Design for Safety / Design for the Environment in the Semiconductor Industry

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SESHA Academic Lecture Series
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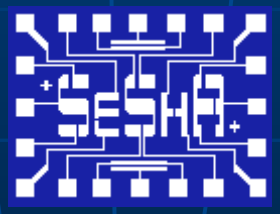


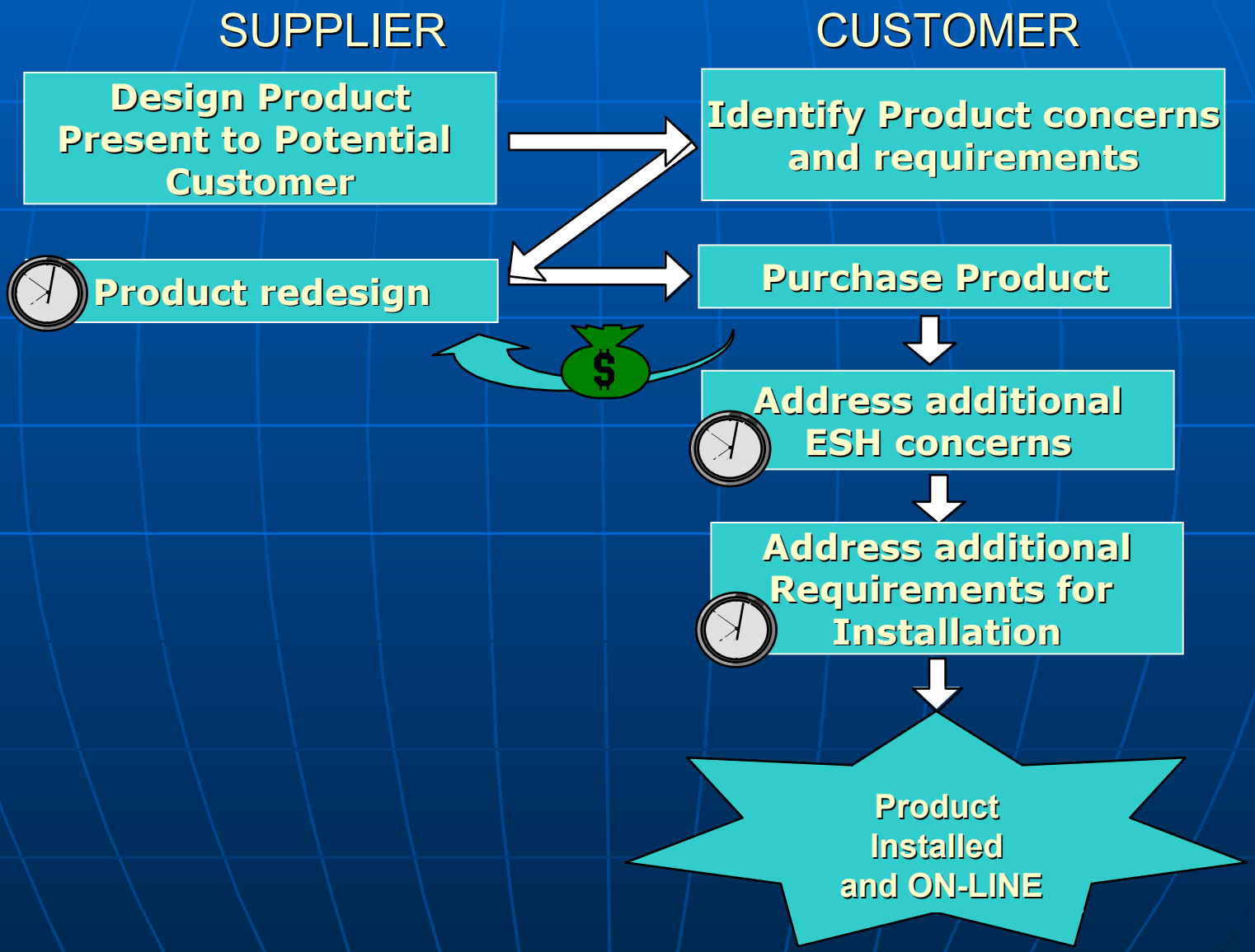
DfS/DfE in the Semiconductor Industry

- What is the concept?
- How is it applied?
  - Semiconductor Manufacturing Equipment Industry
  - Device Manufacturing
- The benefits

DfS/DfE Concept

- A management decision-making process to minimize the life-cycle costs of ESH impacts on business operations, by considering those impacts systematically during the design process
- Comprehensive incorporation of ESH into the overall process

