Research Method and Process

Prepared for CSE Capstone Course

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What is Research?

"Systematic investigation towards increasing the sum of knowledge"

(Chambers 20th Century Dictionary)

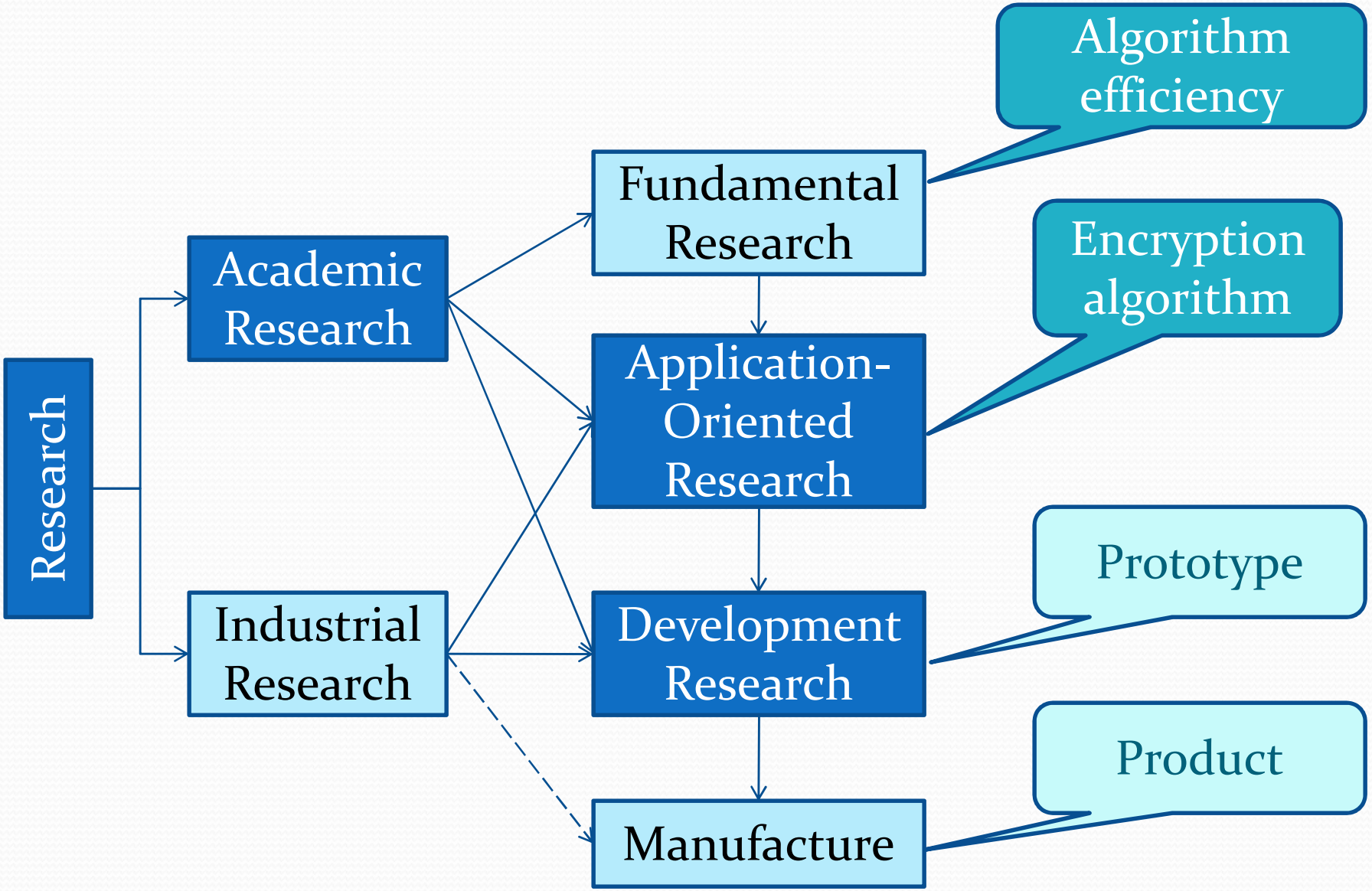
"An endeavour to discover new or collate old facts etc. by the scientific study of a subject or by a course of critical investigation."

