Week 13, November 30

Electronics Product Manufacturing & Software for DFM

Fall 2017

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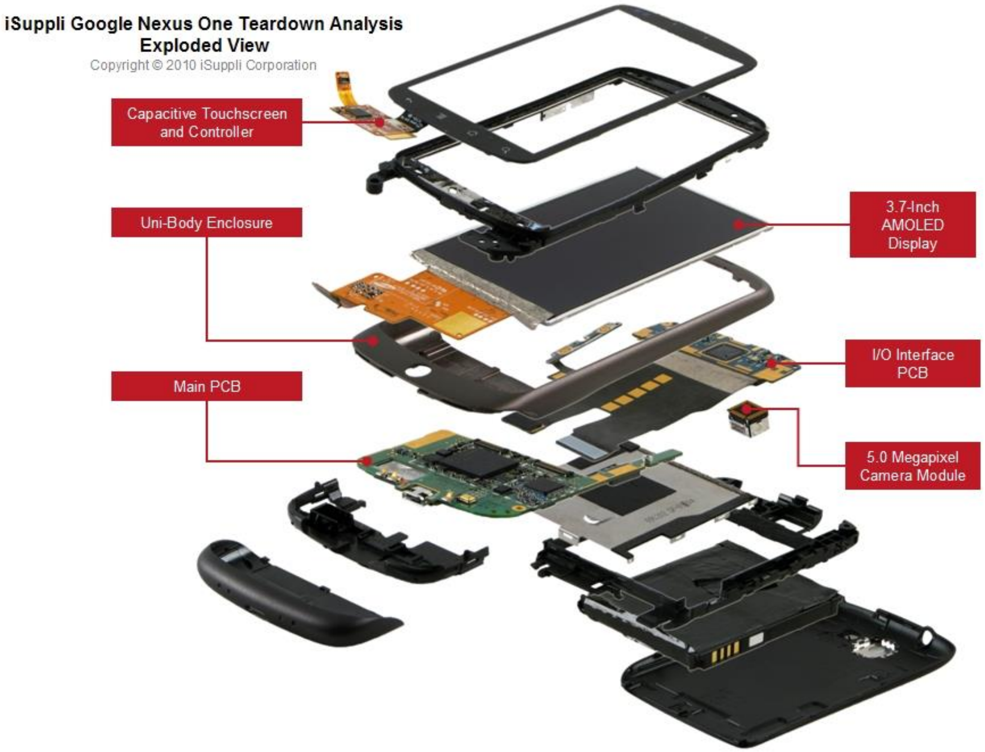
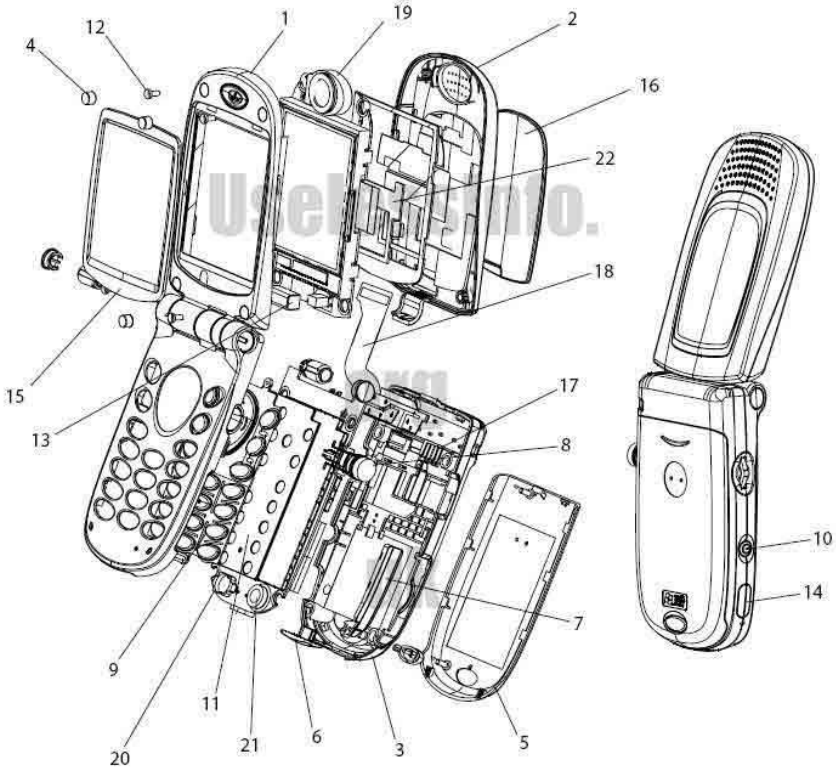
Department of Mechanical and Aerospace Engineering
Seoul National University

Electronics personal products

<Camera> <LCD display>

Cell Phone

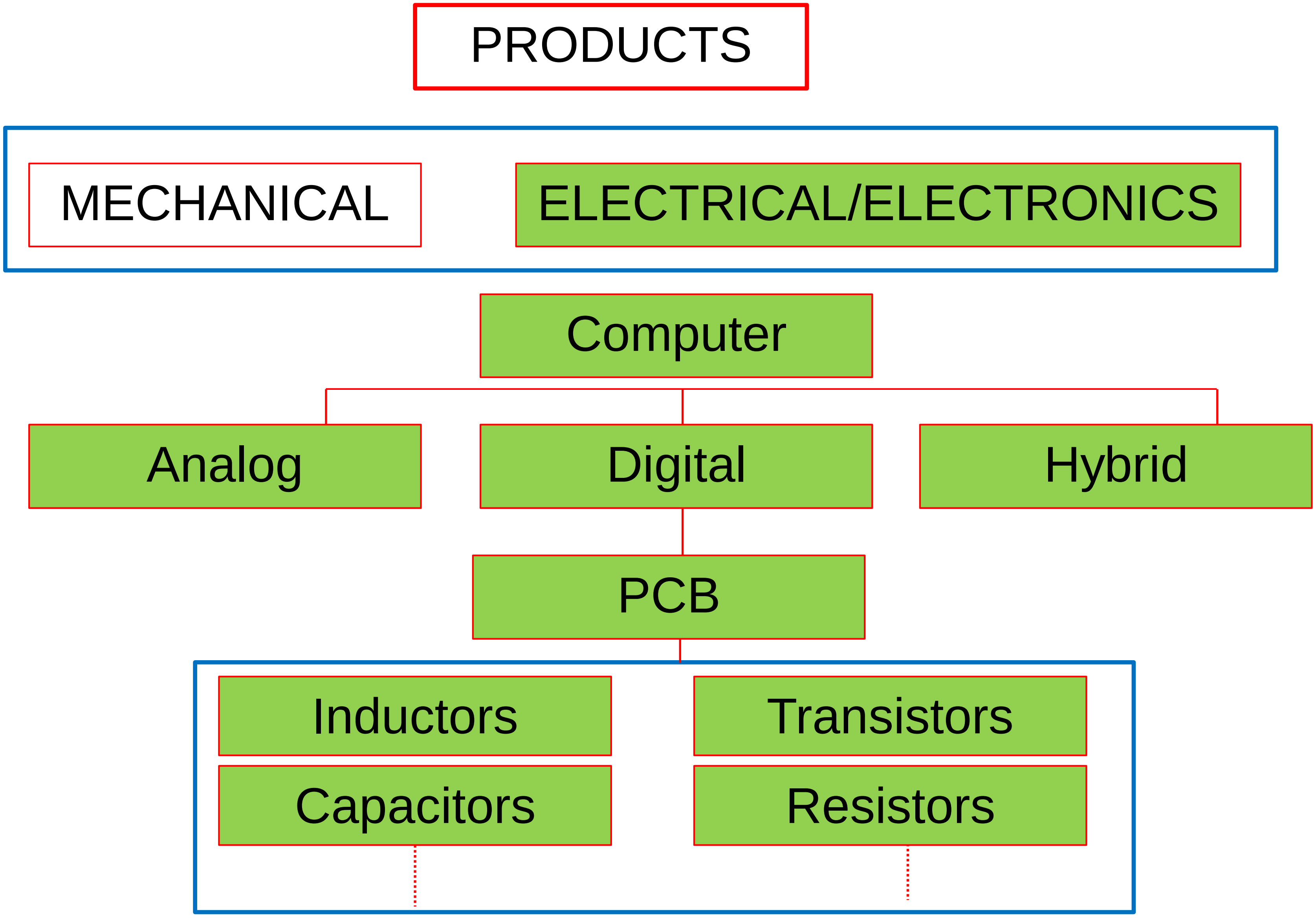




<LCD module>

<Cell Phone exploded view>

Electronic components

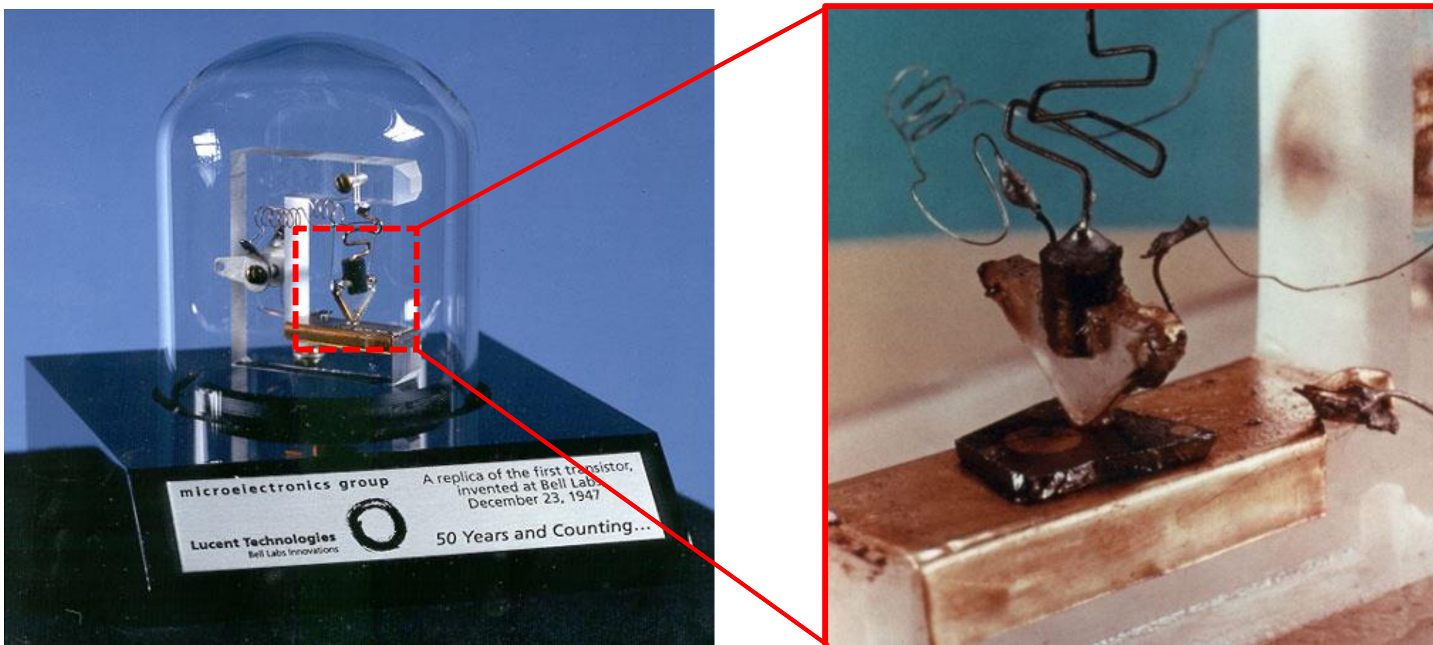


Cathode Rays & the Discovery of the Electron

Basic question like the charge of the particles was +ve or -ve remained undetermined until 19th century.

- Early research in electrical and magnetic phenomena: 1600 to 1800
- Invention of telephone : 1876
- Invention of the light bulb : 1880
- Invention of the radio: 1897. Electron was identified

Semiconductor Era



The first transistor, a point-contact Germanium device, was invented at Bell Laboratories in 1947. This image shows a replica.

- First Transistor, AT&T Bell Labs, 1947
- First Single Crystal Germanium, 1952
- First Single Crystal Silicon, 1954
- First IC device, TI, 1958
- First IC product, Fairchild Camera, 1961

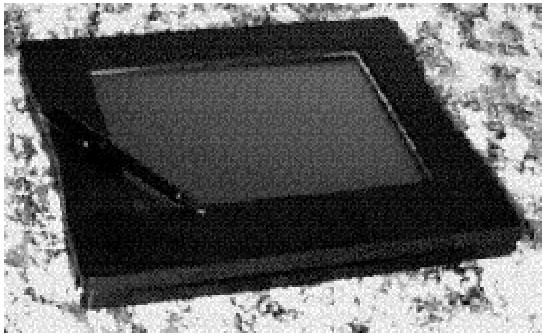
Microprocessors & Microcomputers

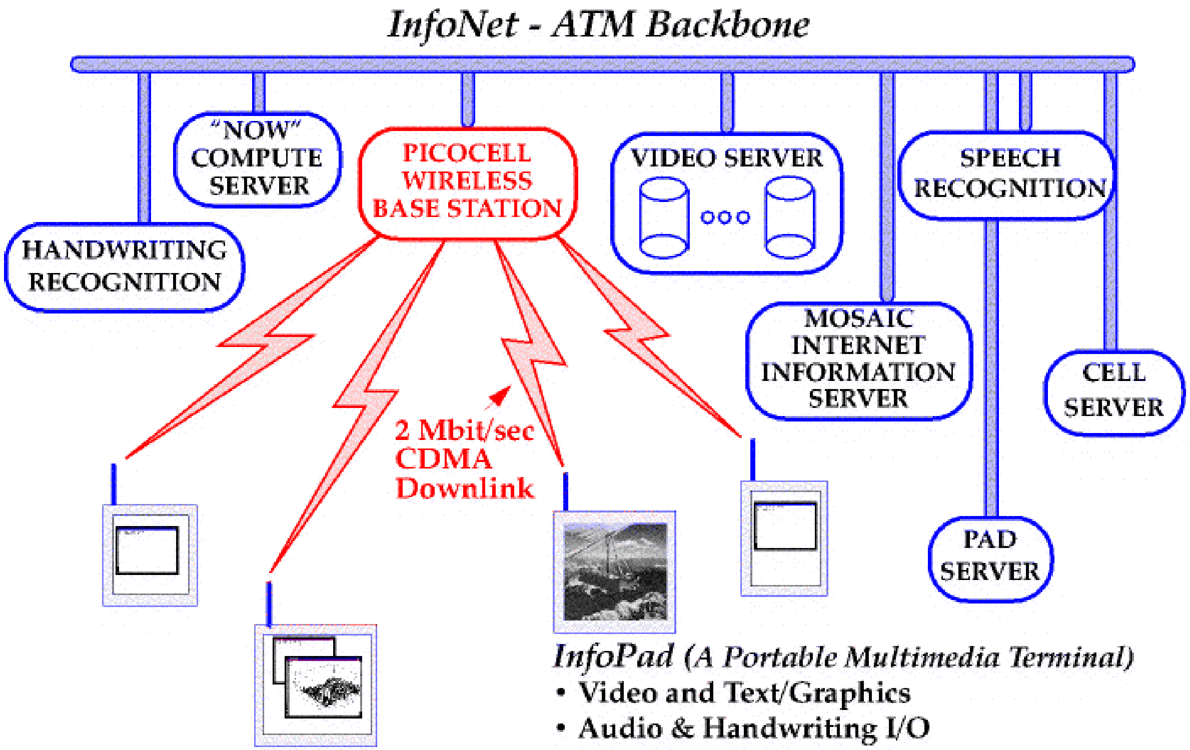
- Microprocessors invented (Intel): 1971
- First commercial MPU (8080&6800): 1975
- First personal computers: 1975
- Apple & Radio Shack computers: 1977
- IBM Personal Computer: 1981

IBM 5150 as of 1981

1990s: Infopad

- Designed to store short note
- Based on the concept of a spiral notebook
- Searchable and expandable





Design flow levels of electronic components

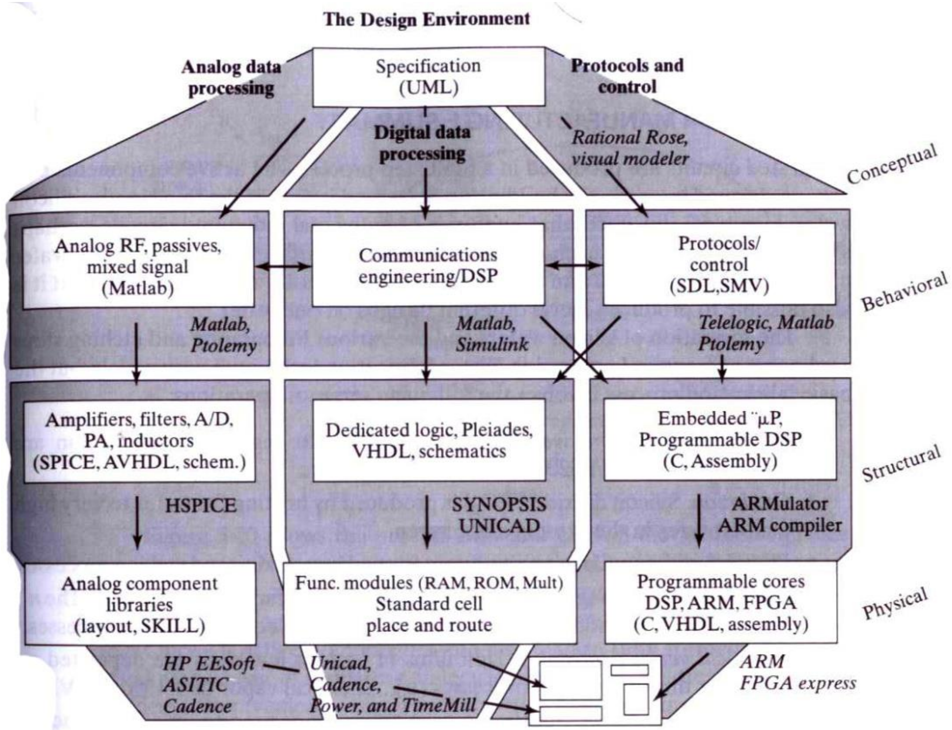


Figure 5.9 Design flow and levels for complex devices—for example, a wireless PDA (courtesy R. Brodersen, 2000).

- The defined global function of the device.
- Sub-function (coordinate with the global function)
- Assembly of these subfunctions
- The creation of specific transistors and circuit layouts

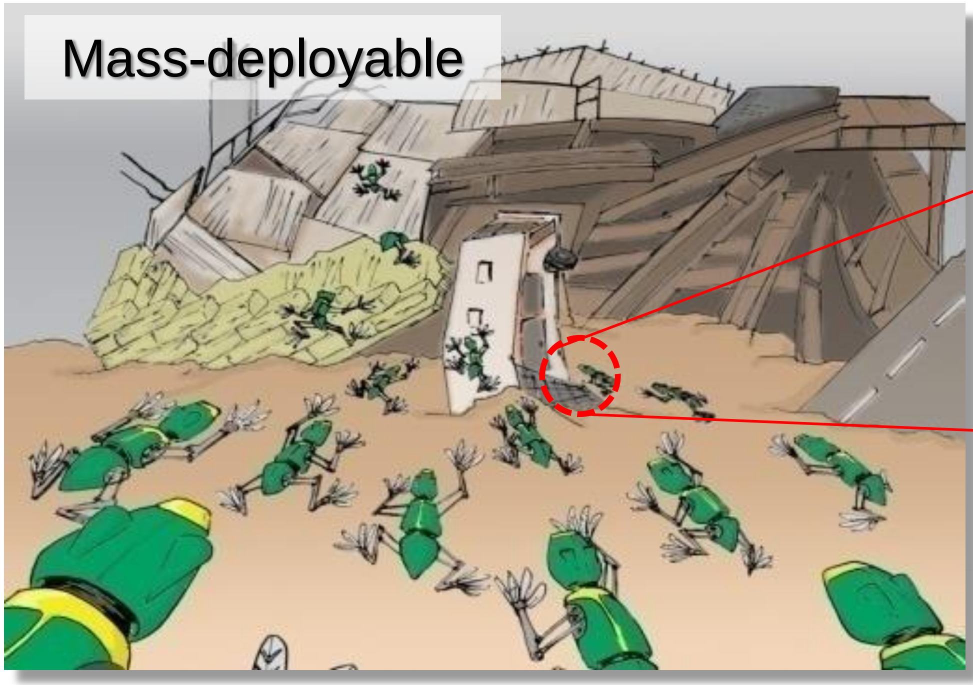
2010s

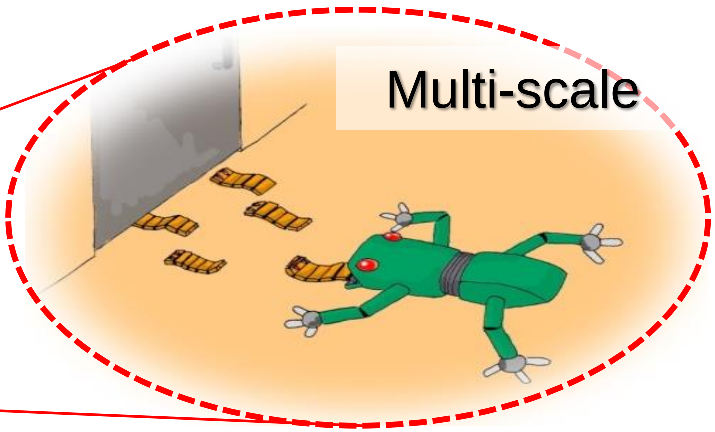
Galaxy Tab

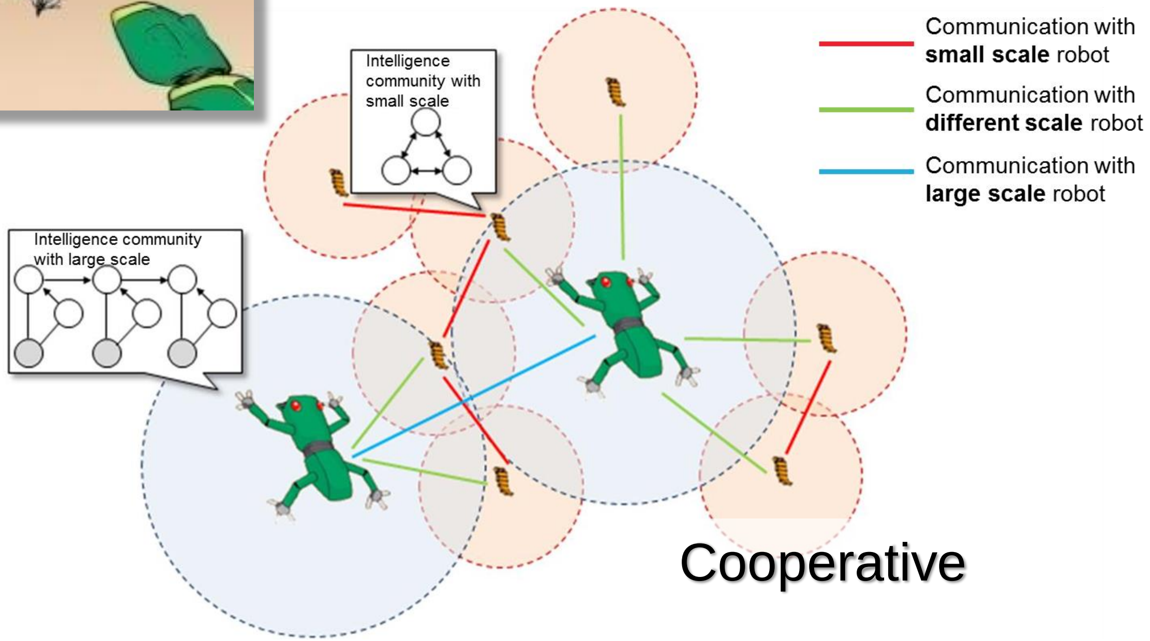
iPad/iPod

Multi-scale robots

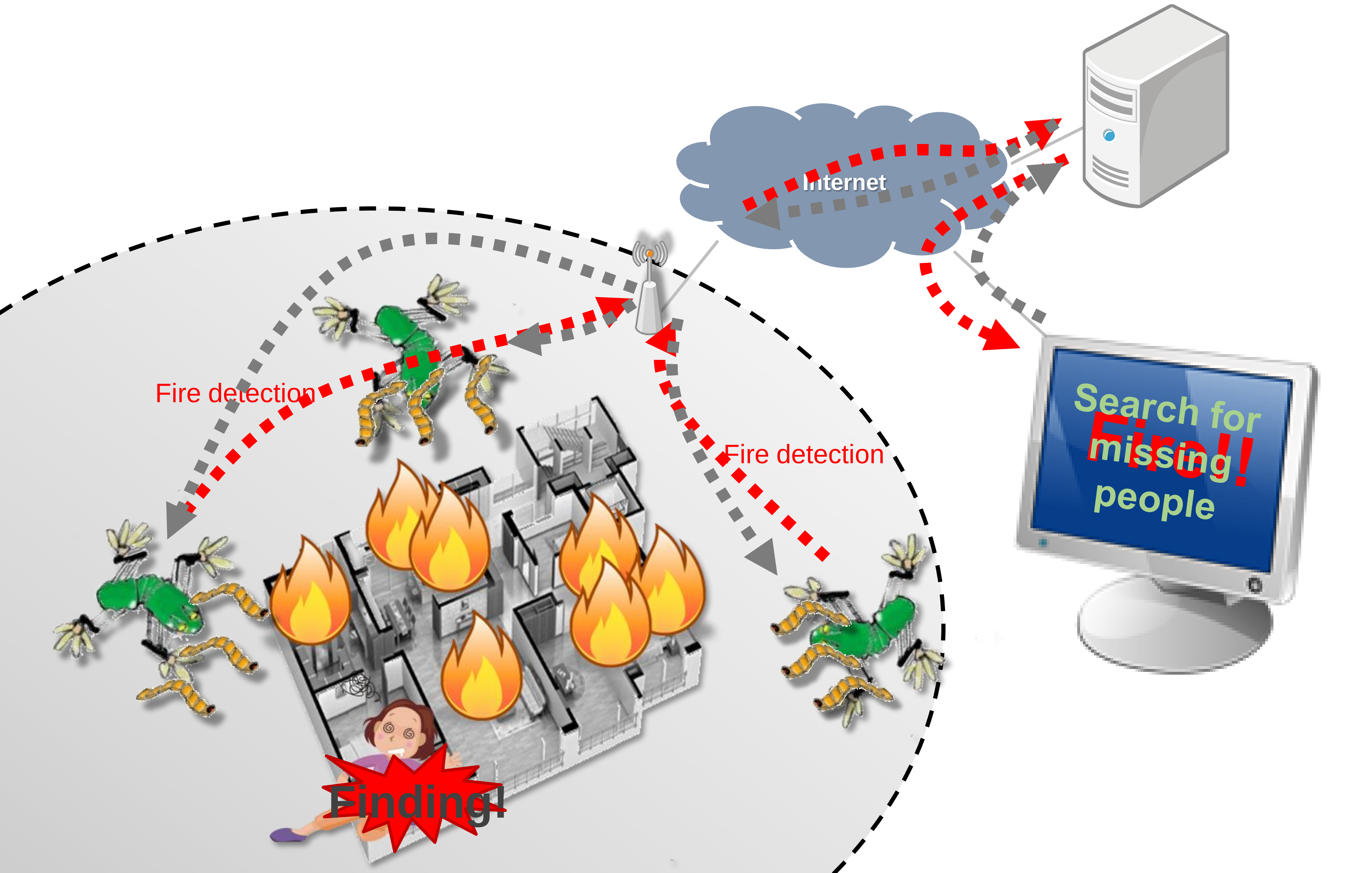
Multi-scale Mass-deployable Cooperative Robot



