DESN2000 MECH Workshop

Week 2 – Functional Representation

Class overview

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Overview of Functional Design

Overview of Functional Design	Creating Functional Requirements	Key FR Creation Principles	Advanced FR Method: EMS Model	Project Time!	Summary
5 min	5 min	25 min	10 min	65 min	5 min
All	All	All	All	All	All

Overview of Functional Design - Process

W2 DESN Lecture and Workshop

Today's Workshop

1. EXPLORE CUSTOMER DOMAIN

A. Identify Target Customers
B. Solicit Customer Needs
C. Extrapolate Customer needs in big picture

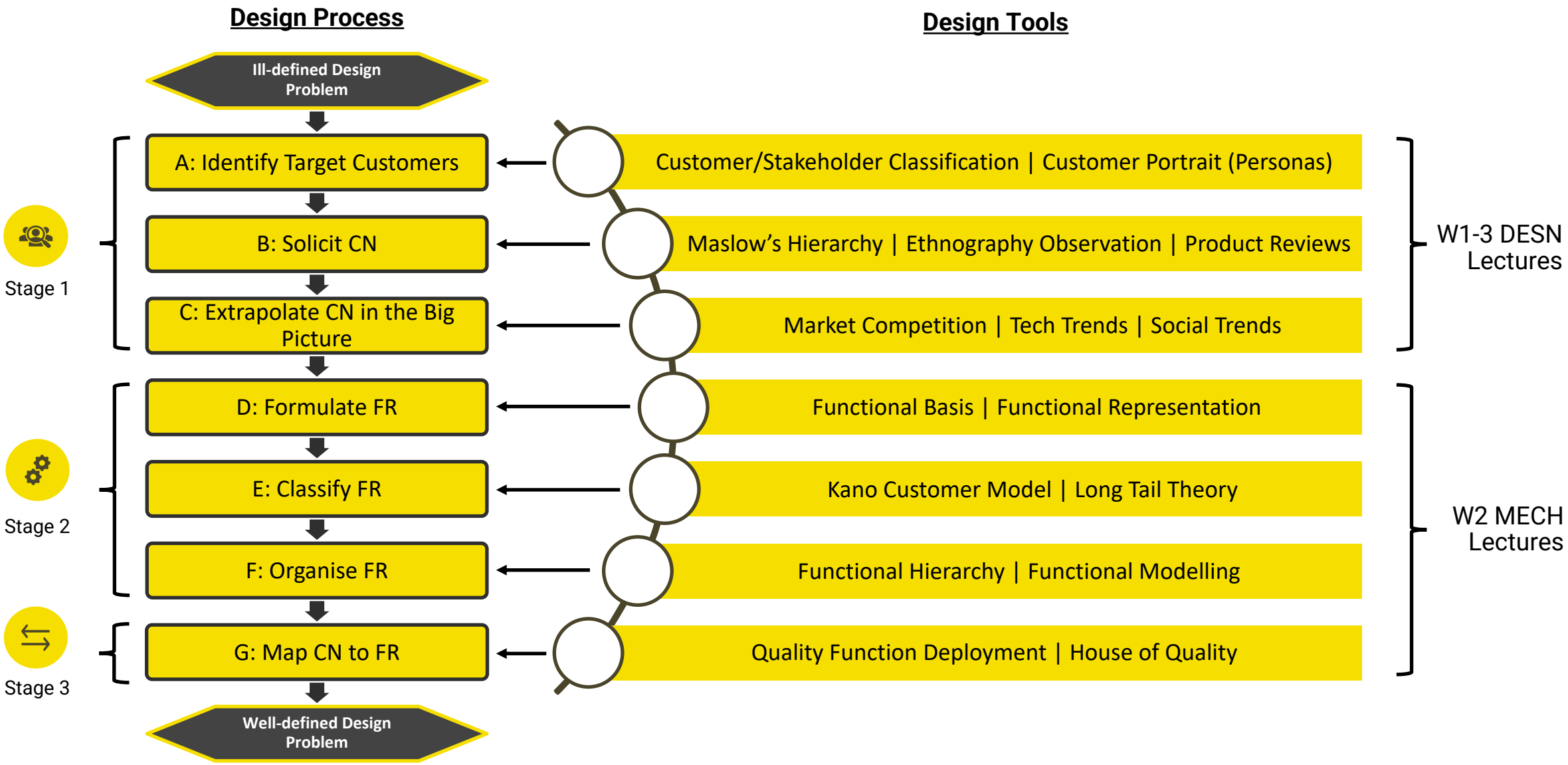
2. EXPLORE FUNCTIONAL DOMAIN

D. Formulate Functional Requirements
E. Classify Functional Requirements
F. Organise Functional Requirements

3. MAP BETWEEN CUSTOMER AND FUNCTIONAL DOMAINS

G. Map Custom Needs to Functional Requirements.

Overview of Functional Design - Process



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Creating Functional Requirements

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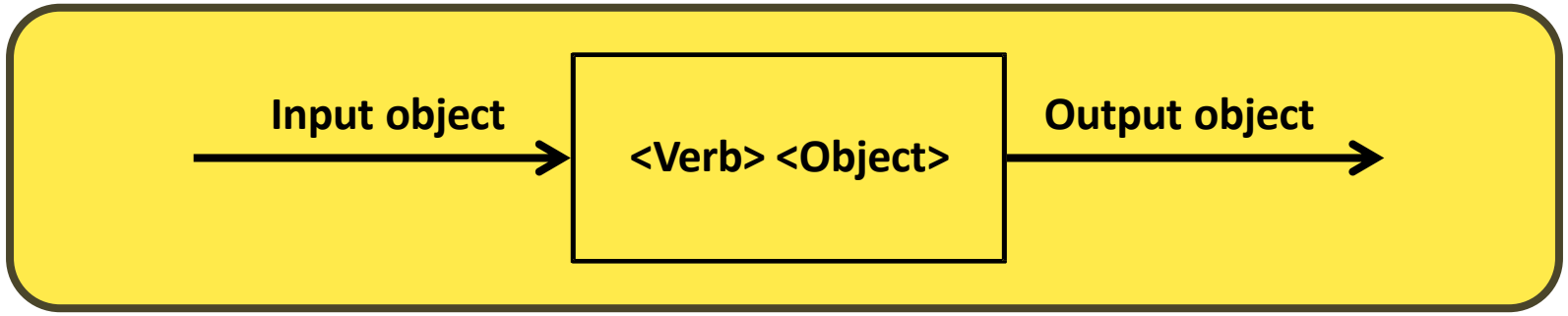
Creating Functional Requirements

- **Recall:** A function **transforms** an **input object/parameter** into an **output object/parameter.**



Verb + Object

Basic Format (what you need)

(Verb + Object 1) to/from/with/through (Verb +Object 2)

(Verb + Object) in context

Advanced Options (not needed but welcome to research if you are curious)

