Mechanical Analysis and Design
ME 2104

Lecture 5

Function

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

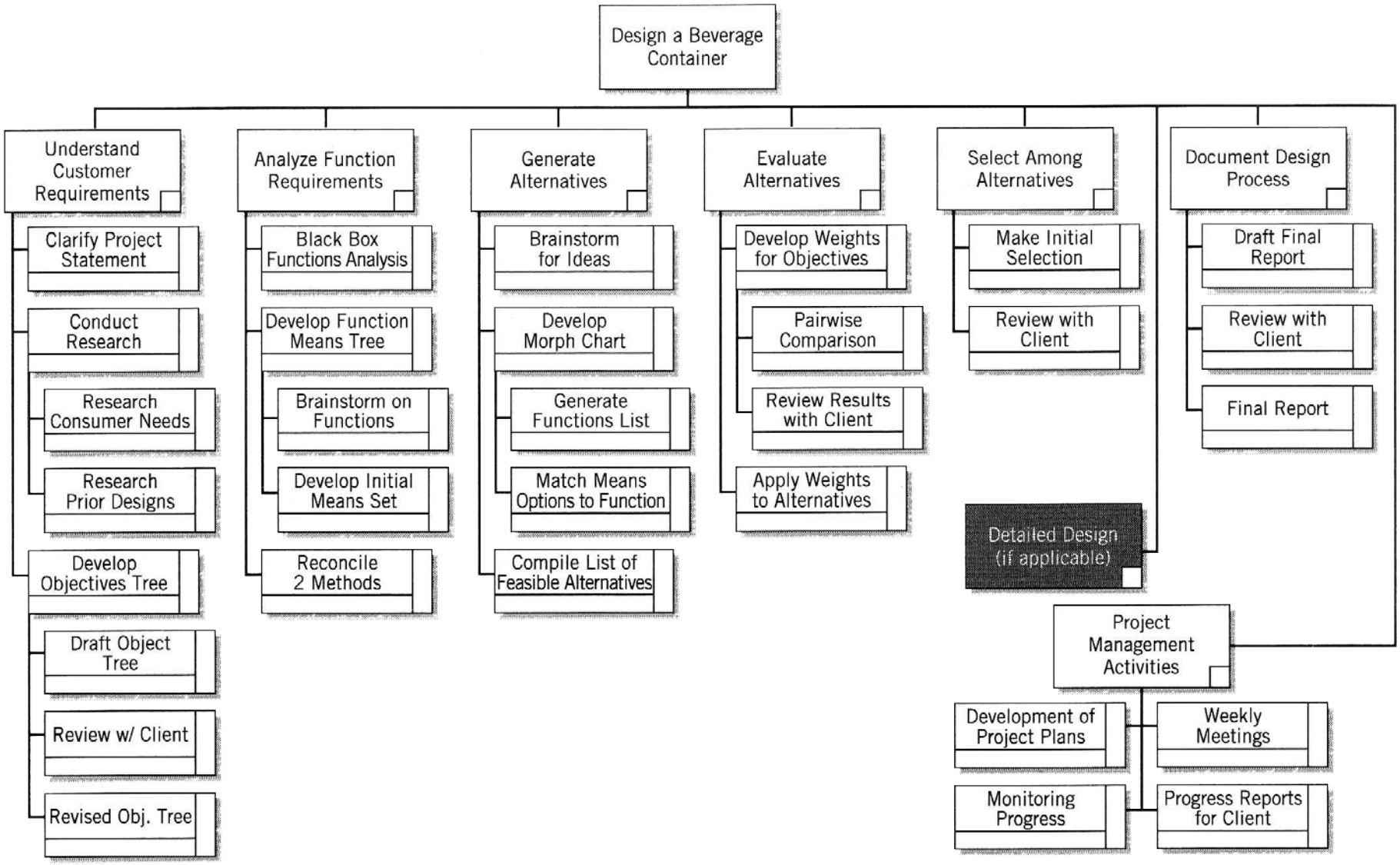
Plan for today

- Clarify issues from the last week (15 min)
- Lecture (35 min)
  - » Functional Model
- Team meeting (Finish OT, start FM) (45 min)
- Additional lecture (15 min)
  - » Modelling Tennis ball server

Clarify issues from the last week

- Team issues:
  - » Reports from Coaches – mixed success
  - » Coaches MUST be present in the group
  - » Objective of having a meeting:
    - – Review progress on work given in previous meeting
    - – Understand requirements for next meeting
    - – Distribute work
  - » Take tasks step by step – if finish ask your coach to help you identify new tasks
  - » Coaches are already assessing you…

Clarify issues from the last week



Deliverables for Phase 1 (Vision and Concept)

Submission on Moodle: Report in word and pdf and presentation ppt
29th October @ 17:00 – Word and pdf

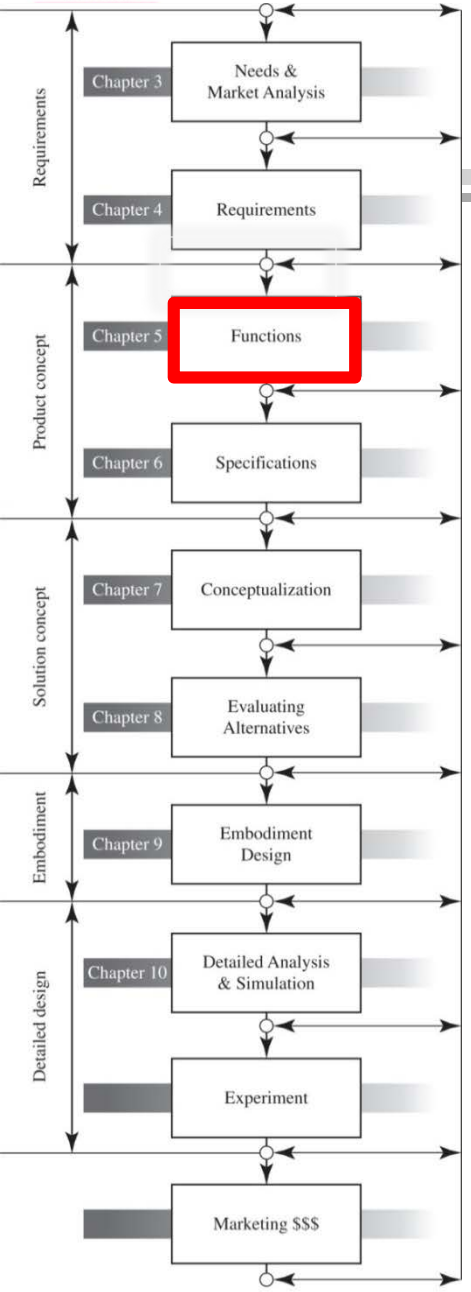
Presentation: Groups 1-5: 30th October @ 11:00 (AG21) (PPT+Notebook)
Groups 6-10: 3rd November@10:00 (ELG01) (PPT+Notebook)

Team management:
- Working agreement
- Team Branding and Logo
- WBS
- Team calendar
- Gantt chart
- **Group Notebook**

Requirements:
- Figure of Merit analysis
- Budget, very short Introduction
- Market Research
- Client Statement/Constraint
- Objective Tree and Weightings
- **Preliminary Requirements List**

Function:
- Black Box - Functional Model
- **Full Actual Functional Model**
- Preliminary Parameter Analysis

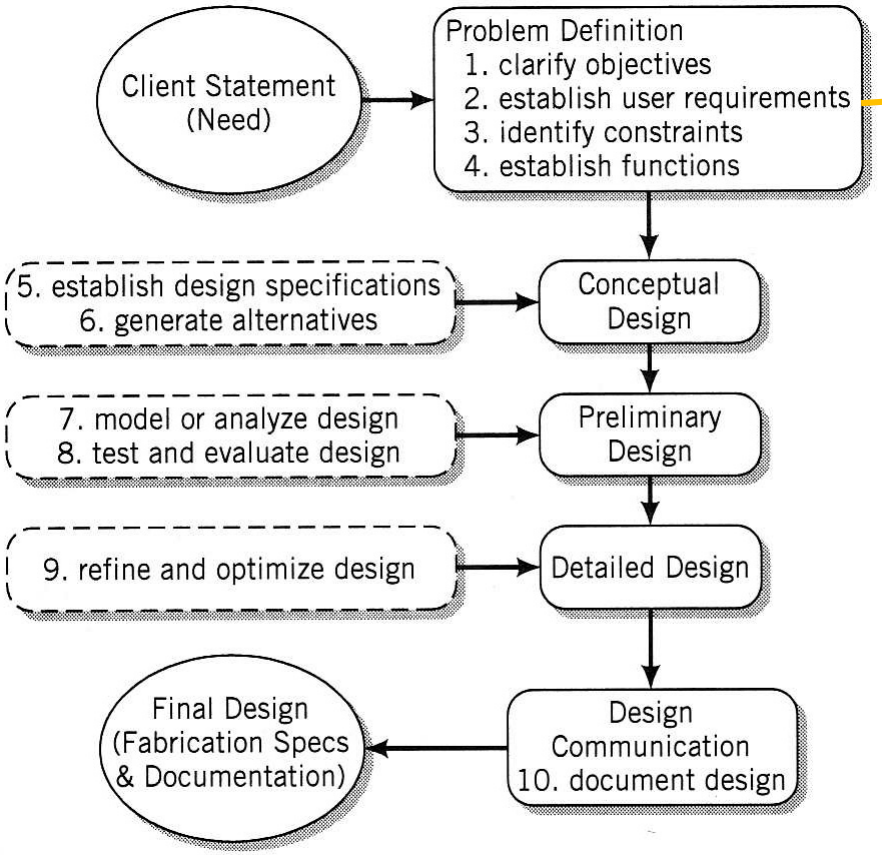
QFD1:
- Competitors analysis
- Weighting of the Objectives
- Importance of Functions
- Projectile motion and pressure calc.
- Morphological Chart
- Concept Variants
- Team Vision
- Plan for Phase 2 – Embodiment



Functions - Lecture

- Engineering Design Process 2nd Edition, Chapter 4
  - » Discuss the essentials of function analysis
  - » Create function structures based on need statements
  - » Discuss the importance of function analysis

Phase 4: Establish Function

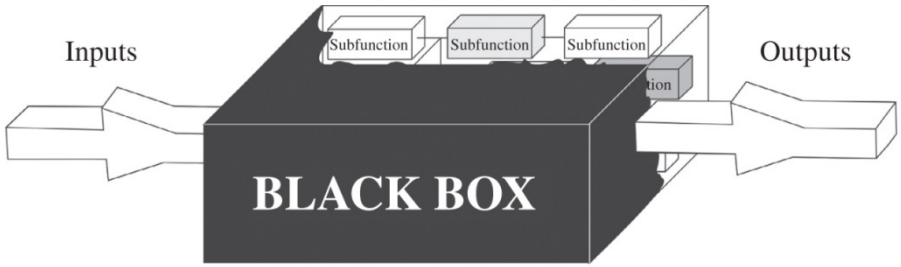


1. Clarify Objectives – The Objectives tree method
   - Prepare list of objectives
   - Order the list
   - Draw the objectives tree
2. Establish user requirements
3. Identify constraints
4. Establish functions
   - Create 'black box' model of the product
   - Break down overall function in sub-functions
   - Connect sub-function chains together
   - Define the system boundaries (Constrains)