(The Concise Oxford Dictionary)

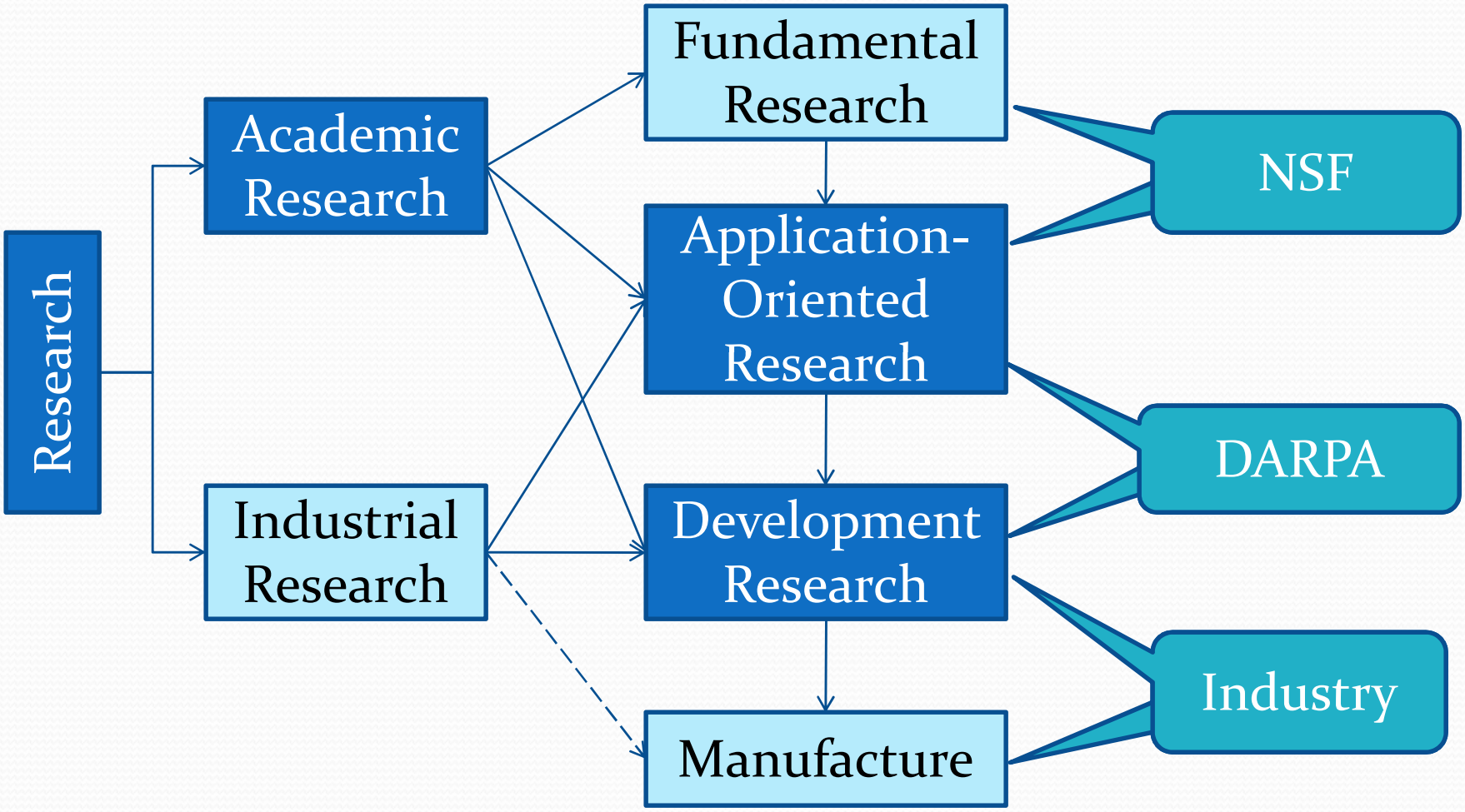
What is Research?

