UNIVERSITY OF TRENTO

ICT Innovation – Spring 2016

MSc in Computer Science and MEng Telecom. Engineering
EIT Masters ITA, S&P,SDE

Lecture 05 – Product Architecture and Design for Manufacturing

Prof. Fabio Massacci

Product Development Process

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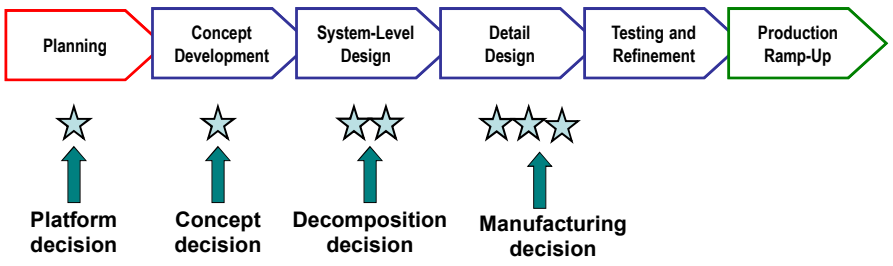
- Product architecture is determined early in the development process
- Detailed design is important for manufacturing



Product Architecture: Definition

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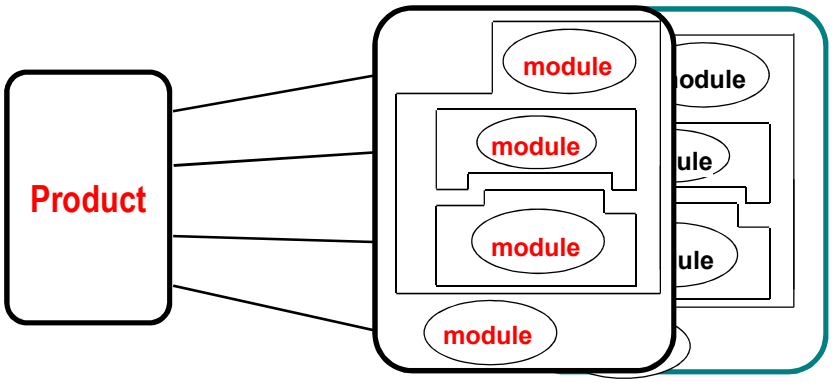
- The arrangement of functional elements into physical chunks which become the building blocks for the product or family of products.



Trailer Example: Modular Architecture

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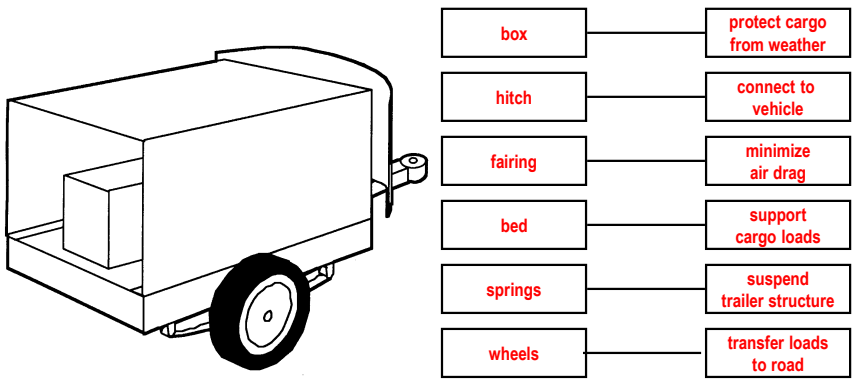

Trailer Example: Integral Architecture

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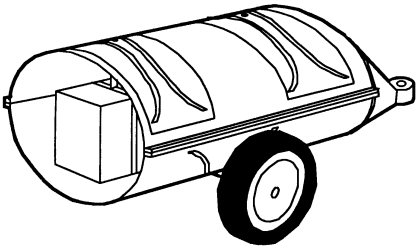

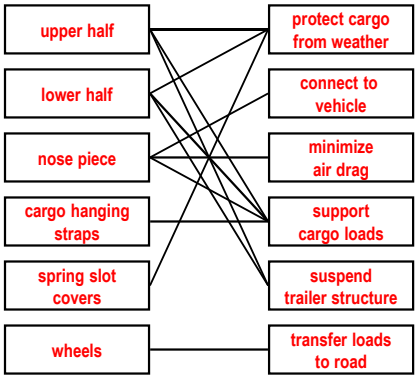

What is this?