The "Old" Model



The "Ideal" DfS/DfE Model

SUPPLIER

CUSTOMER

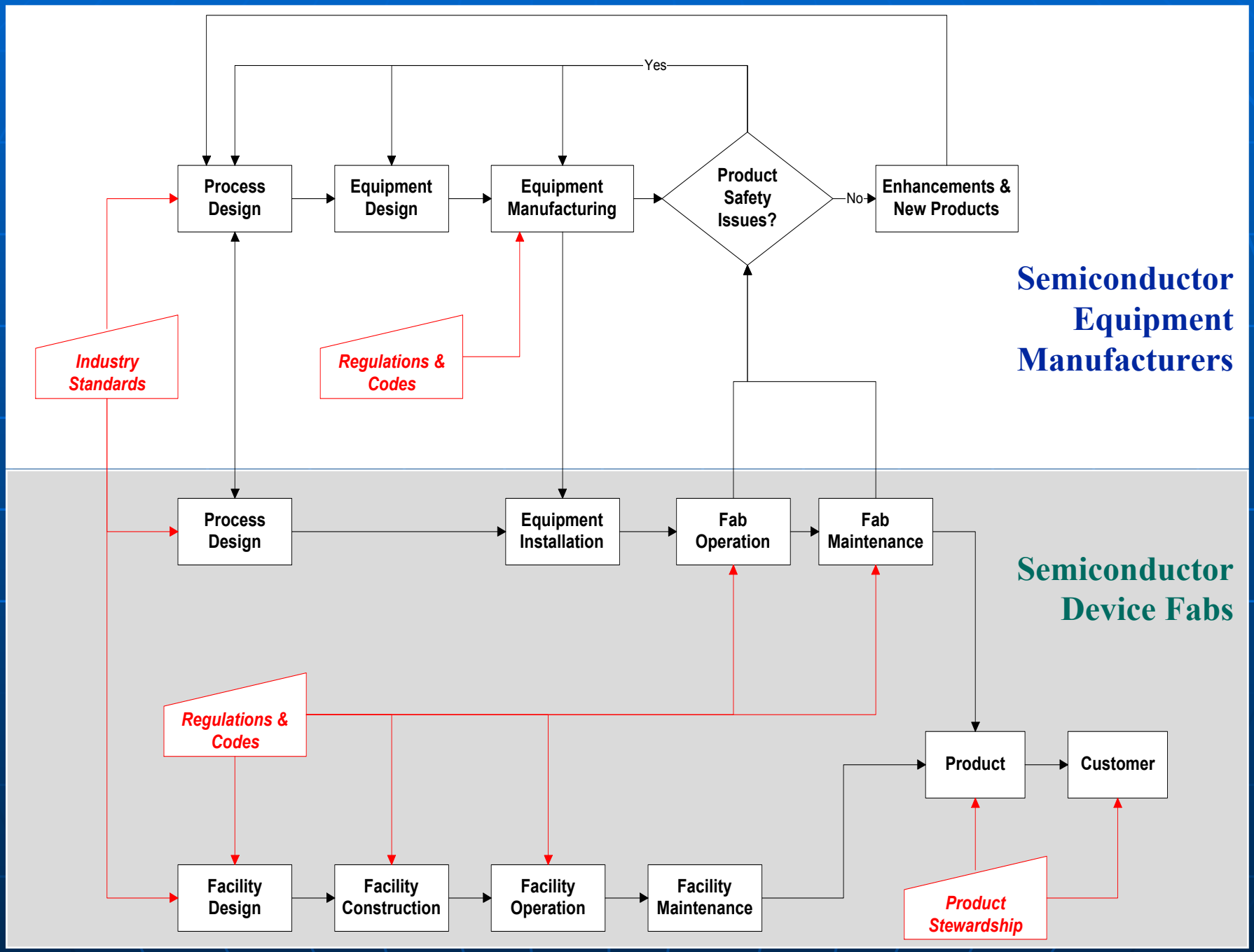
- *Engineering*
- *ESH*
- *Facilities*

Identify Product Concerns and requirements

Design Product, Present to Customer

Purchase Product

Product Installed and ON-LINE


Yes
Process Design
Equipment Design
Equipment Manufacturing
Product Safety Issues?
No
Enhancements & New Products
Industry Standards
Regulations & Codes
Semiconductor Equipment Manufacturers
Process Design
Equipment Installation
Fab Operation
Fab Maintenance
Semiconductor Device Fabs
Regulations & Codes
Product
Customer
Facility Design
Facility Construction
Facility Operation
Facility Maintenance
Product Stewardship