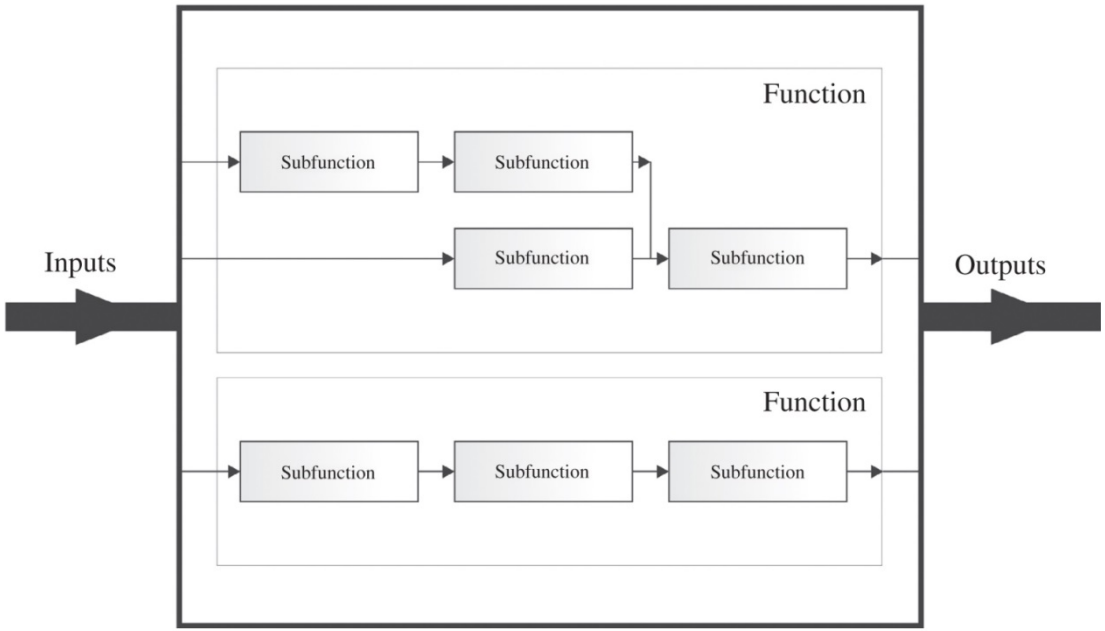
Objectives Tree and Functional Model

- Objectives are *qualities* the object should *have*
  - » *Clients* tend to speak in terms of objectives
- The Functions are *what* the product *does* without considering any particular solution
  - » *Engineers* tend to speak in terms of functions
- Identifying the basic functions an object does, and then determining solutions for these functions separately, leads to better solutions for the overall problem
- Two levels of functions:
  Overall functions and Sub-functions
- A product function is defined in a block diagram known as a *Functional Model*

Functional Model



Black Box System Model



Transparent Box Model

Figure 5.1 The box diagram.

- The overall function of a product is the relationship between its inputs and outputs
- Functions often have underlying law of physics or engineering
- Functions should consider what the product does (the problem) and ***NOT*** how it should do it (the solution)

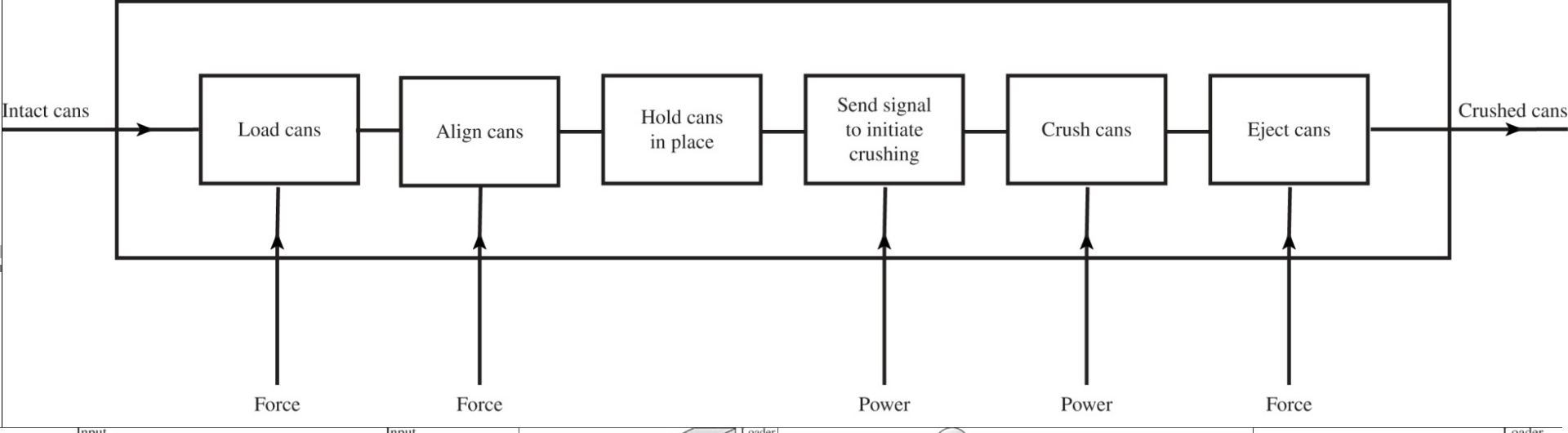
Functional Model Definitions

- Functional model
  - » It is a picture, a graphical representation
  - » The overall function of a product is sub-divided into smaller, more elemental (i.e. atomic) **sub-functions**
  - » The sub-functions are connected by the **flows** on which they operate

- Sub-functions
  - » Simpler expressions of part of the product's overall function
  - » Expressed in ***verb-object* form** at a consistent level of detail

Why to create and use Functional Models?

- It places the emphasis on ***what*** has to be accomplished rather than ***how***
- It makes clear the various sub-systems or functions that need to be solved in order to solve the entire problem
- Enhances the creativity of the design team by allowing them to focus on one sub-function at a time
- Sub-functions may be derived from objectives tree (or customer needs)



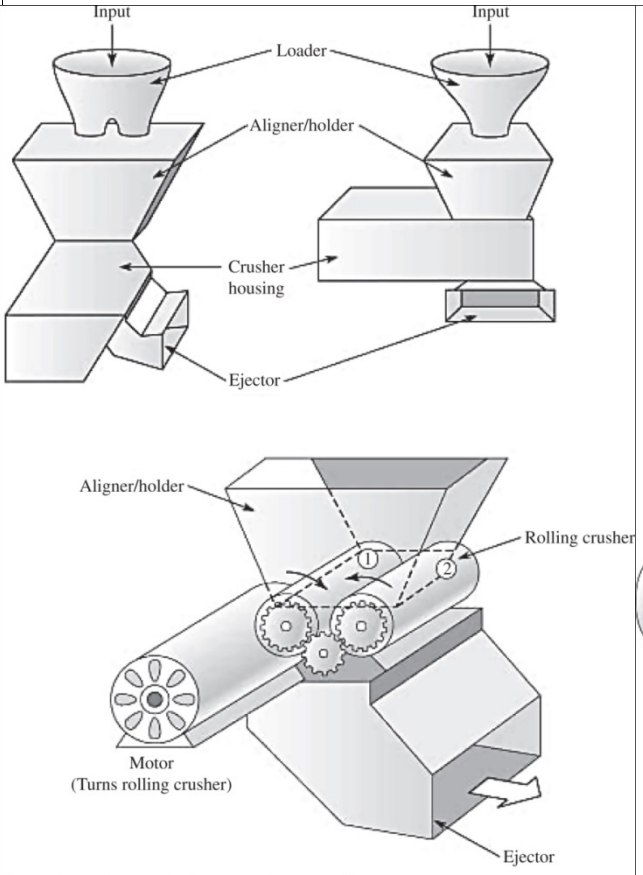


Figure 8.14 Concept I of automatic can crusher.

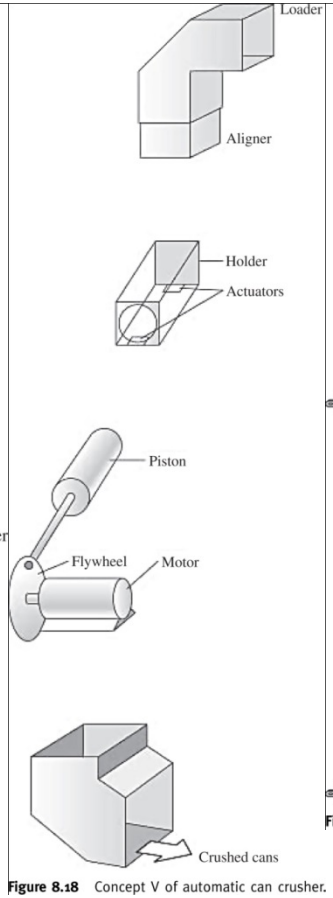


Figure 8.18 Concept V of automatic can crusher.

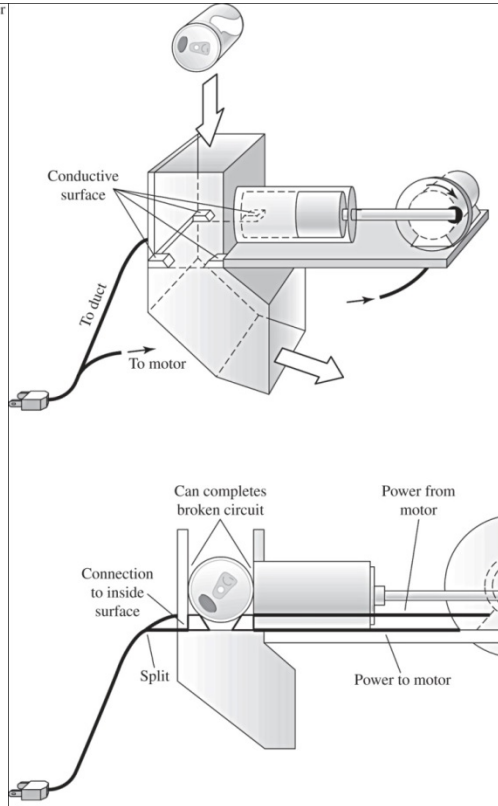


Figure 8.17 Concept IV of automatic can crusher.

