Design Methodology in the Development of Mechatronic Products

- Part 3

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Agenda

- Concept Selection
- Concept Testing
- Set Final Specifications
- Design for Manufacturing

Concept Selection – Example: Reusable Syringe

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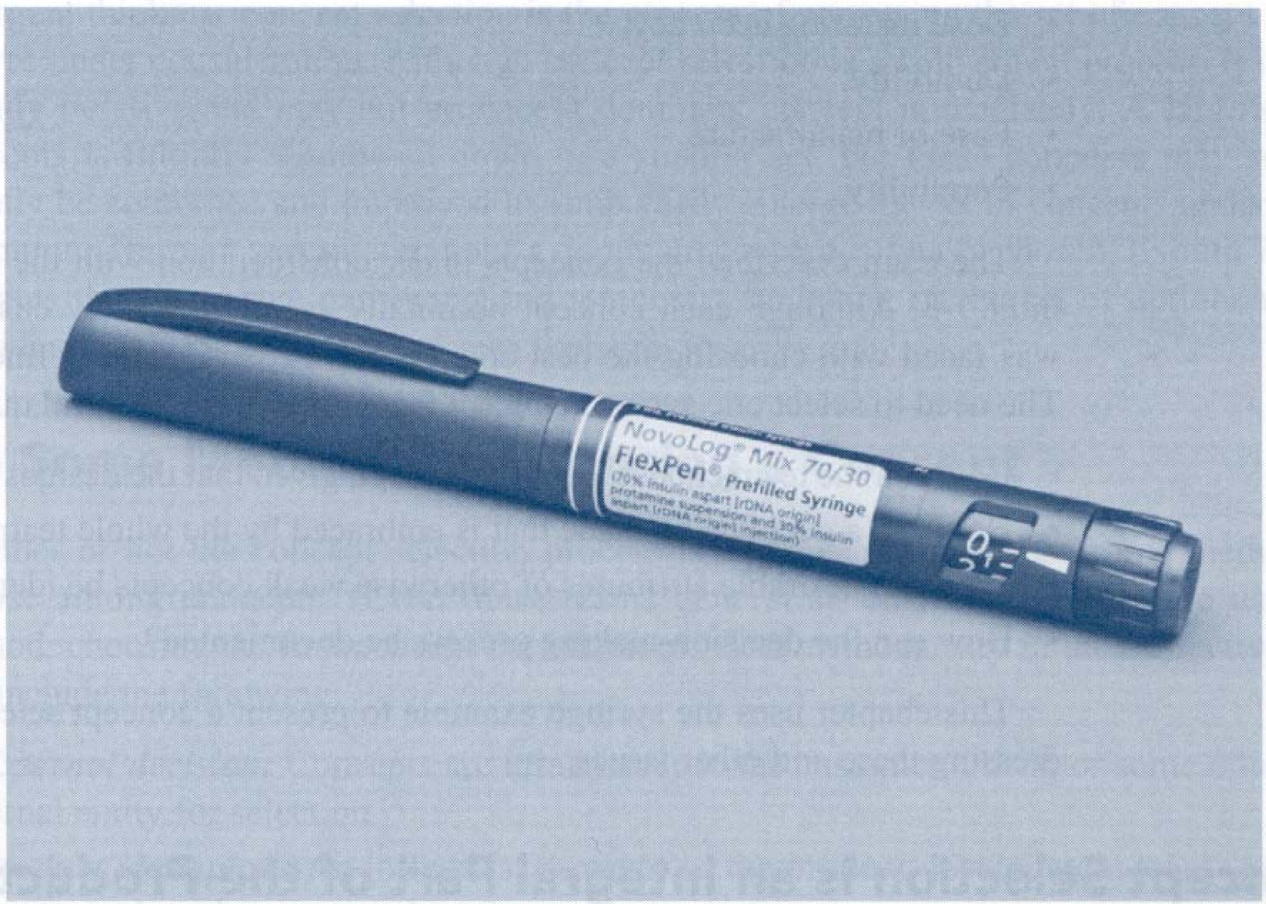

Courtesy of Novo Nordisk Pharmaceuticals Inc.

Concept Selection

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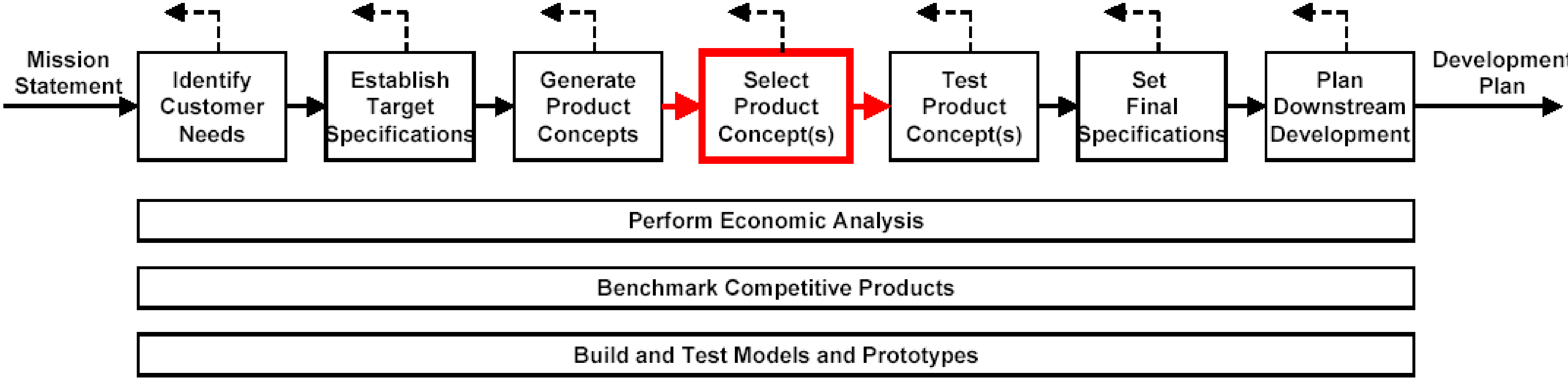

What are the Goals of Concept Selection

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Concept selection is the process of ***evaluating concepts with respect to customer needs and other criteria***, thus comparing the relative strengths and weakness of the concepts, and ***selecting one or more concepts for further investigation, testing, or development.***

All Teams Use Some Method for Choosing a Concept

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External decision

Concepts are turned over to the customer, client, or some other external entity for selection.

Product champion

An influential member of the product development team chooses a concept based on personal preference.

Intuition

The concept is chosen by its feel. Explicit criteria or trade-offs are not used.The concept just *seems* better.

Multivoting

Each member of the team votes for several concepts. The concept with the most votes is selected.

Pros and cons

The team lists the strengths and weaknesses of each concept and makes a choice based upon group opinion.

Prototype and test

The organization builds and tests prototypes of each concept, making a selection based upon test data.

Decision matrices

The team rates each concept against prespecified selection criteria, which may be weighted.

