VLSI Testing
積體電路測試

Diagnosis and Physical Failure Analysis

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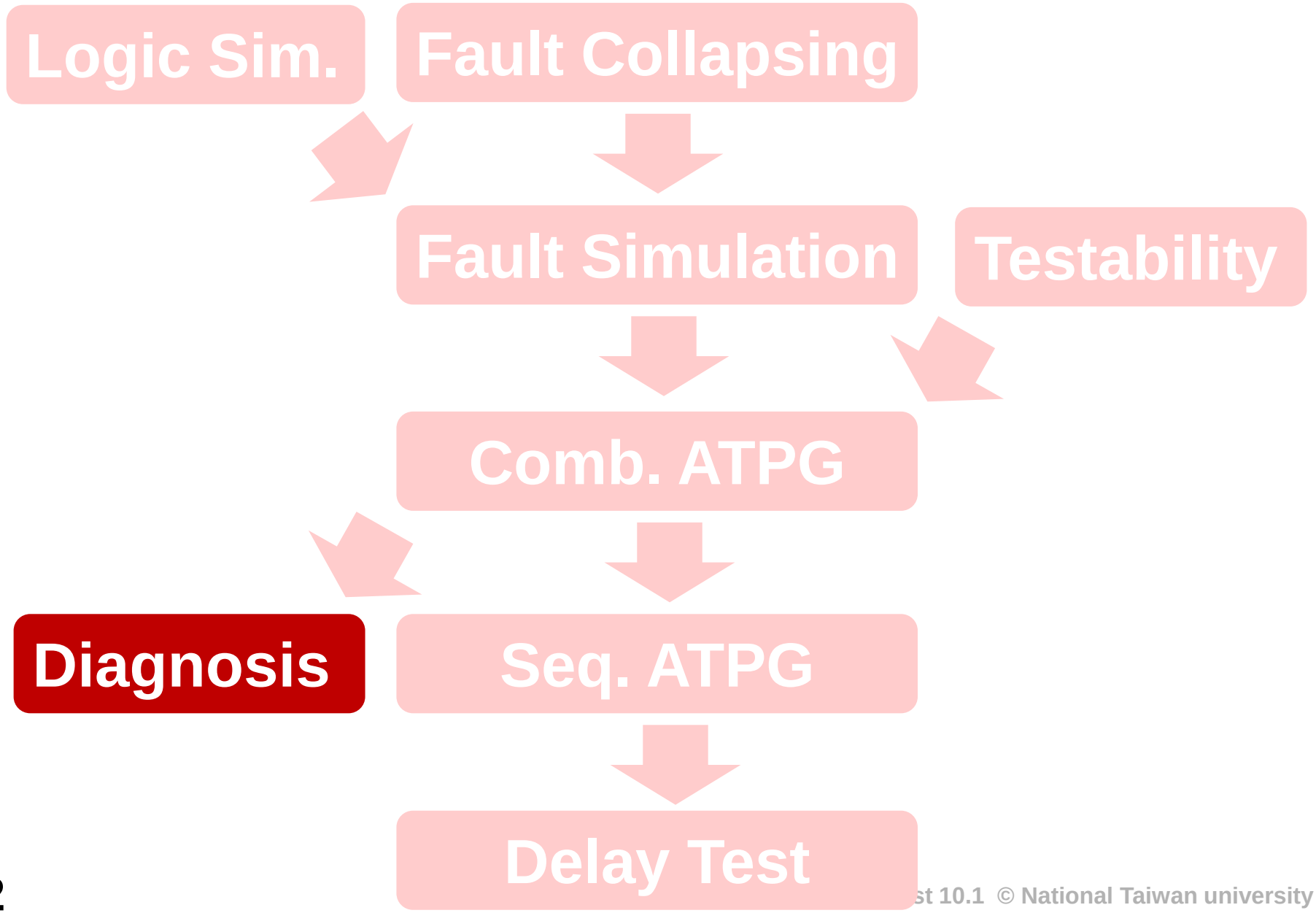
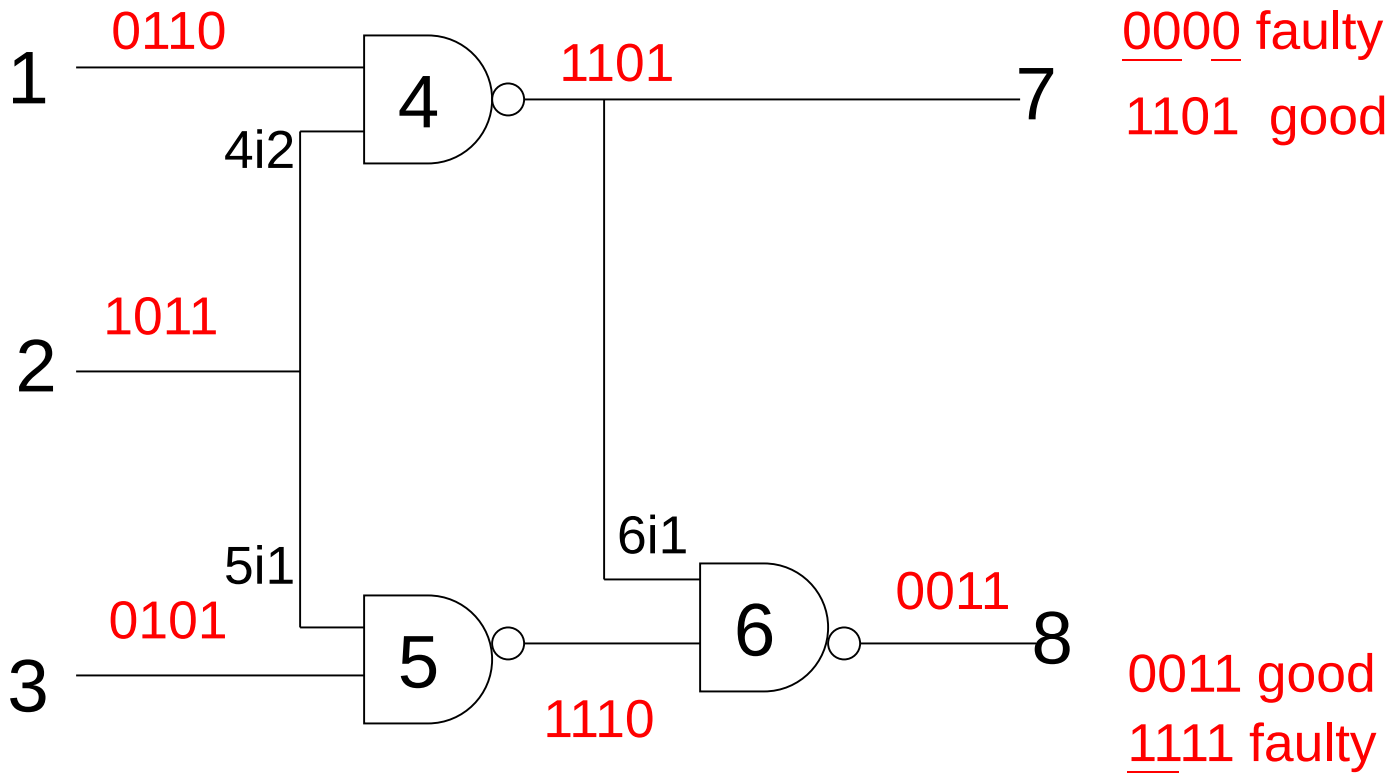
Course Roadmap (EDA Topics)



