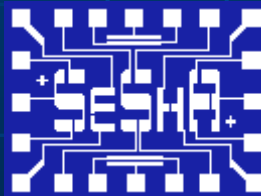


Design for Safety / Design for the Environment in the Semiconductor Industry

Brian Sherin, CSP
co-Founder, EORM / President, ESHconnect

Jen Jeng
Associate EHS Consultant, EORM

SESHA Academic Lecture Series
October 2001



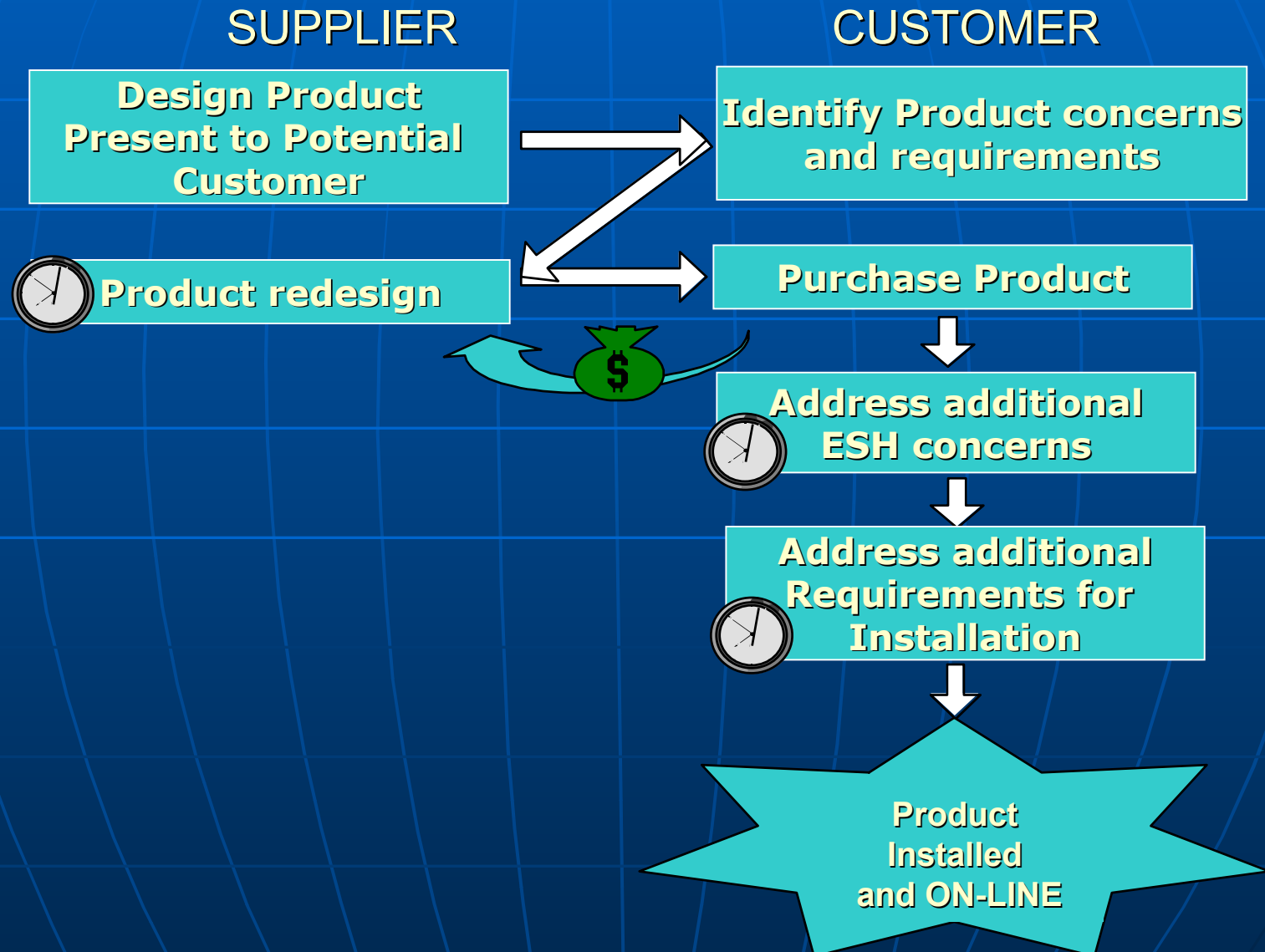
DfS/DfE in the Semiconductor Industry

- 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

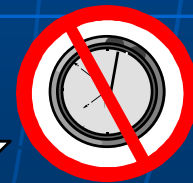
- *Engineering*
- *ESH*
- *Facilities*

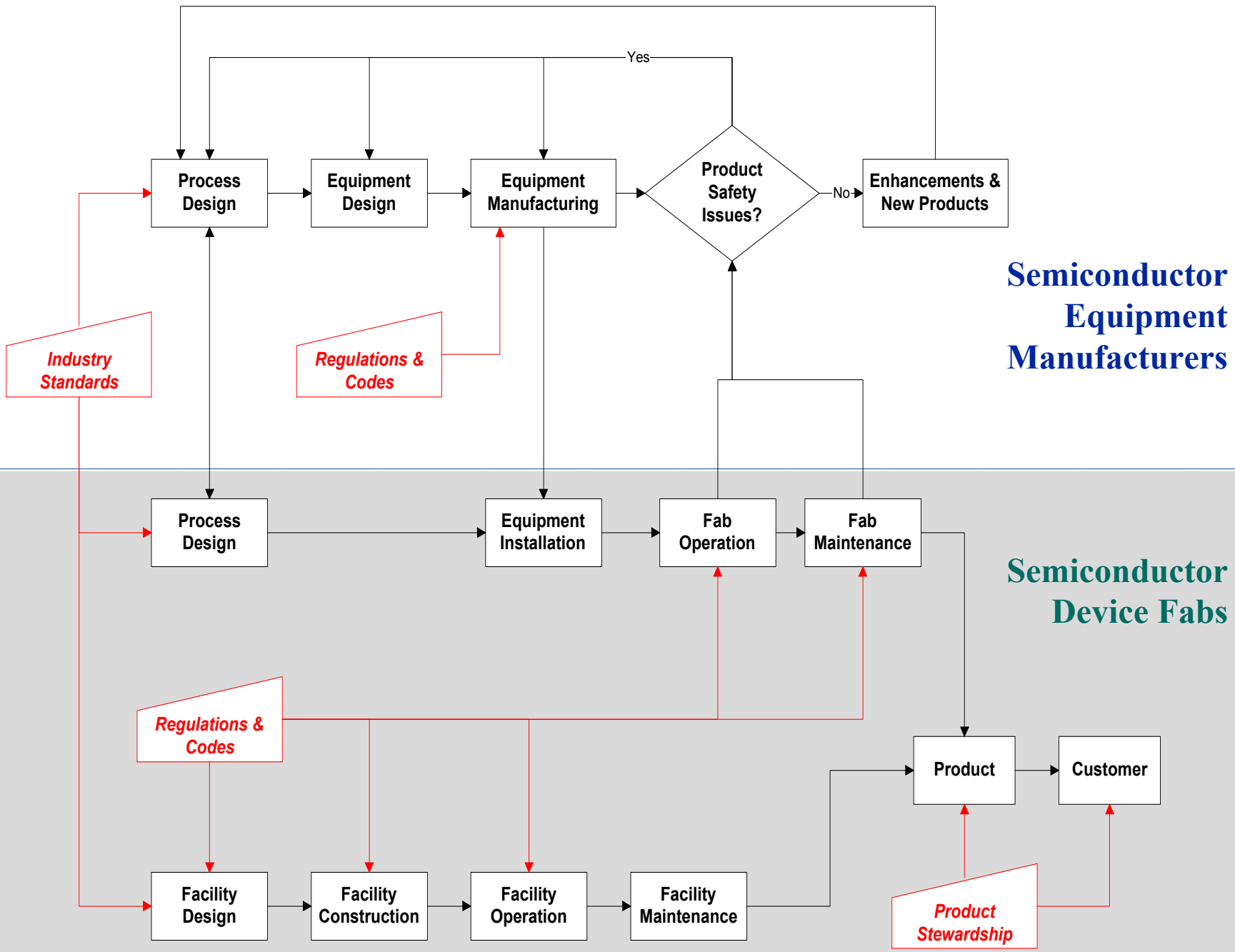
**Identify Product Concerns
and requirements**