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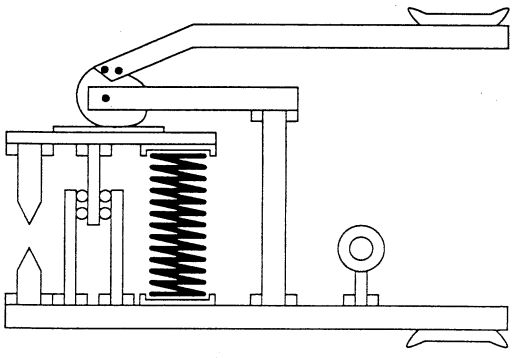

Nail Clippers?

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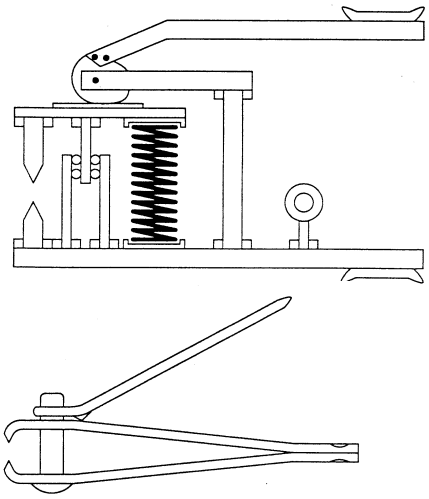

Modular Product Architectures

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- **Implementation**
  - Chunks implement one or a few functions entirely.
  - Interactions between chunks are well defined.
- **Efficient?**
  - Simplicity of design
  - Reusability for a product family or platform.
- **Robust to asymmetric wear and tear of components**
  - Only stressed components must be made of high quality material (or can be replaceable)

Swiss Army Knife

Sony Walkman

Platform Architecture of the Sony Walkman

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Integral Product Architectures

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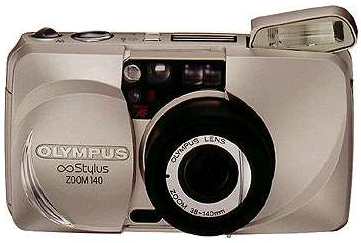
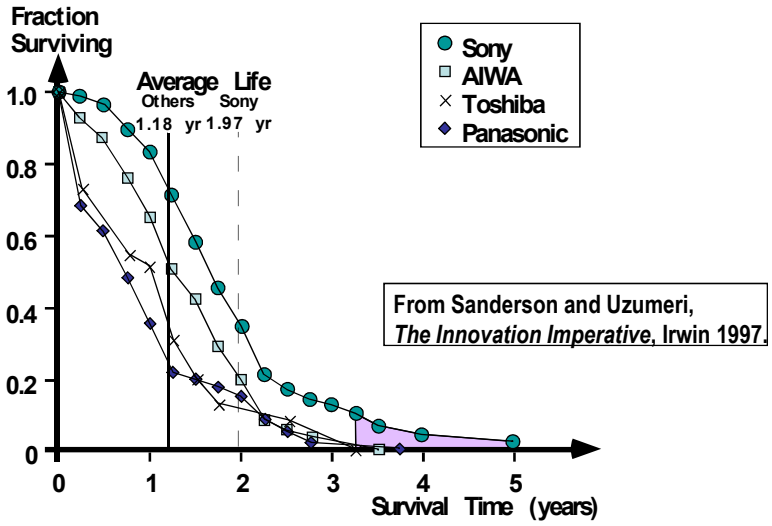
- **Implementation**
  - Functional elements are implemented by multiple chunks,
  - A chunk may implement many functions
  - Interactions between chunks are poorly defined.
- **Efficient?**
  - reduces costs → make one part instead of two and assembling them
  - Harder to design
  - Performance may increase
- **Fragile to asymmetric wear and tear of components**
  - If some part of frame wears out → must replace whole wheel