Motivating Problem

- **One chip failed on tester, your manager wants you to figure out what is wrong with this *circuit under diagnosis (CUD)***
  - **What should you do?**



Why Am I Learning This?

- **Diagnosis helps to**
  - **Find fault or defects**
  - **Improve Yield**

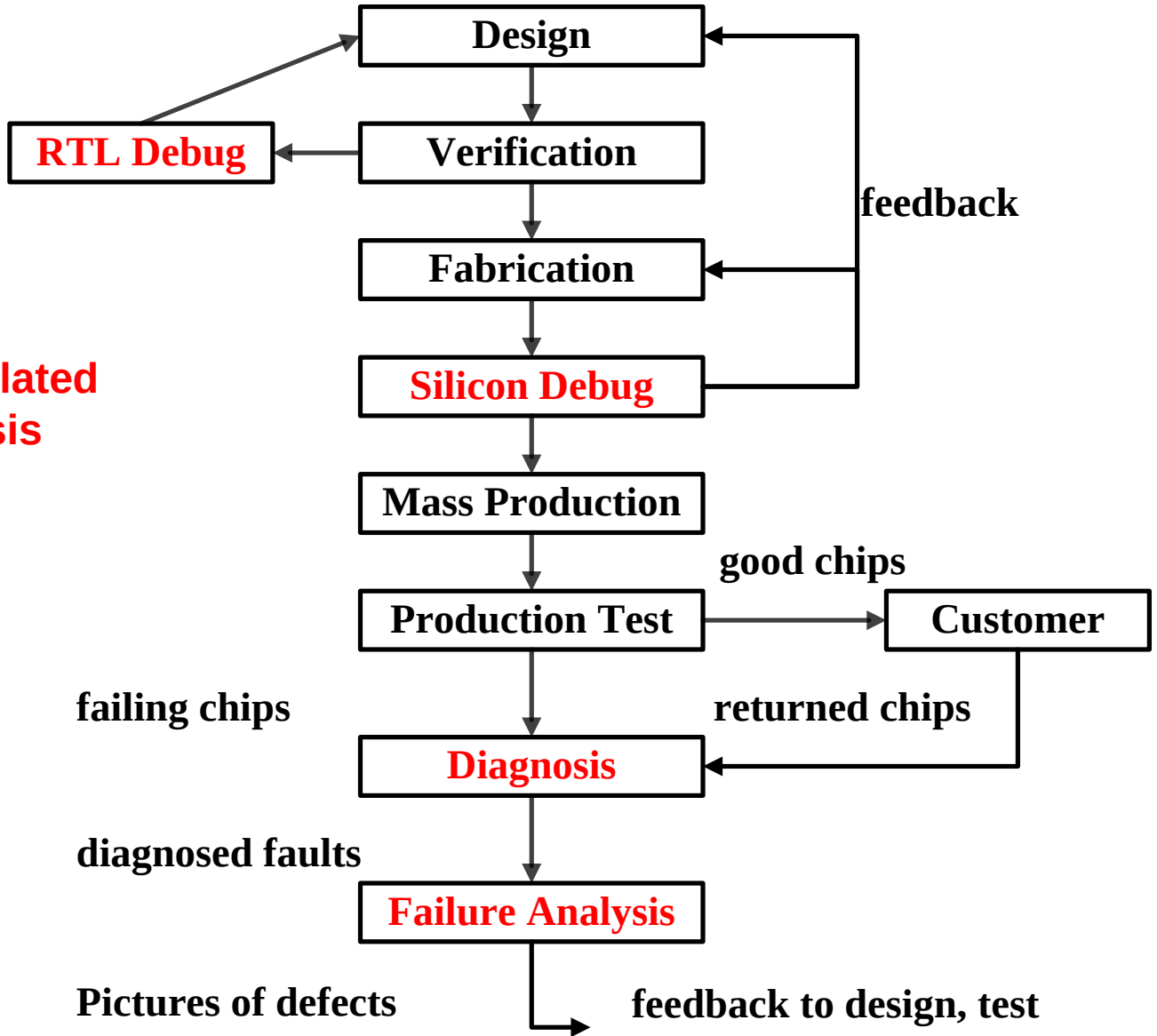
"In diagnosis,
think of the easy first."

