ECE 459/559
Secure & Trustworthy Computer Hardware Design

Introduction

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Spring 2017

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Goals

- Learn state-of-the-art security primitives and methods, including emerging technologies and security trends
- Integration of security as a design metric, *NOT* an afterthought
- Protecting intellectual property (IP) against piracy & tampering
- Understand attacks and how to provide countermeasures
- Understand vulnerabilities in design and fabrication processes
- Understand component design and supply chain vulnerabilities

Some Topics Covered

- Cryptographic cores
  - Vulnerabilities & processing overhead
- Attack vectors
  - Physical, Invasive vs. non-invasive
- Physically unclonable functions (PUF)
- True random number generators (TRNG)
- Anti-piracy
  - Watermarking, passive & active hardware metering
- FPGA Security
  - Trusted design in FPGAs
- Hardware Trojans – detection & prevention
- Counterfeit detection & avoidance

Motivation for Hardware Security

- HW security is becoming increasingly important

  "Hardware security sneaks into PCs,"
  – Robert Lemos, CNET News.com, 3/16/05

  "Microsoft reveals hardware security plans, concerns remain,"
  – Robert Lemos, SecurityFocus 04/26/05

  "Princeton Professor Finds No Hardware Security In E-Voting Machine,"
  – Antone Gonsalves, InformationWeek 02/16/07

  "Secure Chips for Gadgets Set to Soar,"
  – John P. Mello Jr. TechNewsWorld, 05/16/07

  "Army requires security hardware for all PCs,"
  – Cheryl Gerber, FCW.com, 7/31/2006

- www.trust-hub.org

Example: Time for Smart Cards

- By end of 2006, many European countries migrated to smart cards
  - Voting: In Sweden you can vote with your smart card which serves as a non-repudiation device
  - Telecommunications: Many cellular phones come with smart cards in Europe and will soon be shipping in the United States
  - Mass Transit: British Air relies on rail and air connections more than most airports
- In 2006, ~27M contactless cards were in circulation in the US, the number was estimated to top 100M in 2011
  - Example: DHS requires port workers to have smart ID cards
  - Entertainment: Most DSS (Digital Satellite Service) dishes in the US use smart cards

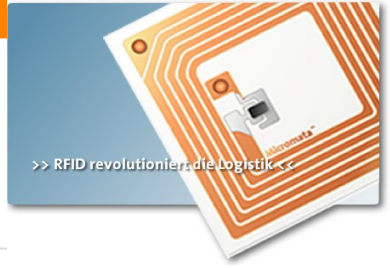
Smart Cards – Attacks

"Access Control: Smart Cards Under Attack - Literally,"
– Ken Warren, Security Magazine, 3/17/06

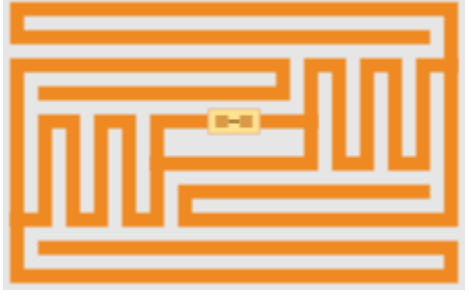
"Keep Your Enemies Close: Distance Bounding Against Smartcard Relay Attacks,"
– Saar Drimer and Steven J. Murdoch, USENIX SECURITY, 2007

"Vulnerability Is Discovered In Security for Smart Cards,"
– John Markoff, New York Times, 5/13/2002

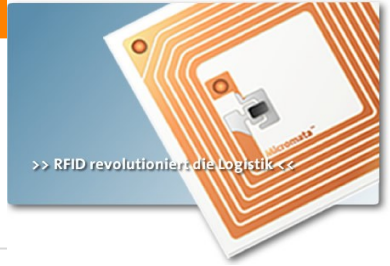
Example: RFIDs



- Radio-frequency identification (RFID) – the use of an object for the purpose of identification and tracking using radio signals
- Most RFID tags contain at least two parts:
  - Integrated circuit for storing and processing information, modulating and demodulating a RF signal, and other special functions
  - Antenna for receiving & transmitting the signal
- Some RFID tags are active (battery powered) and some are passive

