Hardware Security and Trust

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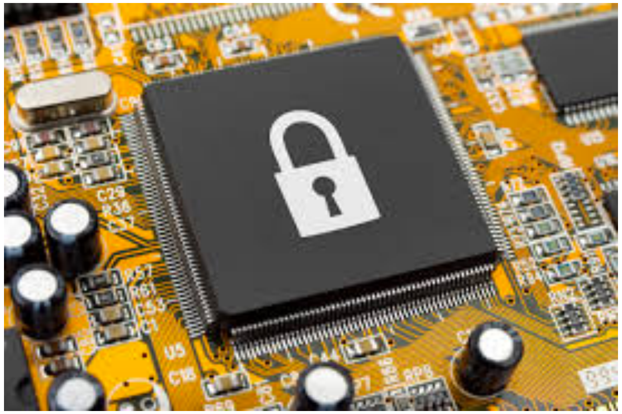
cnrs
advancing the frontiers

Motivation

- **Security** and **trust** play a critical role as computing is intimately integrated in the infrastructures we depend on



- Hardware Security
  – dealing with (secret) data in hardware devices
- Hardware Trust
  – dealing with design and manufacturing of devices

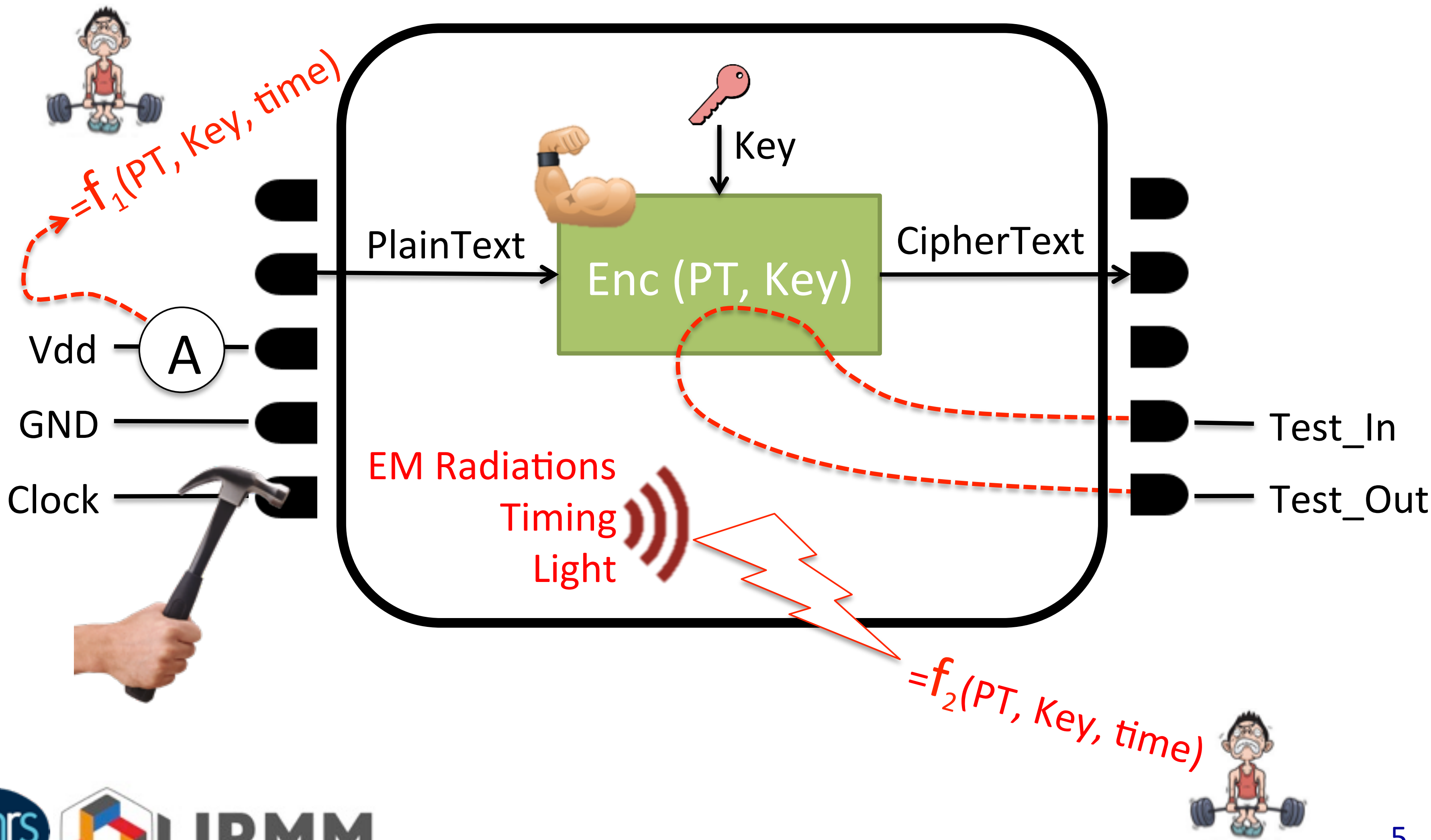
HARDWARE SECURITY

Scenario

- How to protect a (digital) secret:
  - Secure storage of confidential data
  - Cryptographic capabilities

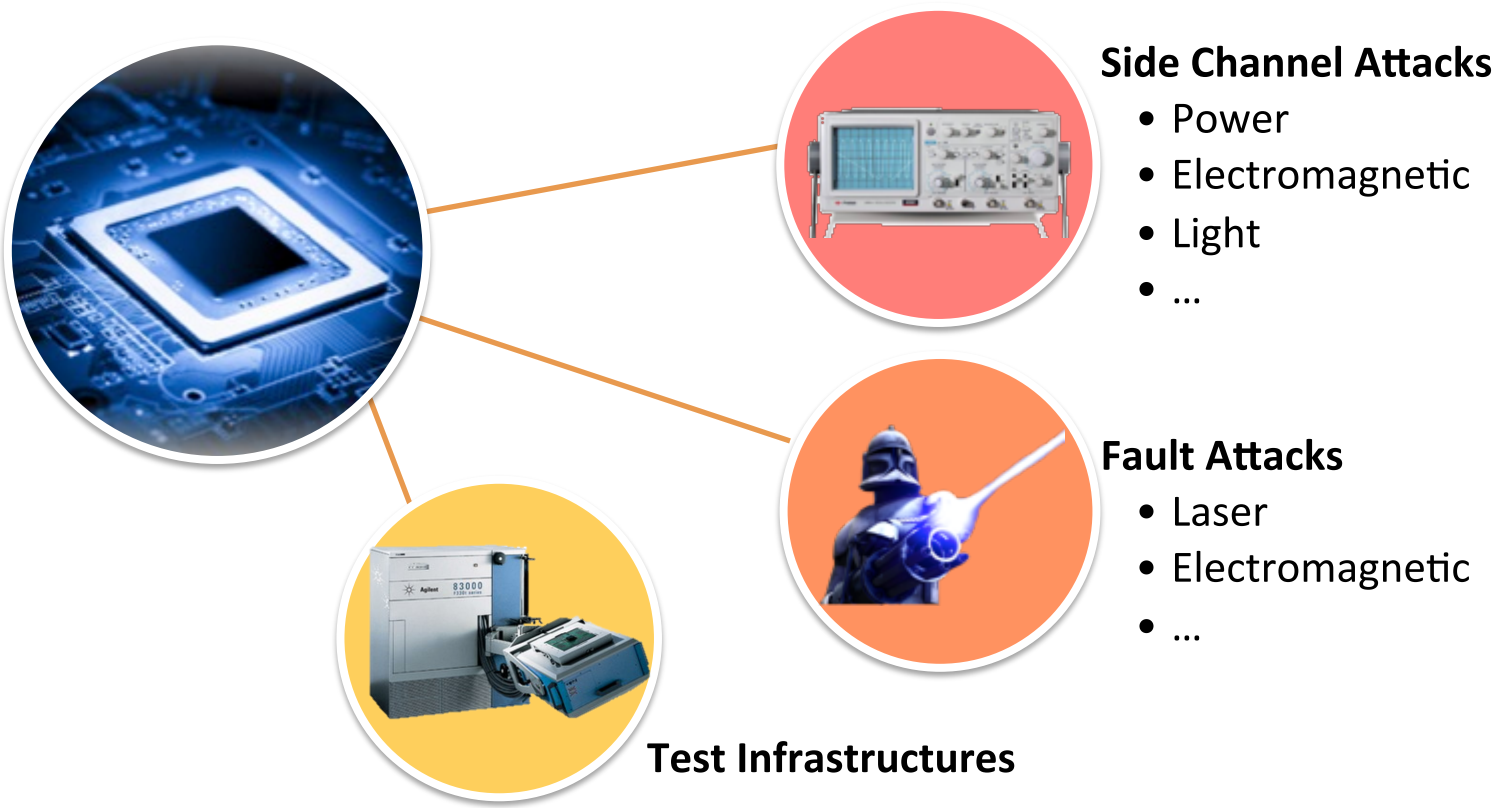
- Implementation:
  - Crypto algorithms integrated as hardware devices
  - E.g., smartcards, crypto-cores, crypto-processors, hardware security module

