

Chapter 9: Product Architecture

Product Design and Development

Fourth Edition

by Karl T. Ulrich and Steven D. Eppinger

Product Design and Development

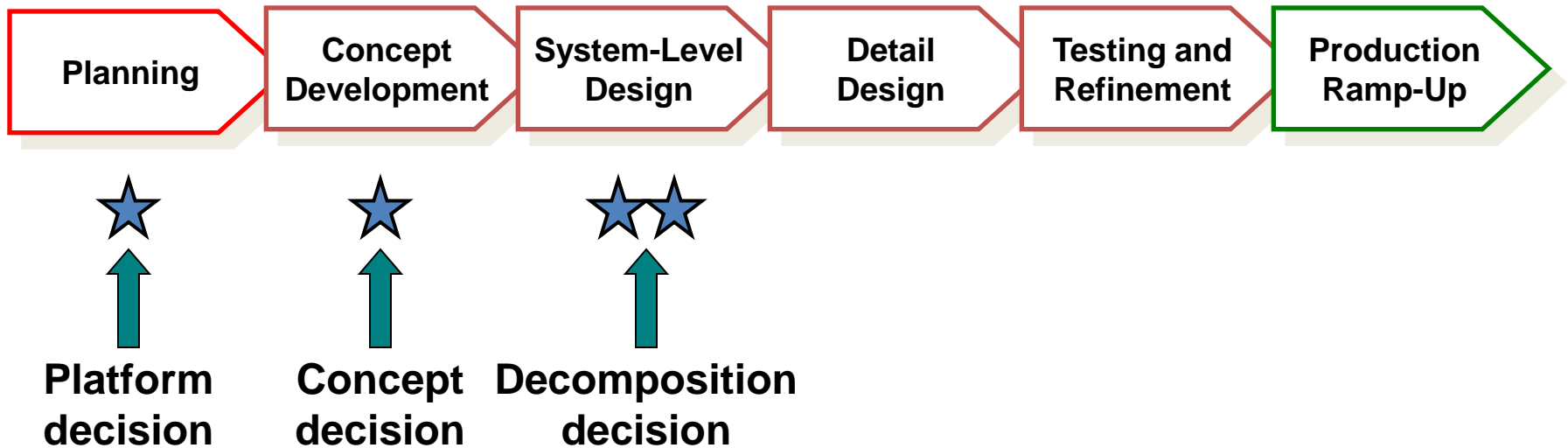
Karl T. Ulrich and Steven D. Eppinger

2nd edition, Irwin McGraw-Hill, 2000.

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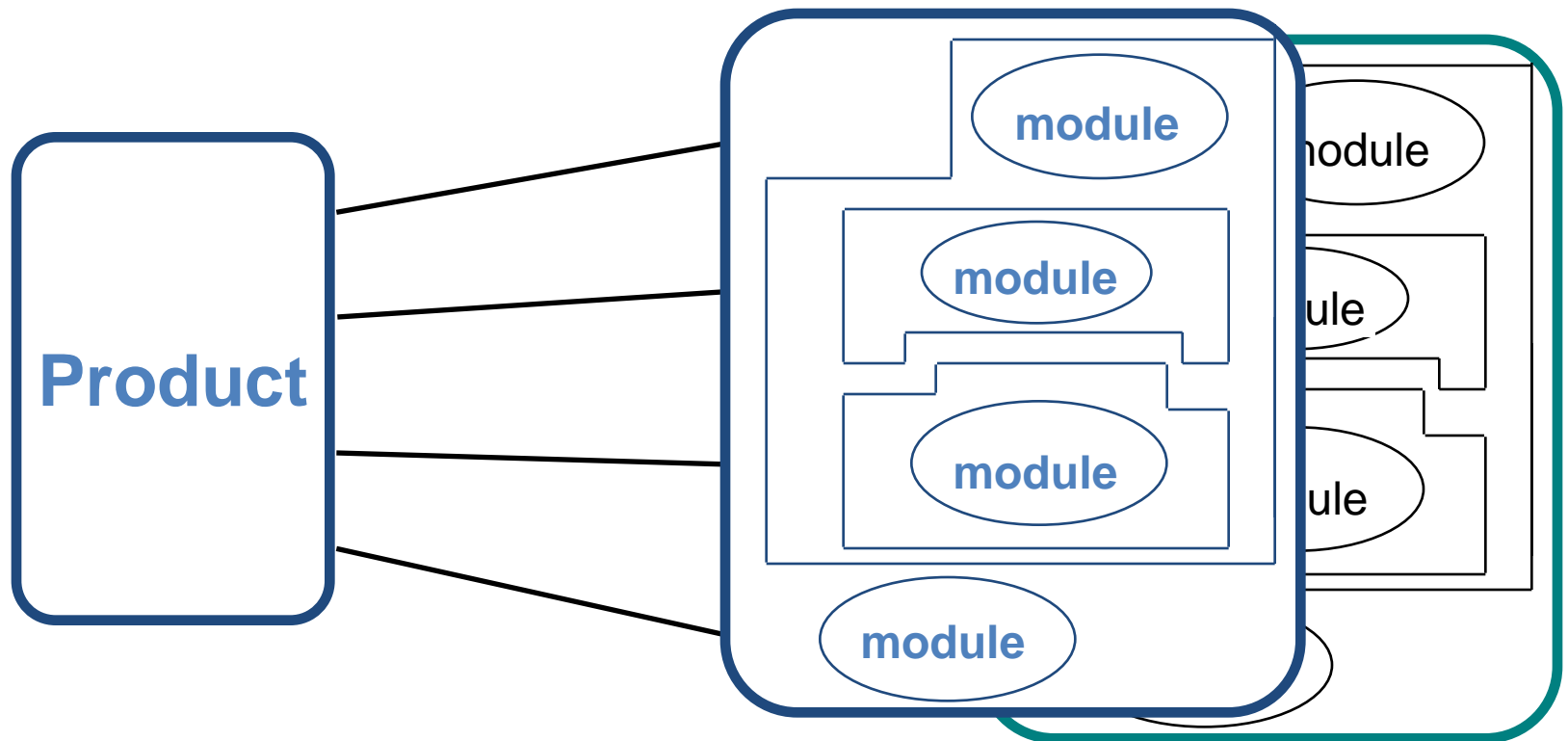
Product Development Process



Product architecture is determined early in the development process.

Product Architecture: Definition

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



Aspects of Product Architecture

- Modularity
- Point of product differentiation

Importance of Product Architecture

- Decided early and drives design
- Impacts manufacturing cost
- Impacts product evolution
- Impacts organization structure of design teams

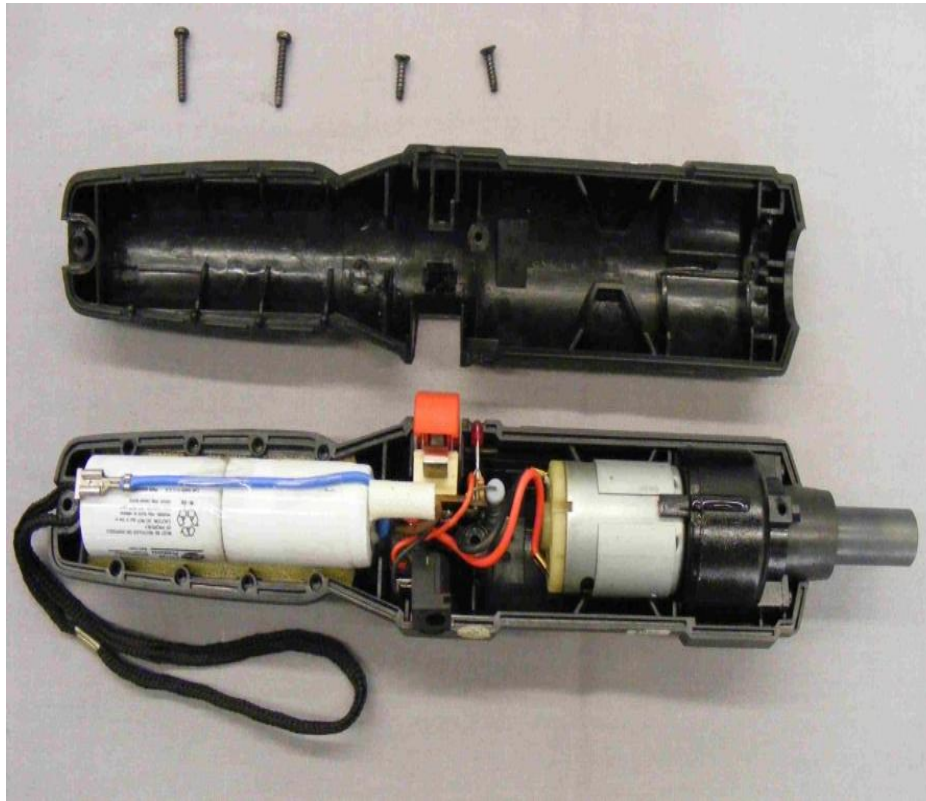
Modular Design Displays the Following Properties:

- Each physical chunk implements one or a few functional elements in their entirety
- The interactions between chunks are well defined (i.e. the interfaces are well defined)

Integral Product Architectures

- Functional elements are implemented by multiple chunks, or a chunk may implement many functions.
- Interactions between chunks are poorly defined.
- Integral architecture generally increases performance and reduces costs for any specific product model.

