DESN2000 – Engineering Design 2

Workshop Material

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

Never Stand Still | Faculty of Engineering

Week 2:

Functional Representation

Design Journals

- Due **8PM Friday 14th October**
- All entries need to be on OneNote by then
- Any other entry made past this will be ignored

Interim Presentation

- Soft copy slides need to be submitted by **9pm on Sunday 2nd October (end of WEEK 3)**
- Presentations will take place during Week 4 workshops (or Week 5 if need be)

Presentation Content

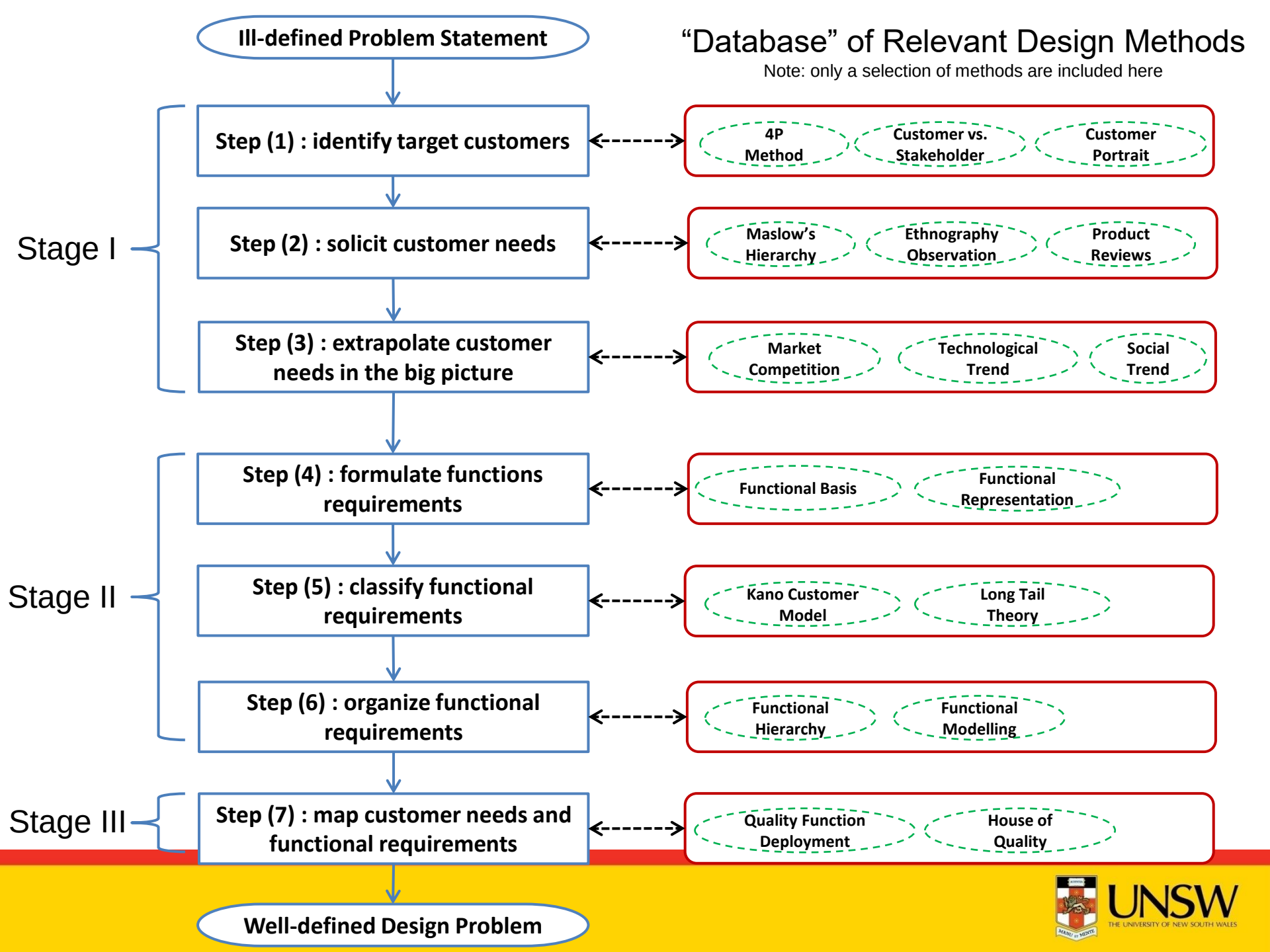
- Interpretation of project brief → Week 1 brainstorm
- Formulation of design problem → Today's workshop
- Investigation of preliminary design concepts → market research
- Work responsibilities and schedule for the rest of term → project management schedule