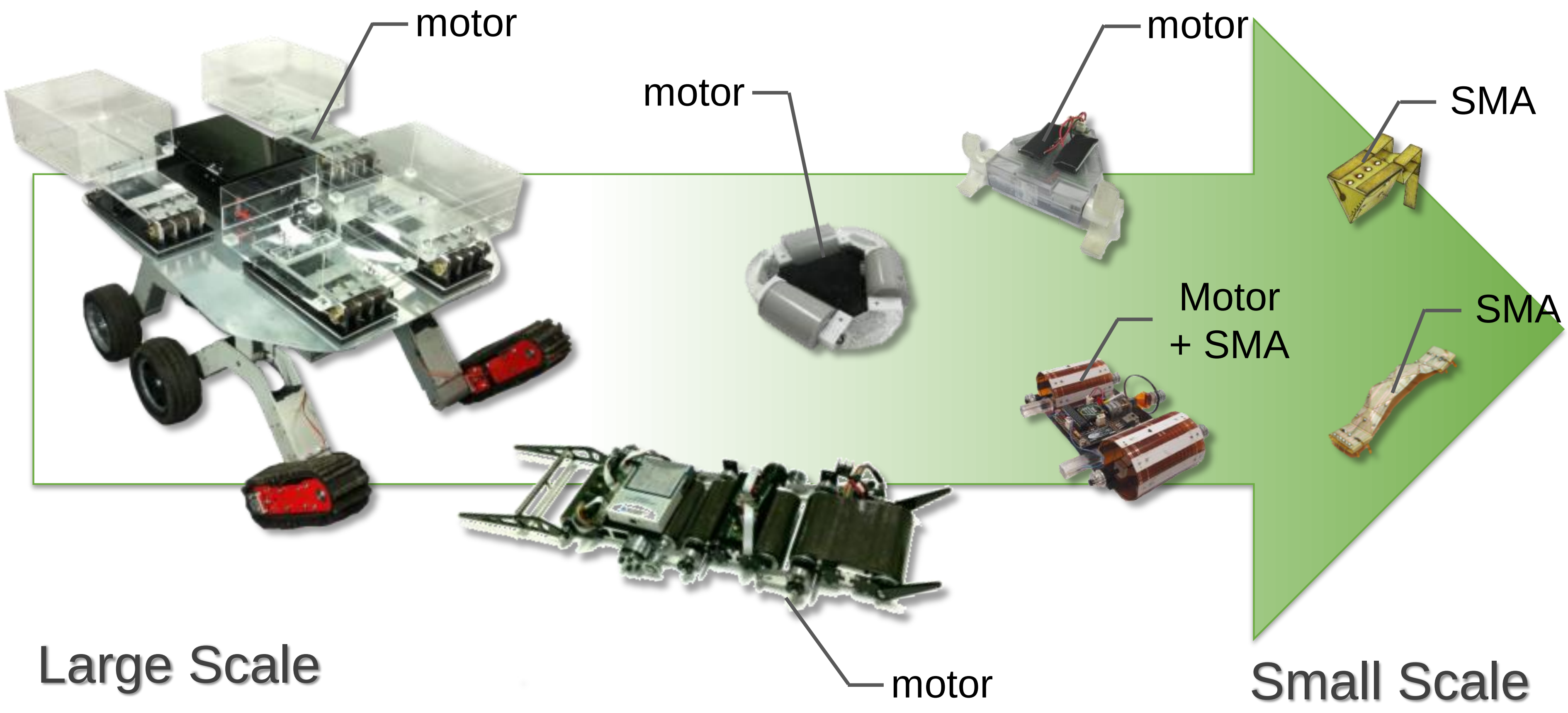




Multi-scale Mass-deployable Cooperative Robot

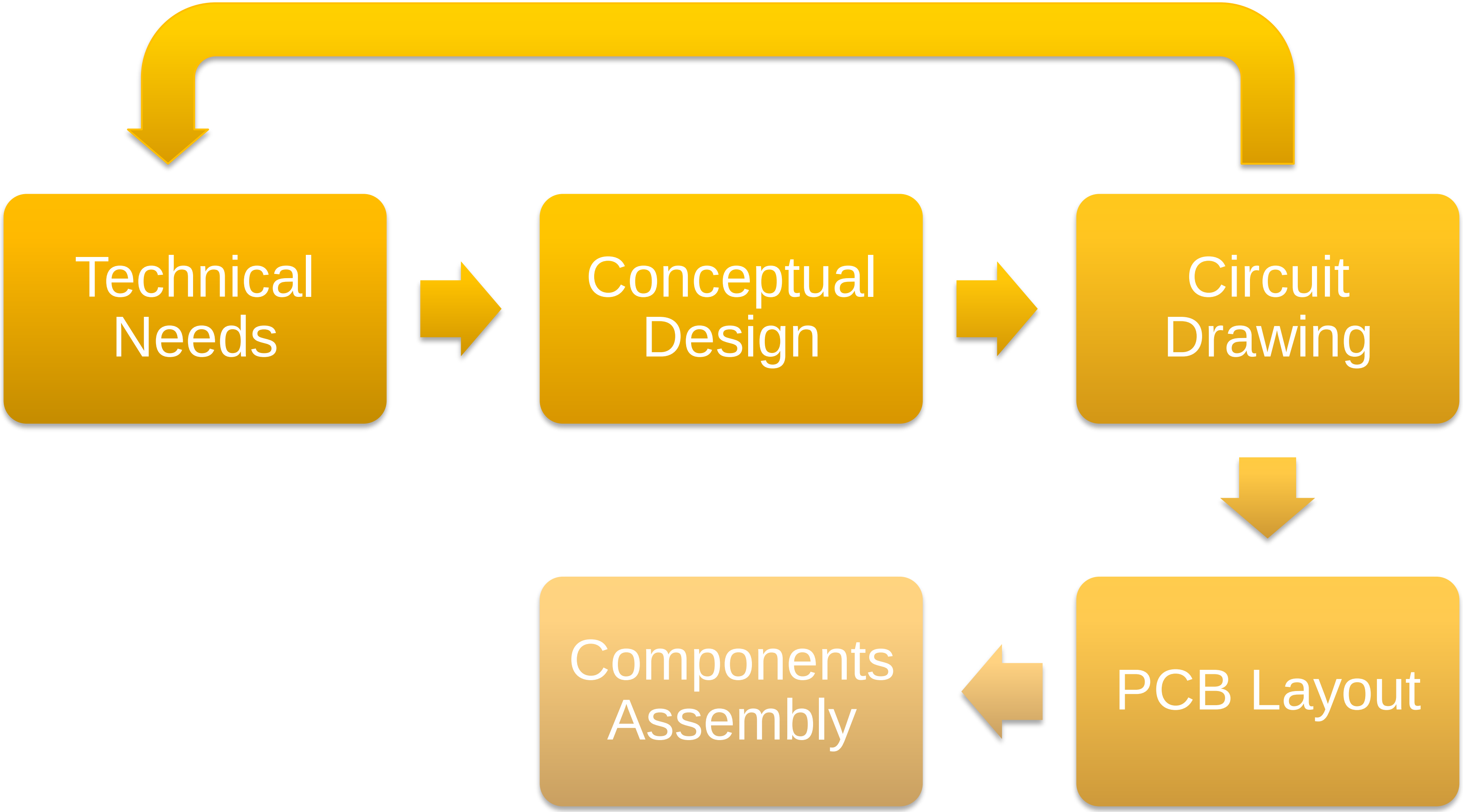


Multi-scale Robot



Multi-scale Mass-deployable Cooperative Robot (video)

PCB Design & Manufacturing Process



PCB Design Factors

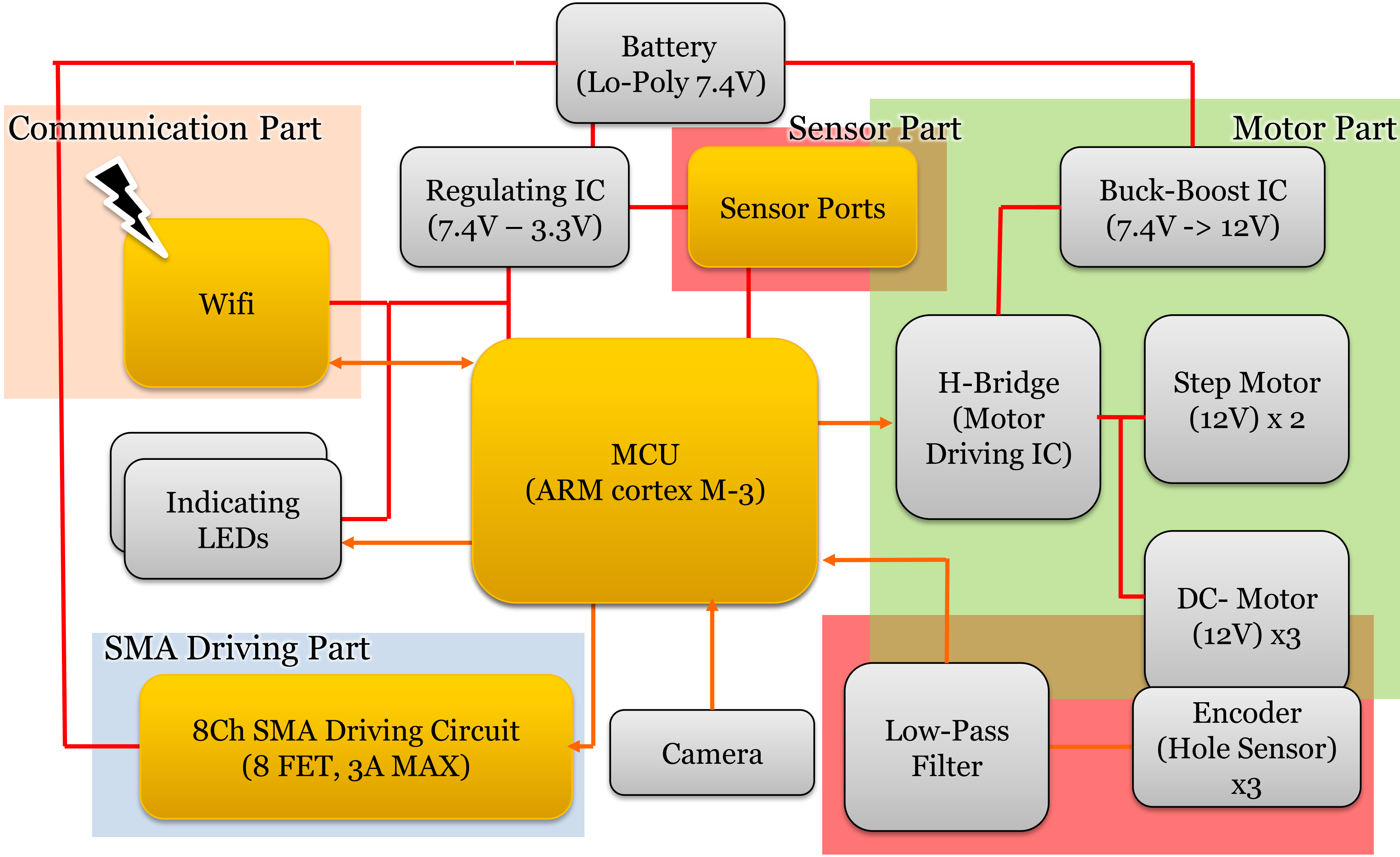
- PCB Design Factors
  - Dimension of Board
  - Dimension of each Components
  - Connector Position
  - Impedance matching
  - Absolute Maximum Current(Power)
- Needs from Customers
  - Driving Voltage
  - Driving Current
  - Data Transfer Rate
  - Sensors
  - etc.

Brief Design Concept of PCB

- Robot Board Design
  - Wireless Communication(High Speed)
  - Motor Driver(DC-Motor, Step-Motor)
    - Buck-Boost Converter(7.4V → 12V)
    - Encoder for RPM Control
  - 3-axis Gyroscope
  - Indicating LED
  - 8 channel SMA Driver
  - Camera
  - Board Outline

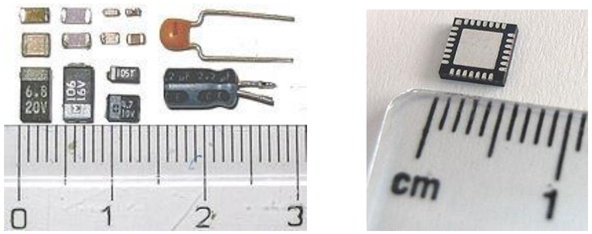
Conceptual Design of PCB

- Block Diagram of Functions of PCB



Components Selection

- Design Factor of Components
  - Size
    - SMD, DIP, SO-8 etc.
  - Absolute Maximum Values
    - Maximum Voltage
    - Maximum Current
    - Etc.
  - Heat dissipation
  - Power Consumption
  - Frequency characteristics
  - Cost
  - Delivery Time
  - Etc.



Size of SMD(Surface-mount Device) Components & DIP type Device

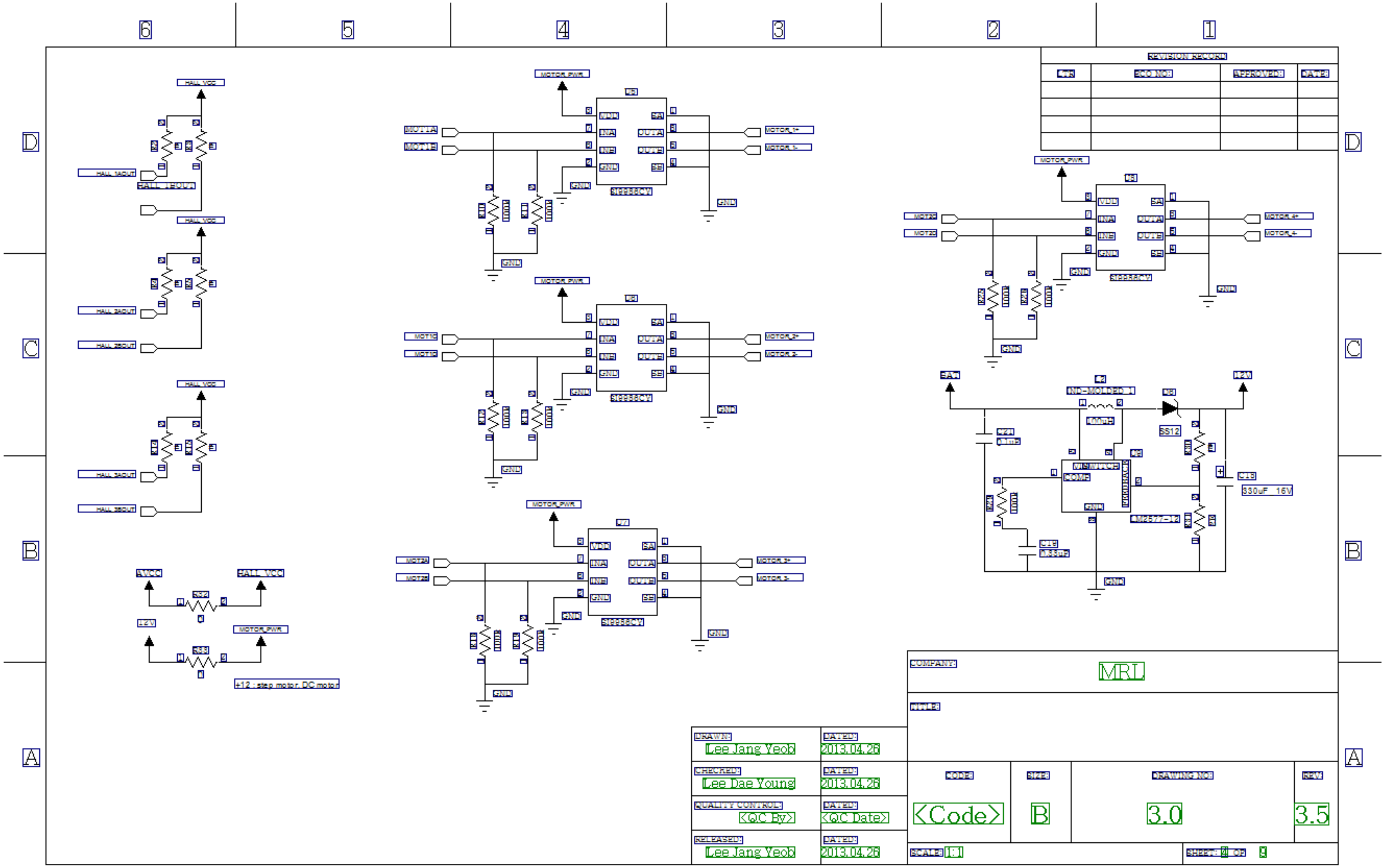
Absolute Maximum Ratings [1][2][3]

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation [4]	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage [5]	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	150°C	100°C
Soldering Information			
P0008E-Package (10 seconds)	260°C	260°C	260°C
NAB0008A- or LMC0008C-Package (10 seconds)	300°C	300°C	300°C
M-Package			
Vapor Phase (60 seconds)	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C
ESD Tolerance [6]	400V	400V	400V

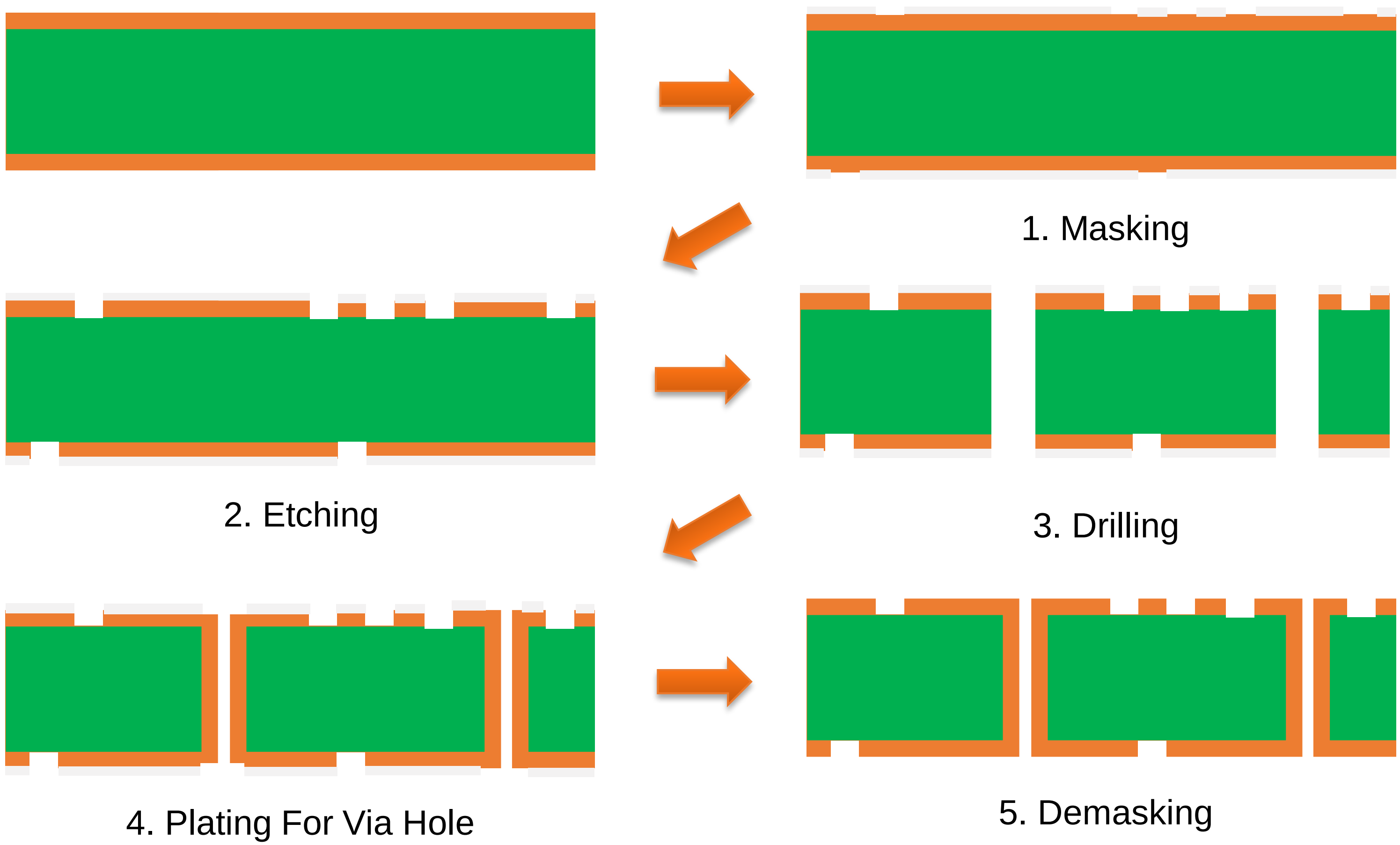
Absolute Maximum Ratings of LM741

Circuit CAD Design

- Circuit Examples (Motor Driver)

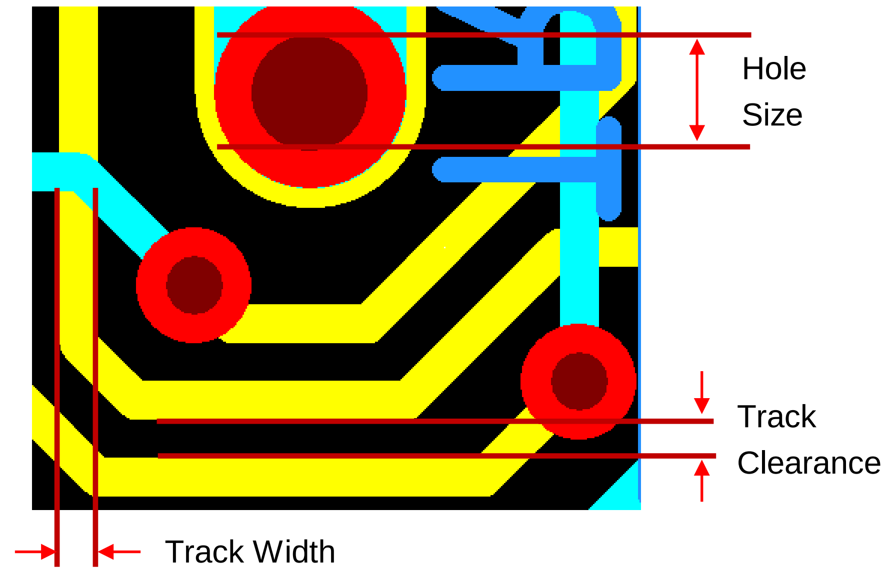


Basic Process of PCB

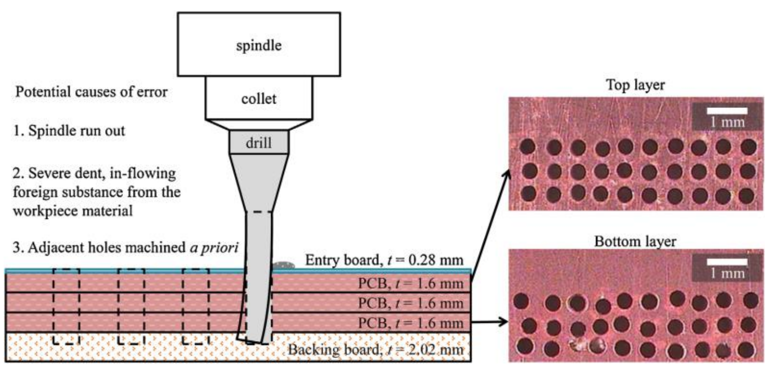


Design for Manufacturing in PCB

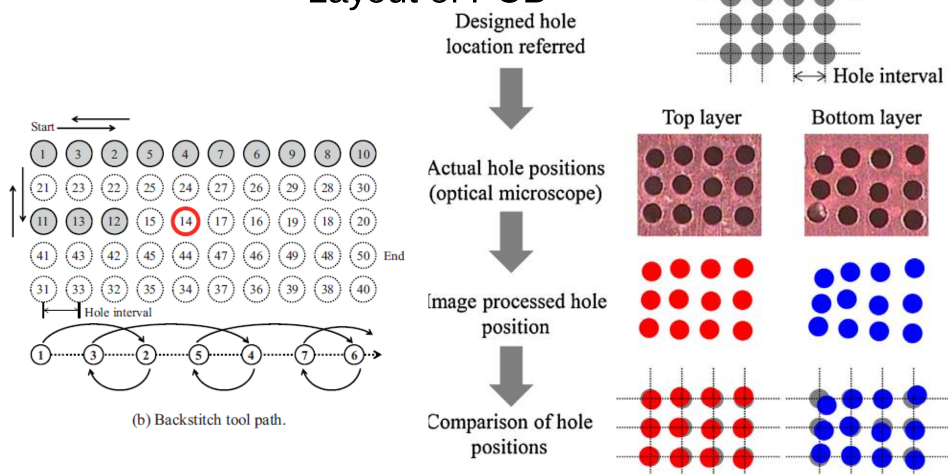
- Basic Design Factors
  - Clearance
    - Track to Track
    - Hole to Hole
    - Hole to Track
  - Hole Size
    - Standard Holes
      - 1mm, 2mm (o)
      - 1.22mm (x)
  - Track Width
    - Current Limit



Layout of PCB



Hole misalignment



Method of measuring the positioning errors for the drilled holes

Moon, J. S. et al, 2014, "Effect of Backstitch Tool Path on Micro-drilling for Printed Circuit Board," Precision Engineering - Journal of the International Societies for Precision Engineering and Nanotechnology

Design for Manufacturing in PCB (cont.)

- PCB Design Factors
  - Plating Materials
    - Gold
    - Silver
    - Lead
    - Etc.
  - Copper Film Thickness
    - 0.5OZ (18μm)
    - 1OZ (35μm)
    - 2OZ (70μm)

Cross Section of PCB

PCB Design Guidance (example)

■ Absolute Maximum Voltage & Minimum clearance

DC, AC, Peak Voltage	With Protection Layer	Without Protection Layer
	Minimum Clearance(mm)	Minimum Clearance (mm)
0~30	0.25	0.65
31~50	0.4	0.65
51~150	0.5	0.65
151~330	0.75	1.3
301~530	1.5	2.5
Over 500	0.003 mm/V	0.005 mm/V

■ Absolute Maximum Current & Track Width (Copper Film Thickness = 1OZ)

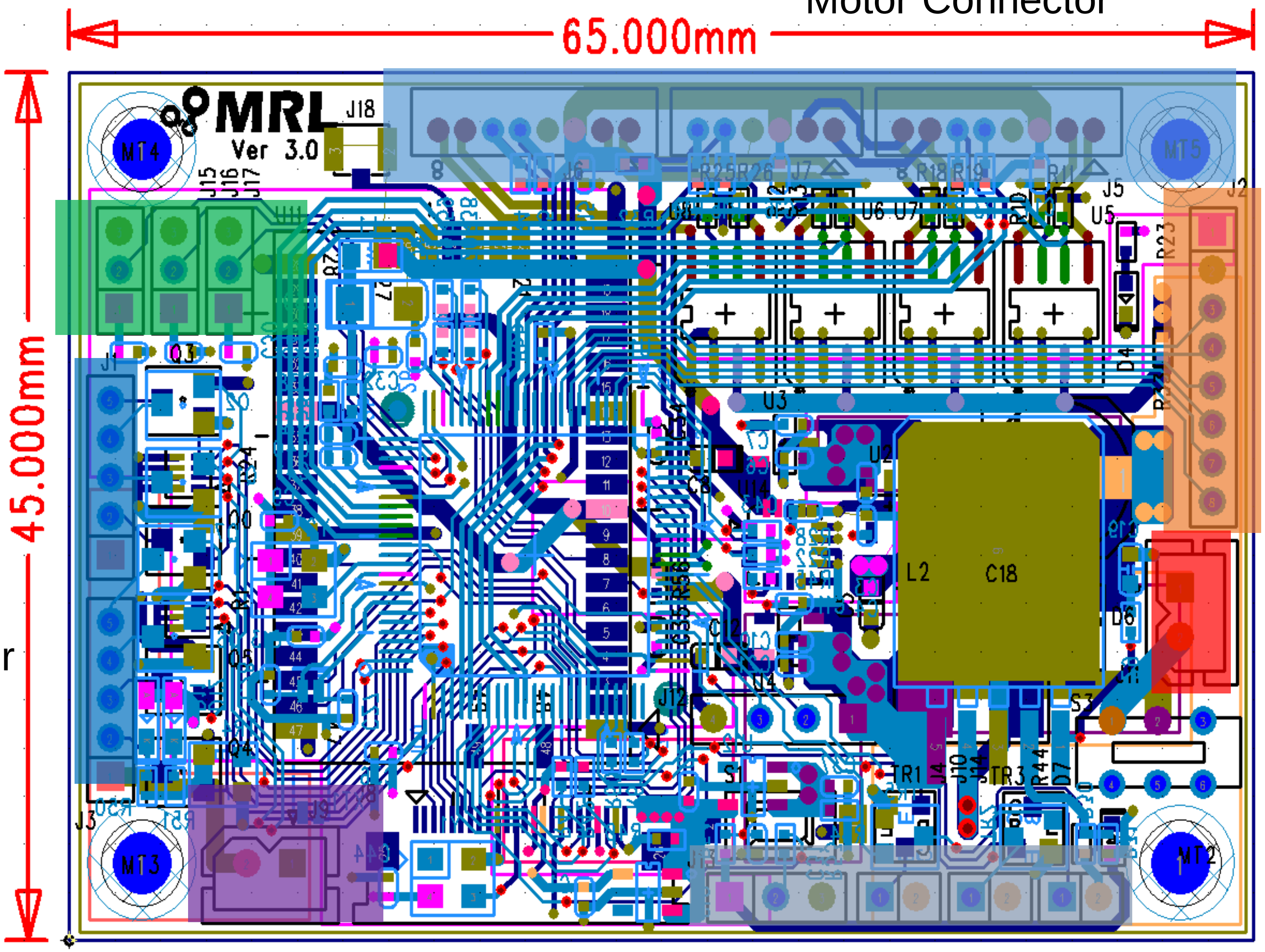
Track Width (mm)	Amps(A)
0.4	1.0
0.6	1.4
0.8	1.8
1.0	2.2
1.5	3.0
2.0	3.4
3.0	3.8

※Note : This Guidance follows HANSAEM DIGITEC Inc.