High-Performance Wheels



Compact Camera

Product Model Lifetime



Choosing the Product Architecture

- **Architecture decisions relate to product planning and concept development decisions:**
  - Product Change (copier toner, camera lenses)
  - Product Variety (computers, automobiles)
  - Standardization (motors, bearings, fasteners)
  - Performance (racing bikes, fighter planes)
  - Manufacturing Cost (disk drives, razors)
  - Project Management (team capacity, skills)
  - System Engineering (decomposition, integration)

The concepts of integral and modular apply at several levels:

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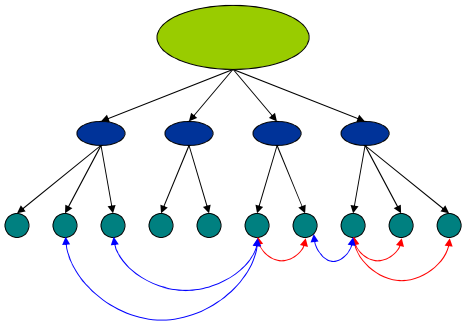
- **Decomposion**
  - system
  - sub-system
  - Component
- **Interaction**
  - within chunks ⟺
  - across chunks ⟺



Product Architecture = Decomposition + Interactions

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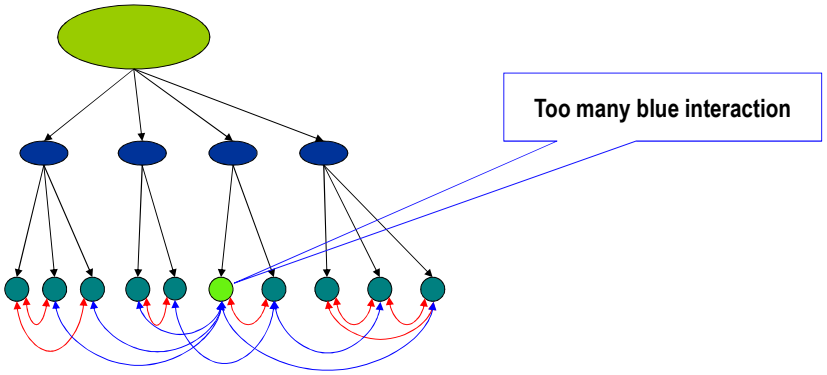
- **Interaction across chunks increases fragility**
  - Cannot be tested before assembly
  - Requires higher precision of assembly or robustness of components



Product Architecture = Decomposition + Interactions

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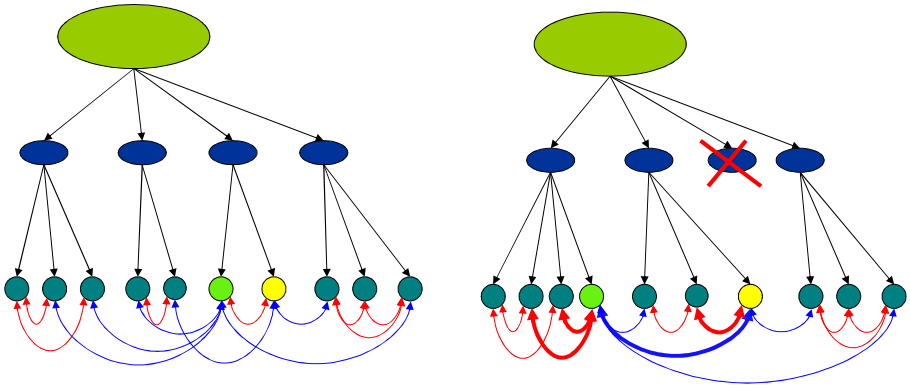

