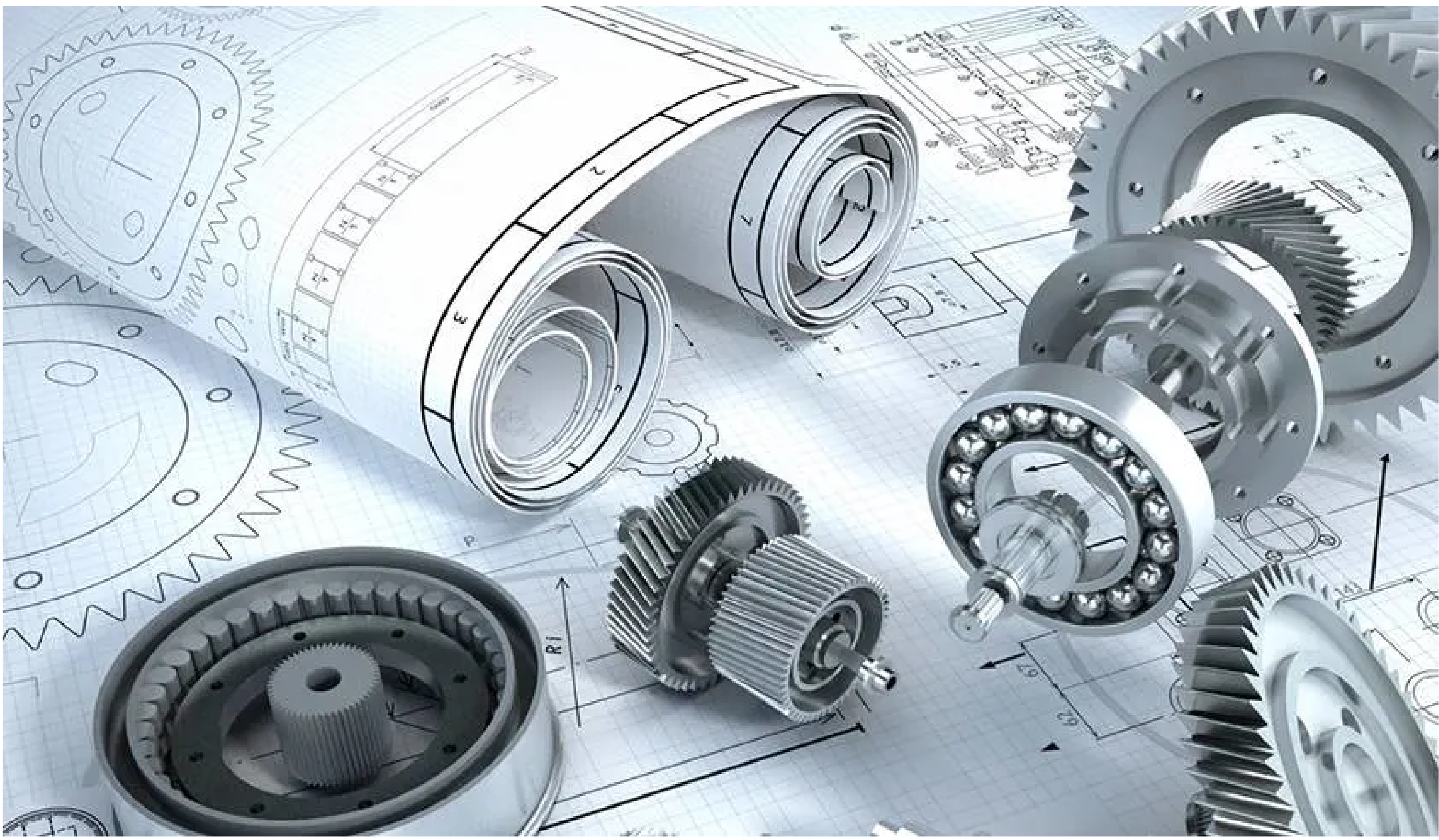
# Student Engineer Handbook

ESC102-PRAXIS II

ENGINEERING SCIENCE

UNIVERSITY OF TORONTO




Cathy (Yuchun) Feng


APR 2021

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# 1. Introduction

## 1.1. How to Use This Handbook

This handbook is intended to be used as a review and collection of the learning outcome of Praxis I and Praxis II for myself in future engineering practice.

# 2. Positionality

## 2.1. Design Values

### 2.1.1. Ethics

In general, My design value highly aligns with the United Nations sustainable development goals including quality education, health and well-being, as well as sustainable cities and communities.

### 2.1.2. Learning and Opportunity-Seeking Mindset

At this point, I see myself as a humble student pursuing engineering and science at the University of Toronto. However, as a student, I remind myself to keep an “engineering mindset”, learning while thinking about how the knowledge could be applied to practical circumstances in real-life scenarios, which, I believe, can not only give me a better understanding of the theoretical knowledge but also prepare me well when I enter the industry. With a value for learning and practising, I train myself to have an opportunity-seeking mindset, in which I enjoy the process of exploring new ideas and not discarding any idea without sufficient development and rigorous decision-making.

## 2.2. Skills and Interests

With the aforementioned mindset, I am dedicated to participating in various opportunities. My research interests focus on physics, biomedical engineering, aerospace engineering, and computer science. I like my courses to have a mix of discovering how things function and applying skills into practice, which is precisely why I chose to pursue my current program of studies in the Division of Engineering Science. These research interests have driven me to seek out opportunities in relevant fields.

As a summer student at the University of California, Los Angeles, I worked on the innovation of medical devices and built an electrocardiogram in a team of two using Arduino microcontrollers, Computer-Aided Design, and 3D printers, which involved concepts in electrical circuit design, cardiac electrophysiology, and biophysics. Through this project, I was able to enhance my creative thinking ability, practical thinking ability, as well as teamwork and communication skills.

I have also taken two computer science courses that focus on data structure and algorithms and developed software in two hackathons and one Google Solution Project, where I was able to design innovative ideas with tools including JavaScript, HTML, python, and C.

I am also an active member of the University of Toronto Aerospace Team for avionics and recovery subsystems, where I learned a lot about the practical application of the engineering design process. In the recovery subsystem, I modelled a wind profile integrated with a standard atmospheric model on MATLAB to estimate drifting in order to be able to find the rocket remains after falling back to the ground. In the avionics subsystem, I participated in designing for the circuit in the launch control system in the Ground Station and presented in a design review to the audiences from Launch Canada.

Last but not least, I have relatively decent drawing skills which I do not usually mention but are unexpectedly helpful during the engineering design process. I started learning watercolour painting at 5 and Chinese Painting at 7. I also self-learned oil painting and am able to complete artworks independently starting from scratch. This skill enables me to quickly convey my ideas to the team and allows me to produce graphical representations for deliverables such as reports and presentations.

One oil painting that I enjoyed with

With a broad interest in several fields of science and a value in multi-talented development, my goal in the future is to be more involved in the fields that I am interested in. Potentially, my value for expertise will also encourage me to pursue education in a graduate school. As a result, I seek any opportunity to participate in interesting projects and learn from people who are experienced in leading-edge technology.

## 2.3. Strength

In addition to my values and interests that I mentioned in previous sections, I identified some of my strengths when working in a team.