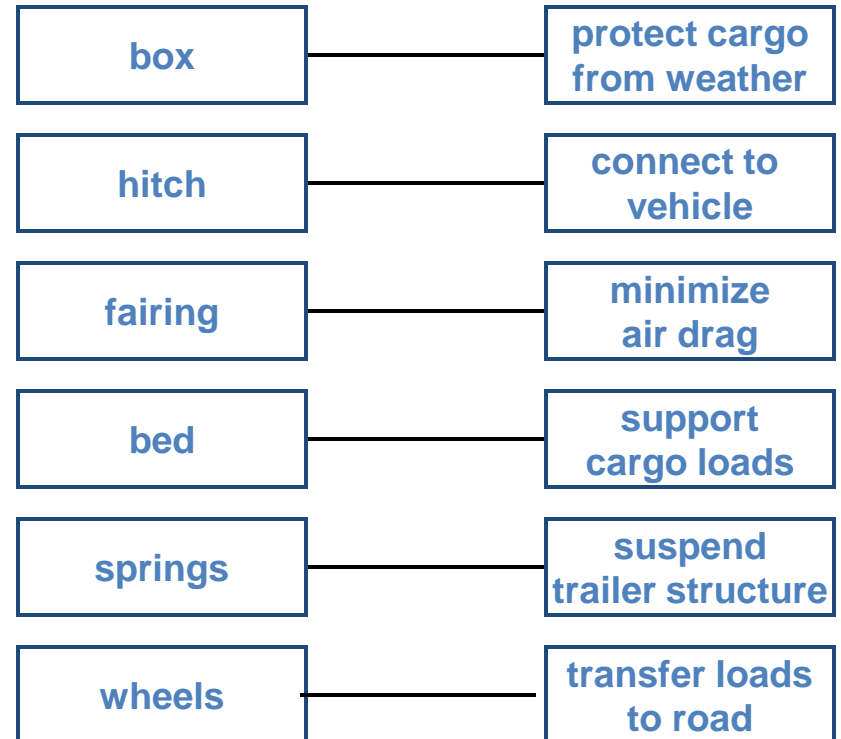
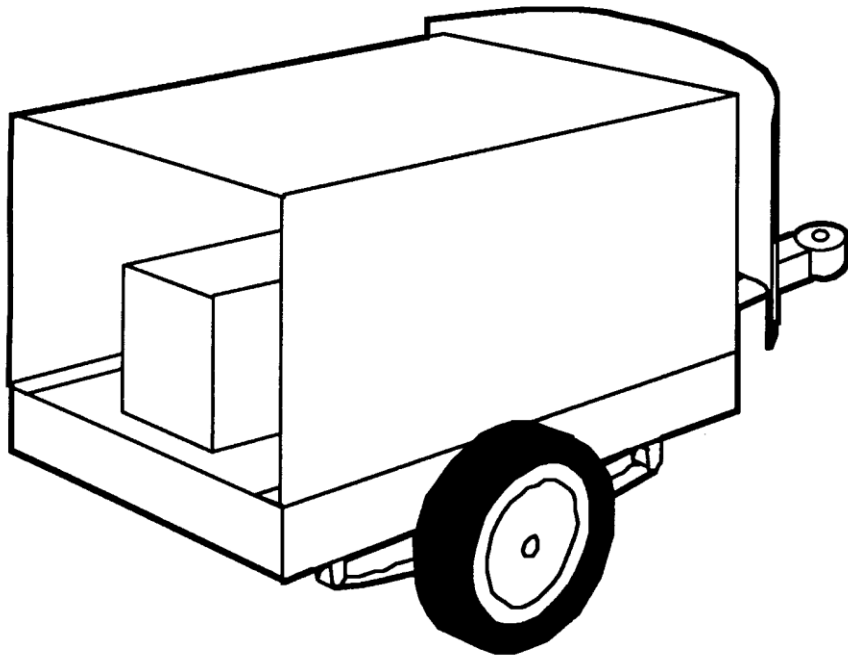
Modular or Integral?



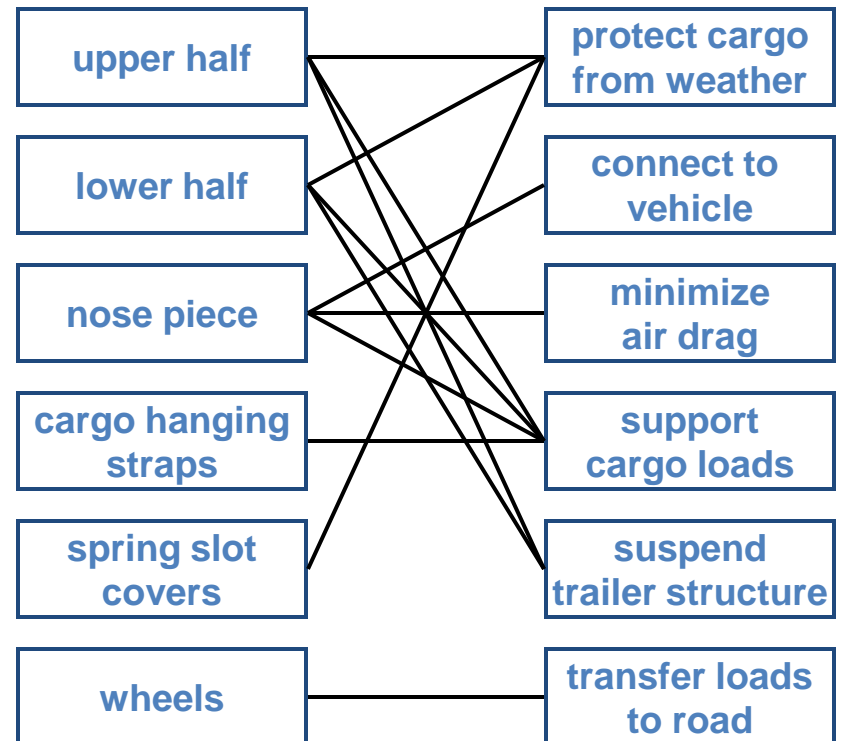
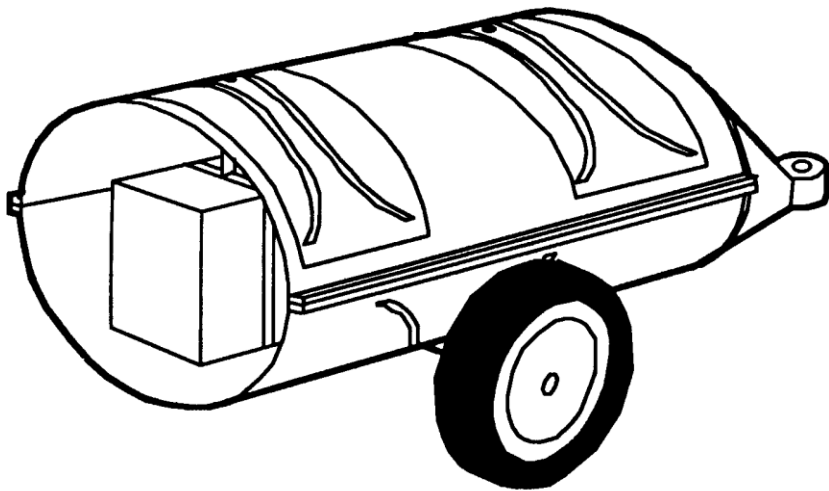
Examples

- Video Games
 - Modular: gaming systems (e.g. GameCube)
 - Integrated: stand-alone arcade games
- Power Supplies
 - Modular: power bricks
 - Integrated: on-board power converter