It is strongly recommended to check the specification of PCB for each company.

PCB Layup Design

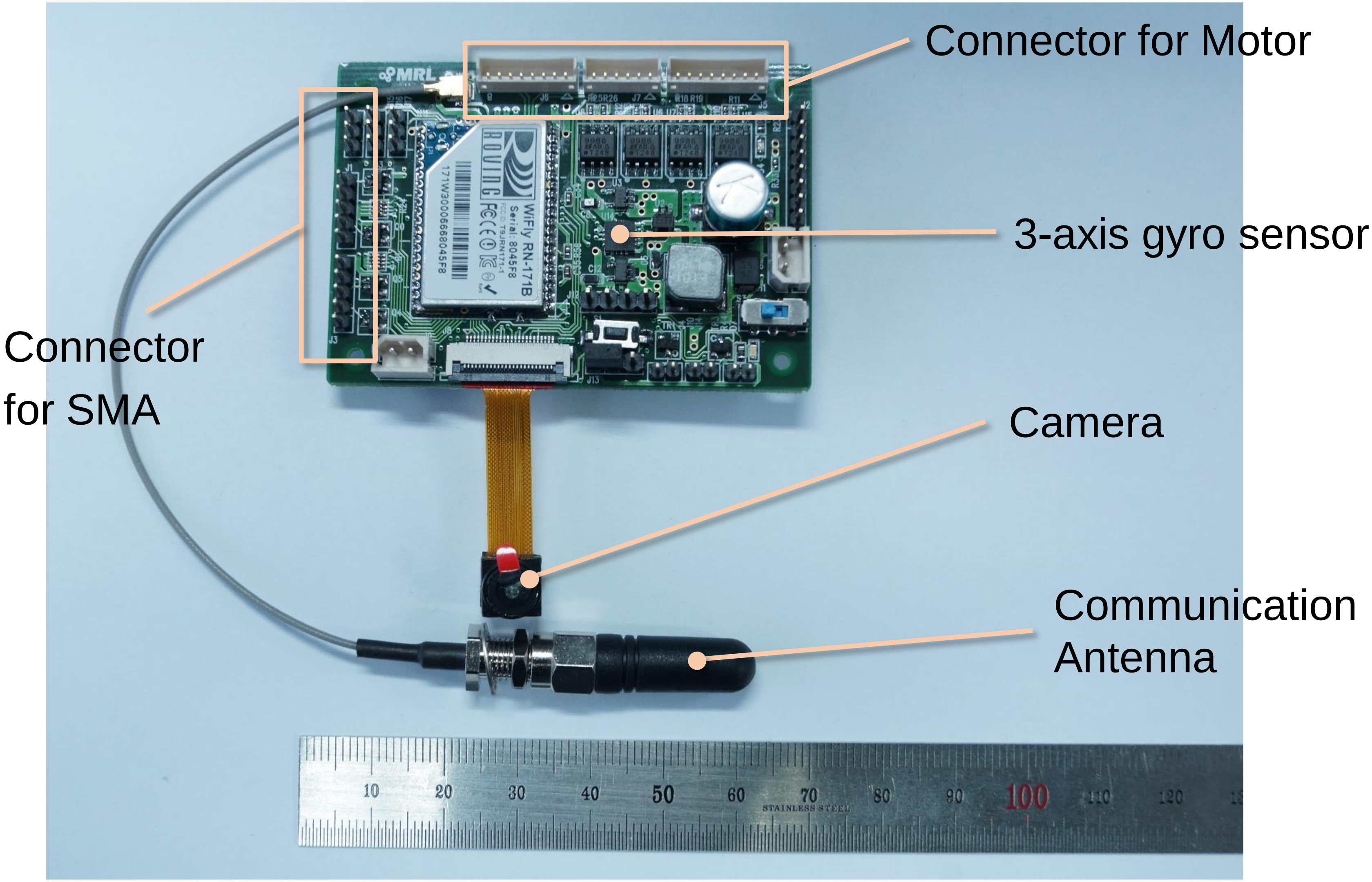
- PCB Layout Examples



SMT(Surface Mounting Technology)

PCB Assembly Process, WILSON PROCESS SYSTEMS

Final Product



Deformable Wheel Robot

Deformable Soft Wheel Robot using Hybrid Actuation

Je-sung Koh, Dae-young Lee, Seung-won Kim,
Kyu-Jin Cho

Seoul National University
Mechanical & Aerospace Eng.
Biorobotics Laboratory

Seoul National University
Mechanical & Aerospace Eng.
Multi-scale Robotics Laboratory

Flexible Display

2013 Samsung Flexible OLED Phone and Tab Concept

Design for Foldable Structure (Chair)

The Ottakringer ladder-chair was inspired by a 19th-century model found in a monastery library in Tyrol, Austria. Ottakringer is the name of the Vienna suburb where it is manufactured today by Section N. The Ottakringer has two purpose functions, as ladder and as chair. Whether it is a collapsible is debatable, for it occupies about the same amount of practical space in both roles.

Design for Foldable Structure (cont.)

Designed by
Eduard Bohtlink (1986-95)

75

Design for Foldable Structure (Bicycle)

Design for Foldable Structure (Keyboard)

The Smart Fun roll-up rubber keyboard will withstand all the coffee, Coke and Big Mac that a nerd may spill. It can be cleaned in hot water at 60° C (140° F). Its relatives, the Smart Indupact and Smart Medic, were designed for workshops, laboratories and clinical environments, and can take even tougher cleaning. One day – or so this author foresees – all portable PCs will have ultraflat collapsible keyboards and screens that project onto the nearest wall or float freely in the air.

Design for Foldable Structure (Airplane)

The 1954 RNAF Gannet, by Fairey in the UK, is a three-seat shipboard early-warning aircraft that was designed to take off and land from an aircraft carrier. Its wings fold back for compact on-board storage.

The aircraft carrier USS Franklin D. Roosevelt Sentinel with collapsible aircraft on the flight deck, *c*. 1970. These days many helicopters and military aircraft have rotor blades and wings that fold to save space on aircraft carriers.

Attachment, Wire Bonding and Packaging

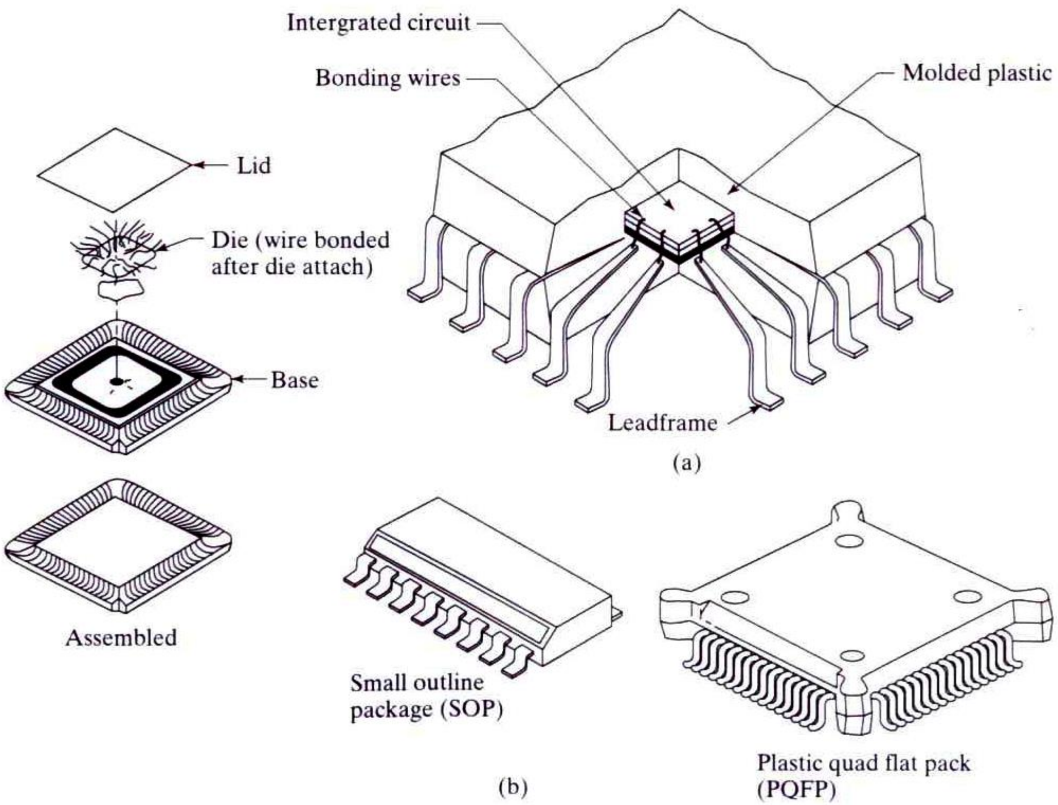
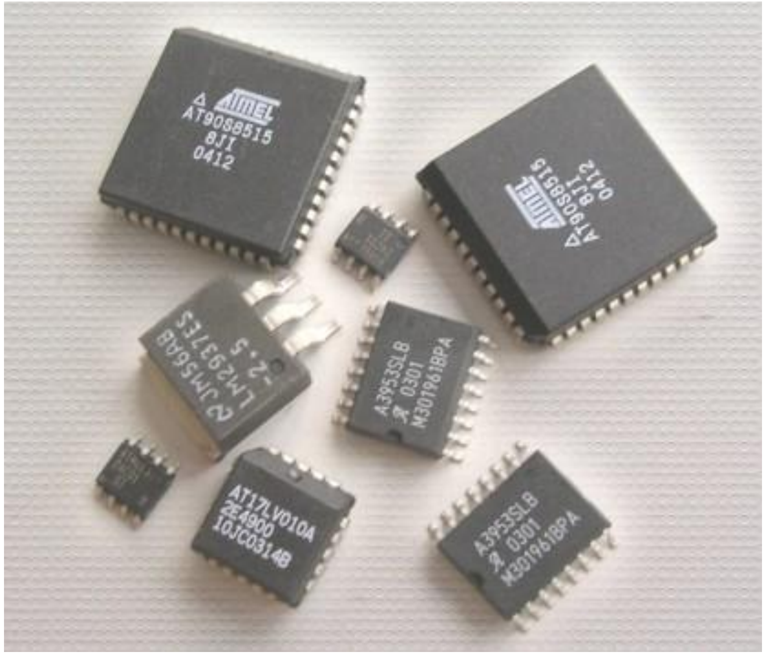


Figure 5.32 Quad flat packaging (QFP) (adapted from Kalpakjian, 1995).



Semiconductor Manufacturing

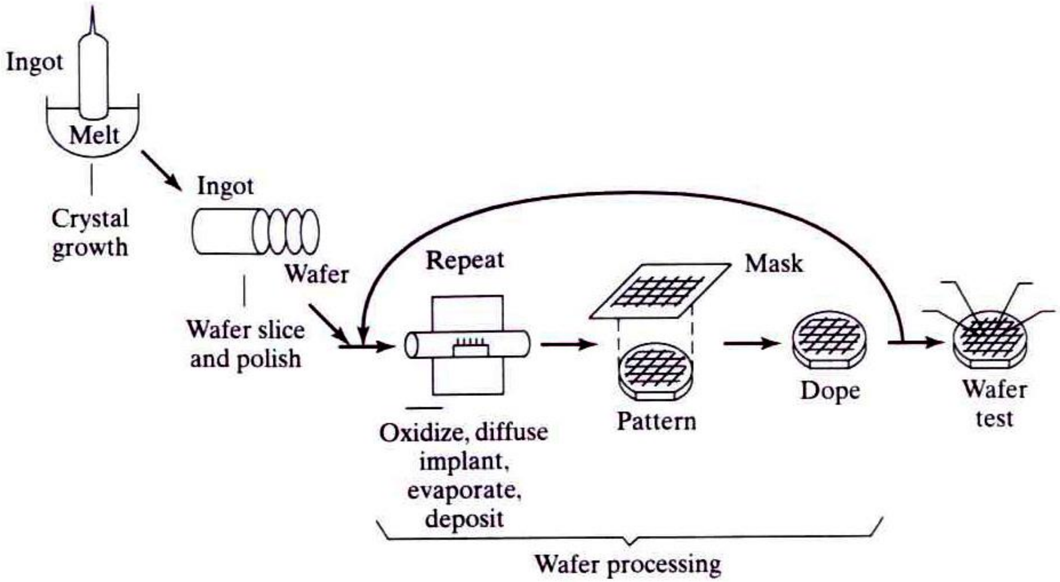


Figure 5.10 IC manufacturing process flow.

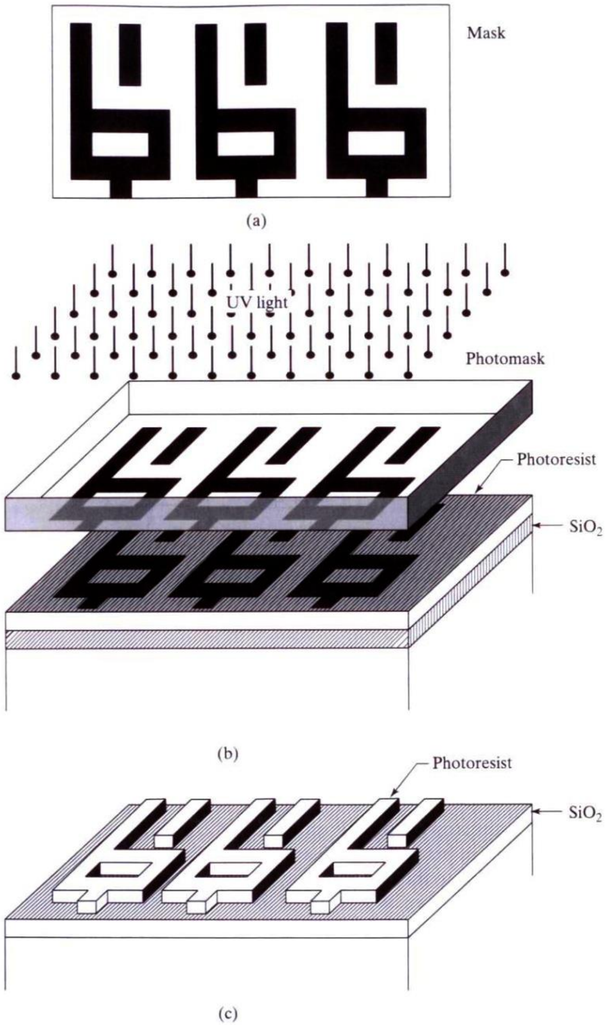


Figure 5.18 Simplified photolithographic process steps for proximity printing.

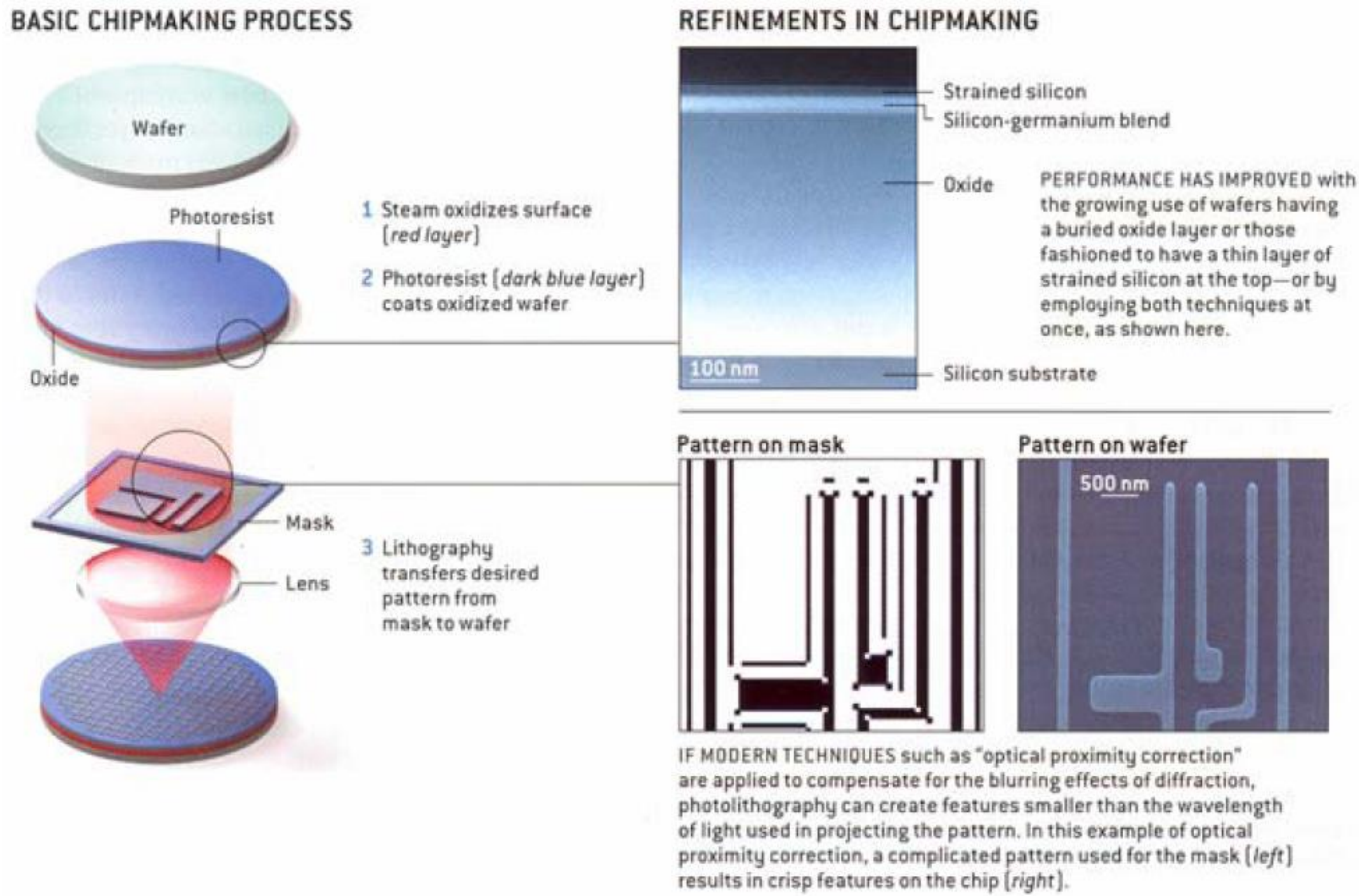
Photolithography

1. Crystal growth and wafer production
2. Oxidation: SiO_2 is produced by heating the wafer to very high temp.
3. Photolithography: Circuit patters are formed

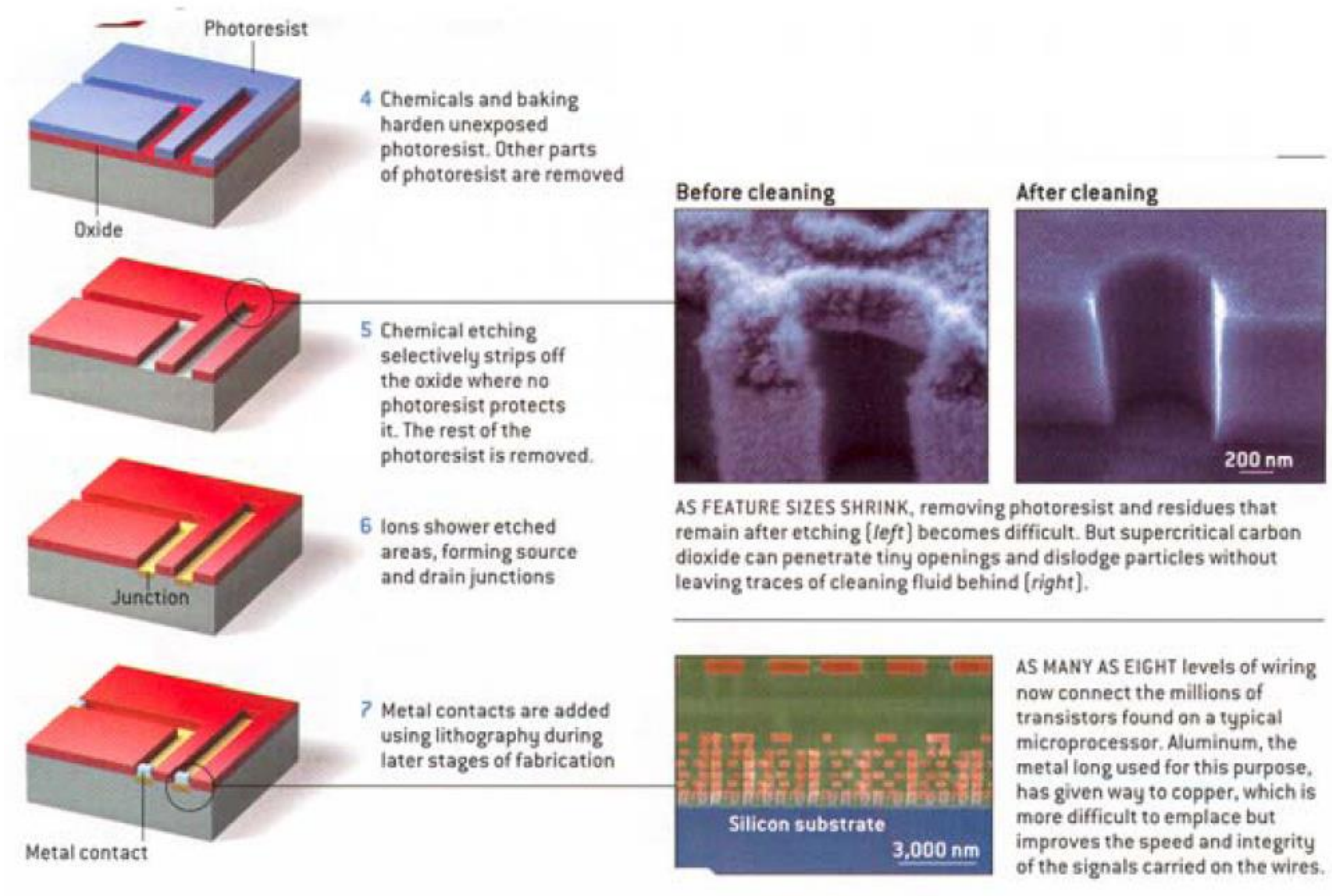
Semiconductor manufacturing (contd.)

4. Doping: The n^+ and p^+ dopants are added by ion implantation.
5. Chemical Vapor Deposition
6. Interconnect creation
7. Testing and packaging

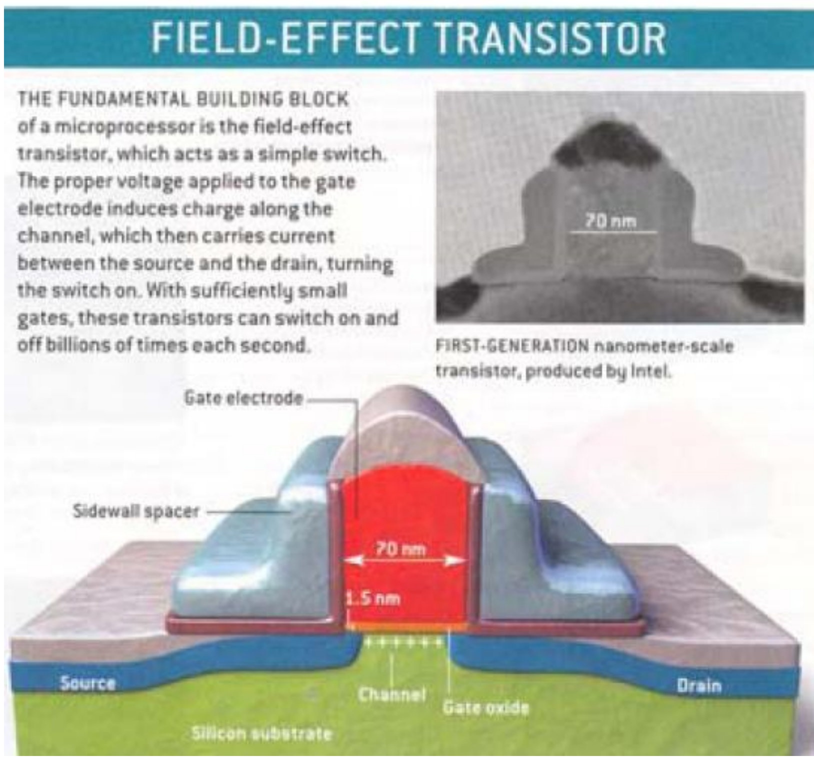
Chipmaking Processes

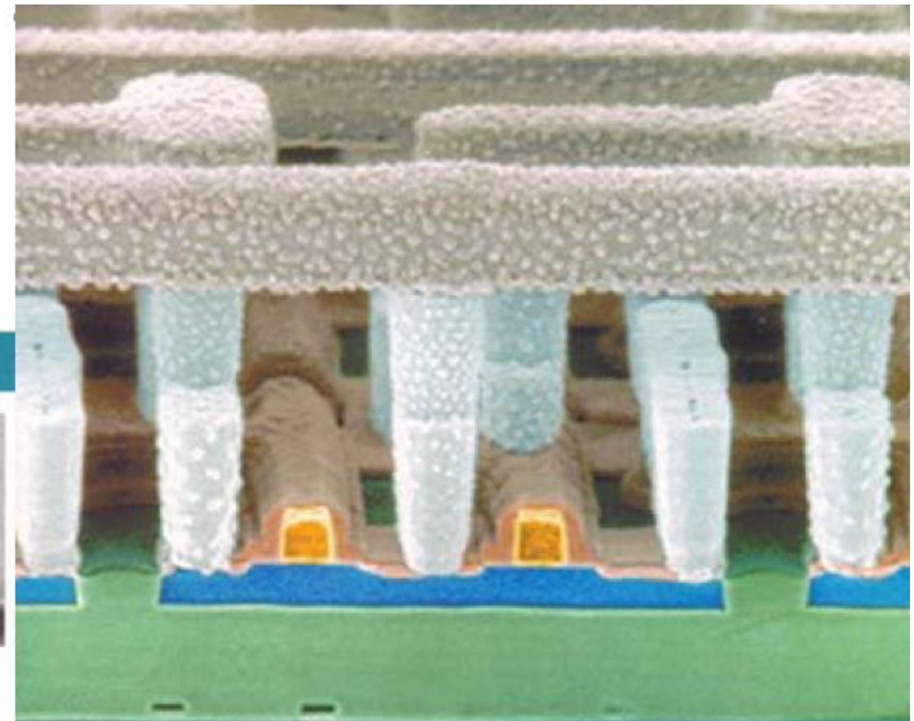


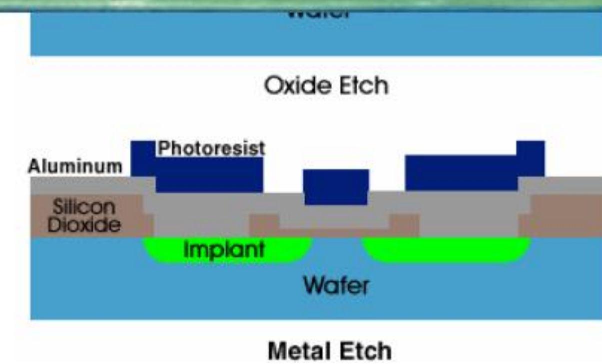
Chipmaking Processes



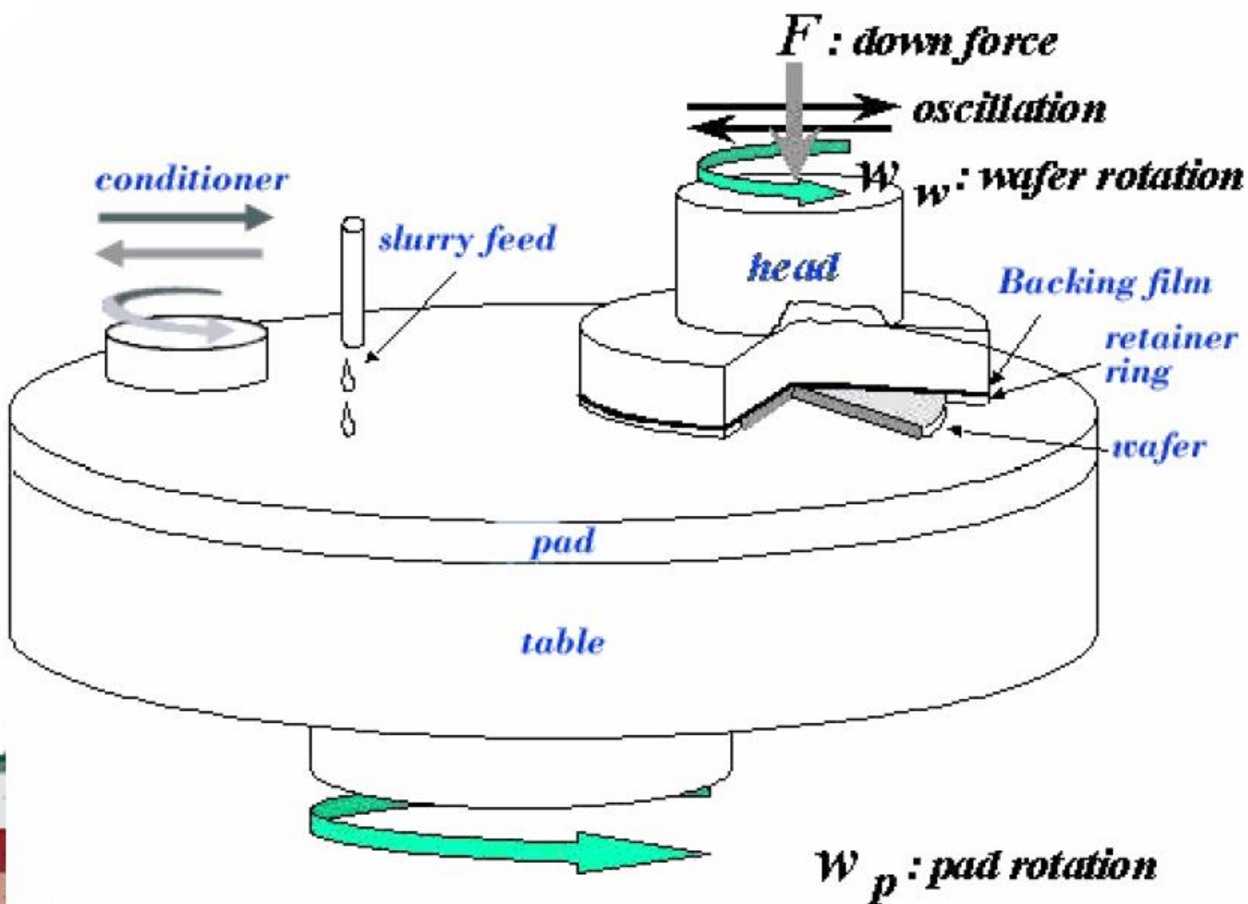
Geometry of Transistor in a chip

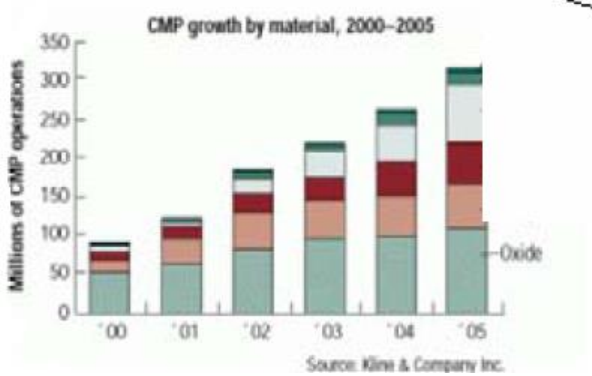






Chemical Mechanical Polishing (CMP)