Based on the peer feedback from TELS, in terms of engineering design, I did very good in terms of secondary research, which ensured that the team has considered all uncertainties. I was also "a huge help in developing objectives, thinking through things methodically and breaking things up into small parts" that the team could develop further.

In terms of teamwork, based on the participation feedback from Praxis II, I am a "very bright individual and was always ready to participate both in the breakout rooms and in the class-wide discussion". According to TELS II, I was "extremely engaged and dedicated to the tasks" that we did, and I made "bouncing ideas around the group much easier" with my "creative mind". Last but not least, my teammates highly appreciated my "positive and motivational attitude" towards all of the activities and how I tried my best to stimulate conversations and keep everyone on the same page.

## 2.4. Weakness and Biases

In order for this handbook to serve as a reference for the future me, it is also important to address some aspects that need some improvement.

### 2.4.1. Get Anchored to My Own Ideas

A piece of feedback I got from TELS was that I tended to get really anchored by my favourite ideas and opinions. When I was anchored, I participated less in conversations that I was not interested in and instead explored the specific idea I found inspiring. However, since my judgement could go wrong, I sometimes got too involved in certain aspects that were “irrelevant or unproductive”, making it hard for the team “to move onto more important issues”. This discouraged me from promoting productive discussion and made it difficult for the team to build or bounce around new ideas.

### 2.4.2. Seldom Seek Input from Team Members

The weakness in the subsection above might discourage my teammates from openly bringing up their own thoughts since there is already a really strong voice in the team. I also put a relatively little amount of effort into seeking input from my teammates once I have an opinion in mind. As well, completing a task by myself without communicating with other teammates, which I sometimes tend to do, might lead to some discontinuities from my teammates’ parts especially when the tasks we work on are for a deliverable such as the Request for Proposal (RFP).

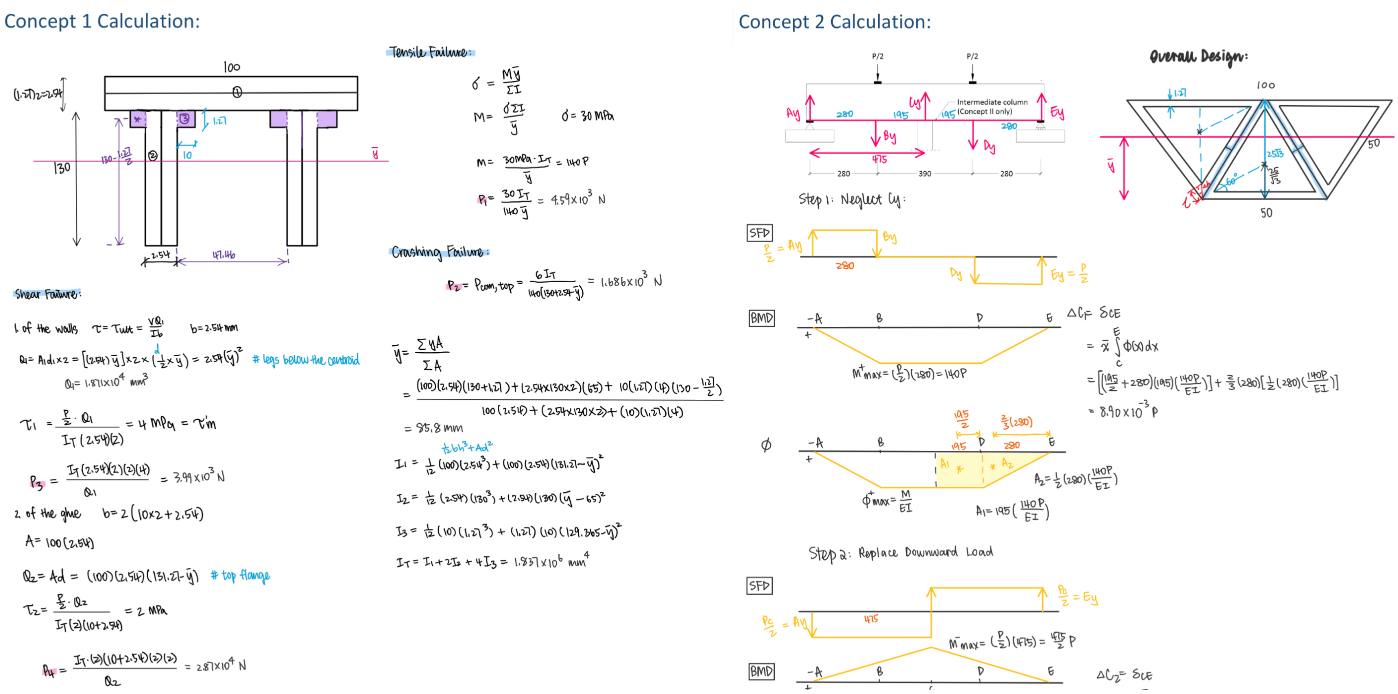
# 3. Personal Engineering Design Products

This section summarizes a few outcomes and representations of some of my previous engineering design practice, which allows the following sections to refer back to. I will, in fact, also assess the effectiveness of different types of representations that played corresponding important roles in each design. The assessment of types of representations could also be put in the TMF section, but my belief in “forms follow functions” taught by Professor Irish encourages me to create a form that evenly spreads out pictures and words and avoids readers from flipping back and forth between two sections.

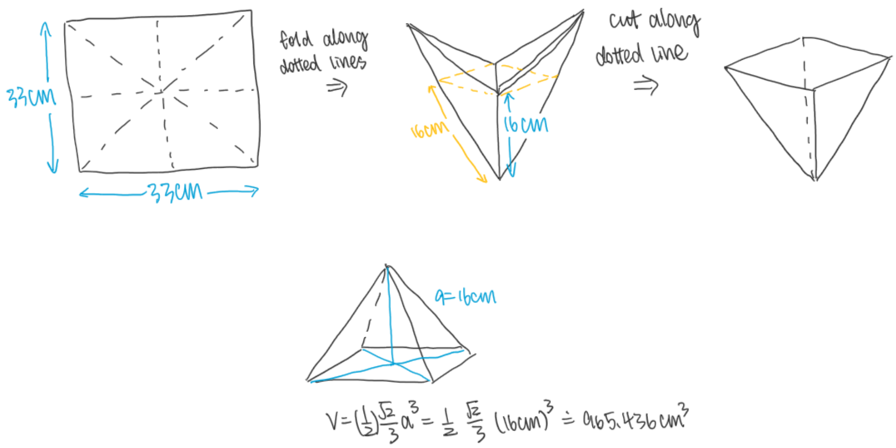
## 3.1. Matboard Bridge [CIV102]

### 3.1.1. Calculations

One of the valuable outcomes from the engineering design process for the matboard bridge in CIV102 was in the form of calculations. We were required to design two completely concepts that met different sets of requirements. In order to verify the concepts against specific requirements, calculations were needed to produce evidence that allowed the team to proceed to the next step. This type of representation is vital for designs related to material science and structural physics and will be seen again in some of the outcomes introduced later.