Implementation Attacks



Implementation Attacks – Types of Attacks

Access to secure devices storing other parties' secrets



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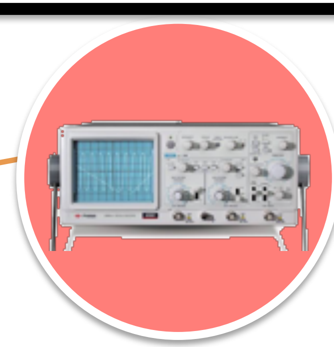
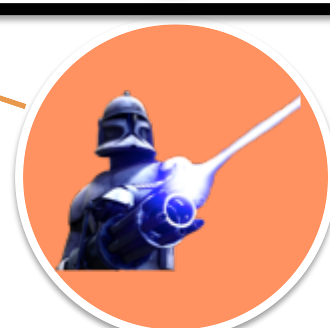


Side Channel Attacks

- Power
- Electromagnetic
- Light
- …



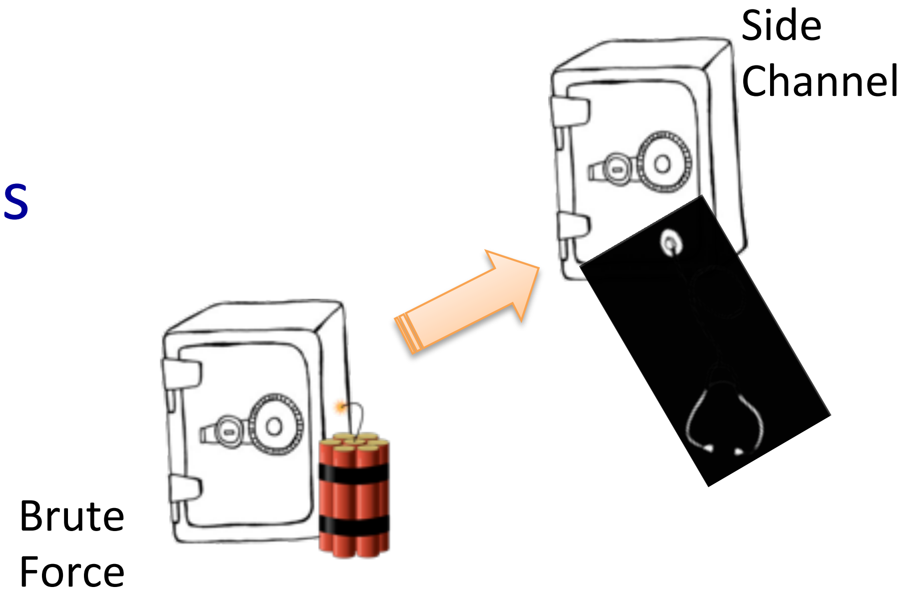
Fault Attacks

- Laser
- Electromagnetic
- …

Test Infrastructures

Side-Channel Attacks

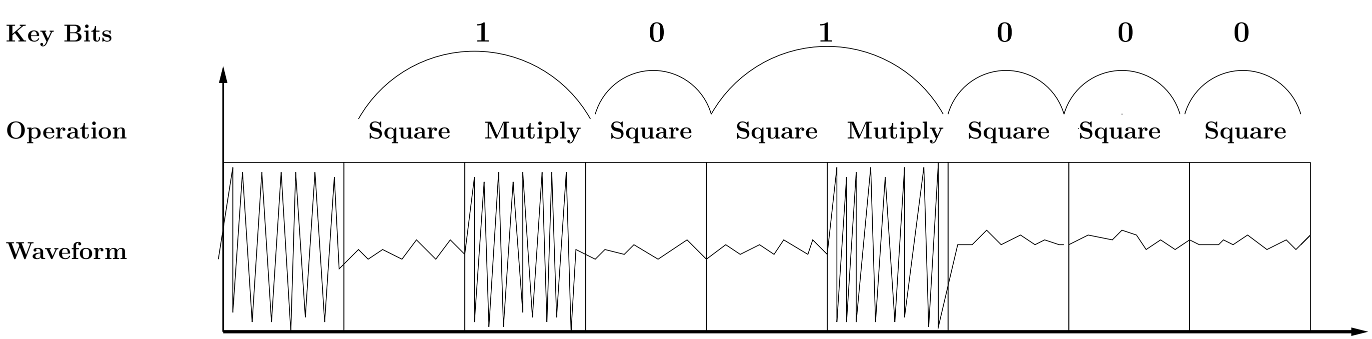
- Based on information gained from the non-primary interface of the physical implementation of a cryptosystem
  - Timing information
  - Power consumption
  - Electromagnetic leaks
  - Sound
  - Light
  - ...



Simple Power Analysis on RSA

```
Input:    X, N, K=(k_{j-1}, …, k_1, k_0)_2
Output:   Z = X^K mod N

    Z = 1;
    for i=j-1 downto 0 {
        Z = Z * Z mod N //Square
        if (k_i==1) {
            Z = Z * X mod N //Multiply
        }
    }
```



Simple Power Analysis

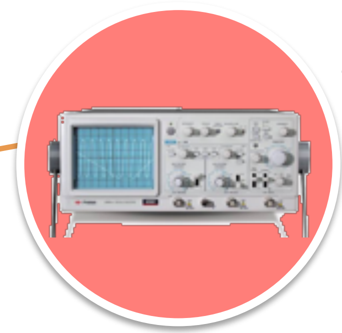
- Actually not so simple…
  - Noise
  - Interrupts
  - Multi-core architectures
  - Peripherals
  - …

Countermeasures

- Goal: removing the correlation between processed data and the physical interface
- Methods:
  - Masking: adding randomness in the intermediate values and operations
  - Hiding: making side-channel independent of intermediate values and operations

    e.g., constant power consumption

Implementation Attacks – Types of Attacks



Side Channel Attacks
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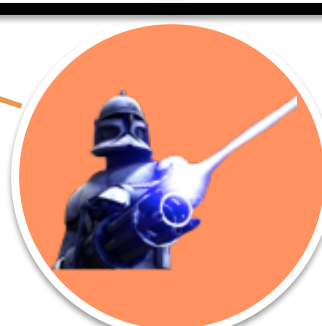