The Iterative Nature of the Concept Selection Process

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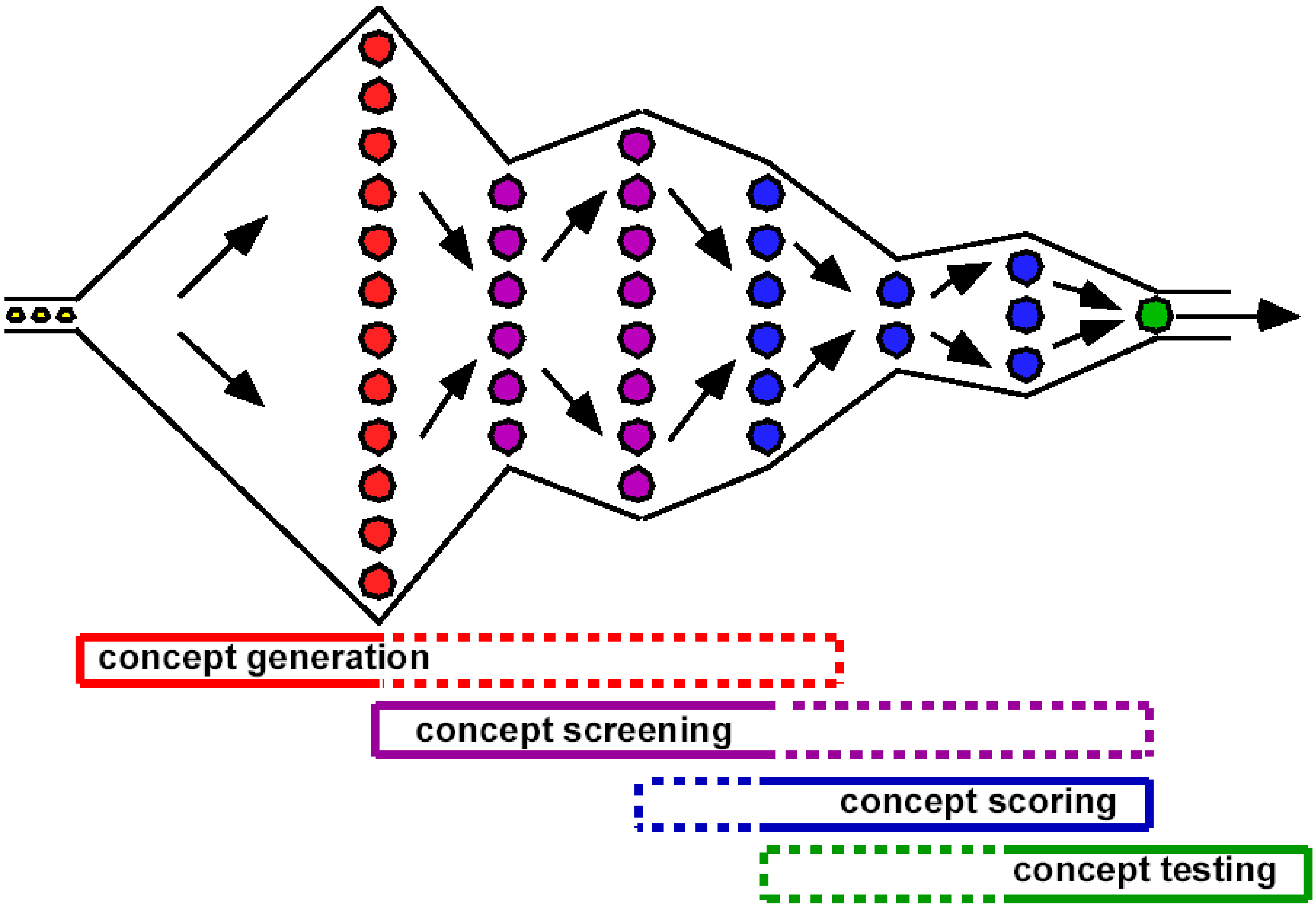

Step 1: Prepare the Selection Matrix

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SELECTION CRITERIA	A	B	C	D	E	F	G	REF.
	CONCEPT VARIANTS							
Ease of Handling	0	0	–	0	0	–	–	0
Ease of Use	0	–	–	0	0	+	0	0
Number Readability	0	0	+	0	+	0	+	0
Dose Metering	+	+	+	+	+	0	+	0
Load Handling	0	0	0	0	0	+	0	0
Manufacturing Ease	+	–	–	0	0	–	0	0
Portability	+	+	–	–	0	–	–	0
PLUSES	3	2	2	1	2	2	2	
SAMES	4	3	1	5	5	2	3	
MINUSES	0	2	4	1	0	3	2	
NET	3	0	–2	0	2	–1	0	
RANK	1	3	7	5	2	6	4	
CONTINUE?	Yes	Yes	No	No	Yes	No	Yes	

Step 2: Rate the Concepts

- The ***rating*** is based on:

"+" = " better than"

"0" = "the same as"

"-" = " worse than"

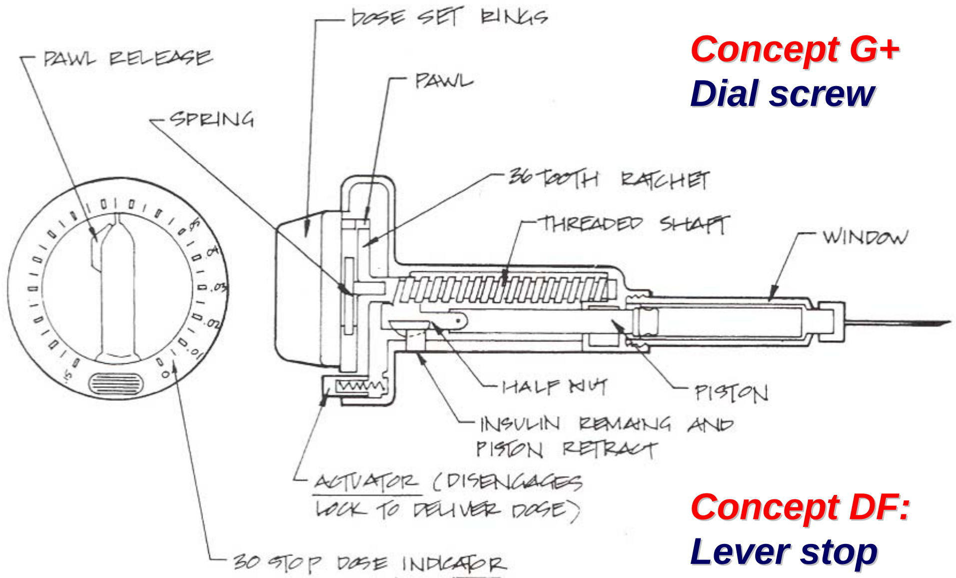
Step 3: Rank the Concepts

- The ***rank*** is based on:

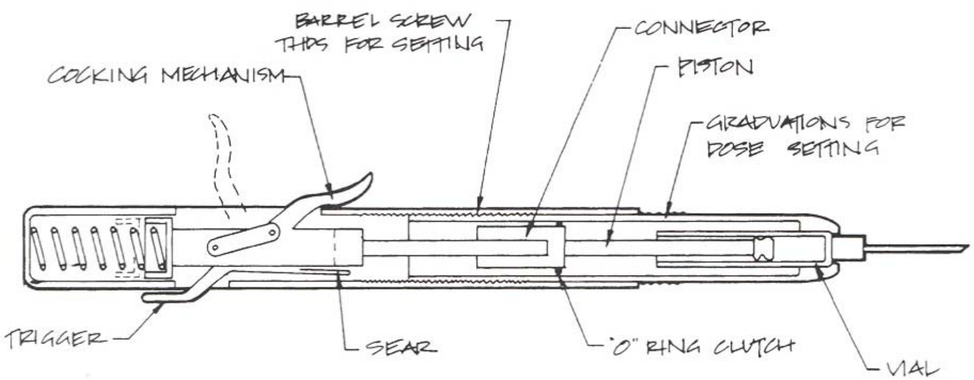
Summation of “+:s” , “0:s” and “-:s” respectively.