Calculations from Matboard Bridge, CIV102

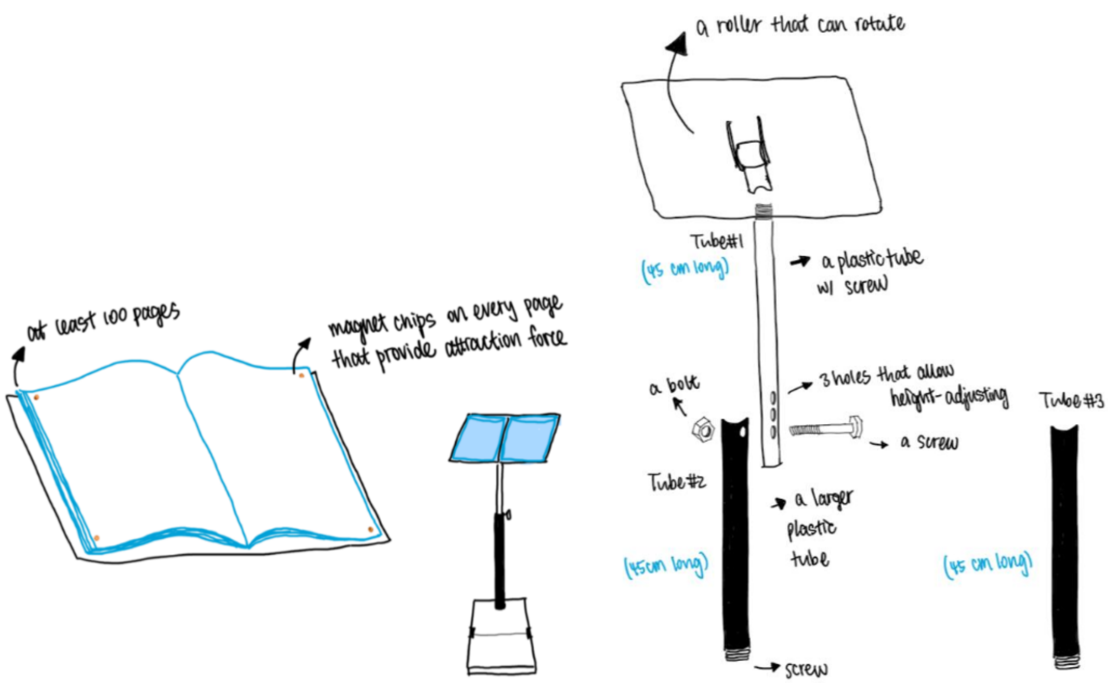



Calculations from Showcase, Praxis II

## 3.2. Music Stand [Praxis I]

### 3.2.1. Drawings

As mentioned above, I sometimes use drawings to convey ideas for the structural aspects of designs. Not surprisingly they were used for the divergence process for the music stand in Praxis I.



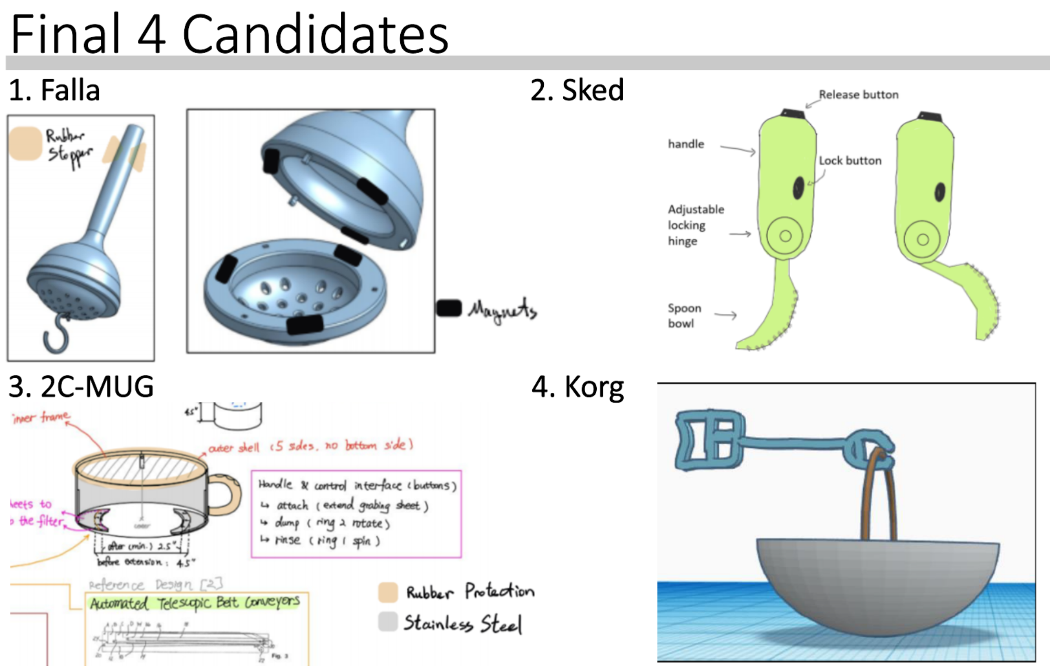

Drawings from Candidates and Tools Critique, Praxis II

## 3.3. Recommendation for Kitchen Sink Cleaner [Praxis I]

For the Design Critique at the end of Praxis I, my team recommended a design product that facilitates and improves the cleaning process of kitchen sink filters.

### 3.3.1. Computer-Aided Design

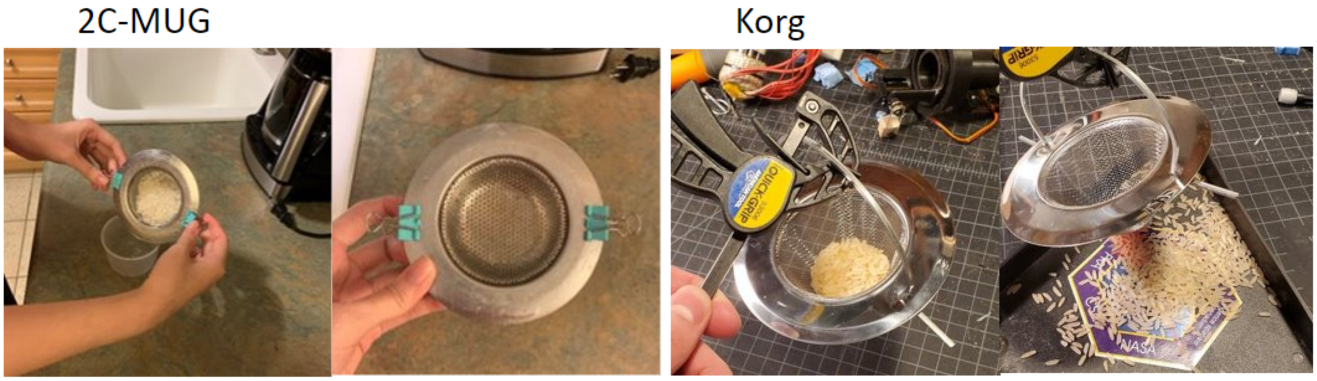
Computer-Aided Design was also utilized during some engineering design practice. Even though I never actually made any 3D representations myself, I was able to benefit from those created by my teammates or the design team. It gives a better visual representation since some designs require presentation that is not limited to a 2D plane.




3D representations (top left and bottom right corners) from the Candidate Critique that my team was given in Praxis I

### 3.3.2. Physical Prototype

Physical prototypes were also used to simulate certain features of a design and enabled the team to perform some proxy testings that verify the effectiveness of the design against certain requirements.