(Martin H. Fischer)

Diagnosis

- Introduction
- Logic Diagnosis
- Scan Chain Diagnosis (*not in exam)
- Failure Analysis (*not in exam)
- Conclusions

Life Stages of a Chip



Definitions in Our Class

- ***Verification:*** **before chip fabrication**
  - **Check if design conforms to specifications**
- ***Debug:*** **design is *wrong***
  - **Identify *design errors* that cause failures**
    - ***RTL debug* (before chip fabrication)**
    - ***Post silicon debug* (after chip fabrication)**
- ***Diagnosis:*** **design is *correct*, after chip fabrication**
  - **Identify *faults (defects)* that cause failures in physical chips**
    - ***Software diagnosis*: do not open IC package, use software**
    - ***Hardware diagnosis*: open package use hardware equipment**
- ***Physical Failure Analysis (PFA) or Failure Analysis (FA)***
  - **Open IC package, locate and examine root cause of defects**
  - **Take pictures and feedback to design, fab. and test**

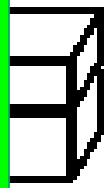
*** NOTE: Different companies may use different names**

Real-world Case

- **Q: QA testing found some chips failed only 0ºC testing**
  Pass room temperature and 100ºC
  Caused 60 DPM defect level
  What would you do?

- **A. Sell them anyway**
  B. Throw them away
  C. Other choice ….

- **fault**



Why Diagnosis?

- 1. Yield improvement
  - Diagnosis helps to fix design or fabrication problems
  - Fix broken parts with redundancy (e.g. memory)
- 2. IC quality assurance
  - Diagnosis helps to improve fab/design/test
- 3. Shorten time to market
  - Diagnosis identifies the obstacles to volume production
- 4. Easier Physical Failure Analysis
  - Diagnosis makes the search space small
- All the above make our boss happy …

Diagnosis Becomes Key Issue

- **ITRS'2005/2006 Roadmap**

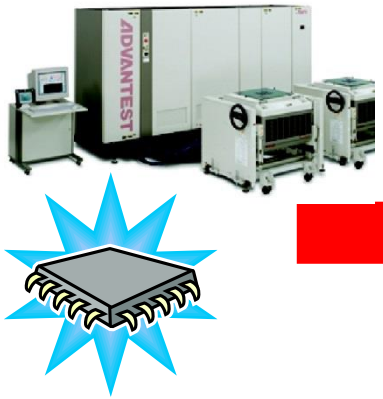
DIFFICULT CHALLENGES (IN PRIORITY ORDER)

(1) TEST FOR YIELD LEARNING (SUMMARY)

Test's peripheral role as a feedback loop for understanding underlying defect mechanisms, process marginalities, and as an enabler for rapid fab process yield learning and improvement has traditionally been considered a secondary role to screening hard defects. With the increasing reduction in feature (and defect) sizes well below optical wavelengths, rapidly increasing failure analysis throughput times, reduction in failure analysis efficacy, and approaching practical physical limits to other physical techniques (pica, laser probes), the industry is reaching a strategic inflection point for the semiconductor business where the criticality of DFT and test enabled diagnostics and yield learning becomes paramount.

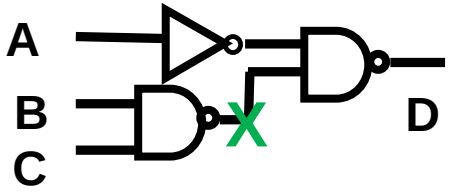
Typical Diagnosis Flow

Test CUD



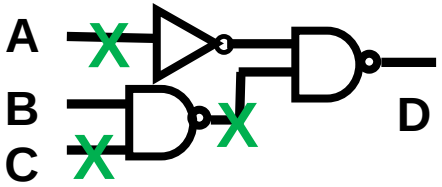
Failure log

ABC	D
000	0
110	1
011	1



Diagnosis Software

Fault 3 diagnosed



Fault Simulate

Fault 1

ABC	D
000	0
110	1
011	1

Fault 2

ABC	D
000	0
110	1
011	1

Fault 3

ABC	D
000	0
110	1
011	1

Fault dictionary

What is a Good Diagnosis?

