Mechanical Analysis and Design
ME 2104

Lecture 8

Performance Specification

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www.staff.city.ac.uk/~ra600/intro.htm

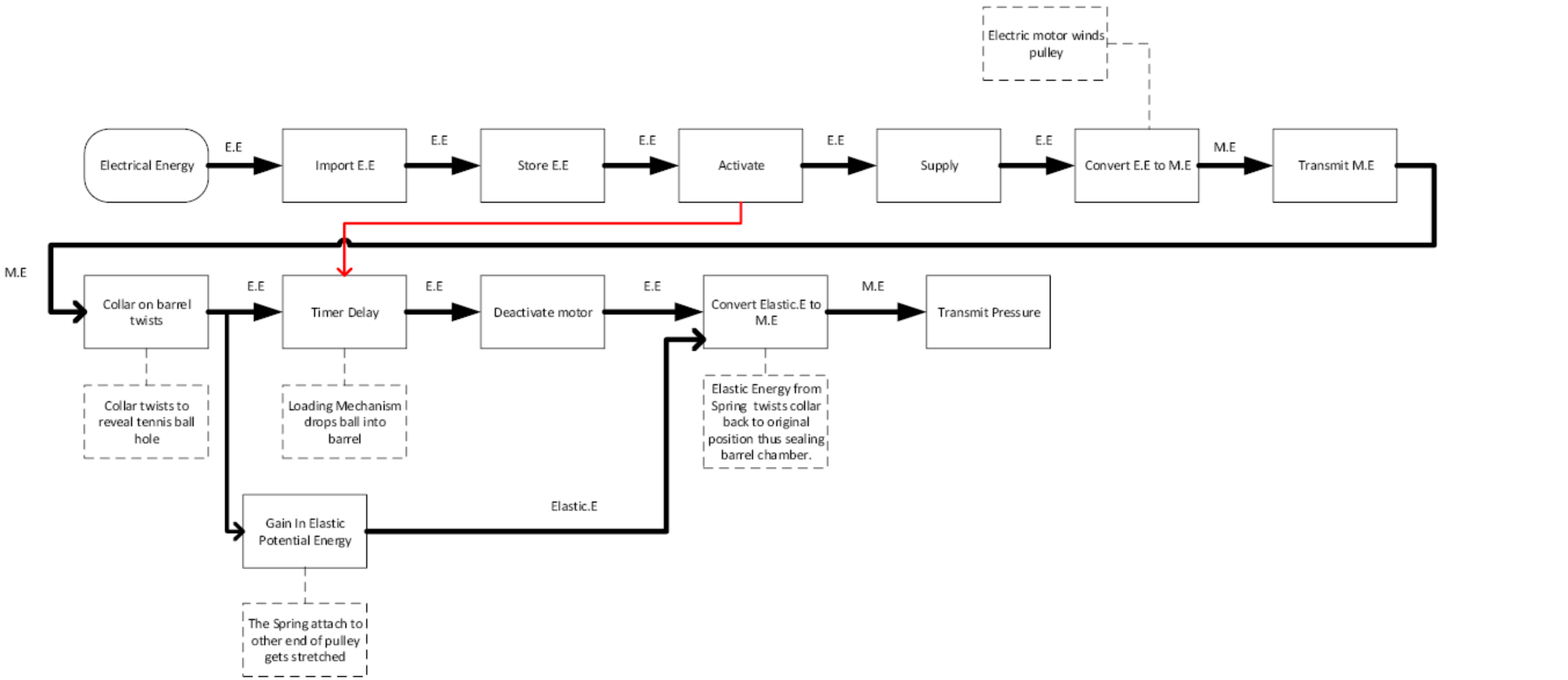
Plan for today

- Feedback - 1st Project Review (20 min)
- Lecture (30 min)
  - » Performance specification
- Team meeting (update FM, Engineering characteristics) (45 min)
- Additional lecture (15 min)
  - » Morphological chart

Feedback on 1st Project Review

- Objectives tree (OT) – exactly 4 levels
- Functional model (FM) - emphasis on 4 functions:
  - » multi-ball server with automatic loading
  - » automatic aiming
  - » good sealing
  - » automatic pressure adjustment and launching
- In QFD: 3rd level objectives from OT with weighting in rows
Functions from FM in columns
- Use calculations in conceptual design – Performance spec.
- Gant chart - regularly updated and used to identify critical path.
- Requirements list

V. SEALING SUBFUNCTIONAL MODEL



Laser Mounted Barrel	Master Switch	Activates Timer	Multiple Switch	Electri Motor	Target distance	Wind Check Sensors	Flaps Rotate	Timer Delay	Gain in Gravitational potential energy	Collar on barrel twists, easy access for balls	Elastic energy in spring during sealing	Energy conversion	consists of pulley system	Transmits pressure	Ball Sensors	High velocity Launch	Change in angle	High gas velocity	Control launch	Guide ball without problems	Reduce Friction	Activate and deactivate motor	variation in speed of process

