2.008 Design & Manufacturing II

Spring 2002

Systems Design

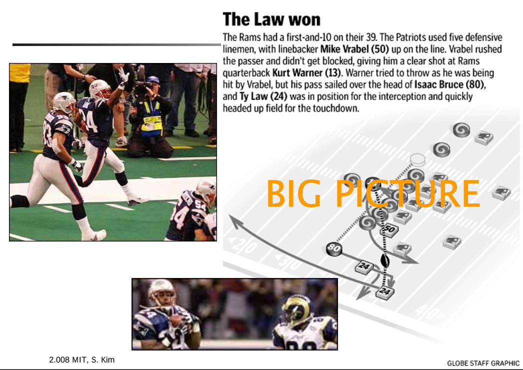
1

- HW#1 due today.
- No HW today.
- Reading, Kalpakjian, P177-199
- Monday 2/16, Holiday
- Tuesday 2/17, Monday's lecture & lab group A
- Wednesday 2/18, Yo-Yo case study

2

Image removed due to copyright considerations.

Super bowl 2002



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Systems Design

- Is Pats a good team?
- Is MIT a good school?
- Am I a good teacher?

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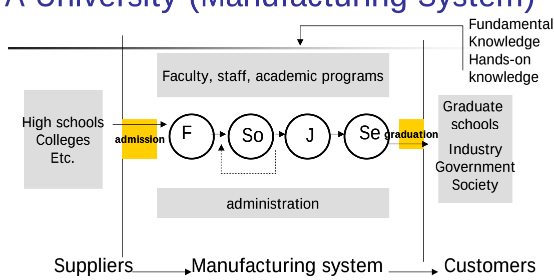
A University (Manufacturing System)



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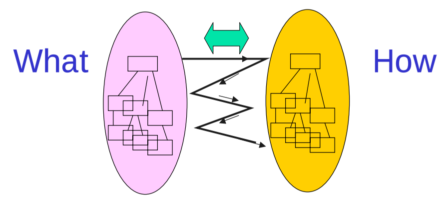
Good Design

- lecture room ?
- Boston T ?
- Logan Airport ?
- Honda Civic ?
- Government ?

Design Domains

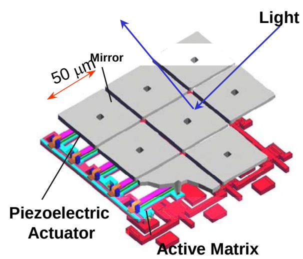
"What" to "How", "Top" to "Bottom"



No impromptu designs!!

Case study

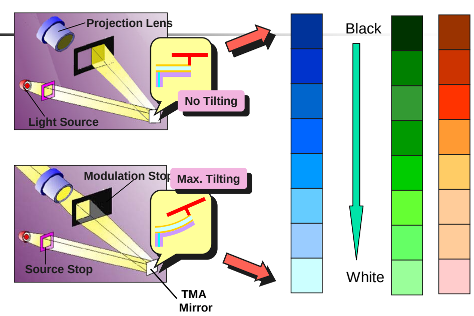
TMA(thinfilm micromirror array)



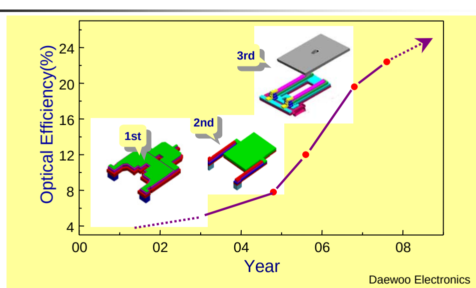
Mirror Array on Piezoelectric Actuator Array

Daewoo Electronics

TMA

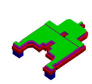


Evolution of TMA Pixels



Functional Requirements of TMA

1st Generation



FR1= light reflection
FR2= mirror tilting

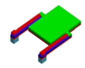
DP1= cantilever top surface
DP2= PZT sandwich

$$\begin{Bmatrix} FR1 \\ FR2 \end{Bmatrix} = \begin{bmatrix} X & X \\ X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \end{Bmatrix}$$