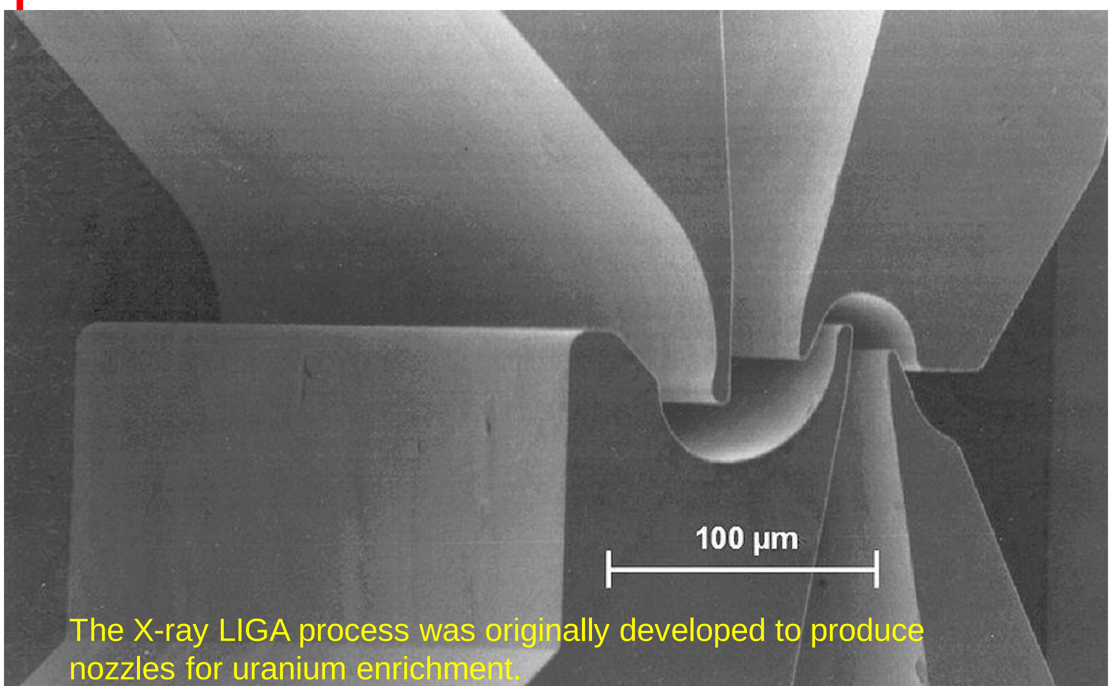




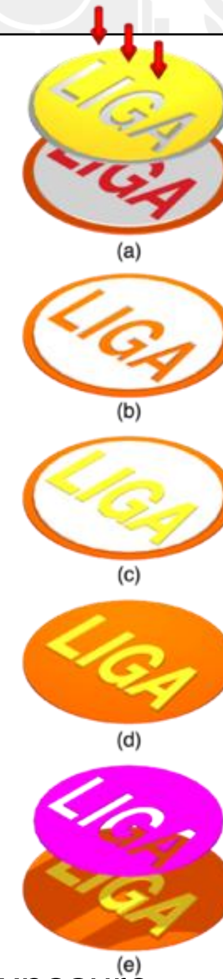
Chip Manufacturing (video)

LIGA

LIGA is a German acronym for Lithographie, Glavankformung, Abfomung (Lithography, Electroplating and Molding) that describes a fabrication technology used to create high-aspect-ratio microstructures.

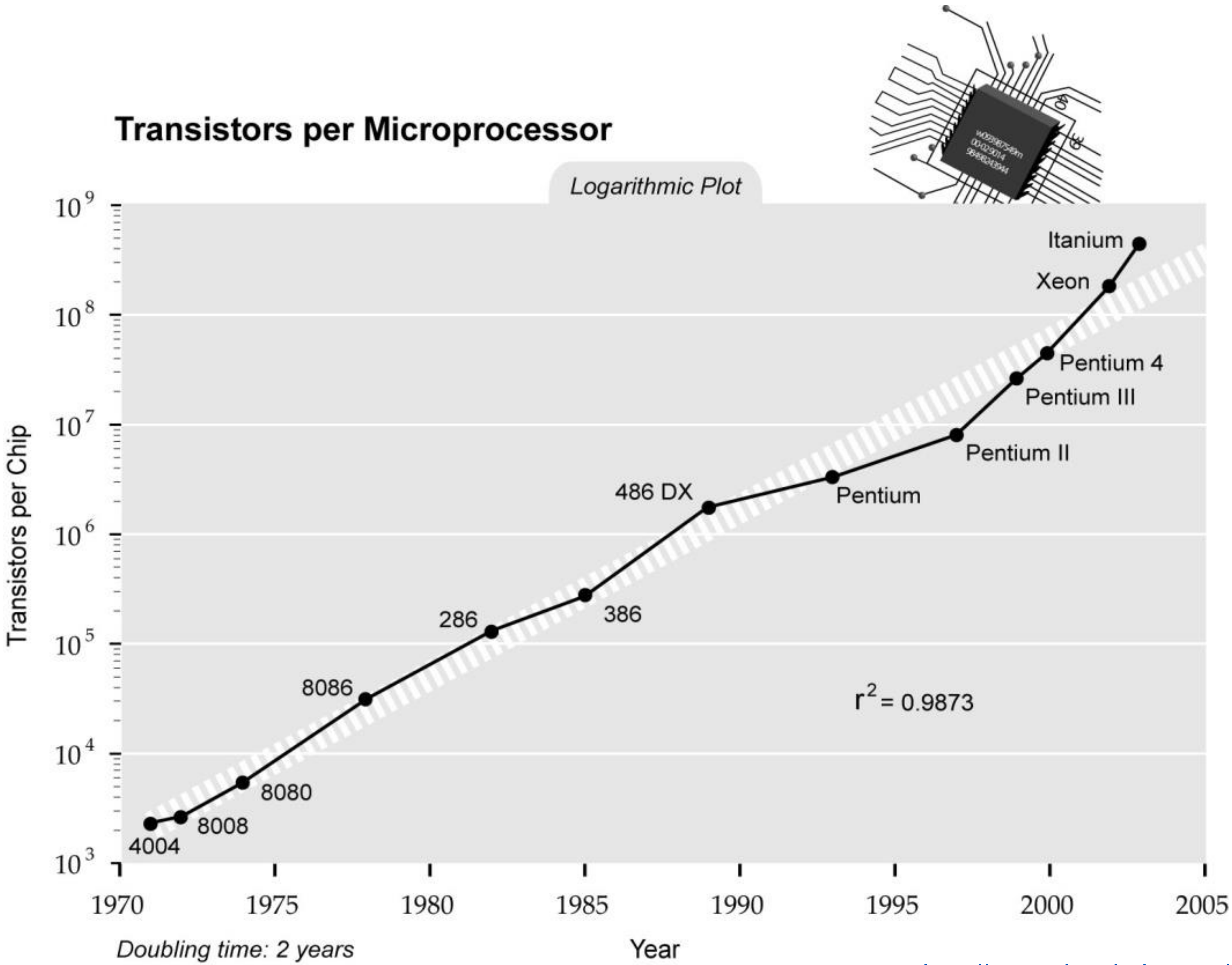


http://en.wikipedia.org/wiki/File:LIGA-Doppelumlenksystem.jpg



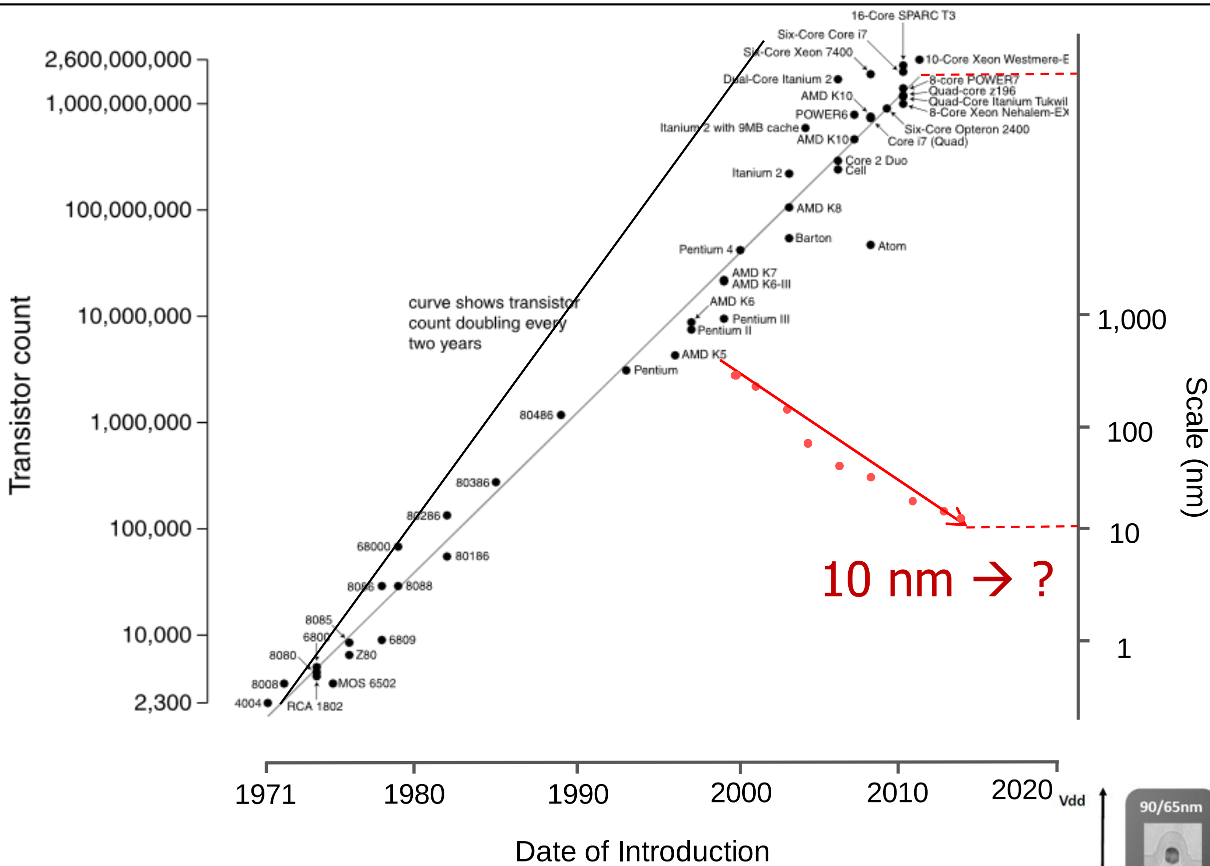
(a) exposure
(b) Development
(c) Electroforming
(d) Stripping
(e) Replication

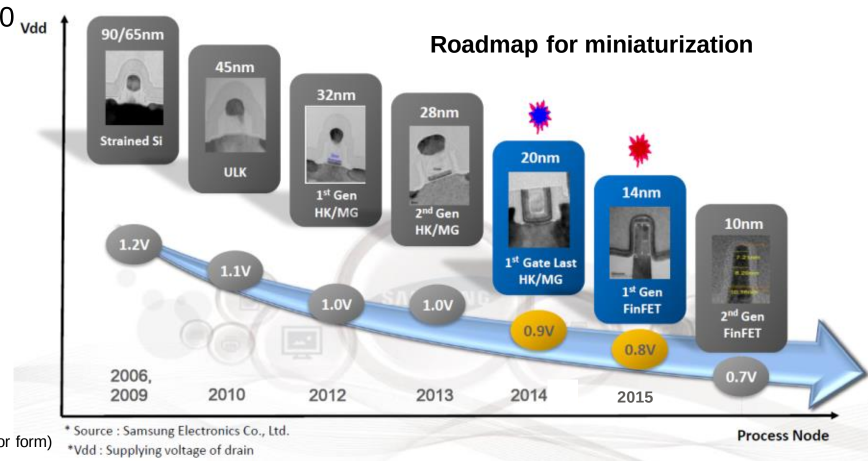
Transistors per Microprocessor



http://www.singularity.com/charts/page63.html

Moore’s Law



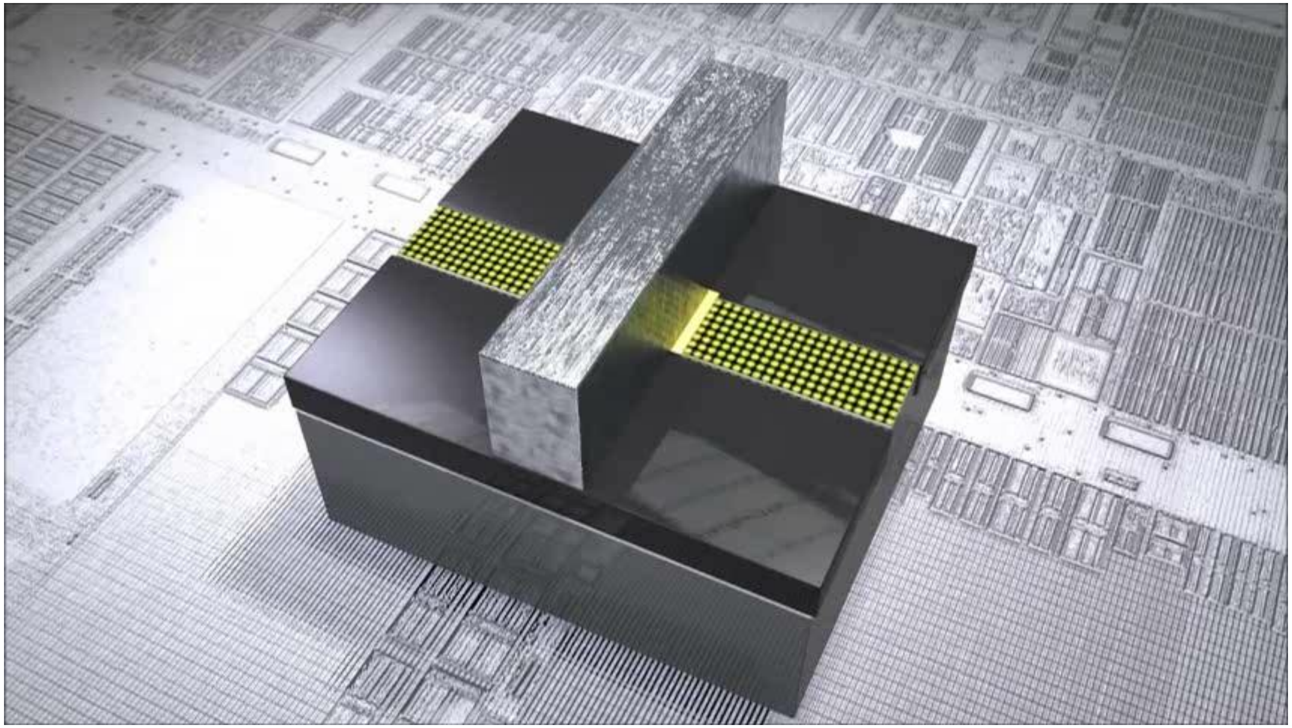


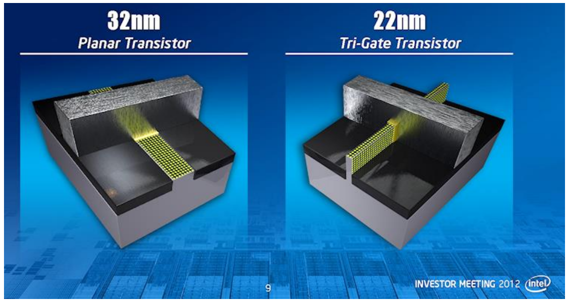
http://en.wikipedia.org/wiki/Moore's_law

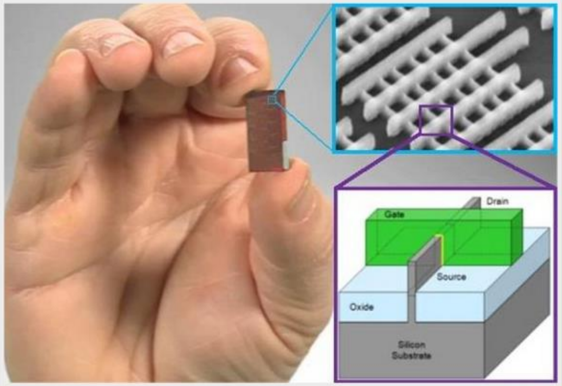
*FinFET (fin field effect transistor, 3-D Tri-Gate transistor form)

3D transistor

FinFET (fin field effect transistor, 3-D Tri-Gate transistor form)



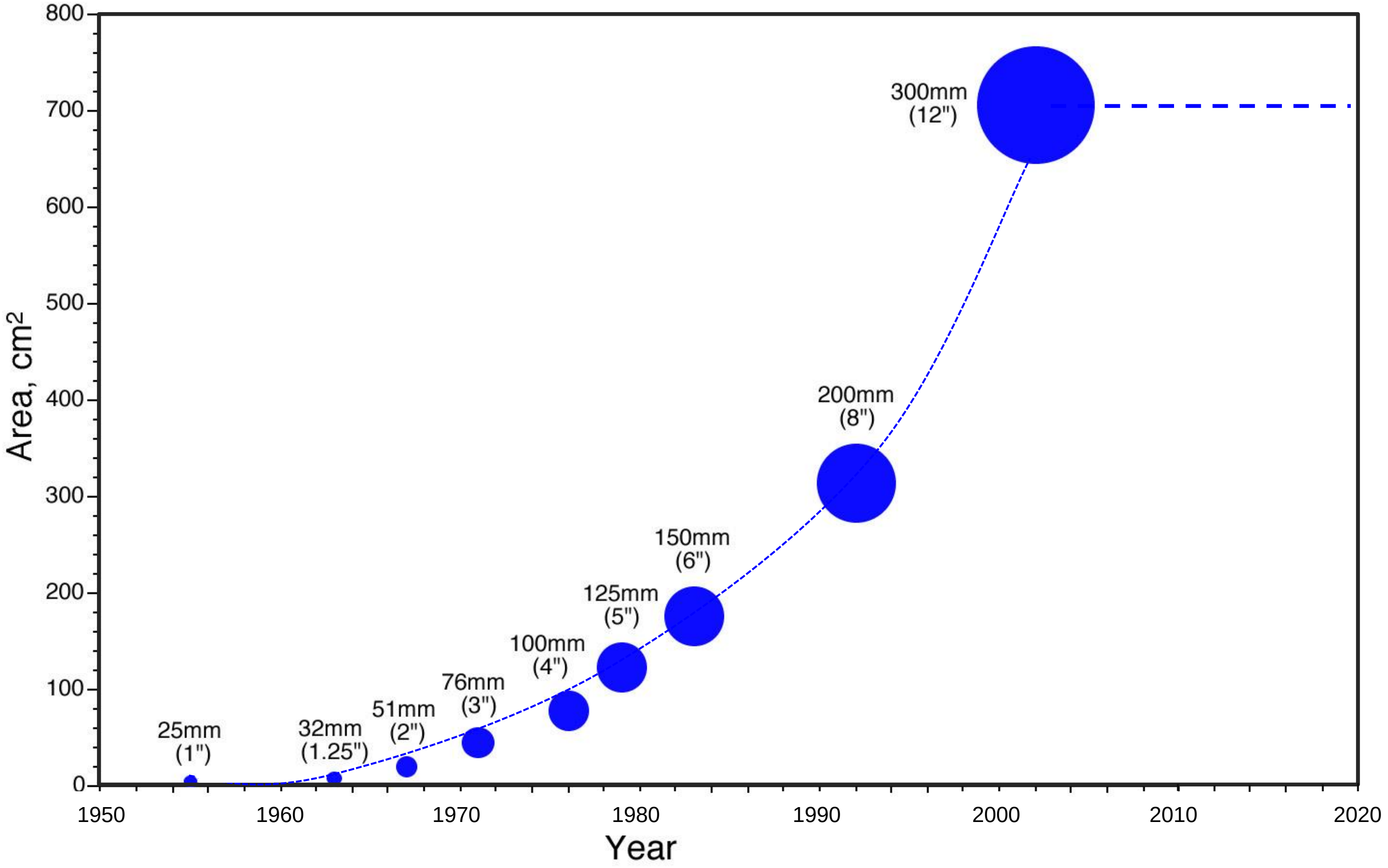




Intel's new Ivy Bridge processor will use TriGate transistors (top right), which use a 3D fin (diagram bottom right) to improve switching.

Intel, http://www.youtube.com/watch?v=YIkMaQJSyP8

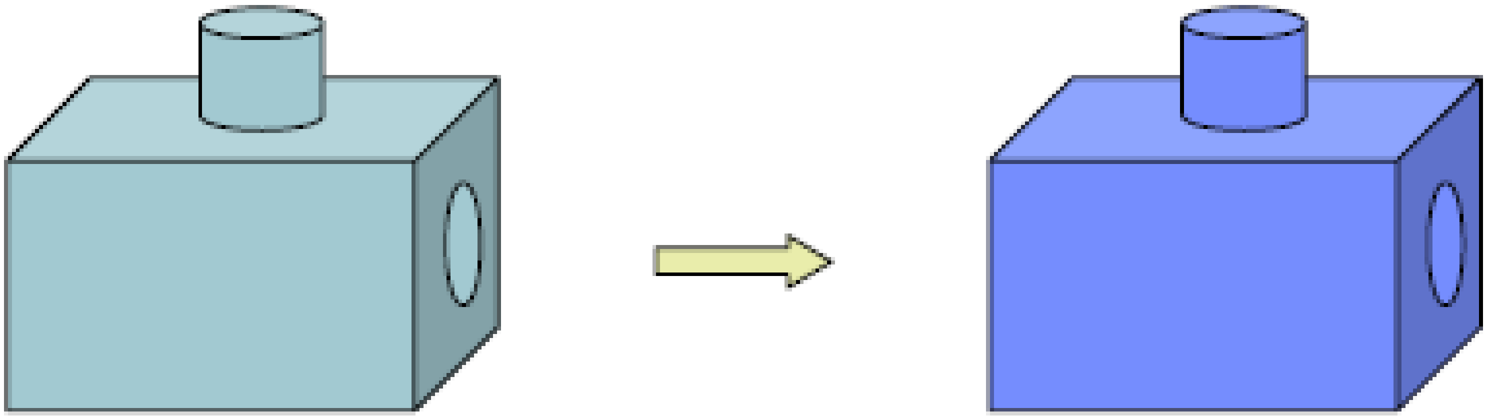
Commercial Silicon Wafers



Wafer (substrate for microelectronic): a thin slice of semiconductor material used in the fabrication of integrated circuits and other micro devices

From Design to Manufacturing

- Now we are in the Manufacturing domain

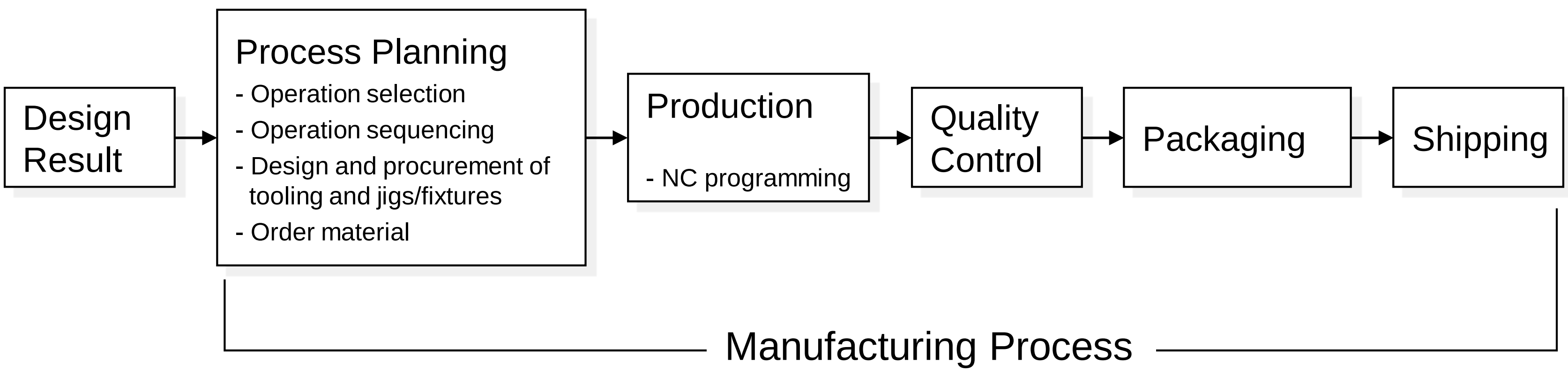


- Design domain:
  - How to create geometry

- Manufacturing domain:
  - How to make part
  - Need to consider
    - Manufacturing process
    - Material
    - Machine

Computer-Aided Manufacturing (CAM)

- Definition
  - The technology concerned with the use of computer systems to plan, manage, and control manufacturing operations through either direct or indirect computer interface with the plant's production resources.



< Main Phases of discrete part manufacturing >

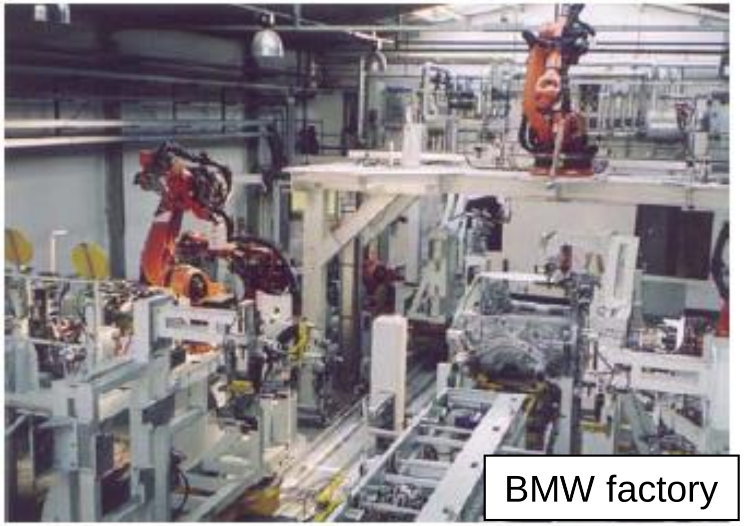
CAM Software

- NC software
  - NC is a system in which actions are controlled by direct insertion of numerical data at some point. The system must automatically interpret at least some portion of this data

    - Electronic Industries Association (EIA)
  - Computer Numerical Control (CNC)

- Robot programming software
  - Selecting and positioning tools and work-pieces for NC machines

Hyundai factory



BMW factory

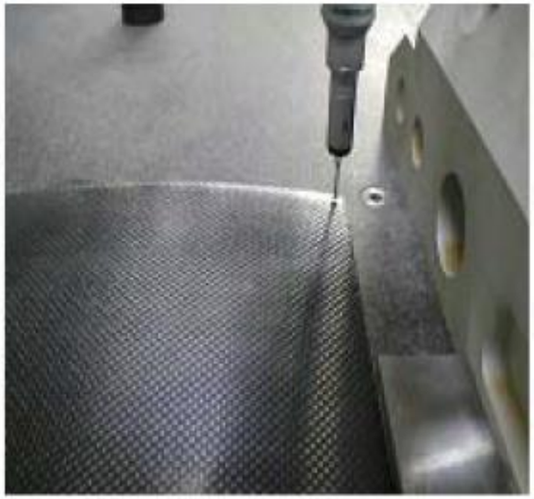
CAM Software (cont.)