Class	Basic	Flow restricted	Synonyms
Branch	Separate		Switch, Divide, Release, Detach, Disconnect, Disassemble, Subtract,
		Remove	Cut, Polish, Sand, Drill, Lathe
	Refine		Purify, Strain, Filter, Percolate, Clear
	Distribute		Diverge, Scatter, Disperse, Diffuse, Empty Absorb, Dampen, Dispel, Resist, Dissipate
Channel	Import		Input, Receive, *Allow*, Form Entrance, *Capture*
	Export		Discharge, Eject, Dispose, Remove
	Transfer		
		Transport	Lift, Move
		Transmit	Conduct, Convey
	Guide		Direct, Straighten, Steer
		Translate	
		Rotate	Turn, Spin
		Allow DOF	Constrain, Unlock
Connect	Couple		Join, Assemble, *Attach*
	Mix		Combine, Blend, Add, Pack, Coalesce
Control Magnitude	Actuate		Start, Initiate
	Regulate		Control, *Allow*, *Prevent*, Enable/Disable, Limit, Interrupt, Valve
	Change		Increase, Decrease, Amplify, Reduce, Magnify, Normalize, Multiply, Scale, Rectify, Adjust
		Form	Compact, Crush, Shape, Compress, Pierce
		Condition	
Convert	Convert		Transform, Liquefy, Solidify, Evaporate, Condense, Integrate, Differentiate, Process
Provision	Store		Contain, Collect, Reserve, *Capture*
	Supply		Fill, Provide, Replenish, Expose
	Extract		
Signal	Sense		Perceive, Recognize, Discern, Check, Locate
	Indicate		Mark
	Display		
	Measure		Calculate
Support	Stop		Insulate, Protect, *Prevent*, Shield, Inhibit
	Stabilize		Steady
	Secure		*Attach*, Mount, Lock, Fasten, Hold
	Position		Orient, Align, Locate