**Design Product,
Present to Customer**

Purchase Product

**Product
Installed
and ON-LINE**





Semiconductor Equipment Manufacturers

Semiconductor Device Fabs

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

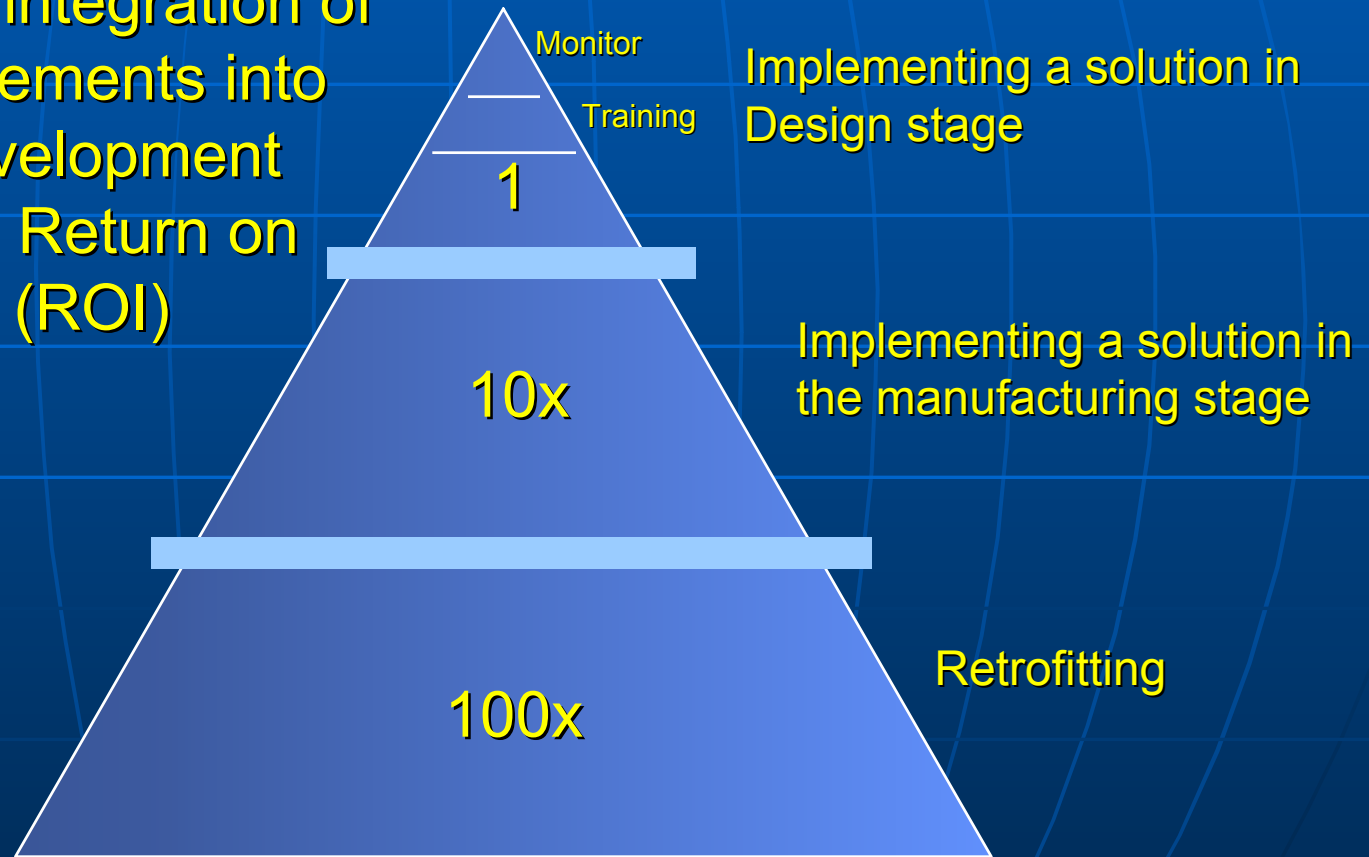
- Industry Standards
 - SEMI Safety Guidelines:
 - SEMI S2 Product Safety Guideline
 - SEMI S8 Ergonomics/Human Factors
 - Other guidelines
- Regulatory Requirements
 - OS&H Regulations
 - Building Codes and Fire Codes (ex: UFC Articles 51 and 80, NFPA 318)
 - European Union / CE (MD, LVD, EMC)

