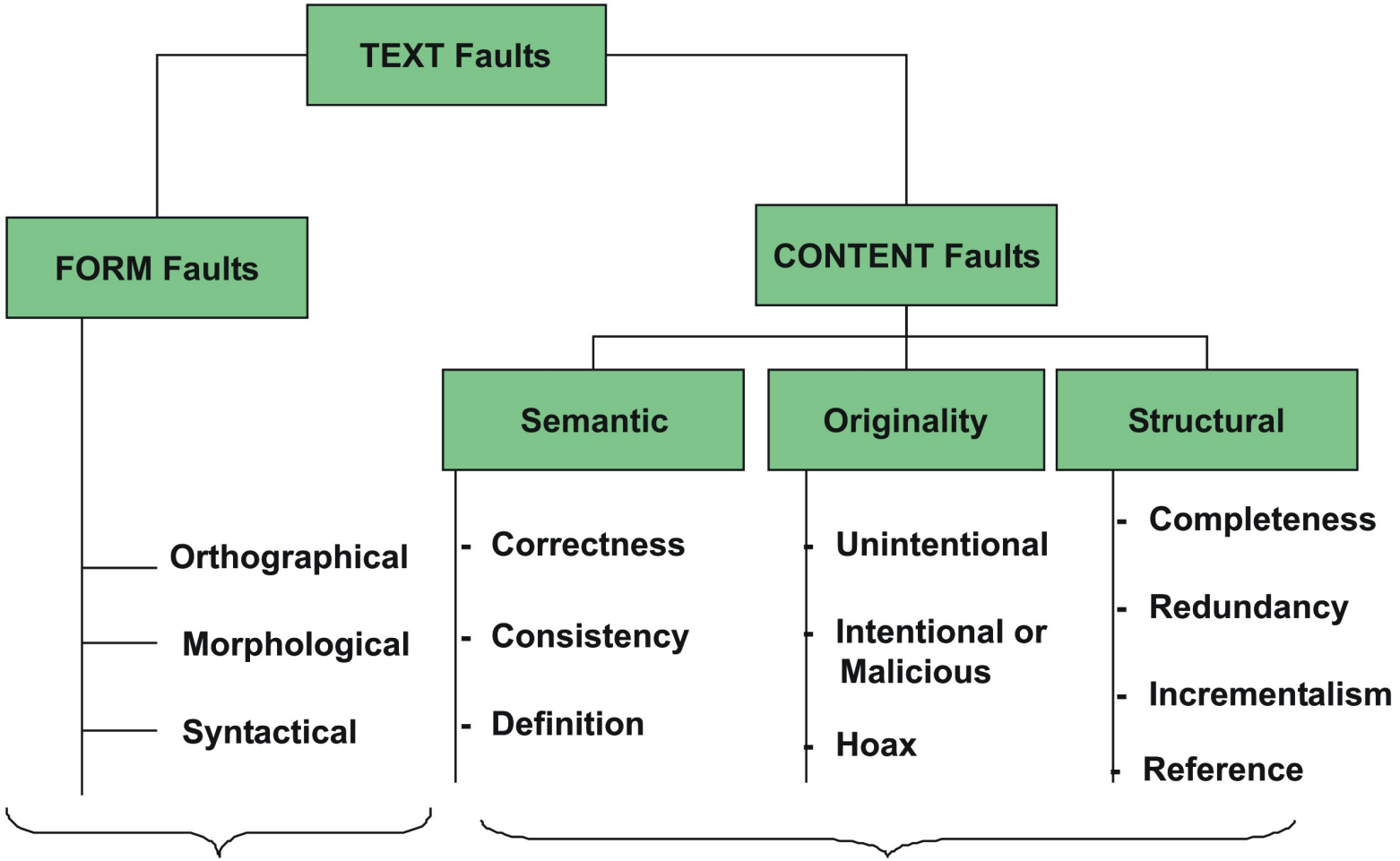
# Building a System






# Prerequisites Of Design


manuscripts, research papers, patents, reports, product manuals, specifications, design and program documentations, handbooks, monographs, textbooks, etc., etc.
Documents
Texts
Natural language
Non-Texts
All other parts
Sentences
“Body”
Titles, headers, etc.
“Adjuncts”
References
Formal
Statements
Graphical
Information
Multimedia
Presentations




Detected and removed by editors also, tools exist: CLAT, etc.

Detected and removed by expert evaluators tools are needed – this is our research

# Ontology Faults

"**Ontology**": A structured representation of the relationships between the concepts of a field (taxonomy with more than one relationship)

An "**ontology fault**" exists when the relationship of one top concept of a field to the others is not identified in a field that has two or more top concepts

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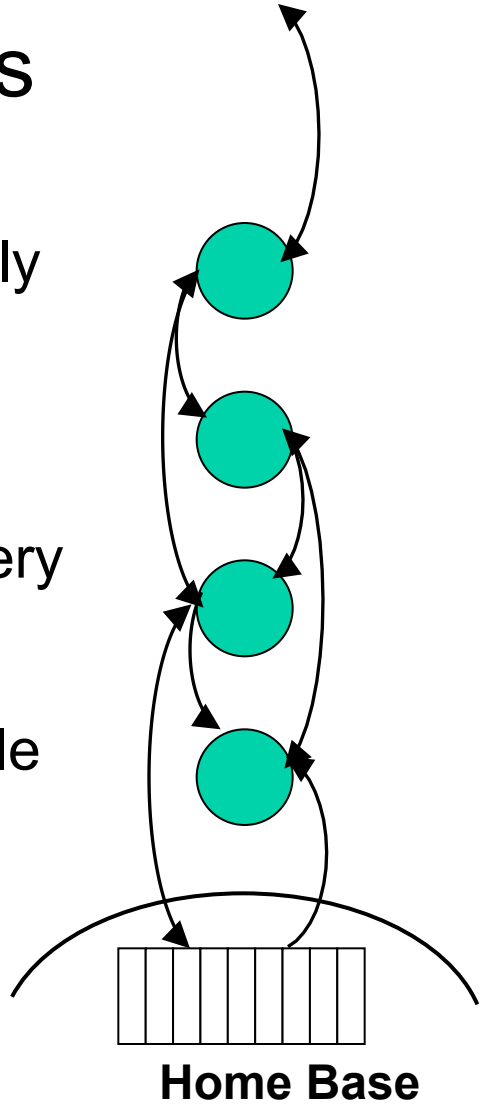
# A Spacecraft Relay Chain for Interstellar Missions

1. Launch a low cost DiSTAR spacecraft every N months; the design can evolve continuously
2. Use the chain of spacecraft to relay communications to Earth and back to the leading spacecraft
3. Introduce redundancy at spacecraft level: every spacecraft can dependably communicate to M = 2, 3, or more, closest neighbors; then the loss of M-1 adjacent spacecraft is tolerable
4. Slow down all spacecraft ahead of the gap to repair the chain
5. Never stop launching better and better DiSTAR spacecraft!



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