Example Vocabulary of **Verbs**

Source: Stone, Robert B. Wood, Kristin L, | Development of a Functional Basis for Design

Class	Basic	Sub-basic	Complements
Material	Human		Hand, foot, head ,etc.
	Gas		
	Liquid		
	Solid		
Signal	Status	Auditory	Tone, Verbal
		Olfactory	
		Tactile	Temperature, Pressure, Roughness
		Taste	
		Visual	Position, Displacement
	Control		

Class	Basic	Sub-basic	Bond graph based complement	
			Effort analogy	Flow analogy
Energy	Human		Force	Motion
	Acoustic		Pressure	Particle velocity
	Biological		Pressure	Volumetric flow
	Chemical		Affinity	Reaction rate
	Electrical		Electromotive force	Current
	Electromagnetic	Optical	Intensity	Velocity
		Solar	Intensity	Velocity
	Hydraulic		Pressure	Volumetric flow
	Magnetic		Magnetomotive force	Magnetic flux rate
	Mechanical	Rotational	Torque	Angular velocity
		Translational	Force	Linear velocity
		Vibrational	Amplitude	Frequency
	Pneumatic		Pressure	Mass flow
	Radioactive		Intensity	Decay rate
	Thermal		Temperature	Heat flow

Usage & Degree of Specification	
Class only Least Specific▼	
Basic or *Sub-basic* + *Class* More Specific▼	
	Basic or *Sub-basic* + *Complement* Most Specific▼
Overall increasing degree of specification ➟	

Example Vocabulary of **Nouns**

Source: Stone, Robert B. Wood, Kristin L, | Development of a Functional Basis for Design

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Key FR Creation Principles

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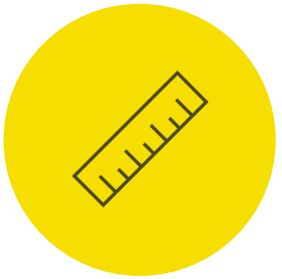
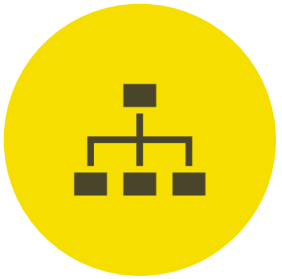
Key FR Creation Principles

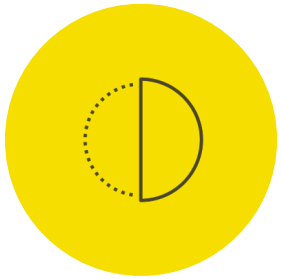
1. SOLUTION NEUTRAL



2. SPECIFY RANGE OF VALUES



3. DECOMPOSED FROM TOP TO BOTTOM



4. DIFFERENTIABLE FROM CUSTOMER NEEDS

Principle 1: Solution Neutral

- **2 min rapid activity:** In your teams, **write down 5 solutions** (more if you can think of them) you could **accomplish** the functional requirement of: **Transport a Child**.

Principle 1: Solution Neutral

- Even **within a product subsection**, there are **many methods to design the same product**.




- These devices all fit the FR of “Carry a Child”, but all approach it in a slightly different manner and facilitate very different additional functions.

Principle 2: Specify Range of Values

- **2 min rapid activity:** In your teams, provide **2 improved versions** of the following functional requirements, **following Principle 2**.