Step 4: Combine and Improve the Concepts

Concept G+
Dial screw



Concept DF:
Lever stop



New (DF) and revised concept (G+) for the syringe.

Step 5 and Step 6

- ***Step 5: Select One or More Concepts***
- ***Step 6: Reflect on the Result and the Process***

Concept Scoring – Step 1: Prepare the Selection Matrix

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		Concepts							
		A (reference) Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of Handling	5%	**3**	0.15	3	0.15	4	0.2	4	0.2
Ease of Use	15%	**3**	0.45	4	0.6	4	0.6	3	0.45
Readability of Settings	10%	2	0.2	**3**	0.3	5	0.5	5	0.5
Dose Metering Accuracy	25%	**3**	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	**3**	0.45
Ease of Manufacture	20%	**3**	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	**3**	0.3	3	0.3	3	0.3	3	0.3
	Total Score	2.75		3.45		3.10		3.05	
	Rank	4		1		2		3	
	Continue?	No		Develop		No		No	

Step 2: Rate the Concepts

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Relative Performance	*Rating*
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Step 3: Rank the Concepts

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The ***total score*** for each concept is the ***sum of the weighted scores:***

.

$$S_j = \sum_{i=1}^{n} r_{ij} w_i$$

where

r_{ij} = raw rating of concept j for the ith criterion
w_i = weighting for ith criterion
n = number of criteria
S_j = total score for concept j

Step 4, 5 and 6

- Step 4: Combine and Improve the Concepts
- Step 5: Select One or More Concepts
- Step 6: Reflect on the Result and the Process

Concept Testing

Concept Testing

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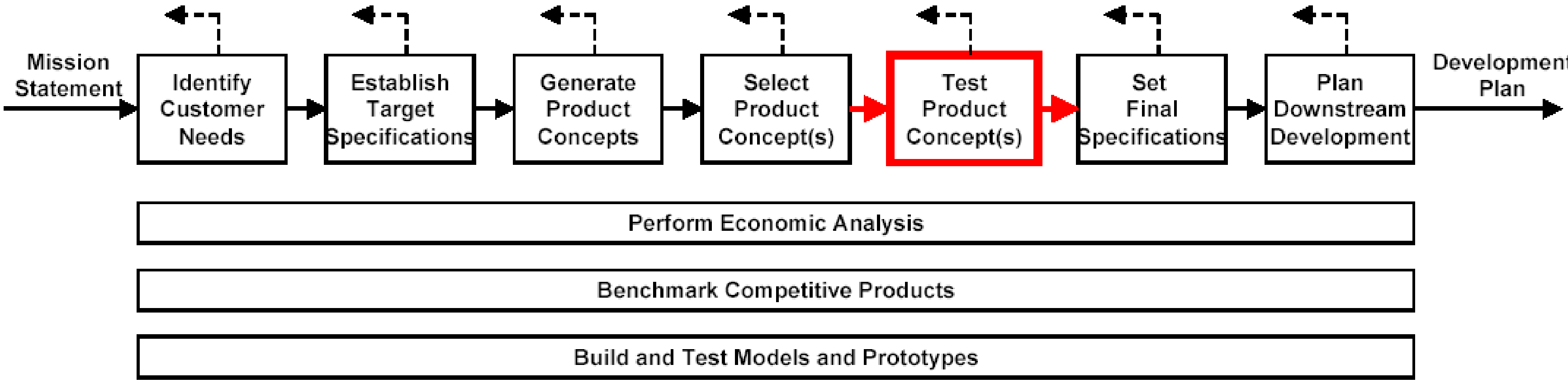

Step 1: Define the Purpose of the Concept Test *p 147*

The ***primary questions*** addressed in concept testing are typically:

- ***Which of several alternative concepts should be pursued?***
- ***How can the concept be improved to better meet customer needs?***
- ***Approximately how many units are likely to be sold?***
- ***Should development be continued?***

Step 2: Choose a Survey Population

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The team should *choose a survey population* that *mirrors the target population* in as many ways as possible.

Factors Favoring a Smaller Sample Size	Factors Favoring a Larger Sample Size
• Test occurs early in concept development process. • Test is primarily intended to gather qualitative data. • Surveying potential customers is relatively costly in time or money. • Required investment to develop and launch the product is relatively small. • A relatively large fraction of the target market is expected to value the product (i.e., many positively inclined respondents can be found without a large sample).	• Test occurs later in concept development process. • Test is primarily intended to assess demand quantitatively. • Surveying customers is relatively fast and inexpensive. • Required investment to develop and launch the product is relatively high. • A relatively small fraction of the target market is expected to value the product (i.e., many people have to be sampled to reliably estimate the fraction that value the product).

Step 3: Choose a Survey Format

The ***following formats*** are commonly used in concept testing:

- ***Face-to-face interaction***
- ***Telephone***
- ***Postal mail***
- ***Electronic mail***
- ***Internet***

Step 4: Communicate the Concept

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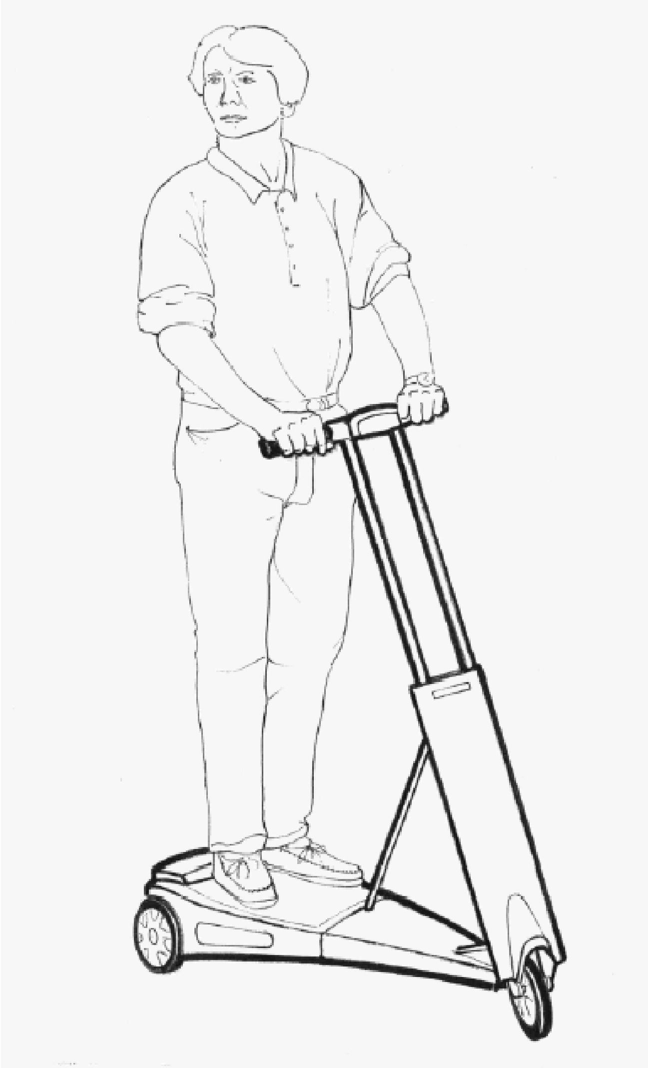
Example: Verbal Description (of the scooter)

- The product is a lightweight electric scooter that can be easily folded and taken with you inside a building or on public transportation.
- The scooter weighs about 25 pounds. It travels at speeds of up to 15 miles per hour and can go about 12 miles on a single charge.
- The scooter can be recharged in about two hours from a standard electric outlet.
- The scooter is easy to ride and has simple controls — just an accelerator button and a brake.