Process of functional design

- **Stage (I): Explore customer domain**
  1. **Understanding your customer needs (CNs) with tools from the DESN workshops.**
     - Week 1: understanding the project brief, problem, and empathizing with user(s).
     - Week 2: understanding user personas and the user research plan.
     - Week 3 onwards: executing your user research plan + extracting insights on customer needs.
- **Stage (II): Explore functional Domain**
  1. **Assign** functional requirements (FR) to seize the opportunity
     - Propose and represent FRs based on the solicited CNs
  2. **Classify** the assigned FRs to determine the innovation priority
     - The Kano Customer Satisfaction Model
  3. **Organize** the assigned FRs to frame a unique design problem
     - Complete, minimal, and independence principles
- **Stage (III): Map between customer and functional domains**
  1. **Map** CNs in the customer domain to FRs in the functional domain
     - Use Quality Function Deployment to build a House of Quality

A metaphor of functional design

- How to host a VIP guest a home-made dinner?
  1. Know who are your guests
  2. Solicit the guest's preferences
  3. Understand popularity of seasonal food
  4. **Assign the requirements of cooking**
  5. Determine which food might excite your guests
  6. Organize the food into appetizer, first course, entrée, main course, and desert, etc.
  7. Check if the guest is satisfied with the experience


Ill-defined Problem Statement
"Database" of Relevant Design Methods
Note: only a selection of methods are included here
Stage I
Step (1) : identify target customers
4P Method
Customer vs. Stakeholder
Customer Portrait
Step (2) : solicit customer needs
Maslow's Hierarchy
Ethnography Observation
Product Reviews
Step (3) : extrapolate customer needs in the big picture
Market Competition
Technological Trend
Social Trend
Stage II
Step (4) : formulate functions requirements
Functional Basis
Functional Representation
Step (5) : classify functional requirements
Kano Customer Model
Long Tail Theory
Step (6) : organize functional requirements
Functional Hierarchy
Functional Modelling
Stage III
Step (7) : map customer needs and functional requirements
Quality Function Deployment
House of Quality
Well-defined Design Problem
UNSW
THE UNIVERSITY OF NEW SOUTH WALES

Things to do for the step (1) of functional design

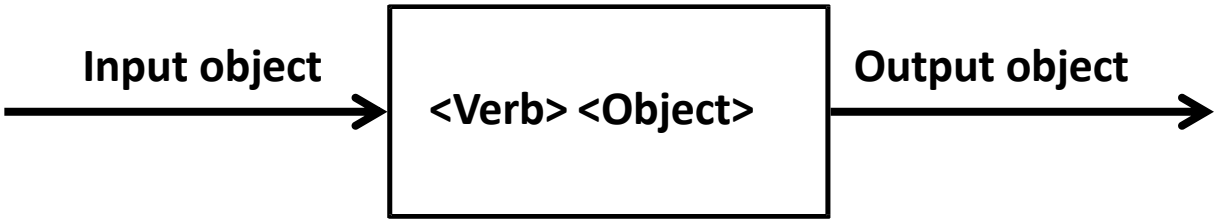
- Determine who are the target customer(s)
- Determine who are the relevant stakeholder(s)
- Describe the target customer(s)

This is done in the DESN workshops

How to represent a FR?