Trailer Example: Modular Architecture



Trailer Example: Integral Architecture



Integral vs. Modular

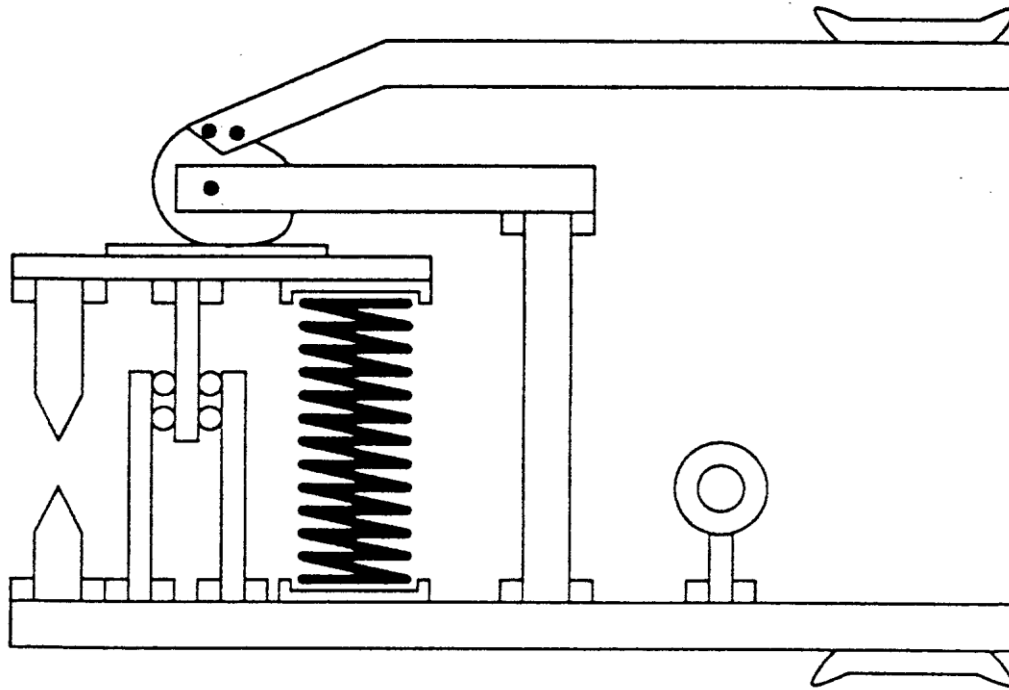
Integral

- Higher system performance
- Tightly coupled design teams
- Hard to change

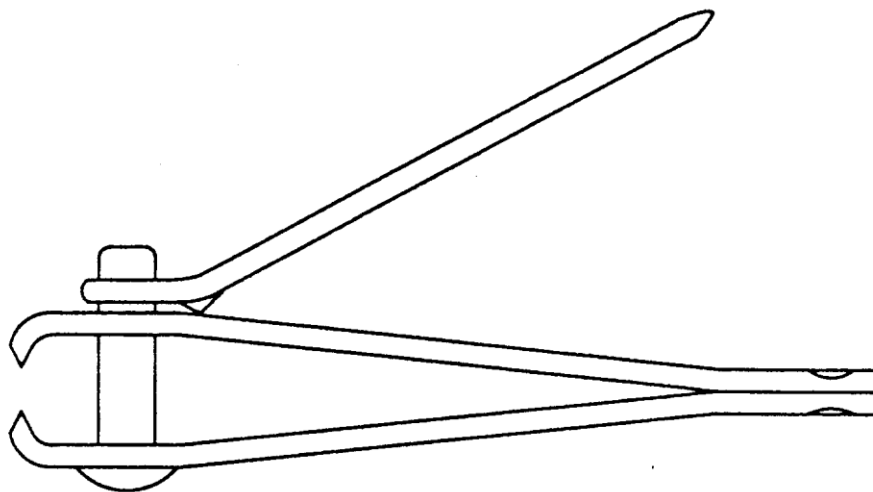
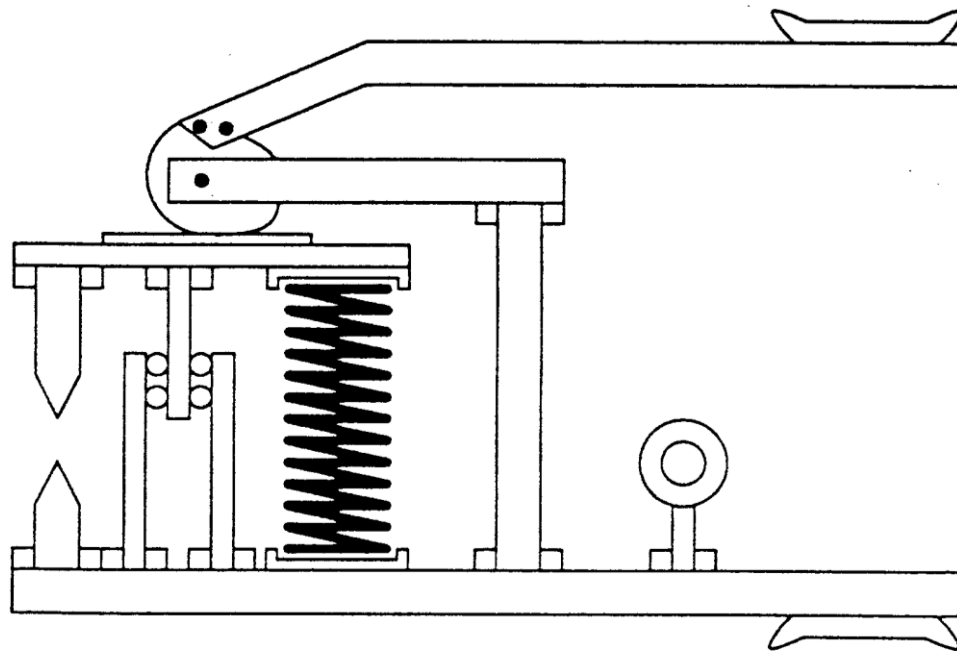
Modular

- Reduced performance
- Decoupled design teams
- Requires clear definition of interfaces
- Increased flexibility
- Accommodates made-to-order products

What is this?



Nail Clippers?



Modular or Integral Architecture?



**Motorola StarTAC
Cellular Phone**

**Apple
iBook**



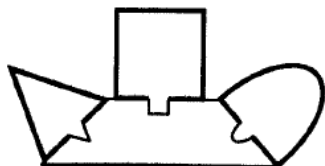
**Ford
Explorer**



**Rollerblade
In-Line Skates**

Types of Modularity

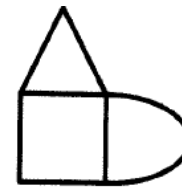
- Slot-Modular Architecture
 - unique interfaces for attachment to a base element (e.g. pacemaker leads)
- Bus-Modular Architecture
 - common interfaces for attachment to a base element (e.g. USB connectors on a computer)
- Sectional-Modular Architecture
 - Common interfaces between elements without a base element (e.g. legos & piping)



Slot-modular
architecture

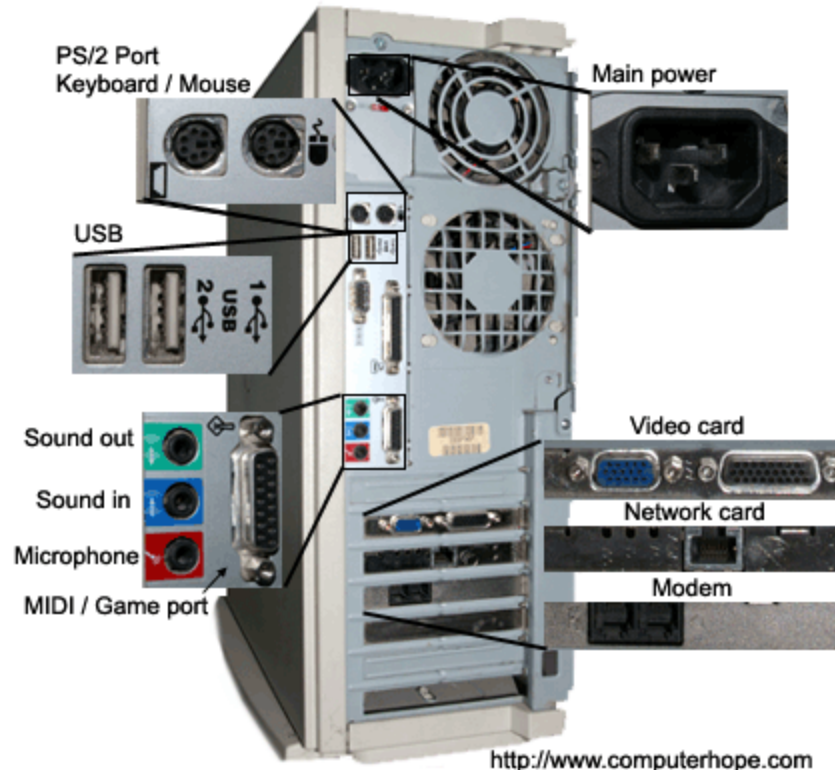


Bus-modular
architecture

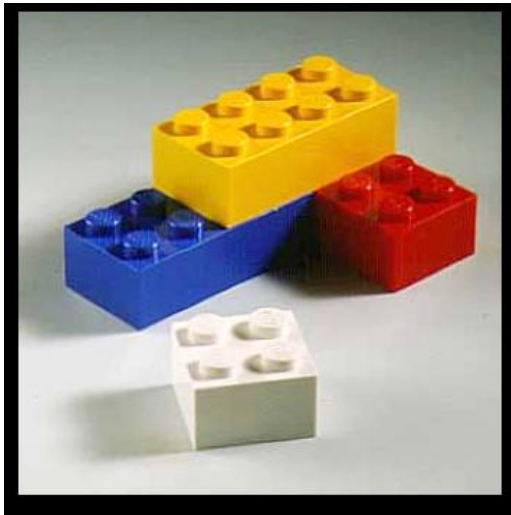
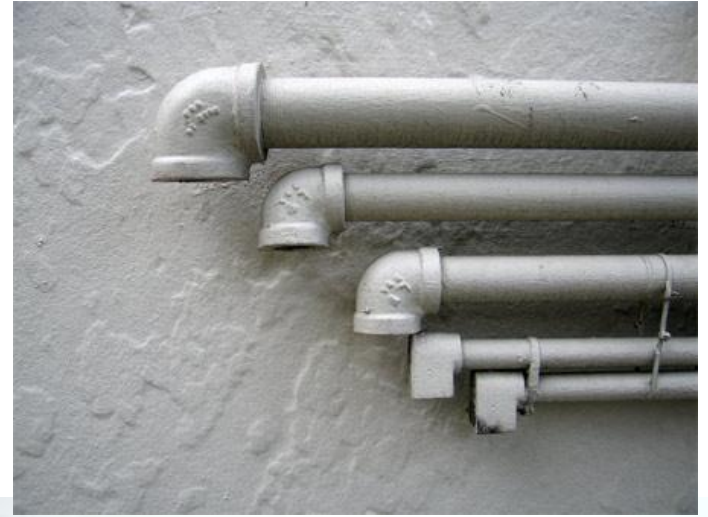


Sectional-modular
architecture

Back of computer case and each connection



Bus?
Slot?
Sectional?