Step 4: Communicate the Concept



Example: Sketch

Step 4: Communicate the Concept

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Example: Photo

Example: Rendering

Step 4: Communicate the Concept

Example: Storyboard

Step 4: Communicate the Concept

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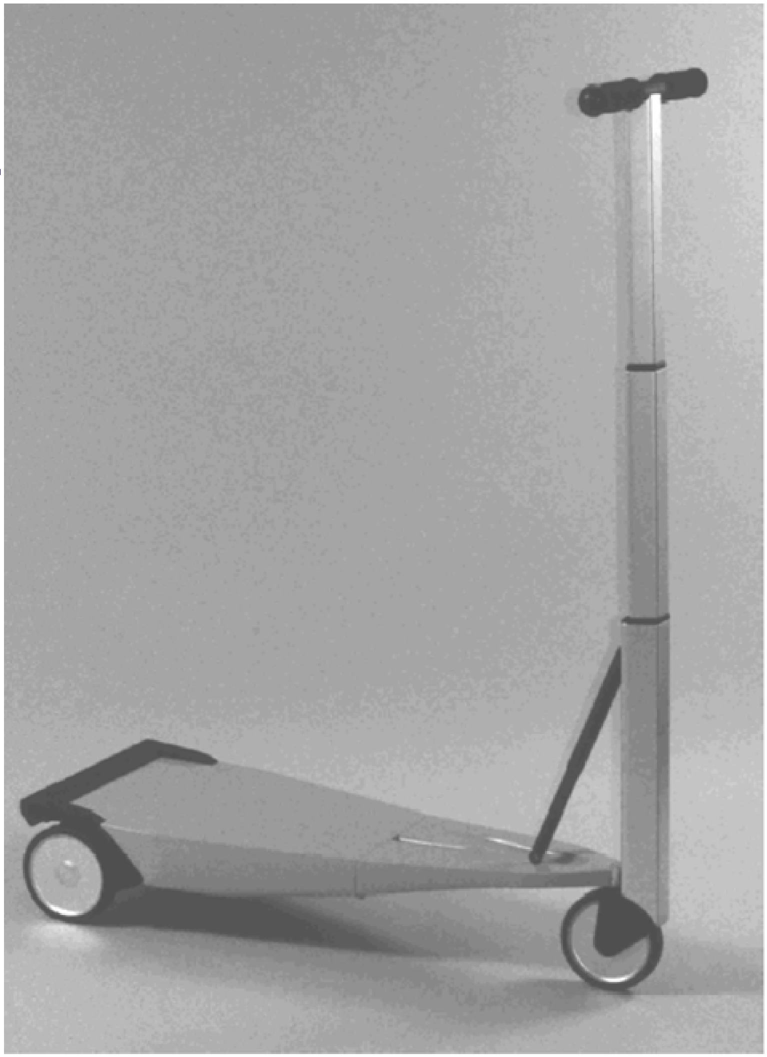

Example: Appearance Model

Step 4: Communicate the Concept

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Example: Working Prototype

Step 5: Measure Customer Response

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– If the product were priced according to your expectations, how likely would you be to purchase the scooter within the next year?

☐	☐	☐	☐	☐
I would **definitely not purchase** the scooter.	I would **probably not purchase** the scooter.	I **might or might not purchase** the scooter.	I would **probably purchase** the scooter.	I would **definitely purchase** the scooter.

Comments:

- ***What would you expect the price of the scooter to be?***
- ***What concerns do you have about the product concept?***
- ***Can you make any suggestions for improving the product concept?***

Step 6: Interpret the Results

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If the team is simply interested in comparing two or more concepts, interpretation of the results is straightforward.

Forecasting Sales

$$Q = N \times A \times P$$

- Q = sales (annual)
- N = number of (annual) purchases
- A = awareness x availability (fractions)
- P = probability of purchase (surveyed)

$$= C_{def} \times F_{def} + C_{prob} \times F_{prob}$$

On Product and Systems Architecture

BSDB p 52

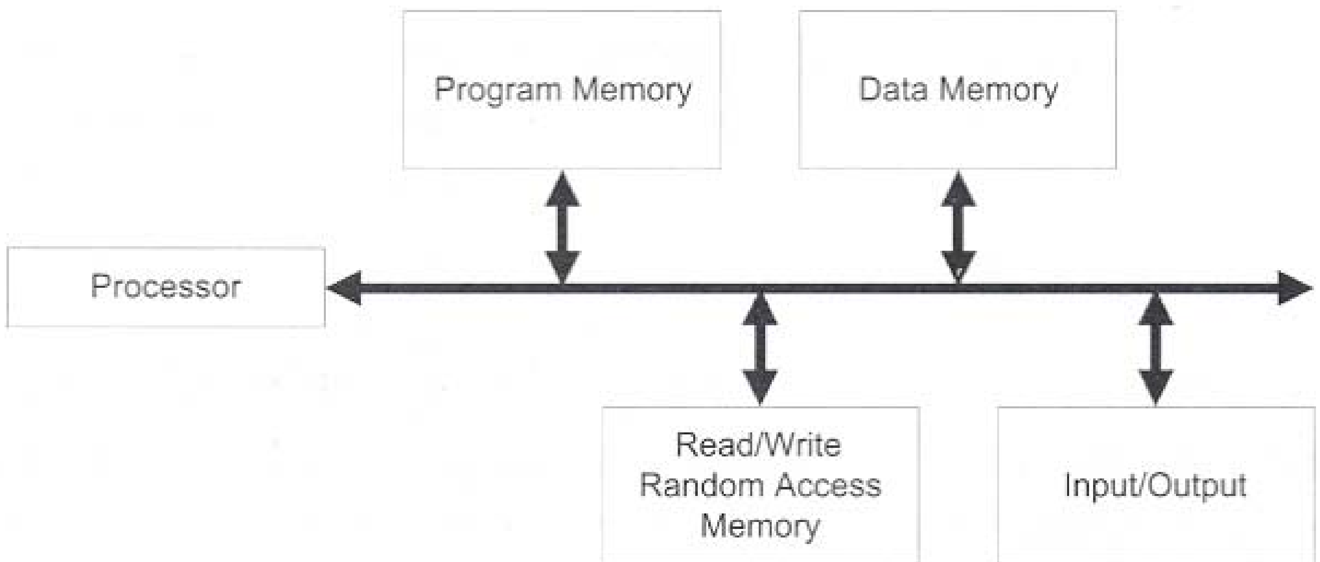
Within electronic engineering and software engineering, as well as for products in general, the term *architecture*, or more specifically *product architecture*, is used to describe *the organization and structure of a system or a product and the ways in which the various elements of the product/system interact.*

The *choice of product/system architecture* is therefore likely to be a *critical factor in determining the way in which an intelligent machine or a product operates.*