Semi Equipment Manufacturers and Device Maker Interactions

- Needs to be viewed as an integrated process
- Clearly defined responsibilities
  - Suppliers
  - Procurement
  - Process Engineering/Production
  - Facilities
  - ESH
- Clear lines of communication

Industry and Regulatory Drivers

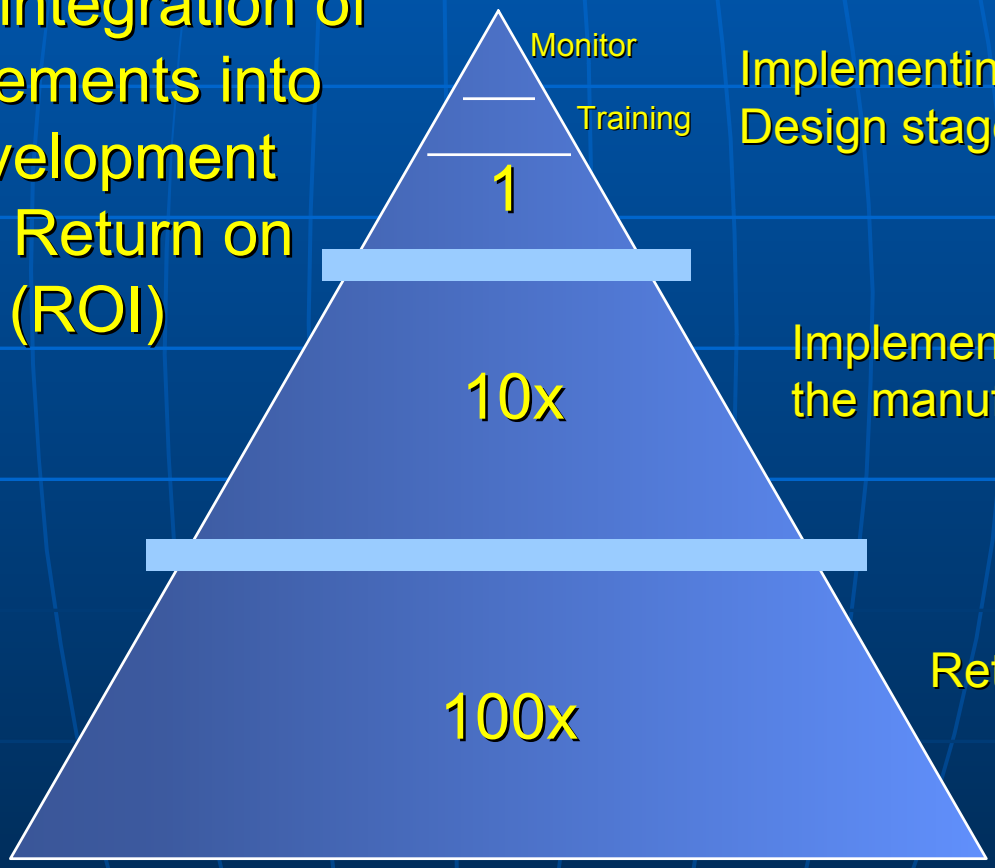
- Industry Standards
  - SEMI Safety Guidelines:
    - SEMI S2 Product Safety Guideline
    - SEMI S8 Ergonomics/Human Factors
    - Other guidelines
- Regulatory Requirements
  - OS&H Regulations
  - Building Codes and Fire Codes (ex: UFC Articles 51 and 80, NFPA 318)
  - European Union / CE (MD, LVD, EMC)

Process Design

- Train process and equipment design engineers in the concepts
  - Integrate into the very earliest stages of design
    - Process Chemistry
    - Resource Conservation
- Cost Benefits of early integration

Return on Investment

- *Timing* for integration of EHS requirements into product development determines Return on Investment (ROI)