- Process planning software
  - The act of preparing detailed work instructions to machine or assemble a part of parts

    - Computer-Aided Manufacturing, Chang et al., 1998
  - Process plan; operation sheet; route sheet
  - Computer-Aided Process Planning (CAPP)

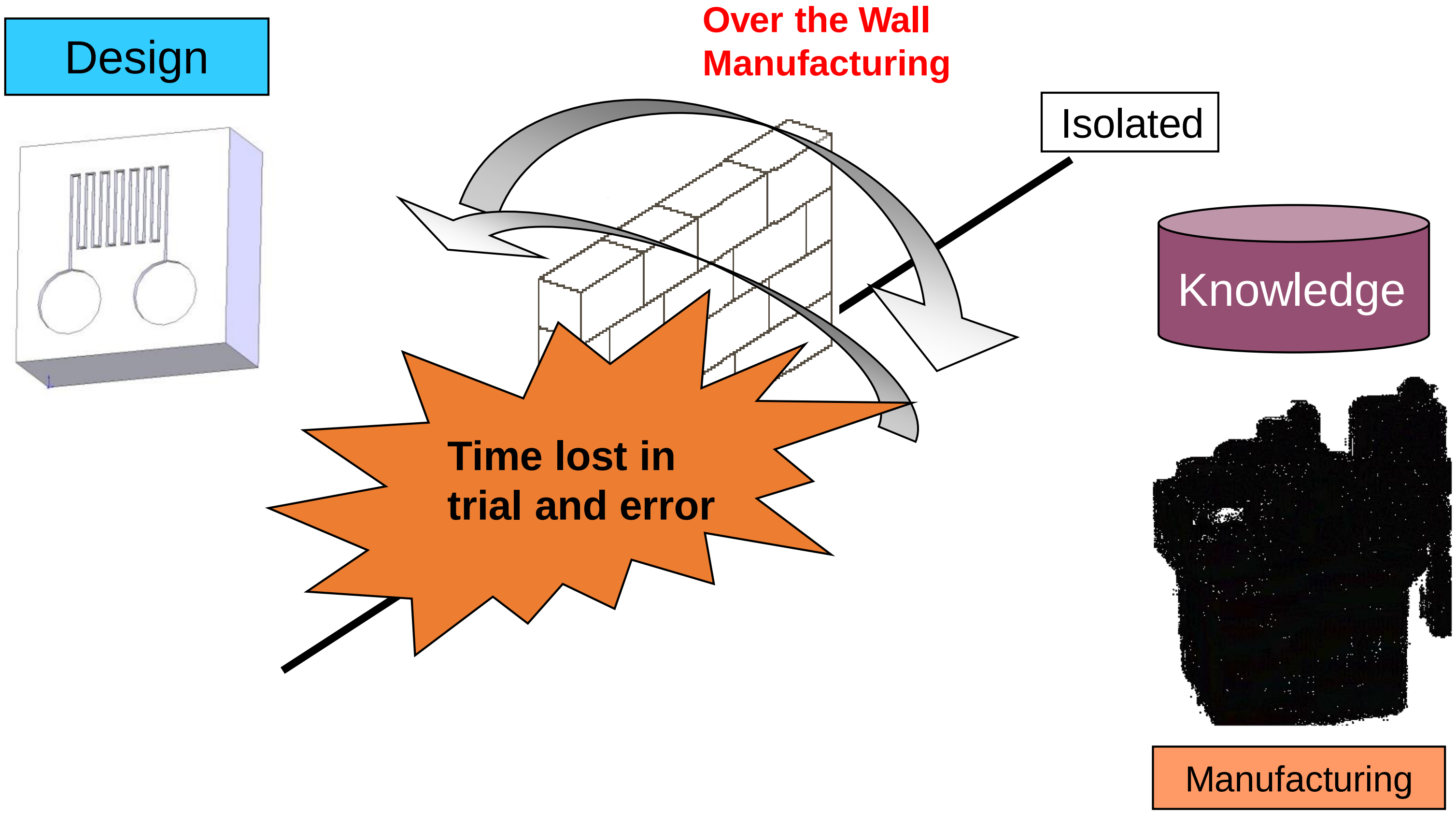
- Inspection software
  - Coordinate Measuring Machine (CMM)





Problems in Traditional Production

- Some barriers Between design and manufacturing process

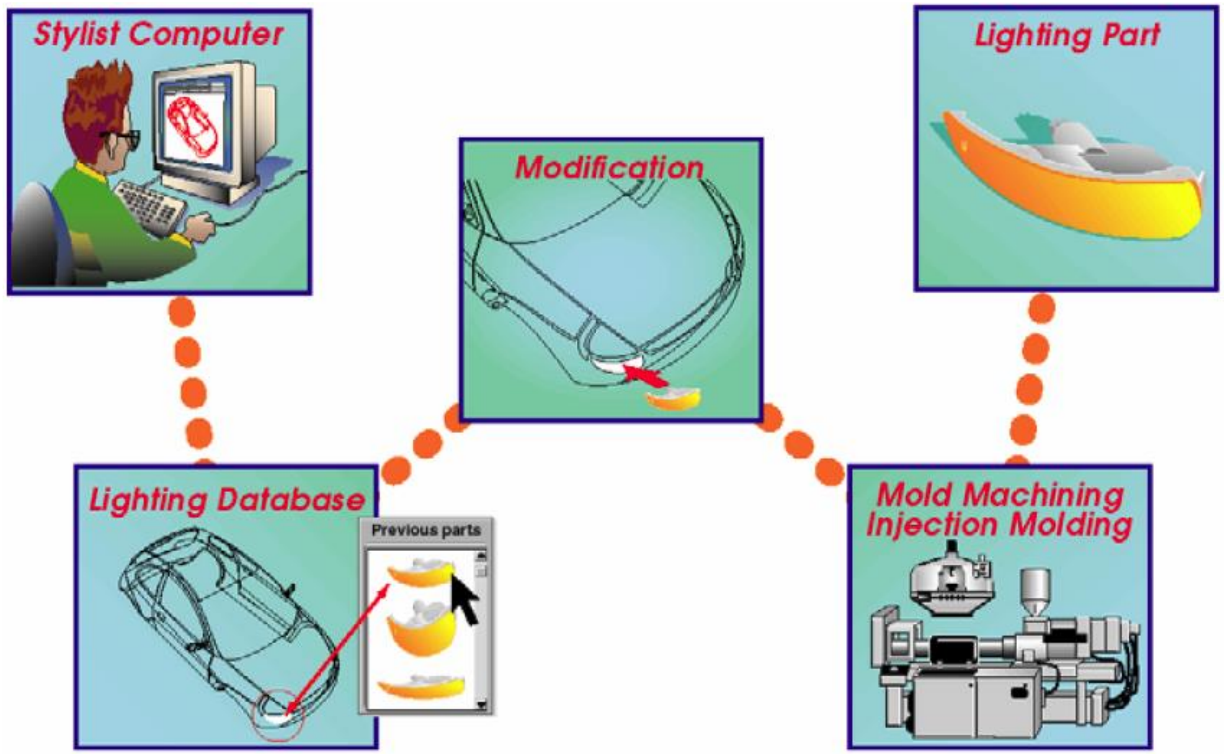


< Diagram of tradition design and manufacturing process >

CAD/CAM Integration

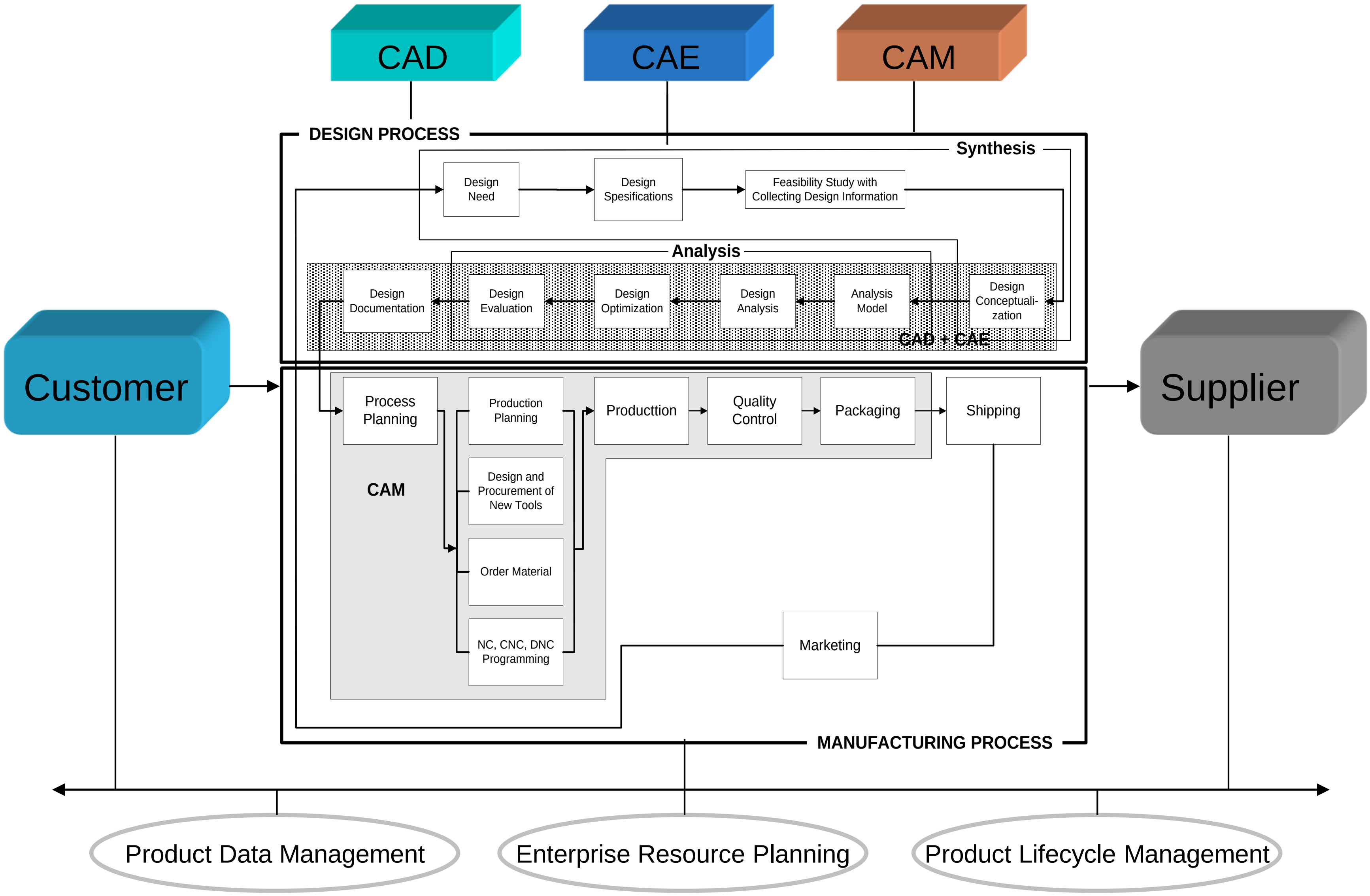
- Goal of integration
  - To facilitate coordination of work and information flow across organizational boundaries

– "Enterprise Integration Modeling", Charles J. Petrie, The MIT Press

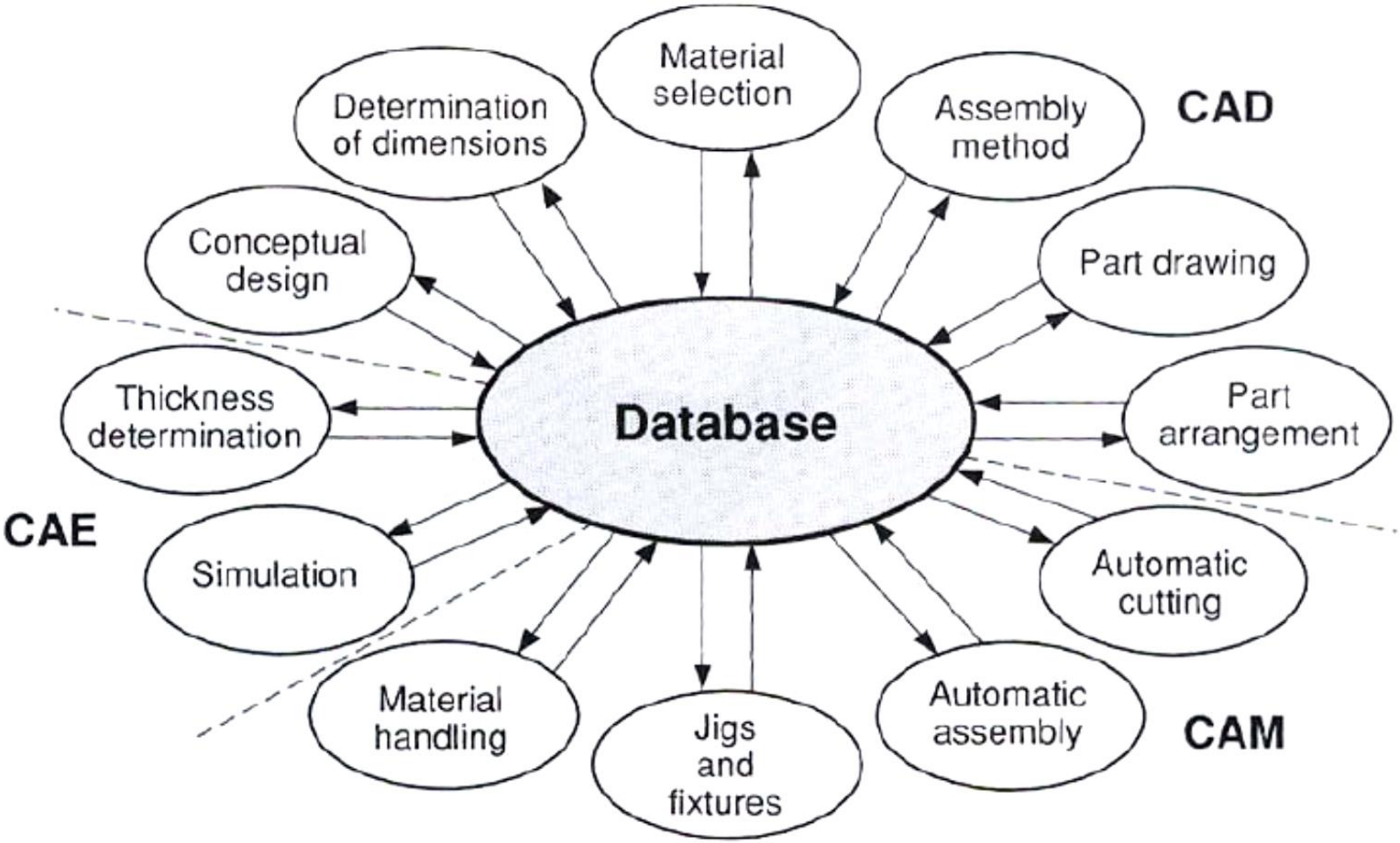


< Example concept of CAD/CAM integration >

Integration in Product Cycle Level



Integration in Database Level



Integration in Commercial Package Level

- Integrated CAD/CAE/CAM/PDM/…
- All in one package
  - Dassult systems: CATIA, DELMIA, INOVIA… SolidWorks, CosmosWorks…
  - PTC: Pro/Engineering, Windchill…
  - UGS: Unigraphics, Teamcenter, Technomatix…

Coupling Modes in Integration

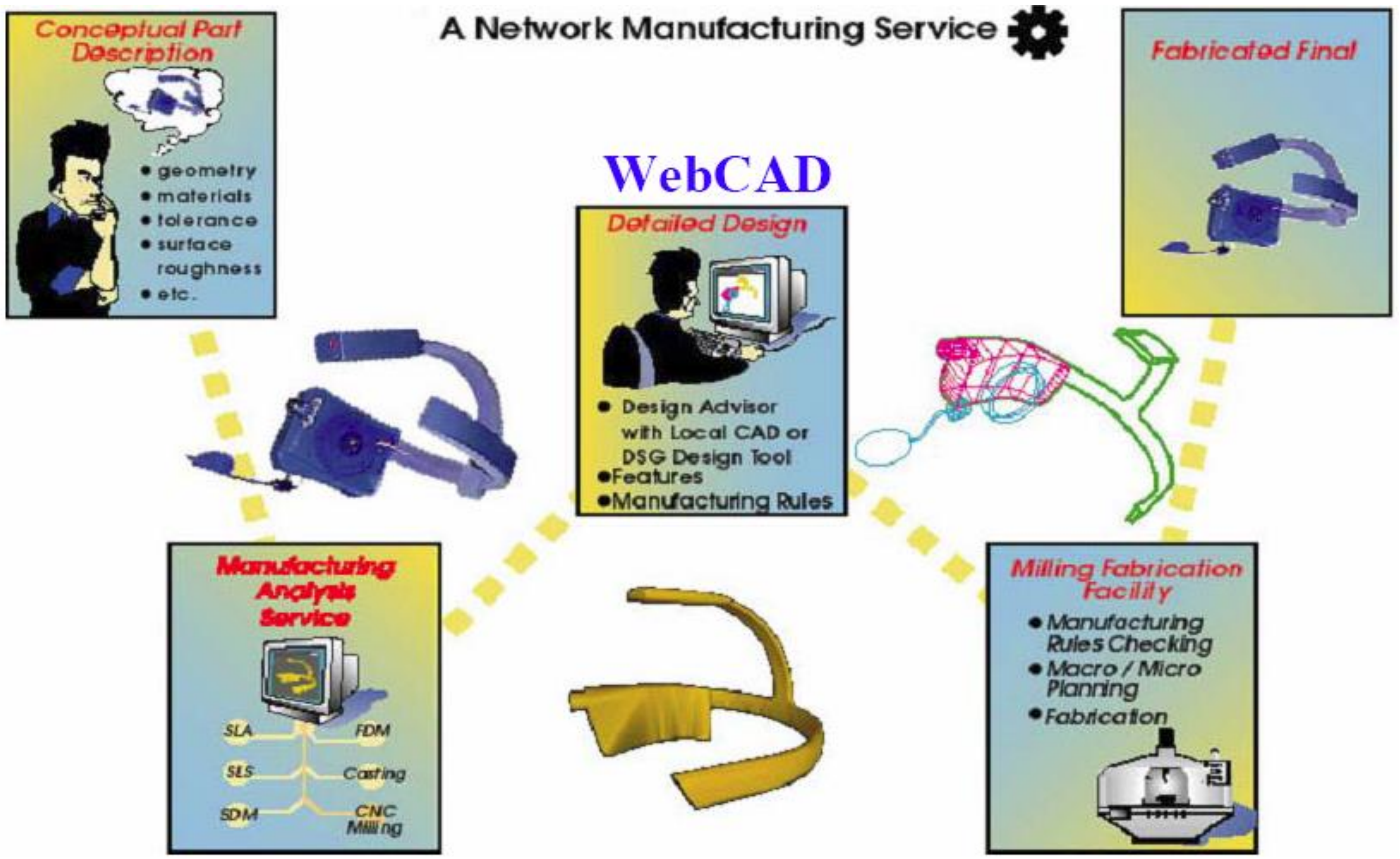
- There are 3 types of coupling modes between design and manufacturing

Coupling Mode	Pros	Cons	Example
Loose/ Repetitive	Flexible design	Cost & delay for redesign	Conventional CAD/CAM
Stiff/ One-way	Guaranteed Manufacturing	Less design freedom	CyberCut, MOSIS
Strong/ Bidirectional	Moderately flexible design, guaranteed manufacturing	Some loss of design freedom	SmartLite, SmartFab

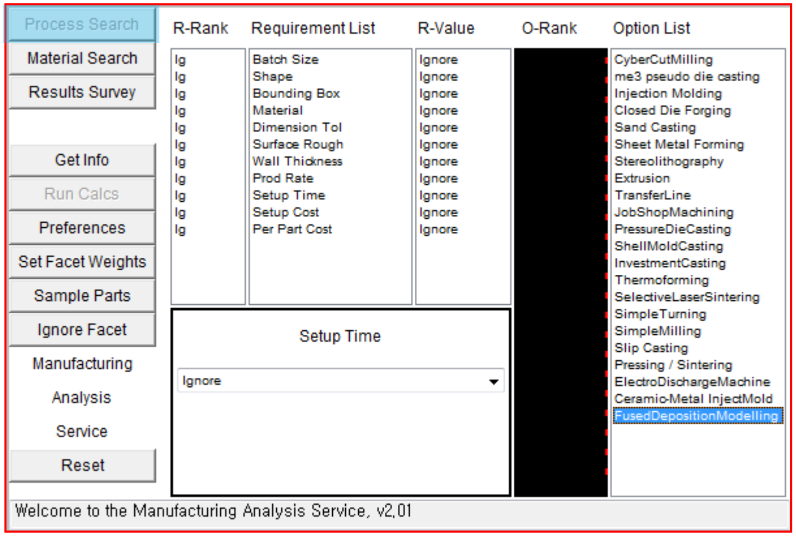
Reference: Ahn, S. H., McMains, S., Sequin, C. S., and Paul K. Wright*, 2002, "Mechanical Implementation Services for Rapid Prototyping," Journal of Engineering Manufacture, Proceedings of the Institution of Mechanical Engineers Part B, Short Communications in Manufacture and Design, Vol. 216, pp. 1193-1199, August (SCI, 0.281).

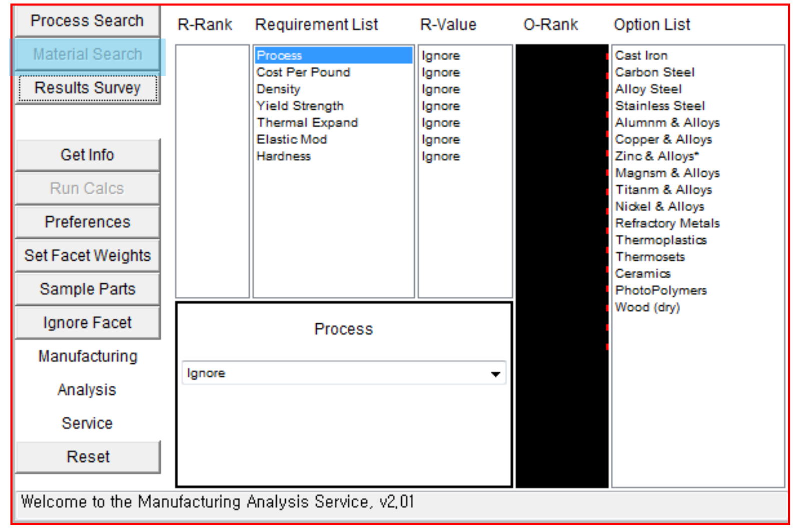
Example Solutions of Stiff mode

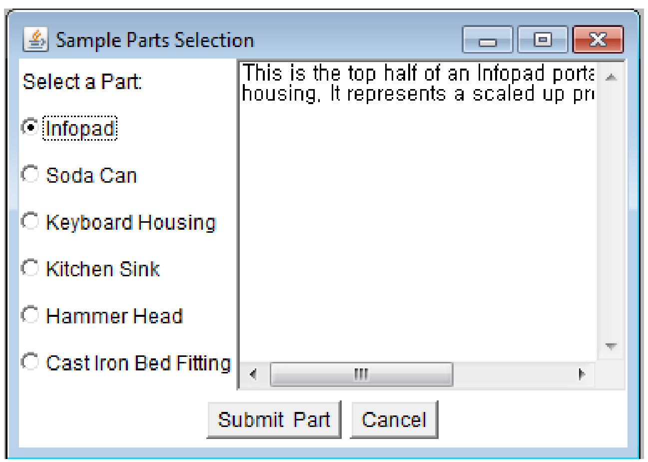
- CyberCut paradigm

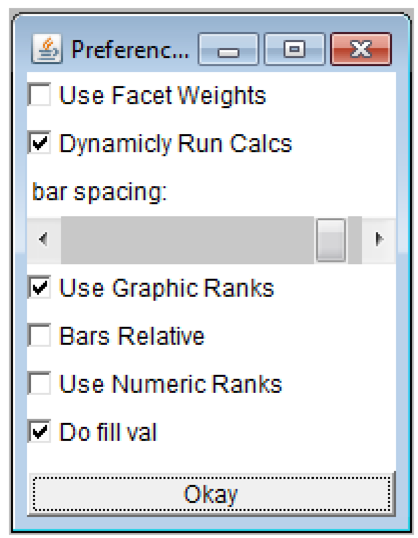


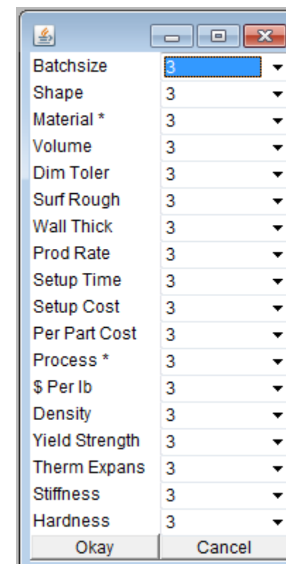
Manufacturing Advisory Service (MAS)











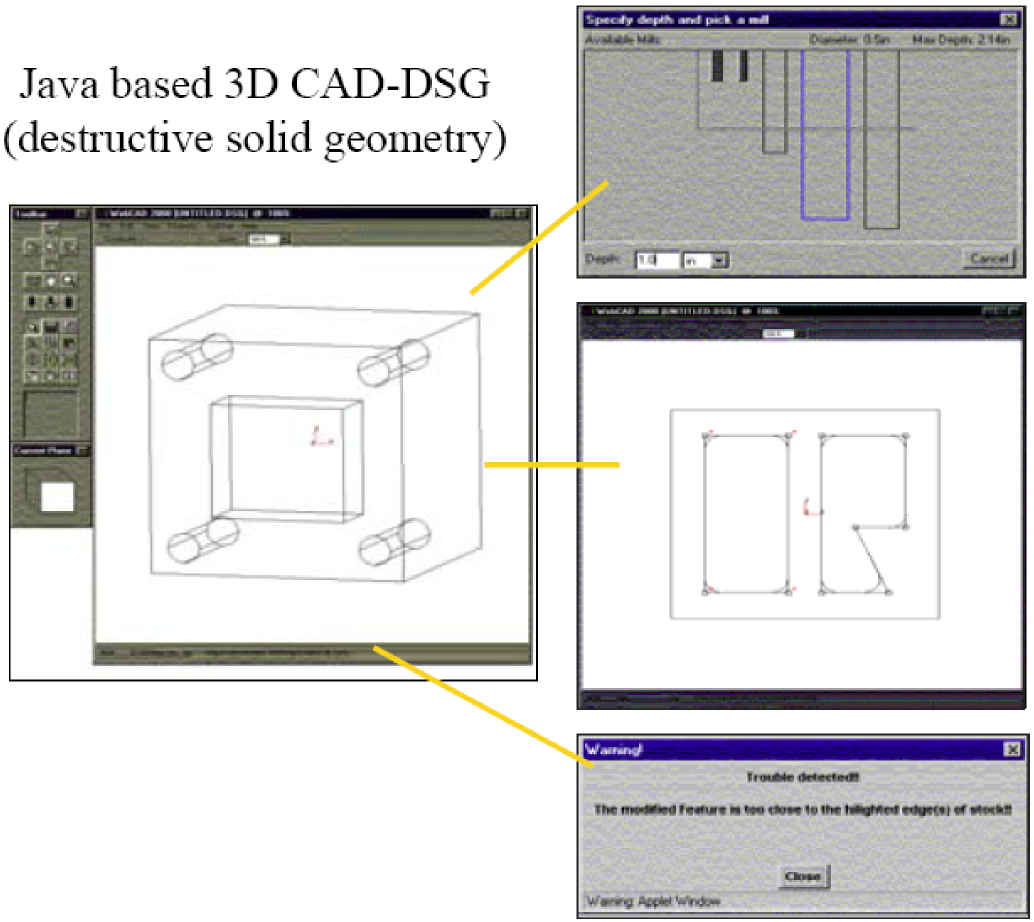
Charles Smith, 1999, "The Manufacturing Advisory Service: Web Based Process and Material Selection," Ph.D. thesis, UC Berkeley.

http://dfm.snu.ac.kr/mas/index.html

Example Solutions of Stiff mode (cont.)