- Research is a formal way of going about asking questions
- Uses methodologies
- Many different kinds (e.g. market research, media research and social research)
- Basic research methods can be learned easily:
  - Quantitative research (e.g. survey)
  - Qualitative research (e.g. face-to-face interviews; focus groups; site visits)
  - Case studies

Types of Research



Sponsors of Research



Steps of Conducting Research

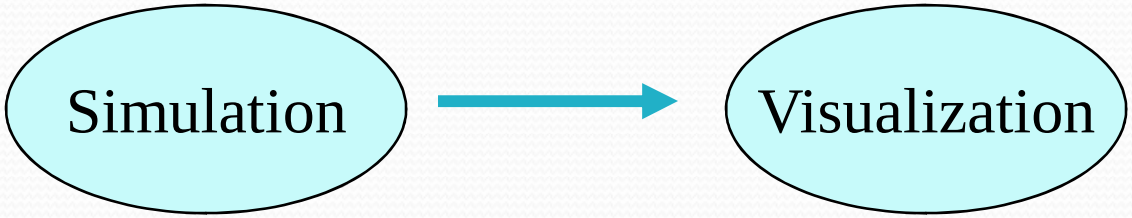
1. Define Research Objectives and Questions
2. Review literature and select appropriate framework.
3. Research methods
4. Implement a sample solution, simulation, prototype
5. Collect data
6. Analyze data, interpret results and evaluate the system
7. Disseminate findings (write report and present results).

Elements of Research Questions

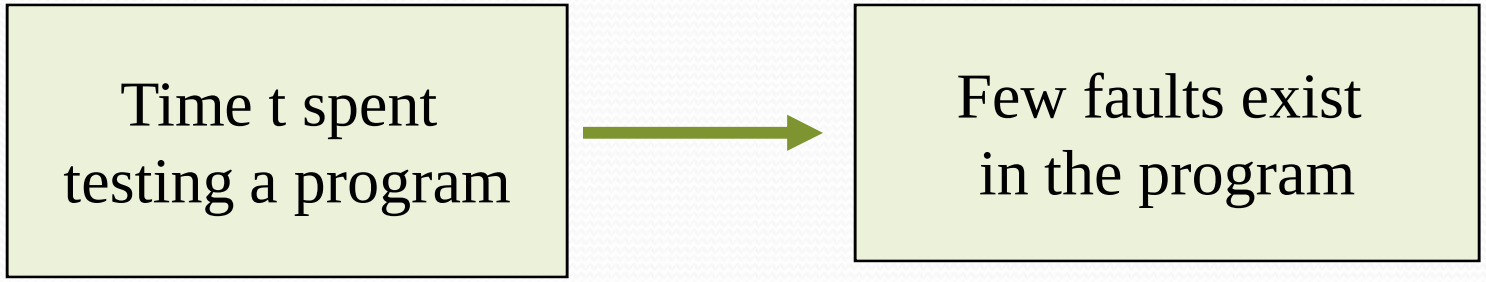
- Constructs
  - Concepts, often complex
  - Not directly measurable
- Variables
  - Something we can measure
  - Concrete measured expressions to which we can assign numeric values
  - A concept may be characterized in several variables
- Models
  - Express variables and their relationships
  - Represent concepts in a simplified way
  - Capture main features interested in the research (Abstraction)

Propositions and Hypotheses

- A proposition represents relationships among **concepts**



- A hypothesis represents relationships among **variables**



Literature Review

It is wise to learn from
your own mistakes

It is shrewd to learn from
other people's mistakes

Literature review is to learn from
other people's work as well as own work

What is other people's work?