Fault Attacks
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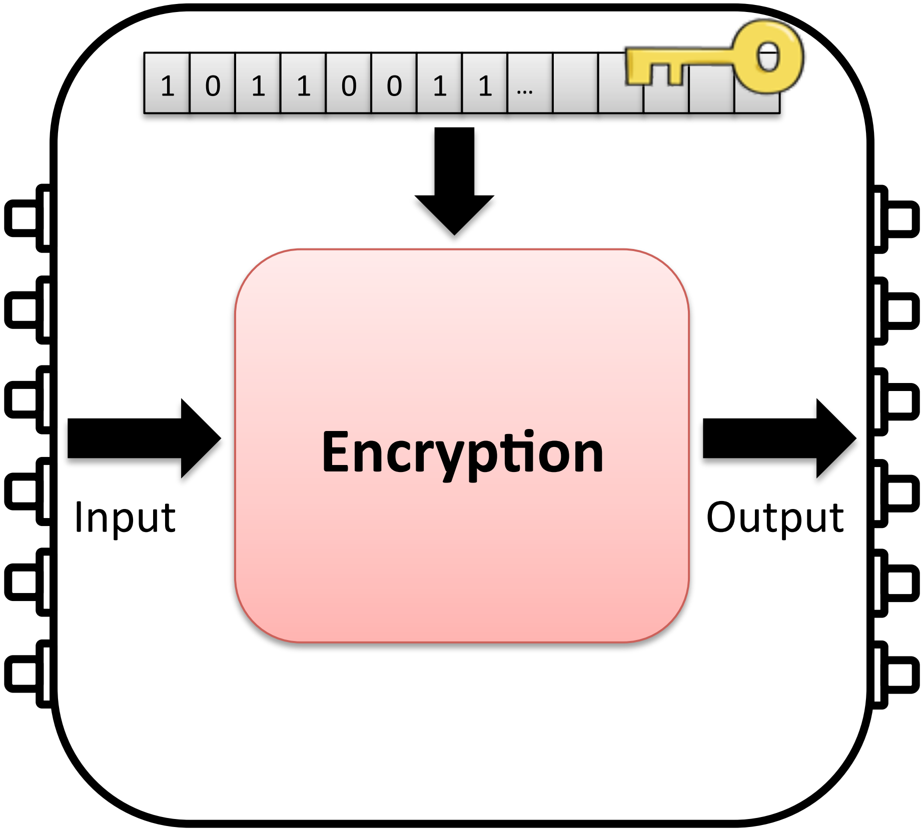
Test Infrastructures

Fault Attacks



<u>Hypothesis</u>: Injection forces a '0' on a single bit of the secret key

1) C_{OK}=E(P)

2) Calculate C'=E(P), while injecting a fault

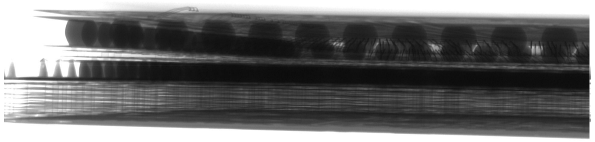
3) If C' = C_{OK} → target bit is '0' else → target bit is '1'

Injection means

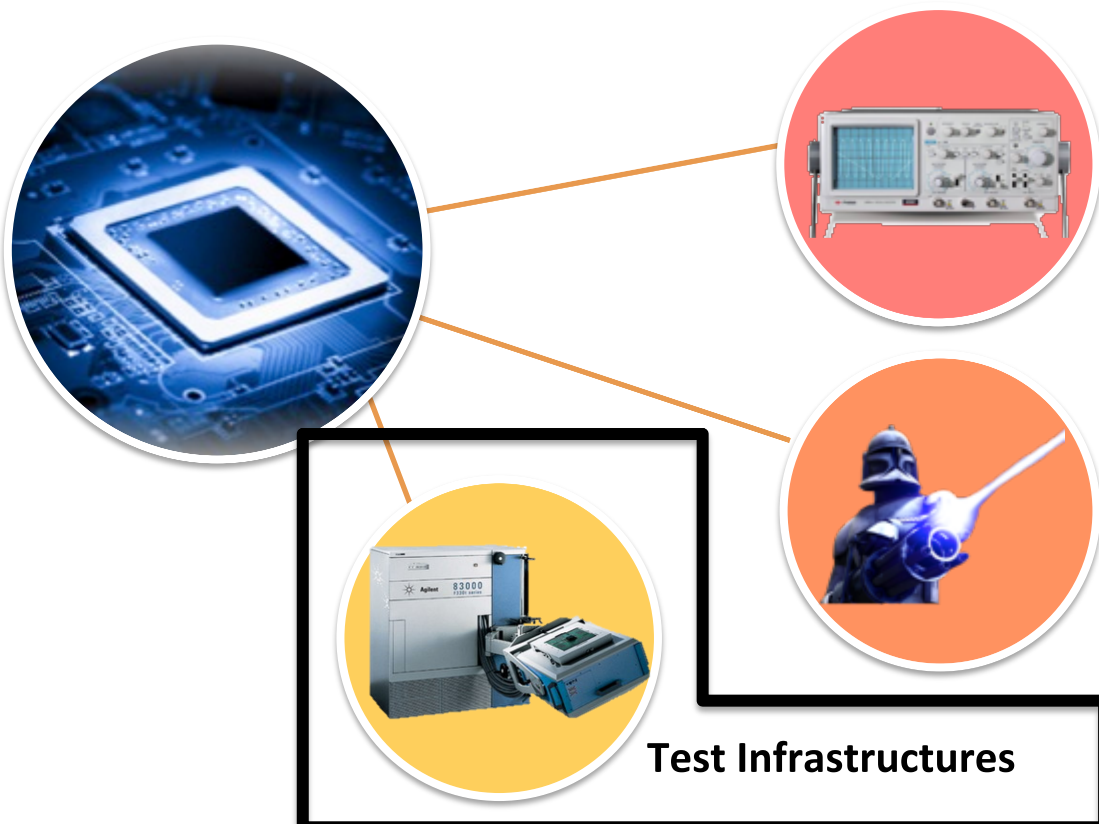
- To inject faults affecting critical paths
  - Under/over powering
  - Altering the clock
  - Altering the temperature
- To inject precise faults in space and time
  - Laser injections
  - Electro Magnetic injections

Countermeasures

- IC Packaging
- Fault detectors:
  - Laser/light, bulk current
  - They can generate false positives
- Error detectors, based on redundancy



Implementation Attacks – Types of Attacks



Side Channel Attacks

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Fault Attacks

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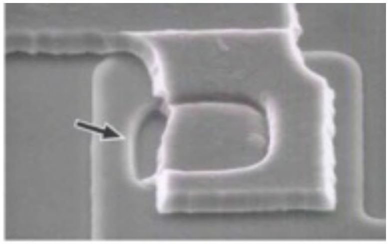
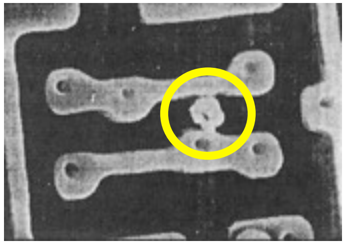
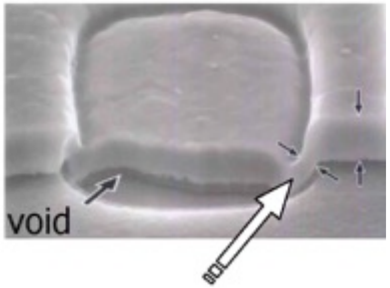
Manufacturing Process