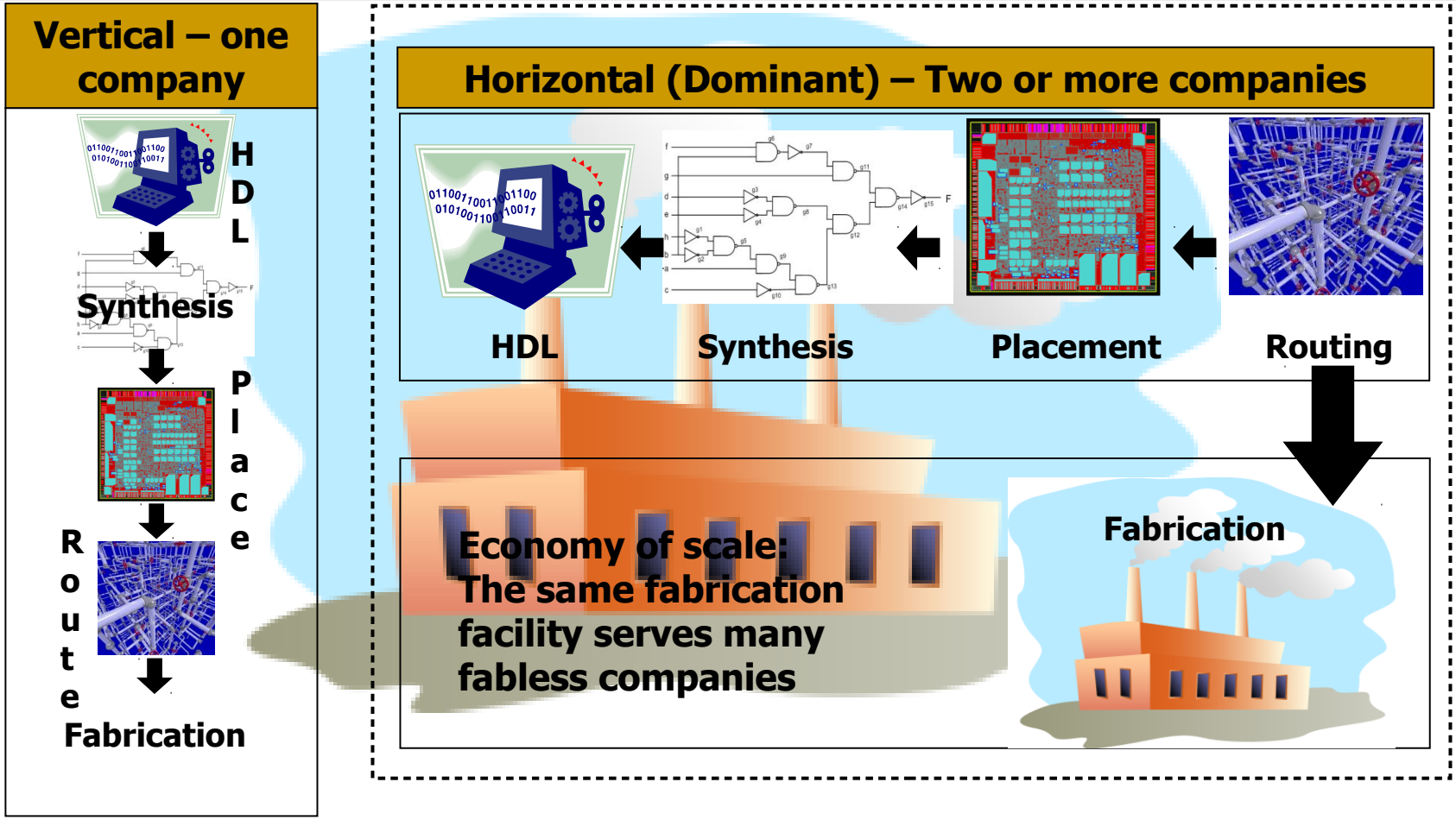


Example: RFIDs



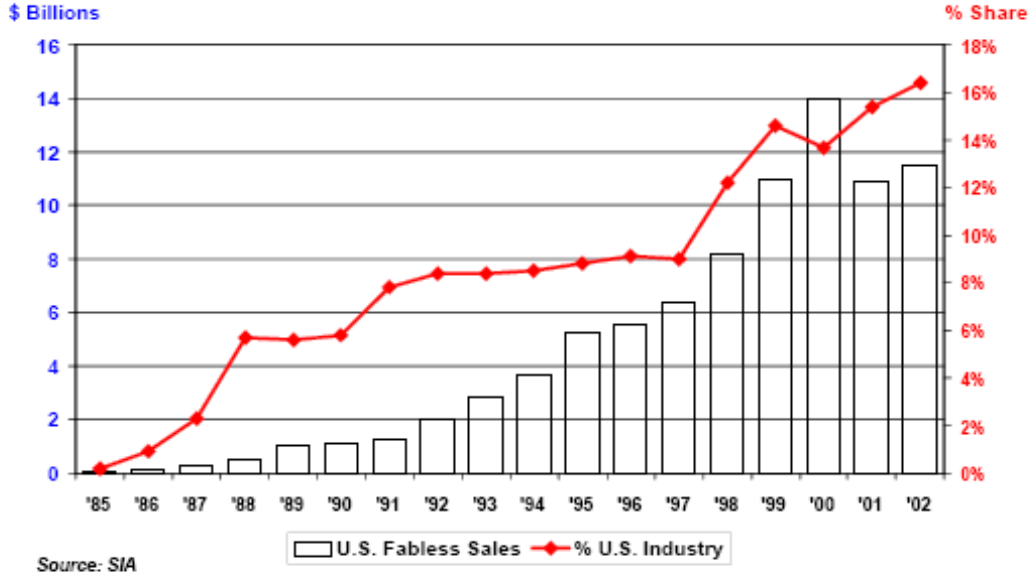
- Many applications in securing transactions:
  - Inventory Control Container / Pallet Tracking
  - ID Badges and Access Control
  - Fleet Maintenance Equipment / Personnel Tracking in Hospitals
  - Parking Lot Access and Control
  - Car Tracking in Rental Lots
  - Product Tracking through Manufacturing and Assembly
- Challenge: Can we create security mechanisms light enough to be suitable for RFIDs?

Semiconductor Industry
A Shift in the Business Model



Semiconductor Industry Business Model

The fabless/foundry business model has grown to 16% of the U.S. chip industry. The trend is strongest in the leading process technology portion of the industry

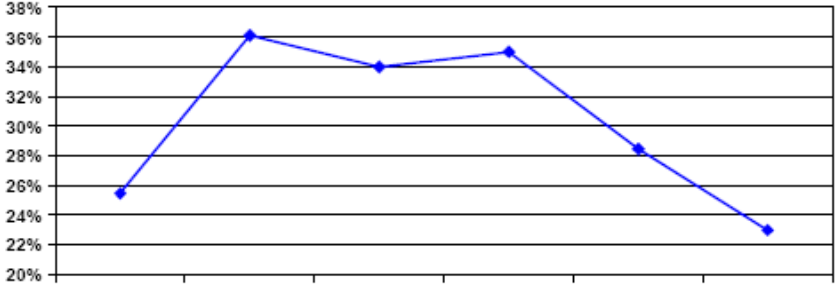


Source: SIA

Leading-Edge Technology

The cost of building a full-scale, 300 mm wafer 65 nm process fabrication plant is about $3bn; TSMC has spent more than $9bn!

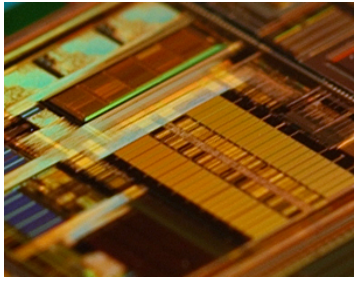
U.S. industry's share of capital expenditures falling and in leading edge semiconductor manufacturing capacity.