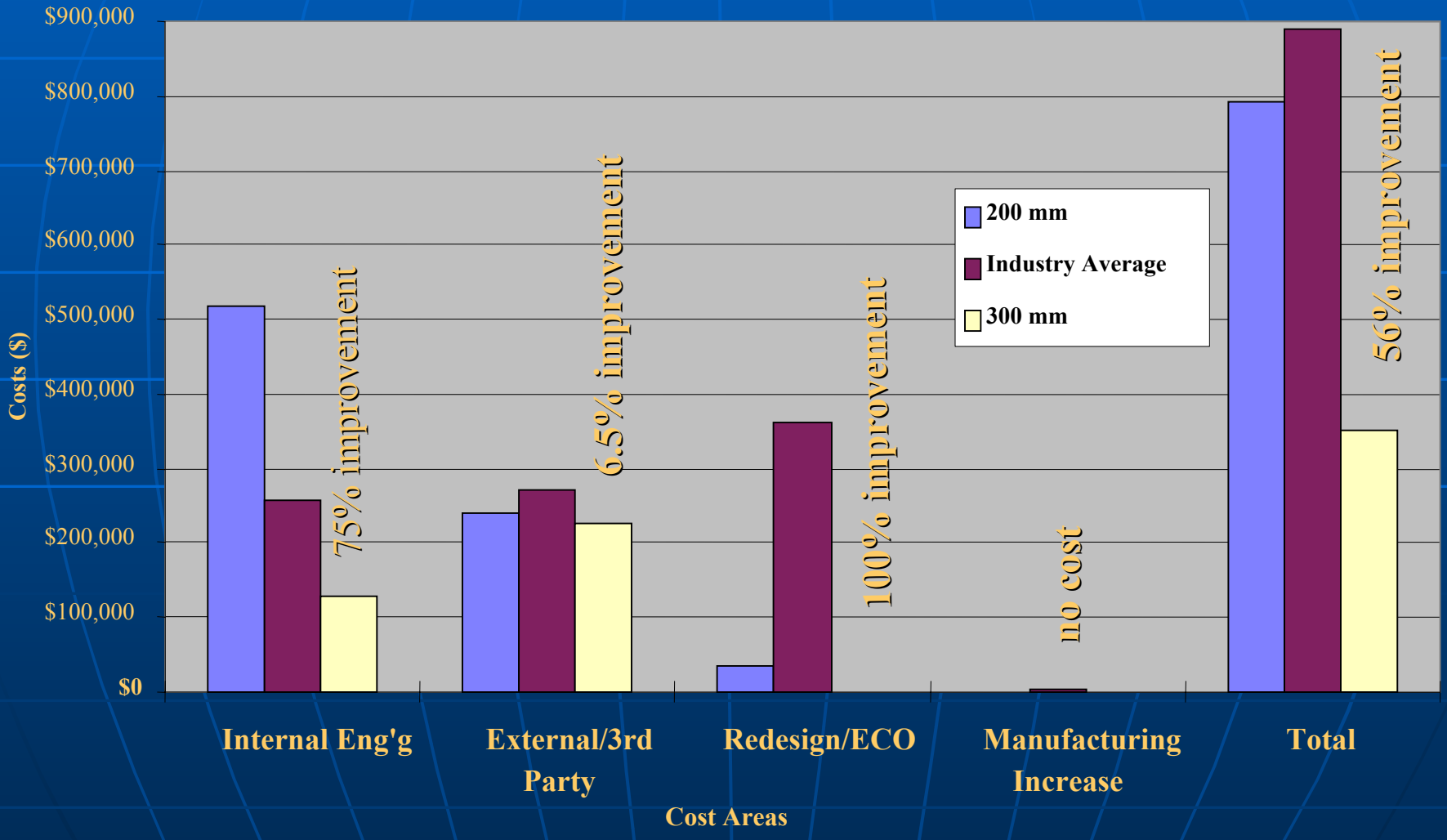


Implementing a solution in Design stage

Implementing a solution in the manufacturing stage

Retrofitting

Cost of SEMI S2 Compliance



ESH Benefits

- FINANCE
  - ROI; Cost-Benefit; impact on growth potential; bank lending; insurance coverage
- SALES/MARKETING
  - Cost of Ownership (COO) for customers, marketing advantage, customer satisfaction, positive PR
- SERVICE
  - Customer Satisfaction, serviceability of products, products designed to facilitate easier and safer accessibility
- LEGAL
  - Liability; compliance
- HUMAN RESOURCES
  - Employee safety, productivity & morale
- ENGINEERING:
  - Time to develop new product