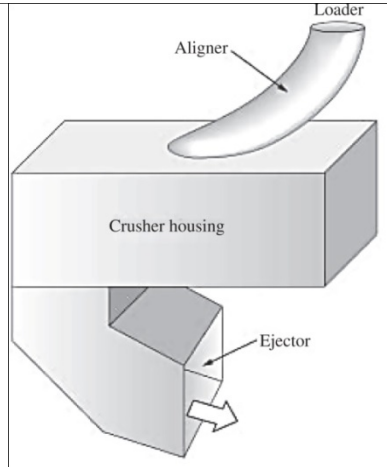
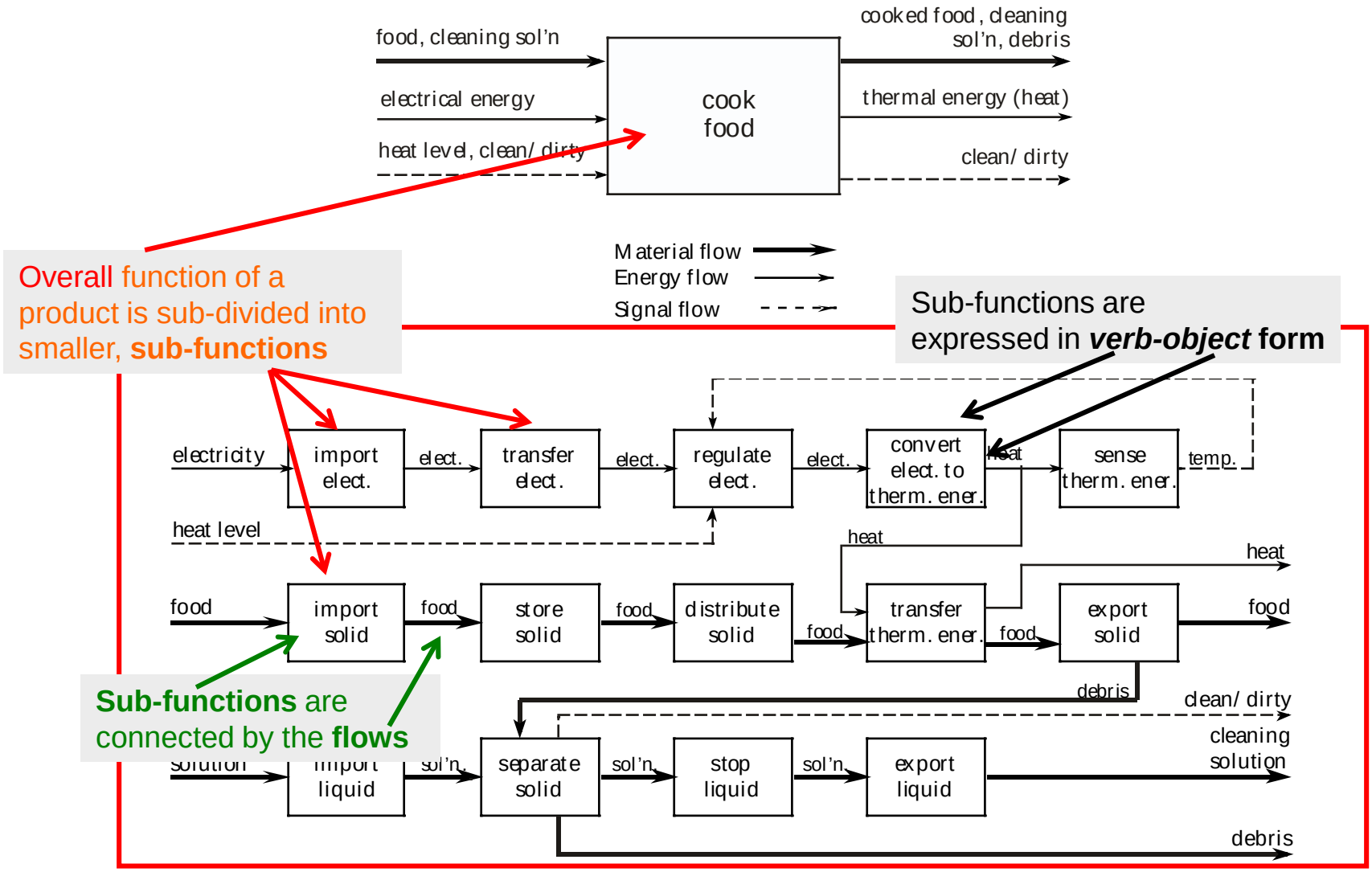


Figure 8.16 Concept III of automatic can crusher.

Visual Functional Mode - Definition

A **functional model** is a graphical representation of the functions a product performs on its inputs and outputs



Functional Model Basics

- A functional description is a combination of a function (verb) acting on a flow (object)
  - » *Function* - the operation that the product performs on a flow or a set of flows to transform it from its input state to its output state
  - » *Flow* - a material, energy or signal that is used by or affects the product
    - – Think of a flow as anything that is input to the product or an output of the product

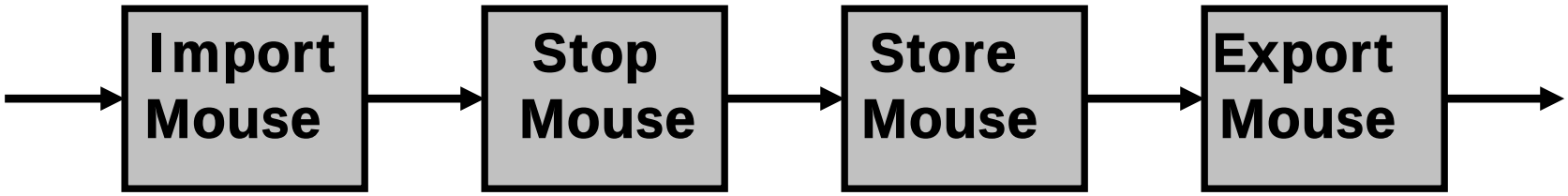
Functional Model Basics (1)

- Functional description form:
  Function (Verb)–Flow (Object)
  - » Examples of functional descriptions

	Function	Flow
The overall function of a student:	Learn	Concepts
The overall function of a bumble ball:	Entertain	User
The overall function of a mechanical pencil:	Deposit	Lead

Functional Model Simple Example

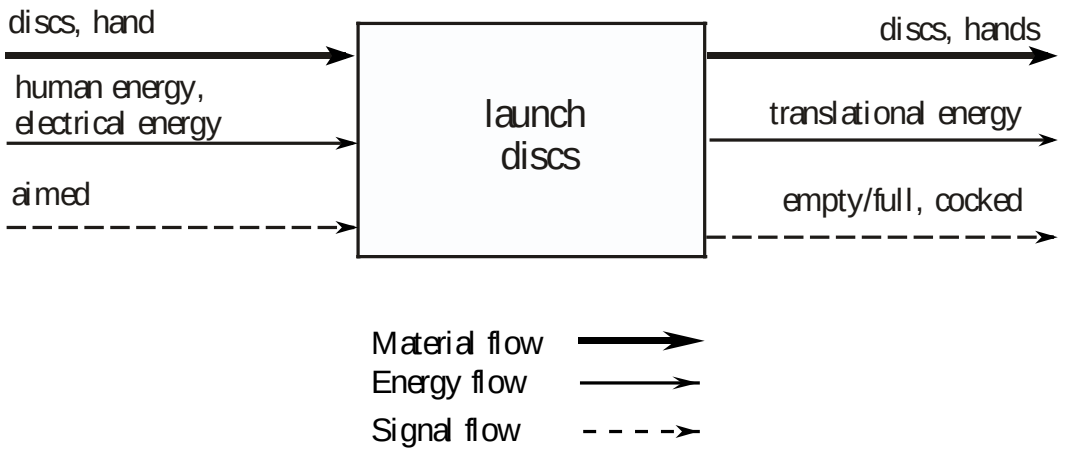
- Think about designing a “better” mouse trap
  - » What functions must it accomplish?
  - » Take a few minutes as a team and brainstorm about mousetrap functions
- View the diagram below:
  - » Does it match your ideas? Note the verb + noun construction.
  - » Can you see that solving these “functions” separately can lead to a wider range of potential designs?



(Attract Mouse)

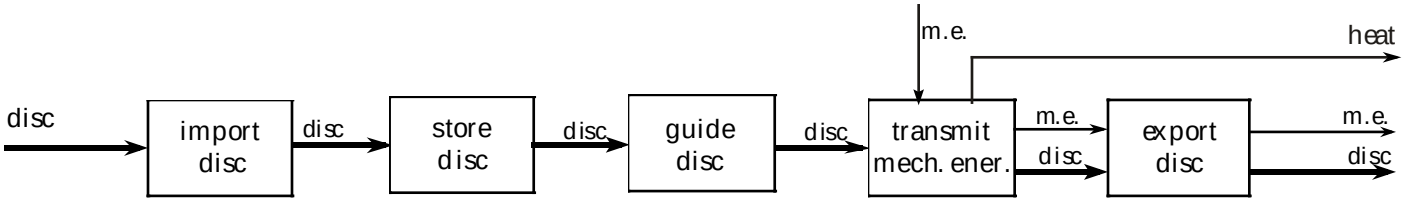
Functional Modeling Procedure

- Step 1: Create a “black box” model of the product
  - » State overall function of product
    - – Use your objective tree high level objectives to help determine the overall function
  - » Identify input and output flows
  - » Possibly related to lowest level objectives



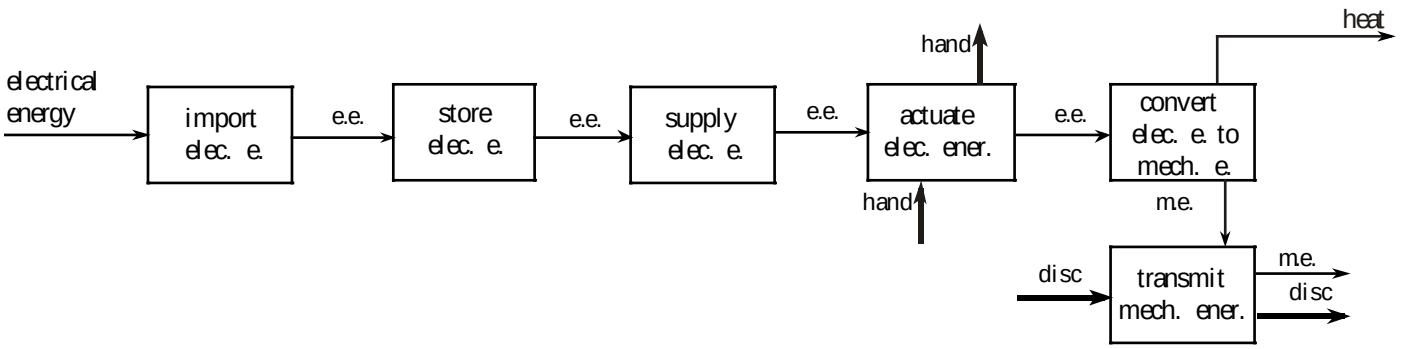
Functional Modeling Procedure

- Step 2: Break down overall function into sub-functions
  - » Follow each input flow through the product and imagine what function the product performs *on* the flow
  - » The *Zen* approach: *BE* the flow



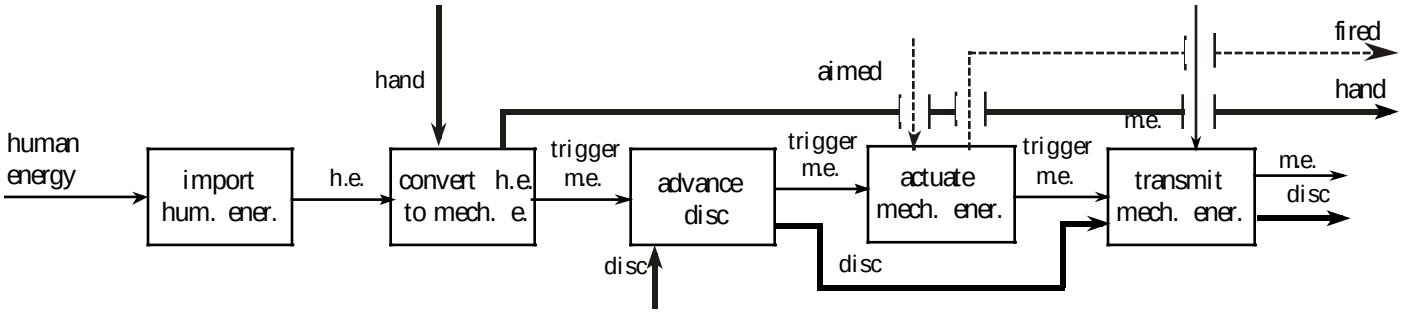
Functional Modeling Procedure

- For the flow of *electrical energy*, what is its associated sub-functions?