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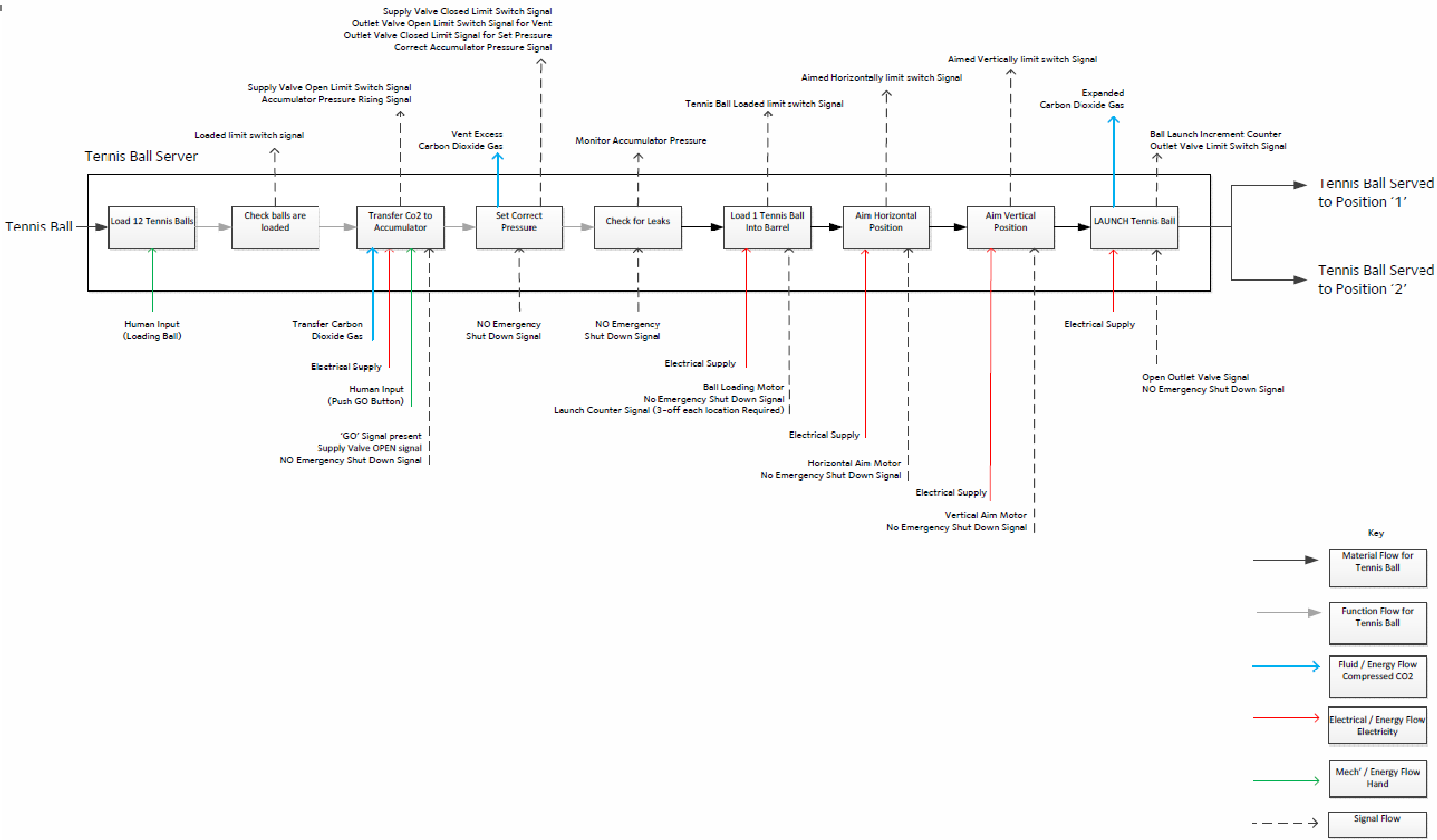
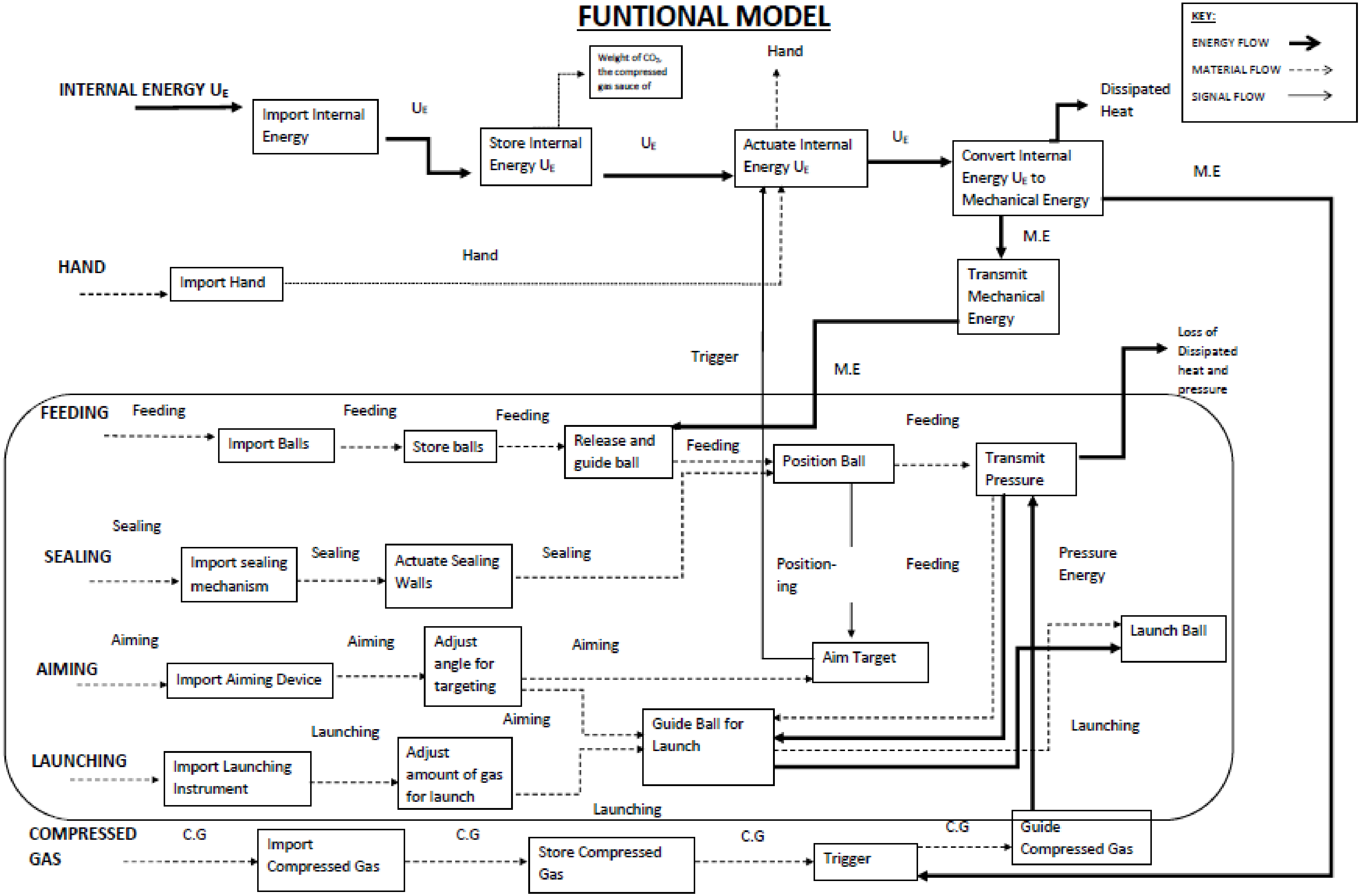
Group 5 'Set 5' Tennis Ball Server

Functional Model

Revision 02



FUNTIONAL MODEL



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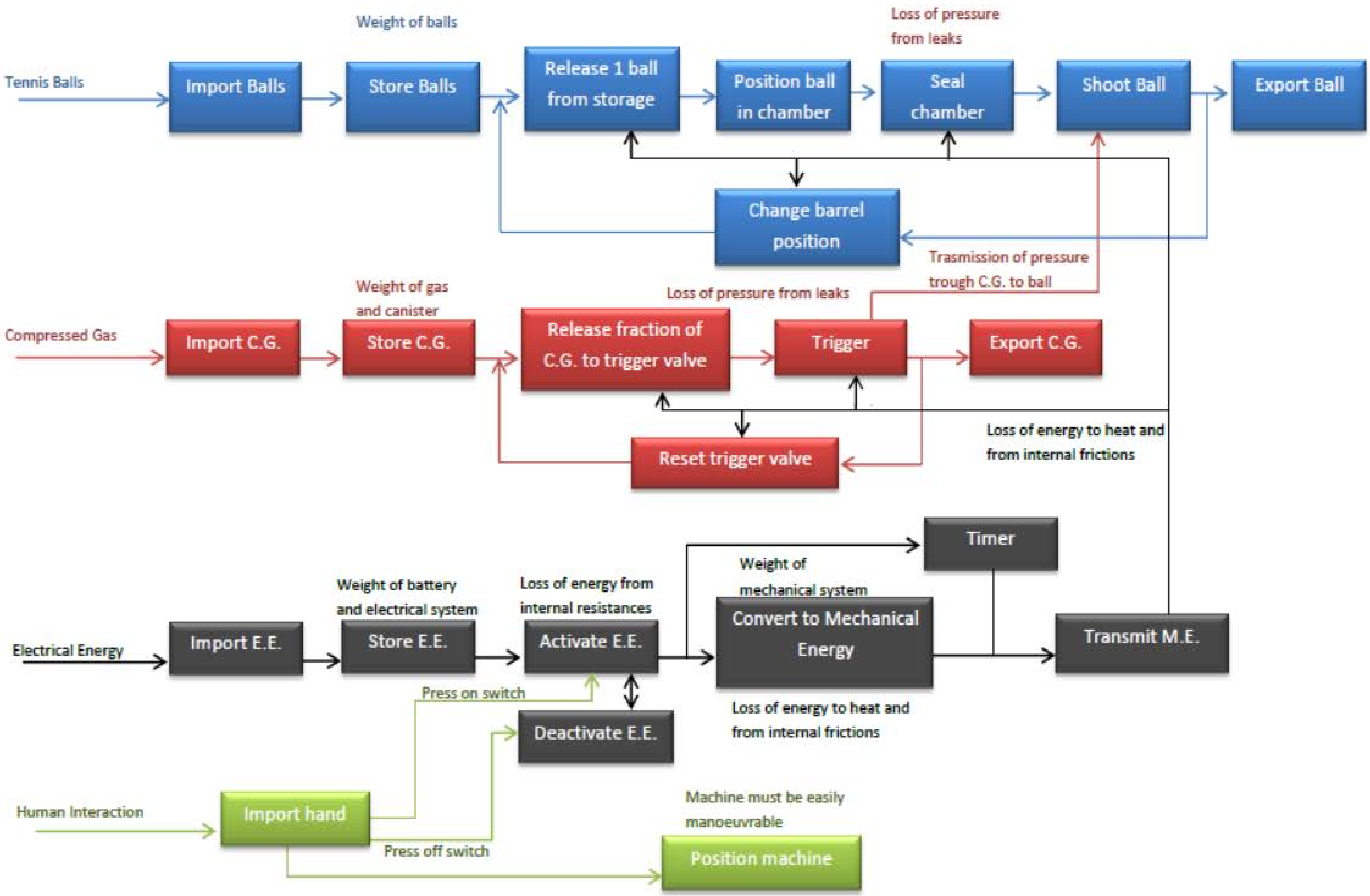
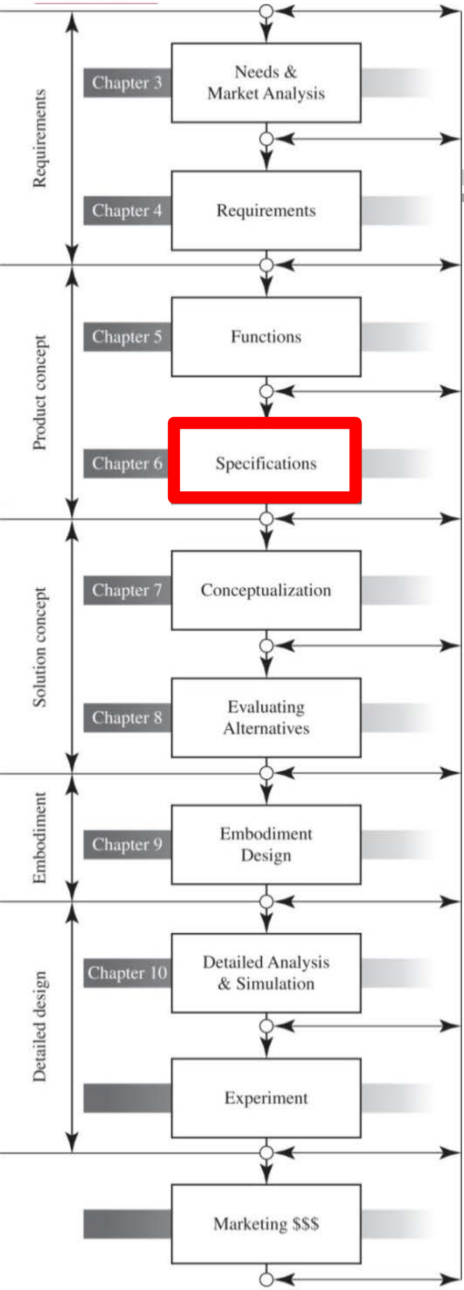
Functional model for Tennis Ballzooka™