What they write

books, articles, reports, manuals, web pages

What they say

interviews, discussion, news,

What they do

observation

What they make

hardware, software, robots, image, device

How to Find References

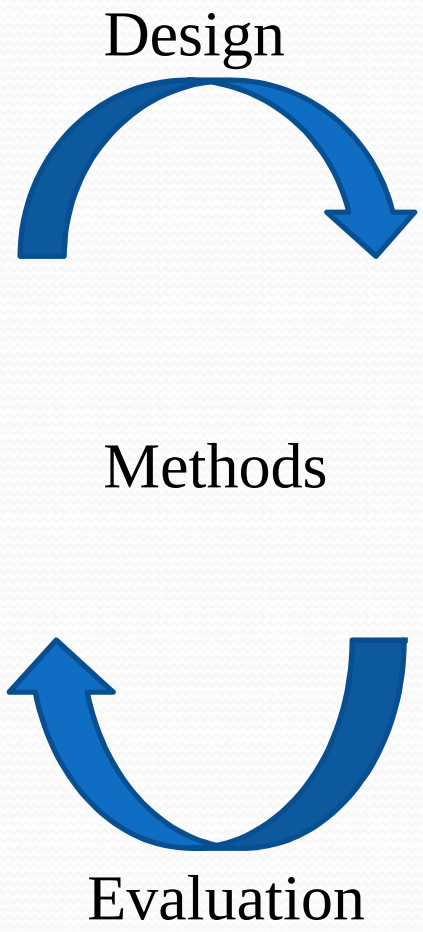
- Search Engine
  - Keyword, topic, title, or author search
    - Web, databases
  - Reference Chain Search
    - Find more related papers from the reference list of a paper you have.
- Other resources
    - Library, your bookshelf, other people

Information Filtering: Be Selective

- Relevance:
  - Keywords (unreliable)
  - Abstracts (better)
  - Skim read (best)
- Authority
  - Citation count
  - Reputed conference and journals (ranking)
  - Read biography of authors, recognized expert in the field

Methodology

- Objectives
  - High performance
  - Low cost
  - High Dependability



- Deliverables
- Simulation
- Prototype
  - Hardware
  - Software
  - Others

Research Methods

- Qualitative: Helps us flesh out the story and develop a deeper understanding of a topic and "bigger picture" of the problem
  - Classification
  - Case studies
  - Narrative research
  - face-to-face interviews
- Quantitative: Involves information or data in the form of numbers
  - Surveys
  - Experiments
  - Analytical studies

Data Collection

- Experimental
- Non-Experimental (Analytical)
- Quasi-Experimental

Data Analysis and Evaluation

- Probability and stochastic process
- Statistics
- Model
- Cause-effect relationships

- Qualitative
- Quantitative
- Hybrid

Case Study: Design of a Fault-Tolerant System (Tandem Computer)

1. Define System Objectives
2. Limit the Scope
3. Define the Layers of Fault Handling
4. Define Reconfiguration and Repair Boundaries
5. Design Fault Handling Mechanisms
6. Identify the Hardcore
7. Evaluate the design against the objectives
8. Return to step 3 and iterate if necessary

Design Method

1. Design Objectives

Consideration in Defining Objectives

- System design is a trade-off among *performance*, *cost*, and *dependability*.
- Major factors can be considered:
  - System application ranges/domain
  - Performance: Speed, throughput, capacity, bandwidth, etc.
  - Dependability: Reliability, availability, security, safety, etc.
  - Granularity of fault isolation and repair
  - Graceful degradation of performance in case of a fault
  - Division of the responsibility between hardware and software
  - Cost effectiveness

Design Objectives of Tandem Computer

- *Mean Time to Failure MTBF = several years*
  (100 years originally)
- *No single point of failure*
- *On-line repair*
- *Quick mean time to repair*: After one fault, the system is vulnerable to a second fault until the first is repaired.
- *Protection against service and operator errors*.
- *Self-checking logic*: The first fault can be detected by the checking mechanism.
- Fault-tolerant networking and communication protocols.
- Fault-tolerant power supply

2. Limit the Scope

- In order to make good trade-off, the scope of the objectives must be limited.
- Field factors for refining the objectives:
  - What is the maintenance strategies?
    - Is field repair possible?
    - Is on-line repair possible?
    - What are acceptable replacement units?
    - What is the response time of field service people?
  - What are the dominant faults?
    - Single or multiple? software or hardware faults?
  - What are the failure rates of various parts?
  - What parts of the system should be included in fault-tolerance design?
    - Central control, memory, I/O device, power?