Establishing the Architecture

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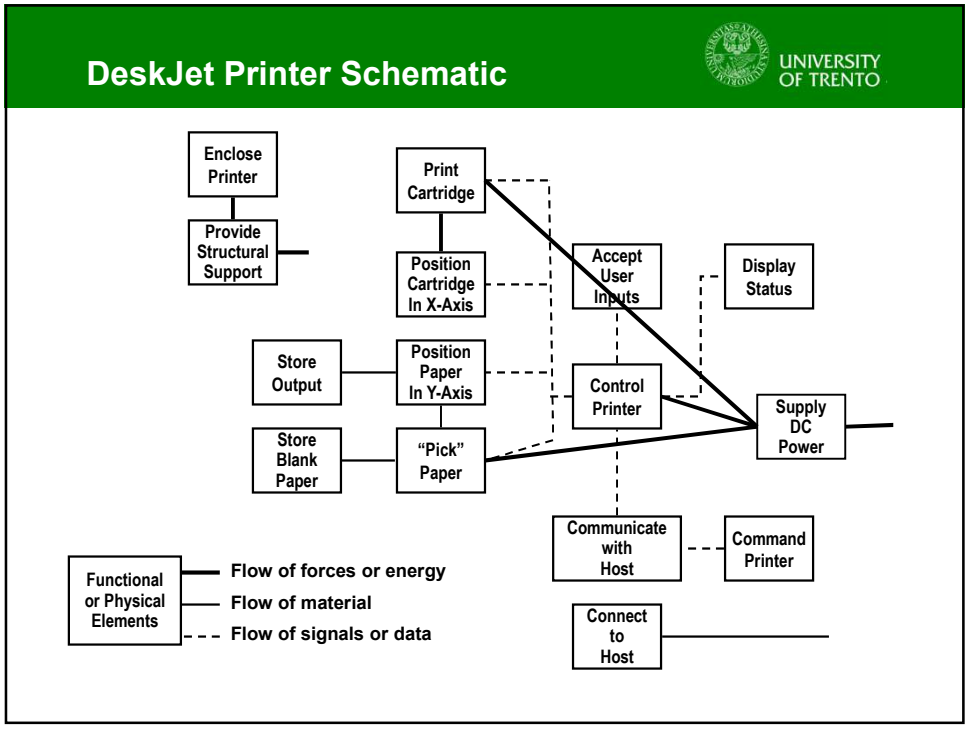
- **To establish a modular architecture,**
  - create a schematic of the product,
  - cluster the elements of the schematic to achieve the types of product variety desired


DeskJet Printer Schematic
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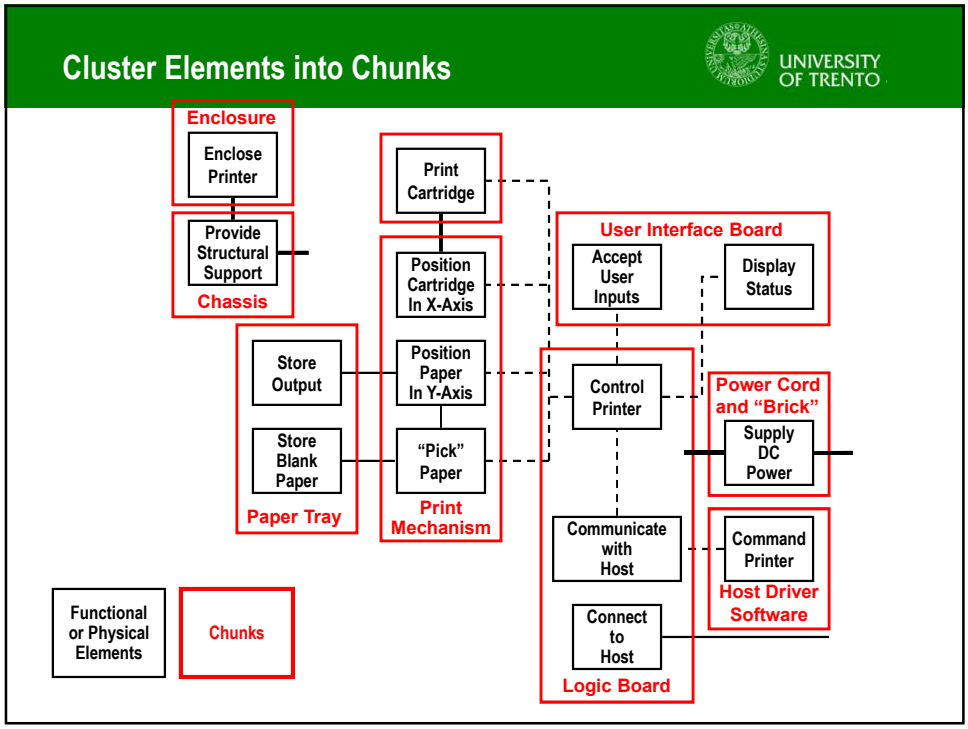
Enclose Printer
Provide Structural Support
Print Cartridge
Position Cartridge In X-Axis
Store Output
Position Paper In Y-Axis
Store Blank Paper
"Pick" Paper
Accept User Inputs
Display Status
Control Printer
Supply DC Power
Communicate with Host
Command Printer
Connect to Host
Functional or Physical Elements
Flow of forces or energy
Flow of material
Flow of signals or data