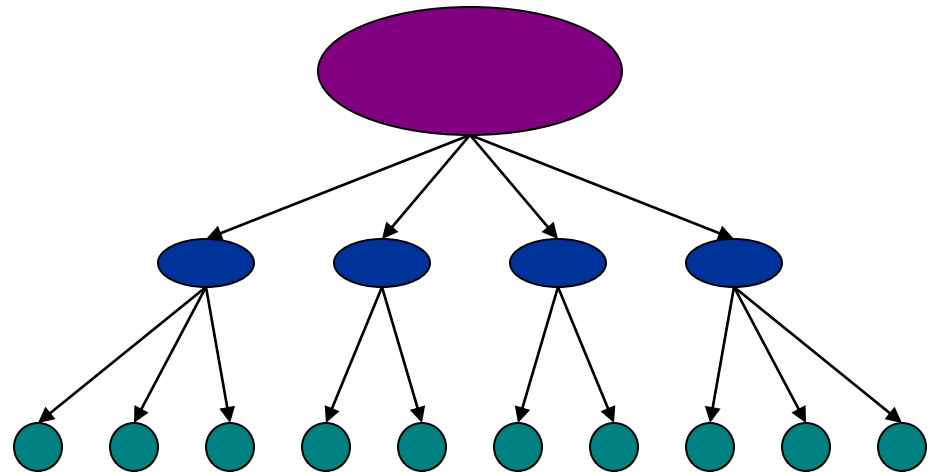
Choosing the Product Architecture

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:

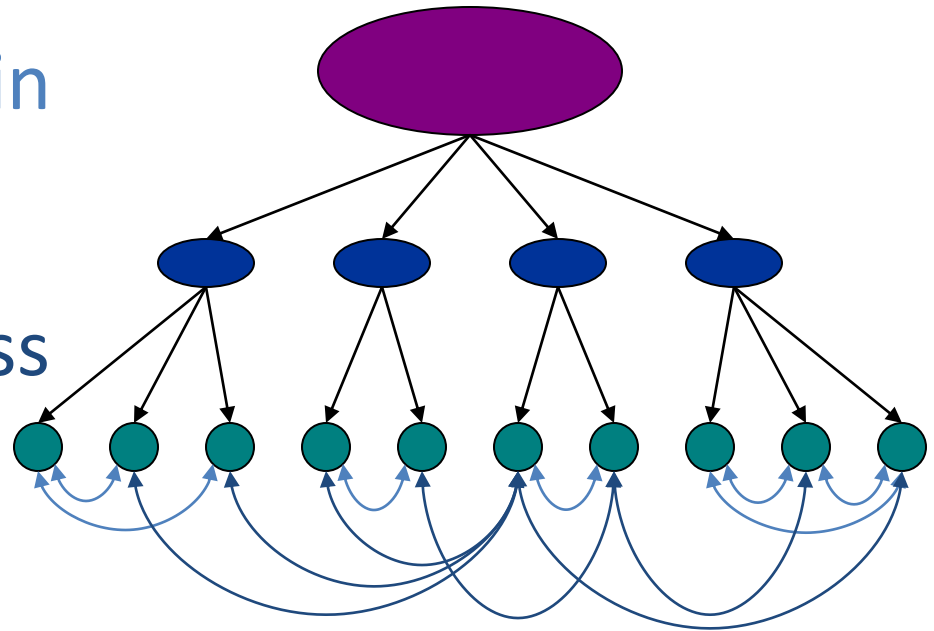
- system
- sub-system
- component



Product Architecture = Decomposition + Interactions

↔ Interactions within chunks

↔ Interactions across chunks



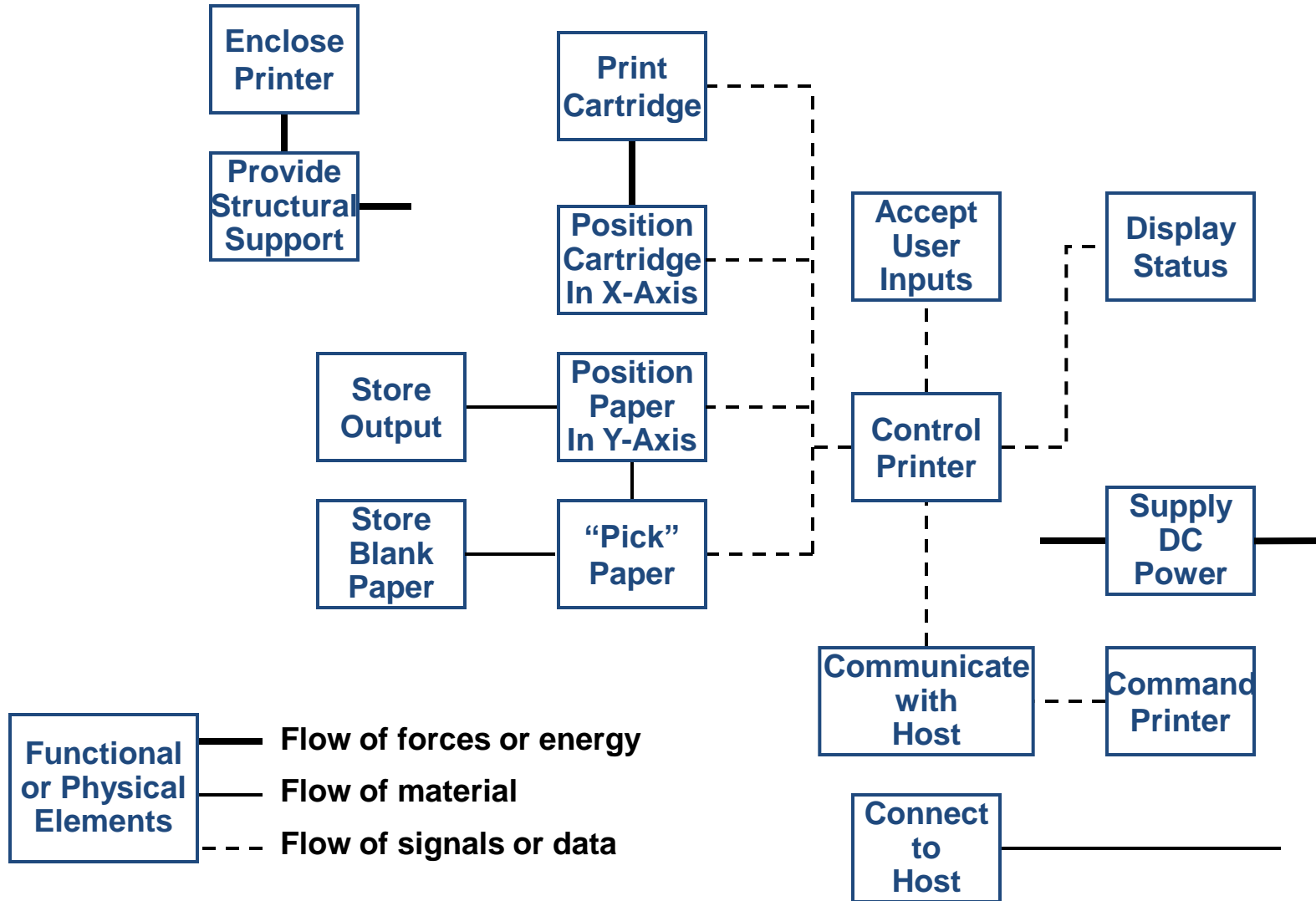
Product Architecture Example: Hewlett-Packard DeskJet Printer