3. Define the Layers of Fault Handling

- A system consists of a hierarchy of levels.
- Faults can occur at any level, and mechanisms handling the faults can be implemented at each level

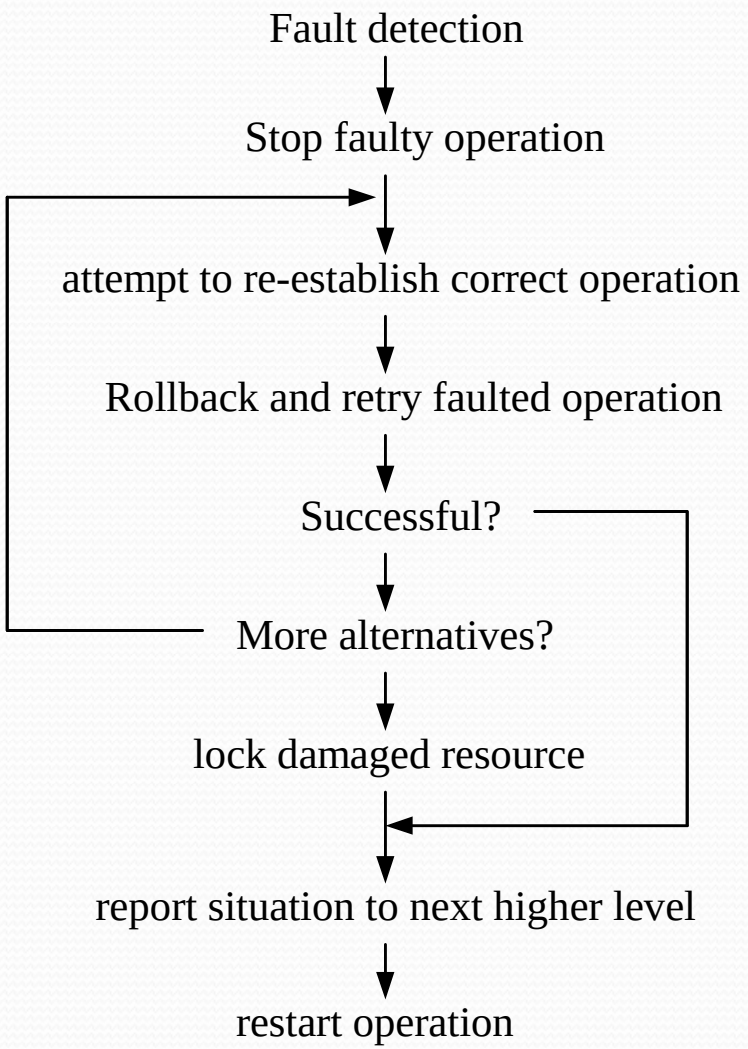
Level	Error source	Detection	Error recovery	Response time
Application	Program	Reasonable checking	Job retry	10^{-1} sec
OS	Design	Consistency on data structure	Process retry	10^{-3} sec
Macrocode	α-particles flip memory state	Memory protection	Error correction code	10^{-4} sec
Microcode	Race condition	Error detection codes	Instruction retry	10^{-6} sec
Hardware	Environmental transient fault	Replication	Majority voting	10^{-7} sec

4. Define Reconfiguration and Repair Boundaries

- Define conceptual and physical boundaries for error confinement and isolation;
- Define boundaries for reconfiguration and repair;
- Recover from faulty operations