- General representation of function
  - Function = <Verb+Object>
  - Function = <Verb+Object1>to/from/with/through<Object2>
  - Function = <Verb+Object> in the <context>
- Functional Basis is a “vocabulary” of verb and object

- Graphical representation of function



Basic Principles of function formulation

a) Function should be described in a solution-neutral fashion
b) Function should be specified with a range of values
c) Function should be decomposed to the bottom
d) Function should be differentiated from customer need

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

Vocabulary of **Verbs**

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 ➡	

Vocabulary of **nouns** in terms of material, signal, and energy

Principle (a): describe FRs in solution-neutral way

Transport a child?

Principle (b): specify a range of values for the FRs

Support a person

Support the weight of a person

Support the weight of between 50kg and 100kg

Range of Values

Contain coffee

Contain a certain amount of hot liquid

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

Range of Values

FRs of a power screw driver (1)

- FR_1: process electricity
  - FR_{11}: Store electricity
  - FR_{12}: Supply electricity
  - FR_{13}: Transmit electricity
  - FR_{14}: Actuate electricity
  - FR_{15}: Regulate electricity

Do your research and specify a range of values!

FRs of a power screw driver (2)

- FR_2: process electricity
  - FR_{21}: convert electricity to torque
  - FR_{22}: change torque
  - FR_{23}: transmit torque
  - FR_{24}: rotate solid
  - FR_{25}: dissipate torque

Do your research and specify a range of values!

Principle (c):FR can be decomposed

- You can follow two directions to decompose a FR
- Decompose <Verb>
  - E.g.,<relocate><table> = (<lift>, <move>, and <drop>)<table>
  - E.g., <document><information> = (<collect>, <store>, <organize> and <retrieve>) <information>
- Decompose <Object>
  - E.g., <relocate><office> = <relocate> (<computer>, <furniture>, and <documents>)
  - E.g., <document><information> = <document> (<text>, <photo>, <audio>, and <video>)

Principle (d): differentiate FR from CN

CN: care of premature new born babies

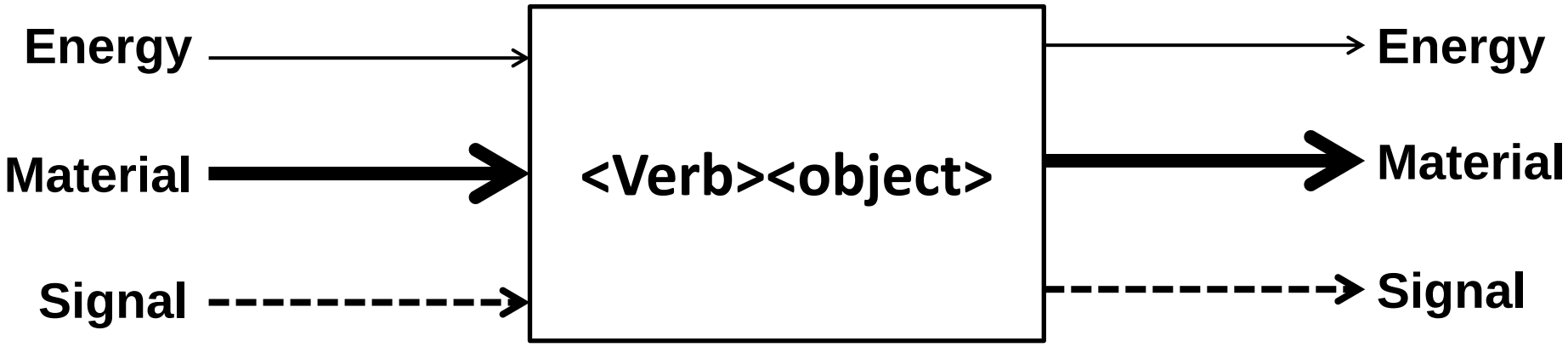
What does it mean to an engineered system?

- FR_1: provide extra oxygen
- FR_2: keep a high air humidity
- FR_3: maintain a certain temperature
- FR_4: monitor bio signal
- FR_5: communicate to doctor and nurser
- FR_6: transport the baby
- FR_7: observe without touch
- FR_8: support the baby

So, what is a good FR?