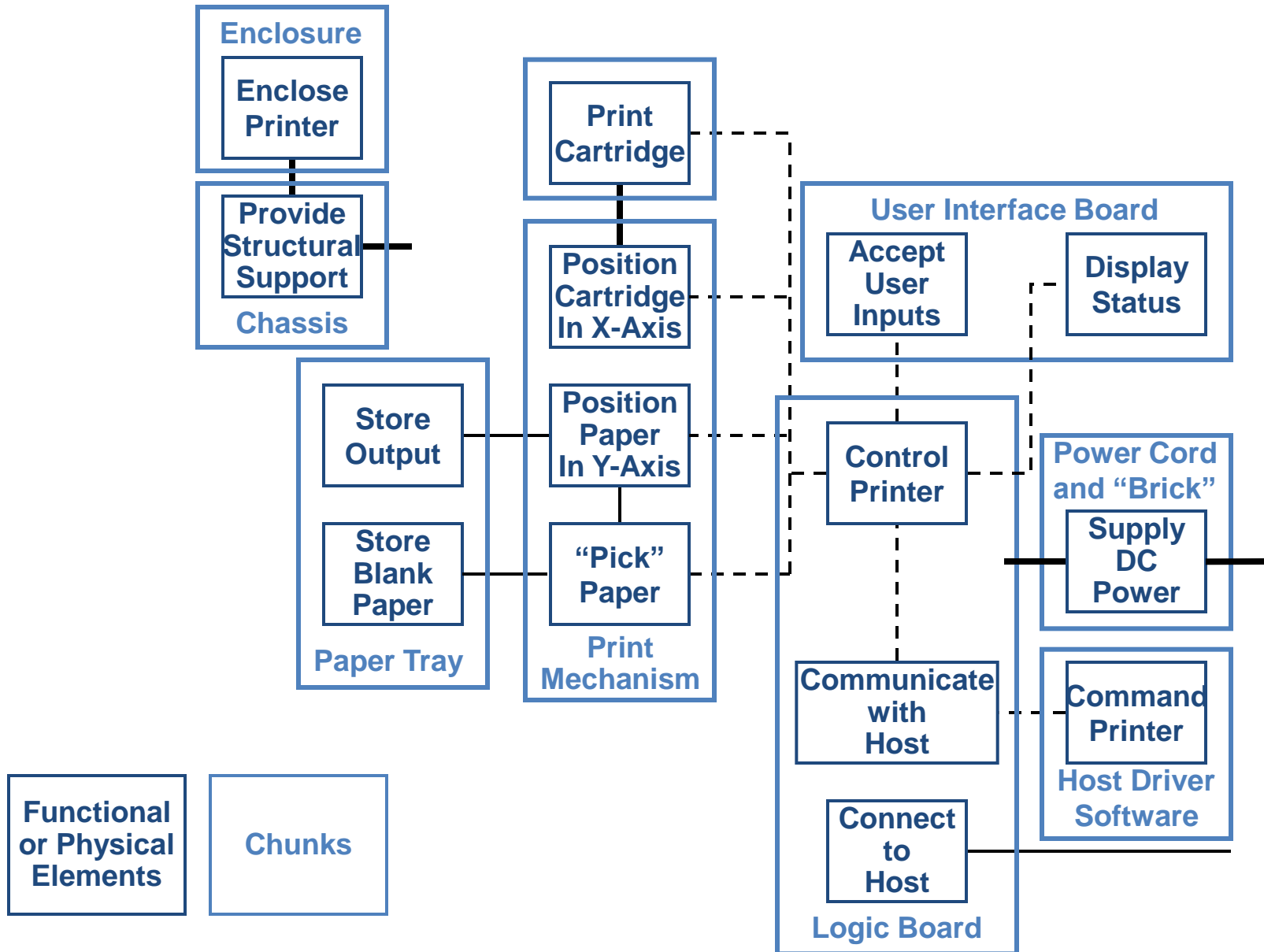
Establishing the Architecture

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

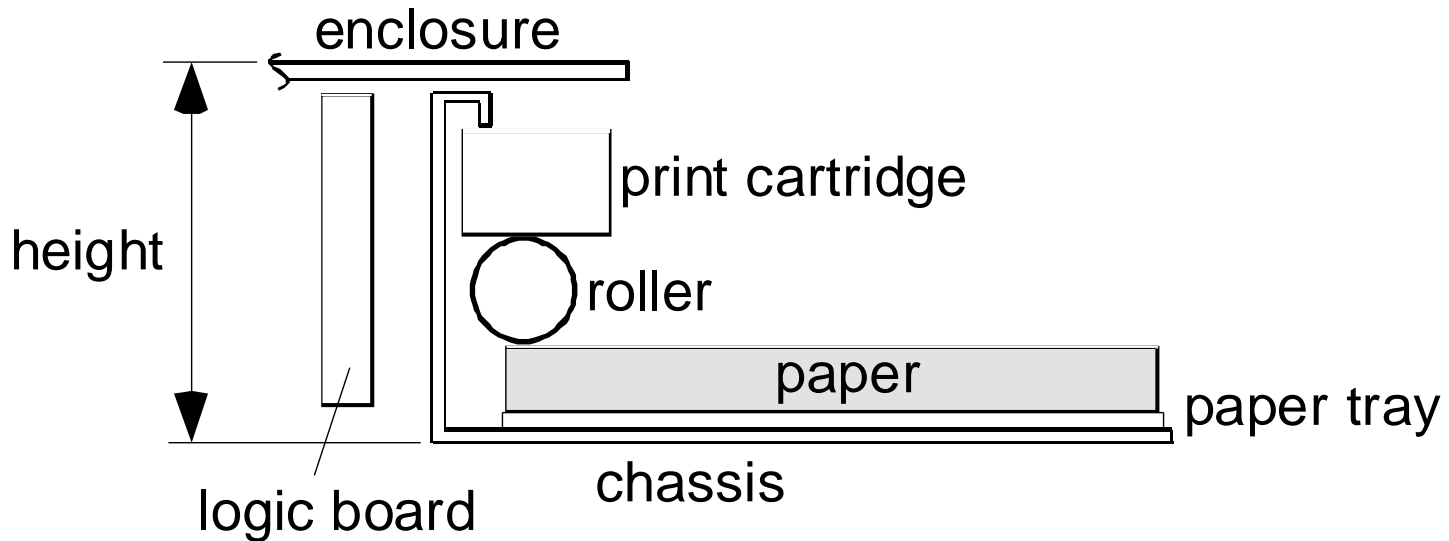
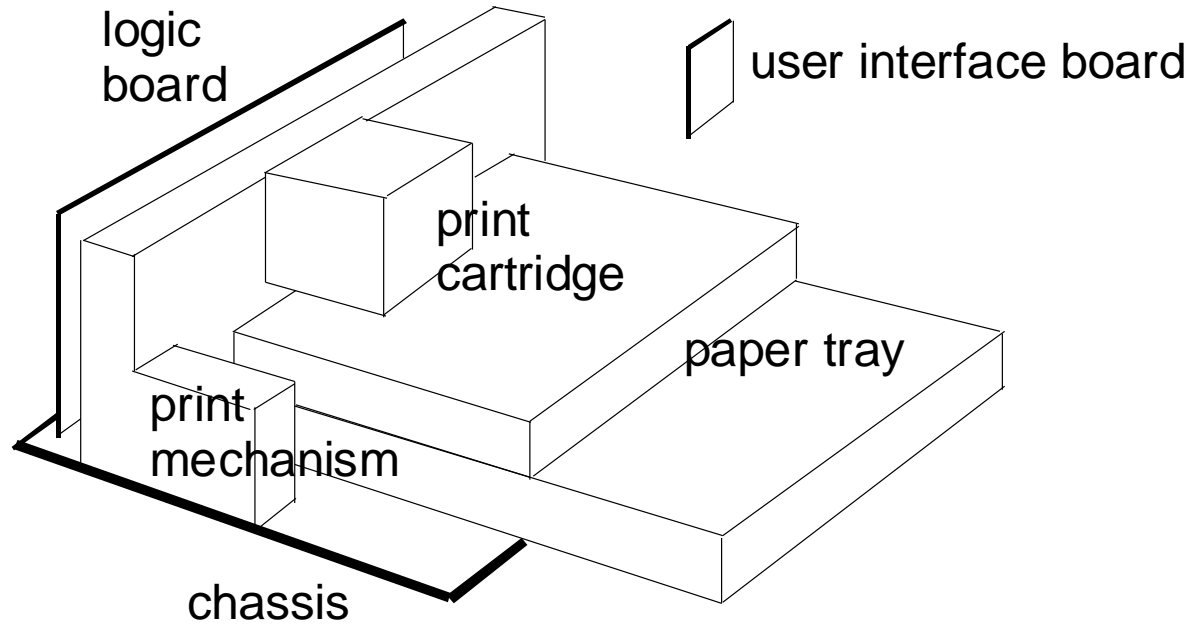
DeskJet Printer Schematic