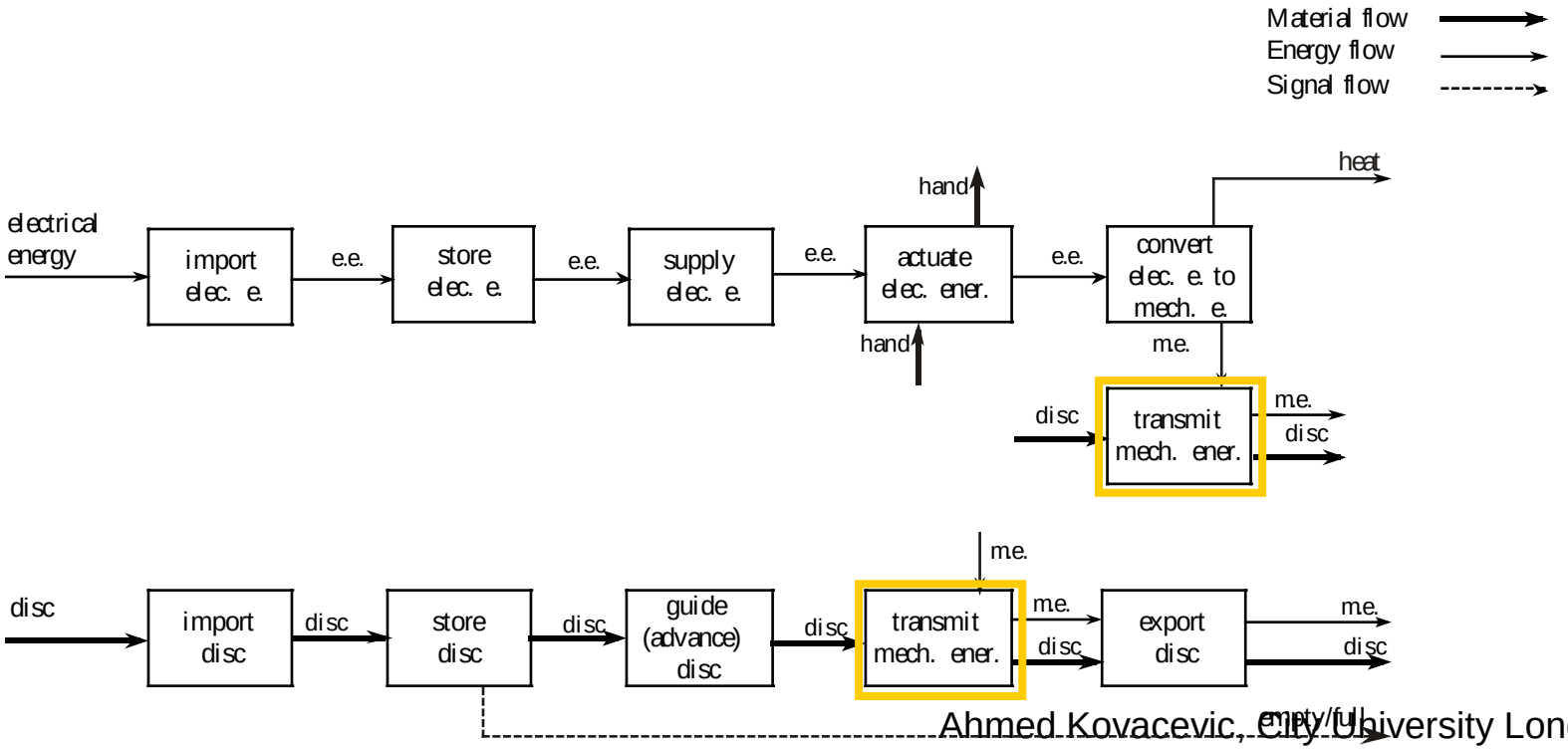
Functional Modeling Procedure

- Flow of *the user mechanical energy*,
- what are associated sub-functions?



Functional Modeling Procedure

- Step 3: Connect the sub-function chains together
  - » This may require additional sub-functions or connecting flows



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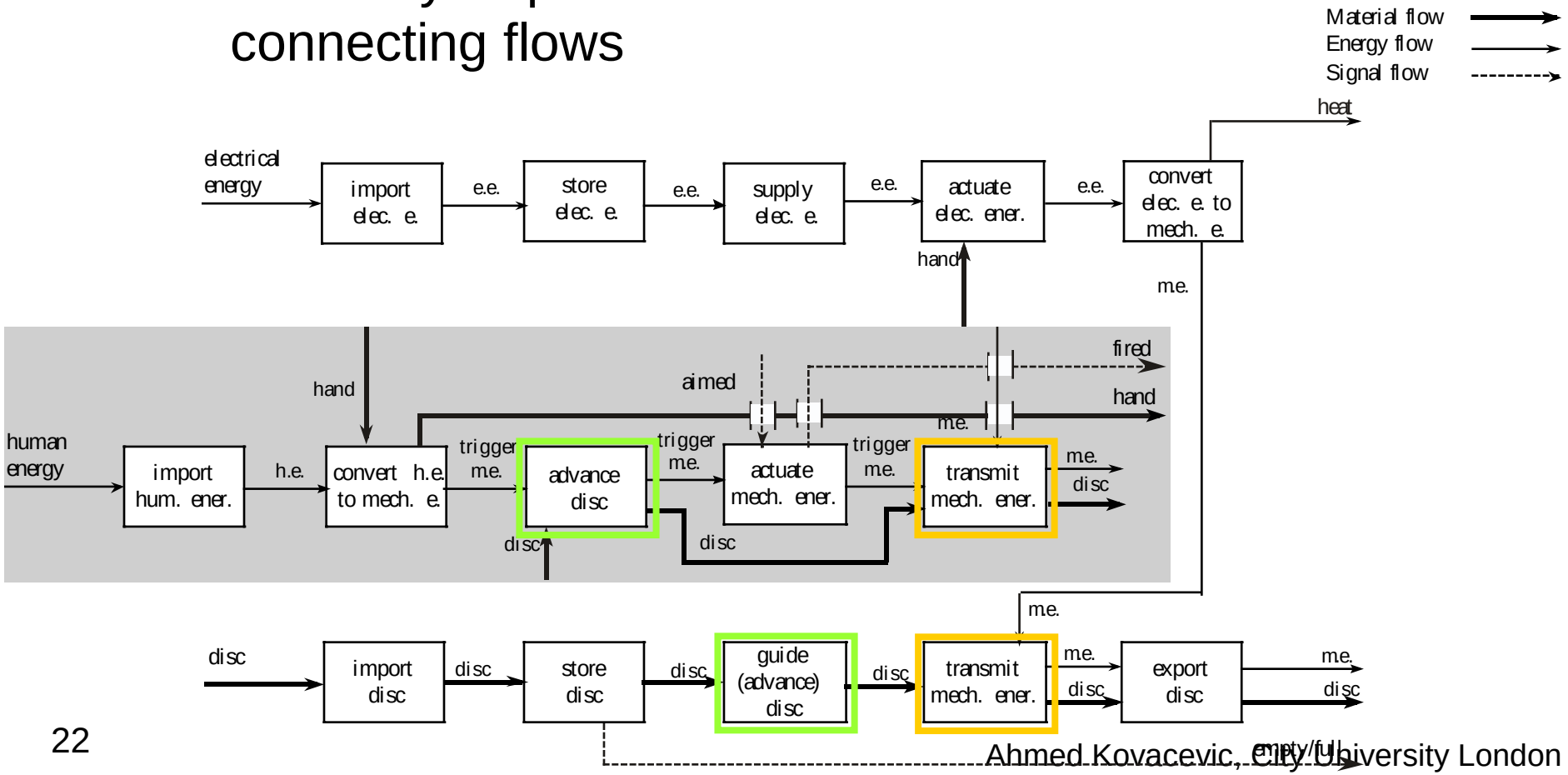