- CyberCut – Feature 1. WebCAD

Java based 3D CAD-DSG
(destructive solid geometry)



DFM paradigm

1. Tool diameter & Depth

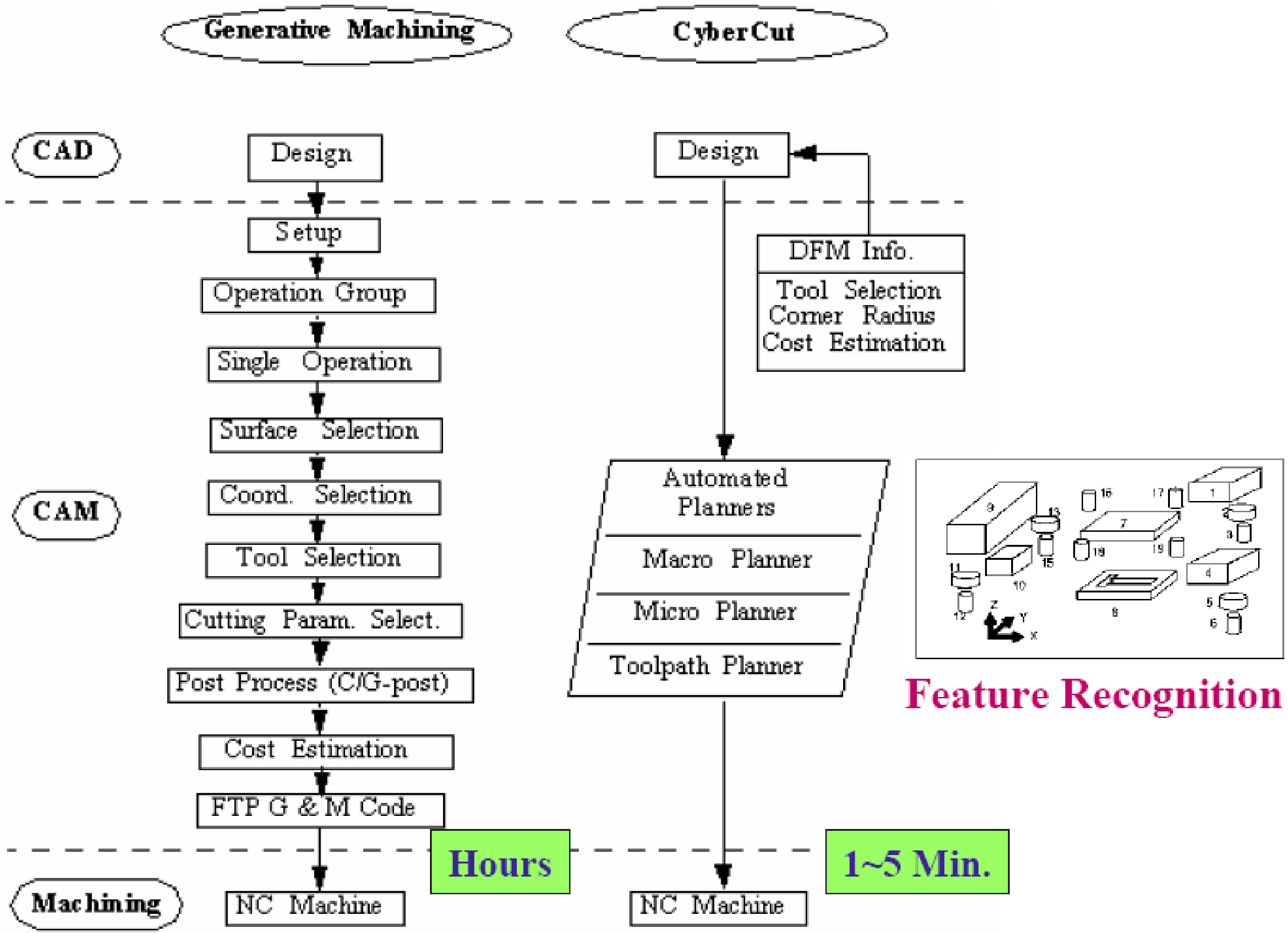
2.WYSIWYG:
Corner radius

3.Design Rule Checker

Ahn, S. H., Sundararajan, V., Smith, C. E., Kannan, B., D'Souza, R., Sun, G., Kim, J., McMains, S., Smith, J., Mohole, A., Sequin, C. H., and Wright, P. K., 2001, "CyberCut : An Internet Based CAD/CAM System," ASME Journal of Computing and Information Science in Engineering, 1, pp. 52-59.

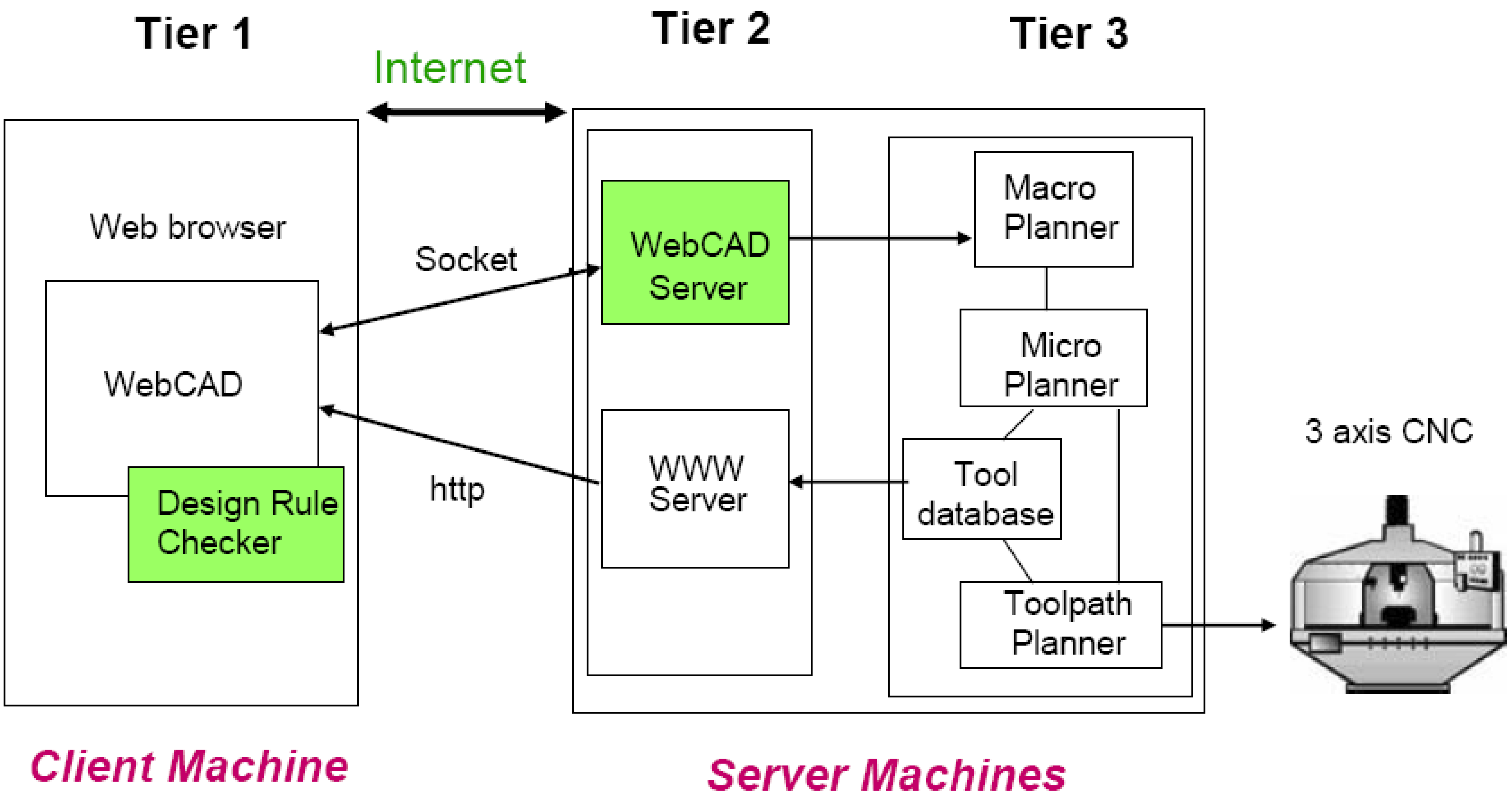
Example Solutions of Stiff mode (cont.)

- CyberCut – Feature 2. Automated Process Planning



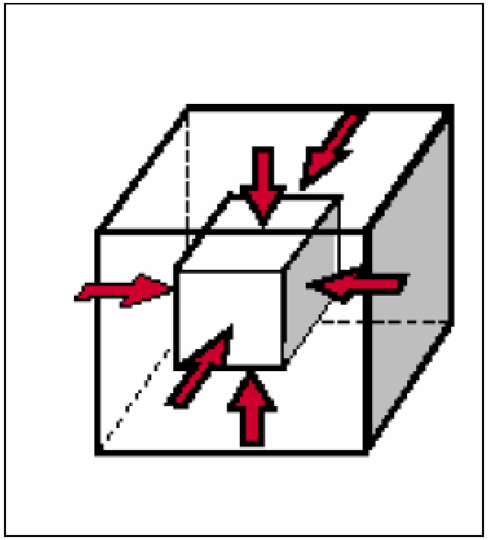
Example Solutions of Stiff mode (cont.)

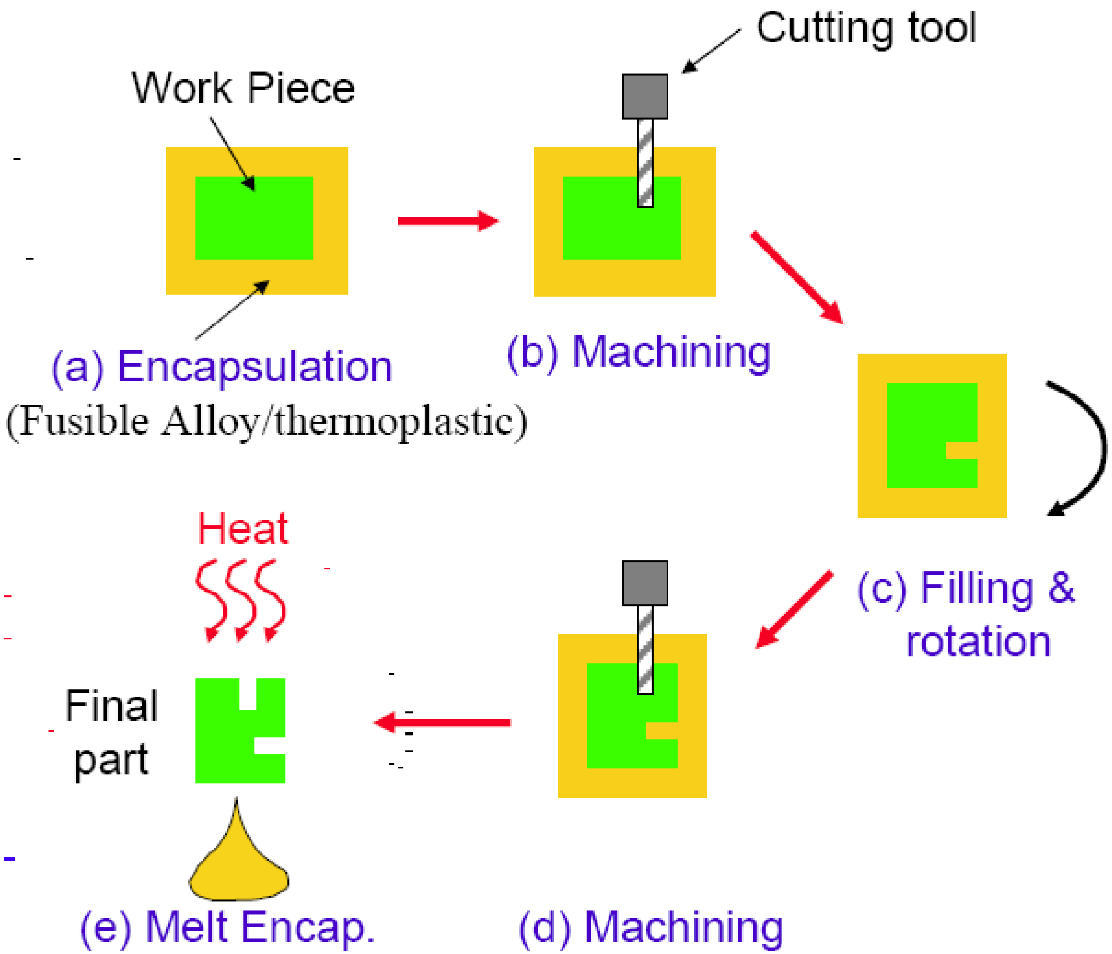
- CyberCut – Network communication



Example Solutions of Stiff mode (cont.)

- CyberCut – Feature 3. Universal fixture

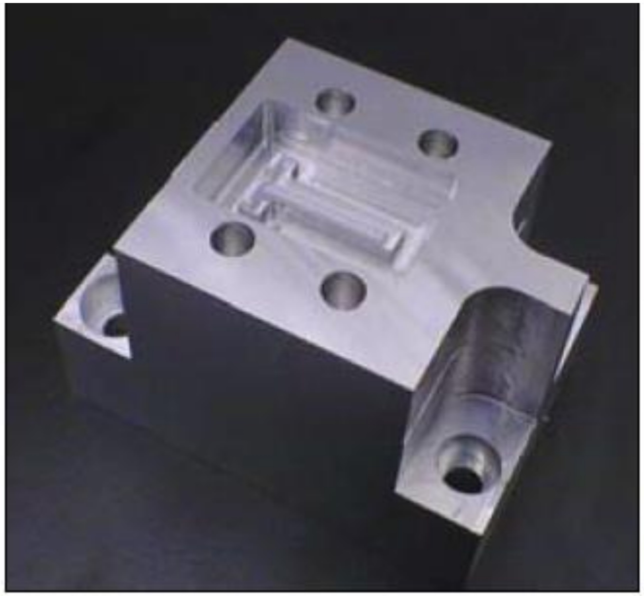


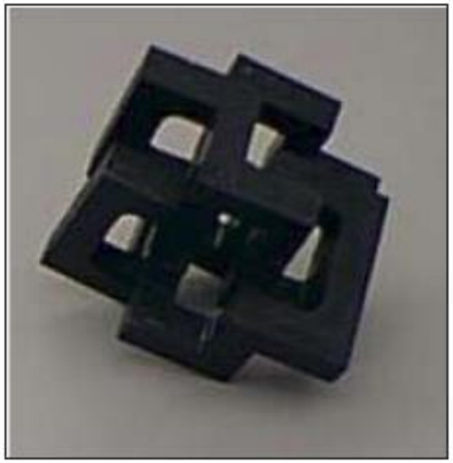


Ahn, S. H. and Paul K. Wright, 2002, "Reference Free Part Encapsulation (RFPE): An Investigation of Material Properties and the Role of RFPE in a Taxonomy of Fixturing Systems," Journal of Manufacturing Systems, Society of Manufacturing Engineers, Vol. 21, No. 2, pp. 101-110, November (SCIE).

Example Solutions of Stiff mode (cont.)

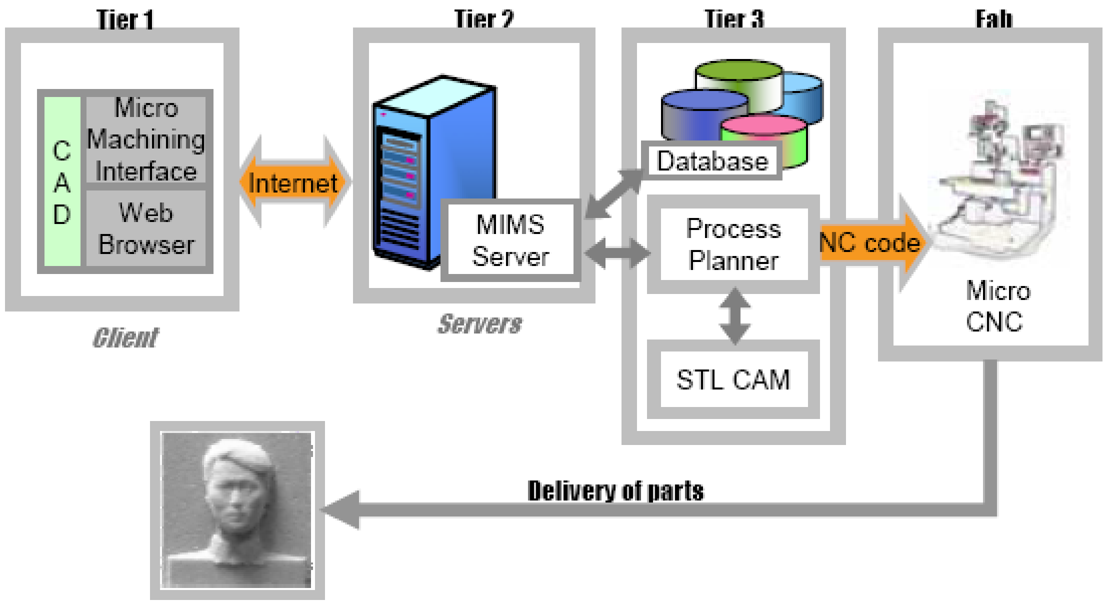
- CyberCut – Fabricated parts



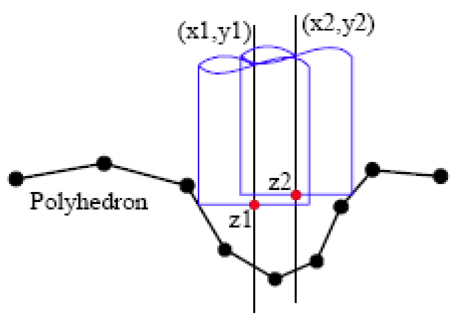


Web-based CAD/CAM Integration

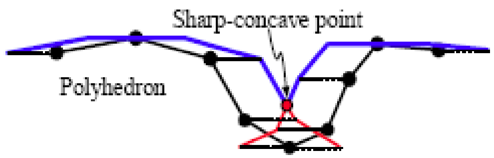
- Micro Machining System (MIMS)
  - Micro machining service using the internet
  - Communication with 3-tier client-server model
  - Upload STL file



< Communication architecture >



< Point-based Approaches >

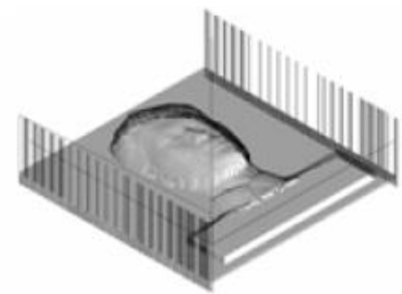


< Curve-based approaches >

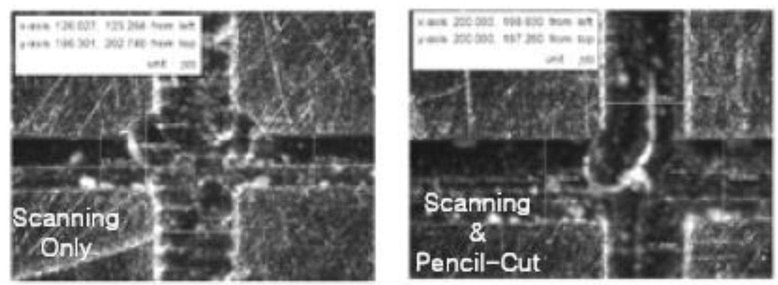
Ahn, S. H.*, Kim, Dong-Soo, Chu, W. S., and Jun, Cha-Soo, 2005, "MIMS: Web-based Micro Machining Service," International Journal of Computer Integrated Manufacturing, Taylor & Francis Ltd. (England), Vol. 18, No. 4, pp. 251-259, June (SCIE, IF 0.722, DOI: 10.1080/09511920400030187, ISSN: 0951-192X).

Web-based CAD/CAM Integration (cont.)

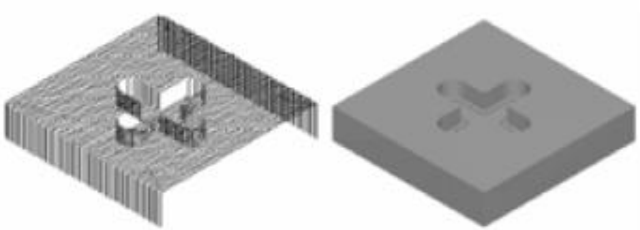
- Micro Machining System (MIMS)
  - Provide the NC code viewer
  - Fabricated by micro-endmill according to scanning and pencil-cut toolpath



< G&M Codes on NC code Viewer >

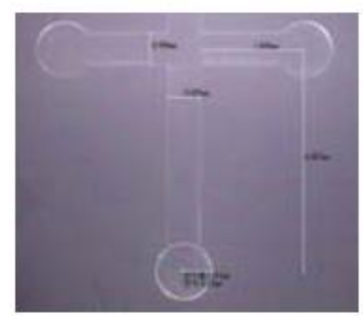


< Micro channel>



< Two Types of Toolpath >

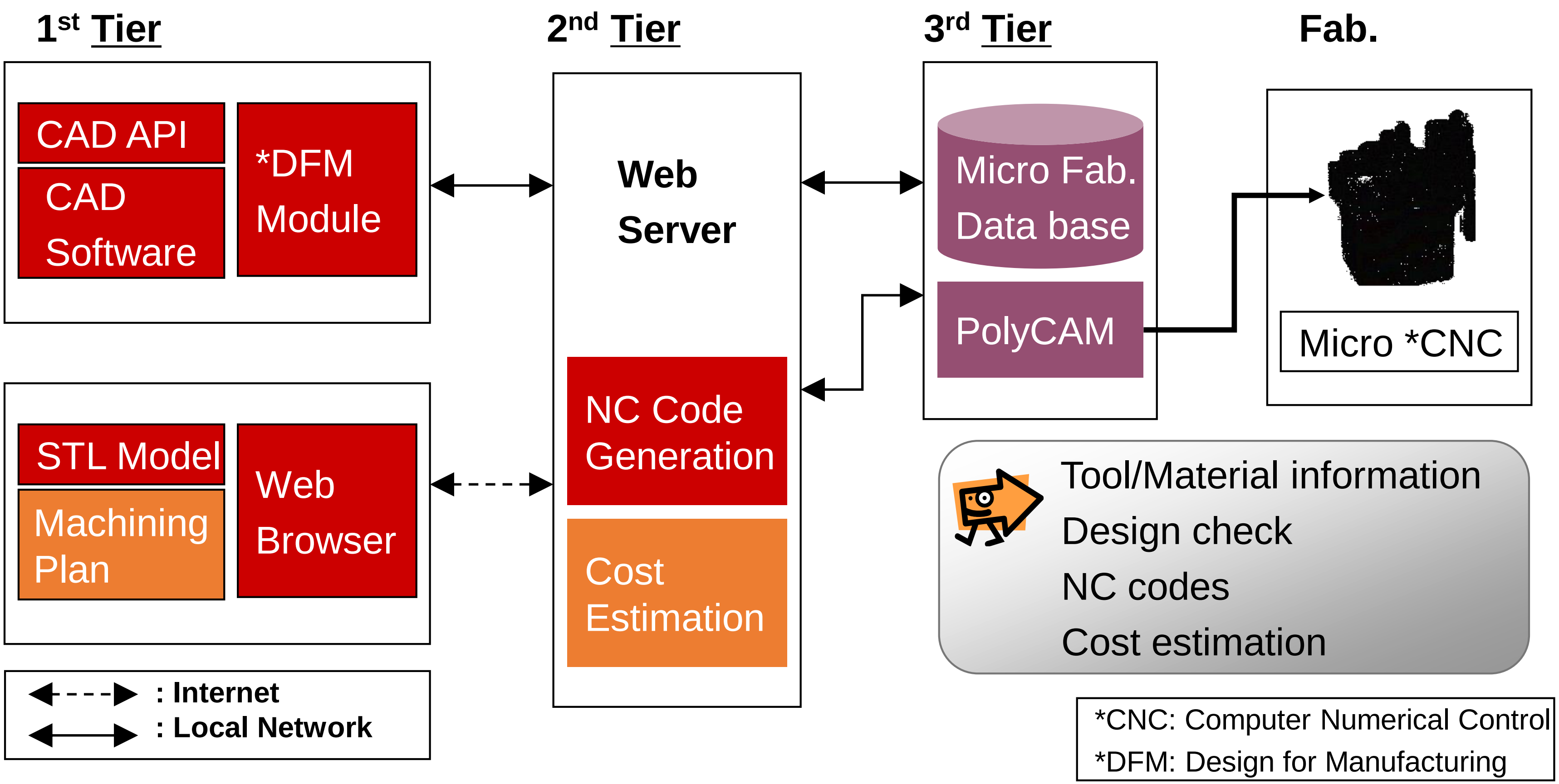
< 3D Scanned Head >



< Micro Fluidic Channel >

Web-based CAD/CAM Integration (cont.)

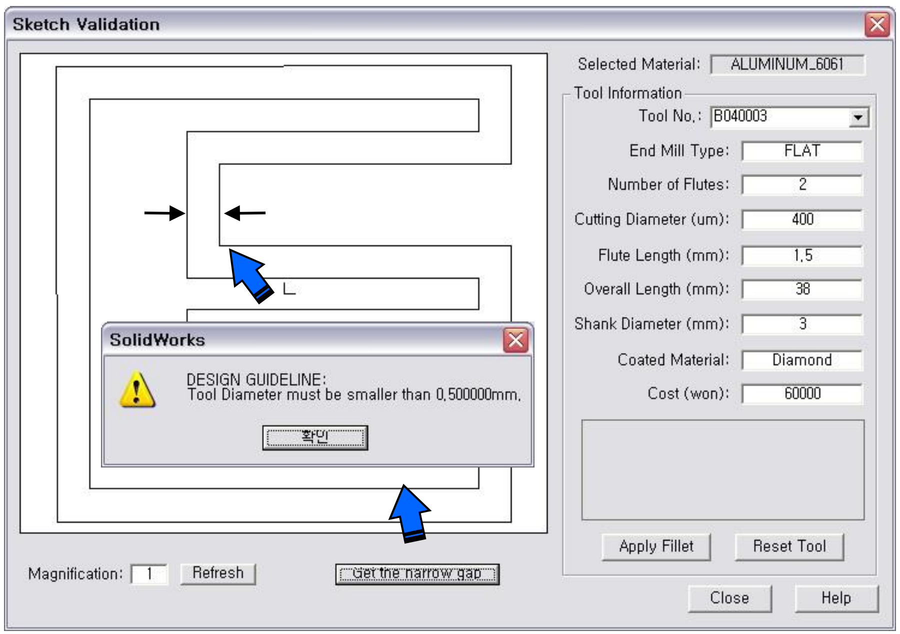
- SmartFab
  - Micro machining using SolidWorks



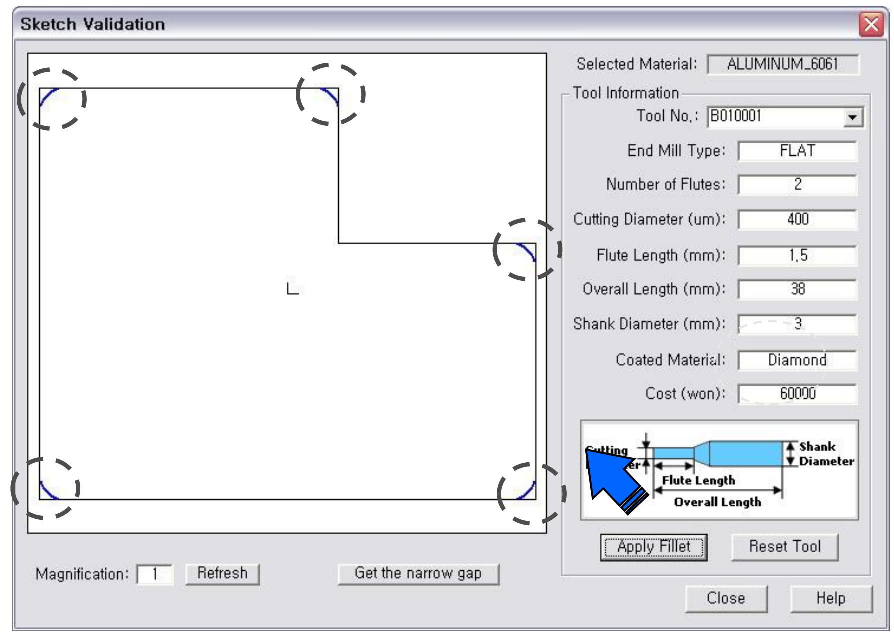
< Architecture of SmartFab >

Web-based CAD/CAM Integration (cont.)