Leading Edge	< 0.4µ	< 0.3µ	< 0.3µ	< 0.2µ	< 0.2µ	< 0.16µ

Source: SICAS/SIA

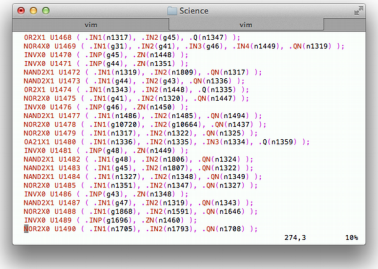
Hardware Threats



IP Vendor

System Integrator

Manufacture



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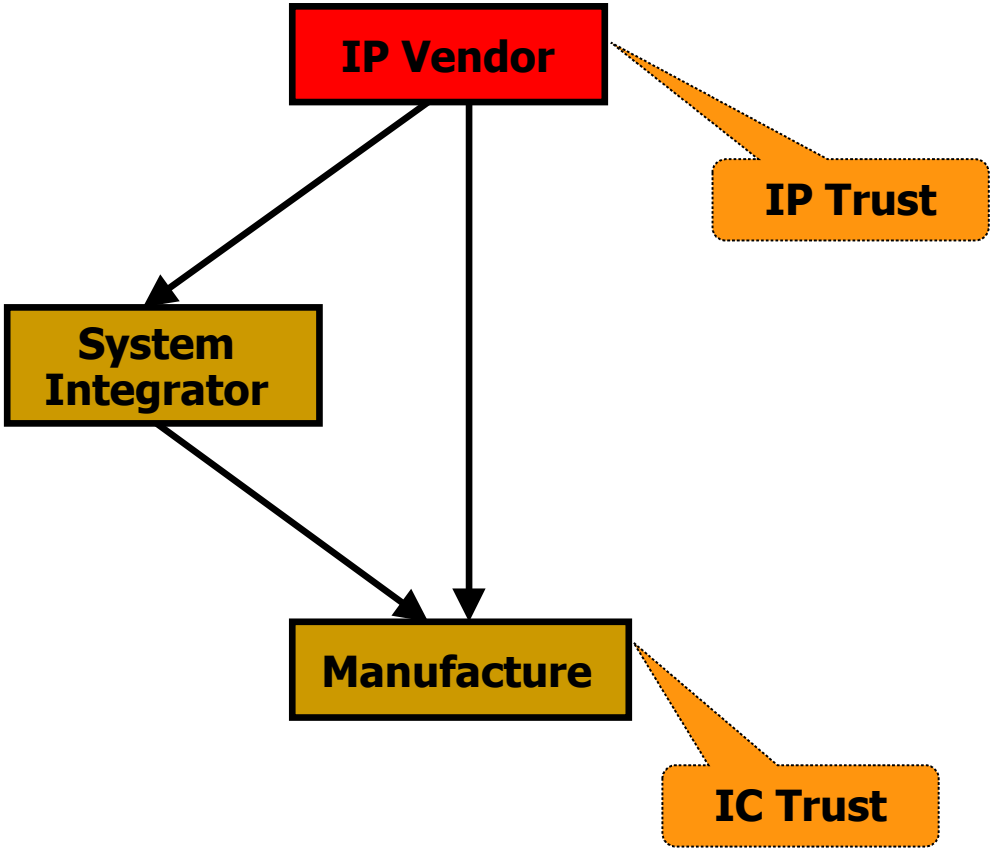
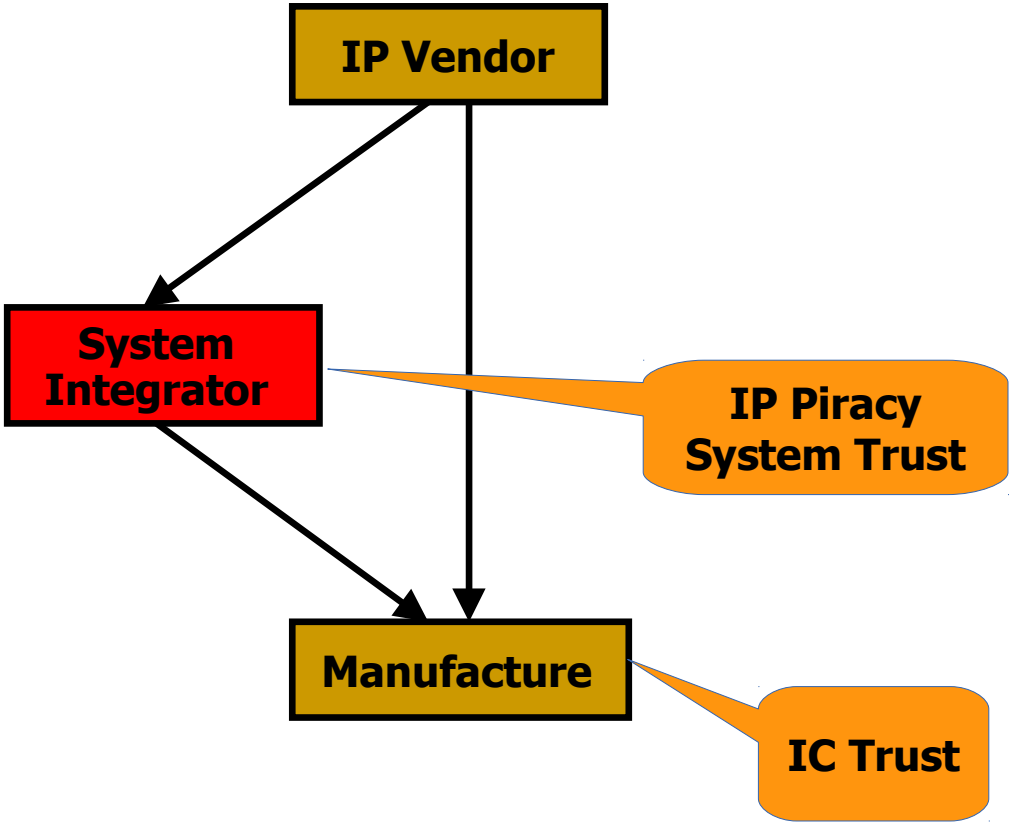
Any of these steps can be untrusted