- 1. Correct diagnosis result
  - Real defect is contained in *diagnosed fault list*
    - *Wrong diagnosis* sometimes is worse than *no diagnosis*
- 2. High *ranking*
  - Actual defect ranked high (say, top 5) in diagnosed fault list
- 3. Good *diagnosis resolution*
  - Very few faults in diagnosed fault list
- 4. Efficient diagnosis algorithm
  - Short computation time
  - Small storage space

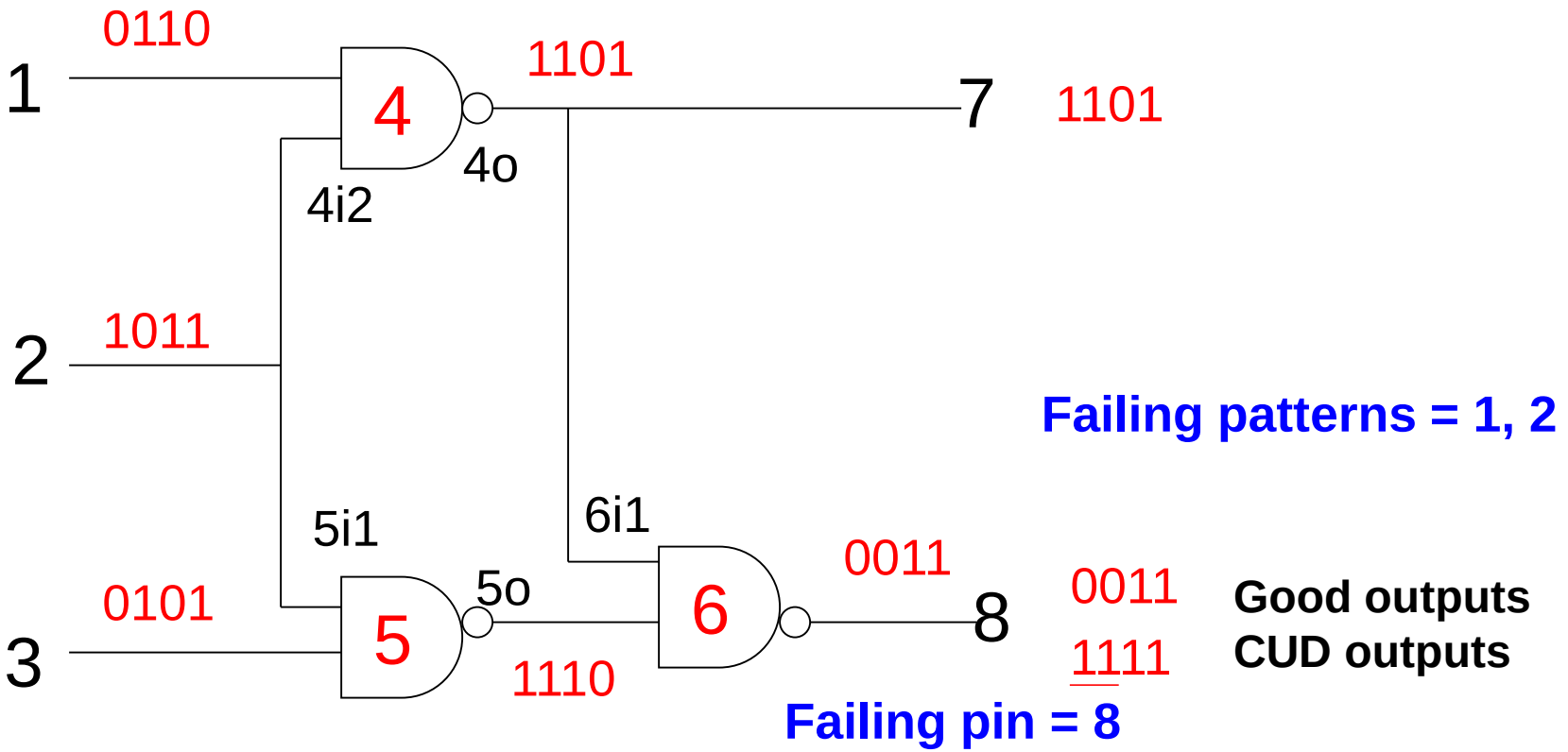
Assumptions of Diagnosis

- 1. Design is correct. We diagnose manufacturing defects
- 2. Less faults is more likely
  - Single fault is more likely than double faults
  - But multiple faults do occur in reality
- 3. Real defect behavior is hard to model
  - Fault model (SSF/TDF) not always accurate for diagnosis
  - But hopefully, we can find defect very closed to diagnosed fault

Fault Model Not 100% Accurate for Diag.