Image by 1st Gen. TMA –96' 12

Functional Requirements of TMA

2nd Generation



FR1= light reflection
FR2= mirror tilting

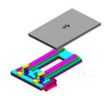
DP1= cantilever top surface
DP2= PZT sandwich

$$\begin{Bmatrix} FR1 \\ FR2 \end{Bmatrix} = \begin{bmatrix} X & O \\ X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \end{Bmatrix}$$

by the 2nd Gen. TFAMA - 1997.07

Functional Requirements of TMA

3rd Generation

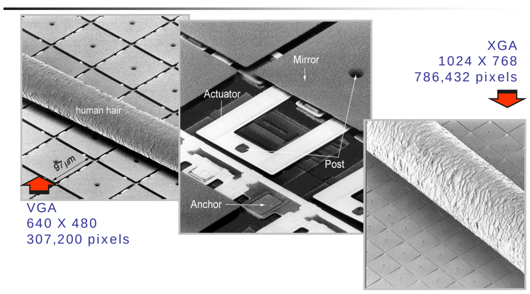


FR1= light reflection
FR2= mirror tilting

DP1= cantilever top surface
DP2= PZT sandwich

$$\begin{Bmatrix} FR1 \\ FR2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \end{Bmatrix}$$

TMA

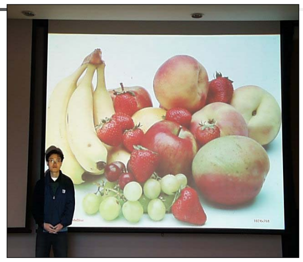


VGA
640 X 480
307,200 pixels

XGA
1024 X 768
786,432 pixels

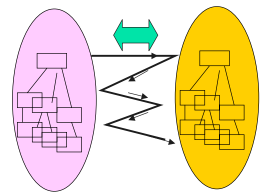
Image by the 3rd Gen. TMA - 1997.12

XGA Image, Nov. 1999



Good Design in small scale products?

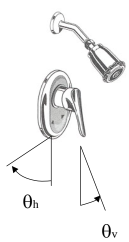
"What" to "How", "Top" to "Bottom"



Design Axioms

Example: Shower Faucet

Functional Requirements
- Temperature
- Flow rate



Independence Axiom

- Maintain the independence of FRs.
  - Shower faucet example

FR1= Temperature
FR2= Flow rate

DP1= Hot water
DP2= Cold Water

$$\begin{Bmatrix} FR1 \\ FR2 \end{Bmatrix} = \begin{bmatrix} X & X \\ X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \end{Bmatrix}$$

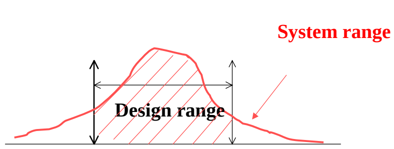
FR1= Temperature
FR2= Flow rate

DP1= Horizontal Angle
DP2= Vertical Angle

$$\begin{Bmatrix} FR1 \\ FR2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \end{Bmatrix}$$

Information Axiom

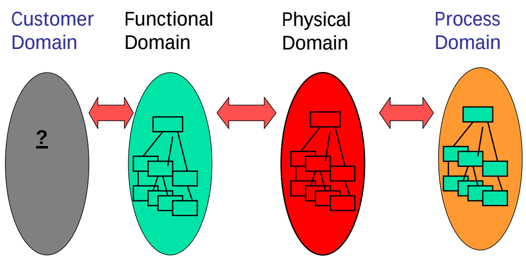
- Minimize the information content of the design



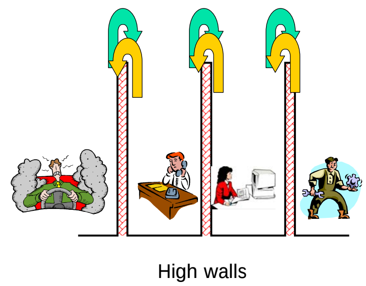
Functional Requirements

- Al Cans
- 12 FRs

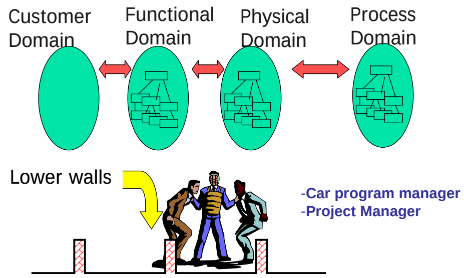
Systems View–
Four Design Domains



Isolated domains



Concurrent Engineering



Four domains

Manufacturing systems	CA	FR	DP	PV
Maretials	Performances	Properties	Micro-structure	Processes
Software	Attributes desired	Output of programs	Input variables	Subroutines
Business	ROI	Business goals	Business structure	Resources
Organization	Customer satisfaction	Functions	Programs offices	People resources

Systems Design

- Customer Satisfaction
- Concurrent Design
- Design for Manufacturing, Assembly and "X"
- Quality Control, Six Sigma
- House of Quality, Takuchi method
- Axiomatic Design

- Any of these efforts in MEMS/Nano?