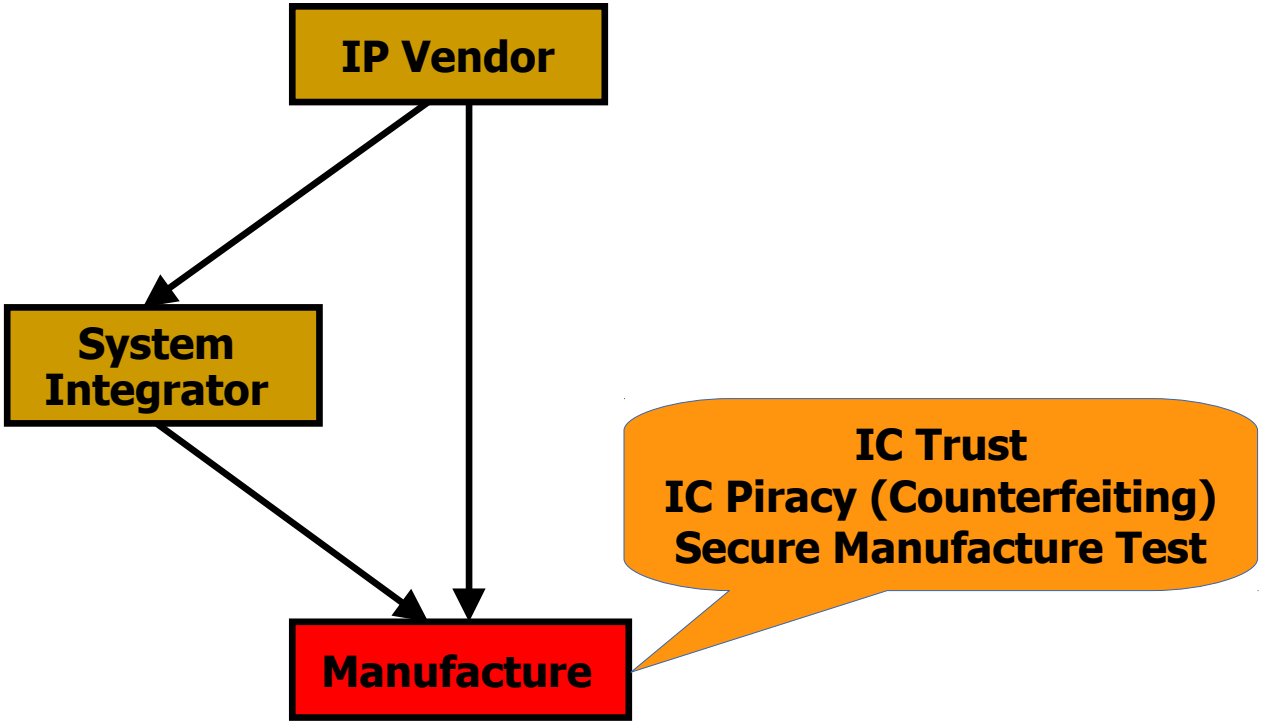
Hardware Threats



Hardware Threats

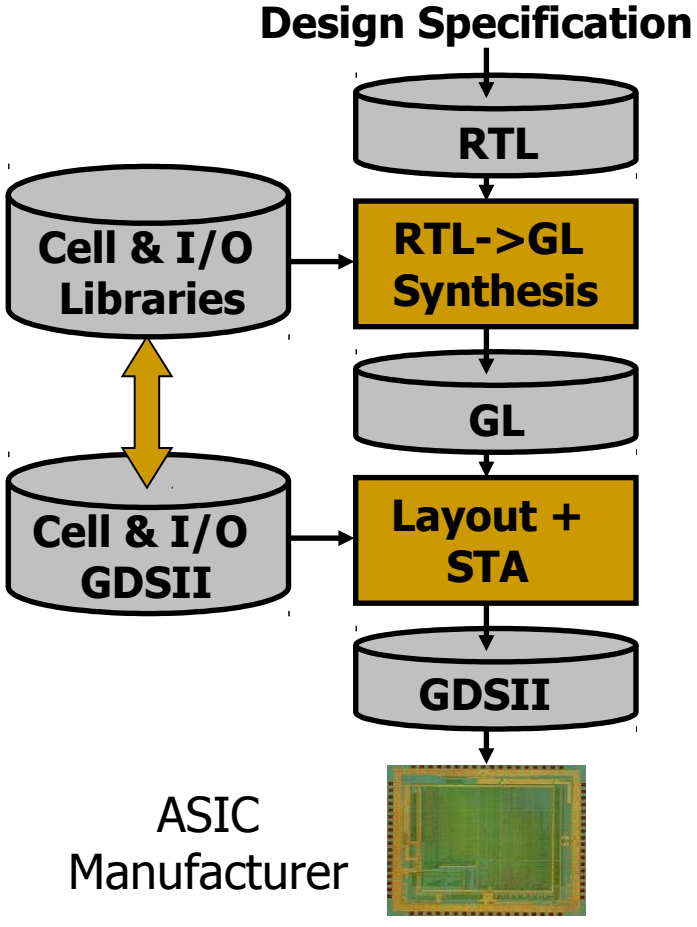


Hardware Threats



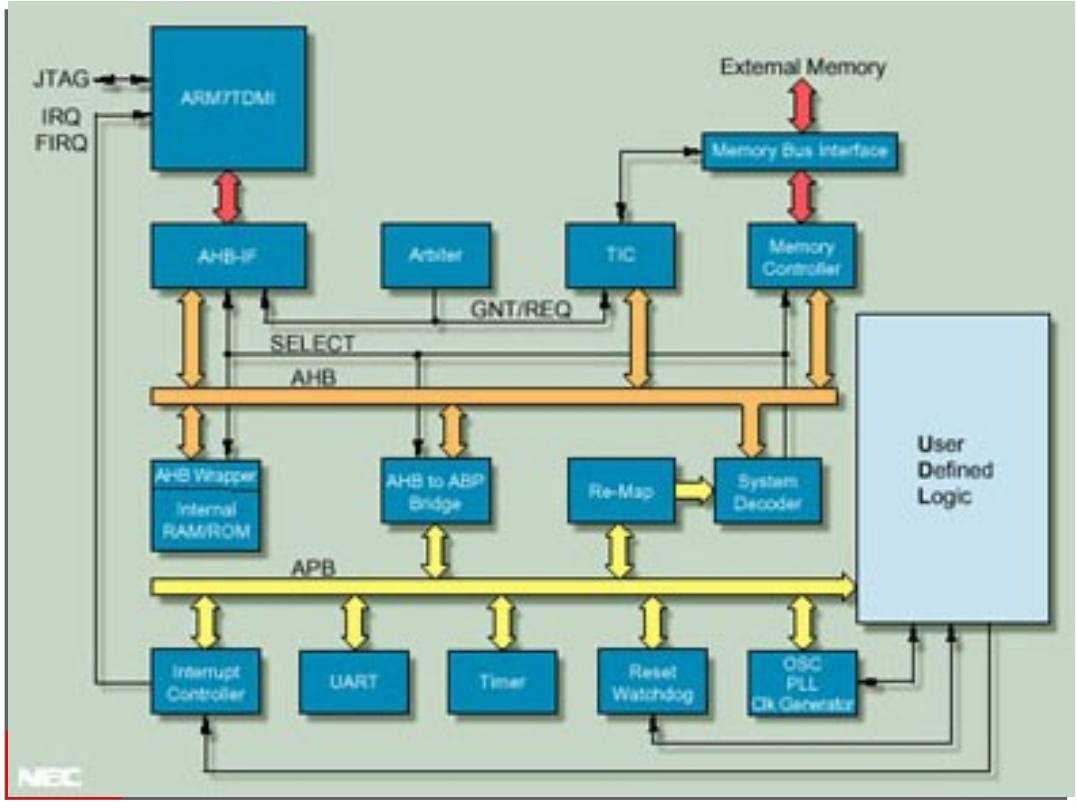
Untrusted

Design Flow – The Old Way