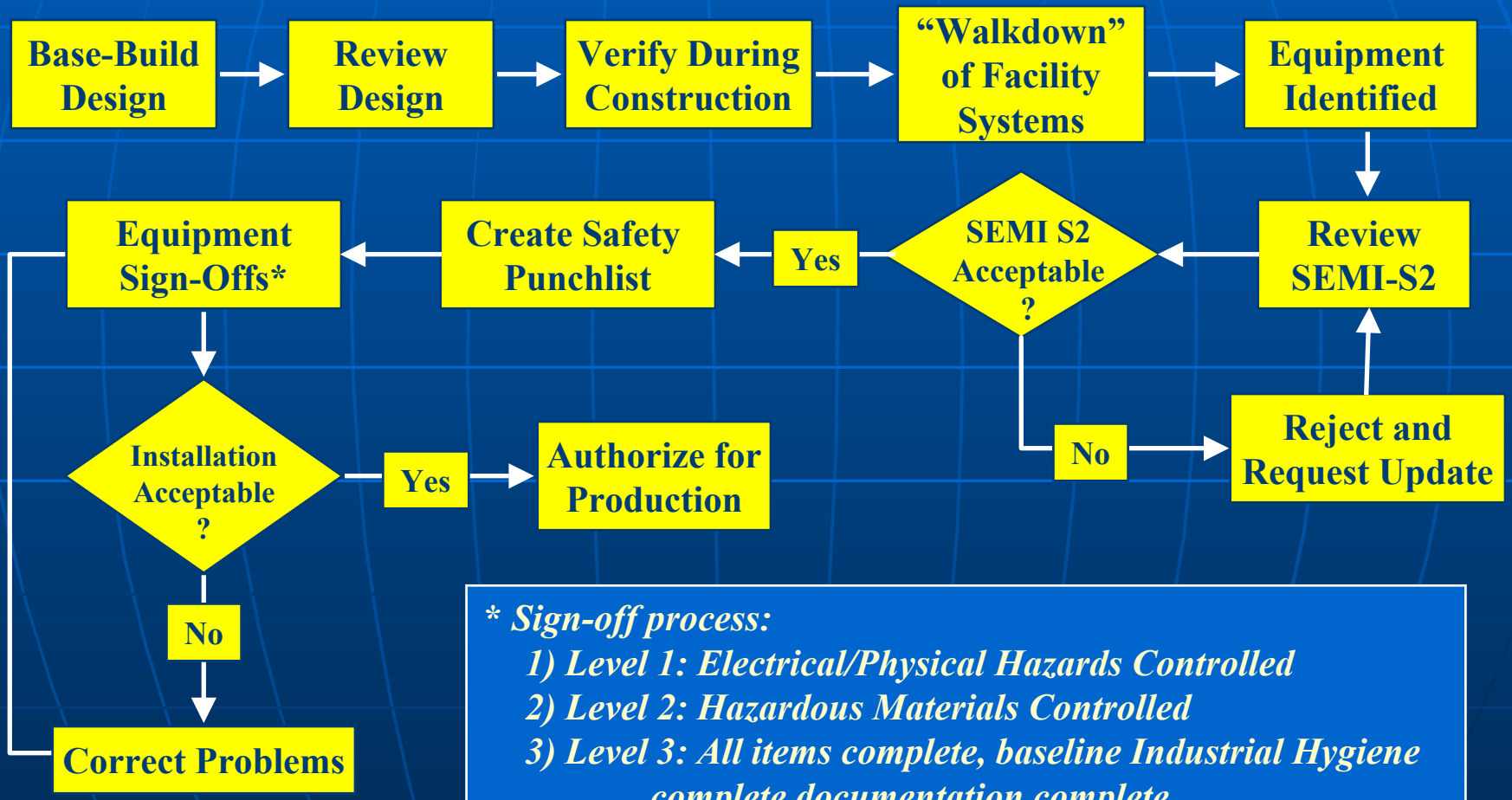
Equipment Design & Manufacture

- Incorporate DfS/DfE Principles in Equipment
  - Materials of Construction
  - Safety Interlocks
- Testing & Certification
  - Internal Programs
  - Use of Third Parties
- Delivery of Equipment and certifications
  - Documentation

Equipment Installation

- Take well-designed equipment and install it in a well-designed and well-operated factory
  - Ensure that all equipment maker safety controls are operational and used during production and maintenance
  - Ensure complete documentation for quality and safety

Facility & Equipment Process



The Benefit of Success

The Success of SEMI S2 & Installation Process

"Potential hazards are to be identified early in the design stage, while it is still easy and cost-effective to correct or eliminate problems."

Source: : Wright, James F., "SEMI S2 - The Semiconductor Industry Takes Safety Matters Into Its Own Hands", *Compliance Engineering*, June 1994, p81-84.

Value of 2 weeks of production: $4M - $40M!!!