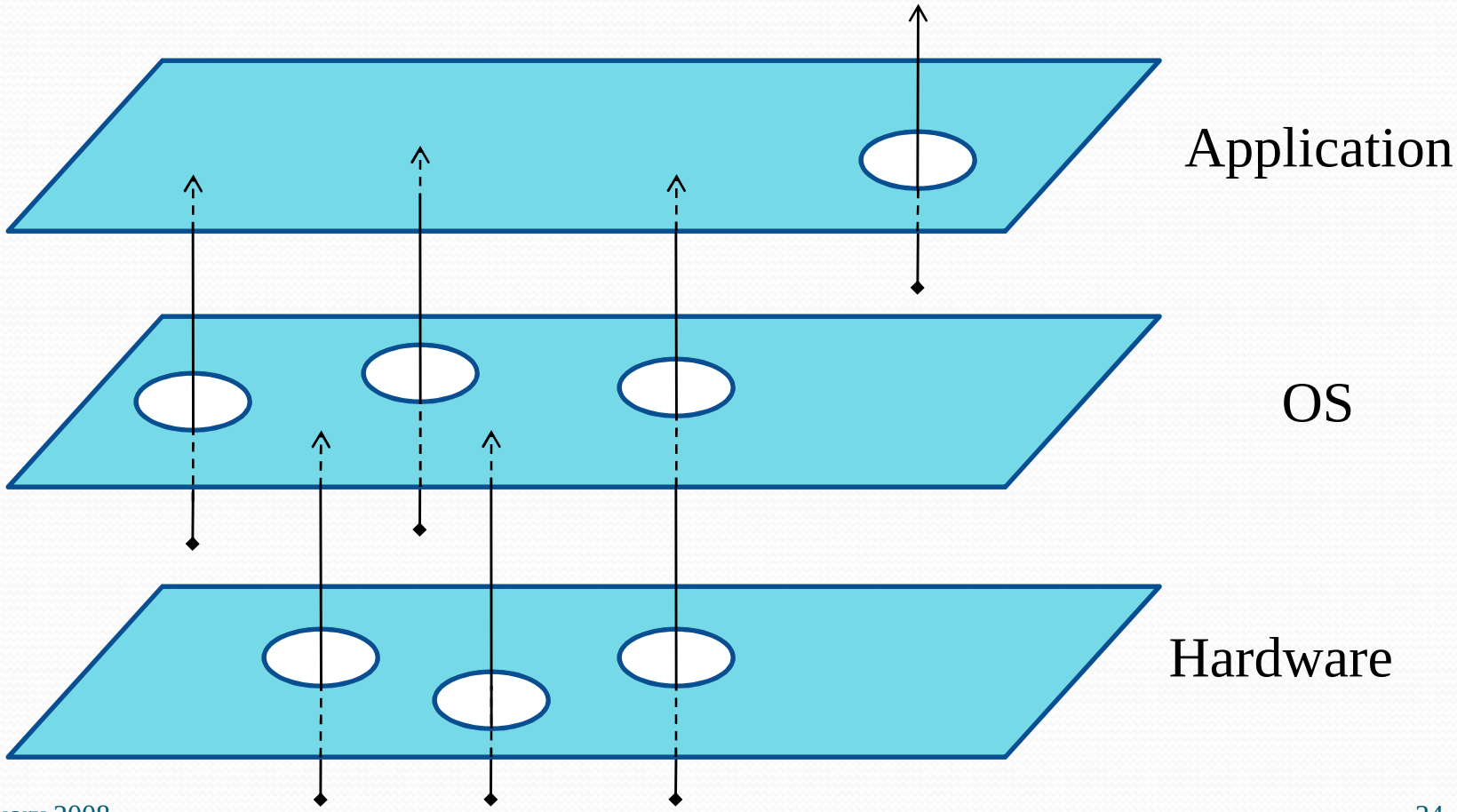
5. Design Fault Handling Mechanisms

- Between conceptual and physical boundaries:
  - Error detection
  - Fault isolation
- Reconfiguration and repair;
  - Switch triggered by fault detection
  - Hot plug and unplug of components
- Recover from faulty operations
  - Forward recovery: Triple Redundancy
  - Backward recovery: check points on stable memory



Fault Handling Mechanisms at Different Layers

- Mechanisms at different layer handles different types faults;
- Escaping errors are caught at an upper layer