Process Design

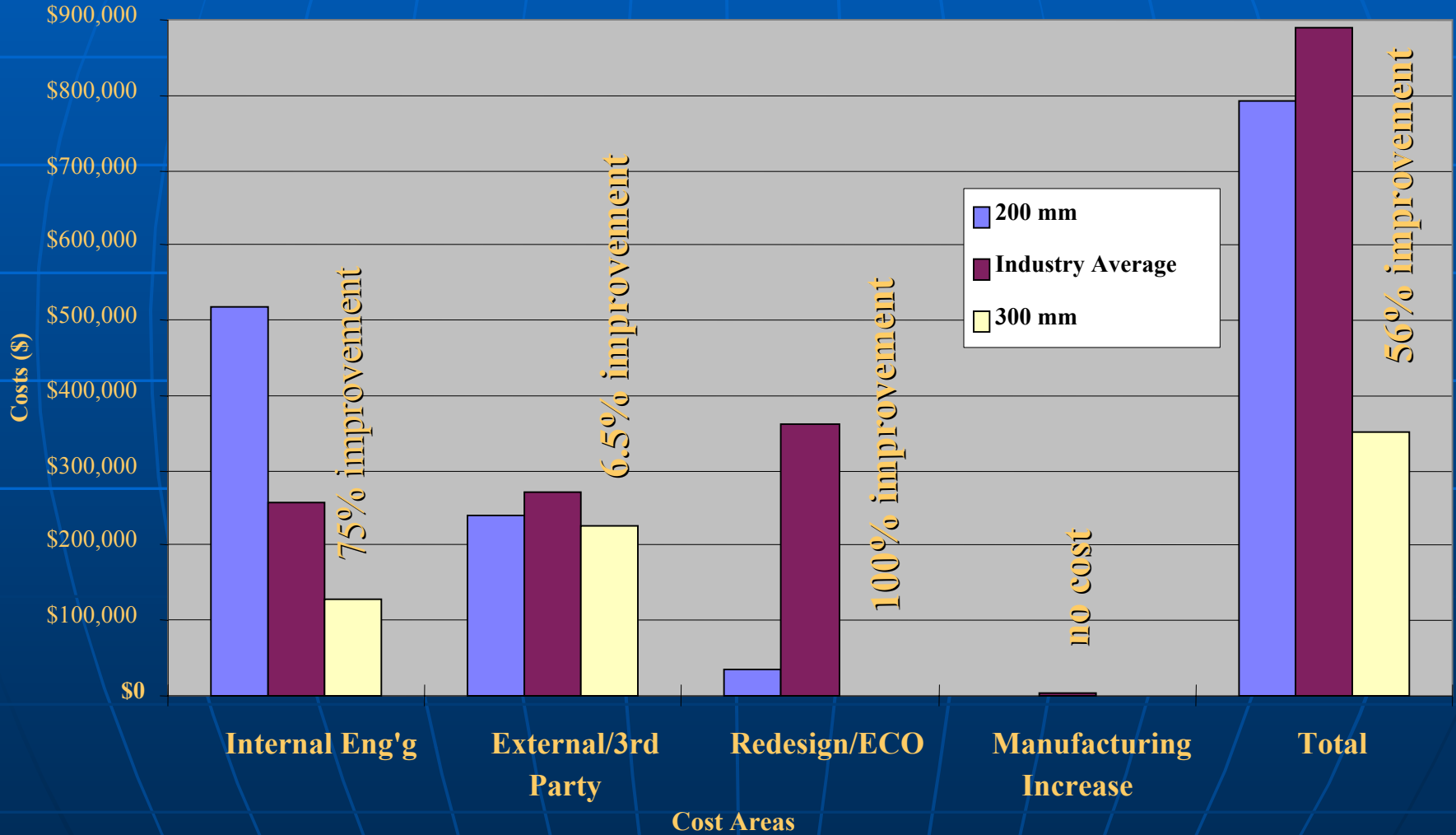
- Train process and equipment design engineers in the concepts
 - Integrate into the very earliest stages of design
 - Process Chemistry
 - Resource Conservation
- Cost Benefits of early integration