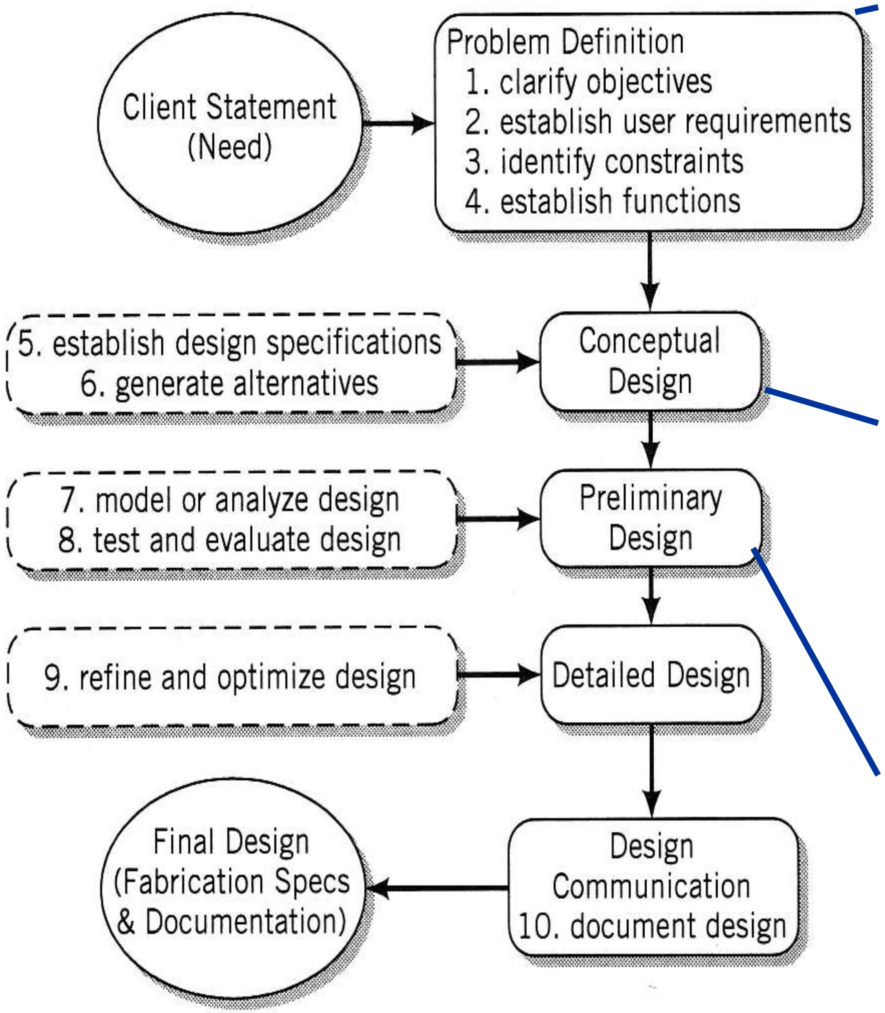




Specification - Lecture (Part 2)

- Engineering Design Process 2nd Edition, Chapter 6
  - » A specification consists of a metric and value
    - – Metrics are usually derived from functions (Chapter 5 & Lecture 5)
    - – **Specifications can be established using different methods; we will use the 'Performance Specification Method' (Chapter 6, section 6.2 & Lecture 8)**

Why to follow a design process?



1. Clarify objectives
   The Objectives Tree method
2. Establish user requirements
3. Identify constraints
4. Establish functions
   The Function Analysis method

5. Establish design specification
   The Performance Specification method The QFD Method (Design Matrix)
6. Generate alternatives
   The Morphological Chart method

7. Model and Analyse design
   Mechanical Design methods
8. Test end evaluate design
   The Weighted Objectives method

Clearly understand the problem which has to be solved
Make sure not to overlook any of important aspects
Set the stage for UNBIASED solutions and Enhance team creativity

Quality Function Deployment

- *Quality* (Objectives tree) is defined first
  - » Customer needs and requirements
  - » Desirable product attributes - qualities
- *Functions* (Functional model) defined and analysed
  - » Function and sub-functions of product subsystems
  - » Required functions to obtain attributes
- *Quality-Function Deployment* (1st QFD) defined
  - » Function and sub-functions of product subsystems required to obtain attributes
- *Engineering characteristics* (2nd QFD) defined
  - » Performance, Prescription, Procedure
  - » Developed physical properties - quantities

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Expressing Specifications

- Three ways to formalize what the user's wish into a property/characteristics suitable for engineers
  - » Prescriptive specifications (or constraints)
    - – Specify *values* for attributes of the designed product/process
    - – Ex.: *The ladder step length can not exceed 20 in.*
  - » Procedural specifications
    - – Identify specific *procedures* for calculating attributes or behavior
    - – Ex.: *Maximum bending stress on a step is computed from* $\sigma_{max} = Mc/I$ *and the step is safe if* σ_{max} *does not exceed* σ_{allow}
  - » Performance specifications
    - – Identify *performance levels* that signify the desired functional behavior has been achieved
    - – Ex.: *A step on a ladder is safe if it supports an 200 kg load*

Expressing Specs. for the Project

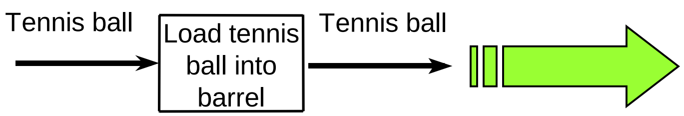
Consider how each of the three types of specifications might apply to the *tennis ball server*

- Prescriptive specifications (or constraints)
  - *The product must have a shipping volume not to exceed 50x50x100 mm*
- Procedural specifications
  - *The accuracy contribution to the products FOM will be calculated as $FOM_{acc} = 100(6 - (d_C + d_D)/2)$, where d_C and d_D are the distances from the target corner to where the ball lands*
- Performance specifications
  - *The ball's trajectory over the net should be less than 15 cm above the net where closer is better*