On Product and Systems Architecture

Von Neumann architecture

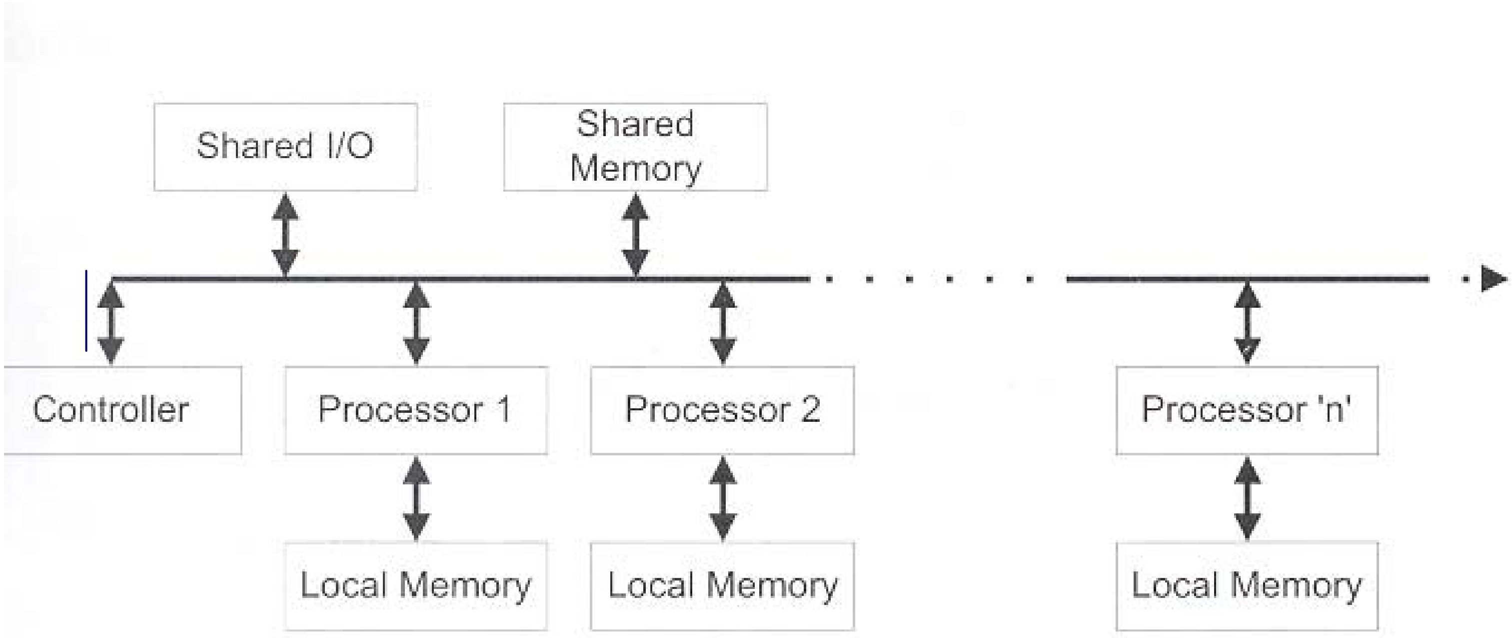
Named after the mathematician John von Neumann, this architecture describes the configuration of most common computer systems. Also referred to as a *random access sequential machine*, a von Neumann architecture assumes the existence of a central processor and read-write random access memory as in the figure. In operation, the processor sequentially executes instructions stored in memory using data stored elsewhere in memory.



On Product and Systems Architecture

Parallel architecture

Parallel architectures are based around a number of processors sharing access to common memory as in the figure. Execution of instructions is allocated to individual processors in turn according to loading, enabling significantly shorter processing times to be achieved.



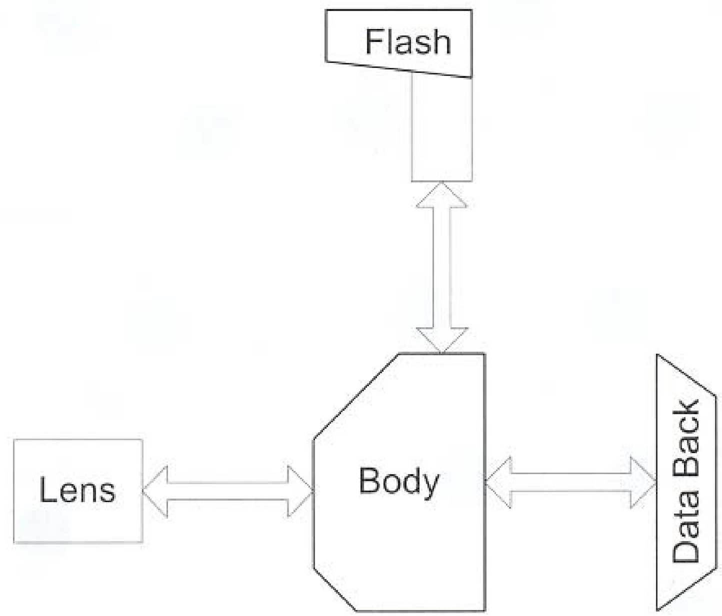
On Product and Systems Architecture

BSDB pp 52 - 53

Distributed and embedded systems architectures

In a distributed architecture, processing power is devolved to individual elements or components within the system, each of which essentially runs its own independent program based on local memory.

Thus in the *camera system*, each of the elements; body, lens, flash gun and data back; contains all the processing capability required to enable it to operate as part of the overall system together with an appropriate interface to enable communication with the other elements of the system.

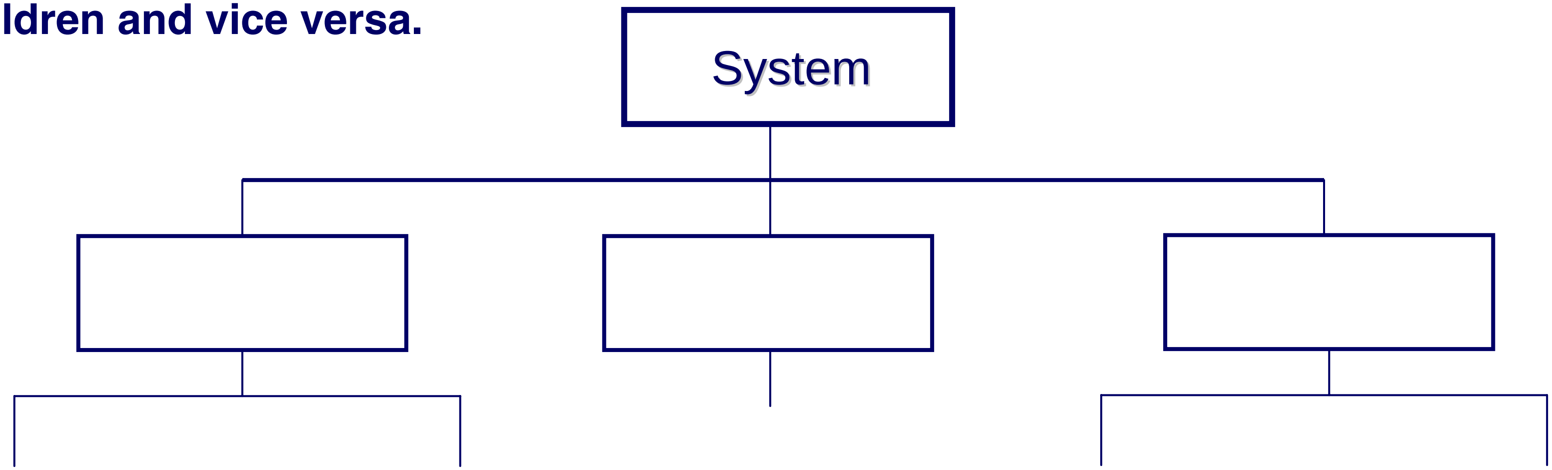


On Product and Systems Architecture

BSDB pp 52 - 53

Hierarchical architecture

A hierarchical architecture is organized as a tree structure such as that shown in the figure, in which each member, with the exception of the topmost member and bottommost members of each branch, are both the parents to the members of the hierarchy in the layer below them and children of a member of the hierarchy in the layer above them. Thus at the top level of the hierarchy sits the complete system while the lowest level of each branch describes one of the individual elements or components that make up the complete system. Information flows up and down the layers in the hierarchy in a strictly ordered manner from parent to children and vice versa.