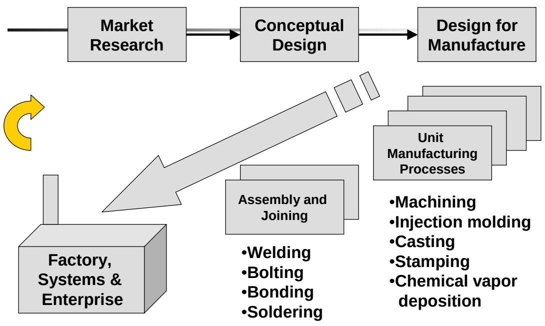
Principles of Design

Axioms

Does scale matter?

- Multi-scale Systems design, 2.76
  - Culpepper & Kim, Fall 2004
- Axiomatic Design, 2.882
  1. N.P. Suh, *Principles of Design*, Oxford, 1990
  2. N. P. Suh, *Axiomatic Design: Advances and Applications,* Oxford, 2001
  3. N. P. Suh, *Complexity: Theory and Applications*, Oxford, 2004

Manufacturing



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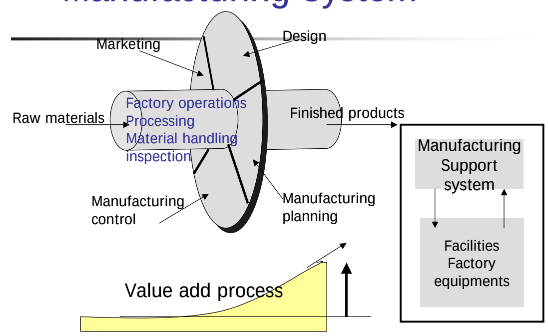
Manufacturing System



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Manufacturing

Transformation of materials and information into goods for the satisfaction of human needs

Big Picture ?

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History

1. Greek "manu factus": made by hand
2. Early mode: piece by piece by skilled artisan
3. In 1750 - 1800: Industrial revolution
   - Early machine tool
   - Concept of factory

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History (cont)

4. 1800's Process specialization
   - Division of labor
   - Eli Whitney, etc., Interchangeable parts
5. Early 1900: Optimization (Manufacturing systems)
   - F.W. Taylor
   - Economy of scale
   - Cost reduction for high volume production
   - Henry Ford's Model T
6. 1950's: Numerical control (Information technology)
   - Automation
   - Lean manufacturing, JIT
   - 6 sigma, ppm

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Post-Industrial-Revolution History of Manufacturing Technologies

- The Industrial Revolution (1770-1830): Introduction of steam power to replace waterpower and animal-muscle power.
- Decline in yearly hours worked per person: From 3000 hours to 1500 hours in Europe and to 1600 hours in North America.
- Increase in labor productivity.
- Increase in GDP per worker: 7 fold in U.S.A., 10 fold in Germany, and 20 fold in Japan.

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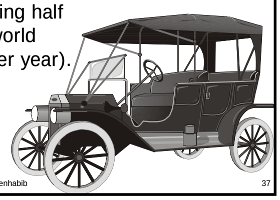
Automotive Manufacturing Industry

- The Ford Motor Co. has been the most studied and documented car manufacturing enterprise.
- The 1909 Model T car was easy to operate and maintain.
- By 1920, Ford was building half the cars in the world (more than 500K per year).



Automotive Manufacturing Industry (cont.)

Table. Motor vehicle production numbers per year per country (in thous.)