Return on Investment

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



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

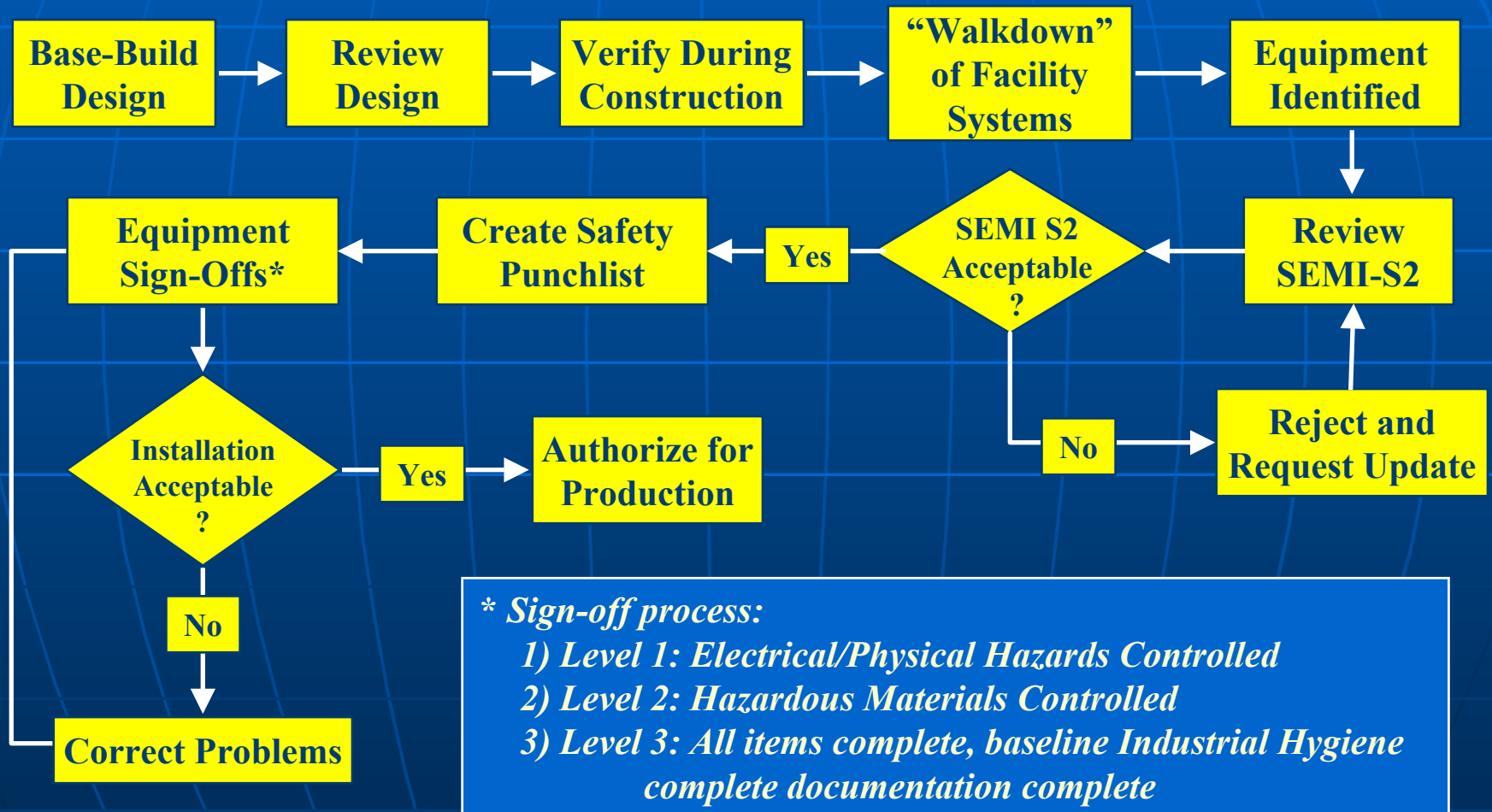
Equipment Design & Manufacture

- 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!!!