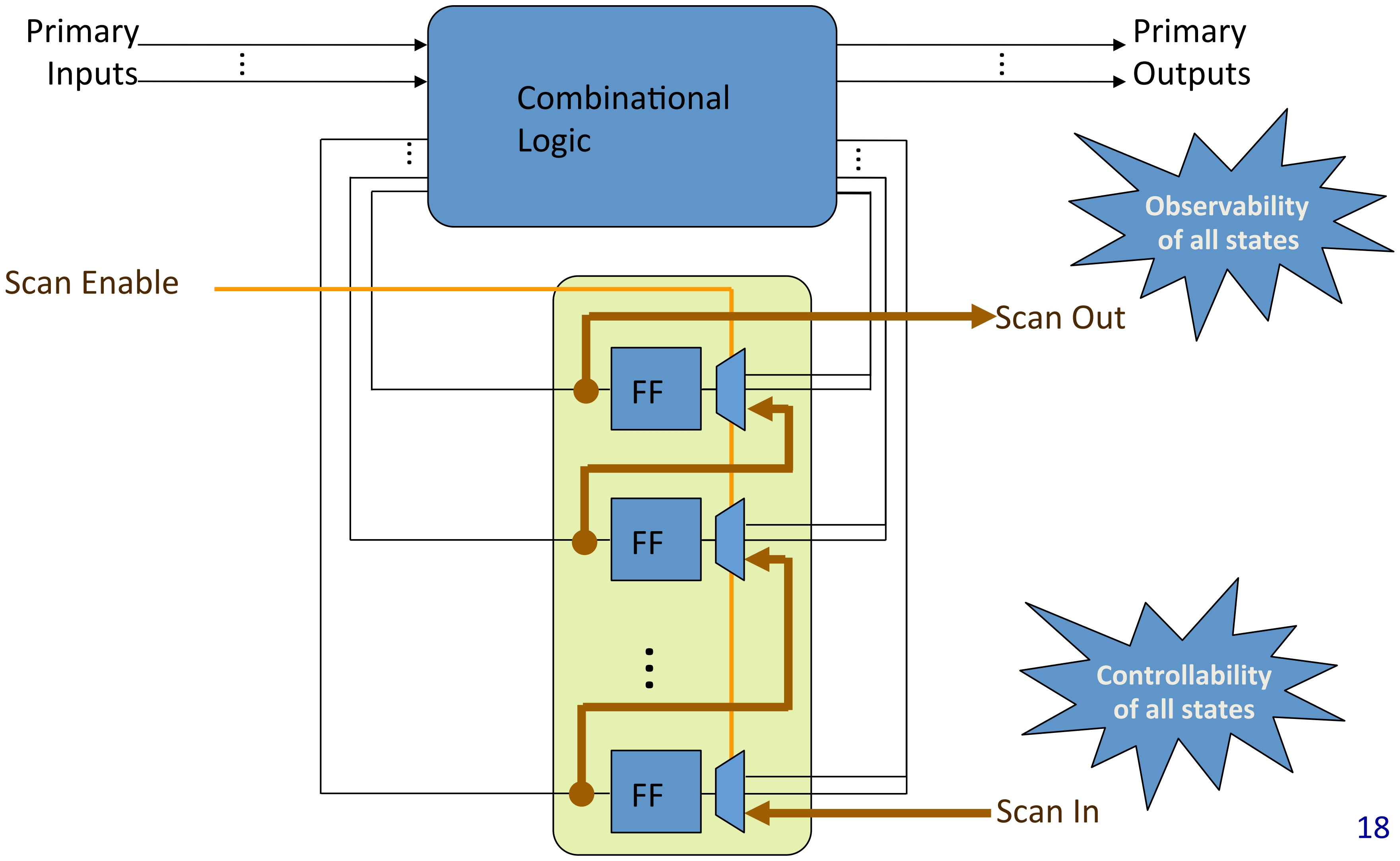
- Manufacturing process of integrated circuit is not totally controlled:
  - Dust, physical mechanisms, spot defect
  - Process variability
  - Assemblage faults





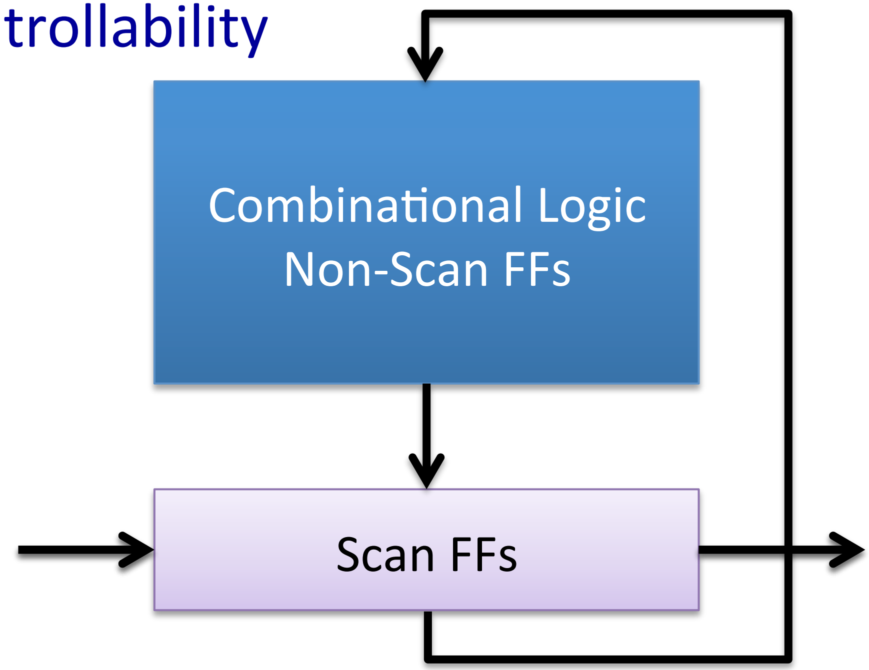


Scan-based Design



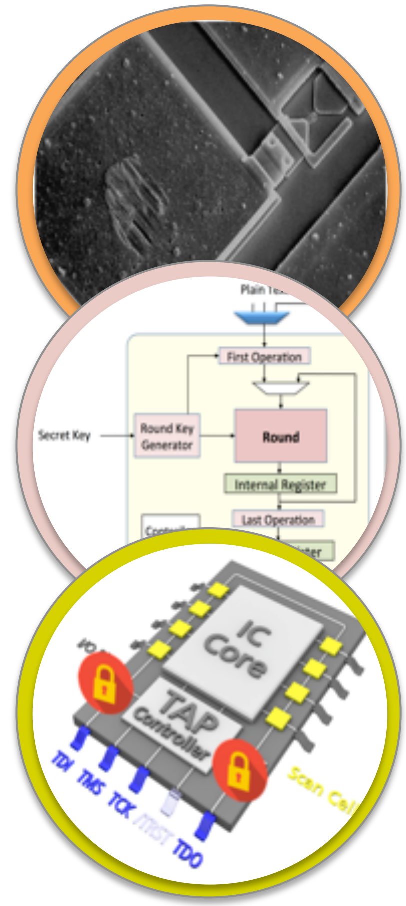
Scan attacks presentation

- Scan attacks:
  - Exploit observability and controllability offered by scan chains
  - Principle: switch between functional and scan modes
  - Goal: Retrieve embedded secret data



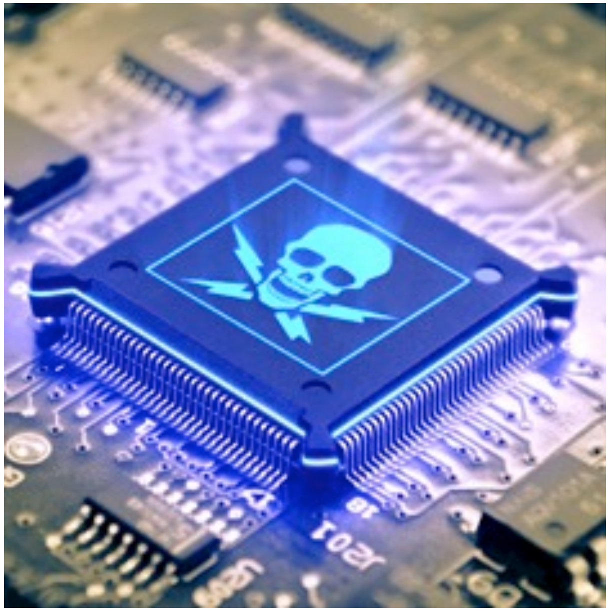
Countermeasures

- Leave the scan chain unbound
- Built-In Self-Test
- Secure Test Access Mechanism
  - Authentication (expensive)
  - No in-field debug/diagnosis
  - Not easy to integrate in design flow
- Scan Chain Encryption