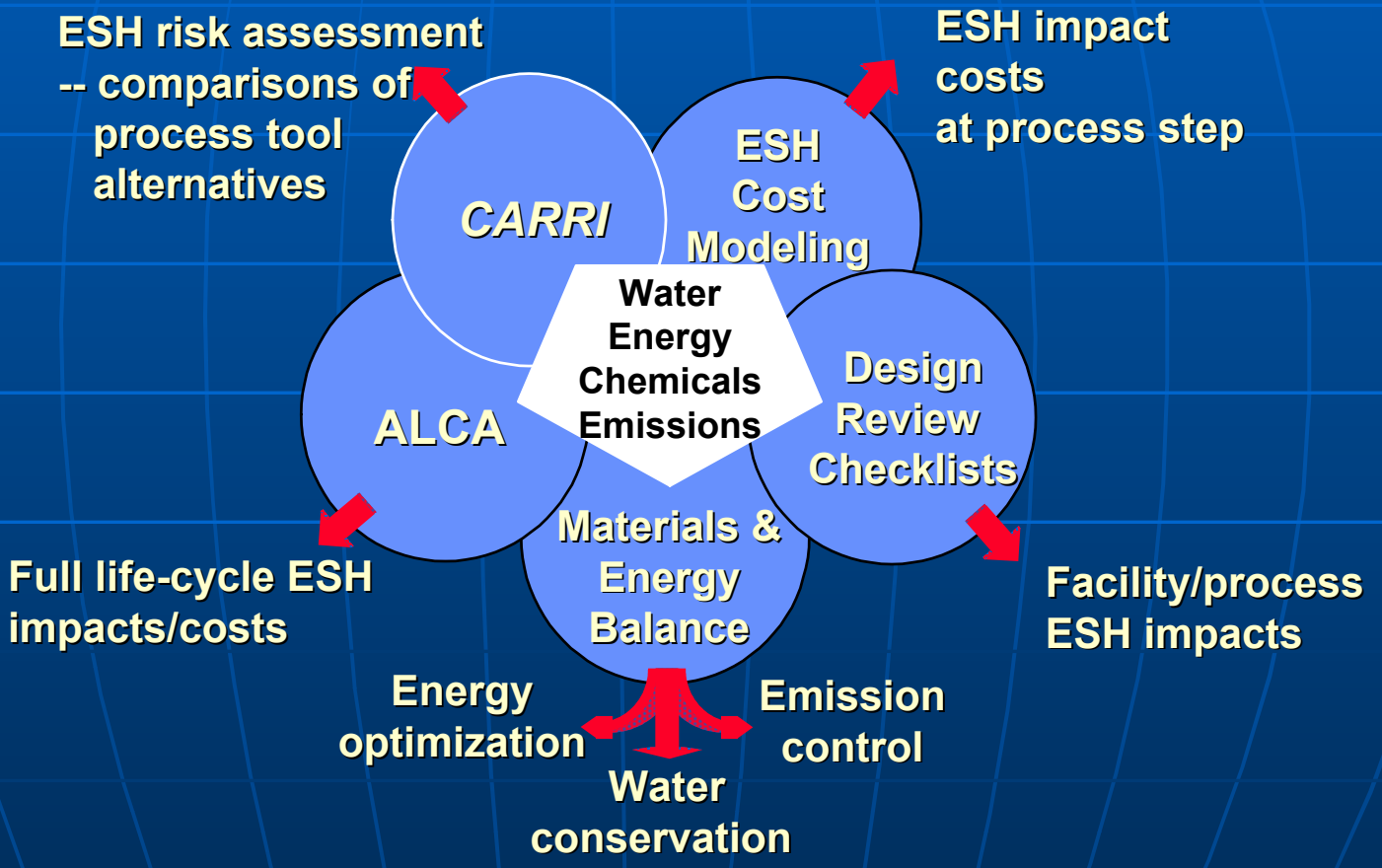
Consequences of Failure

- Cost of New Facilities
  - 200 mm ~US$1.5 Billion
  - 300 mm ~US$2-3.0 Billion
- Cost of Equipment
- Cost of Business Interruption
- Risk to Personnel
  - Short-term
  - Long-term