Cluster Elements into Chunks
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Enclosure
Enclose Printer
Provide Structural Support
Chassis
Print Cartridge
Position Cartridge In X-Axis
Store Output
Position Paper In Y-Axis
Store Blank Paper
"Pick" Paper
Paper Tray
Print Mechanism
User Interface Board
Accept User Inputs
Display Status
Control Printer
Power Cord and "Brick"
Supply DC Power
Communicate with Host
Command Printer
Host Driver Software
Connect to Host
Logic Board
Functional or Physical Elements
Chunks

Geometric Layout

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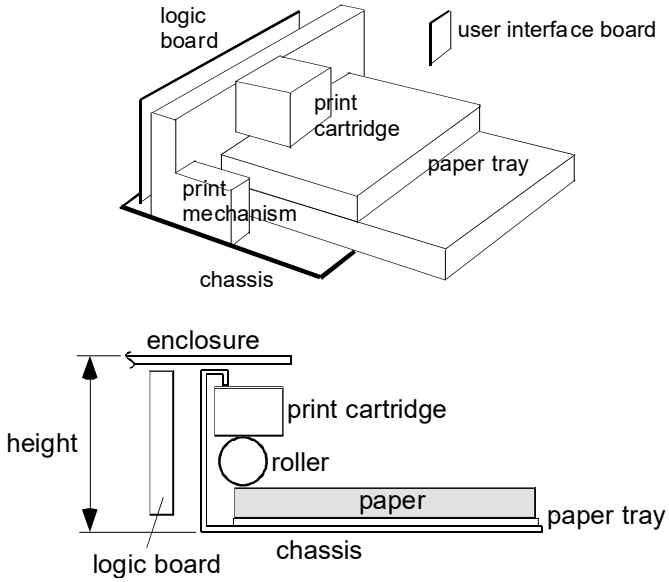

Types of Modularity

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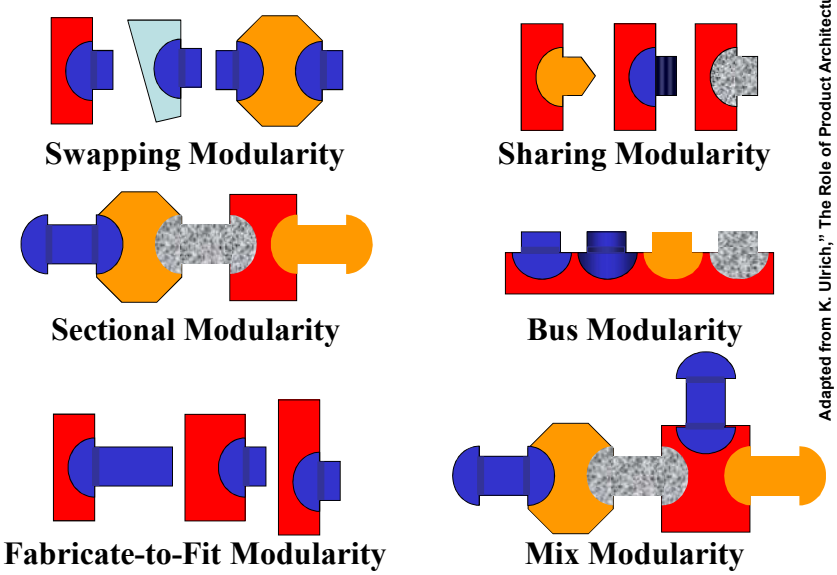

Adapted from K. Ulrich," The Role of Product Architecture in the Manufacturing Firm", *Research Policy*, 1995.