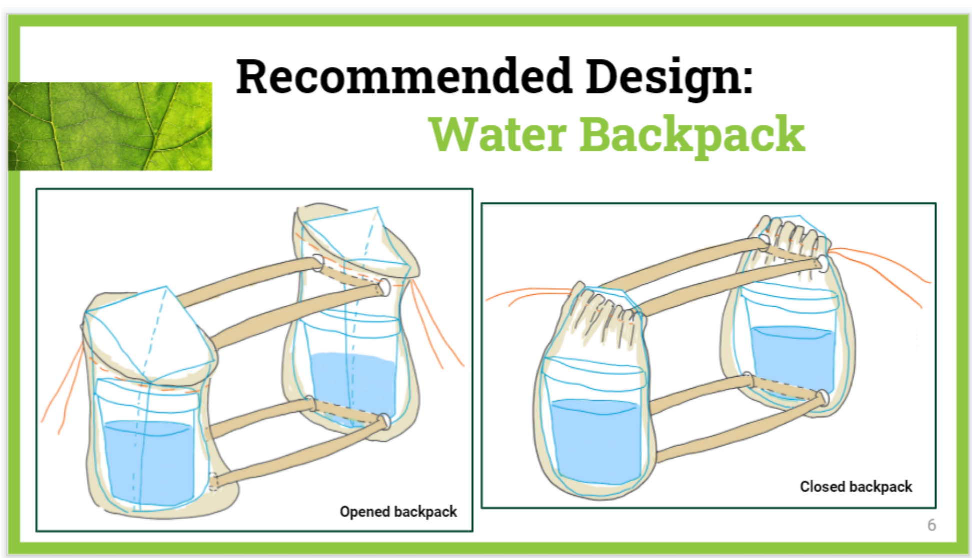



## 3.4. Ergonomic Backpack [Praxis II]

In Praxis II, my team addressed the opportunity of improving water transportation and collection for small-scale gardens in Liberia by designing an ergonomic backpack.

### 3.4.1. Drawings

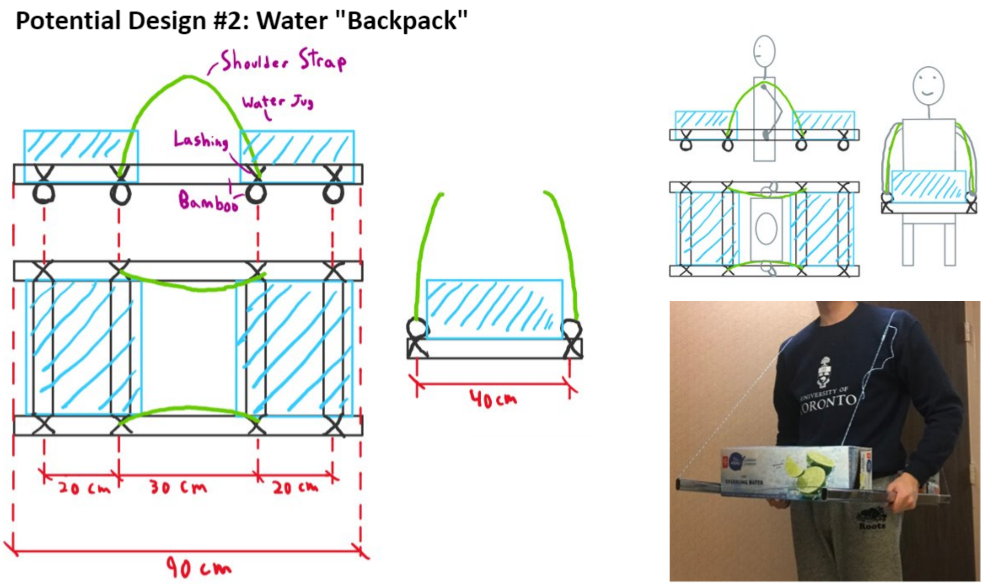
Our design was mainly represented by drawings.




Slides from the showcase

### 3.4.2. Physical Prototype

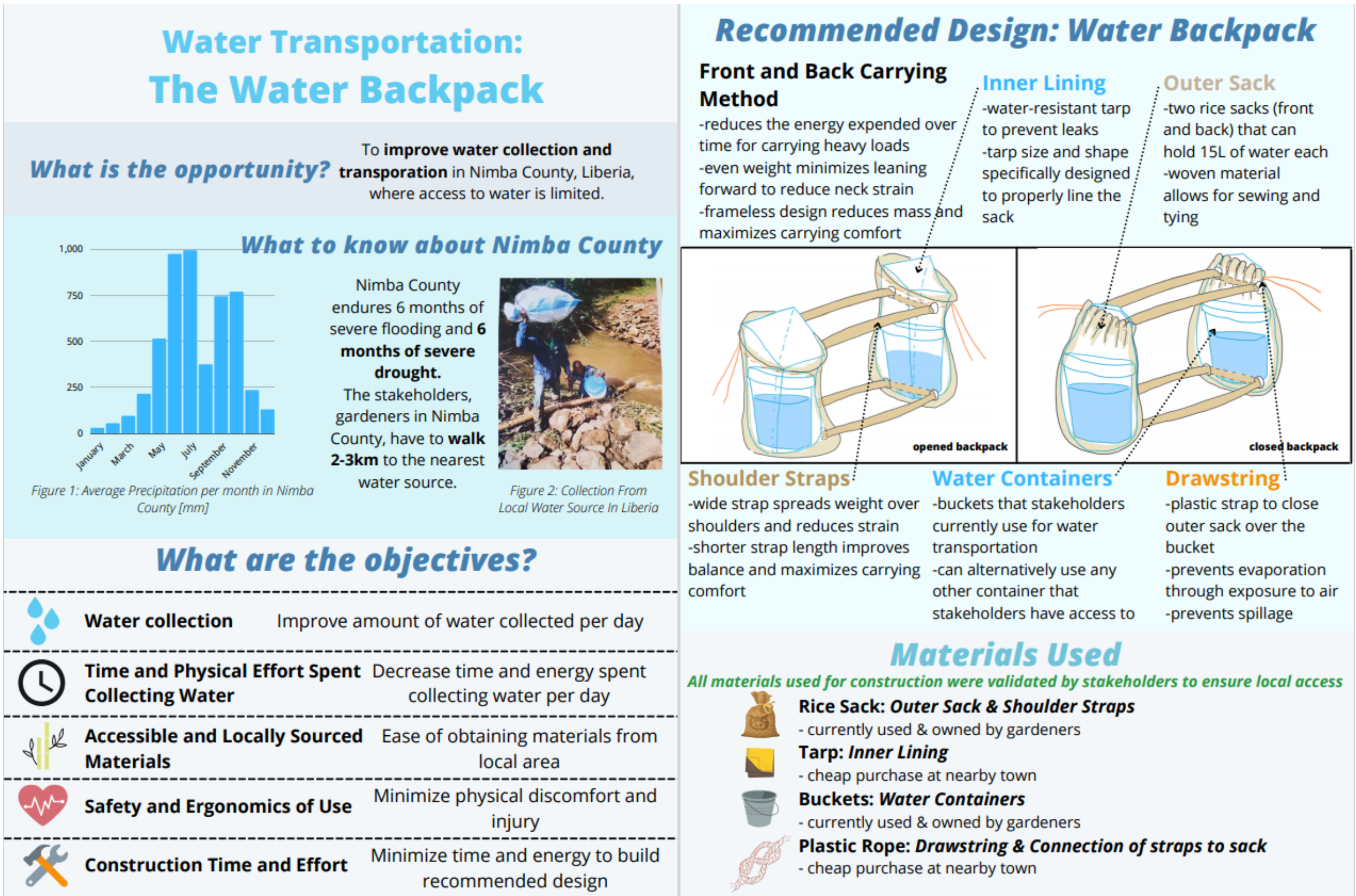
Physical prototypes are made to simulate specific characteristics of the candidate designs in order to conduct proxy tests.