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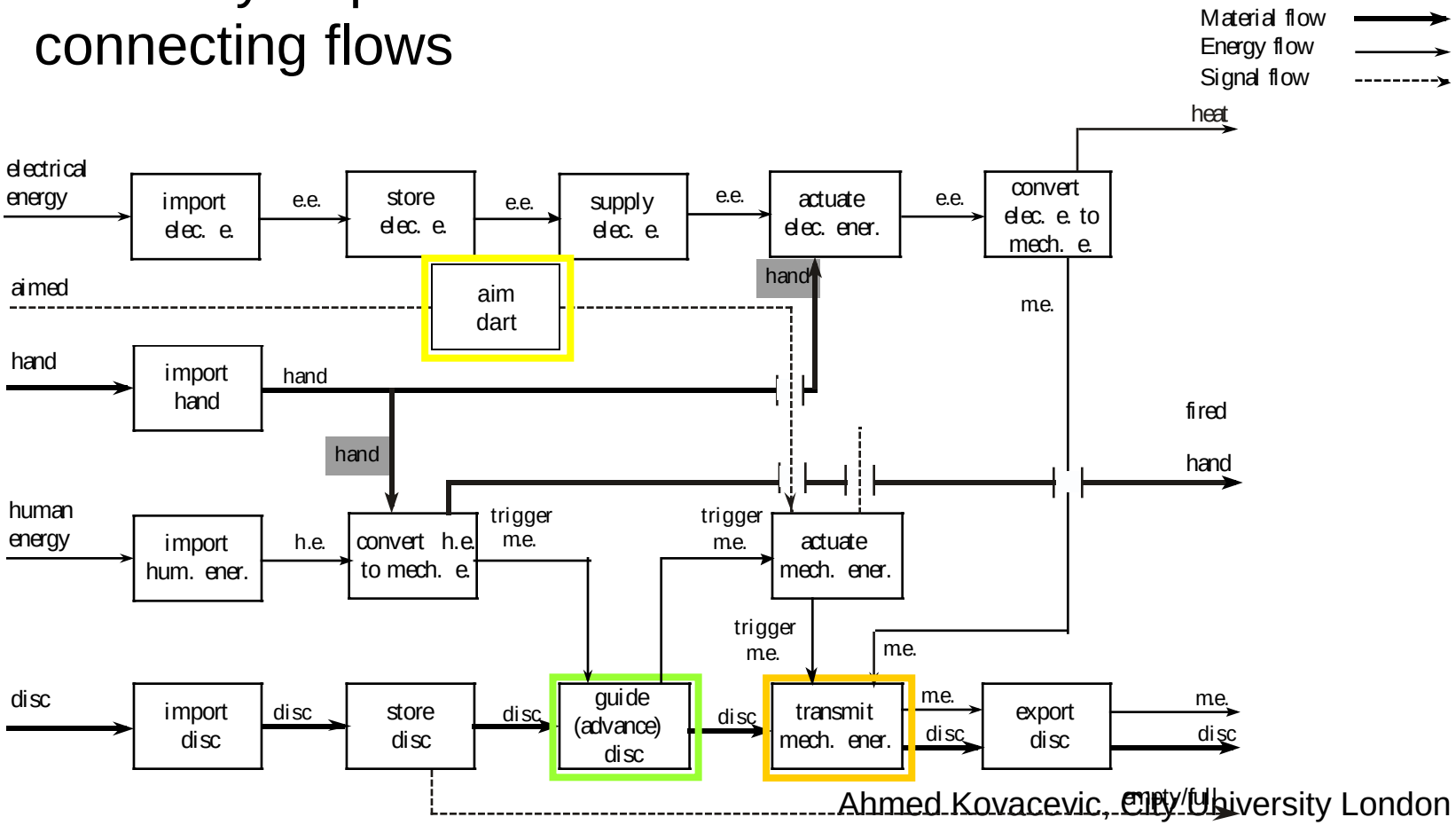
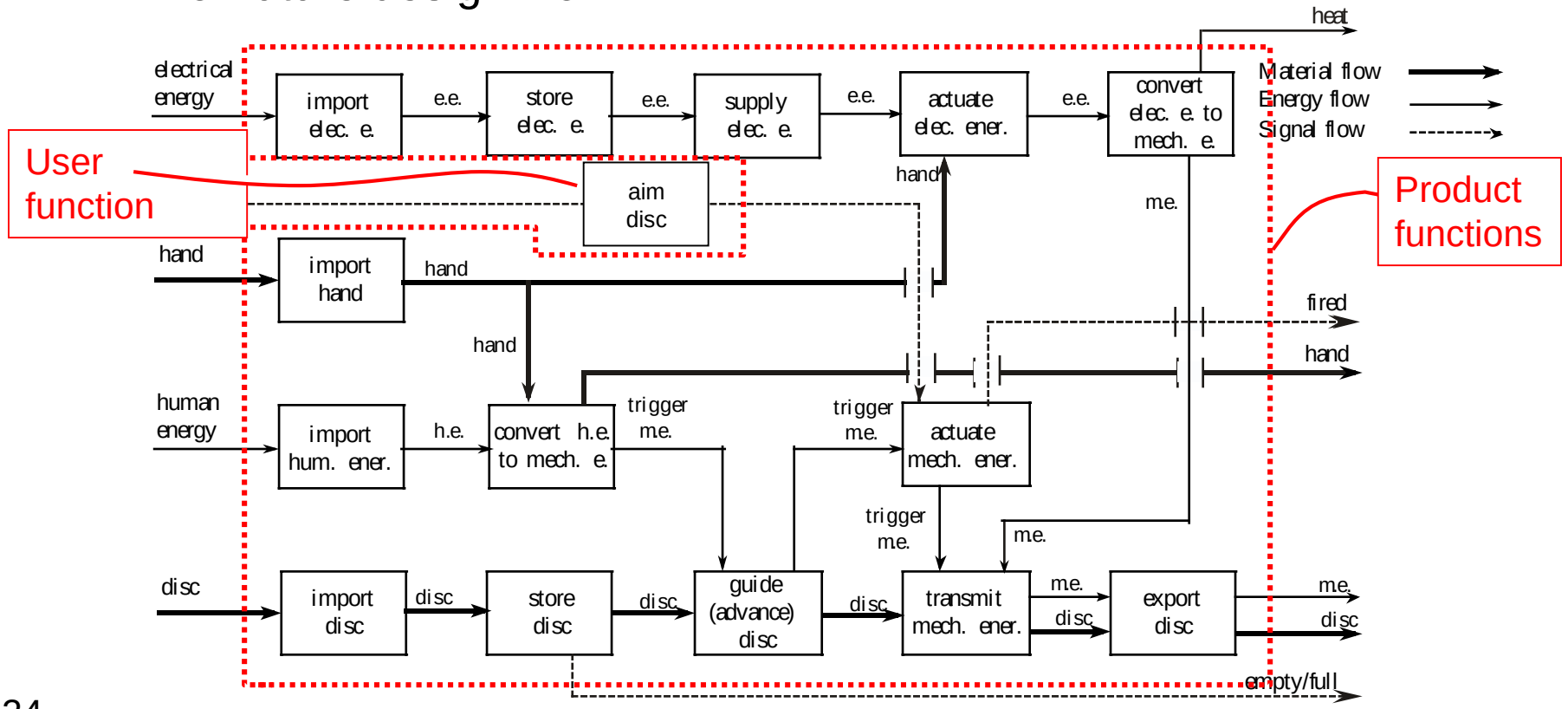


Functional Modeling Procedure

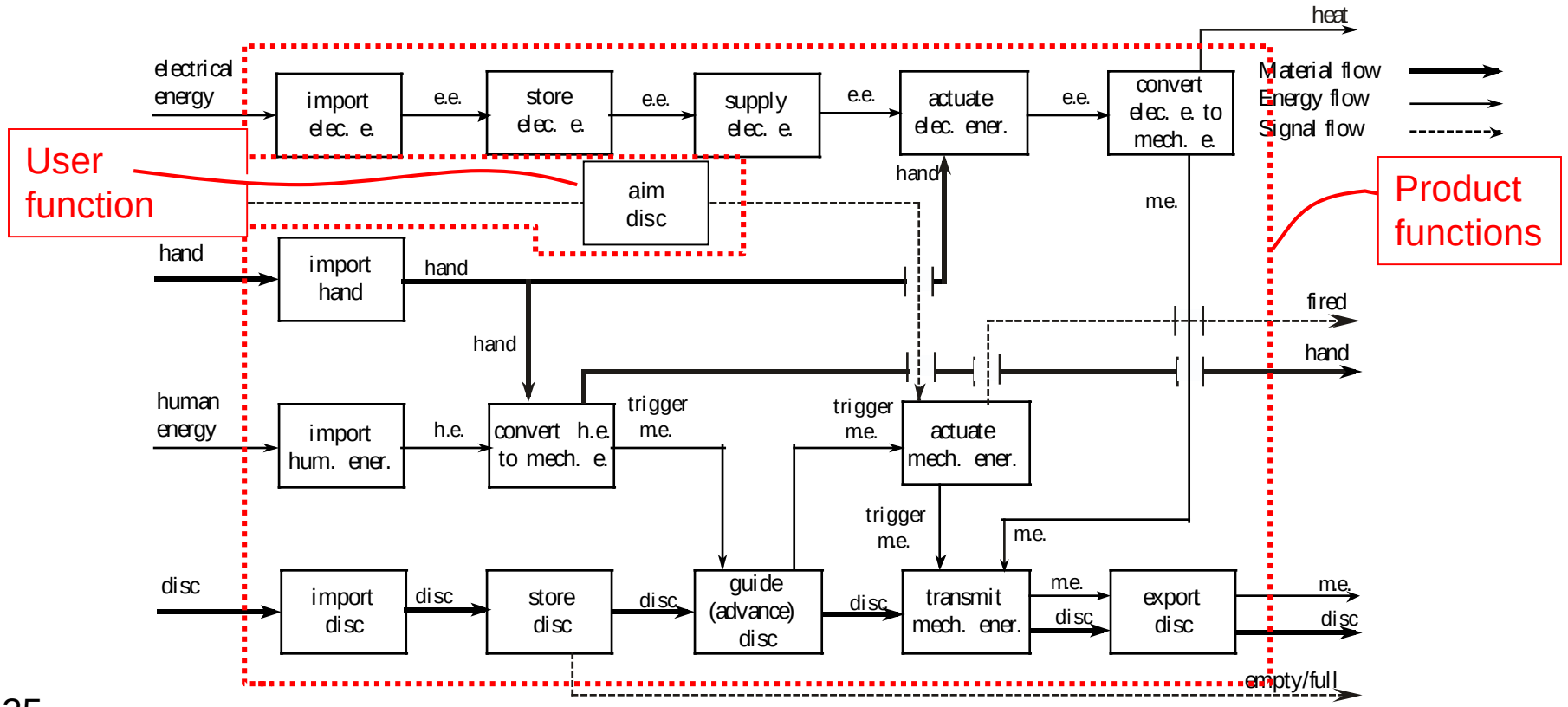
- Step 4: Define the system boundary
  - » This ensures that only product sub-functions are considered for future design work



Functional Modeling Procedure

- Step 5: Identify appropriate components to perform sub-functions and their interactions

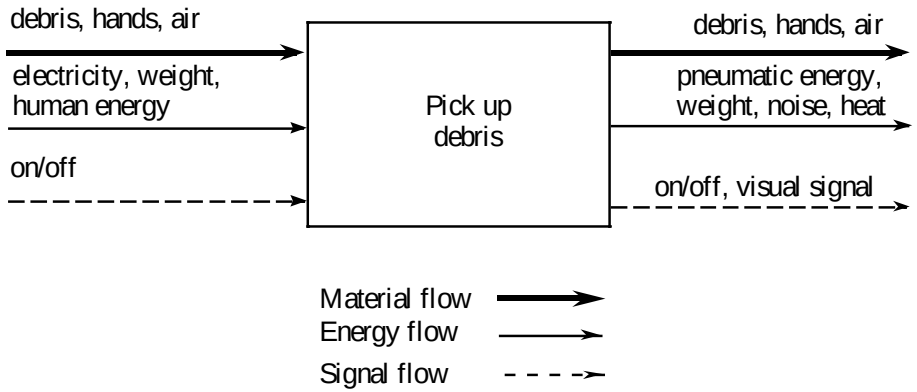
»



Additional Explanation:

Five Steps to a Functional Model

- Step 1: Create a black box model
  - » Identify overall function
  - » Express overall function in verb-object form
  - » e.g. learn material, pass course, obtain degree, etc.
  - » Identify input/output flows



Additional Explanation:

Five Steps to a Functional Model

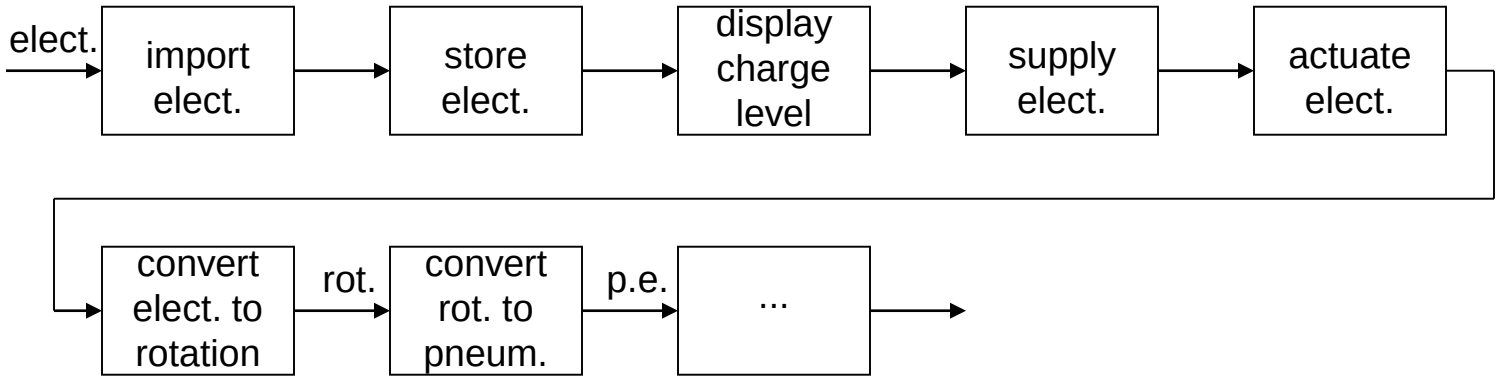
- Step 2: Create function chains
  - » Follow “Zen approach” - *BE* the flow
    - – Think of every operation that the product does to the flow
    - – List all the operations as sub-functions
  - » Express sub-functions in a common language, i.e. the functional basis
  - » Order sub-functions temporally (with respect to time)