The Performance Specification Method

Step 1: *Compile specifications*

- » Use the functional model as a starting point
- » For each sub-function, write an associated specification (independent of any particular solution)
- » Make at least 2 specifications for each sub-function
- » For example:



To ensure smooth passing of just one ball at the time into the barrel:
- Mass of the ball (m_b)
- Diameter of the ball (d_b)
- Diameter of the passing device (D_d)
- No of balls to pass (n_b) …
- Resistance (friction) (R)

- » Add any additional specifications (or constraints) from project sources, such as from the assignment;

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Support for Step 1:

Standard categories for searching for specifications

TABLE 6.1 Checklist for drawing up a requirement list.[2]

Main Headings	Examples
Geometry	Size, height, breadth, length, diameter, space, requirement, number, arrangement, connection, extension
Kinematics	Type of motion, direction of motion, velocity, acceleration
Forces	Direction of force, magnitude of force, frequency, weight, load, deformation, stiffness, elasticity, stability, resonance
Energy	Output, efficiency, loss, friction, ventilation, state, pressure, temperature, heating, cooling, supply, storage, capacity, conversion
Materials	Physical and chemical properties of the initial and final product, auxiliary materials, prescribed materials (food regulations, etc.)
Signals	Inputs and outputs, form, display, control equipment
Safety	Direct safety principles, protective systems, operational, operator and environmental safety
Ergonomics	The man–machine relationship, type of operation, clearness of layout, lighting, aesthetics
Production	Factory limitations, maximum possible dimensions, preferred production methods, means of production, achievable quality and tolerances
Quality	Control possibilities of testing and measuring, application of special regulations and standards
Assembly	Special regulations, installation, siting, foundation, transport limitations due to lifting gear, clearance, means of transport (height and weight), nature and conditions of dispatch
Operation	Quietness, wear, special uses, marketing area, destination (for example, sulphurous atmosphere, tropical conditions)
Maintenance	Servicing intervals (if any), inspection, exchange and repair, painting, cleaning
Recycling	Reuse, reprocessing, waste disposal, storage
Costs	Maximum permissible manufacturing costs, cost of tooling, investment and depreciation
Schedule	End date of development, project planning and control, delivery date

The Performance Specification Method

Step 2: *Sort the engineering specifications by type*

- » Prescriptive (constraints) (m_b, d_b)
- » Procedural (D_d)
- » Performance ($n_b; R$)

Step 3: *Quantify each engineering specification*

- » Engineering specifications should have quantities
- » Express specifications as a range with limits or specific values (in the case of constraints)
- » Quantifying may lead to more detailed specifications
- » For example:

To ensure smooth passing just one ball into barrel: →

$m_b = 35\text{-}50\ g$
$d_b = 47 – 51\ mm$
$D_d > 1.03\ d_b$
$n_b=1$
$R < 1.1\ Pa\ s$

The Performance Specification Method

- **Step 4:** ***Determine testing/verification approaches***
  - » Identify what procedure your team will use to check that each specification is met
  - » State *when* the test or verification will occur in project timeline
  - » Examples :

Quantified specification:

- Loading of the ball easy and smooth
- Straight passages
- Same diameter of the pipe used throughout
- One ball loaded at the time …

Test/verification measure:

- Review of concept variants (diameter and resistance) during concept selection
- Test with 20 balls during the preliminary design phase
- Validate with Simon from Group 4

The Performance Specification Method

Step 5: Compile elements of engineering specification into a single document

Example: Specifications Sheet for Disc Launcher Toy (Partial)

Date	Specification	Resp.	Test/Verification
	Performance Specifications		
12-Feb	Grasping surface can be held by the 95 percentile 4 year old	RBS	Review of concept variants (estimated size of grasping surface) during concept selection
13-Feb	Average diameter of grasping surface < 1 in.	KLW	Verify with engr. drawings during preliminary design phase
14-Feb	Product stores > 80% of user input energy	REF	Measure energy storage potential during proof of concept
12-Feb	> 80% of stored energy is transferred to disc for launch	REF	Measure available energy during proof of concept
12-Feb	Excess energy is dissipated by product	KAG	Review of concept variants during concept selection
13-Feb	Force to press trigger < 0.5 lb.	KLW	Measure triggering force of alpha prototype
	Prescriptive Specifications (Constraints)		
12-Feb	Force to "cock" launcher ≤ 5 lb.	RBS	Review of concept variants during concept selection
12-Feb	Weight < 2 lb.	CAR	Weigh alpha prototype

The Performance Specification Method

Step 6: Evaluate and update specifications as needed throughout the design project

» Make sure identified constraints are not too restrictive as to eliminate a better solution

» If specifications are updated, indicate so in the date column of the sheet

Date	Specification	Resp.	Test/Verification
	Performance Specifications		
12-Feb	Grasping surface can be held by the 95 percentile 4 year old	RBS	Review of concept variants (estimated size of grasping surface) during concept selection
13-Feb	**Average diameter of grasping surface < 1.25 in. (Due to new ergonomic data)**	KLW	Verify with engr. drawings during preliminary design phase
14-Feb	Product stores > 80% of user input energy	REF	Measure energy storage potential during proof of concept
12-Feb	> 80% of stored energy is transferred to disc for launch	REF	Measure available energy during proof of concept

Compile requirements list

Metric	Value	
Dimensions	$20 \times 20 \times 10$ cm	D
Cans crushed	1/5 original volume	D
Weight	$<$ 10 kg	W
Sales price	$<$ \$50	W
Number of parts	$<$ 100	D
People able to use	$>$ 5 yrs	W
Probability of injury	$<$ 0.1%	D
Manufacturing cost	$<$ \$200	W
Steps to operate	1	D
Maintenance cost	$<$ \$10 annually	W
Efficiency rating	$>$ 95 percentile	D
Internal parts enclosed	100%	D
Storage of crushed cans	60	W
Loader capacity	$>$ 30 cans	W
Crush cans	$\geq$ 15 cans/min	W

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Create and fully populate 2nd QFD

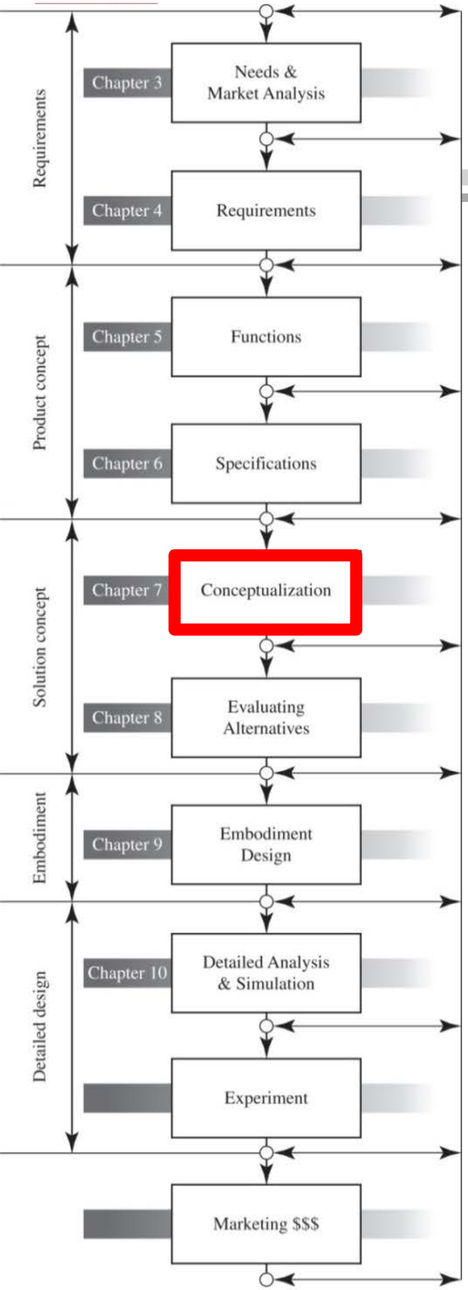
	Probability of injury < 0.1%	Weight < 30 lb	Sales price < $50.00	Number of parts < 100	Dimensions (inch)	Crushing force > 30 lb	People able to use > 5 yrs	Manufacturing cost < $200	Steps to operate (1)	Maintenance cost < $10 annually	Efficiency rating > 95 percentile	Internal parts enclosed (100%)
Consolidate mechanical functions		3		9				6	2		9	
Low standby power drain			1				3				9	
Aesthetically pleasing/blends with surrounding			9	2	6		8	6				
Utilizes ground to stabilize				1								
Less than five assembly steps			3	6			3	1				
Ability to mount to various surfaces		3	6		3		3	3				
Large can capacity loader		3	6		3		3	3	6			
Portable		9	6		3		6	3				
Durable refuse container								3				
Retail for < $50.00			9				9	9				3
Variable length/retractable cord			3				2	1				
Large storage of crushed cans		1	4		3		2	1	6			
Ability to crush various sizes of containers			9	3	8		6	9				
Easy to disassemble			3	6			3	3		6		
Easy cleaning			6				3	1		3		6
Green light to indicate ok to load	9		6				9	2				
Red light to indicate the crushing mechanism is in operation	9		6				9	2				
Yellow light to indicate improper use of the machine	9		6				9	2				
Automatically switches to standby power when not in use											6	
Receiving container on caster		2										
Weather proof			1	3				3		6		9
Crushes glass, plastic and aluminum containers			9	6	3	9	7	9				
Drain for residual liquid from machine	1			1				1		6		
Built from a polymer		6	6					6				
Housing constructed from a formed polymer		6	6					6				
Can counter			3	2			1	2				
Container to hold refuse liquid		2										
Flip open lid												
Colors available			9				3					
Paintable surface			8				2					
Plexiglas window to view operation			8					2				6