Incidental Interactions: do we miss something?

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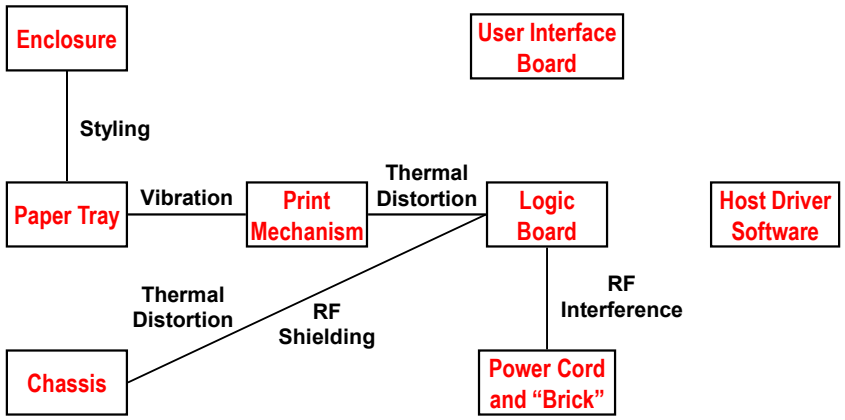

Alternative Solutions

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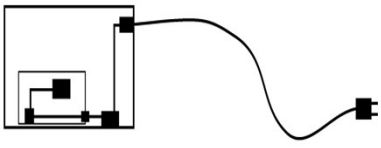
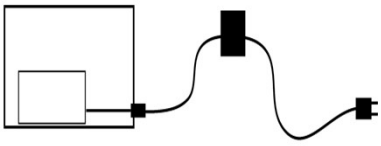
- **Power transformer is an example of a functional brick**
  - Must be certified to be free from safety hazard
  - Limits for AC current 0.7mA, DC current 2mA (after 3.5mA muscle contracts and cannot let go)
- **Inside**
  - Pro: only cable outside,
  - Con: whole certified to avoid electric hazards
  - Con: insulation coating must be cooled
- **Outside**
  - Con: more things to carry
  - Pro: only brick certified against alternate current electric hazard
  - Pro: Insulation coating can use environment itself for cooling





From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

Fundamental Decisions

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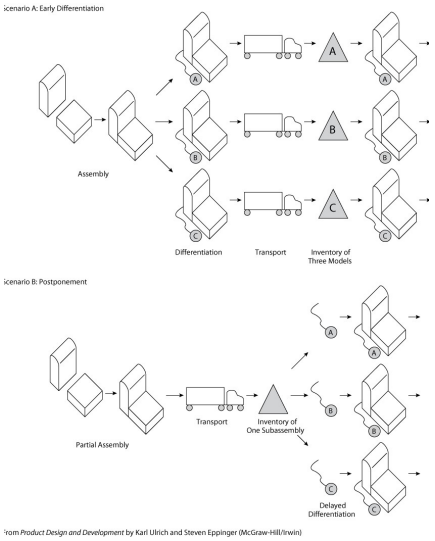
- Integral vs. modular architecture?
- What type of modularity?
- How to assign functions to chunks?
- How do we produce and assembly chunks?
- How many different products do we want?