- SmartFab – Sketch validation
  - Improve machinability
  - Based on the tool information and DFM philosophy



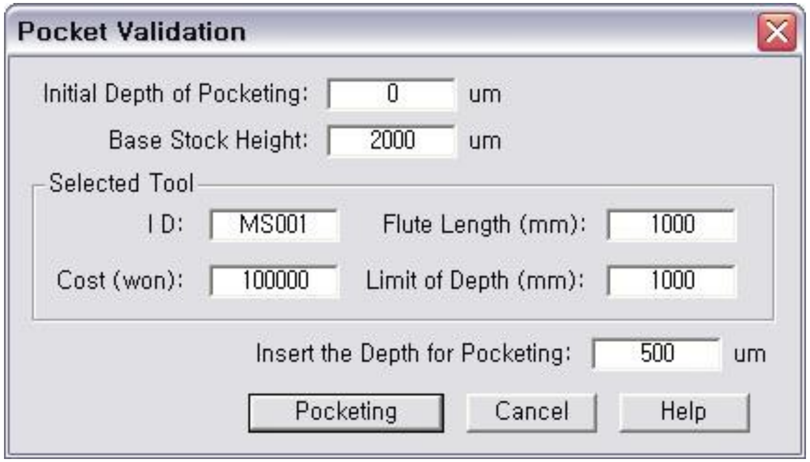
< Check for minimum Gap >

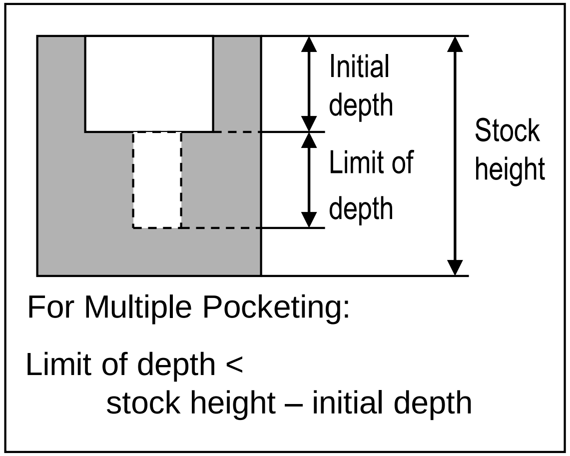


< Check for fillet >

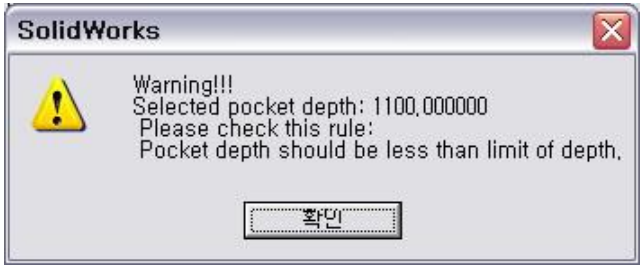
Web-based CAD/CAM Integration (cont.)

- SmartFab – Pocket validation

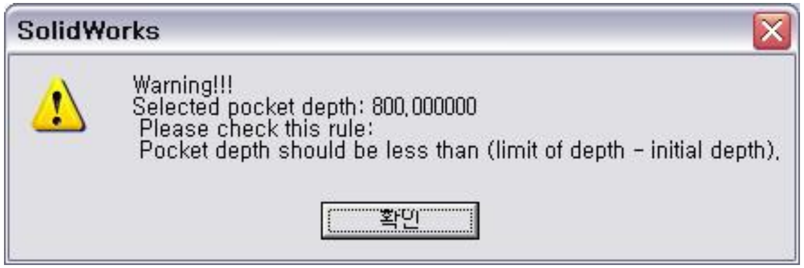




< DFM in pocketing >



Case I. Depth limit



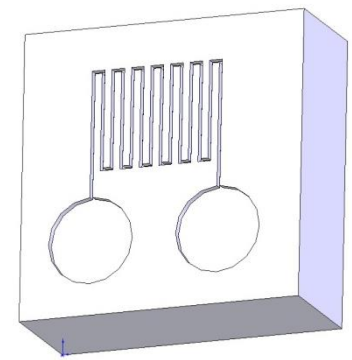
Case II. Depth limit and initial depth

Web-based CAD/CAM Integration (cont.)

- SmartFab – Cost estimation

Cost Estimation Service — Calculate

1. Cw (Workpiece cost)	20
2. Cp (Preparaton cost)	875
3. Cm (Machining cost)	11275
4. Cn (Nonproductive cost)	0
Total cost (Ctotal = Cw + Cp + Cm + Cn) is	12170 (won)



Cp = Tp*W

Tp: Preparation time (0.35 hr)
W : Operator's wage (2500/hr)

Cm = Com+Ct = Tm*W+Ct

Tm: Machining time (0.41 hr)
W: Operator's wage (2500/hr)

Ct = y*(Tm/T) **(11,275 won, 92% of total cost)**

Ct: Tool usage cost
T: Tool life (4 hr)
y: tool cost (100,000)

Manufacturing Advisory Service (MAS)

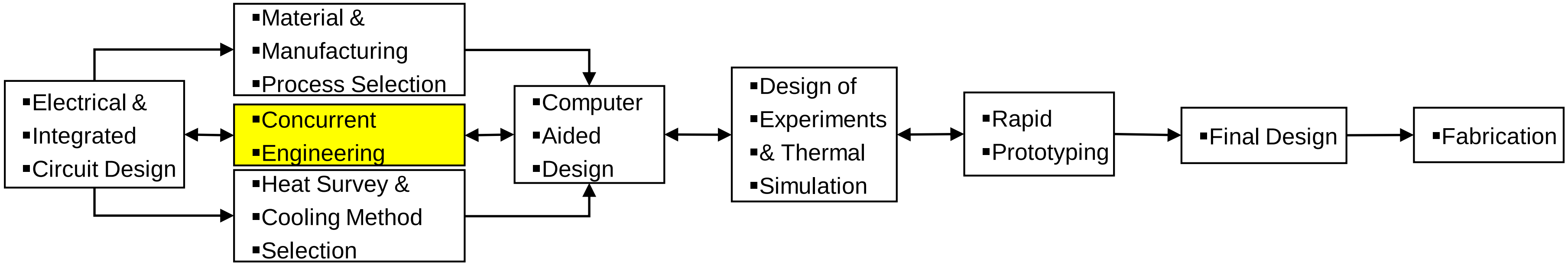
- Concept level manufacturing and
- Material selection tool
  - For educating designers
  - Informing experienced designers about new tech

Enquires about

- Batch size
- Typical tolerances
- Size
- Overall shape
- Cost requirements

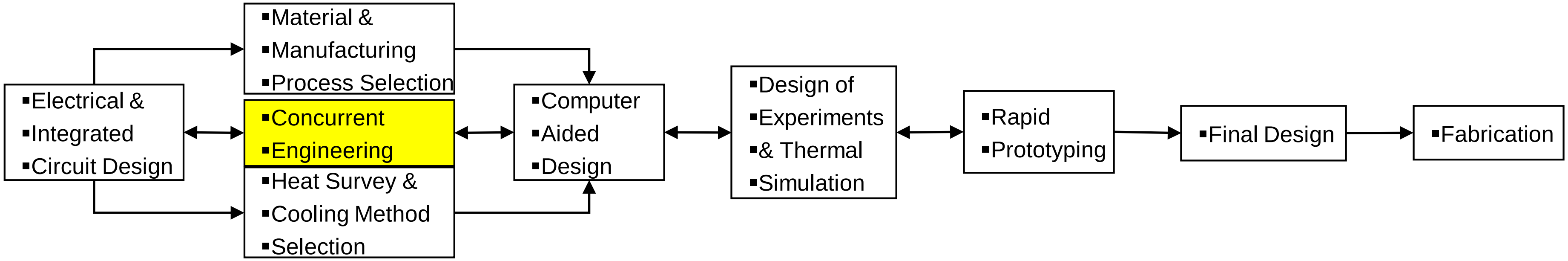
Concurrent Engineering

- DUCADE, Domain Unified CAD Environment, is a web enabled collaborative management system that aids the concurrent design process of electronic printed circuit boards and mechanical enclosures

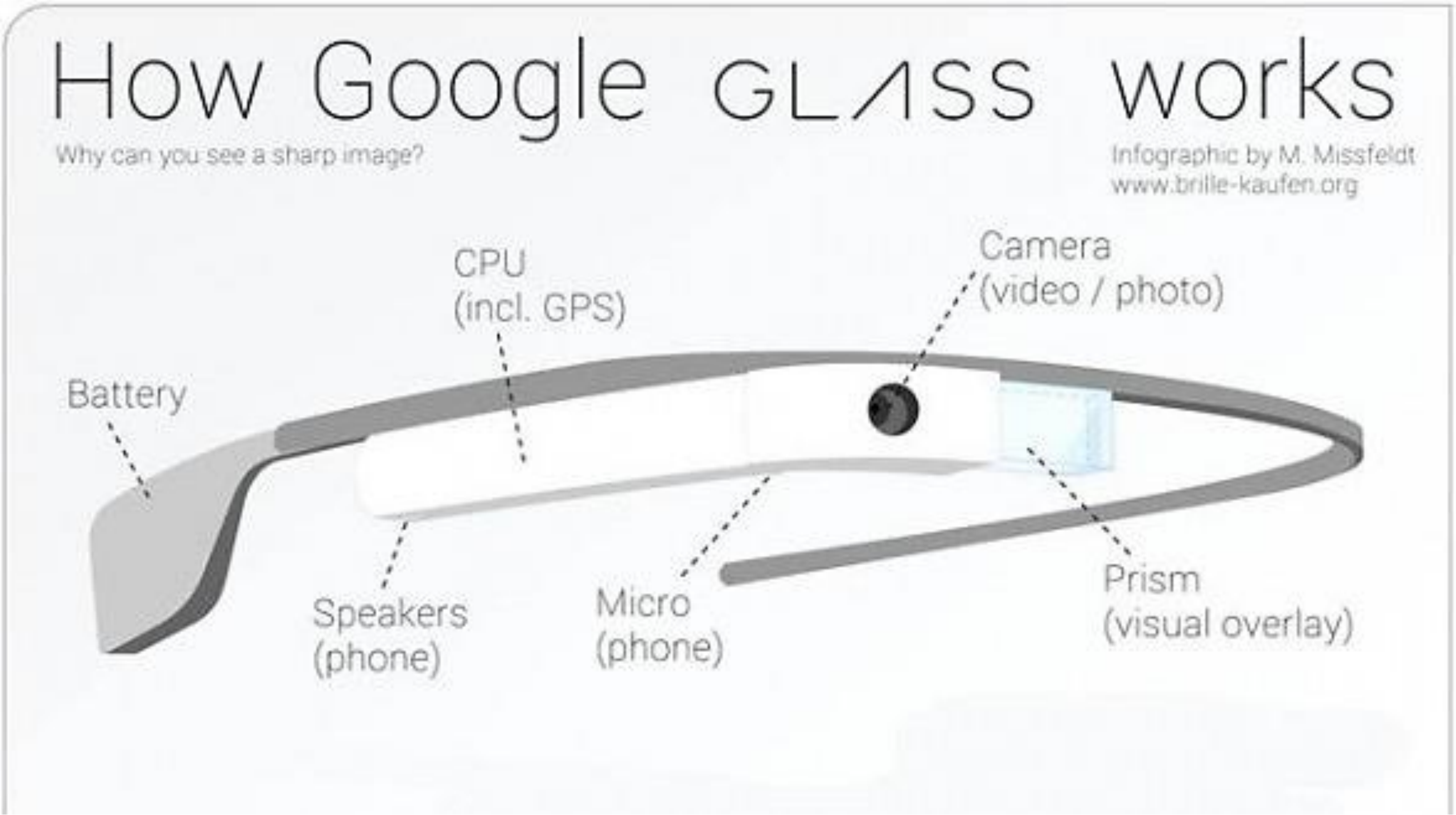


DUCADE

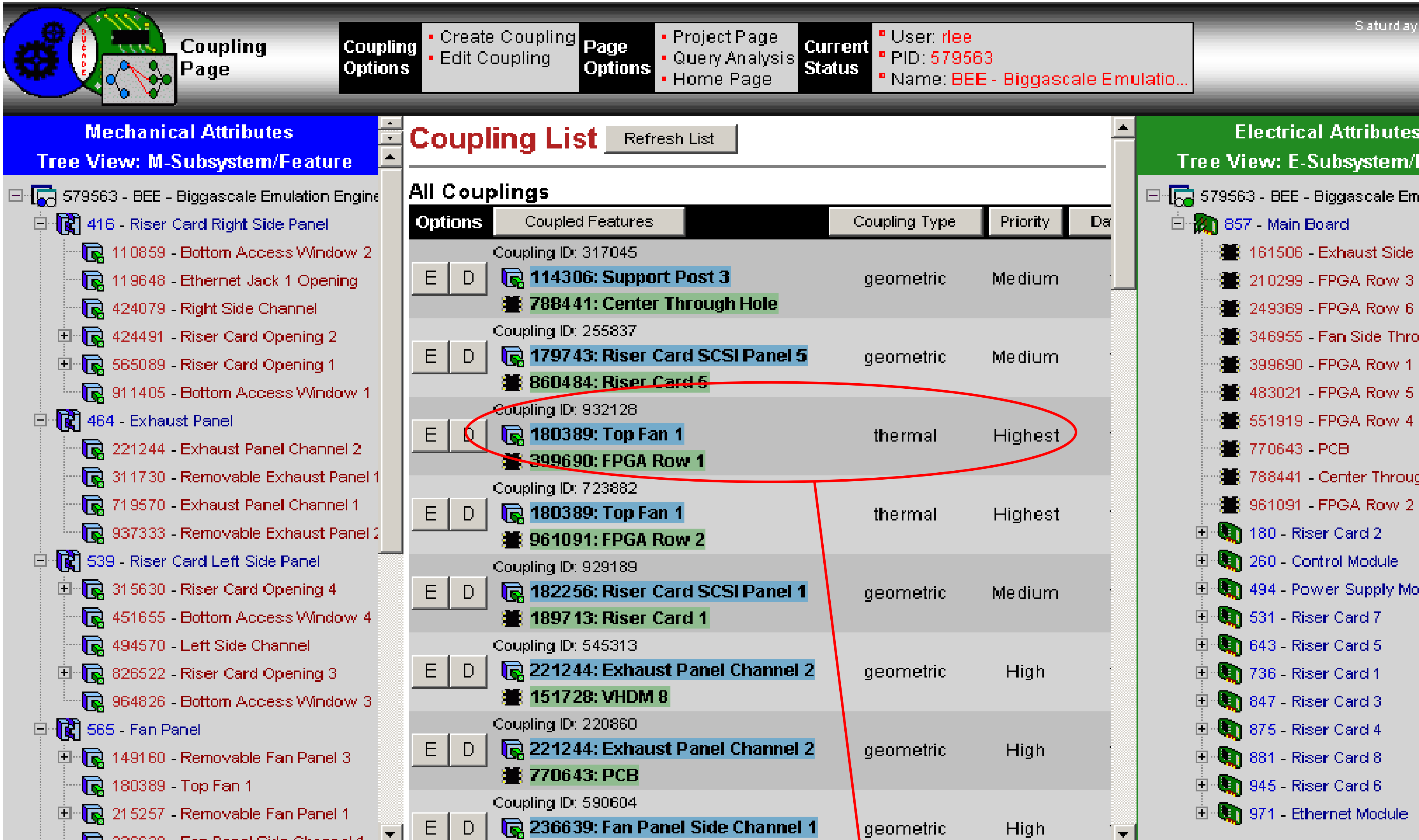
- Tracks couplings between mechanical and electrical features over the life cycle of the product
- Gives feedback to designers when feature properties (size, location, etc.) are altered and coupling criteria are violated
- Compiles history of design changes from both domains



Example (Google glass)



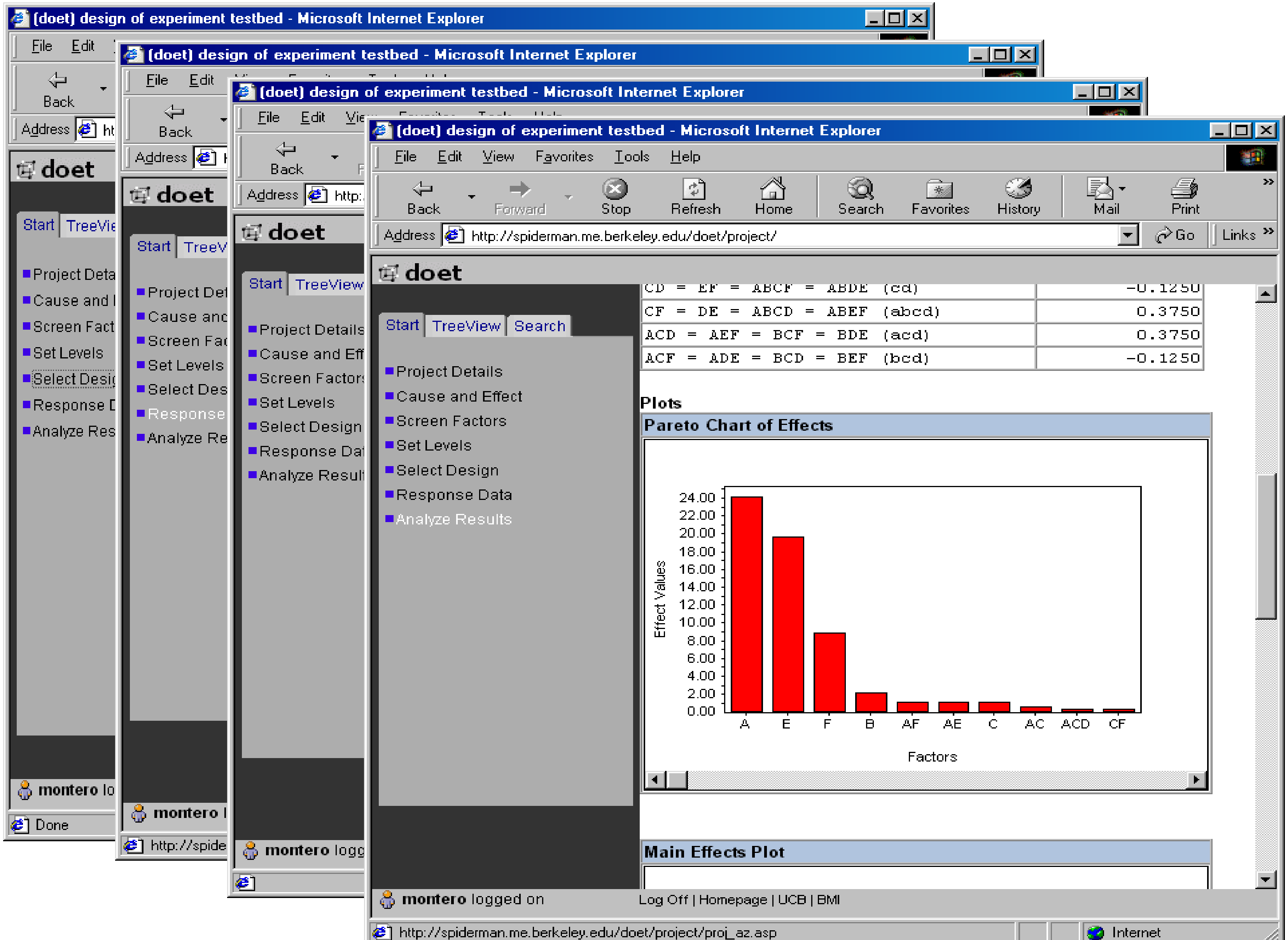
BEE Couplings



Thermal constraint

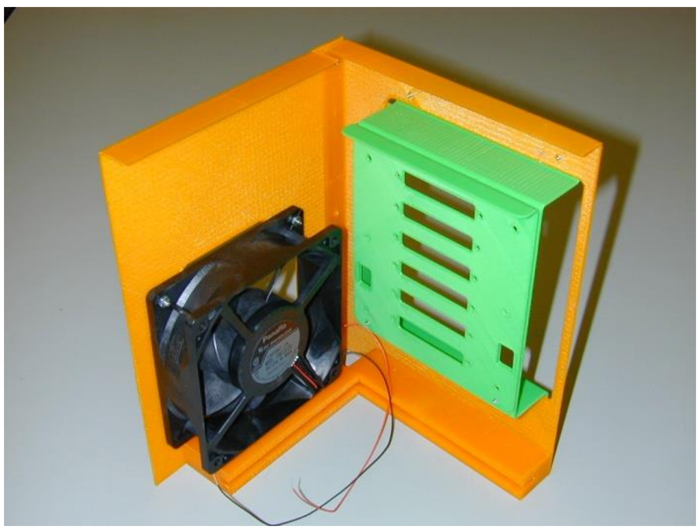
Michael Montero, 2004, "A proposed methodology for the design of electronic-mechanical products," Ph.D. thesis, UC Berkeley.

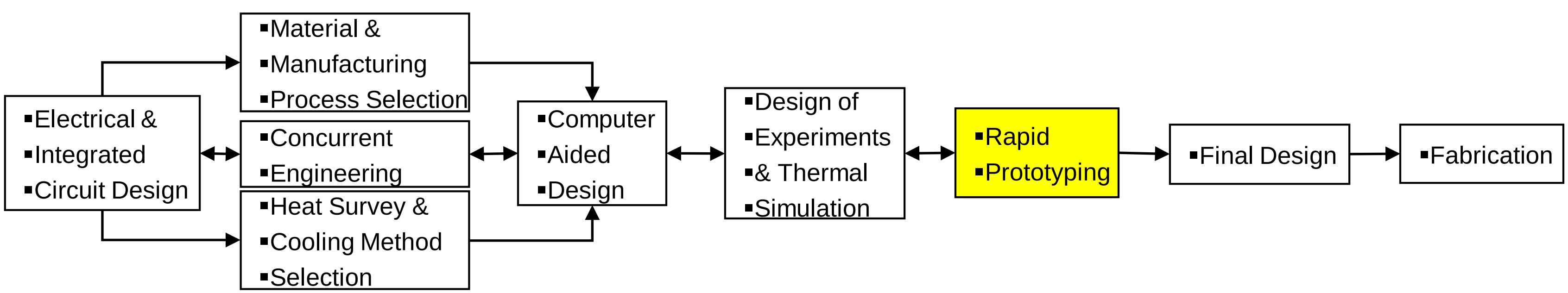
Design of Experiments Testbed (DOET)



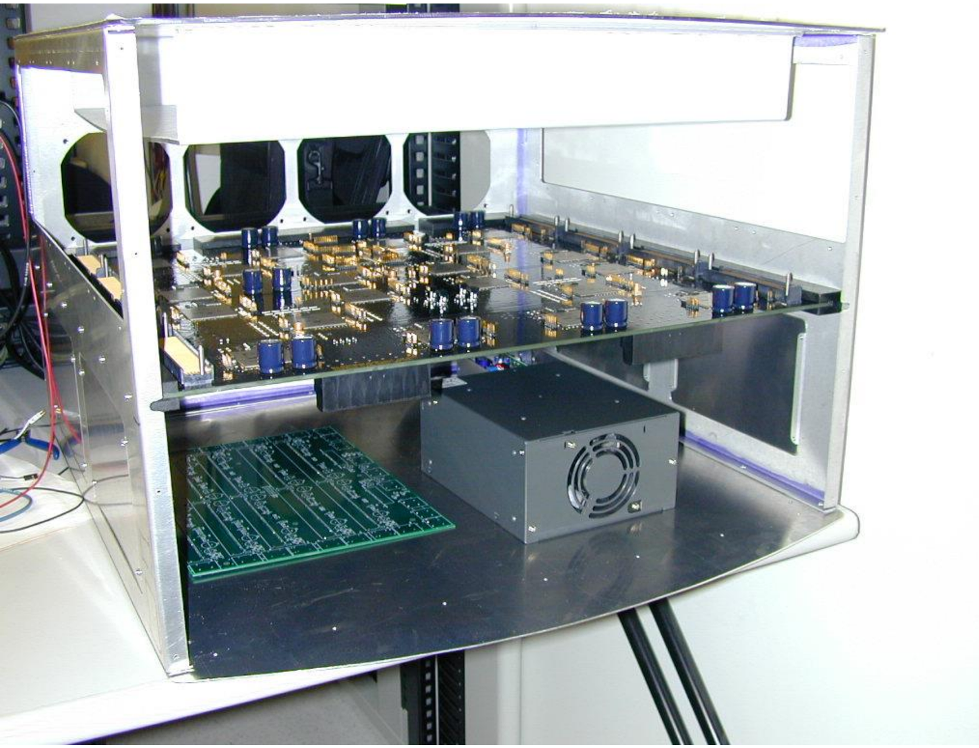
Rapid Prototyping

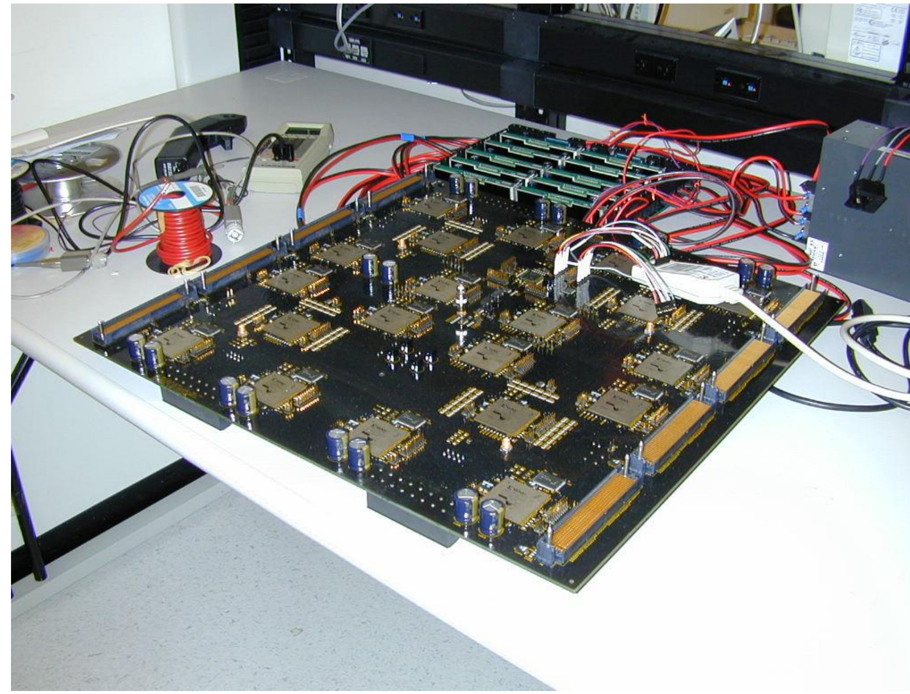
- Clearance and fit between electrical components and mechanical package can be verifed
- Functionality and structural strength of package can also be tested

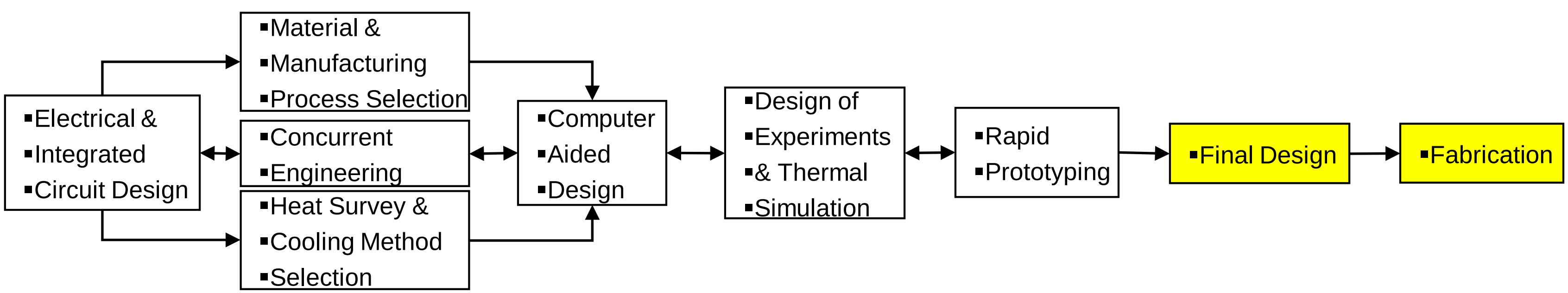




Final design and Fabrication







Broad Integration

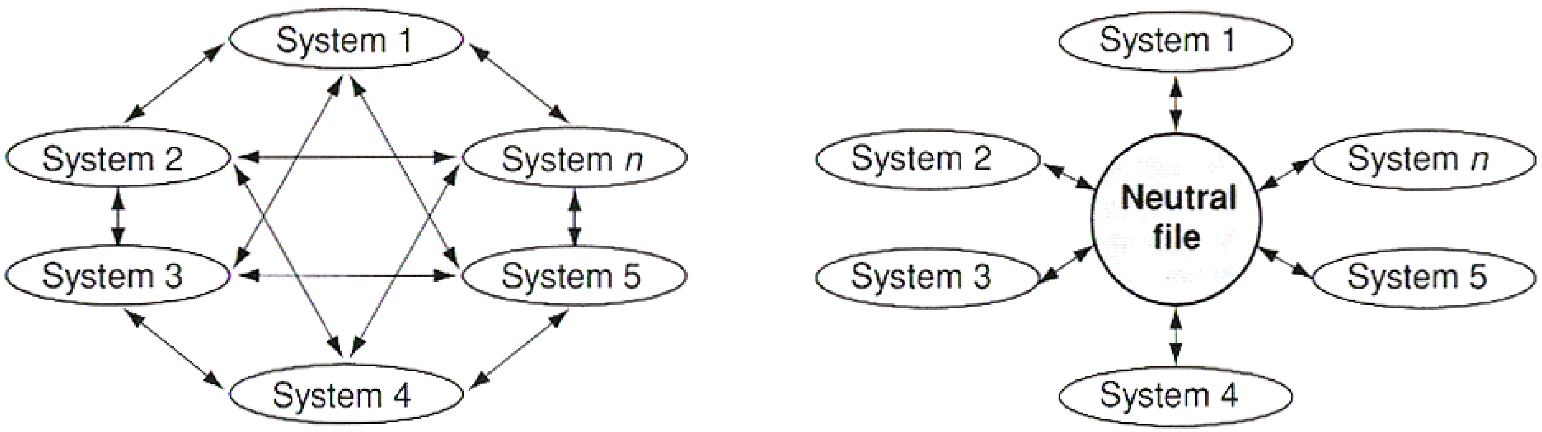
- PDM (Product Data Management)
  - Control CAD file revisions
  - Manage all data related to project