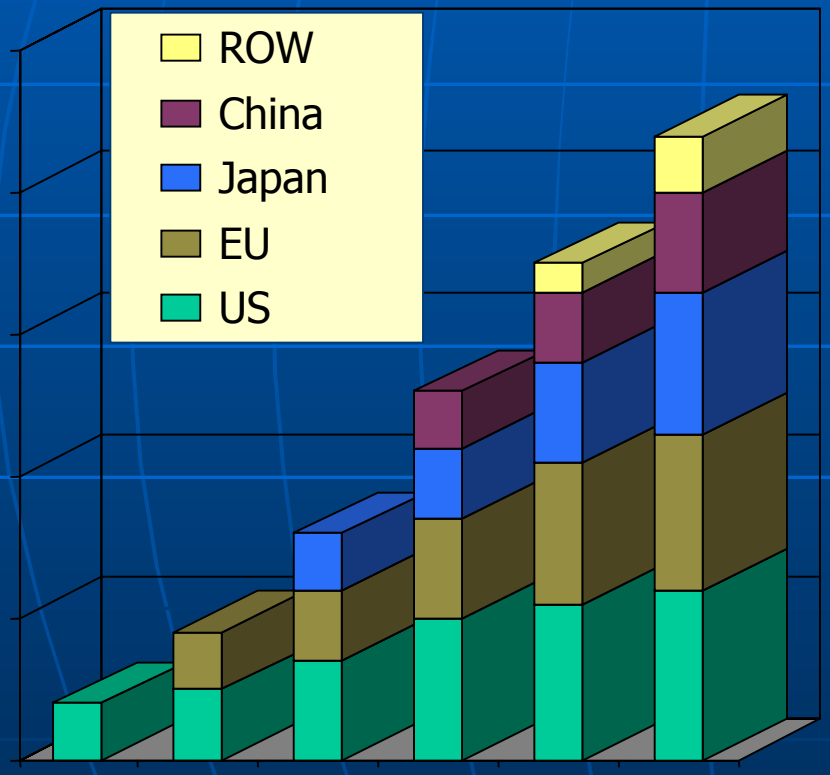
DfE After Production

- Product Stewardship Issues
  - Material Use Restrictions
  - Product Disposal Regulations
  - Product Take-back Requirements
  - Packaging and Eco-labeling

DfS/DfE Design Tools



Increasing Global Restrictions



- Emerging Markets
  - Developing Countries
  - Increasing Regulations
  - Differing Requirements
- Customer Drivers
  - End-user ISO 14001 programs driving suppliers

Resource Conservation: Water

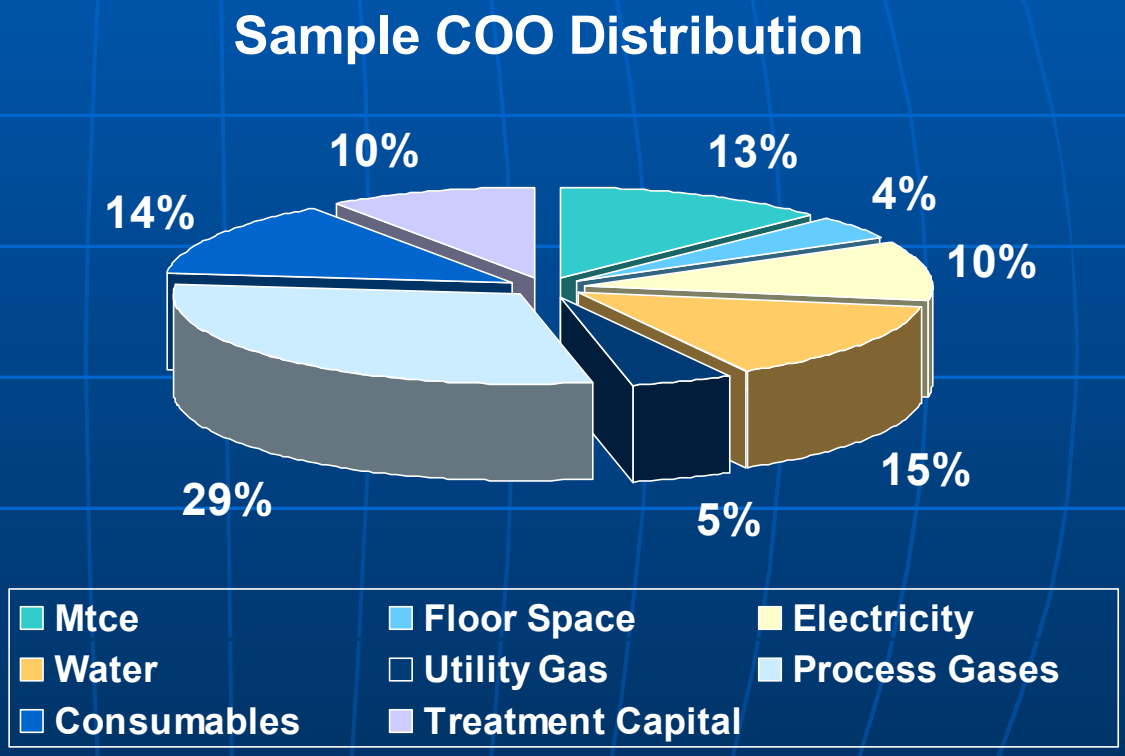
- The average 200 mm fab in 1996 generated 16 million in^2 (~2.5 acres!) of silicon wafers
- Used the **same amount of water as a city of ~26,000 people**
- 300 mm Fab (29M in^2 silicon) is expected to nearly double that usage
- Water costs are expected to be ~$540M per year for all US fabs by 2002