Planning a Modular Product Line: Commonality Table

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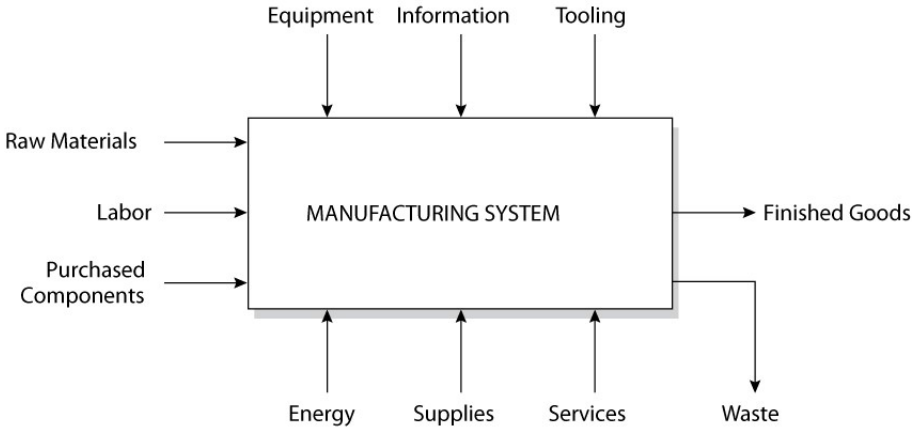
Chunks	Number of Types	Family	Student	SOHO (small office, home office)
Print cartridge	2	"Manet" Cartridge	"Picasso" Cartridge	"Picasso" Cartridge
Print Mechanism	2	"Aurora" Series	Narrow "Aurora" series	"Aurora" series
Paper tray	2	Front-in Front-out	Front-in Front-out	Tall Front-in Front-out
Logic board	2	"Next gen" board with parallel port	"Next gen" board	"Next gen" board
Enclosure	3	Home style	Youth style	"Soft office" style
Driver software	5	Version A-PC Version A-Mac	Version B-PC Version B-Mac	Version C

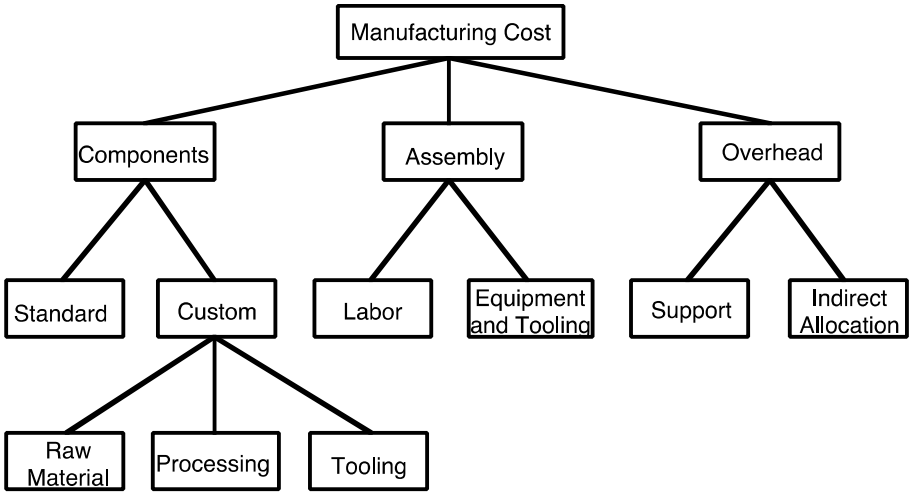
- Differentiation versus Commonality
- Trade off product variety and production complexity

How to actually manufacture the product?



From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

Understanding Manufacturing Costs



Is optimizing manufacturing worth?

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- 2 billion worldwide annual volume
- 7 major producers of 1/2" cassette shells
- JVC licenses the VHS standard
  - dimensions, interfaces, light path, etc
- VHS cassette shells cost ~$0.25 each
- What is a $0.01 cost reduction worth?

Design for manufacturing

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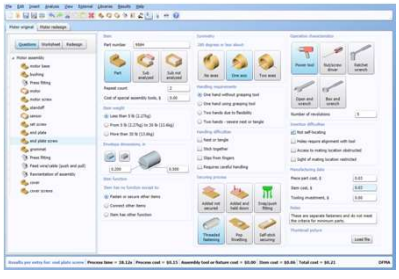
- Product development practice emphasizing manufacturing issues.
- Successful DFM results in lower production cost without sacrificing product quality.
- Obtained through
  - Cross-Functional Teams
  - Specialized Design Rules
  - CAD Tools
    - E.g.Boothroyd-Dewhurst DFMA
    - http://www.dfma.com



Example DFA guidelines from a computer manufacturer.