Support a person

Contain coffee

Principle 2: Specify Range of Values

Support a person

Support the weight of a person

Support the weight of between **50kg and 100kg**

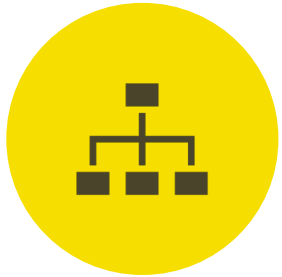
Contain coffee

Contain a certain amount of hot liquid

Contain **150ml of liquid** between the temperature of **40°C and 60°C**

Value range specification

Principle 3: Decompose FRs From Top to Bottom



- **Recall:** FRs can be decomposed using:

Verb Decomposition

Relocate Table
▪ Lift Table ▪ Move Table ▪ Drop Table

Noun Decomposition

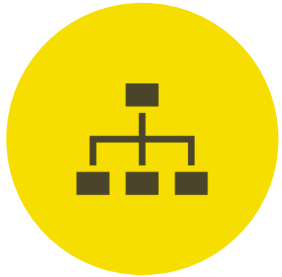
Relocate Office
▪ Relocate Computer ▪ Relocate Furniture ▪ Relocate Documents

Principle 3: Decompose FRs From Top to Bottom

- **Activity (5 mins):** In your teams, decompose the following FR using:
  - Verb Decomposition
  - Noun Decomposition

Input: Missile stored in weapons bay → **FR: Shoot Missile** → Output: Missile flying and rocket ignited

Principle 3: Decompose FRs From Top to Bottom



- An example of what you could write for each method could be:

Verb Decomposition

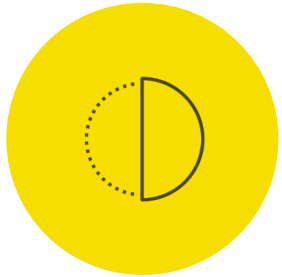
Shoot Missile
▪ Lock missile ▪ Expose missile to aircraft exterior ▪ Ignite missile ▪ Release missile

Noun Decomposition

Shoot Missile
▪ Lock target ▪ Remove safety lock ▪ Open weapons bay doors ▪ Send ignition signal ▪ Send release signal

- Note that these methods don't have to be used in isolation. You likely will find that, both methods will be needed to thoroughly decompose your project's functional requirements.

Principle 4: Differentiable from Customer Needs



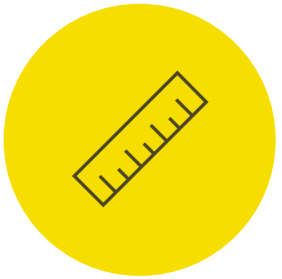
- **Recall: Customer needs fulfil the desires** that customers demand, **functional requirements describe actions** which are needed to achieve that customer need.

- CN: car-related safety
  - CN_1: passenger safety
    - CN_{11}: driver safety
    - CN_{12}: children safety

- FR: protect passenger
  - FR_1: constrain DOF
    - FR_{11}: provide a soft cushioning
    - FR_{12}: constrain degree of freedom

Summary: Key FR Creation Principles

1. SOLUTION NEUTRAL



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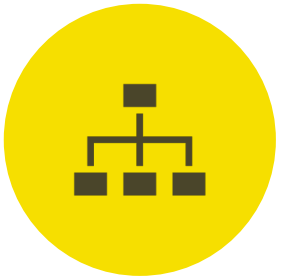

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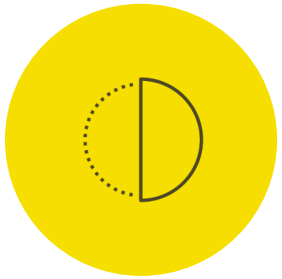

4. DIFFERENTIABLE FROM CUSTOMER NEEDS

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Advanced FR Method: EMS Model