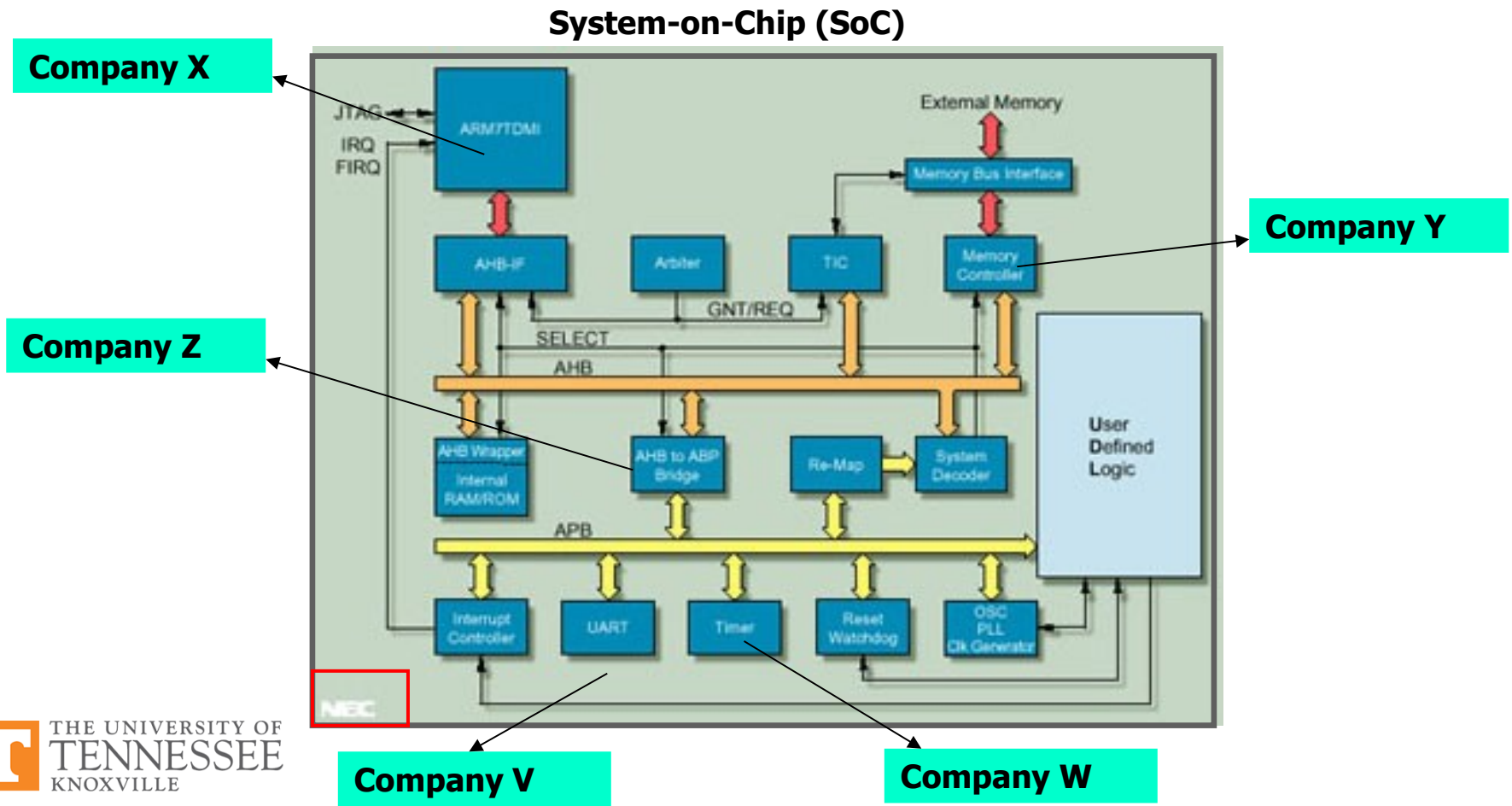


Issues with Third Party IP

System-on-Chip (SoC)



Issues with Third Party IP



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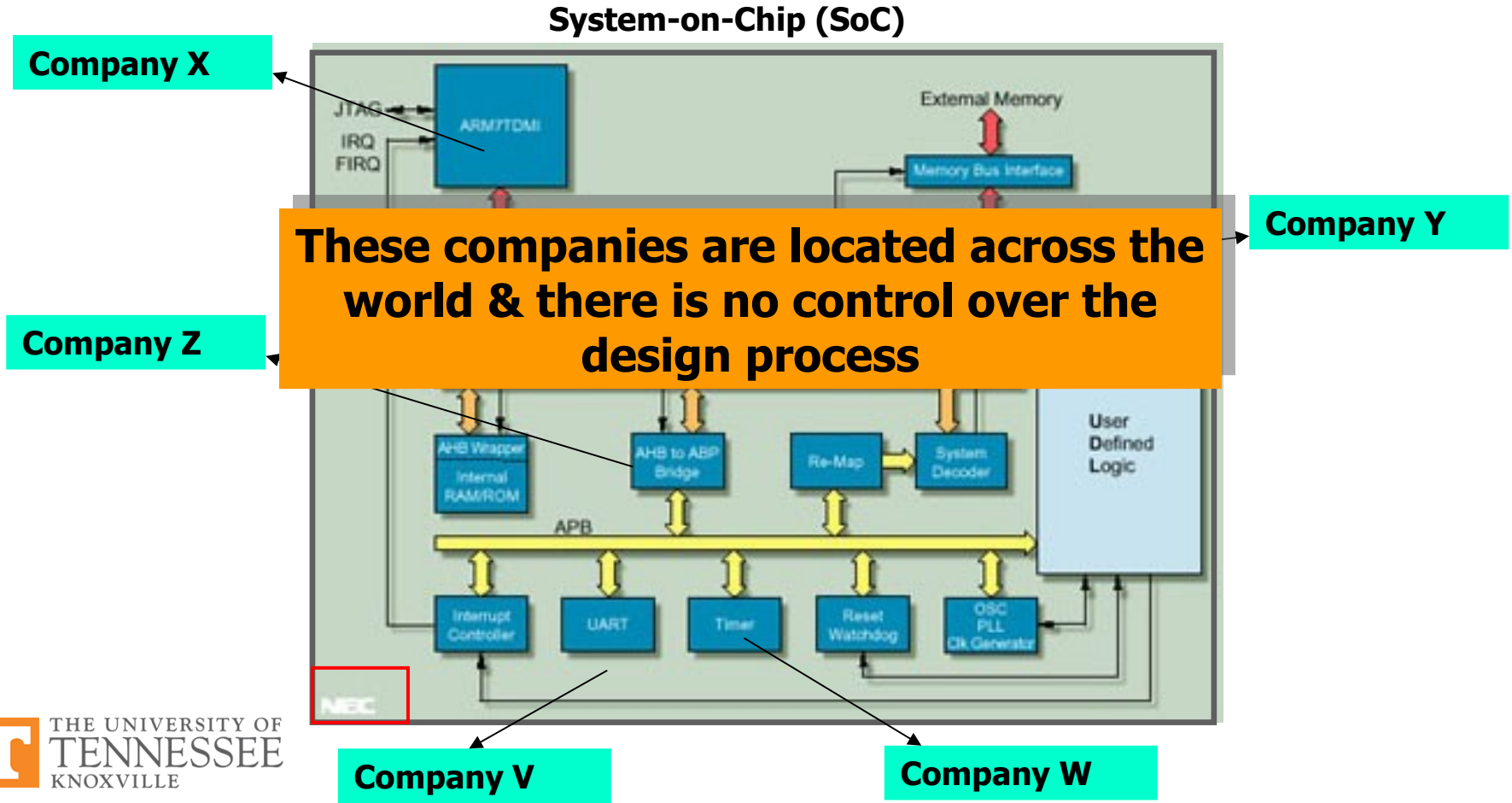
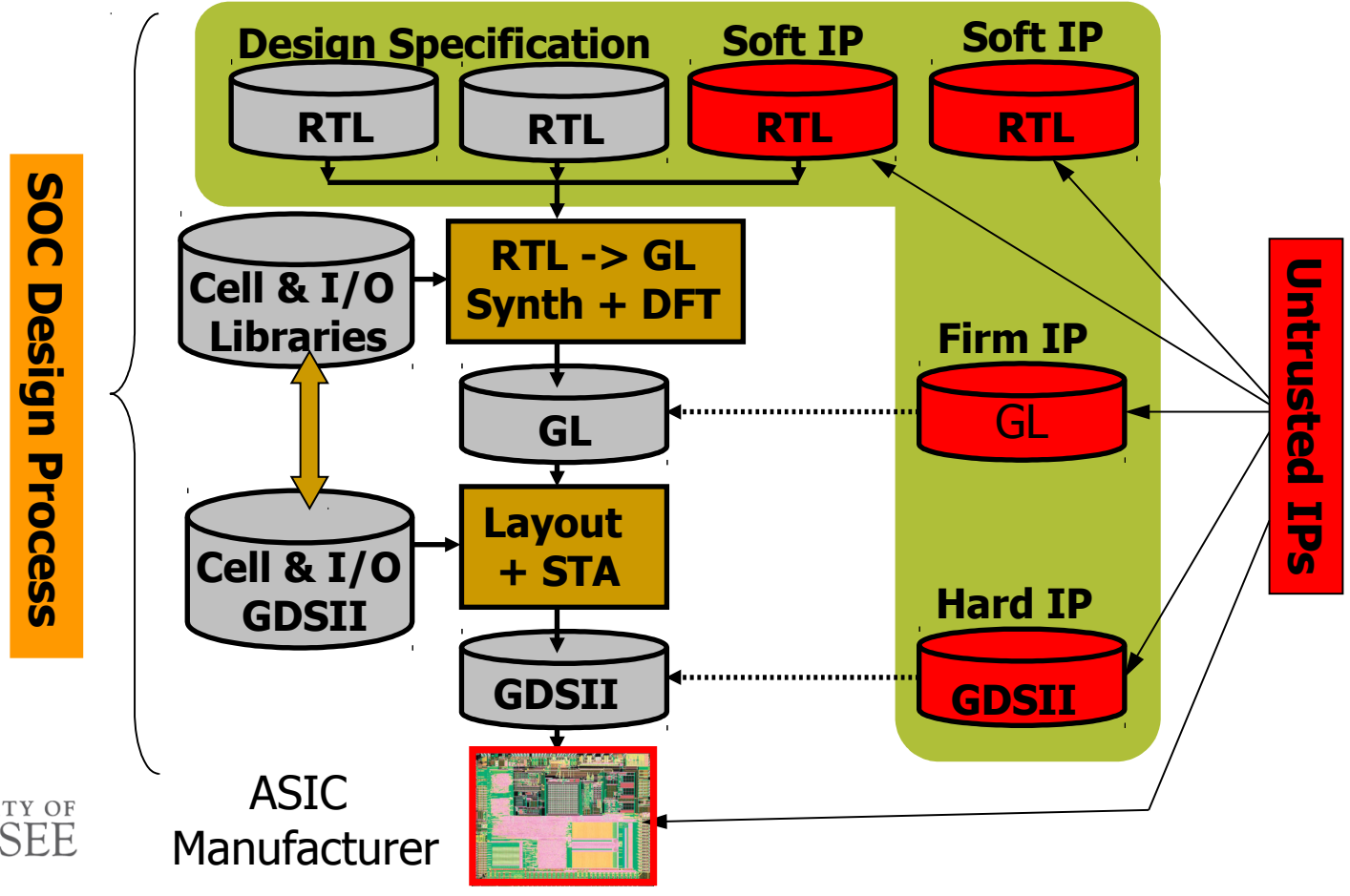