Resource Conservation: Energy

- A typical 200 mm fab uses the same amount of energy as a city of 50,000 people (15-30 Megawatts)
- Energy use has upstream environmental impacts--air pollution, waste production, global warming
- Energy usage is expected to cost US fabs ~$430M per year by 2002 (Source: SEMATECH 1/97 & 10/97)
  - HVAC recirculating fans (including tool exhaust) account for ~50% of fab energy consumption
  - Tools consume ~40% (including UPW, PCW, N2, and vacuum, but not including exhaust)

Cost of Ownership

- The cost of running the equipment can be very expensive.
- $2.5M piece of equipment can cost $500K to install and $300K/yr to run



International Technology Roadmap for Semiconductors

- Chemicals, Materials, and Equipment Management
- Climate Change Mitigation
- Workplace Protection
- Resource Conservation
- ESH Design and Measurement Methods

http://public.itrs.net/

ITRS: Chemicals, Materials, and Equipment Management

- Chemical Data Collection
  - Document and make available environment, safety, & health characteristics of chemicals
- New Chemical Assessment
  - Quality rapid assessment methods to ensure that new chemicals can be used in manufacturing, while protecting human health, safety, and the environment w/o delaying process implementation
- Environment Management
  - Develop effective management systems to address issues related to disposal of equipment, and hazardous and non-hazardous residue from the manufacturing process
- After 2005:
  - Rapid introduction of chemicals and materials into new process requires the understanding of process fundamentals in order to reduce ESH impacts.

ITRS: Climate Change Mitigation

- Reduce Energy Use Of Process Equipment
  - Design energy efficient larger wafer size processing equipment
- Reduce Energy Use Of The Manufacturing Facility
  - Need to design energy efficient facilities to offset the increasing energy requirements of higher class clean rooms
- Reduce High Global Warming Potential (GWP) Chemicals Emission
  - Need ongoing improvement in methods that will result in emissions reduction from GWP chemicals
- After 2005:
  - Reduce Energy Use: The importance of reducing energy use for climate change will grow.
  - Reduce High GWP Chemicals Emissions: No known alternatives and international regulatory pressure to reduce emissions of GWP chemicals.

ITRS: Workplace Protection

- Equipment Safety
  - Need to design ergonomically correct and safe equipment.
- Chemical Exposure Protection
  - Increase knowledge base on health and safety characteristics of chemicals and materials used in the manufacturing and maintenance processes, and of the process byproducts; and implement safeguards to protect the users of the equipment and facility.
- After 2005:
  - Equipment Safety: Need ergonomic principles integrated into the processing and wafer moving equipment for both operation and maintenance aspects, and into the overall manufacturing facility.

ITRS: Resource Conservation

- Reduce Water, Chemicals And Materials Use
  - Requirements for large amounts of water, chemicals, and materials limit sustainable growth.
- Waste Recycle
  - Increase in resource use as the result of increasing process complexity will require that efficient waste recycling methods be developed
- After 2005:
  - Reduce Water, Energy, Chemicals And Materials Use: Need resource efficient processing and facility support equipment and improved water reclaim and recycling methods. Emphasis on resource sustainability will grow.

ITRS: ESH Design & Measurement Methods

- Evaluate and Quantify ESH Impact
  - Need integrated way to evaluate and quantify ESH impact of process, chemicals, and process equipment, and to make ESH a design parameter in development procedures for new equipment and processes.
- After 2005:
  - Evaluate and Quantify ESH Impact: Need integrated ESH design in development of new equipment and processes.

Conclusion

- Purely "compliance model" will only bring companies up to a minimum level that will NOT provide economic advantage
- DFS/DfE model provides companies with competitive advantages

Driving Force

Increase market share

Maintain market access

"Competition in the world marketplace is relentless.

Those who can get the highest quality, price-competitive product to market in the least time are going to be winners."

Customer satisfaction

Decrease cost of ownership

Minimize time to market

Quote from: Carter, D. and B. Baker. 1992. *Concurrent Engineering, The Product Development Environment for the 1990s.* Addison-Welsley Publishing.