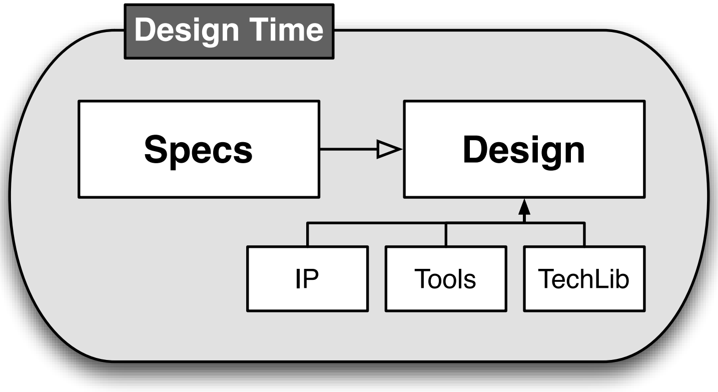
Conclusions - Hardware Security

- Cryptography has +2000 years history and experience
- Hardware Security is still a young research field



HARDWARE TRUST

The Untrusted Chain



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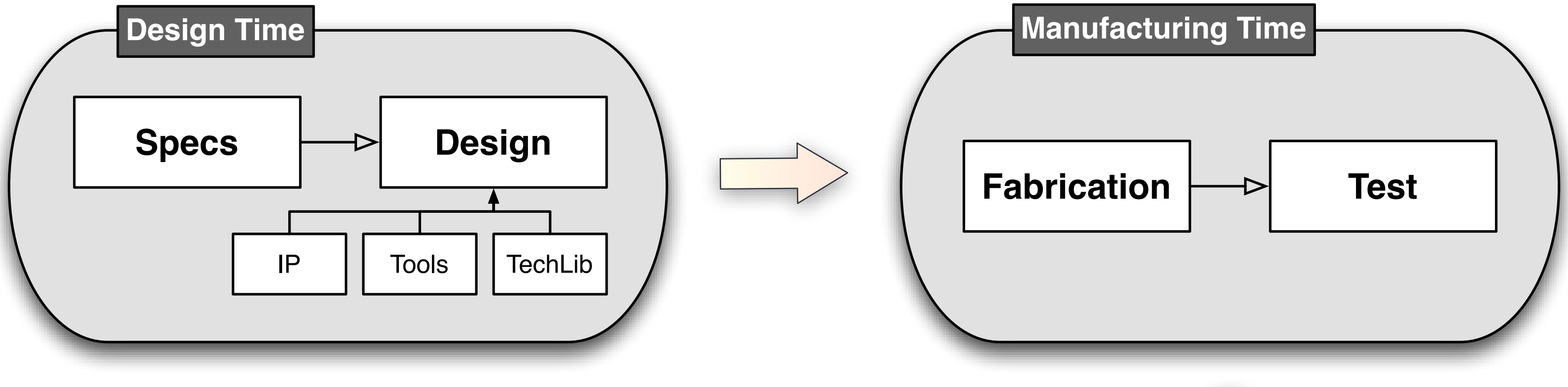

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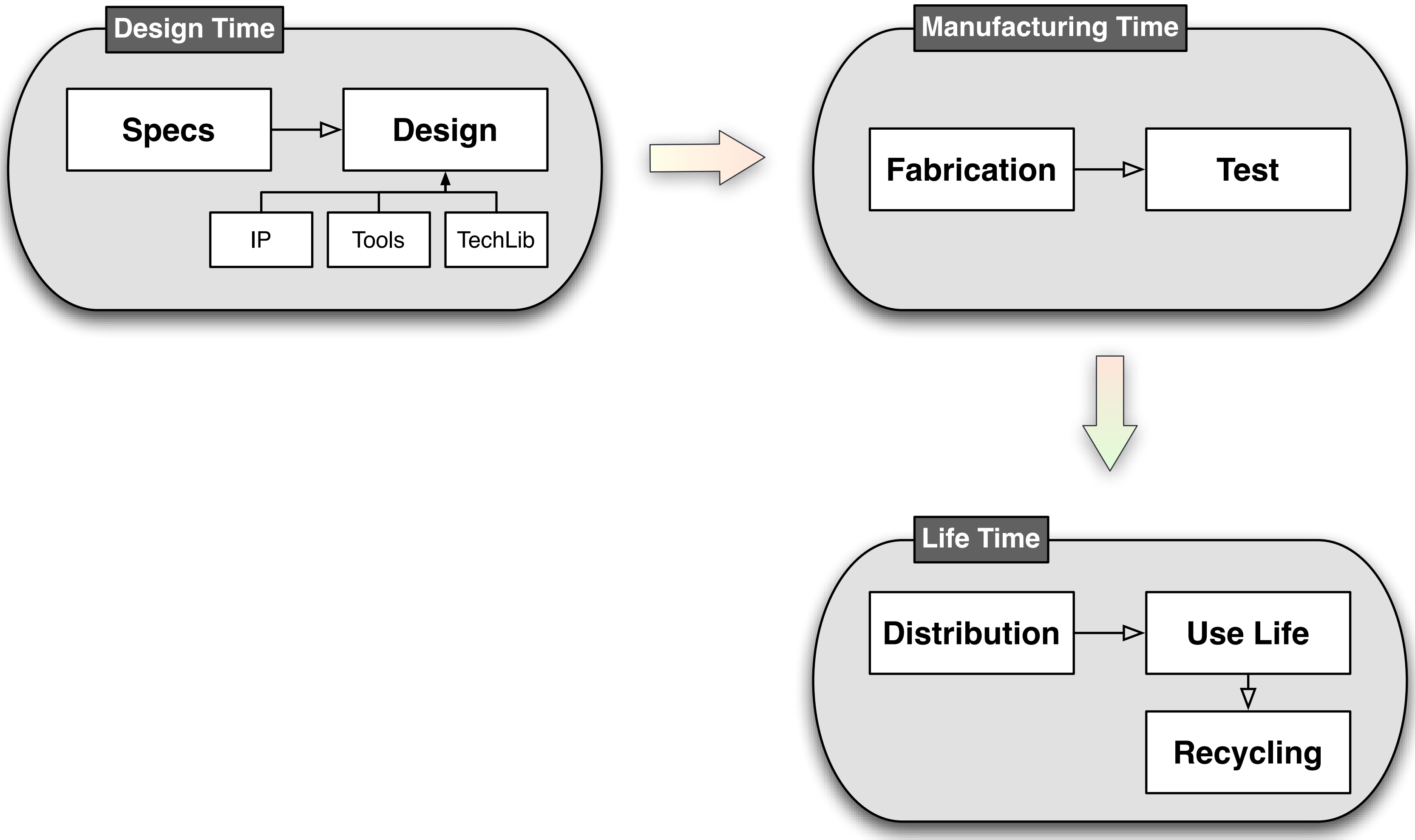