Design Flow – The New Way



Who Develops the IP? Who Designs the IC? Who Fabricates?

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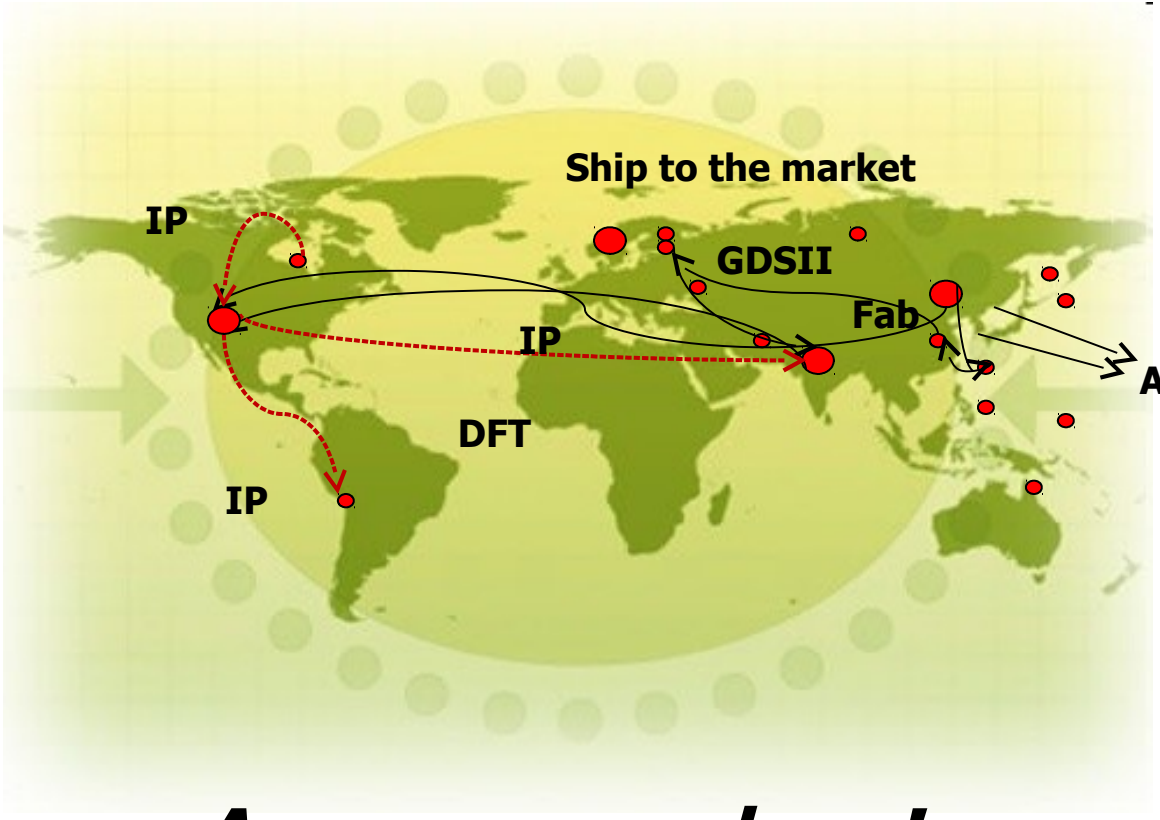
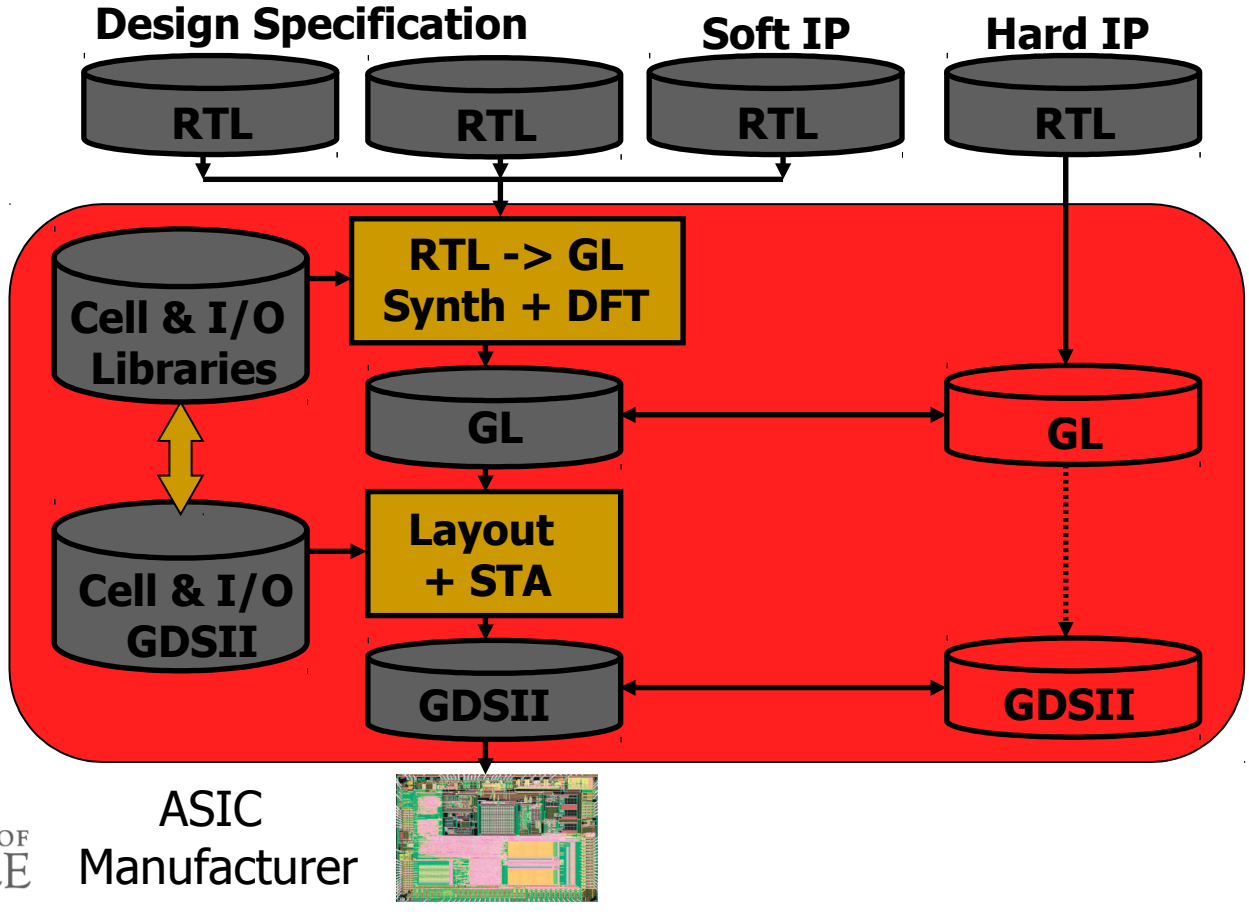
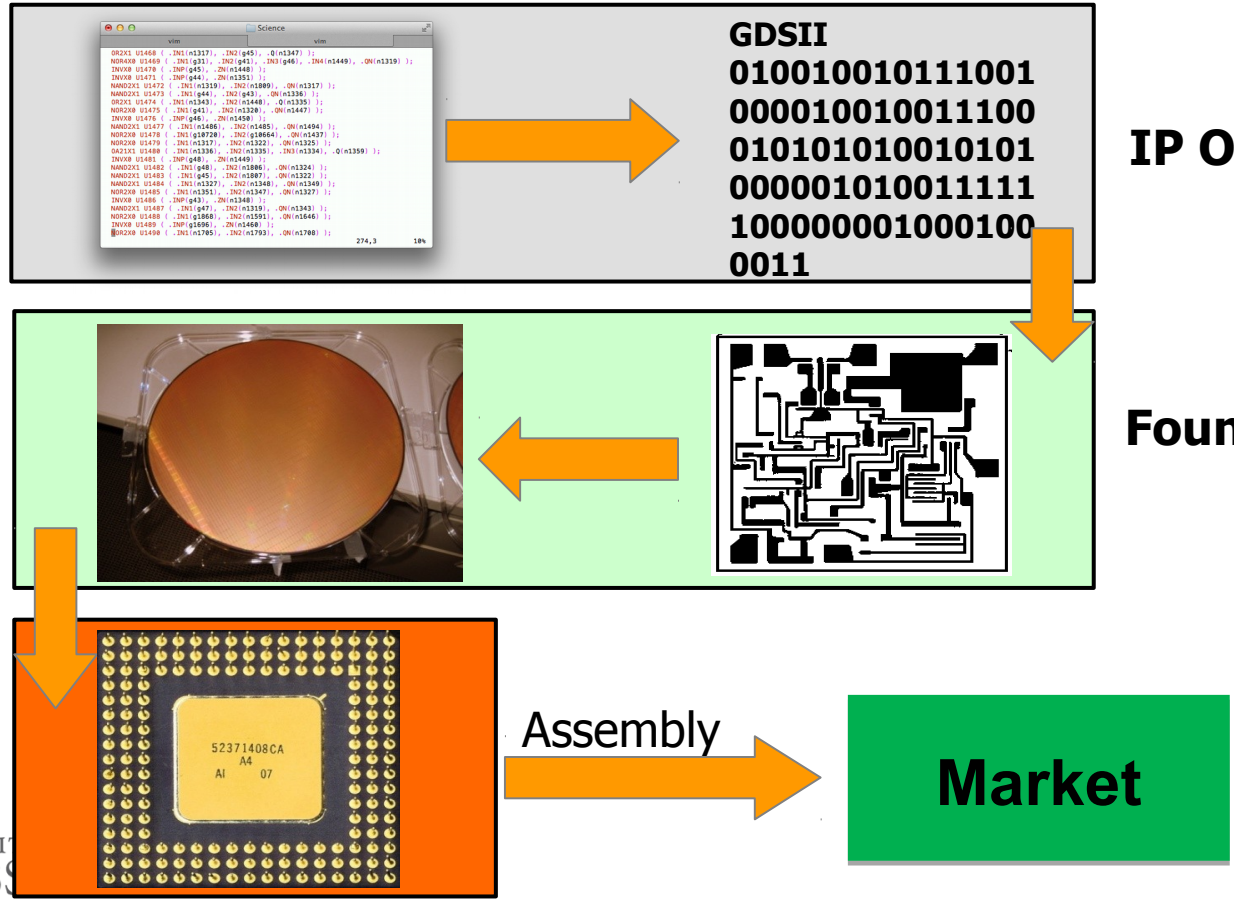


Anyone, anywhere!

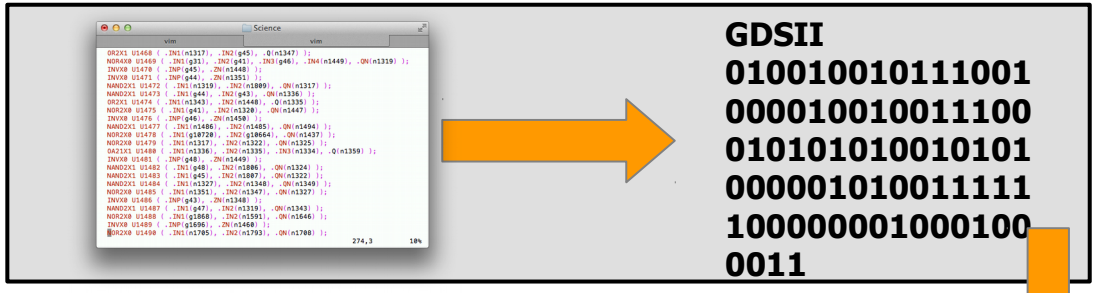
Untrusted System Integrator



Counterfeiting

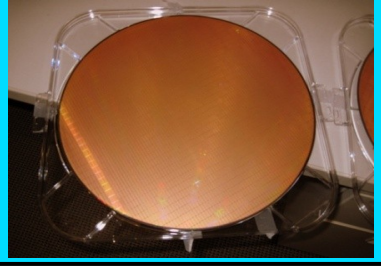


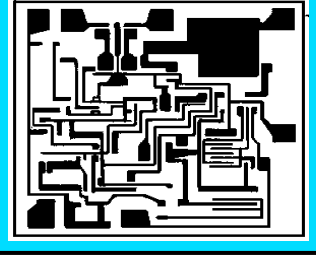
Counterfeiting



GDSII
0100100101110010000100100111000101010100100101000001010011111100000000100010000011

IP Owner

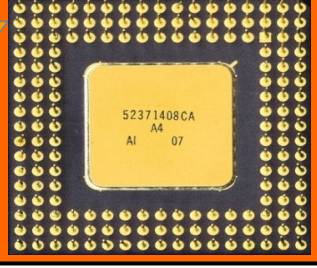




Foundry

Over-produced ICs

Defective or Out-of-spec ICs



Assembly

Market

IC Counterfeiting

- Most prevalent attack today!
- Unauthorized production of wafers
- Estimated that counterfeiting costing semiconductor industry more several billion dollars per year