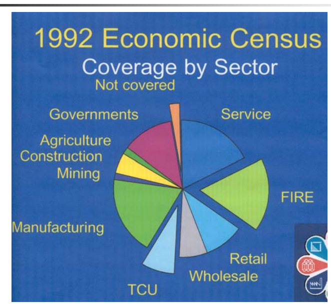
	1899	**1905**	1910	1925	**1950**	1968	1993	**1999**
U.S.A.	3	**23**	187	4,265	**8,005**	10,206	10,864	**13,024**
Canada				161	**388**	1,353	2,237	**3,056**
France	2	**20**	38	177	**357**	2,459	3,155	**3,032**
Germany	1	**4**	13	55	**304**	3,739	3,990	**5,687**
Italy	N/A	**1**	5	40	**127**	1,592	1,267	**1,701**
Japan				N/A	**32**	4,674	11,227	**9,905**
S. Korea						45	2,050	**2,832**
U.K.	1.6	**3**	14	176	**785**	2,183	1,569	**1,972**
World	N/A	**55**	256	4,800	**10,577**	29,745	46,856	**54,947**

Manufacturing Industry

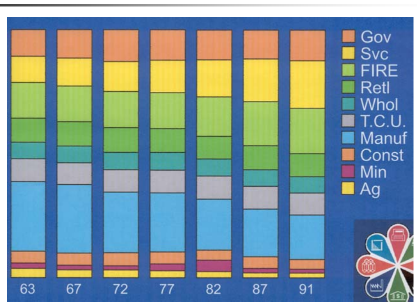
- $4 Trillion, shipments, 1997
  - 1997 Economic Census, U.S. Census Bureau
  - Whole Sale $4 T, Retail $2.5 T
- 459 SIC industries (NAICS)

http://libraries.mit.edu/subjects/course.html

Gross State Product



US Gross State Product, 1992



Big Picture

- Information Technology (digital)
- Globalization
- New Manufacturing Technology
- New Materials

Key Issues

- Engineering disciplines
  - Materials
  - Manufacturing processes
  - Manufacturing equipment
  - Design for manufacturing (DFM)
- Management disciplines
  - Work force
  - Societal obligation
  - For-profit organization
  - 2.96
- Integration
  - Manufacturing systems

Processes of 2.008

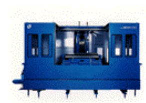
Metal components	Removal	Milling, turning, drilling
	Squeezing	Forging, stamping
	Melting	Casting
Plastic components	Injection molding	
	Thermo forming	
Joining processes	Welding	
	Soldering/brazing	
	Gluing	
Silicon	Deposition	CVD, PVD
	Etching	Wet, dry

Manufacturing Attributes for Decision Making

- Cost
- Rate
- Quality
- Flexibility

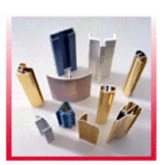
Material removal –the oldest

- Cost:
  - Expensive $100 - $10,000
- Quality:
  - Very high
- Flexibility:
  - Any shape under the sun
- Rate:
  - Slow




Metal squeezing

- Cost:
  - Cheap, $0.1 - $100
- Quality:
  - reasonable
- Flexibility:
  - Shapes limited constant cross-section
- Rate:
  - Fast (cycle time in sec), high volume

Melting

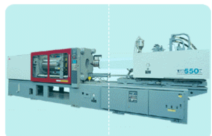
- Cost:
  - Expensive $100 - $10,000
- Quality:
  - Requires post finishing
  - Die casting
- Flexibility:
  - Very flexible, good for large parts
- Rate:
  - Very slow


16V engine block


Machine tool surface plate, gray iron 14,500 lbs

Plastics processing

- Cost:
  - Expensive mold and die, over $10,000
- Quality:
  - Very high
- Flexibility:
  - Opening for ejection
- Rate:
  - Very fast

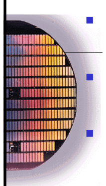


Joining

- Cost:
  - Cheap, but expensive labor
- Quality:
  - Wide range
- Flexibility:
  - Manual vs automated
- Rate:
  - Slow in general

Very Large Crude Carrier (VLCC)

Thinfilm fabrication

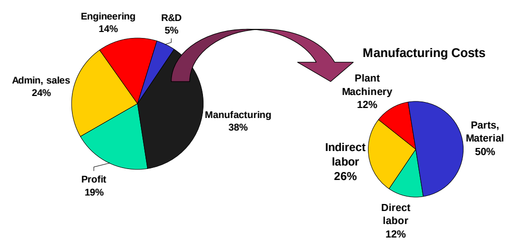


- Cost:
  - Very expensive $Millions
- Quality:
  - Very high
- Flexibility:
  - Any shape in 2-D
- Rate:
  - Slow

300mm dual stage lithography system capable of 110nm resolution

Typical Cost Breakdown

Selling Price



Performance Measures

- Capital cost
- Production rate or capacity
- Cycle time
- Lead time
- Machine utilization
- Work-in-process
- On-time deliveries