Figure 6.8B House of quality for automatic can crusher.

Team meeting

Tasks for next Monday:

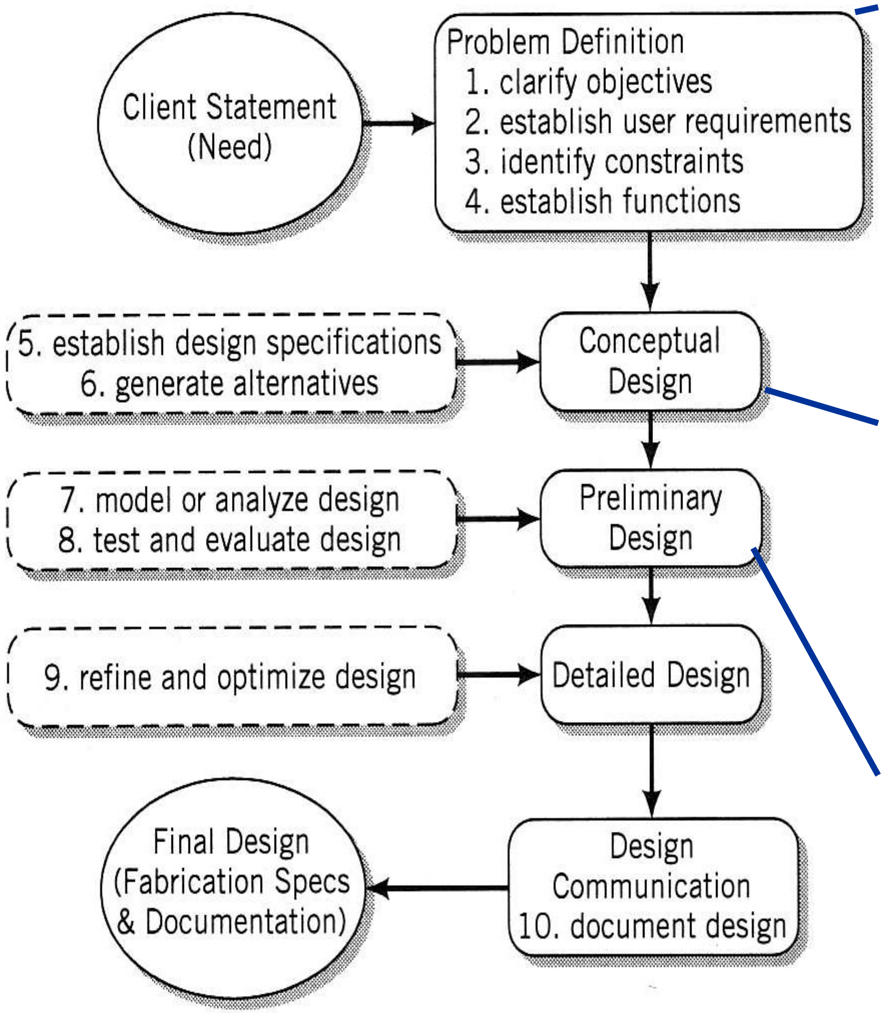
- Update Functional Model:
  - Max 12 functions (loading, aiming, sealing, launch) + 4-8 other functions (cost, weight, innovativeness, ease of operation)
  - At least 2 engineering characteristics for each function
- Prepare QFD2
  - Eng characteristics vs 3rd level Objectives
- Draft of Morphological chart
  - Brainstorming session
  - Morphological chart diagram



Conceptualization

- Engineering Design Process 2nd Edition, Chapter 6
  - » Use systematic methods to generate conceptual designs
  - » Generate a morphological chart
  - » Improve your creative brainstorming techniques

Why to follow a design process?



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Generating & Evaluating Alternatives

- Keys to thinking creatively
  - » Brainstorming
  - » Lateral thinking
- Concept variants generation
  - » Morphological chart
- Use a Decision Matrix to Evaluate Solutions
  - » Estimation of parameters
  - » Decision Matrix

Objectives, functions, characteristics v.s. alternative solutions

- Previously, problem was clarified by use of four design tools
  - » **Objectives Tree:** A way to analyze customer needs and to group them logically
  - » **Functional Model:** An engineering first step at thinking about the general functions that the device must be able to do
  - » **Engineering Specifications:** A first step to specifying performance of the product or process to be designed
  - » **The Quality Function Deployment Method – Design Matrix:** Tool which helps to specify what the product must achieve and the criteria by which the alternative solutions will be judged.

- These clarify the problem - ***they do not give the solution***

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Vertical vs. Lateral Thinking

Vertical Thinking	Lateral Thinking
Goal: ***Selecting*** an idea	Goal: ***Generating*** ideas
focuses on “right or wrong”	no “right or wrong”
is sequential	jumps around
excludes irrelevant info	welcomes all info
tries to finalize	tries to expand possibilities

If vertical thinking is considered exclusively, one might never consider alternative ways to solve a problem

Background: Thinking Creatively

- Successful designers think creatively
- EXERCISE ON CREATIVITY
- Successful designs are those that are fresh, innovative, and elegant, while yet being simple and direct
  - » They are artful *and* functional
- Many good designs, once unveiled, seem obvious
  - » People say, “Why didn’t I think of that?”
- Good designers “think of that” because they have developed the skills of:
  - » Brainstorming
  - » Lateral thinking

Brainstorming

- **Brainstorming** is process of generating as many ideas for solving a problem as possible in a short period of time.
- Keys to successful brainstorming:
  - » ***No criticism of ideas!***
    - – Evaluation comes later
    - – Criticism quenches creative fire; it shuts off the flow of ideas
  - » ***Welcome creative thinking***
    - – Encourage wild ideas
    - – They expand the envelope of ideas, possibly leading to workable solutions we otherwise never would have reached
  - » ***Aim for quantity of ideas***
  - » ***Allow combining and extending ideas***
    - – Encourage interaction among team members
    - – “Run the rut” on an idea