Additional Explanation:

Functional Model Example

- Dustbuster function chains

Objective: Powerful
Related to input flow of electricity



Additional Explanation:

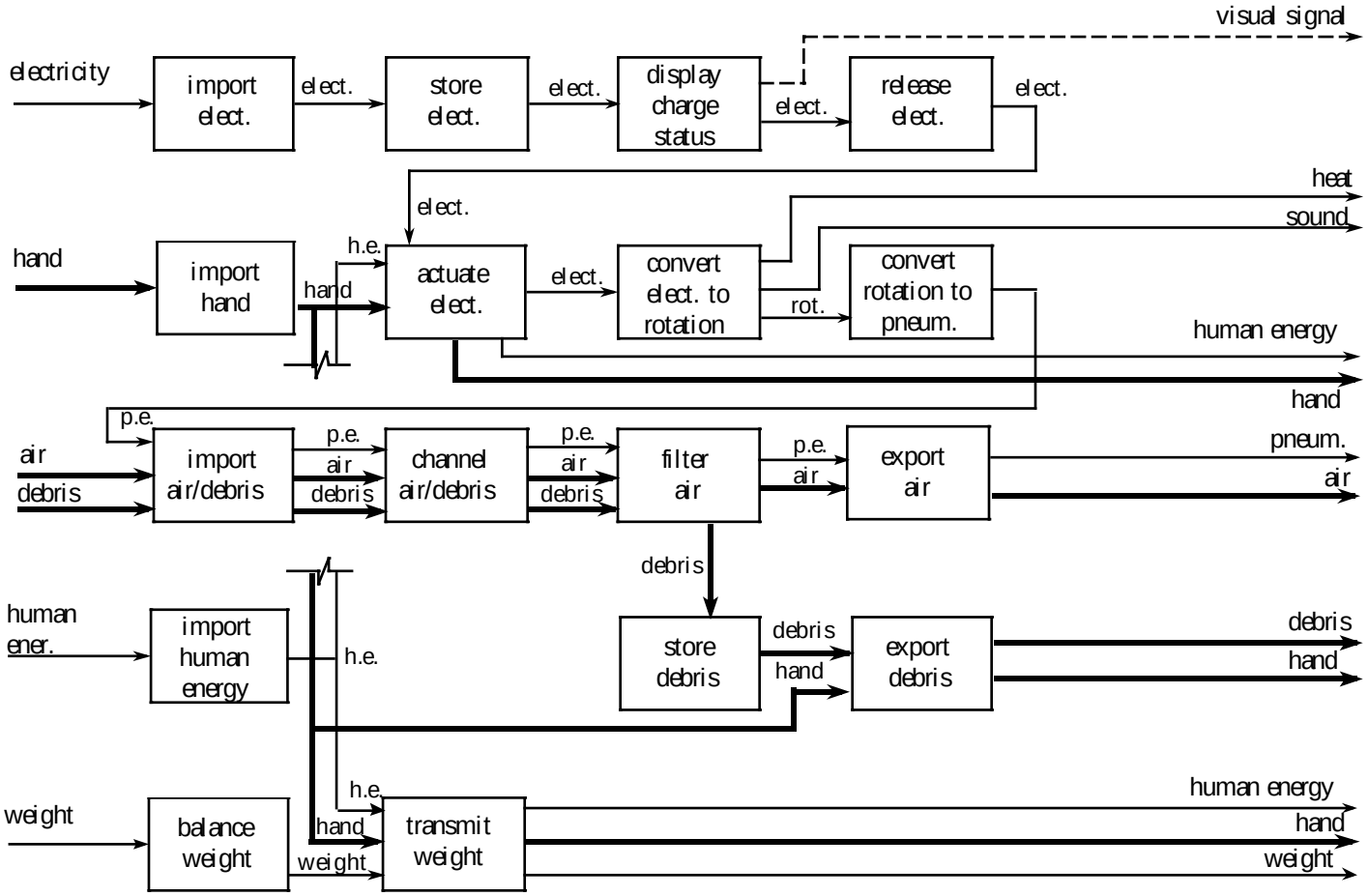
Five Steps to a Functional Model

- Step 3: Connect the function chains together
  - » Connect function chains for each flow
  - » Add/remove sub-functions as necessary
- Step 4: Define the system boundary
  - » Differentiate between user and device functions
- Step 5: Identify components for each sub-function
  - » Many alternative components can perform function

- Final check:
  - » Check if all objectives are covered
    - – Make sure each objective is met by at least one sub-function
    - – If not, sub-functions (or chains) must be added

Functional Model Example

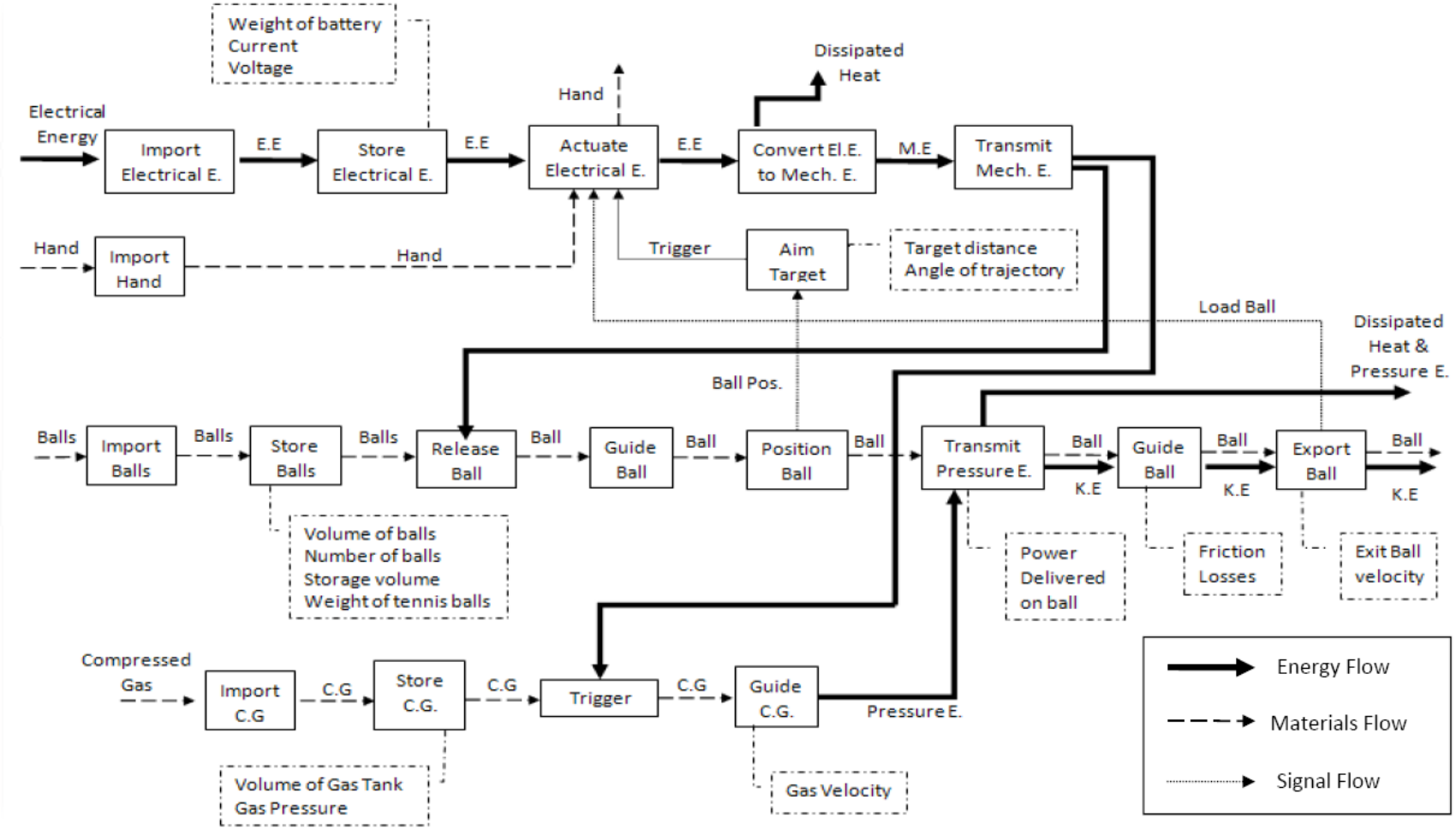
- Aggregating the Dustbuster function chains