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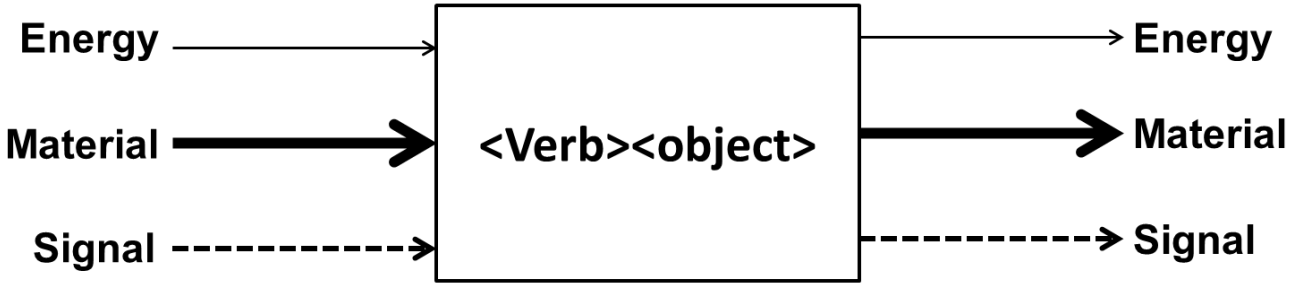
Advanced FR Method: EMS Model

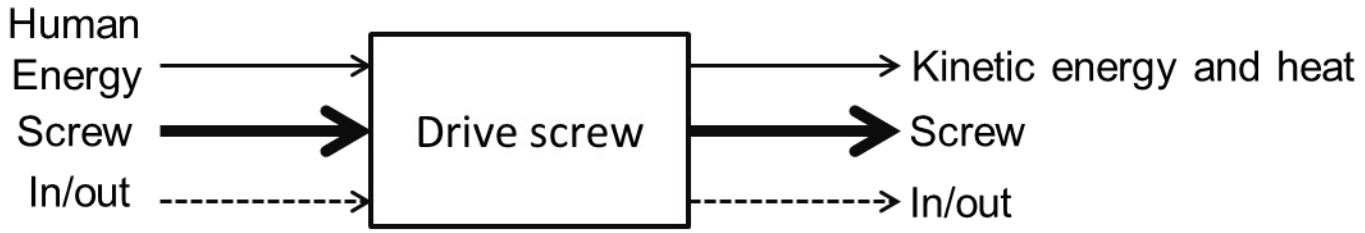
- Defines the input and output parameters in the form of **Energy**, **Material** and **Signal.**