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- Minimize parts count.
- Encourage modular assembly.
- Stack assemblies.
- Eliminate adjustments.
- Eliminate cables.
- Use self-fastening parts.
- Use self-locating parts.
- Eliminate reorientation.
- Facilitate parts handling.
- Specify standard parts.

Example of times for fastening parts

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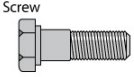
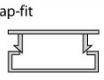
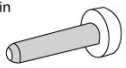
- Different tools for fastening parts differs in
  - Time to fasten
  - Time to unfasten (if at all)
  - Precision
  - Robustness to tear and wear
  - Ability to adjust

Component	Time (Seconds)		
	Min	Max	Avg
Screw 	7.5	13.1	10.3
Snap-fit 	3.5	8.0	5.9

Component	Time (Seconds)		
	Min	Max	Avg
Pin 	3.1	10.1	6.6
Spring 	2.6	14.0	8.3

From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

Design for Assembly

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- **Key ideas of DFA:**
  - Minimize parts count
  - Maximize the ease of handling parts
  - Maximize the ease of inserting parts
- **Benefits of DFA**
  - Lower labor costs
  - Other indirect benefits

$$\text{DFA index} = \frac{(\text{Theoretical minimum number of parts}) \times (3 \text{ seconds})}{\text{Estimated total assembly time}}$$

From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

Method for Part Integration

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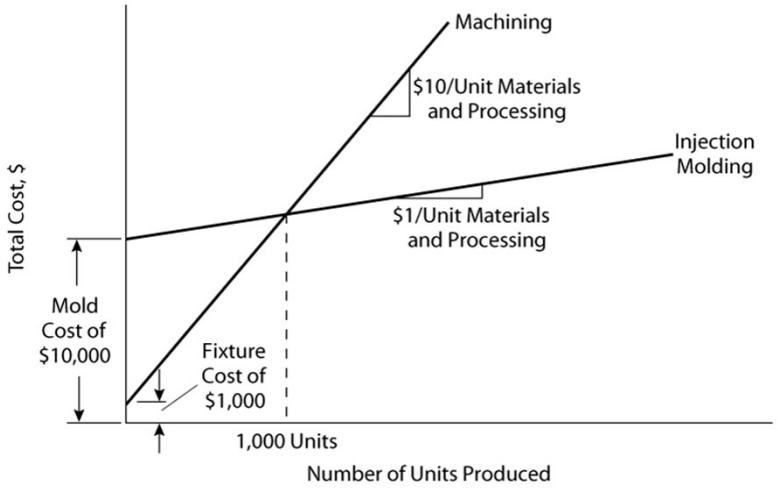
- **Ask of each part in a candidate design:**
  - Does the part need to move relative to the rest of the device?
  - Does it need to be of a different material because of fundamental physical properties?
  - Does it need to be separated from the rest of the device to allow for assembly, access, or repair?
- ***If not, combine the part with another part in the device.***

$$\text{Total unit cost} = \frac{\text{Setup costs} + \text{Tooling costs}}{\text{Volume}} + \text{Variable costs}$$

From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

Different technologies works differently at scale



From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

Practical Concerns

- **Planning is essential to achieve the desired variety and product change capability.**
- **Coordination is difficult, particularly across teams, companies, or great distances.**
- **Special attention must be paid to handle complex interactions between chunks (system engineering methods).**

Product Architecture: Conclusions

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- **Architecture choices define the sub-systems and modules of the product platform or family.**
- **Architecture determines:**
  - ease of production variety
  - feasibility of customer modification
  - system-level production costs
- **Key Concepts:**
  - modular vs. integral architecture
  - clustering into chunks
  - planning product families

Textbook

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Product Design and Development
Karl T. Ulrich and Steven D. Eppinger
5th edition, Irwin McGraw-Hill, 2012

1. Introduction
2. Development Processes and Organizations
3. Opportunity Identification
4. Product Planning
5. Identifying Customer Needs
6. Product Specifications
7. Concept Generation
8. Concept Selection
9. Concept Testing
10. **Product Architecture**
11. Industrial Design
12. Design for Environment
13. **Design for Manufacturing**
14. Prototyping
15. Robust Design
16. Patents and Intellectual Property
17. Product Development Economics
18. Managing Projects