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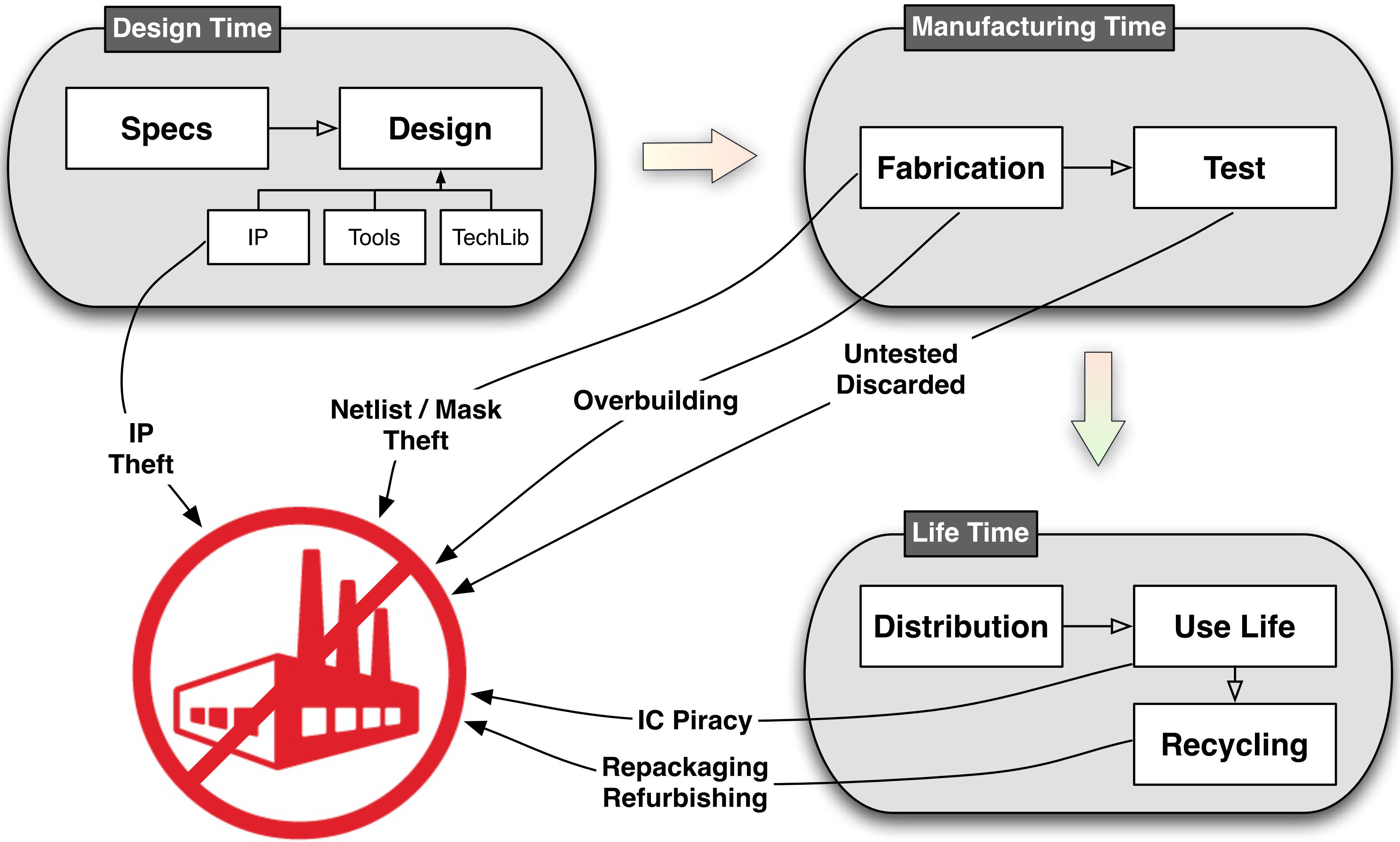

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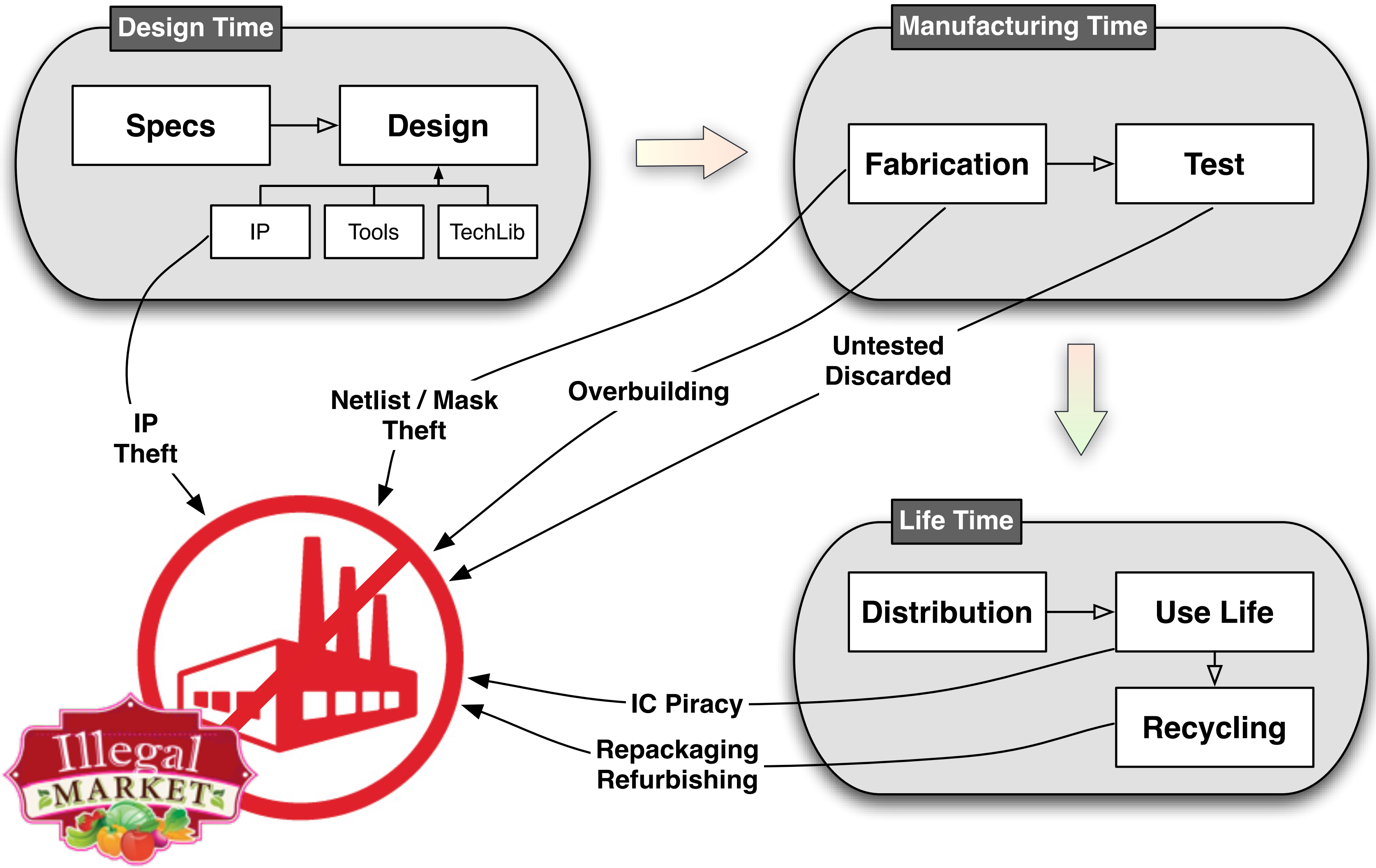