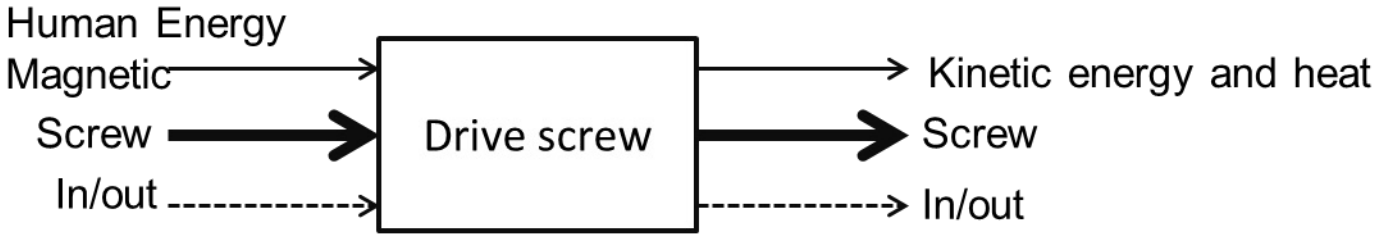


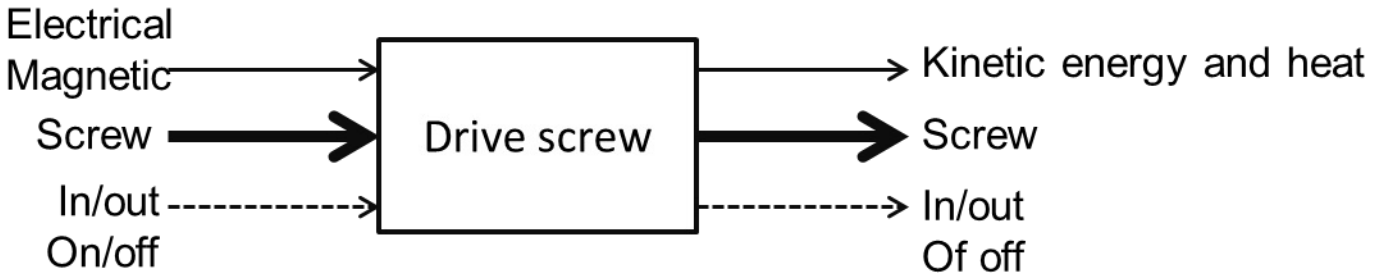
- Enables designers/engineers to **track the types of inputs and output** each FR (which eventually is materialised as a physical component) will need to receive and produce, which **guides design choices** such as material selection etc.
- Also enables **visualisation of how energy, material and signals** are transformed/converted as the **move from one part of the engineering system to the other**.

Advanced FR Method: EMS Model

- Note the minor variations in input and output in each form of screwdriver







Project Time!

- ❑ Finalise your **CNs** if you haven't yet
- ❑ Write your team's **problem statement**
  - ❑ Reminder that problem statement is solution-independent
- ❑ **Map**/derive your FRs from your CNs
- ❑ Decompose your FRs to be more and more **specific**
- ❑ If your team is way ahead of schedule, **start concept generating solutions**!

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Summary

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Evaluation Tools

- Decision matrix
  - Come up with criteria
  - Rank your criteria in terms of importance (scaling factor e.g. 5 most important)
  - Team gives score to each problem
  - Score * scaling factor = scaled score
  - Sum scores for each criteria for final score. Go for problem with highest final score

Decision Matrix: Long Wait Time

Criteria → / Problems ↓	Customer pain 5	Ease to solve 2	Effect on other systems 1	Speed to solve 2	
Customers wait for host	High—Nothing else for customer to do 3 × 5 = 15	Medium—Involves host and bussers 2 × 2 = 4	High—Gets customer off to bad start 3 × 1 = 3	High—Observations show adequate empty tables 3 × 2 = 6	28
Customers wait for waiter	Medium—Customers can eat breadsticks 2 × 5 = 10	Medium—Involves host and waiters 2 × 2 = 4	Medium—Customer still feels unattended 2 × 1 = 2	Low— Waiters involved in many activities 1 × 2 = 2	18
Customers wait for food	Medium—Ambiance is nice 2 × 5 = 10	Low—Involves waiters and kitchen 1 × 2 = 2	Medium—Might result in extra trips to kitchen for waiter 2 × 1 = 2	Low—Kitchen is design/space limited 1 × 2 = 2	16
Customers wait for check	Low—Customers can relax over coffee, mints 1 × 5 = 5	Medium—Involves waiters and host 2 × 2 = 4	Medium—Customers waiting for tables might notice 2 × 1 = 2	Low—Computerized ticket system is needed 1 × 2 = 2	13

Ranking Tool

- This can help rank what user needs or criteria is important to you
- Optional tool to use – can do it qualitatively instead

Step 3: Compare the objectives

	Ease of use	Maintains temperature	Durable	Cost	Aesthetics	Total
Ease of use	———	1	1	1	1	
Maintains temperature	0	———	0	0	0	
Durable	0	1	———	1	1	
Cost	0	1	0	———		
Aesthetics	0	1	0		———	

1 Row of the more important objective

0 Row of the less important objective

Summary

Today we covered:

- ❑ How to create Functional Requirements
- ❑ Key principles to help create good Functional Requirements
- ❑ Examples of advanced FR creation methods for industry
- ❑ Assignment reminders
  - Presentation slides due date: **Sunday Week 3**
  - Presentation day: **during Wednesday Week 4**

Next week:

- ❑ UVP & concept gen on Tues
- ❑ Axiomatic design methods & fasteners on Wed
- ❑ I will be gone next week

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