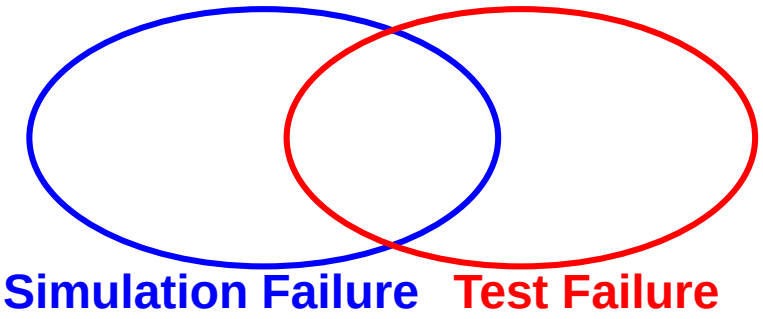
Terminology (1)

- *Failing pattern*
  - Test pattern where CUD outputs differ from good outputs
- *Failing (output) pin* of a failing pattern
  - CUD pin whose output differ from good output



Terminology (2)

- *Test Failures* , TF (aka. *Failure log**)
  - Failing patterns and failing pins of a defective CUD
    - observed on tester
- *Simulation Failures*, SF
  - Failing patterns and failing pins of a fault
    - obtained from fault simulation



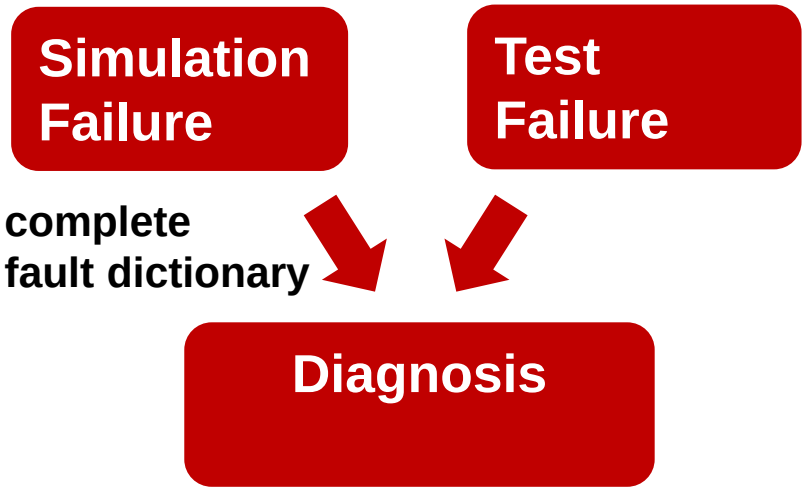
In Diagnosis, Don't Expect TF=SF

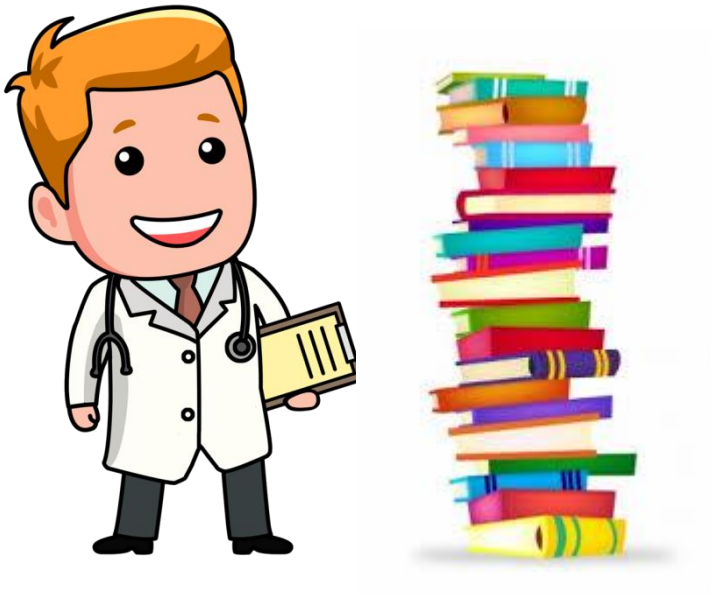
Terminology (3)