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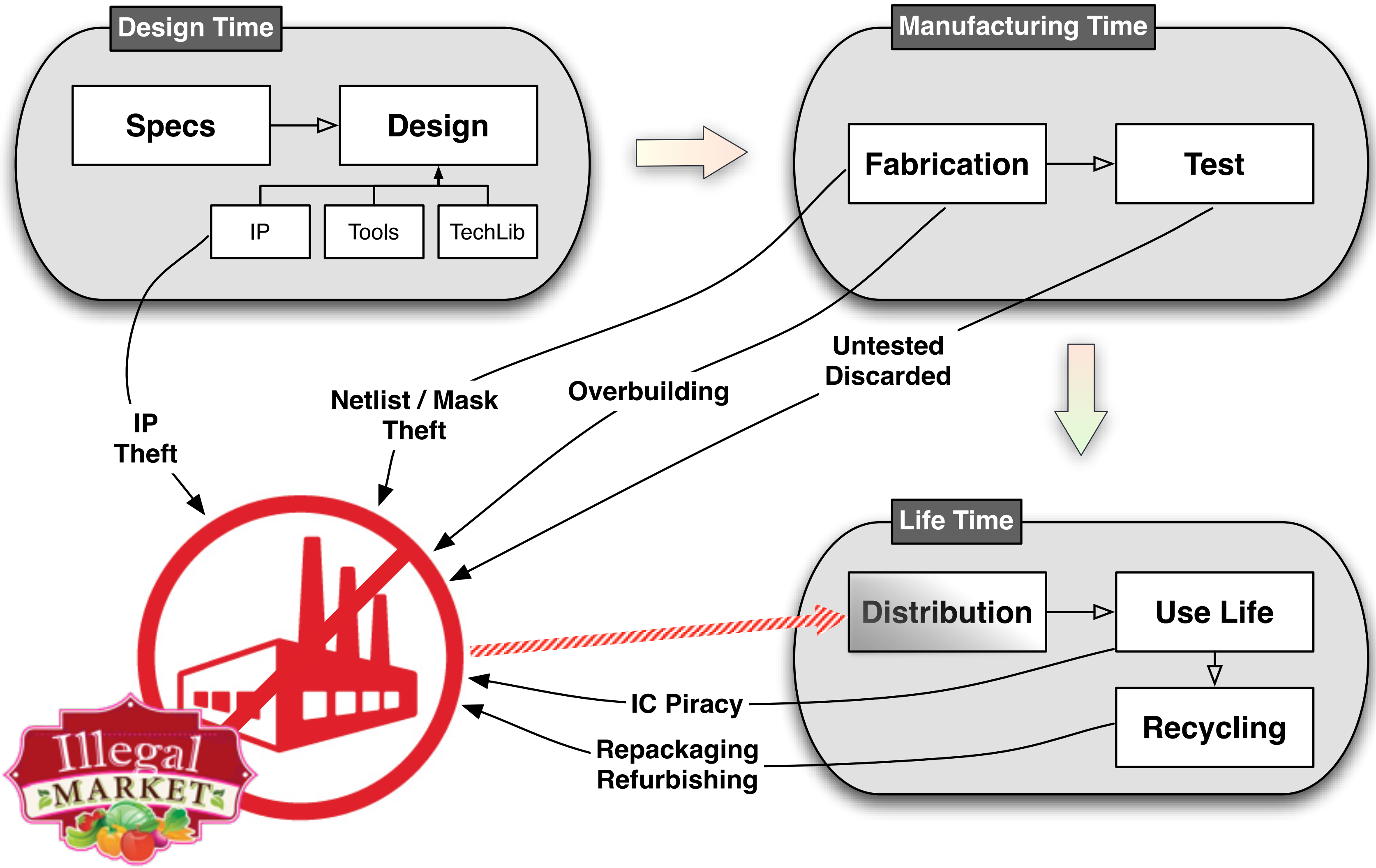

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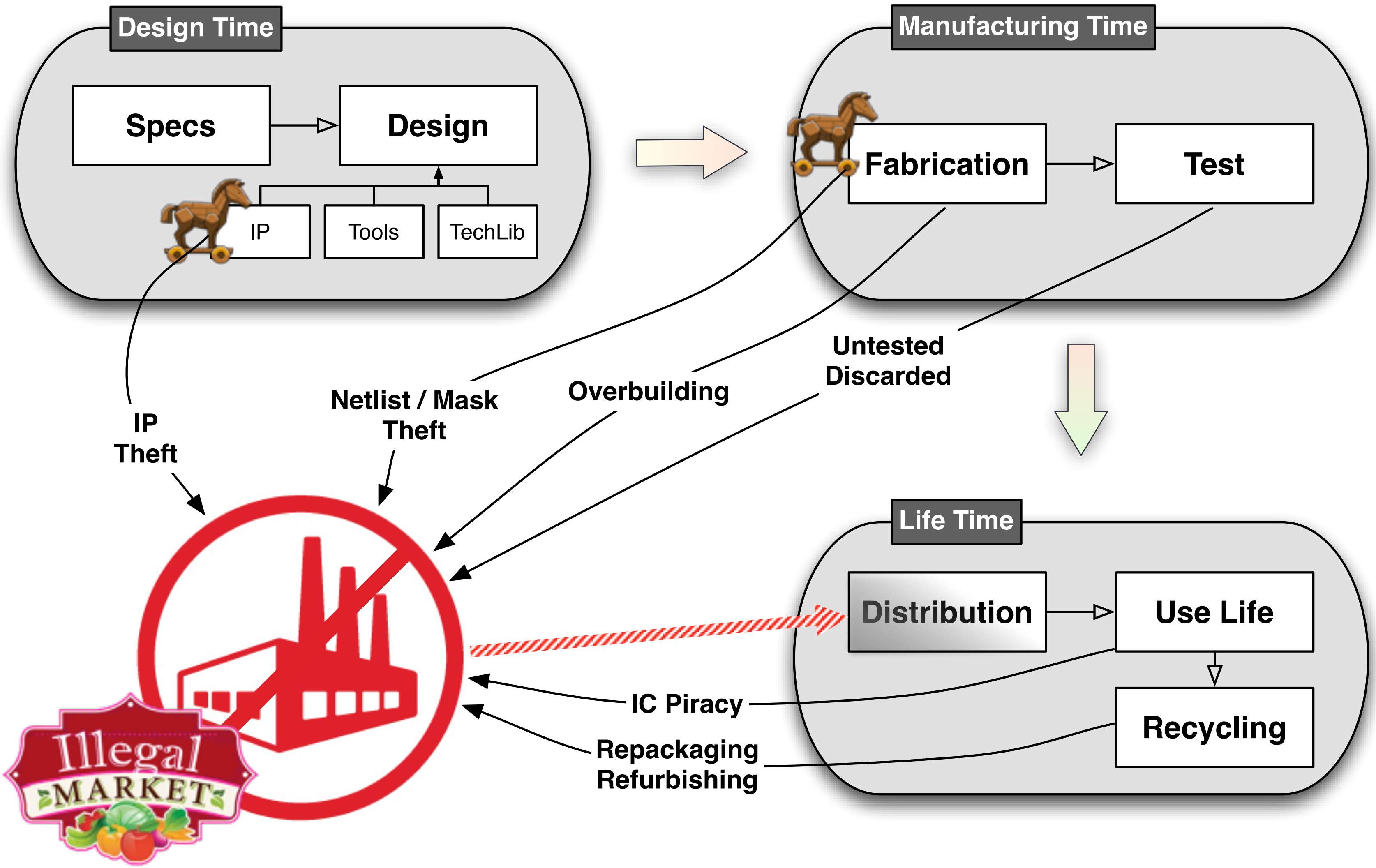


Counterfeiting types

- Recycled, Defective
- Overproduced
- Cloned
- Tampered

Counterfeit types
Recycled

- Electronic component that is recovered from a system and then modified to be misrepresented as a new component
- Problems:
  - lower performance
  - shorter lifetime
  - damaged component

Counterfeit types
Overproduced

- Overproduction occurs when foundries sell components outside of contract with the design houseparts
- Problems:
  - loss in profits for the design and IP owner
  - reliability threats since they are often not subjected to the same rigorous testing as authentic part

Counterfeit types
Cloned

- A copy of a design, in order to eliminate the large development cost of a part
- Methods:
  - Reverse engineering
  - By obtaining IP illegally (also called IP theft)
  - With unauthorized knowledge transfer from a person with access to the design

Counterfeit types
Tampered – Hardware Trojan Horses

- A Hardware Trojan Horse is a malicious modification of an integrated circuit
  - Performed at any design or manufacturing step
- Examples:
  - Backdoors, time bombs
- A real threat?

Counterfeiting detection

- Cleaning, visual inspection
- Microscope & X Ray Inspections
- Side-Channel
- Testing

Counterfeiting prevention

- Aging detectors
- Hardware metering
- IC Camouflage
- IC Authentication
- HT Prevention