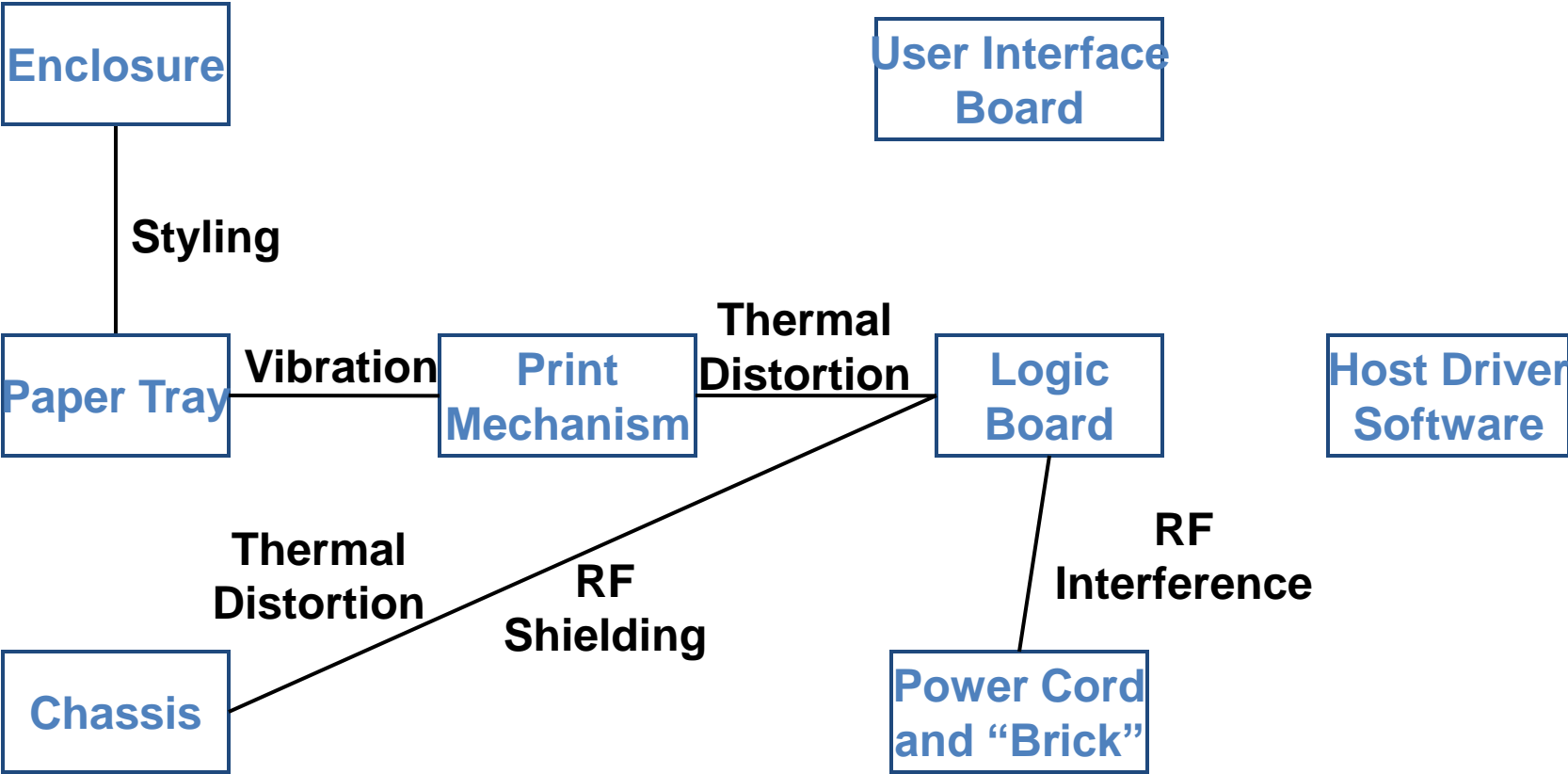
Cluster Elements into Chunks



Geometric Layout



Incidental Interactions



Additional Advantage to Modular Design:

HP products are designed to be recycled. Recycling design features include:

- Modular design to allow components to be removed, upgraded or replaced
- Eliminating glues and adhesives, for example, by using snap-in features
- Marking plastic parts weighing more than 25g according to ISO 11469 international standards, to speed up materials identification during recycling
- Reducing the number and types of materials used
- Using single plastic polymers
- Using molded-in colors and finishes instead of paint, coatings or plating
- Relying on modular designs for ease of disassembly of dissimilar recyclable materials

Planning a Modular Product Line: Commonality Table

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

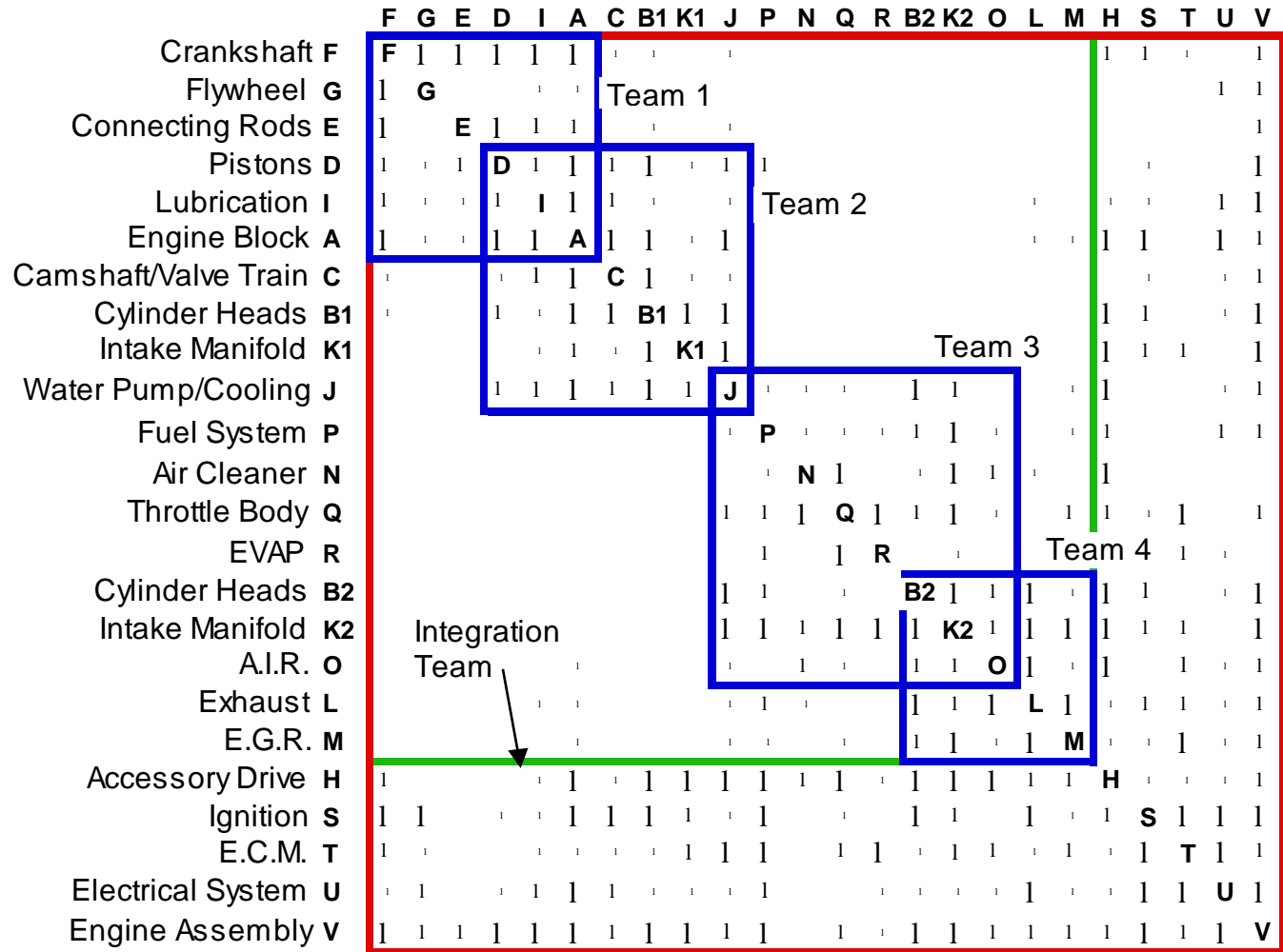
Differentiation versus Commonality

Trade off product variety and production complexity

Fundamental Decisions

- Integral vs. modular architecture?
- What type of modularity?
- How to assign functions to chunks?
- How to assign chunks to teams?
- Which chunks to outsource?

System Team Assignment Based on Product Architecture



Frequency of PDT Interactions
 1 Daily 1 Weekly · Monthly

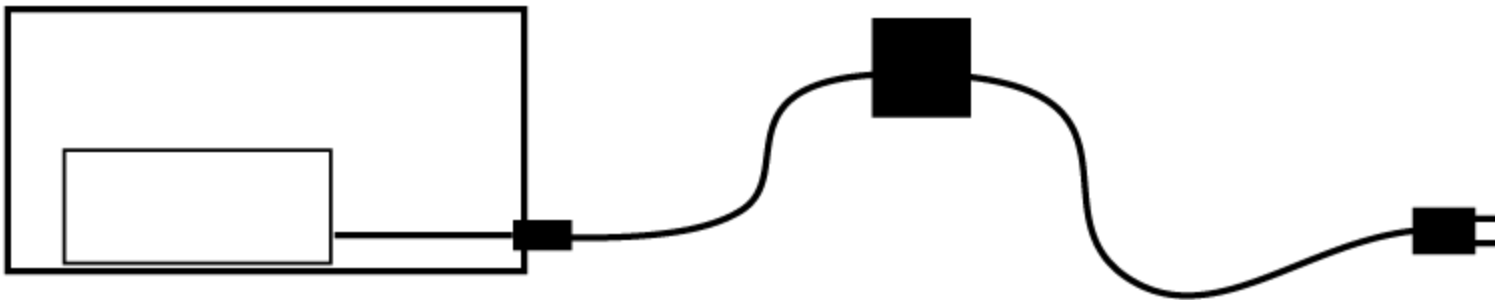
Practical Concerns

- 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

- 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

Power Bricks are annoying to most consumers.
Why are they viewed as a good example of modular design?