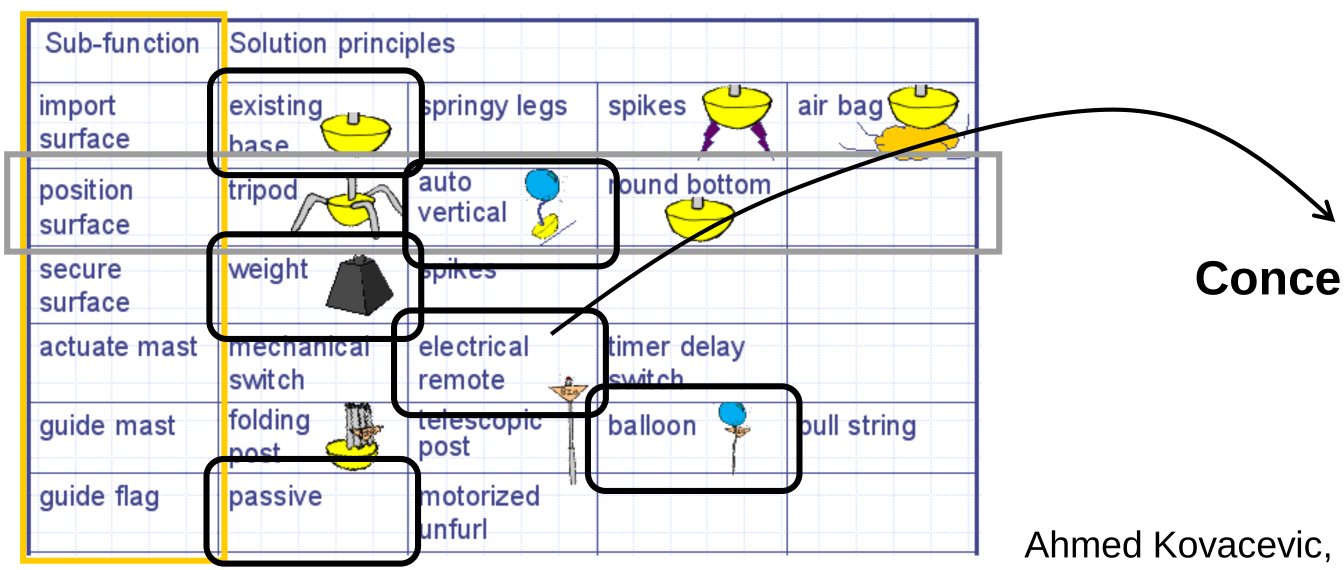
Preparing for Brainstorming

- Make sure the problem is clearly defined and understood by all
  - » **Objectives Trees** help with this
- Focus on a ***sub-function*** rather than on the whole product.
  - » **Functional Models** and **Morphological Charts** help with this
- Assign one person to be the ***moderator***
  - » Moderator manages the session
  - » Make sure the rules are followed
- Assign another person to be the ***note-taker*** or ***scribe***
  - » Scribe writes down **all** ideas suggested
  - » Rotate this responsibility so all have a chance to participate in brainstorming (scribes typically cannot record and generate ideas)

Photo strip about brainstorming

Morphological Chart

- **<u>Used to generate</u>** possible design solutions
  - » After the problem and the function of the device is understood, **brainstorming** can be used to generate potential solutions
- **<u>Very useful</u>** visual way of organizing and assessing the range of possible solution combinations for a problem
- **<u>Very simple</u>** – it is a **<u>table</u>**
  - » Sub-functions listed in the first column
  - » Possible solutions to each sub-function shown in the rows to the right
  - » Possible solutions then selected to form a concept variant



Concept variant

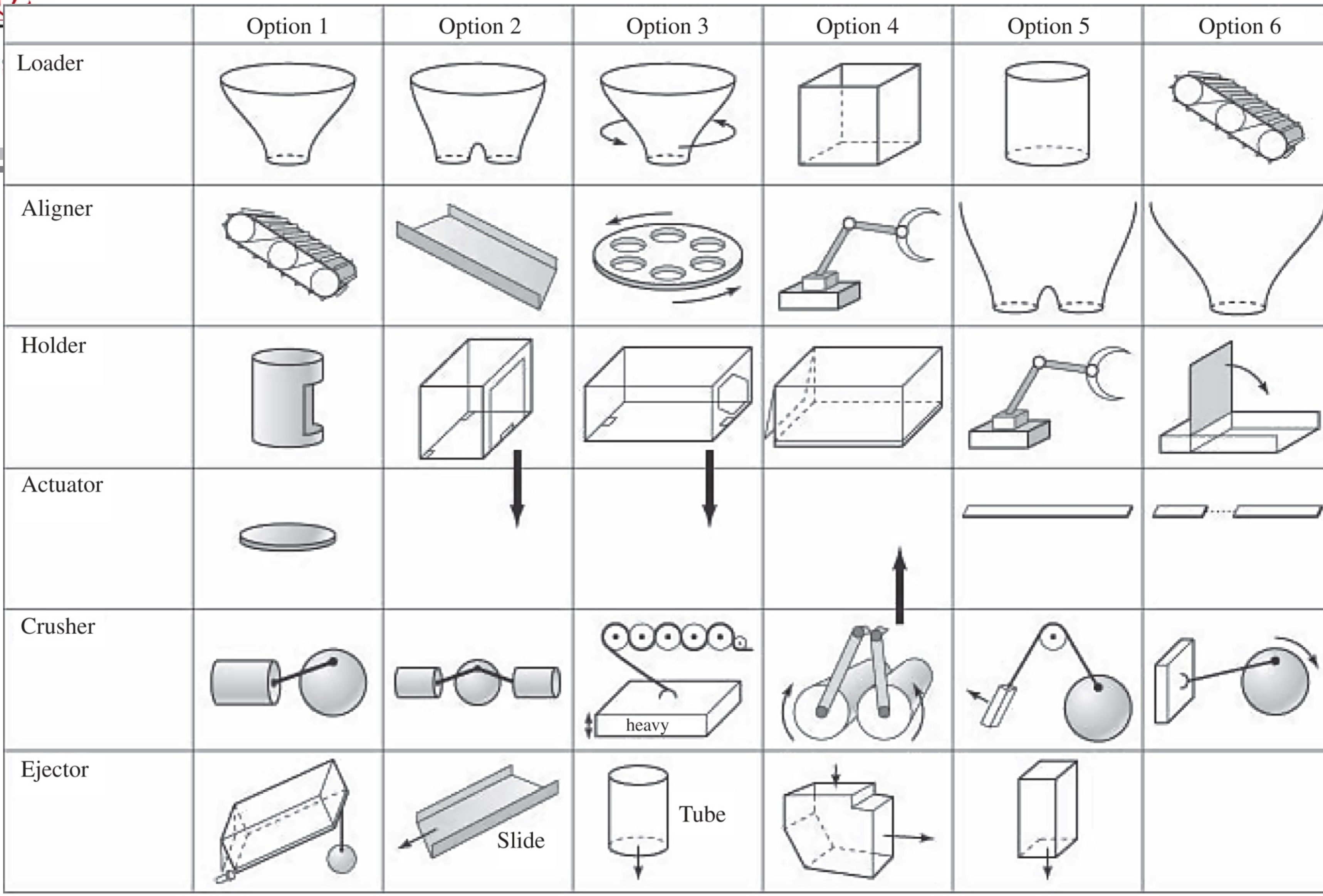


Figure 7.5 Morphological chart of automatic can crusher.