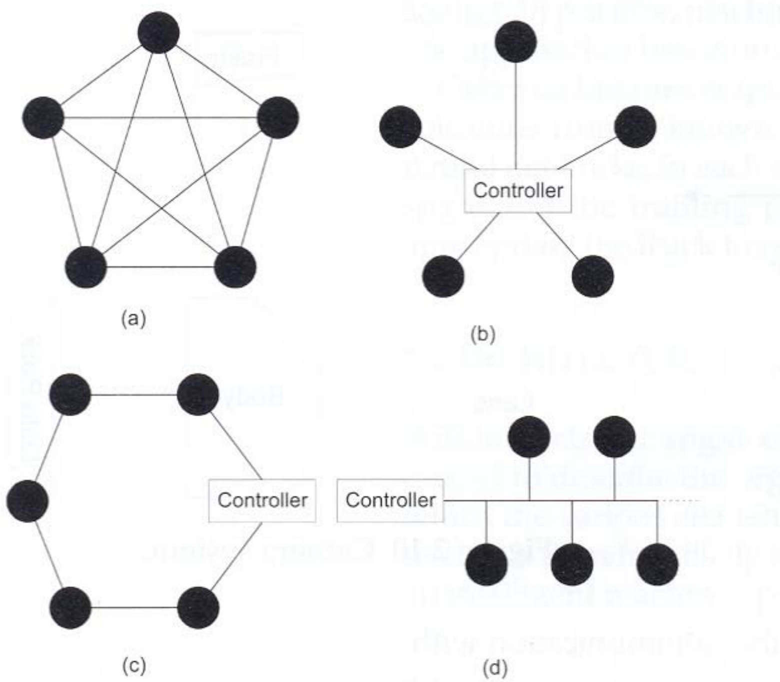


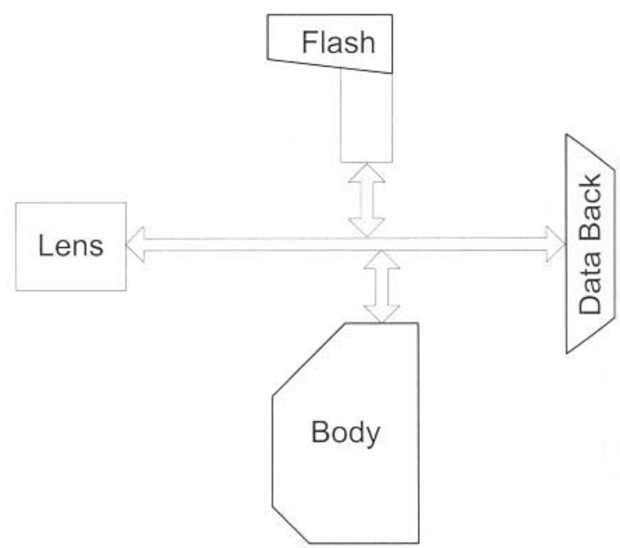
On Product and Systems Architecture

BSDB pp 52 - 53

Network architectures

Networks may take a variety of forms such as those shown in the left figure. Unlike a hierarchical configuration, all members of a network are essentially equal, though there may be some bias in order to assign priorities to certain nodes. Each node of the network can itself be based around a microprocessor or micro controller which provides local processing power and hence forms the basis of the distributed and embedded system that is at the heart of many mechatronic systems. Thus, the camera, below, can be redrawn as a bus architecture with the processor in the main body acting as system controller.





What is Product Architecture?

*In a product the **physical elements** are typically organized into several major **physical building blocks** or **chunks** or simply **subsystems.***

*A **product architecture** is the scheme by which the **functional elements of the product are arranged into physical chunks and by which the chunks interact.***

*The **product architecture** belongs to either of the two main groups:*

- ***Integral architecture***
- ***Modular architecture***

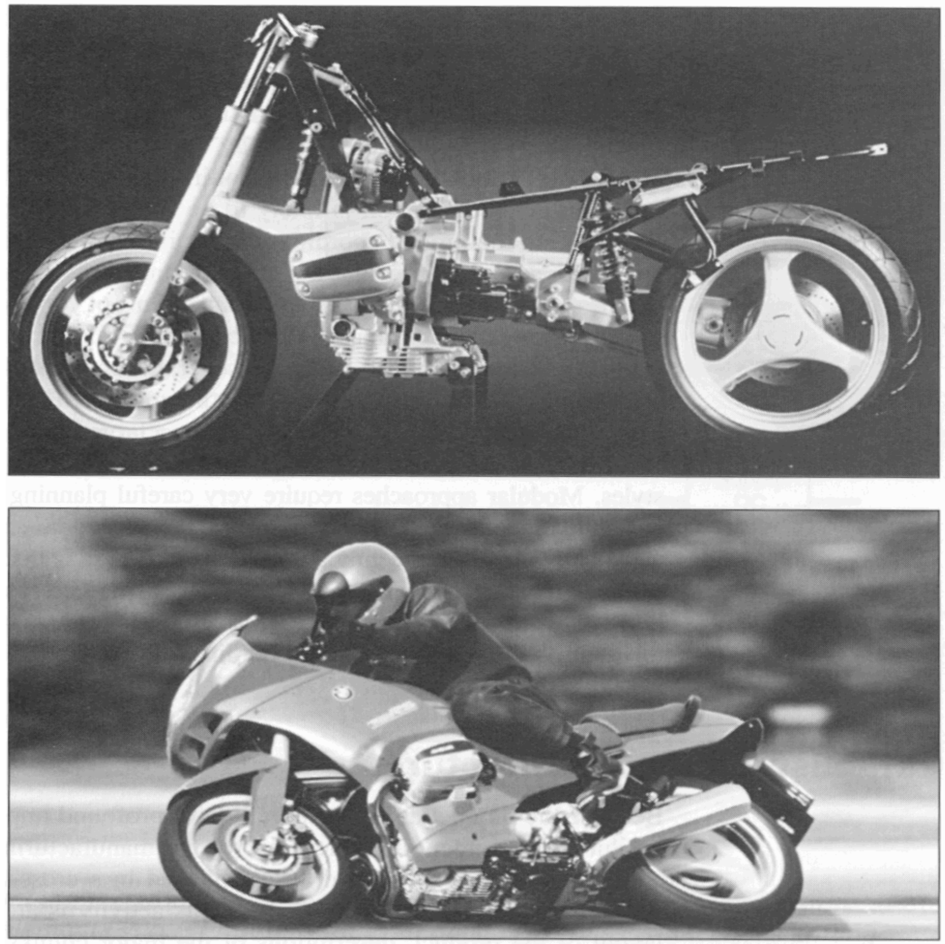
Integral Product Architecture

An ***integral product architecture*** *exhibit one or more of the following properties:*

- ***Functional elements of the product are implemented using more than one chunk.***
- ***A single chunk implements many functional elements.***
- ***The interactions between chunks are defined and may be incidental to the primary functions of the product.***

Example – Integral Product Architecture

The BMW R1100RS exhibits function sharing and an **integral architecture** with the design of its transmission chunk.



(Courtesy of BMW.)