- PLM (Product Life-cycle Management)
  - Product Development Management (PDM)
  - Include all actors (company departments, business partners, suppliers, OEM, and customers)
  - Share product data
  - Apply common processes
  - Leverage corporate knowledge

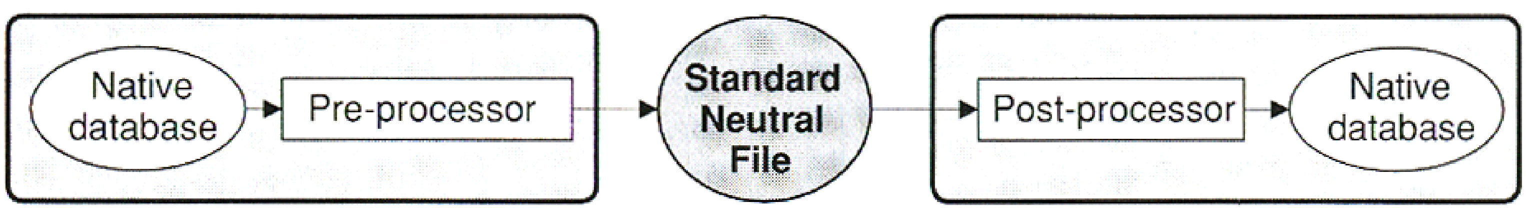
Data Exchange

- Standard formats for data exchange
  - IGES (Initial Graphics Exchange Specification)
    - 3D CAD data
  - STEP (Standard for the Exchange of Product model data)
  - DFX (Drawing eXchange Format)
    - 2D drawing data
  - STL (Stereo Lithography)
    - De facto standard in rapid prototyping
  - VRML (Virtual Reality Modeling Language)
    - 3D model on web

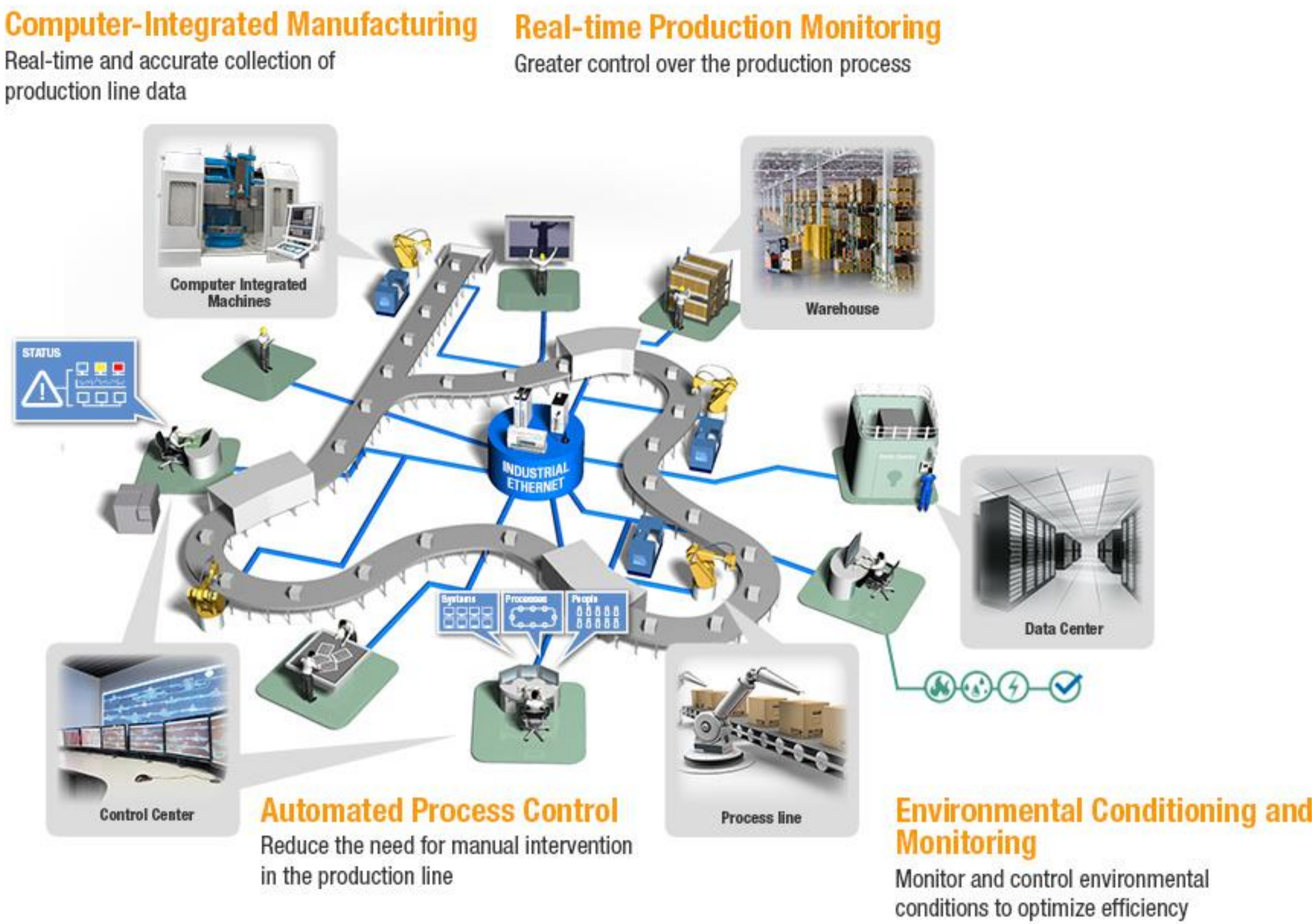
Data Exchange (cont.)



(a) (b)

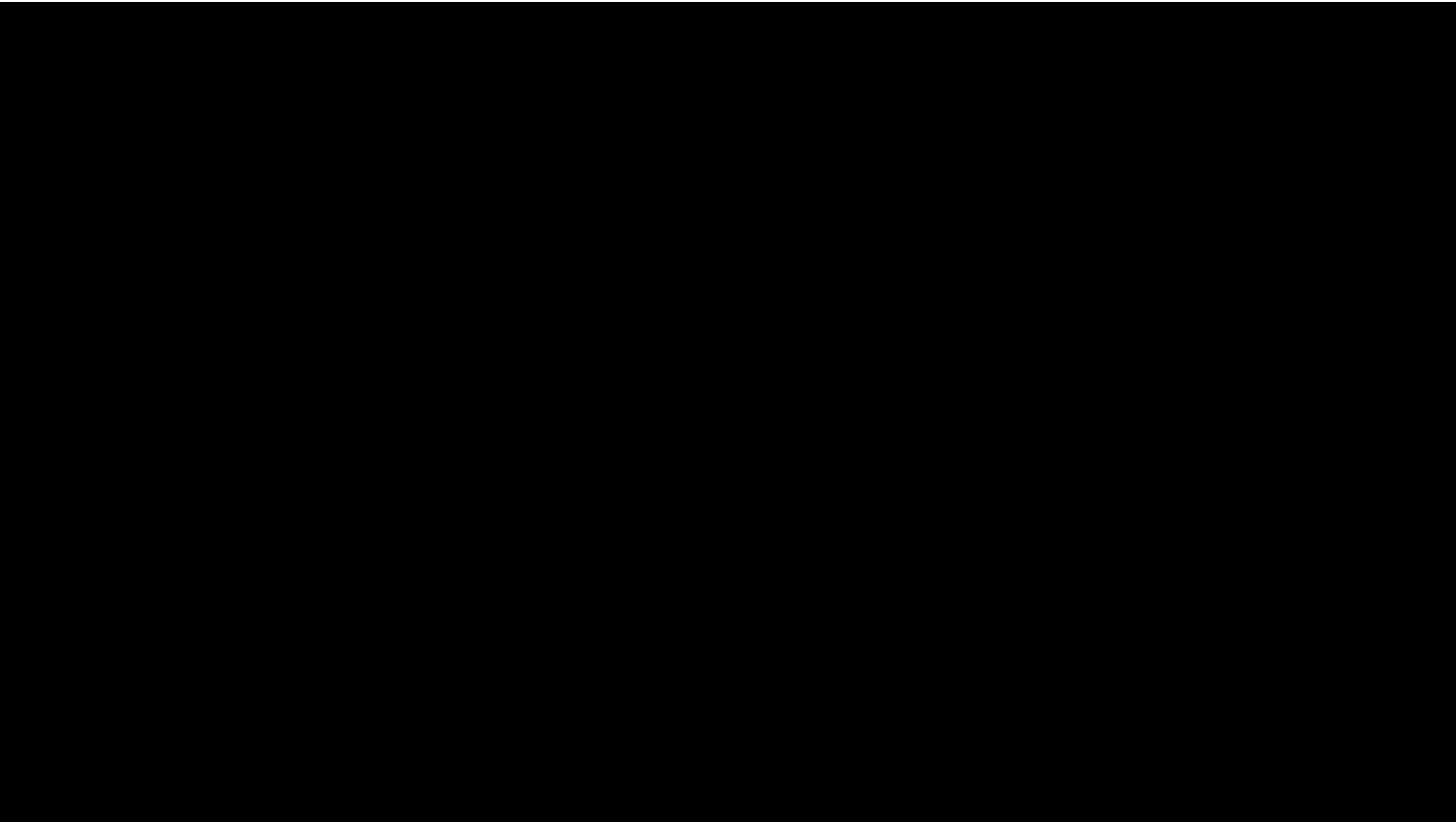


Smart Factory (Manufacturing)



Source: MOXA (http://www.moxa.com/Event/DAC/2013/Factory_Automation_IO/index.htm)

Smart Factory (Manufacturing)



https://www.youtube.com/watch?v=9R_P8FpslBY

Business Plan

Introduction

- Mission Statement
- Product Use and Market Introduction

VDM Product Description

- Overview
- Detailed Drawings
- Design for Manufacturability

Scuba Diving Market

- Economics
- Demographics
- Existing Product

VDM: Venus Dive Monitor

Business Plan (cont.)

Manufacturing & Marketing

- Strategy and Cost Estimates

VDM Prototypes Costs

- Personnel
- Overhead Costs
- Prototype Production Costs

Financial Scenarios (Expected return etc.)

Appendix (Part Assembly drawings etc.)

http://www.theequitykicker.com/2007/02/28/uncertainty-and-the-need-to-plan/

Business plan (example of VDM)

Venus Dive Monitor
Adonis Ltd.

Final Business Plan
ME221 eManufacture.com

Rob Frankenberg
Michelle Khine
Duane Kubischta
Kiha Lee
Matt Onsum
Andy Walker

The Venus Dive Monitor (VDM) by Adonis Ltd.

1.0 Introduction

1.1 Mission Statement:

Adonis will revolutionize the scuba diving industry with the introduction of the world's first hands free dive computer. The Venus Dive Monitor (VDM) will allow today's diver to monitor critical information without removing his eyes from the ocean environment, thereby eliminating the stop-and-go diving necessitated by current dive computers.

1.2 Product use and market introduction:

Every time a diver submerges into the underwater frontier he must constantly monitor key data such as depth, bottom time and remaining oxygen. A digital dive computer, which dangles near the diver's waist, generally provides this information. This requires the diver to stop swimming, remove his eyes from the ocean environment and fumble around to find the dive computer. Such stop-and-go diving reduces the time the diver can spend enjoying the underwater world and, in an environment that allows for movement in three dimensions, may cause disorientation - especially in a strong current.

The VDM addresses these problems; it displays the essential information to the diver in his peripheral vision. It allows the diver to keep his hands free and his eyes on the ocean. No more disorientation, no more unwanted movement in currents and more time to enjoy the surroundings.

The VDM will make its entry into the dive computer market by targeting dive instructors and dive boat operators. Seeing expert divers sport the VDM will encourage their clients to adopt the VDM and allow for VDM to become a significant player in the dive computer market and rapidly generate a significant return on investment.

Business plan (example of VDM)

- VDM Product Description

2.0 VDM Product Description

2.1 Overview

The Venus Dive Monitor (VDM), by Adonis Ltd., is a scuba diving accessory that allows a diver to continuously monitor his dive data by placing that information in his peripheral vision. The diver's depth, bottom time, remaining air pressure, and water temperature are displayed on an LCD screen that is attached to an armature assemble mounted to the diver's mask. An overview of this system is shown in Figure 2.1.

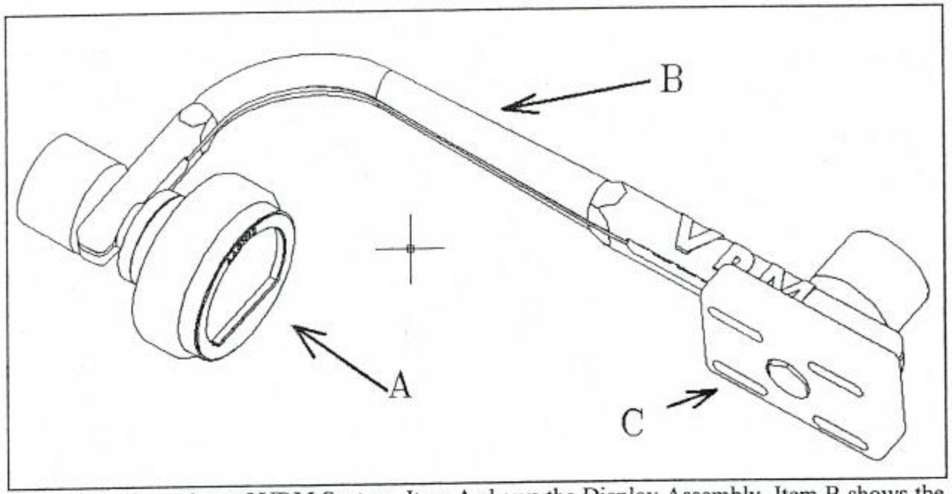


Figure 2.1: Overview of VDM System. Item A shows the Display Assembly, Item B shows the Armature Assembly, and Item C shows the Mask Attachment Assembly.

The Display Assembly (A) consists of an LCD screen fitted into a circular housing. This housing fits into a pin with a spherical head that goes through the armature slot and is threaded into a tightening knob. The spherical head allows the display to rotate to any preferred viewing angle. The receptive slot in the arm allows the display to slide horizontally to an optimum viewing position. The tightening knob affixes the Display Assembly to the arm in the desired position. The electronics of the LCD display are contained within the housings, and a set of wires brings in the data that gets displayed.

Business plan (example of VDM)

- Scuba Diving Market

3.0 **The Scuba Diving Market**

3.1 **Economics**

In North America alone recreational diving becomes a multi-billion dollar industry.[1]

The overall annual revenue from scuba diving is $1.5 billion in the United States.[2] Of that, the National Sporting Goods Association forecasts $373 million will be spent on purchasing consumer scuba diving equipment this year, up from $362.5 million in 1999.[3]

Scuba diving equipment, in general, includes: buoyancy control devices, fins, masks, regulators, computers, tanks, wet-suits, and dry-suits. A complete basic package costs on the order of $1500.

Dive computers are generally between $250 and $400 and have either a wrist or a console mount -- some with the option of both. Scuba masks generally average between $70 and $100. Various accessories, ranging from dive lights (~$50) to hands-free propulsion vehicles (>$1000), are available to the avid scuba diver.

3.2 **Demographics**

There are approximately 15.5 million certified scuba divers worldwide. In the U.S. alone, there are 8.5 million certified scuba divers. The industry continues to grow: an estimated 500,000 new scuba divers are certified in the U.S. each year.

Scuba divers are generally affluent and well educated. 62% of divers have an average income over $50,000. Half of all scuba divers have a college degree, with almost 40% in professional or managerial occupations. The average scuba diver is thirty-six years old.[4] Though females comprise less than 30% of divers, they are continually growing in size.

While people generally think of scuba diving as a recreational activity, scuba diving is commonly used for search and rescue of downed aircraft, and repair of offshore drilling rigs. For these applications, it is imperative that the divers have unlimited use of their hands and arms.

---

[1] http://www.mtsinai.org/pulmonary/books/scuba/sectiona.htm

[2] http://viewtnamnews.vnagency.com.vn/2000-07/05/Stories/14.htm

[3] http://www.nsga.org

[4] http://www.padi.com/news/stats/default.stm

Business plan (example of VDM)

- Manufacturing & Marketing

acceptance, competing with the current players in the market will be reduced to producing a better and cheaper product, something that Adonis is confident will be done.

The table below summarizes the costs of manufacturing the VDM. A note is needed regarding the pricing of the VDM. The dive computer market is a relatively small one with less than a million units sold per year worldwide. This means that the profit margins on both the wholesale and retail sales must be large in order to support both the manufacturer and retailer respectively. Note, however, that the projected retail price of the VDM enters the low end of the dive computer market with an inexpensive retail price of $250.

Manufacturing Cost Estimates

Printed circuit board[1]	$2
LCD[1]	$4
Misc. electronics[2]	$4
Water proofing[3]	$1
Materials	$1
Assembly labor[4]	$3
Packaging	$0.50
Subtotal	$15.50
Manufacturing set-up[5]	$9
Overhead and labor[6]	$16
Marketing[7]	$6.50
R&D[8]	$1.50
Total	$48.50
Projected Wholesale Price	$175
Projected Retail Price	$250

1 Printed circuit board and LCD costs are estimated based on high volume manufacturing.

2 Miscellaneous electronics include hydrostatic pressure gauge to monitor depth and pressure gauge to monitor remaining air.

3 Waterproofing includes materials for making the unit watertight at pressure. Includes rubber gaskets and silicon sealant.

4 Assembly labor assumes complete assembly of the unit utilizing overseas manufacturing.

5 Manufacturing set-ups include all costs associated with mold making and process set-up. Cost is estimated based on a production run of 160,000 units amortized over three years.

6 Overhead and labor are costs associated with Adonis Ltd. This includes the salaries of the principles of the corporation and all costs of rent, utilities, insurance, accounting, secretarial, custodial and legal. Costs are amortized over three years with a total production of 160,000 units.

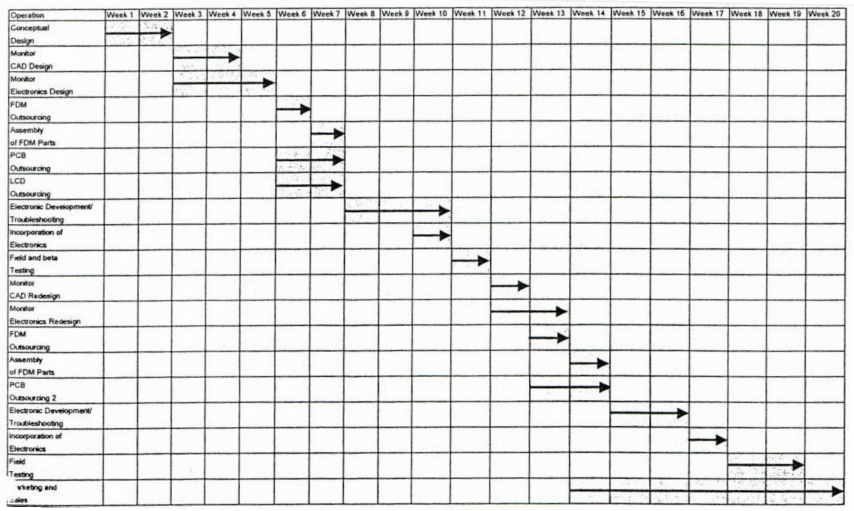
7 Marketing costs assume 24 magazine ads a year, trade show appearances, and other product promotions and giveaways. Costs are amortized over a three-year production run of 160,000.

8 Research and development costs are amortized.

Business plan (example of VDM)

- VDM Prototypes Costs

Personnel



Overhead Costs

Expense	Cost/month (in USD)	Total Expense (in USD)
Compensation	43846	219230
Rent	2500	12500
Insurance	169	845
Utilities		
DSL Connection	250	1250
Power	200	1000
Maintenance	75	375
Computer Leasing		
Hardware	500	2500
CAD License	2000	10000
Furniture Rental	360	1800
Other Expenses	100	500
	Total Overhead Costs	250000

Prototype Production Costs

Cost	Price USD
Overhead	250000
FDM Fabrication @ $500 X 2	1000
PCB Fabrication @ $359 X 2	718
LCD Fabrication	225
Misc. Parts/Components @ $27 X 2	54
Total	251997

Business plan (example of VDM)

- Financial Scenarios

Table 1. Expected returns for worst case scenario

	Year 2000 j=0	2001 j=1	2002 j=2	2003 j=3	2004 j=4	2005 j=5
Sales price		$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00
Number of units sold		1,000.00	10,000.00	50,000.00	40,000.00	37,500.00
Net sales		$ 175,000.00	$ 1,750,000.00	$ 8,750,000.00	$ 7,000,000.00	$ 6,562,500.00
Cumulative net sales		$ 175,000.00	$ 1,925,000.00	$ 10,675,000.00	$ 17,675,000.00	$ 24,237,500.00
Unit cost (target)		$ 67.75	$ 67.75	$ 67.75	$ 67.75	$ 67.75
*Unit cost****		$ 15.50	$ 15.50	$ 15.50	$ 15.50	$ 15.50
Cost of product sold		$ 67,750.00	$ 677,500.00	$ 3,387,500.00	$ 2,710,000.00	$ 2,540,625.00
*Cost of product sold****		$ 15,500.00	$ 155,000.00	$ 775,000.00	$ 620,000.00	$ 581,250.00
Gross margin		$ 107,250.00	$ 1,072,500.00	$ 5,362,500.00	$ 4,290,000.00	$ 4,021,875.00
% gross margin		61.29%	61.29%	61.29%	61.29%	61.29%
Development cost	$ 251,997.00	$ 150,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00
Manufacturing setup cost	$ 1,600,000.00	-	-	-	-	-
Marketing	-	700,000.00	700,000.00	700,000.00	700,000.00	700,000.00
Overhead & labor	-	850,000.00	850,000.00	850,000.00	850,000.00	850,000.00
Total operating expense	$ 1,851,997.00	$ 1,715,500.00	$ 1,805,000.00	$ 2,425,000.00	$ 2,270,000.00	$ 2,231,250.00
Pretax Profit	$ (1,851,997.00)	$ (1,608,250.00)	$ (732,500.00)	$ 2,937,500.00	$ 2,020,000.00	$ 1,790,625.00
% profit		-919.00%	-41.86%	33.57%	28.86%	27.29%
Cumulative profit	$ (1,851,997.00)	$ (3,460,247.00)	$ (4,192,747.00)	$ (1,255,247.00)	$ 764,753.00	$ 2,555,378.00

…ost without amortization
… manufacturing cost

Business plan (example of VDM)

- Financial Scenarios

Table 2. Expected returns for reasonable case scenario

	Year					
	2000 j = 0	2001 j = 1	2002 j = 2	2003 j = 3	2004 j = 4	2005 j = 5
Sales price		$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00
Number of units sold		10,000.00	50,000.00	100,000.00	80,000.00	70,000.00
Net sales		$ 1,750,000.00	$ 8,750,000.00	$ 17,500,000.00	$ 14,000,000.00	$ 12,250,000.00
Cumulative net sales		$ 1,750,000.00	$ 10,500,000.00	$ 28,000,000.00	$ 42,000,000.00	$ 54,250,000.00
Unit cost (target)		$ 48.50	$ 48.50	$ 48.50	$ 48.50	$ 48.50
*Unit cost****		$ 15.50	$ 15.50	$ 15.50	$ 15.50	$ 15.50
Cost of product sold		$ 485,000.00	$ 2,425,000.00	$ 4,850,000.00	$ 3,880,000.00	$ 3,395,000.00
*Cost of product sold****		$ 155,000.00	$ 775,000.00	$ 1,550,000.00	$ 1,240,000.00	$ 1,085,000.00
Gross margin		$ 1,265,000.00	$ 6,325,000.00	$ 12,650,000.00	$ 10,120,000.00	$ 8,855,000.00
% gross margin		72.29%	72.29%	72.29%	72.29%	72.29%
Development cost	$ 251,997.00	$ 150,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00
Manufacturing setup cost	$ 1,600,000.00	-	-	-	-	-
Marketing	-	700,000.00	700,000.00	700,000.00	700,000.00	700,000.00
Overhead & labor	-	$ 850,000.00	$ 850,000.00	$ 850,000.00	$ 850,000.00	$ 850,000.00
Total operating expense	$ 1,851,997.00	$ 1,855,000.00	$ 2,425,000.00	$ 3,200,000.00	$ 2,890,000.00	$ 2,735,000.00
Pretax Profit	$ (1,851,997.00)	$ (590,000.00)	$ 3,900,000.00	$ 9,450,000.00	$ 7,230,000.00	$ 6,120,000.00
% profit		-33.71%	44.57%	54.00%	51.64%	49.96%
Cumulative profit	$ (1,851,997.00)	$ (2,441,997.00)	$ 1,458,003.00	$ 10,908,003.00	$ 18,138,003.00	$ 24,258,003.00

****Cost without amortization*

c anufacturing cost

Business plan (example of VDM)

- Financial Scenarios

Table 3. Expected returns for best case scenario

	Year					
	2000 j = 0	2001 j = 1	2002 j = 2	2003 j = 3	2004 j = 4	2005 j = 5
Sales price		$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00
Number of units sold		20,000.00	80,000.00	150,000.00	120,000.00	112,500.00
Net sales		$ 3,500,000.00	$ 14,000,000.00	$ 26,250,000.00	$ 21,000,000.00	$ 19,687,500.00
Cumulative net sales		$ 3,500,000.00	$ 17,500,000.00	$ 43,750,000.00	$ 64,750,000.00	$ 84,437,500.00
Unit cost (target)		$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00
*Unit cost****		$ 15.50	$ 15.50	$ 15.50	$ 15.50	$ 15.50
Cost of product sold		$ 700,000.00	$ 2,800,000.00	$ 5,250,000.00	$ 4,200,000.00	$ 3,937,500.00
*Cost of product sold****		$ 310,000.00	$ 1,240,000.00	$ 2,325,000.00	$ 1,860,000.00	$ 1,743,750.00
Gross margin		$ 2,800,000.00	$ 11,200,000.00	$ 21,000,000.00	$ 16,800,000.00	$ 15,750,000.00
% gross margin		80.00%	80.00%	80.00%	80.00%	80.00%
Development cost	$ 251,997.00	$ 150,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00
Manufacturing setup cost	1,600,000.00	-	-	-	-	-
Marketing	-	700,000.00	700,000.00	700,000.00	700,000.00	700,000.00
Overhead & labor	-	850,000.00	850,000.00	850,000.00	850,000.00	850,000.00
Total operating expense	$ 1,851,997.00	$ 2,010,000.00	$ 2,890,000.00	$ 3,975,000.00	$ 3,510,000.00	$ 3,393,750.00
Pretax Profit	$ (1,851,997.00)	$ 790,000.00	$ 8,310,000.00	$ 17,025,000.00	$ 13,290,000.00	$ 12,356,250.00
% profit		22.57%	59.36%	64.86%	63.29%	62.76%
Cumulative profit	$ (1,851,997.00)	$ (1,061,997.00)	$ 7,248,003.00	$ 24,273,003.00	$ 37,563,003.00	$ 49,919,253.00

****C[illegible]st without amortization*
[illegible]anufacturing cost

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