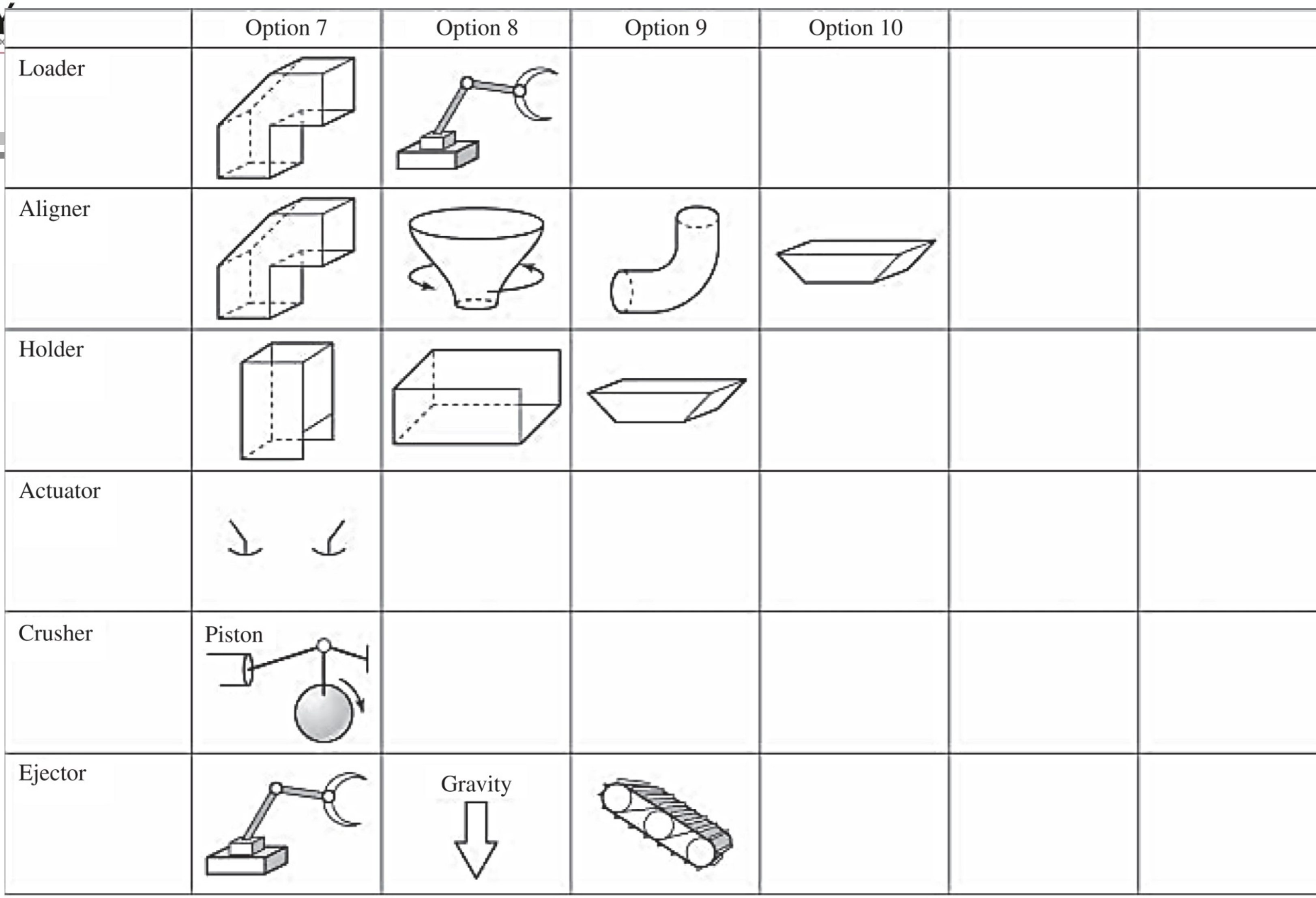


Figure 7.5 Morphological chart of automatic can crusher (continued).

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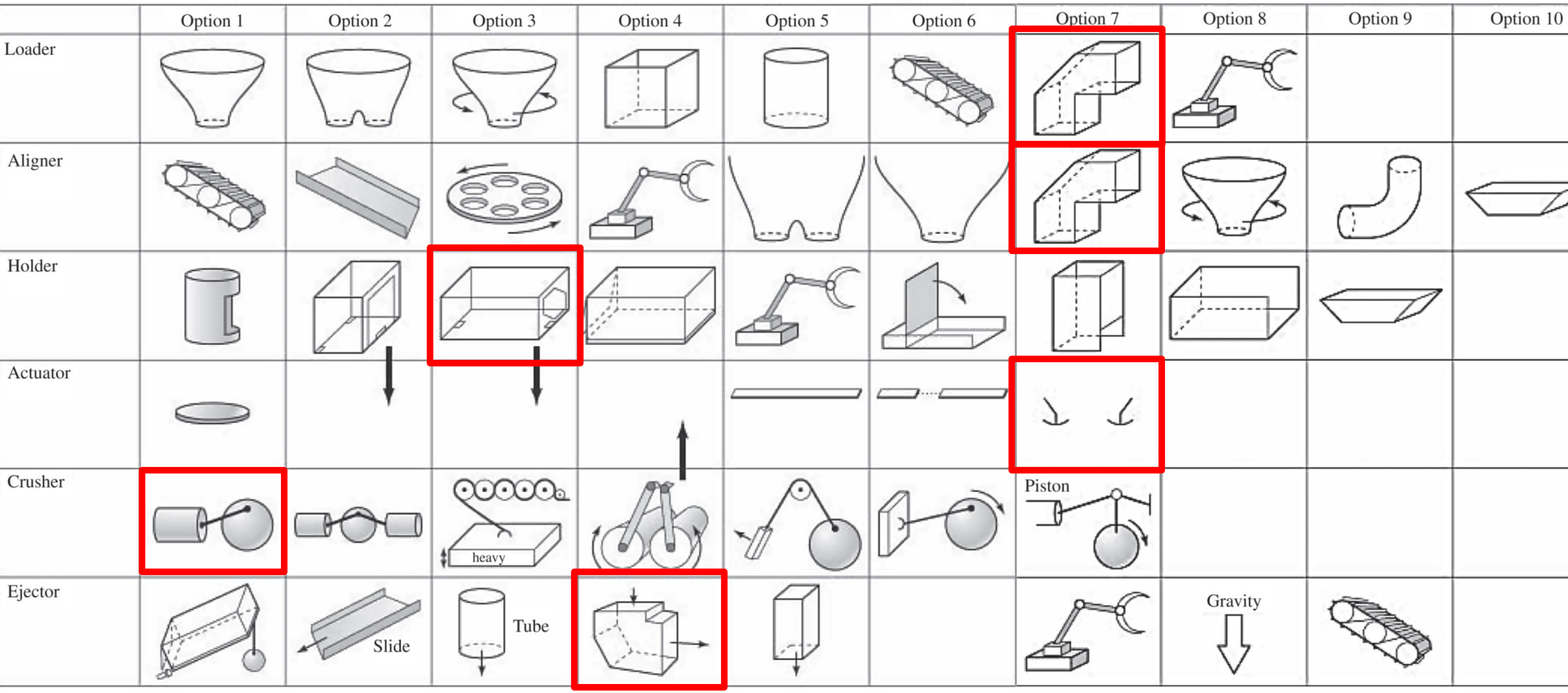
How to create concept variants?



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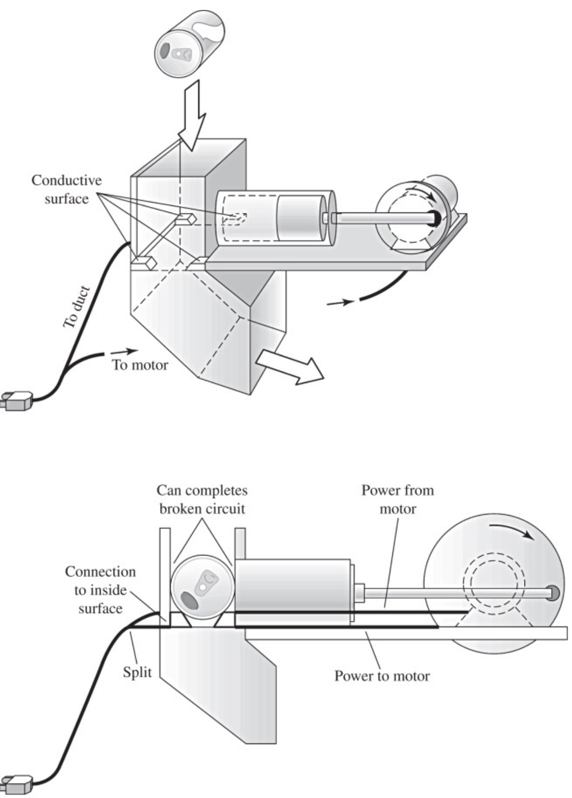

igure 8.17 Concept IV of automatic can crusher.