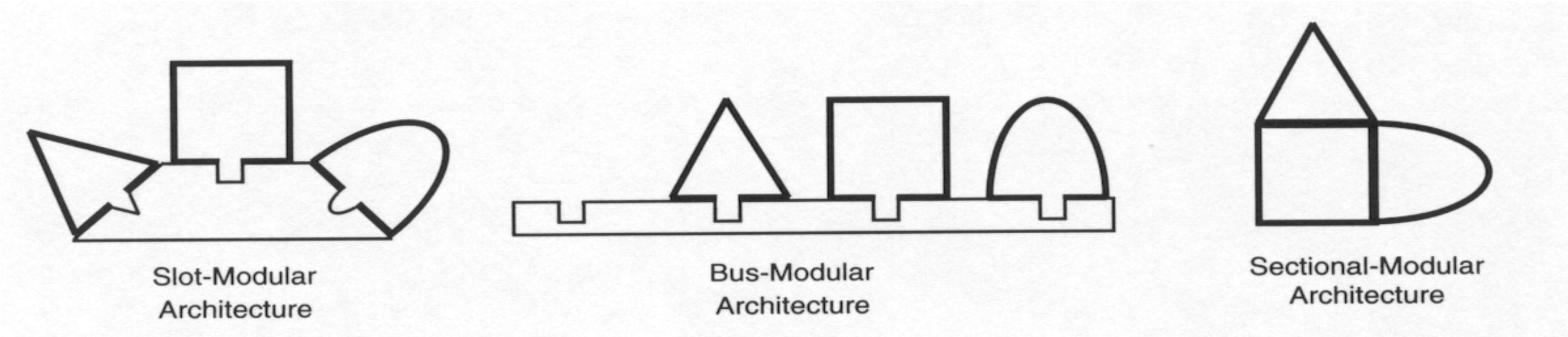
Modular Product Architecture

A ***modular*** *product architecture* *has the following properties:*

- ***Chunks implement one or a few functional elements in their entirety.***
- ***The interactions between chunks are well defined and are*** *generally fundamental to the primary functions of the product.*

In the ***completely modular product*** *each functional element of the product is implemented by* ***exactly one*** *physical chunk and in which there are a few well-defined interactions between the chunks.*

Types of Modularity



Slot-Modular Architecture

Each of the interfaces between chunks in a slot-modular architecture is of a different type from the others, so that the various chunks in the product cannot be interchanged.

Bus-Modular Architecture

In a bus-modular architecture, there is a common bus to which the other chunks connect via the same type of interface.

Sectional-Modular Architecture

In a sectional-modular architecture, all interfaces are of the same type, but there is no single element to which all of the other chunks attach.

Platform Product

A ***platform product*** *is built around a preexisting technological subsystem (a technological platform).*

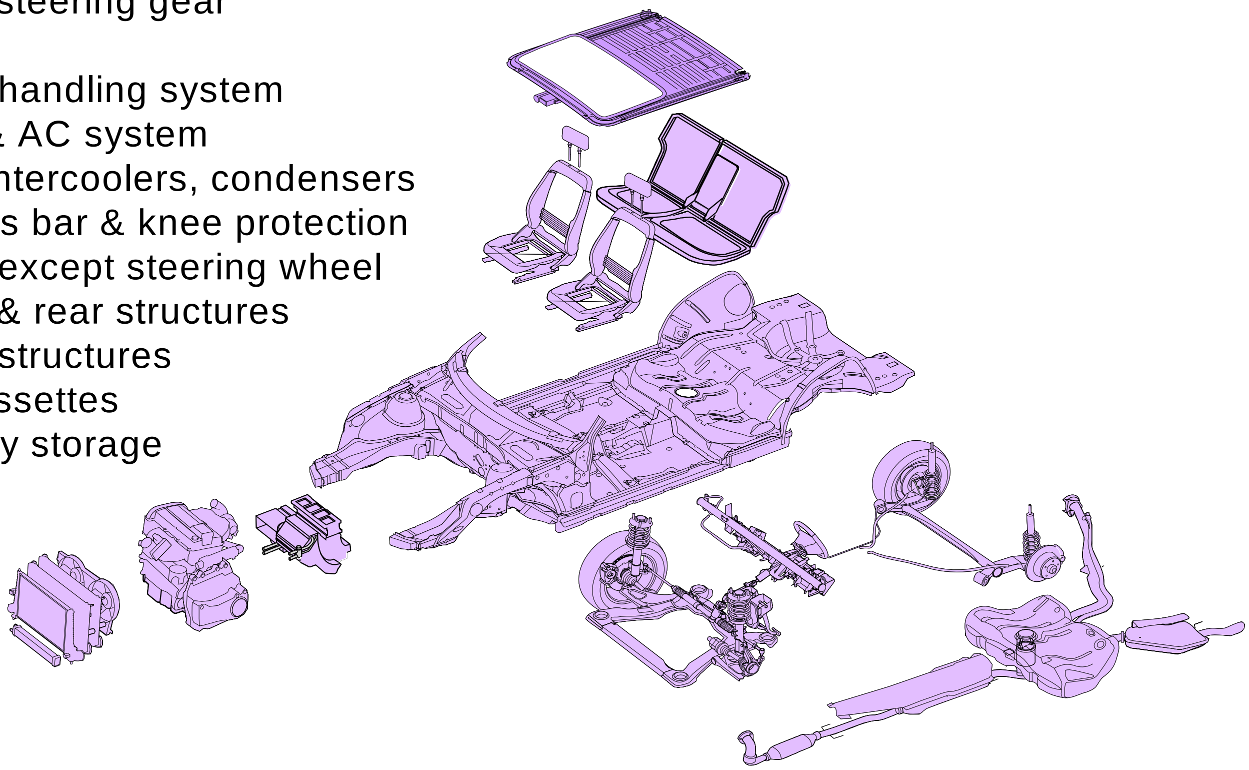
Examples: Sony Walkman and the Hasselblad camera.

Product built on technology platforms are much simpler to develop than if the technology was developed from scratch.