Counterfeiting prevention – Aging Detectors

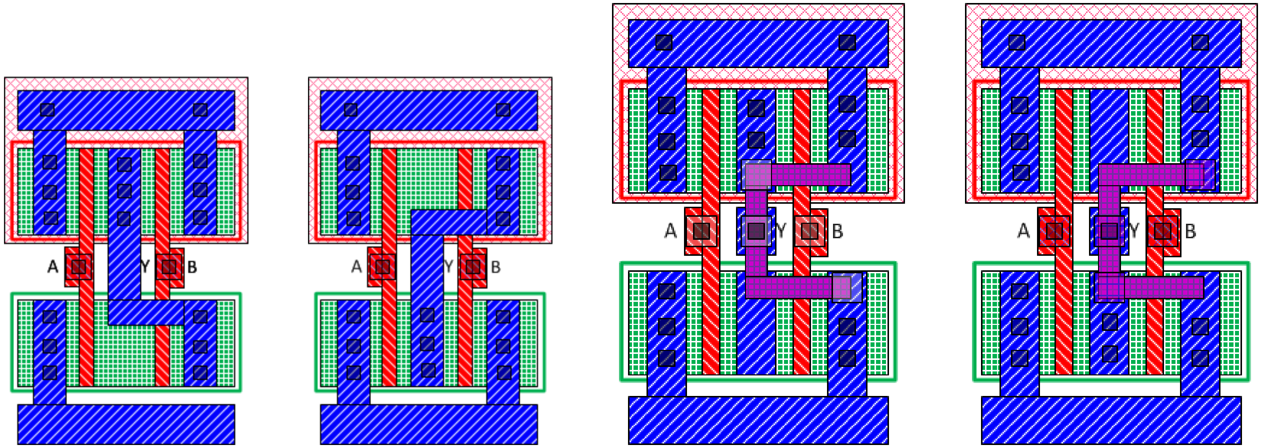
- Sensors in the chip to capture the usage of the chip in the field
  - It relies on aging effects of MOSFETs to change a ring oscillator frequency in comparison with the golden one embedded in the chip.
- Techniques:
  - Fuse-based technology to record usage time
  - Differential measurement

Counterfeiting prevention – Hardware Metering

- A set of security protocols that enable the design house to achieve the post-fabrication control of the produced ICs to prevent overproduction
  - Post-Manufacturing Activation
  - Adding a Finite-State Machine (FSM) which is initially locked and can be unlocked only with the correct sequence of primary inputs
  - Logic Encryption

Counterfeiting prevention – IC Camouflage

- Standard-cells are re-designed not to disclose their identity

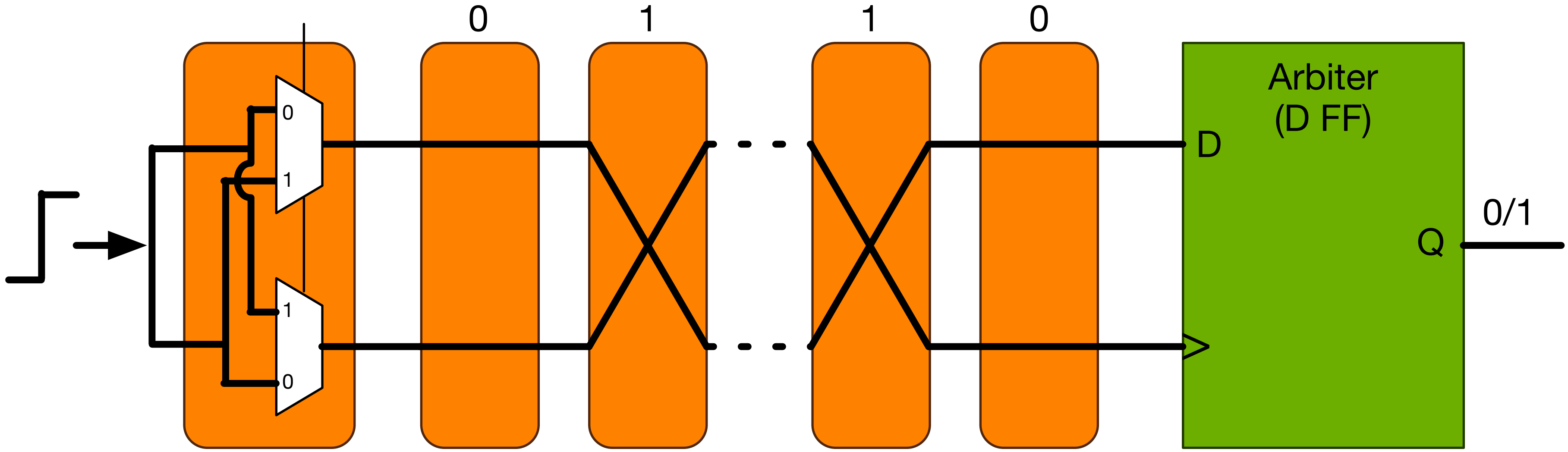


NAND NOR Camouflaged NAND Camouflaged NOR

Counterfeiting prevention – IC Authentication

- Physically Unclonable Functions (PUF)
  - Able to generate random and stable responses
- After manufacturing, each device is challenged by **several random** inputs
- Responses are stored in a secure database
- To authenticate the device, some of the challenges are used during mission mode

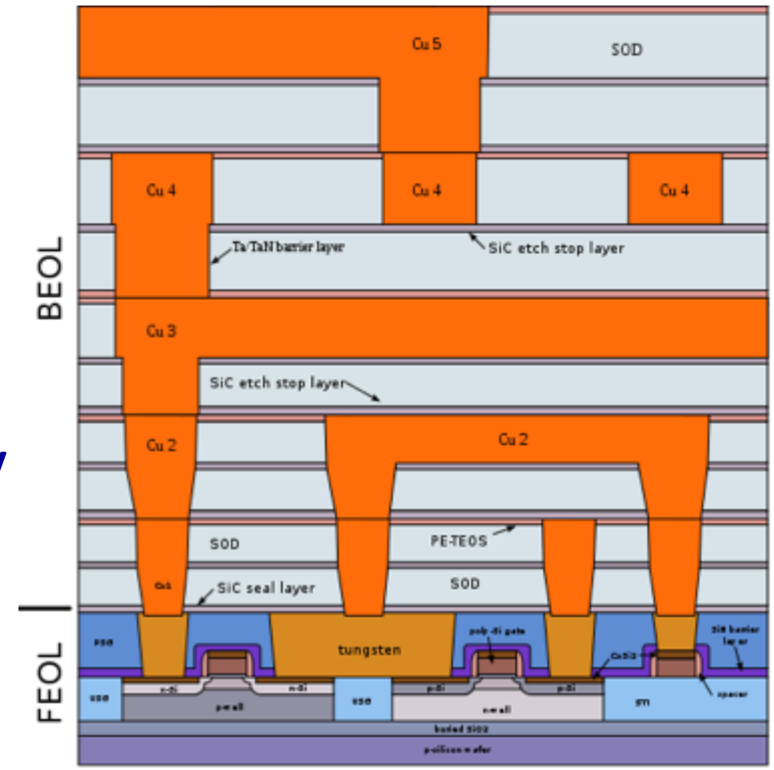
Arbiter PUF



- Delays of all the paths from input to output: nominally identical
- Reality: because of process variations, all different!

HW Tojans prevention – Split Manufacturing

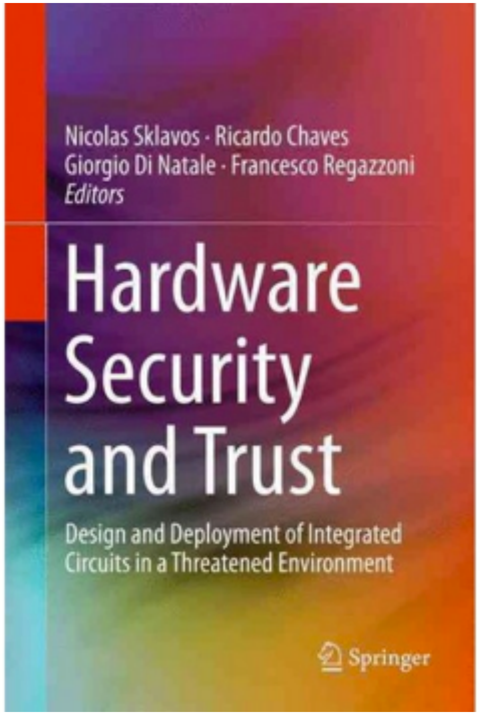
- Front End Of Line (FEOL) layers (transistor and lower metal layers) are fabricated in an untrusted foundry
- Back End Of Line (BEOL) in a trusted low-end fab
- It is considered secure against reverse engineering as it hides the BEOL connections from an attacker in the FEOL foundry



Conclusions

- Hardware Security and Trust are big challenges
- It might become even worst because of:
  - Limited resources (IoT)
  - Safety (autonomous cars)


THANK
YOU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