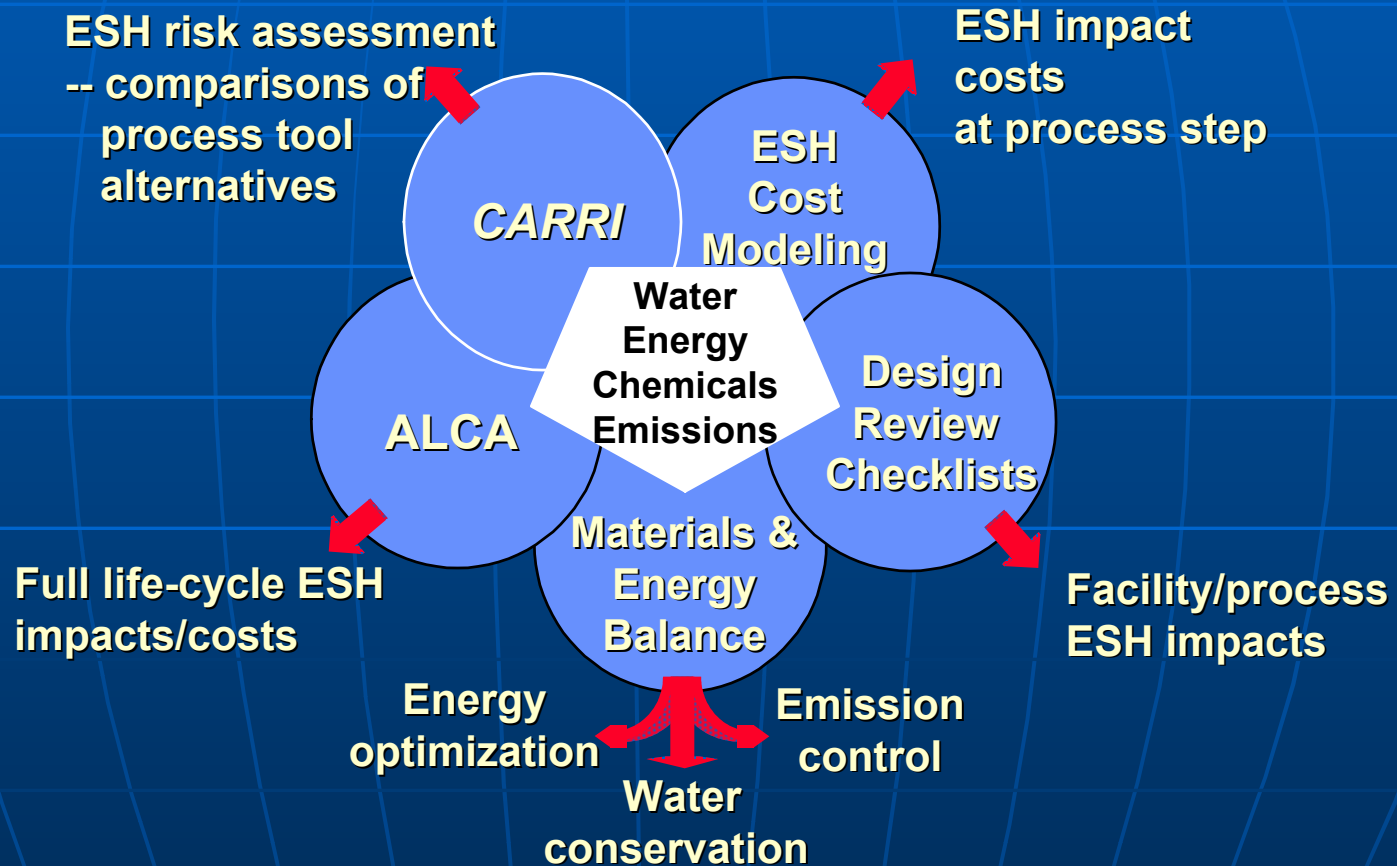
Consequences of Failure

- 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

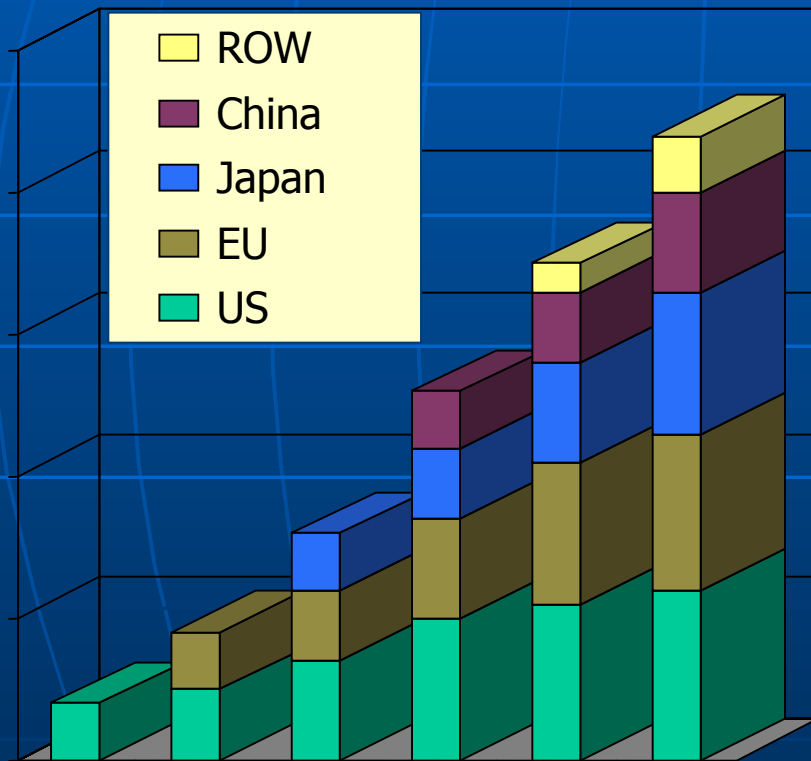
DfE After Production

- 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 in² (~2.5 acres!) of silicon wafers
- Used the **same amount of water as a city of ~26,000 people**