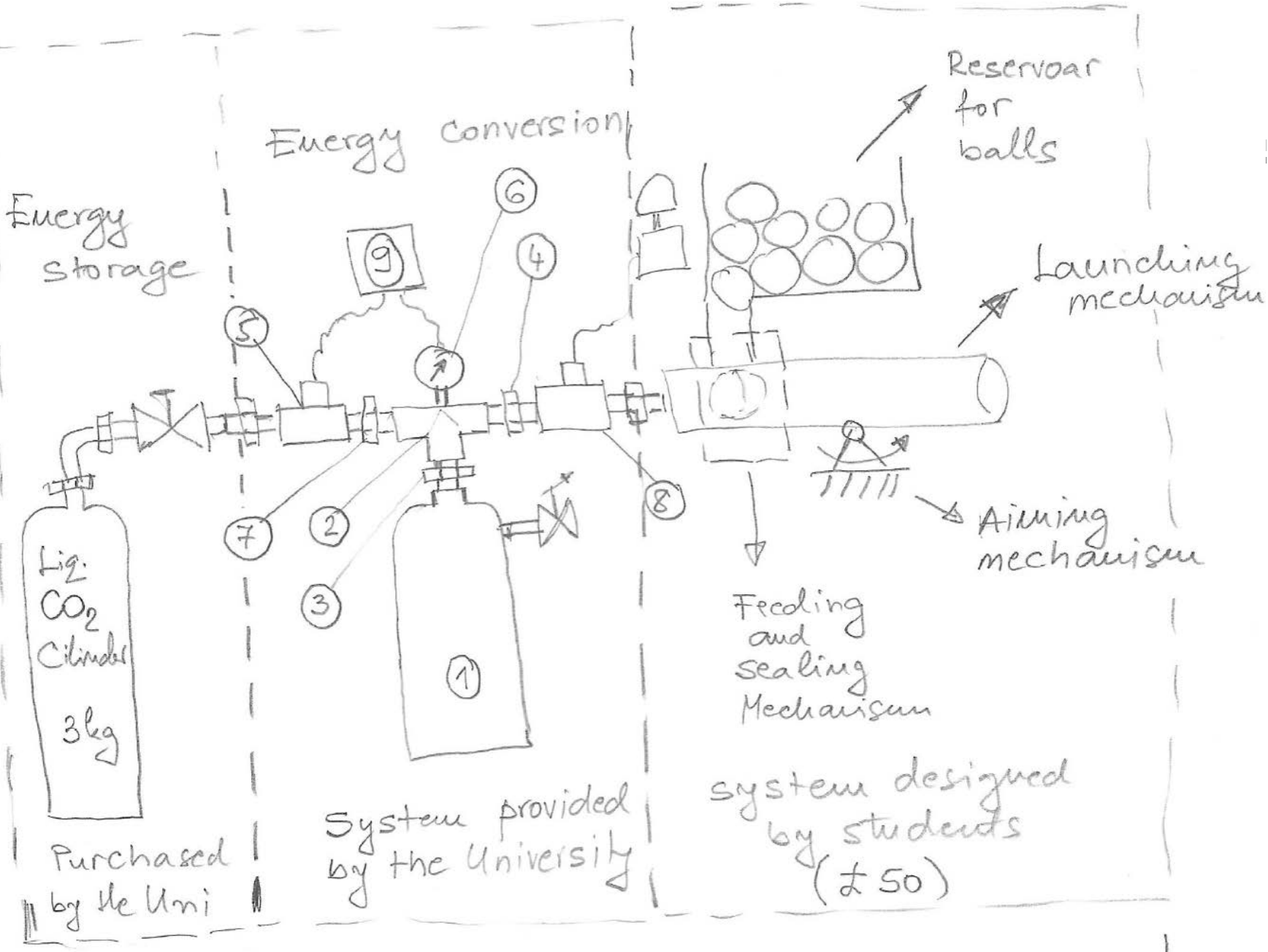


Functional Modeling Summary

- What's the difference between objectives and functions?
  - » Objectives tell us what the final product will "be", what qualities it will have
  - » Functions tell us what the object will "do", without regard to any particular form
    - – Functions will always relate input to output
    - – Functions capture the transformation that takes place between input and output
- Though the difference may seem subtle, it is a very important distinction

Functional model example last year

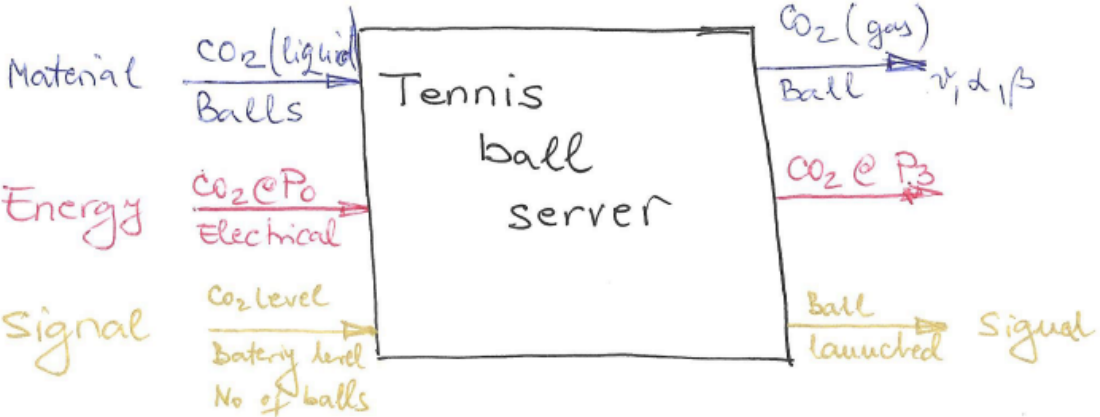



Energy storage
Energy conversion
Reservoar for balls
Launching mechanism
Aiming mechanism
Feeding and sealing Mechanism
Liq. CO_2 Cilinder 3kg
Purchased by the Uni
System provided by the University
system designed by students (£50)
1
2
3
4
5
6
7
8
9

Tennis ball server

①

FUNCTIONAL MODEL



Parameters:

CO_2 pressures [bar]: P_0 - Supply (P_0 = 10 – 300 bar)
P_1 - Regulated [P_1 = 7–10 bar]
P_2 - Launching
P_3 - Discharge [$P_3 \sim 1$ bar]

Ball: N - No of balls
m_b [kg] Mass of the ball
ϕ_B [m] Diameter of the ball

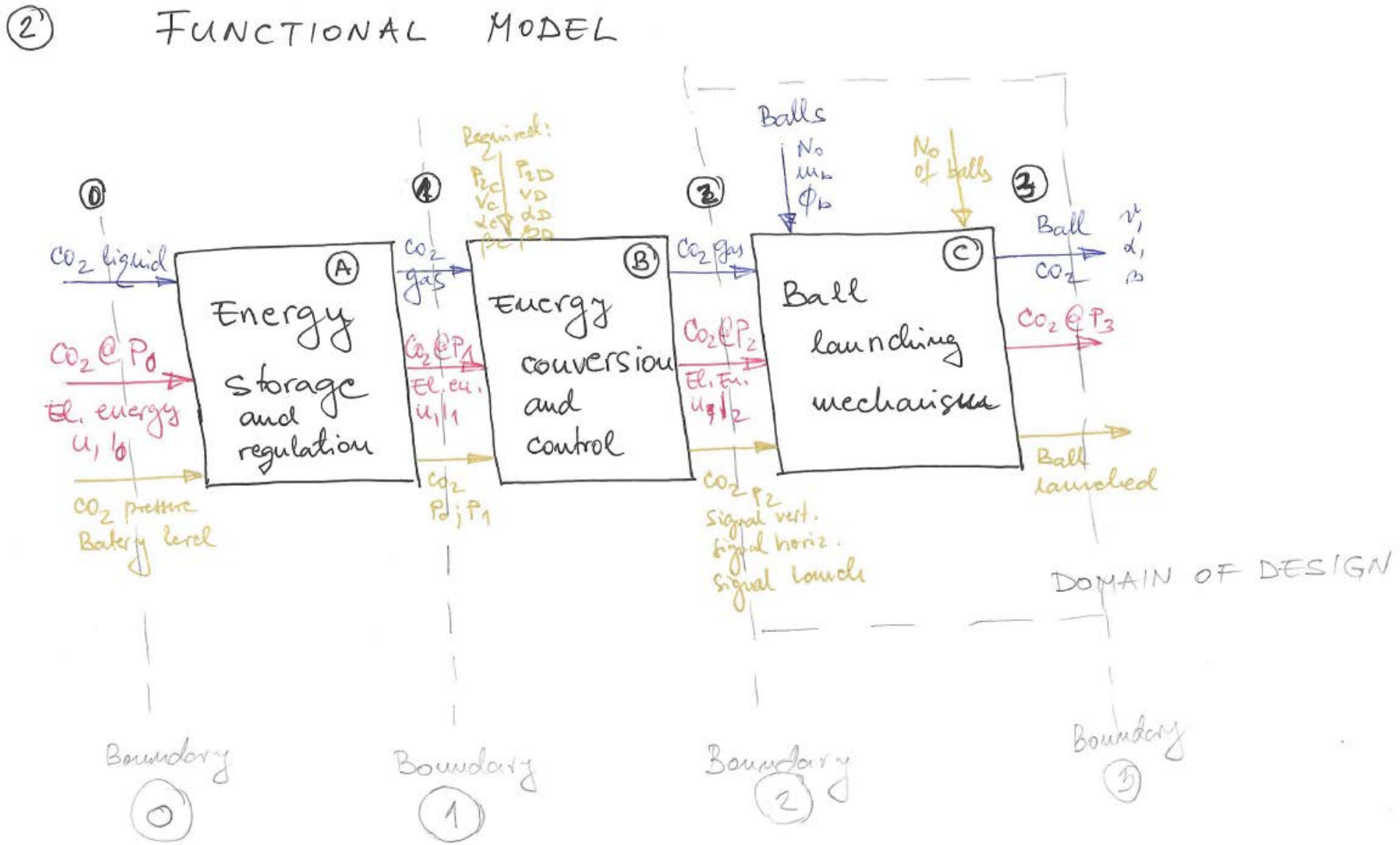
Angles: α [°] - inclination (vertical)
β [°] - deviation (horizontal)

Velocity: v [m/s] - launching velocity

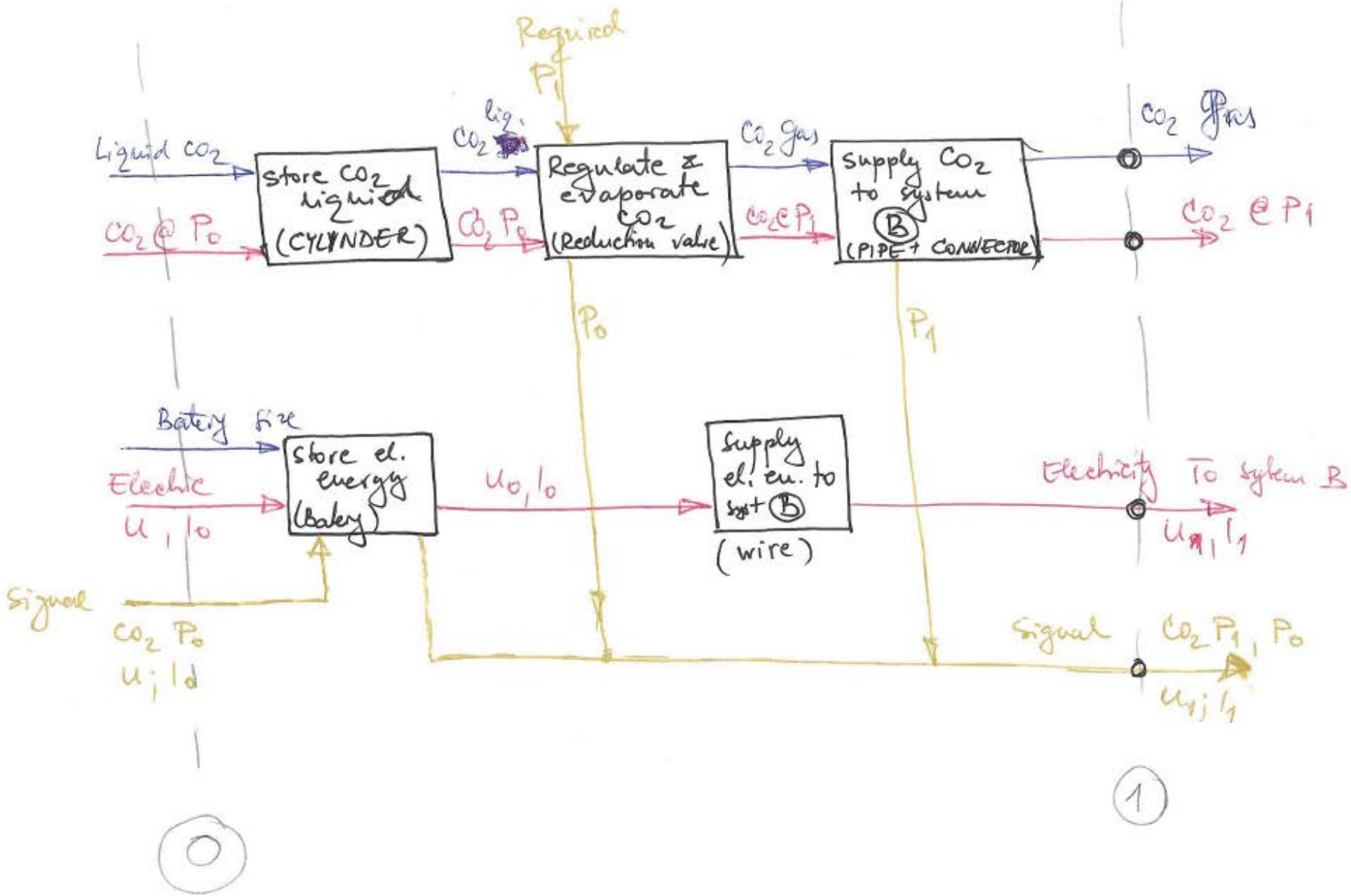
Index for angles, velocity and launching pressure
c - position 1
D - Position 2