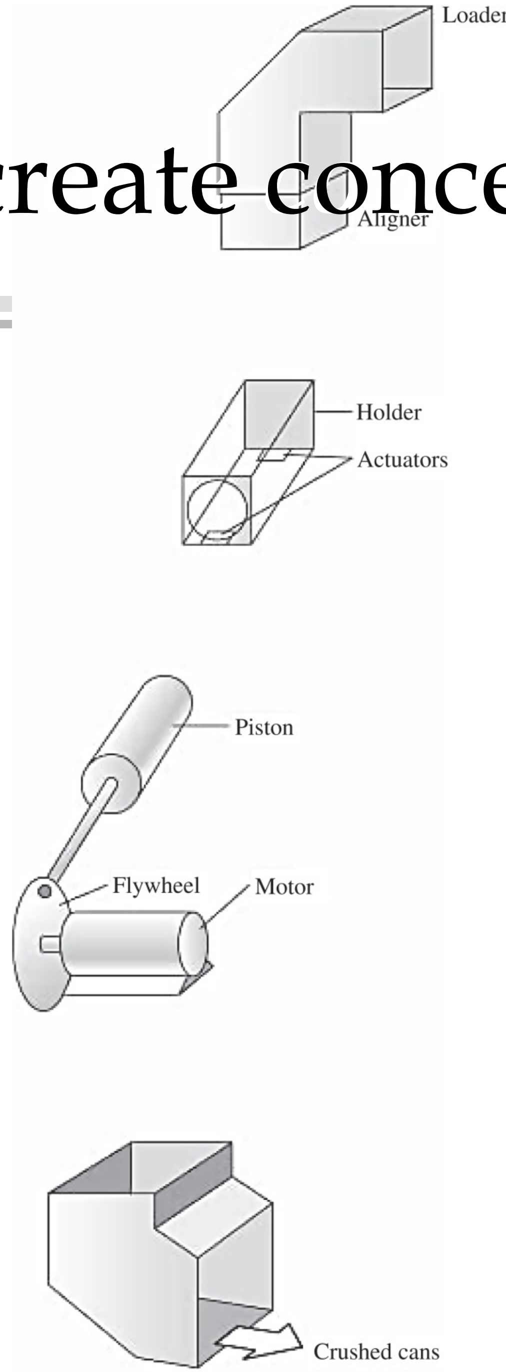

Figure 8.18 Concept V of automatic can crusher.

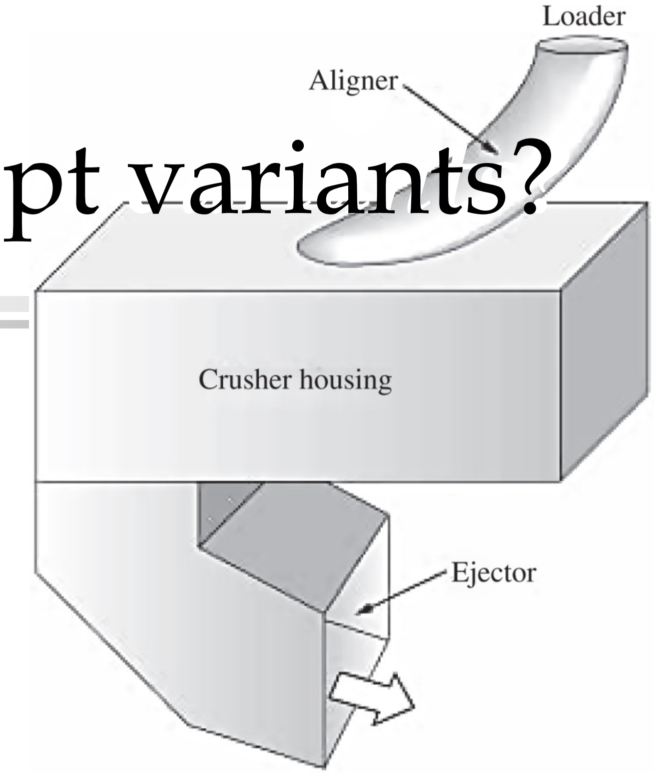

Figure 8.16 Concept III of automatic can crusher.

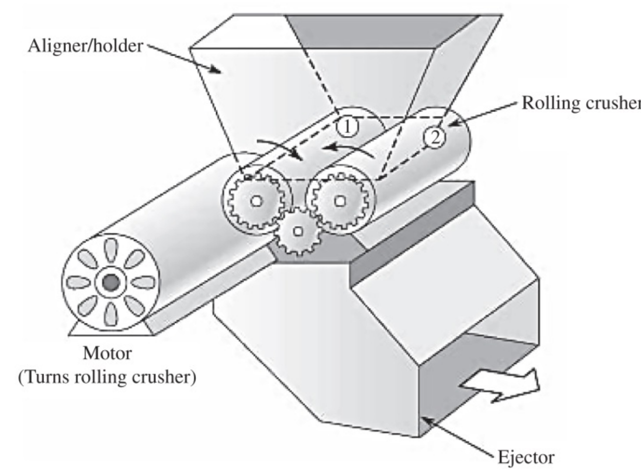

Figure 8.14 Concept I of automatic can crusher.

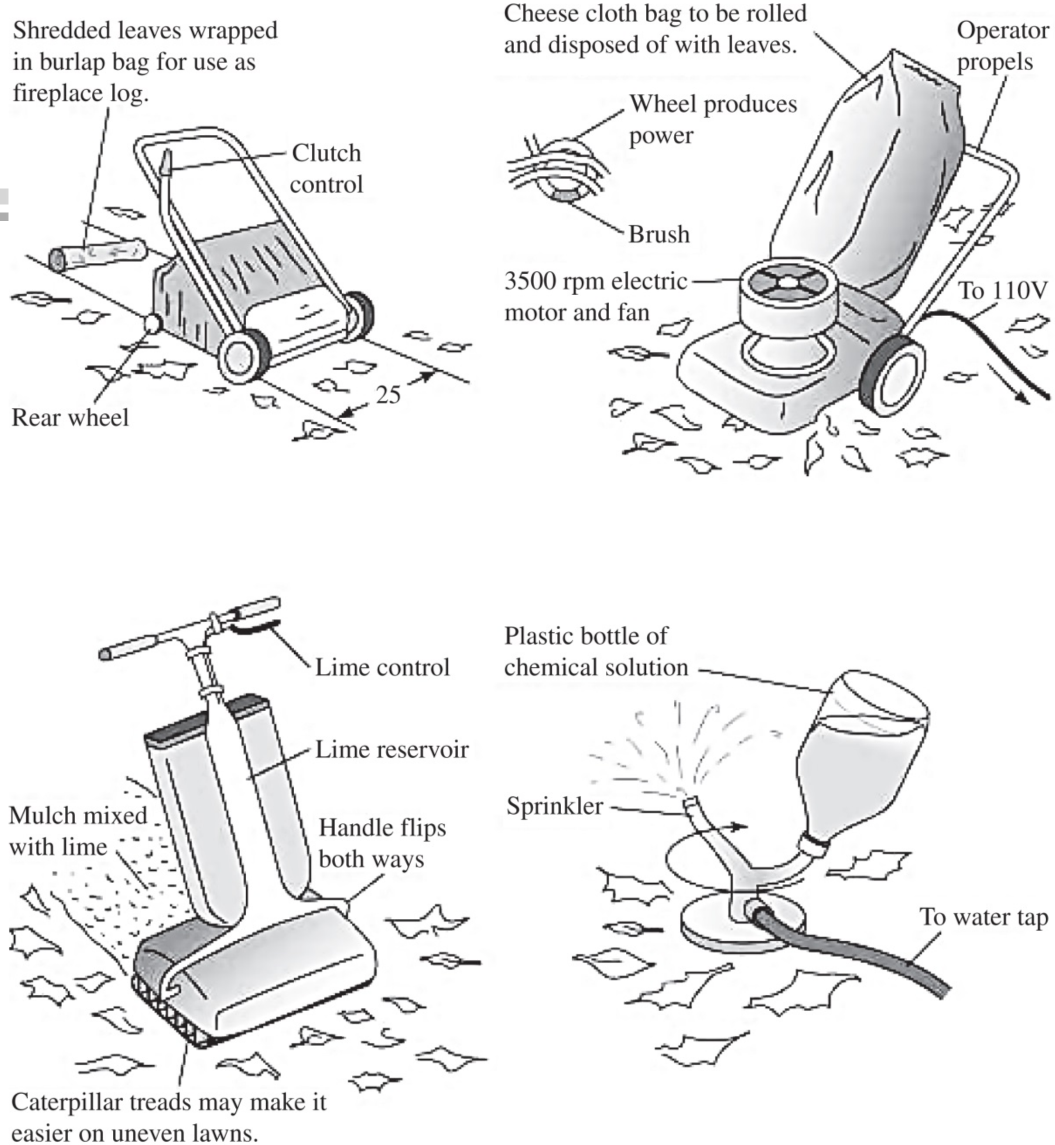

Figure 8.2 Conceptual sketches of yard leaf collector.