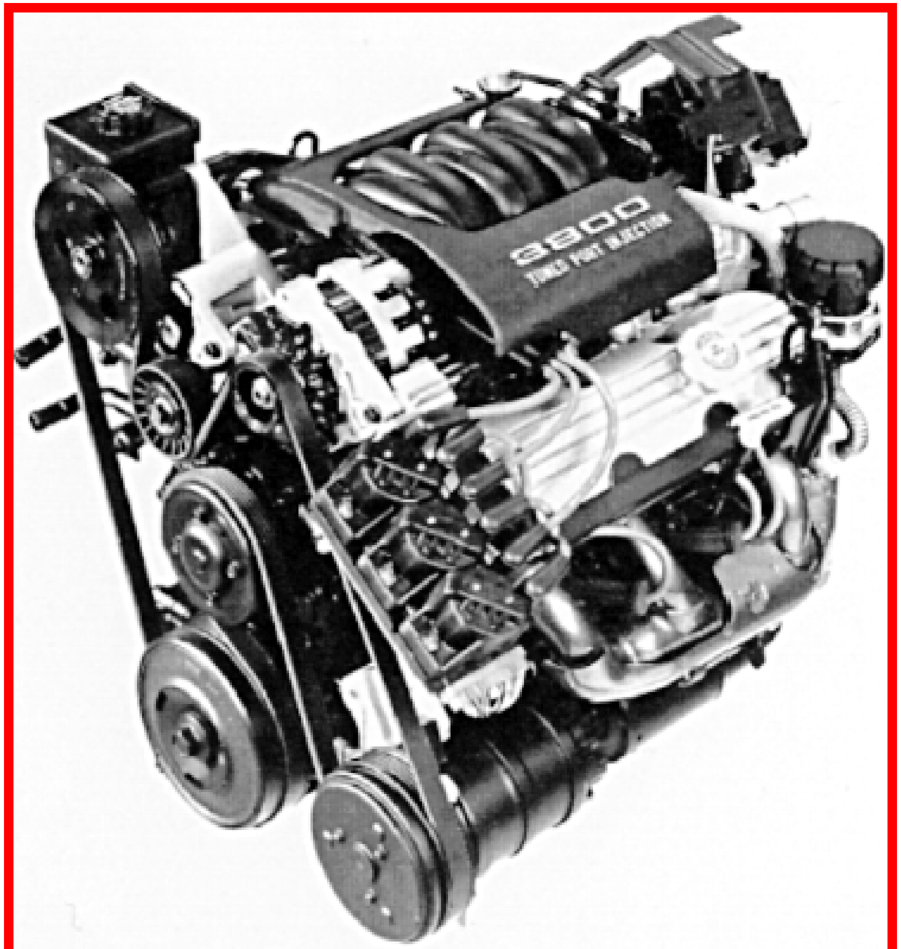
Example – Platform Product

Official GM Platform Definition

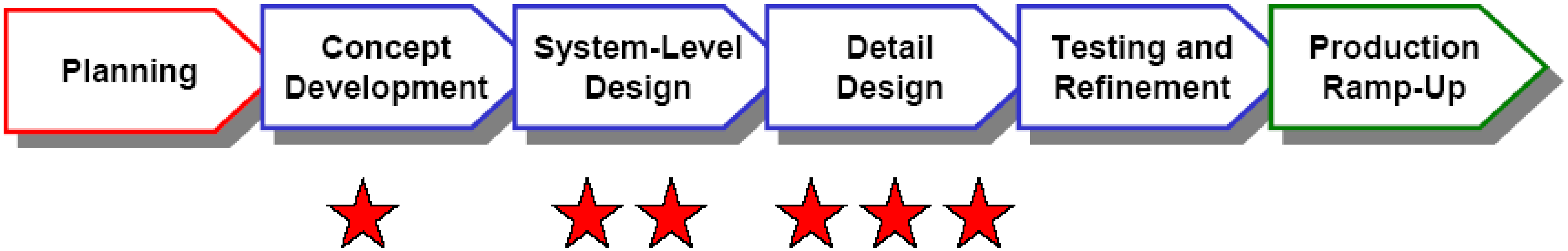
Powertrain: engines, transmissions, shifts
Chassis front & rear: suspensions, brakes
Engine cradle and rear suspension frame
Steering system: steering gear
Exhaust system
Fuel storage and handling system
Heat,Ventilation & AC system
Cooling system, intercoolers, condensers
I/P structure, cross bar & knee protection
Steering column, except steering wheel
Underbody, front & rear structures
Front & rear seat structures
Moveable roof cassettes
Charging & energy storage



Design for Manufacturing



Design for Manufacturing

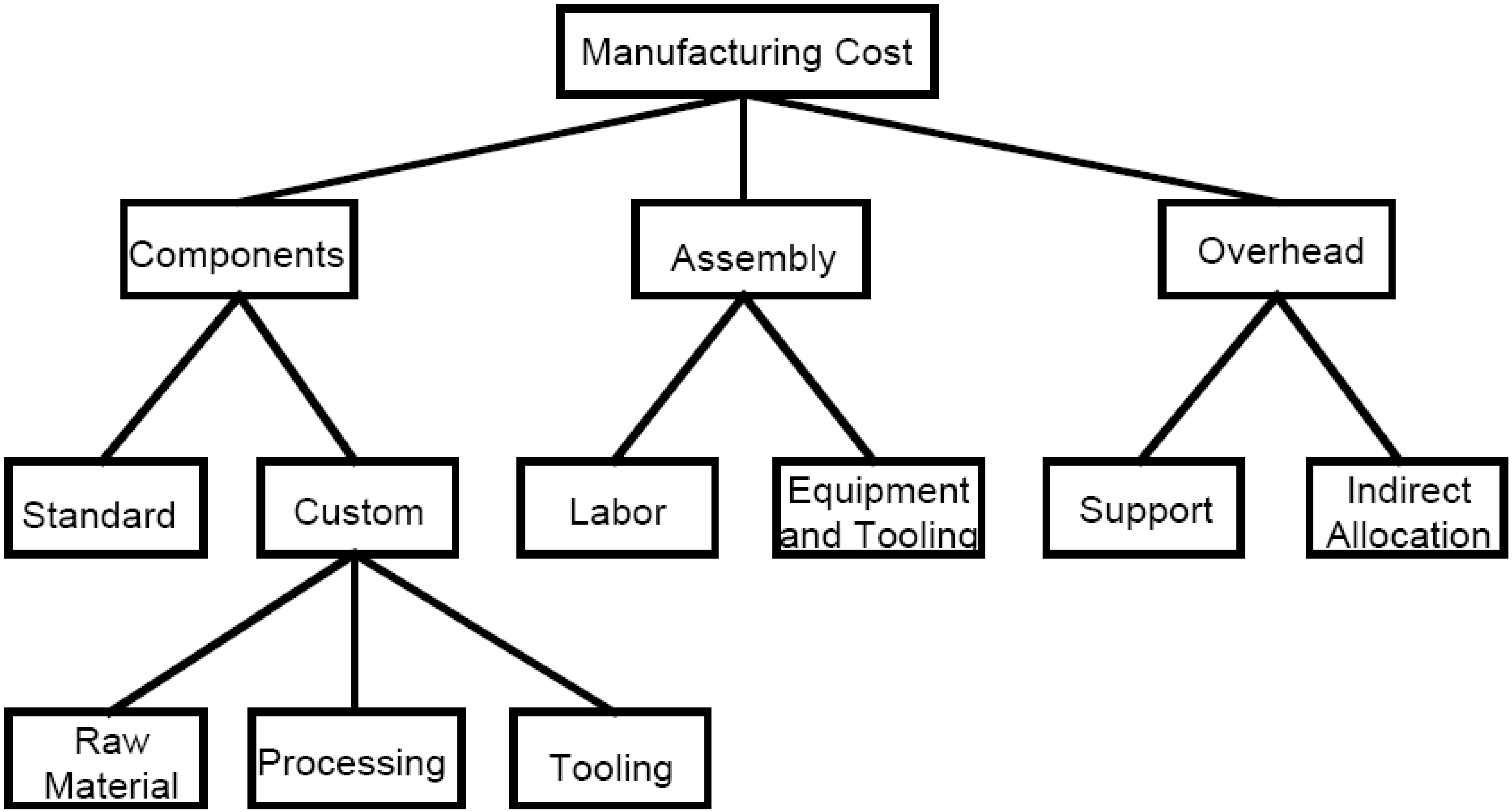


How can we emphasize manufacturing issues throughout the development process?

Design for Manufacturing - Definition

- Design for manufacturing (DFM) is a development practice emphasizing manufacturing issues throughout the product development process.
- Successful DFM results in lower production cost without sacrificing product quality.

Understanding Manufacturing Costs



Methods for Implementing DFM

1. Organization: Cross-Functional Teams

2. Design Rules: Specialized by Firm

3. CAD Tools: Boothroyd-Dewhurst Software

Design for Assembly (DFA)

- 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
- Popular software developed by Boothroyd and Dewhurst.
  - http://www.dfma.com

Design for Assembly (DFA)

Example set of DFA guidelines from a computer manufacturer.

1. Minimize parts count.
2. Encourage modular assembly.
3. Stack assemblies.
4. Eliminate adjustments.
5. Eliminate cables.
6. Use self-fastening parts.
7. Use self-locating parts.
8. Eliminate reorientation.
9. Facilitate parts handling.
10. Specify standard parts.