- *Complete Fault Dictionary*
  - Contains all faults and their simulation failures
- *Partial Fault Dictionary*
  - Contains subset of faults and their simulation failures
- Analogy
  - Test failures ~ patient's symptoms
  - Simulation failures ~ symptoms of a disease
  - Complete fault dictionary
    ~ full collection of symptoms of all diseases
  - Partial fault dictionary
    ~ partial collection of symptoms of some selected diseases

Diagnosis Techniques (1)

- ***Static cause-effect*** **diagnosis**
  - **Pre-compute *simulation failures* for all faults**
    - **Needs *complete fault dictionary***
  - **Analogy: Intern doctor without experience**
    - **Look up patient's symptoms in general pathology book**





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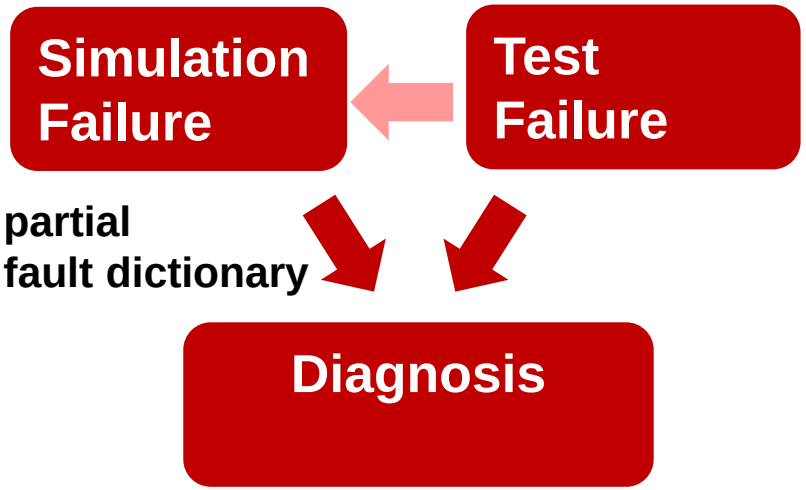
Diagnosis Techniques (2)

- *Dynamic cause-effect* diagnosis
  - Based on test failures, fault simulate a subset of faults
    - Only needs *partial fault dictionary*
  - Analogy: Doctors with some experience
    - Look up patient's symptoms in a specialized pathology book
      - like nerve system , or digestion system



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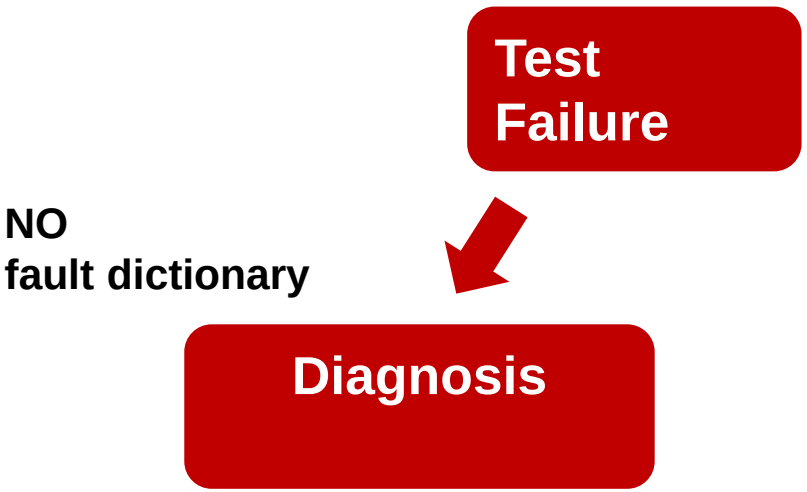
Diagnosis Techniques (3)

- ***Effect-cause*** **diagnosis**
  - **Based on test failures, diagnose fault without dictionary**
  - **Analogy: Very experienced doctors**
    - **No book at all**



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Summary

- What is diagnosis?
  - Identify most likely fault to explain test failure of CUD
- What is good diagnosis?
  - Correctness, ranking, and resolution
- How to diagnose?
  - Static cause-effect, Dynamic cause-effect, Effect-cause