Over production

Off-spec parts

Defective parts

Cloned ICs

Recycled ICs

IC Recycling Process

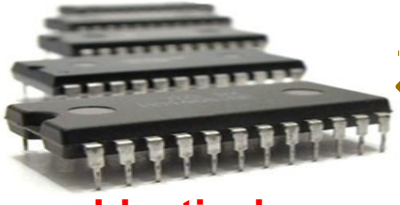
A recycling center

PCBs taken off of electronic systems

ICs taken off of PCBs

Refine recycled ICs

Resold as new



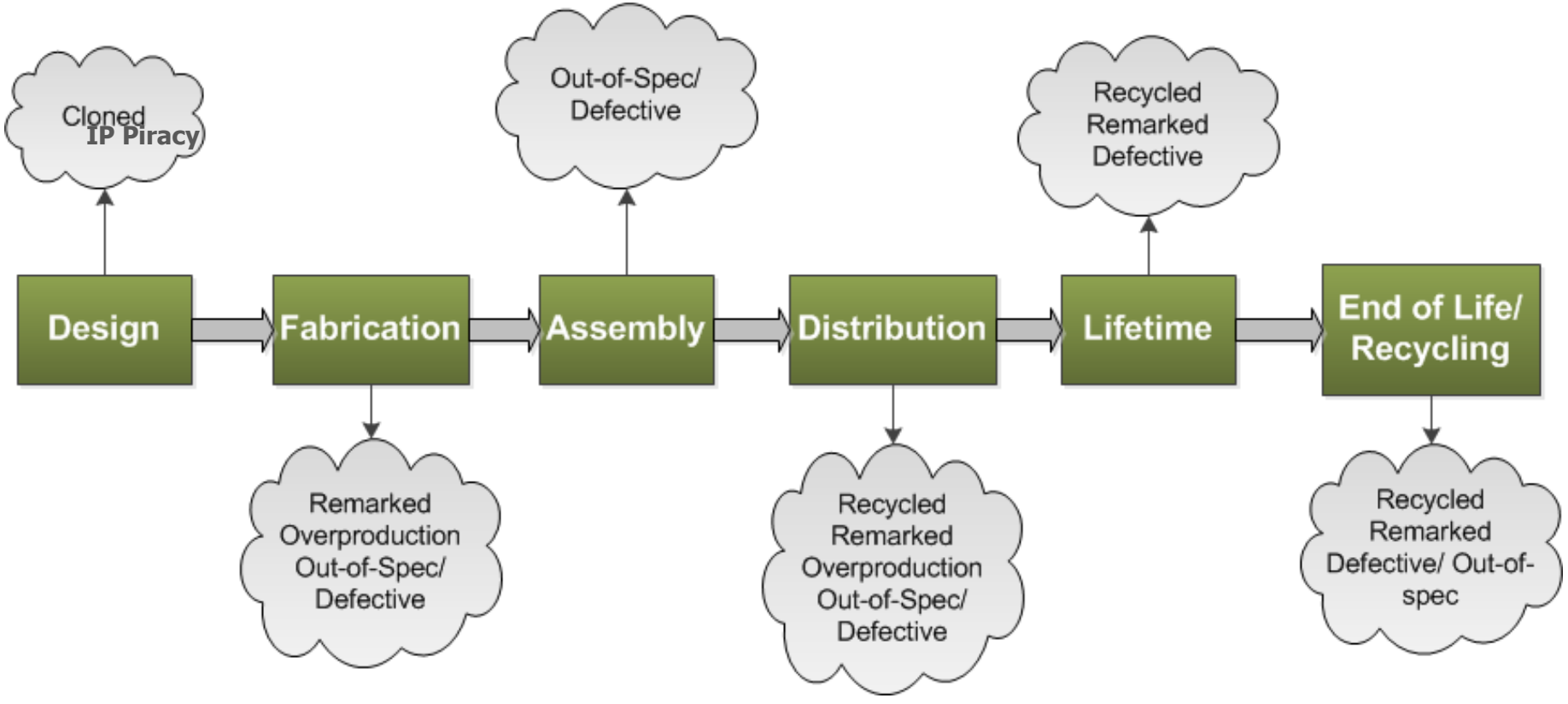
Identical:

Appearance, Function, Specification

Critical Application

Consumer trends suggest that more gadgets are used in much shorter time – more e-waste

Supply Chain Vulnerabilities



Piracy – A True Story…

- In 2000, Chen Jin, finished his Ph.D. in computer engineering at the University of Texas at Austin
- He then returned to China, first to Motorola Research and then to Jiaotong University as a faculty member
- In 2003, he supervised a team that created one of China's first homegrown DSP ICs
- Chen was named one of China's brightest young scientists, funded his own lab, received a huge grant from the government
- In 2006, it was revealed that he faked the chip, having stolen the design from Texas Instruments!

Ref.: “In a Scientists Fall, China Feels Robbed of Glory,” New York Times, May 2006. (link)

Another Story: "The Athens Affair"

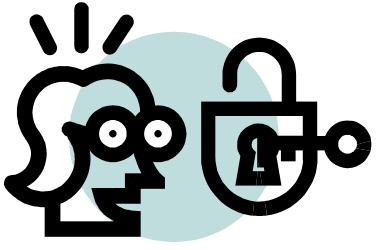
- In March 8, 2005, Costas Tsalikidis, a 38 year old engineer working for Vodafone Greece committed suicide, linked to scandal
- The next day, the prime minister was notified that his cell phone – and those of other high ranking officials – was hacked!
- Earlier, in January, investigators had found rogue software installed on the Vodafone Greece phones by "parties unknown"
- The scheme did not depend on the wireless nature of the devices
- A breach in storing keys in a file – Vodafone was fined €76 million!

Some Basic Definitions

- **Intellectual property** represents the property of your mind or intellect – proprietary knowledge
- The four legally defined forms of IP:
  - **Patents** – register invention with the government, gain legal right to exclude others from manufacturing or marketing it
  - **Trademark** – a name, phrase, sound or symbol used in association with services or products
  - **Copyright** – protections for written or artistic forms of expression fixed in a tangible medium
  - **Trade secrets** – formula, pattern, device or compilation of data that grants user an advantage over competitors

Some Basic Definitions (cont'd)

- **Cryptography**:
  - crypto (secret) + graph (writing)
    – the science of locks and keys
  - The keys and locks are mathematical
  - Behind every security mechanism, there is a “secret” …



  - Locks and keys very useful in security
  - We will discuss more about traditional cryptography, but will also show new forms of security based on HW-based secrets