- Verb + Object Format
- Specified with a range of values
- Described in a solution-neutral manner
- Cannot be further decomposed
- Can be clearly differentiated from CNs
- Follow the functional basis

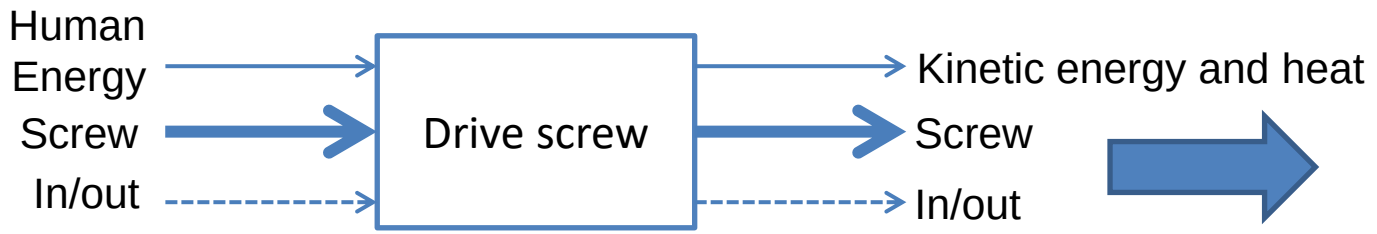
E-M-S Model to represent a function

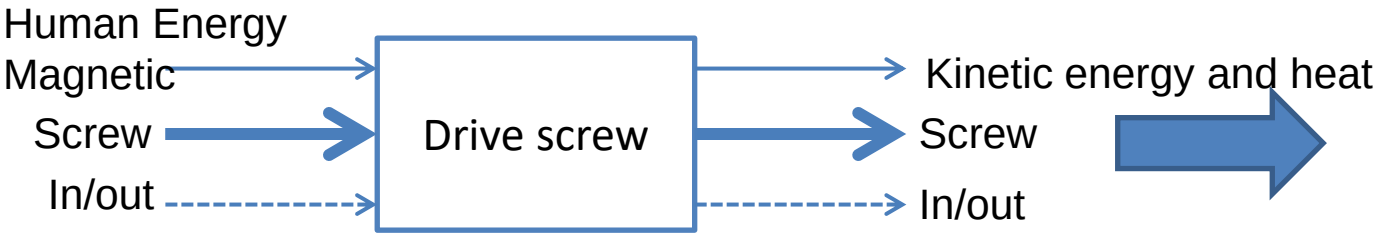


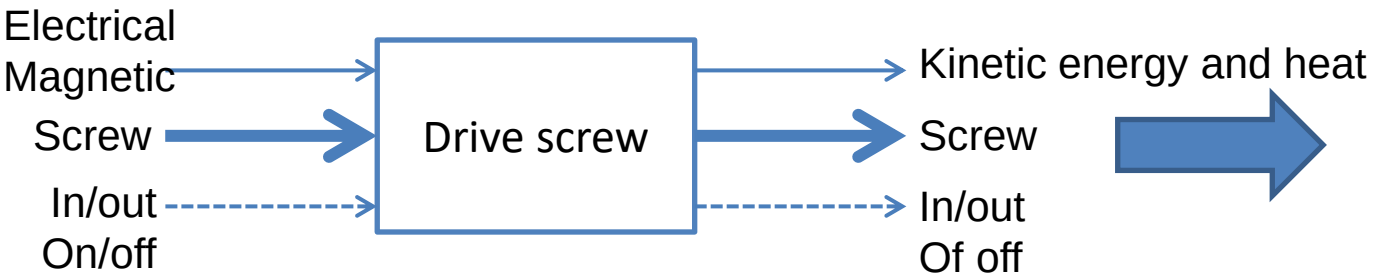
Design Practice (1)

- The above three kinds of screwdrivers are all designed to satisfy the same FR (<install><screw>)
- Please follow the E-M-S functional modelling to describe each screw driver, with respect to, their inputs (energy, material and signal) and outputs (energy, material, and signal)