- 300 mm Fab (29M in² silicon) is expected to nearly double that usage
- Water costs are expected to be ~\$540M per year for all US fabs by 2002

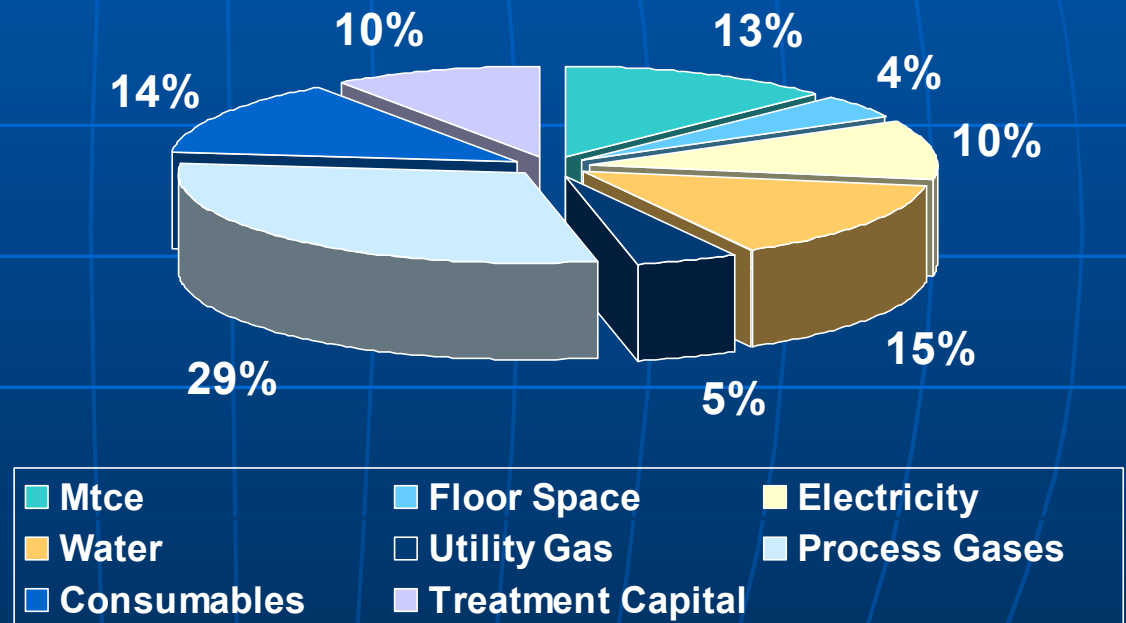
Resource Conservation: Energy

- 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

Sample COO Distribution



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-Wesley Publishing.