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

Point of Product Differentiation

The point in the manufacturing process where a product can only be made into a specific stock keeping unit (SKU)

Delayed Point of Product Differentiation

- The point in the manufacturing process where an item is limited to use for a single specific product is called the “Point of Product Differentiation”
- Delaying the point of product differentiation is called “Late Point Product Differentiation”

Delayed differentiation or **Postponement** is a concept in supply chain management where the manufacturing process starts by making a generic or family product that is later differentiated into a specific end-product. This is a widely used method, especially in industries with high demand uncertainty, and can be effectively used to address the final demand even if forecasts cannot be improved.

An example would be Benetton and their knitted sweaters that are initially all white, and then dyed into different colors only when the seasons customer color preference/demand is known. It is usually necessary to redesign the products specifically for delayed differentiation, and resequence to modify the order of product manufacturing steps.

Advantages of Late Point Product Differentiation

- Reduced inventories
- More easily respond to demand variation

Late Point Differentiation Examples

- Paint where pigment is added at the store
- Benetton sweaters
- HP printers



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Submitted by: DENNIS DEEL (GRAND PRIZE WINNER of the PIZZA CREATIONS RECIPE CONTEST™)
KEY WEST TROPICAL CHEESE BURGER PIZZA

Yields 8 slices
1 Mama Mary's 12" Gourmet Pizza Crust
Olive oil to mist the rim of the crust
1/2 teaspoon Italian Seasoning
1/2 teaspoon Nellie & Joe's Famous Key West Lime Juice
1 cup diced fresh mango
1 cup red bell pepper, chopped
1/4 cup red cucumber, peeled, seeded and chopped
1/4 cup shallots, chopped

Preheat oven to 450°F. Line a vented pizza pan or large baking sheet with parchment baking paper that has been trimmed so edges will not hang over the pan or touch the oven wall, place crust on the pan. Mist the crust and the rim with olive oil. Evenly sprinkle the Italian seasoning over the crust, but not on the edges. Set aside.

In a non-reactive bowl, (glass or plastic), combine lime juice, mango, bell pepper, cucumber, shallots, cilantro and Tabasco Sauce. Stir until well combined, season with salt, to taste. Cover and let marinate at room temperature while cooking ground beef and bacon.

Cook bacon over medium high heat until crispy. Remove to paper towels to drain. In the same skillet add ground beef with crumbled bacon, and freshly ground black pepper, to taste. Brown until meat is no longer pink, transfer meat to paper towels to drain.

Spread the pizza sauce over the crust, but not on the rim. Evenly distribute the hamburger over the sauce, top with crumbled bacon. Take 8 cheese squares and slightly overlap one corner of each square on the rim of crust, squares will overlap each other. Place the remaining cheese square in the middle of the pizza. Drain the marinated mixture, and with a slotted spoon evenly distribute marinated topping over the cheese slices. Reduce oven to 425°F.

Keeping pizza on the pan, bake for 8-10 minutes. To crisp the crust, remove from the parchment-lined pan and place directly on the oven rack for 2-3 minutes. Cool 5 minutes before slicing.

- 1/2 cup cilantro, rough chopped
- 1/4 teaspoon Tabasco Sauce
- Kosher salt
- 4 strips of peppered bacon, crumbled
- 3/4 pound extra lean ground beef
- Freshly ground black pepper to taste
- 3/4 cup pizza sauce
- 9 sandwich size slices of Kraft 2% Sharp Cheddar Cheese

Preheat oven to 450°F.
Remove pizza crust from package.



1 Lightly brush crust with olive oil.



2 Top crust with desired ingredients.



3 Lower oven temperature to 425°F. Bake on oven rack or cookie sheet (middle position) for 7 1/2 to 10 min.

Hint: For a crisper crust, broil until desired appearance is achieved.

Submitted by: ERIN RENOUF MYZLOIE (GRAND PRIZE WINNER of the PIZZA CREATIONS RECIPE CONTEST™)
CHICKEN PESTO CLUB PIZZA

- Yields 8 slices
- 1 Mama Mary's 12" Gourmet Pizza Crust
- Olive oil to mist the rim of the crust
- 1 tablespoon sesame seeds
- 1/2 cup prepared pesto
- 1/2 cup mayonnaise
- 1 tablespoon Dijon mustard
- 2 Roma tomatoes, peeled and sliced

Preheat oven to 450°F. Line a vented pizza pan with parchment baking paper that has been trimmed so edges will not hang over the pan or touch the oven wall. Mist the crust and rim with olive oil, sprinkle with sesame seeds.

Combine pesto, mayonnaise and Dijon mustard, mix very well. Spread over the pizza. Top with tomatoes, chicken, bacon and cheeses.

Reduce oven temperature to 425°F. Keeping pizza on the pan, bake for 10 minutes. To crisp the crust remove from the lined pan and place directly on the oven rack for 3 additional minutes.

Remove from oven. Top pizza with basil leaves and pine nuts.

- 1 1/2 cups cooked chicken, shredded
- 8 slices of bacon, cooked, drained and crumbled
- 1 cup Mozzarella Cheese, shredded
- 3/4 cup Parmesan Cheese, shredded
- 10 basil leaves, rolled and thinly sliced
- 2 tablespoons pine nuts, toasted

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12" Pizza Crusts

Nutrition Facts
Serving Size 1/4 Pizza Crust (57g/2oz.)
Servings per package 12

Amount Per Serving	Calories from Fat 50	% Daily Value*
Calories 190		
Total Fat 6g	9%	
Saturated Fat 1g	5%	
Trans Fat 0g	0%	
Cholesterol 0mg	0%	
Sodium 190mg	9%	
Total Carbohydrate 28g	9%	
Dietary Fiber 1g		
Sugars 1g		
Protein 6g		

*Percent daily values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

INGREDIENTS: Enriched flour (wheat flour, malted barley flour, niacin, ferrous sulfate, thiamine mononitrate, riboflavin, folic acid), water, soybean oil, contains less than 2% of the following: yeast, calcium propionate & potassium sorbate (preservatives), vinegar, salt, dried honey, calcium carbonate, cornstarch, mineral oil, tricalcium phosphate, L-cysteine, calcium stearate, ascorbic acid added as dough conditioner.
Allergens: contains wheat

12" Whole Wheat Pizza Crusts

Nutrition Facts
Serving Size 1/4 Pizza Crust (57g/2oz.)
Servings per package 8

Amount Per Serving	Calories from Fat 47	% Daily Value*
Calories 156		
Total Fat 5g	9%	
Saturated Fat 0g	0%	
Trans Fat 0g	0%	
Cholesterol 0mg	0%	
Sodium 240mg	8%	
Total Carbohydrate 25g	16%	
Dietary Fiber 4g		
Sugars 5g		
Protein 5g		

*Percent daily values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

INGREDIENTS: Whole wheat flour, water, soybean oil, corn, dried honey, yeast, salt, contains less than 2% of each of the following: wheat gluten, salt, yeast, vinegar, honey, wheat calcium propionate and potassium sorbate (preservatives), starch, L-cysteine, soy flour, ascorbic acid added as dough conditioner.
Allergens: contains wheat and soy. Manufactured on shared equipment with egg and milk.