Answer to the design practice





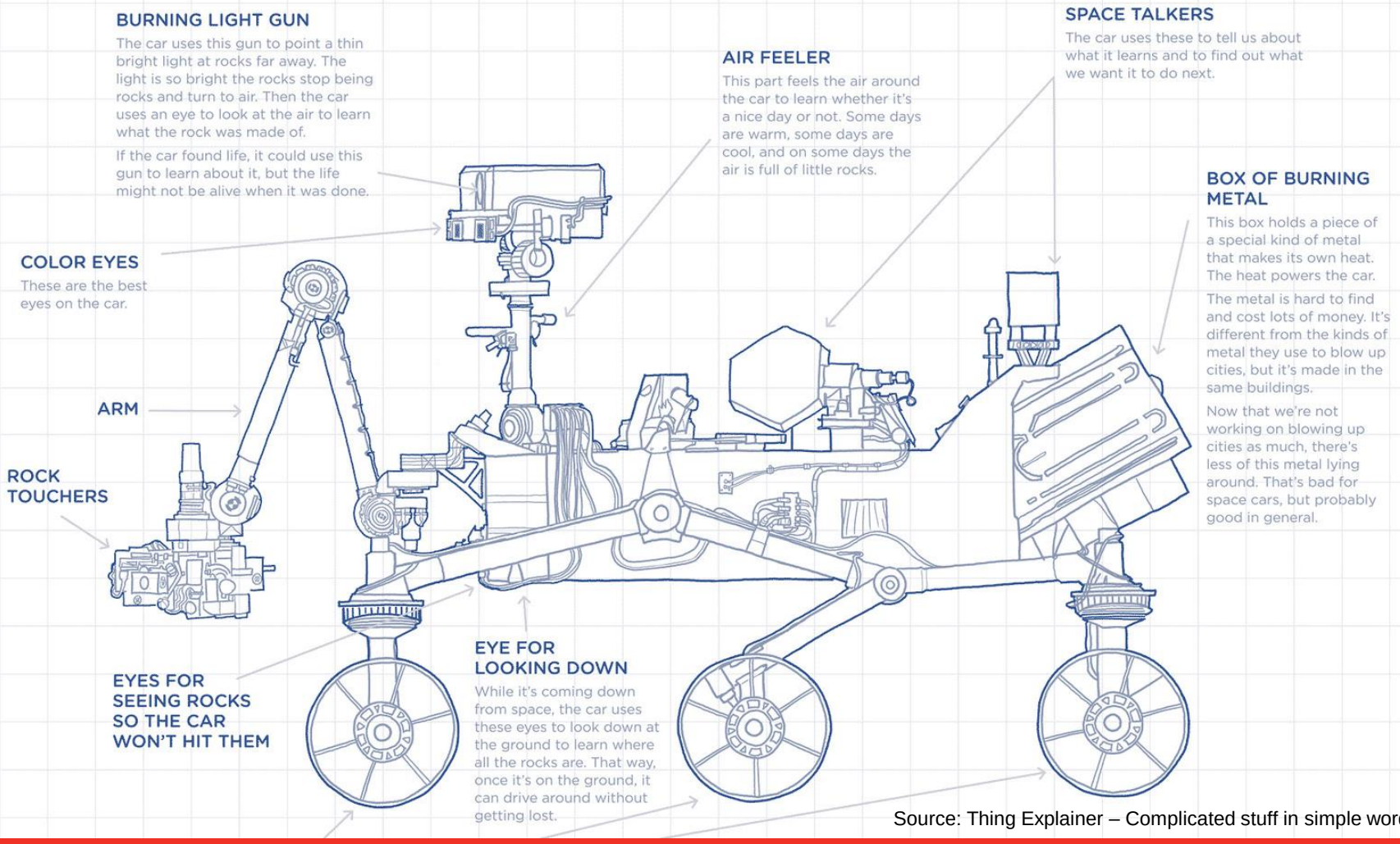


Design Practice (2)

- Abstract 10 functions from the Mars Exploration Rover

SPACE CAR FOR THE RED WORLD

We sent this car to the red world near Earth so it could drive around and look at stuff for us. It's helping us figure out whether that world ever had seas, and whether those seas could have had life in them.



Source: Thing Explainer – Complicated stuff in simple words