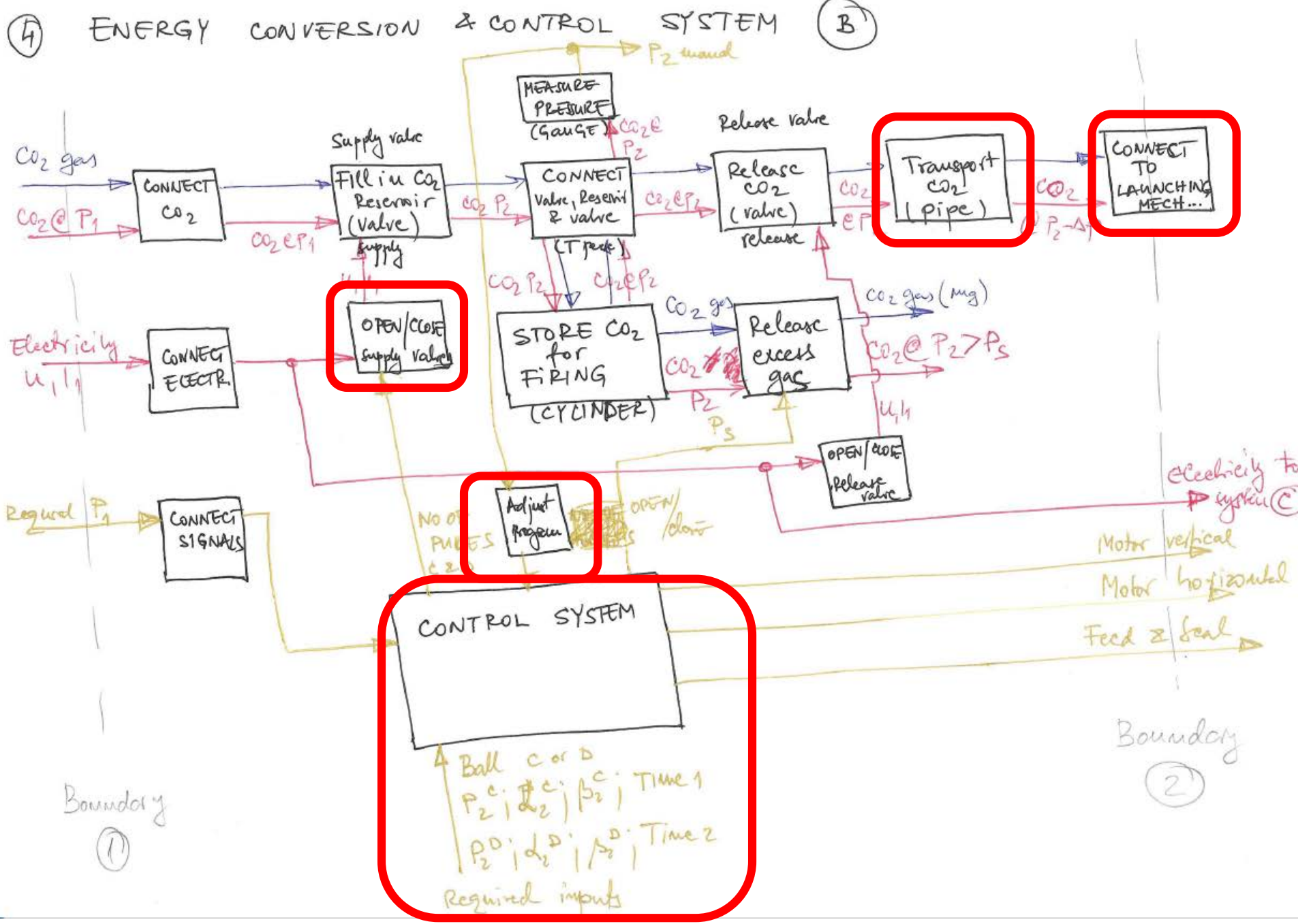
Electrical energy:
$U = 12$ V - voltage
$I =$ A - current

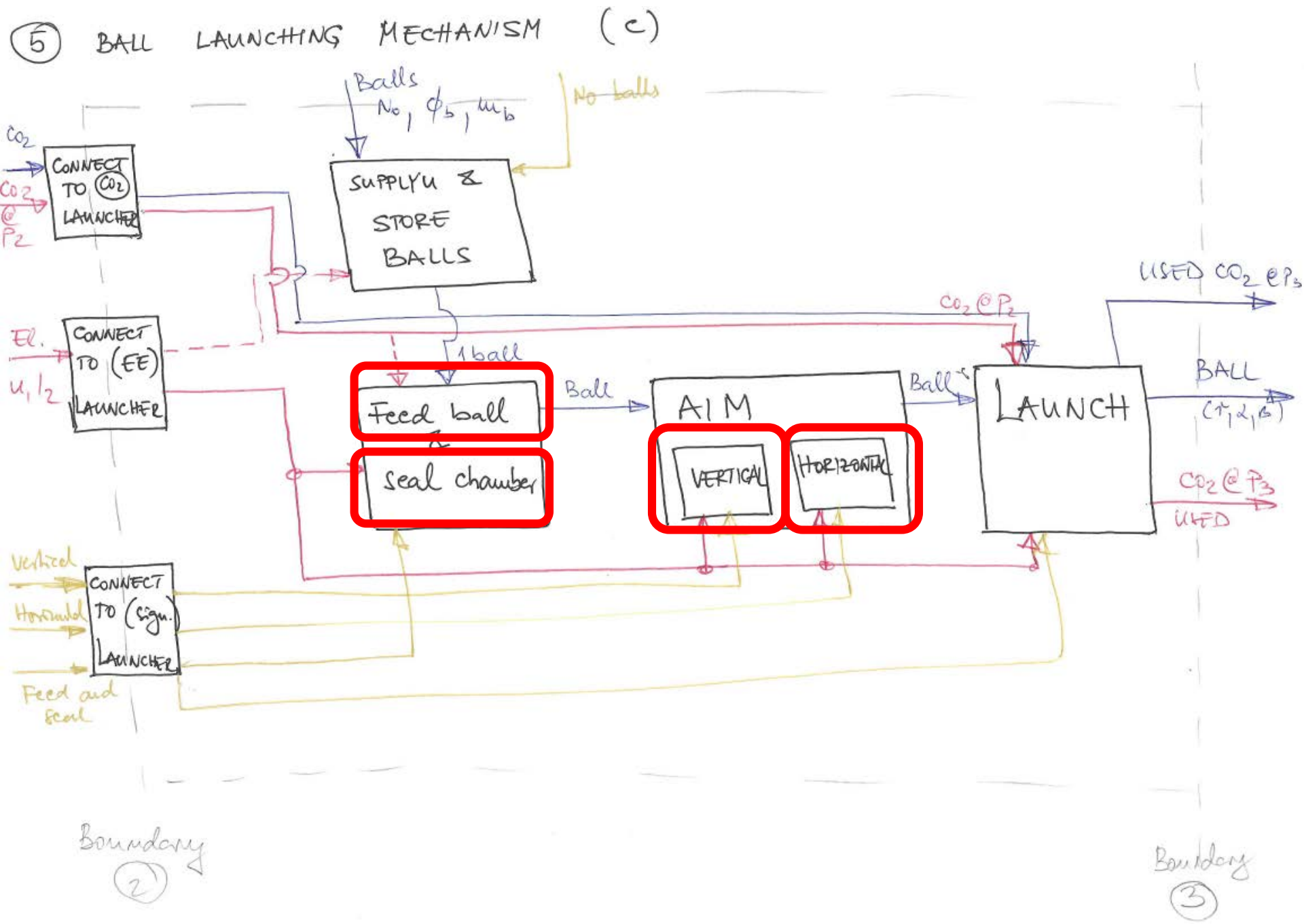
Tennis ball server



(3) ENERGY STORAGE & REGULATION SYSTEM (A)




4
ENERGY CONVERSION & CONTROL SYSTEM
B
P_2 measd
MEASURE PRESSURE (GAUGE)
CO_2 gas
CO_2 @ P_1
CONNECT CO_2
CO_2 @ P_1
Supply valve
Fill in CO_2 Reservoir (Valve)
supply
CO_2 @ P_2
CONNECT Valve, Reservoir & valve
(T piece)
CO_2 @ P_2
Release valve
Release CO_2 (valve)
release
CO_2 @ P_2
Transport CO_2 (pipe)
CO_2 @ $P_2 - \Delta P$
CONNECT TO LAUNCHING MECH...
Electricity
U_1, I_1
CONNECT ELECTR.
OPEN/CLOSE supply valve
CO_2 P_2
CO_2 @ P_2
STORE CO_2 for FIRING (CYLINDER)
CO_2 gas
CO_2
P_2
P_s
Release excess gas
CO_2 gas (mg)
CO_2 @ $P_2 > P_s$
U, I
OPEN/CLOSE Release valve
Required P_1
CONNECT SIGNALS
Adjust Program
No of PULSES
OPEN/close
CONTROL SYSTEM
Ball C or D
P_2^C | α_2^C | β_2^C | TIME 1
P_2^D | α_2^D | β_2^D | Time 2
Required inputs
Electricity to system C
Motor vertical
Motor horizontal
Feed & seal
Boundary 1
Boundary 2


5 BALL LAUNCHING MECHANISM (c)
Balls
No, ϕ_b, m_b
No balls
CO_2
CONNECT TO CO_2 LAUNCHER
CO_2 @ P_2
SUPPLY n & STORE BALLS
USED CO_2 @ P_3
CO_2 @ P_2
El.
U_1 I_2
CONNECT TO (EE) LAUNCHER
1 ball
Feed ball
Seal chamber
Ball
AIM
VERTICAL
HORIZONTAL
Ball
LAUNCH
BALL
($\uparrow_1$, $\downarrow_2$, β)
CO_2 @ P_3
USED
Vertical
Horizontal
CONNECT TO (Sign.) LAUNCHER
Feed and Seal
Boundary 2
Boundary 3

Examples of competitors

Deliverables for Week 4

» Updated Notebook, Updated Gantt Chart
» Meeting minutes from last week
» Finalised & weighted Objectives Tree in 3 or 4 levels
» Market research
» Functional Model

Team Meeting