6. Identify the Hardcore

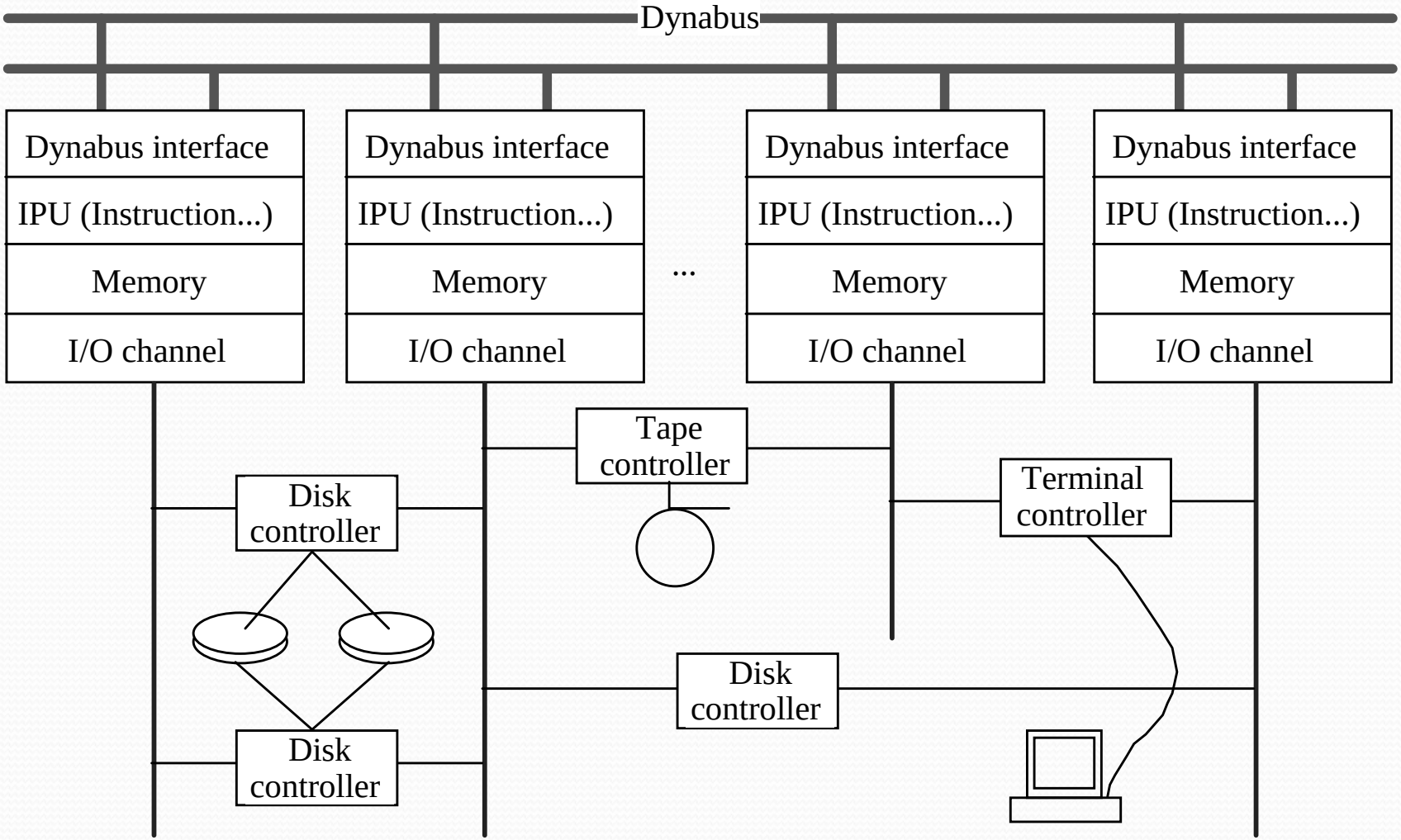
- Who will watch the watchdog?
- A fault-tolerant system needs to implement a **hardcore** to act as the watchdog to oversee the fault-tolerant mechanism
- The hardcore itself must be an independent fault-tolerant system;
- Evaluate the hardcore against the following points:
  - Are the hardcore exercised as a part of normal operation? Otherwise, latent faults may accumulate to multiple faults.
  - Is the hardcore dependable enough to meet the reliability requirement of the entire system?
  - Is the coverage sufficient?
  - Are there any common-mode failures (related multiple faults)?