12" Deep Dish Pizza Crust

Nutrition Facts
Serving Size 1/8 Pizza Crust (57g/2oz.)
Servings per package 8

Amount Per Serving	Calories from Fat 50	% Daily Value*
Calories 190		
Total Fat 6g	9%	
Saturated Fat 1g	5%	
Trans Fat 0g	0%	
Cholesterol 0mg	0%	
Sodium 190mg	9%	
Total Carbohydrate 28g	9%	
Dietary Fiber 1g		
Sugars 1g		
Protein 6g		

*Percent daily values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

INGREDIENTS: Enriched flour (wheat flour, malted barley flour, niacin, ferrous sulfate, thiamine mononitrate, riboflavin, folic acid), water, soybean oil, contains less than 2% of the following: natural garlic butter flavor, yeast, calcium propionate & potassium sorbate (preservatives), vinegar, salt, dried calcium stearate, ascorbic acid added as dough conditioner.
Allergens: contains wheat, dairy

12" Thin & Crispy Pizza Crusts

Nutrition Facts
Serving Size 1/4 Pizza Crust (57g/2oz.)
Servings per package 8

Amount Per Serving	Calories from Fat 50	% Daily Value*
Calories 190		
Total Fat 6g	9%	
Saturated Fat 1g	5%	
Trans Fat 0g	0%	
Cholesterol 0mg	0%	
Sodium 190mg	9%	
Total Carbohydrate 28g	9%	
Dietary Fiber 1g		
Sugars 1g		
Protein 6g		

*Percent daily values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

INGREDIENTS: Enriched flour (wheat flour, malted barley flour, niacin, ferrous sulfate, thiamine mononitrate, riboflavin, folic acid), water, soybean oil, contains less than 2% of the following: yeast, calcium propionate & potassium sorbate (preservatives), vinegar, salt, dried calcium stearate, ascorbic acid added as dough conditioner.
Allergens: contains wheat

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If for any reason you are dissatisfied with our product, clip the date code from the front of the package and return it along with your sales receipt and written comments for a full refund to:

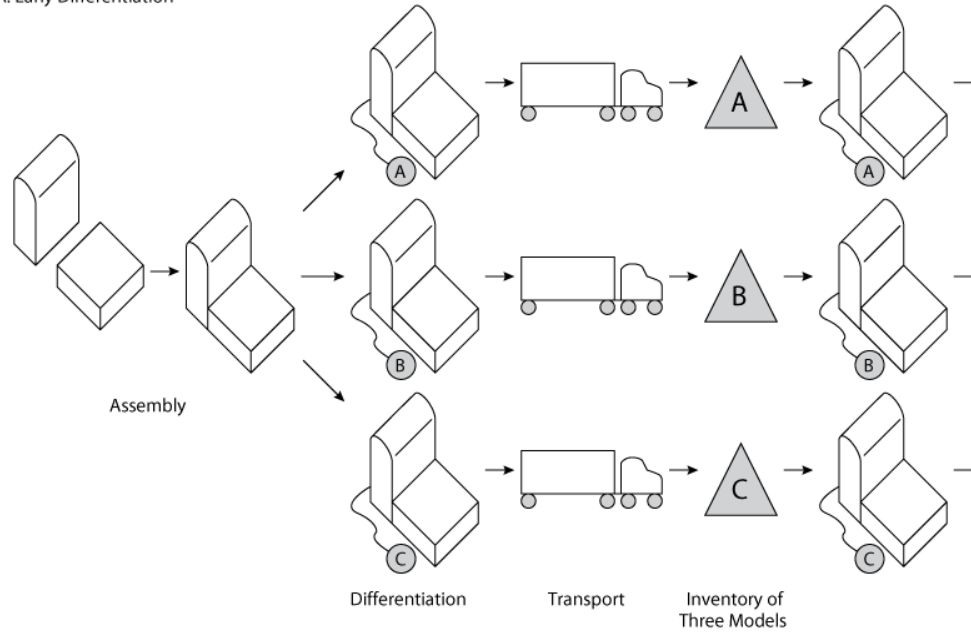


Modular Design allows for Late Point Differentiation

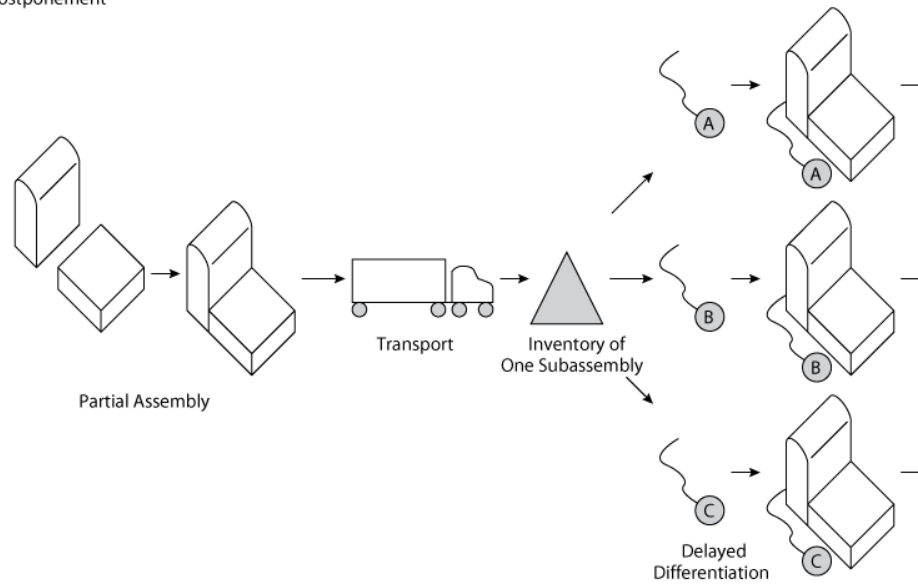
Benefits of Late Differentiation

- Easier to control
- Faster reaction to customer requirement
- Lower inventory costs
- Fewer interfaces

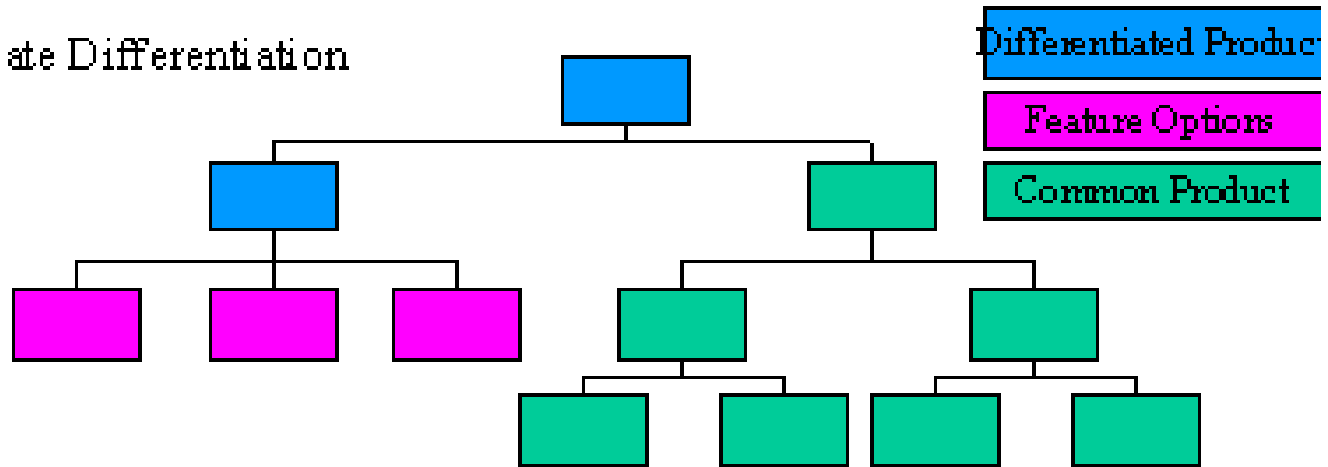
Scenario A: Early Differentiation



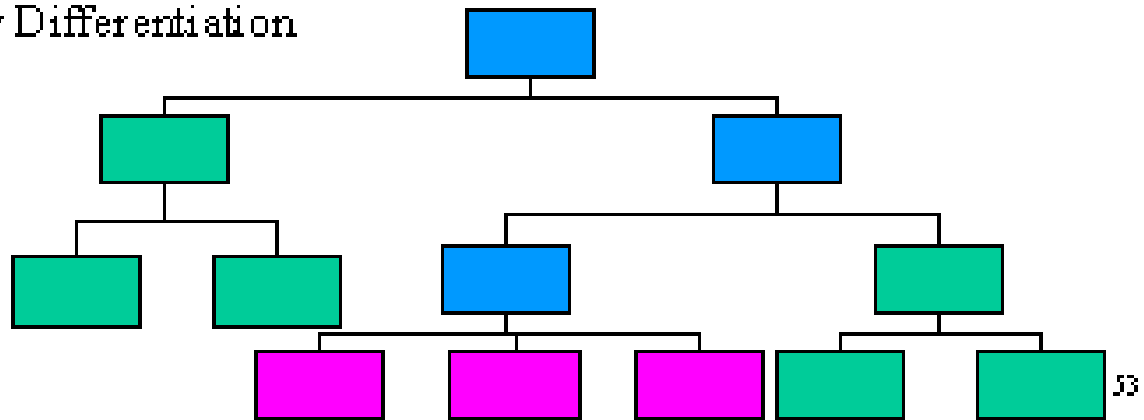
Scenario B: Postponement



Late Differentiation



Early Differentiation



Late Point Differentiation Principles

- The differentiating elements of the product must be concentrated in one or a few chunks
- The product and production process must be designed so that the differentiating chunk(s) can be added to the product near the end of the supply chain.

Platform Planning

The process of deciding what should be shared across products and what should be unique across products?

For example:

- How many driveshafts should you have for a Ford F150?

Platform Planning

- Attempts to resolve the tension between
 1. Differentiating the product for various customers
 2. Taking advantage of the economic benefits of using common components
- Product architecture will determine what trade-offs are available... if no good options are available, see if the options can be improved by changing the product architecture