7. Evaluate the design against the objectives

- Establish a model for evaluation
  - Combinatorial model
  - Stochastic model
- Model evaluation
- Compare the revaluation results against design objectives

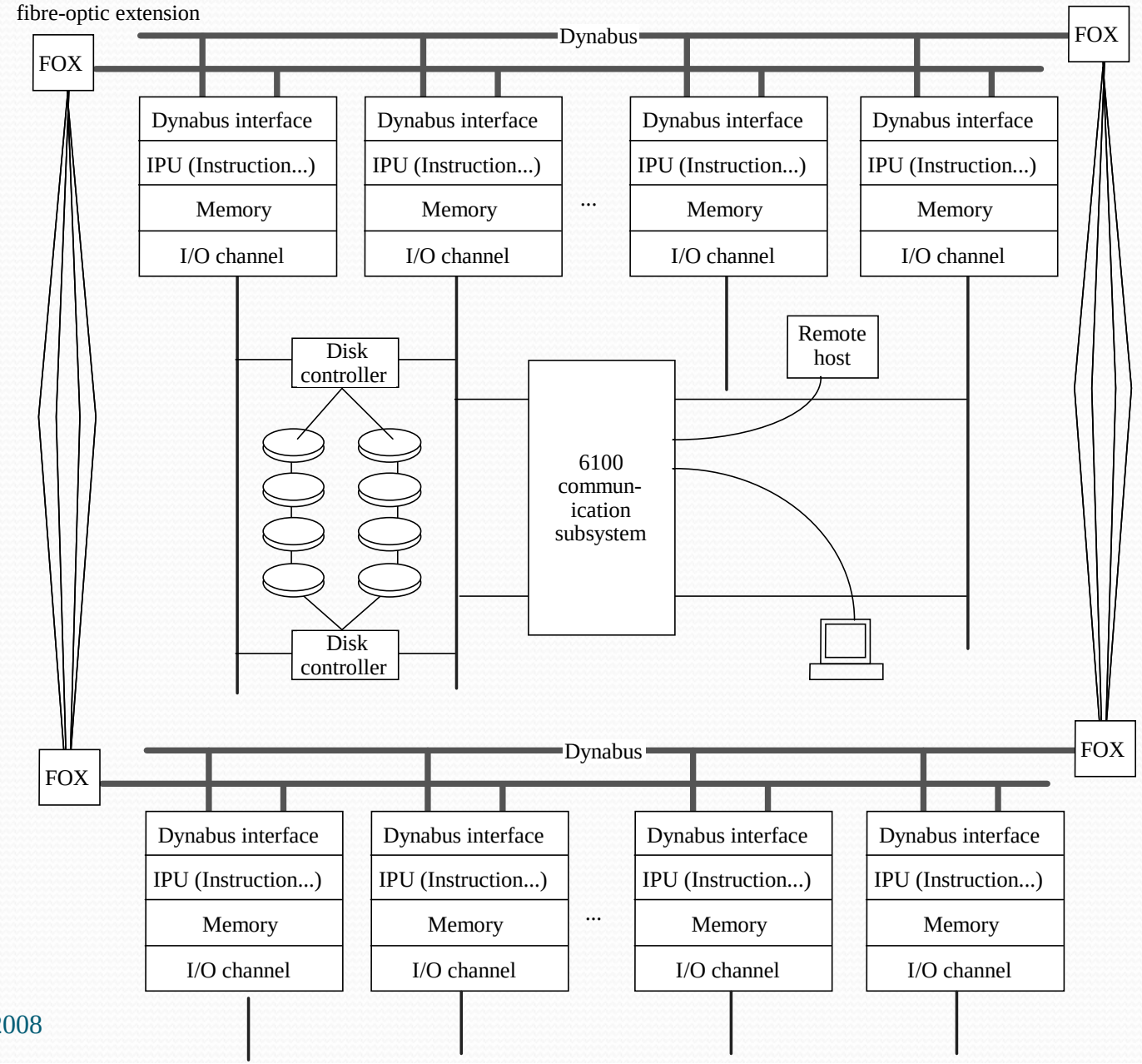
8. Return to step 3 and iterate if necessary

Example: Tandem Computer



Original Tandem 1976

Example: Tandem Computer (contd.)



Tandem
1990