Slide from Beta Release, Praxis II

### 3.4.3. One-Pager

One-pager is an effective representation to quickly introduce the opportunity and design features to a deliverable with many audiences who are potentially not familiar with engineering design, such as the showcase.




One-pager for Showcase, Praxis II

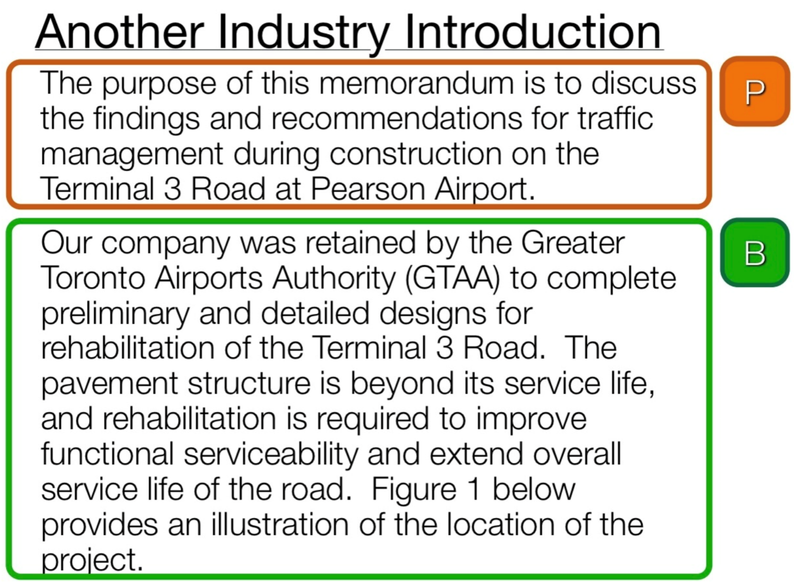
# 4. Tools, Methods, and Frameworks (TMFs)

## 4.1. Models

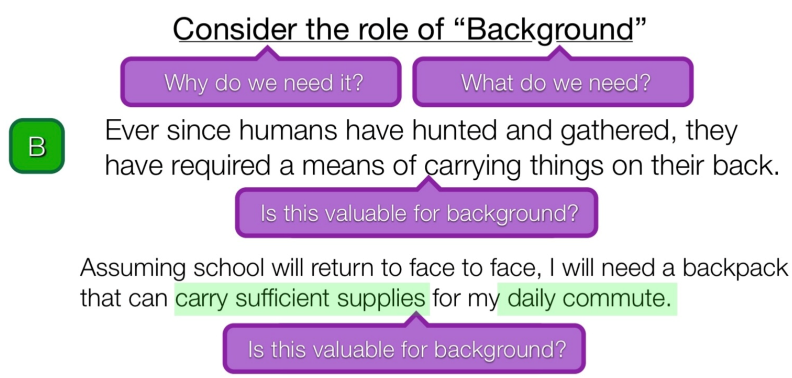
### 4.1.1. PUBS

PUBS stands for purpose, unknowns, background, and set-up. It is a useful tool when writing an informative introduction.

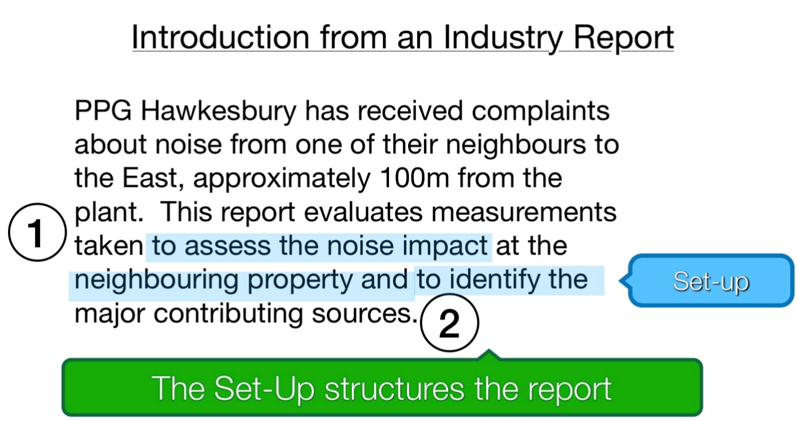
- Purpose: establish the goal that the report is trying to achieve
  - Example (all screenshots come from P1-03 Writing Introduction [Slides]):



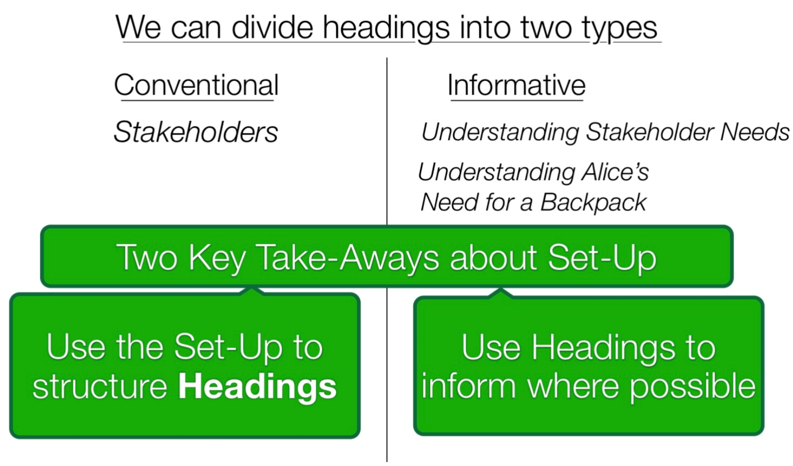

- Unknown: introduce something that is waiting to be found out by the report
- Background: inform the readers with relevant information that can lead to the theme of the report
    - A good example of background (2nd one):



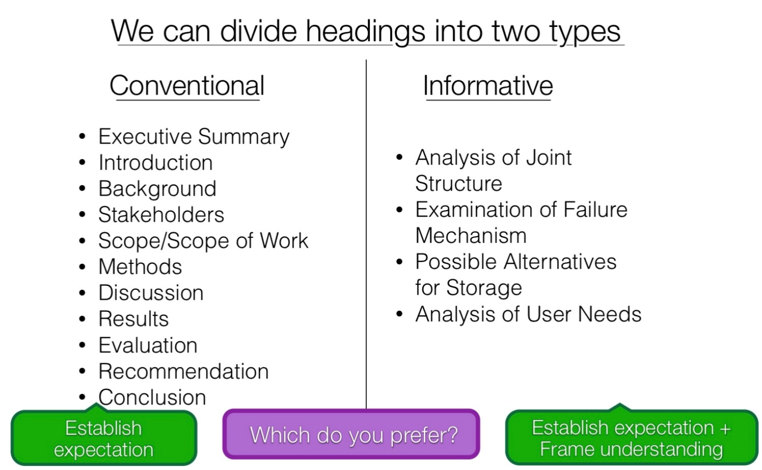

- Set-up: set up the headings and sections in the report
    - An example of set-up:




    - Two key take-aways about set-up:




- Speaking of headings, here is a bunch of headings suggested by conventional and informative types:




An example of an introduction using PUBS is my first report of Praxis I: the Personal Engineering Recommendation (coherency is not the best but you can see I was trying my best using this model):

A. PURPOSE, BACKGROUND, AND OBJECTIVE

purpose

The purpose of this report is to find the place that is the most suitable for me to live for the rest of my first year in university. With a shift from high school to university that marks a modern rite of passage for incoming first-year students[1], this period of young adulthood usually involves moving out of home for the first time or cooking for one's own meals. During the pandemic when classes are moving online, as an international student who lives alone in Toronto with limited budgets, I need to rigorously and carefully select a new accommodation that meets my requirement for happiness and security. Because of this objective, I have an opportunity to evaluate the characteristics of the place that I am looking for and to eventually converge upon a recommended place with engineering-style decision making.

background

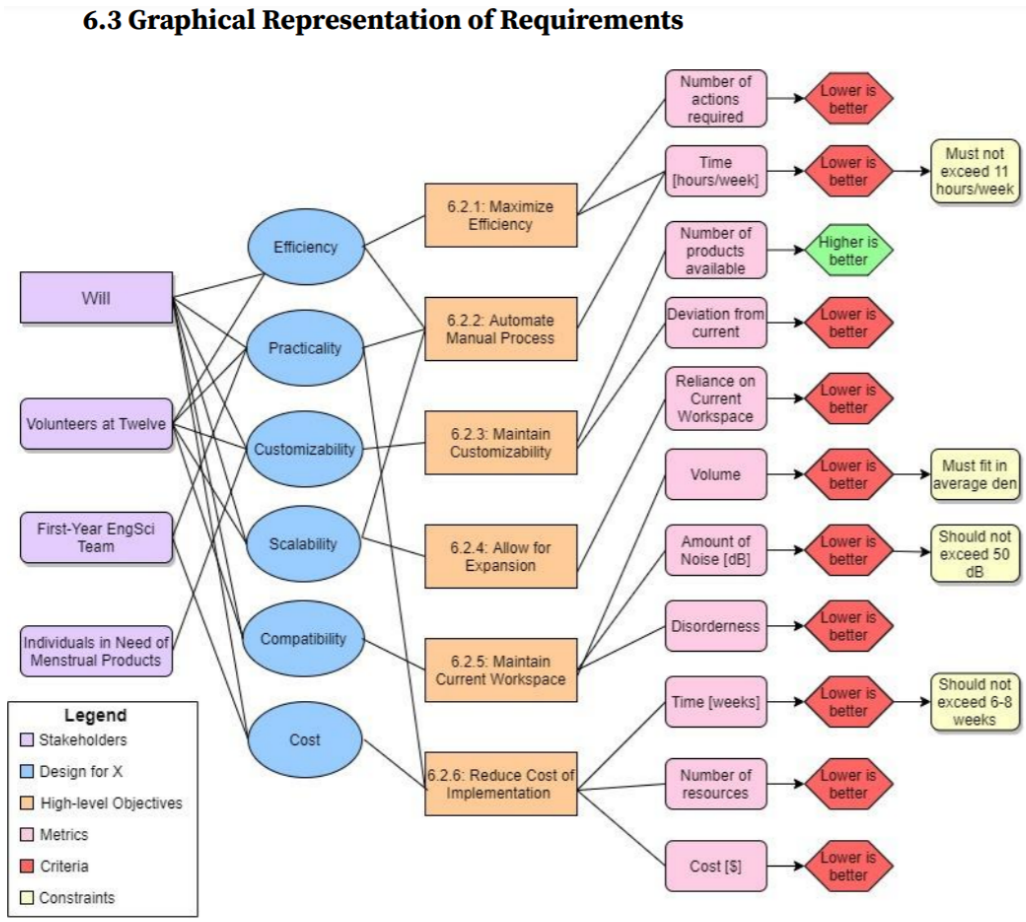
unknowns

set-up

#### 4.1.2. Requirement Model

- Objective: what a candidate design should do or be;
- Metrics: a measurable quantity that allows comparing candidate designs;
- Constraints: a cut-off quantity that could cause a sudden loss in the utility (the utility-characteristic graph has a vertical segment indicating a sudden decrease);
- Criteria: a descriptive rubric that measures the degree of utility when comparing candidate designs regarding one characteristic (the utility-characteristic graph should be a continuous line or curve);
    - Example: the lighter the structure the better;

It is sometimes good to create a graphical representation of the Requirement Model. I recommend inserting the graph between the "Stakeholder Analysis" section and "Requirements/Objectives" section in order to give readers an idea of what to expect from the detailed objectives. Sometimes, in fact, it could be confusing for readers to see 7 pages of requirement tables without a concise summary to refer to. Thus, this structure can quickly show the relationships between the stakeholders and your requirements which makes the report more cohesive and comprehensible.




Graphical representation of requirements of Request for Proposal in Praxis II

### 4.1.3. PIAA

PIAA is one of the tools that my teams found helpful when framing an opportunity. It becomes self-explanatory when I tell you it stands for "perceive, interpret, assess, and act" (P1--01-04--Perceive-Interpret-Assess-Act). Instead of going from "perceive" directly to "act", using PIAA can give the team a more profound understanding of the stakeholders' needs. One example that helped me understand PIAA is one of the sample Framing Sprint Analysis by an anonymous team shared by the Praxis I teaching team in the writing workshop:

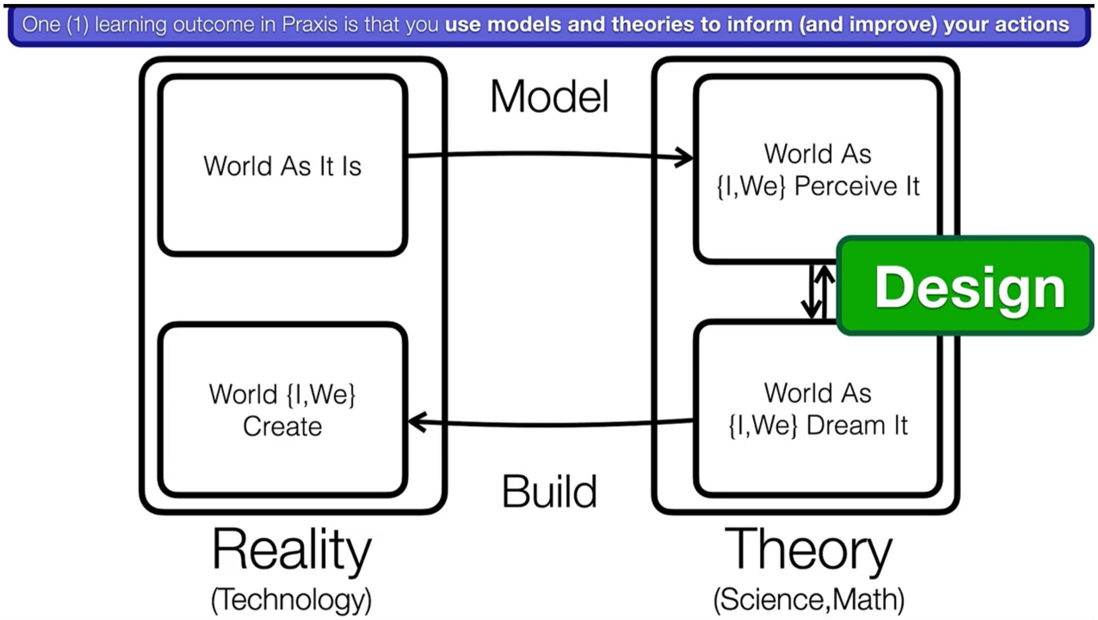
> In our Design Brief, the U of T students along with the U of T Governing Council and the U of T faculty were considered as the stakeholders. Initially, there was no model in place to guide our process of determining the needs of the stakeholders. For the first few meetings as a team, verbal brainstorming discussions occurred. Although the brainstorming process was useful in helping us articulate our ideas, we required more structure to move forward. Eventually the Perceive, Interpret, Assess, Act (PIAA) model was employed in order to determine the needs of the stakeholder in a more efficient way. Initially, our group began our process by listing various perceptions about the needs of each group. Based on these perceptions, we interpreted why each stakeholder would want a particular aspect to be considered in a potential solution. For example, in the perception stage, we stated that we believed that U of T students would desire a low - cost solution [1]. As we moved to the interpretation stage, we justified this perception by interpreting why a low- cost solution may be desired [2]. In the example of the U of T students, we believed a low - cost solution would be desired as students already pay a significant amount for tuition. In the assessment stage, a survey was sent to a group of U of T students belonging to various faculties and years of study to assess if our interpretations were correct [3]. The information gathered from the survey assessment was then used in the act stage of the PIAA model to finalize the determined needs of the stakeholders. For instances where the stakeholders could not be surveyed directly (i.e. in the case of the U of T Governing Council and U of T staff), our assessment stage consisted of research that confirmed the needs of these stakeholders[3].

Sample 2_Redacted-1.pdf shared by Praxis I teaching team

There is a connection to the team's position when using PIAA. Specifically, how you perceive yourself affects how you perceive the world, which consequently influences how you would interpret, assess, and act. Thus, it is important to think about positionality and possible biases while using PIAA to frame the opportunity.

### 4.1.4. Hoover Dam

Hoover Dam is a hydroelectric power generation structure on the Colorado River. Humans perceived potential for valuable hydroelectric power from the River thus utilized scientific means to understand the geographic and mechanical information in order to create a model that could then be transformed into a dam in reality. Similarly, Hoover Dam became the name for an analytical model that allows us to perceive and interpret information from the world, understand what we are aiming for, and translate that theory into a feasible design implemented in the real world (P1--01-02--ModellingEngineering).




Slides from P1--01-02--ModellingEngineering

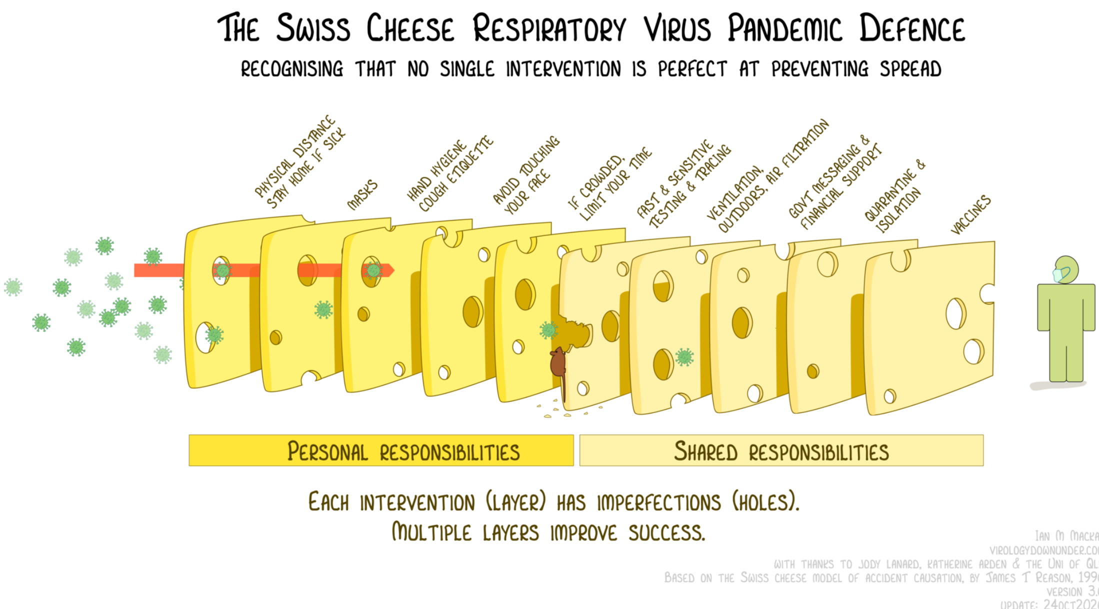
### 4.1.5. Toulmin Model

Toulmin Model is a tool for engineers to make credible claims and arguments with comprehensibility. I find it effective in terms of encouraging the readers to stay committed to unintuitive ideas.


Slides from P1--01-03--Building a Strong Argument

### 4.1.6. The Swiss Cheese Model [2]

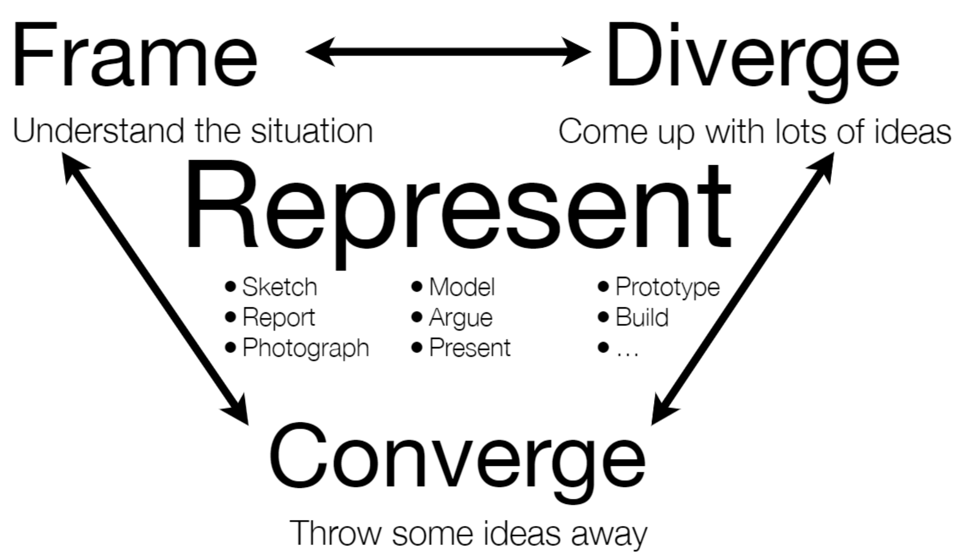
The Swiss Cheese Model is a risk management tool with a holistic thought process that can filter out different types of risks or imperfections layer by layer. Below is a good example that is relevant to the ongoing global pandemic:




The Swiss Cheese Model for the protection against COVID-19

#### 4.1.7. FDCR

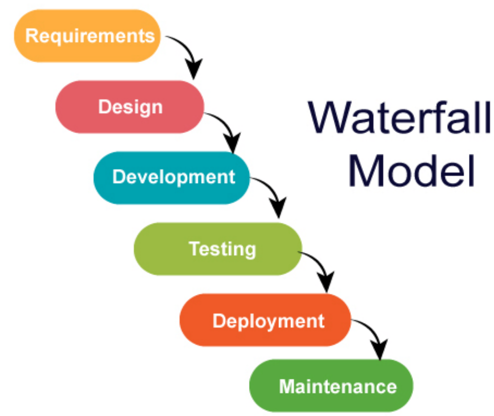
FDCR, standing for framing-diverging-converging-represent, is the most important design process utilized in Praxis. It gives a general outline that allows sufficient flexibility for the team to conduct each phase using other tools and models. For example, framing can be done using PIAA. Tools I find effective for the divergence and convergence phases will be introduced in detail in the next subsection.




Slides from Synchronous 03 in Praxis I

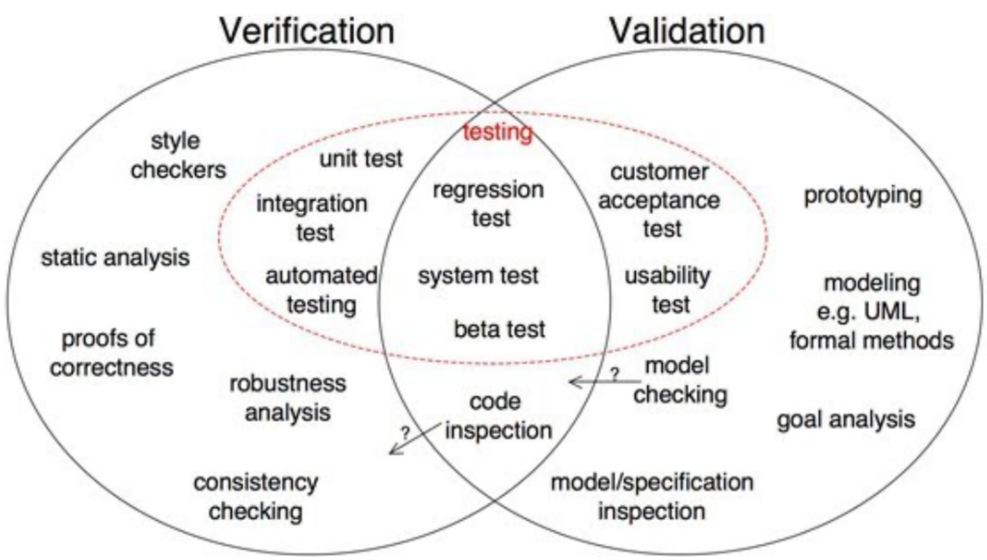
### 4.1.8. Waterfall Model [1]

The Waterfall Model is one of the earliest models used by IT companies to develop software. When designing software, there are lots of steps to take before going straight to coding. Specifically, the design will undergo verification and validation processes that involve prototyping and proxy testing. Waterfall Model adopts these processes and divides them into phases that are responsible for the up-to-date functionality of designs in a long run.




- Verification and Validation

The major difference between verification and Validation is that verification is about making sure the design works while validation is about making sure the team understands the stakeholders' needs thoroughly. A few examples can be found in lecture slides of Synchronous 20 in Praxis II:




A range of V&V techniques. Note that "modeling" and "model checking" refer to building and analyzing abstracted models of software behaviour, a very different kind of beast from scientific models used in the computational sciences

Slide of Synchronous 20 in Praxis II

- Advantages

One aspect I like about this model is that it has another development phase after testing, which gives the team a chance to review the performance of the design and to improve it before launching. It also provides a maintenance phase for the team to be responsive to any feedback from the stakeholders, enhancing the design with updates and new versions.

### 4.1.9. More

For your information, here is a table of more models for the engineering design process that you can look up in the future if needed:

**Table 1 A comparison of engineering design process models**

| Models | Establishing a need phase | Analysis of task phase | Conceptual design phase | Embodiment design phase | Detailed design phase | Implementation phase |
|---|---|---|---|---|---|---|
| Booz et al. (1967) | X | New product strategy development | Idea generation / Screening & evaluation | Business analysis | Development / Testing | Commercialisation |
| Archer (1968) | X | Programming / data collection | Analysis / Synthesis | Development | Communication | X |
| Svensson (1974) | Need | X | Concepts | Verification / Decisions | X | Manufacture |
| Wilson (1980) | Societal need | Recognize & formalize / FR's & constraints | Ideate and create | Analyze and/or test | Product, prototype, process | X |
| Urban and Hauser (1980) | Opportunity identification | Design | | Testing | | Introduction (launch) / Life cycle management |
| VDI-2222 (1982) | X | Planning | Conceptual design | Embodiment design | Detail design | X |
| Hubka and Eder (1982) | X | X | Conceptual design | Lay-out design | Detail design | X |
| Crawford (1984) | X | Strategic planning | Concept generation | Pre-technical evaluation | Technical development | Commercialisation |
| Pahl and Beitz (1984) | Task | Clarification of task | Conceptual design | Embodiment design | Detailed design | X |
| French (1985) | Need | Analysis of problem | Conceptual design | Embodiment of schemes | Detailing | X |
| Ray (1985) | Recognise problem | Exploration of problem / Define problem | Search for alternative proposals | Predict outcome / Test for feasible alternatives | Judge feasible alternatives / Specify solution | Implement |
| Cooper (1986) | Ideation | Preliminary investigation | Detailed investigation | Development / Testing & Validation | X | Full production & market launch |
| Andreasen and Hein (1987) | Recognition of need | Investigation of need | Product principle | Product design | Production preparation | Execution |
| Pugh (1991) | Market | Specification | Concept design | | Detail design | Manufacture / Sell |
| Hales (1993) | Idea, need, proposal, brief | Task clarification | Conceptual design | Embodiment design | Detail design | X |
| Baxter (1995) | Assess innovation opportunity | Possible products | Possible concepts | Possible embodiments | Possible details | New product |
| Ulrich and Eppinger (1995) | X | Strategic planning | Concept development | System-level design | Detail design | Testing & refinement / Production ramp-up |
| Ullman (1997) | Identify needs / Plan for the design process | Develop engineering specifications | Develop concept | Develop product | | X |
| BS7000 (1997) | Concept | Feasibility | Implementation (or realisation) | | | Termination |
| Black (1999) | Brief/concept | Review of 'state of the art' | Synthesis / Inspiration | Experimentation / Analysis / reflect | Synthesis / Decisions to constraints | Output / X |
| Cross (2000) | X | Exploration | Generation | Evaluation | Communication | X |
| Design Council (2006) | Discover | Define | Develop | | Deliver | X |
| Industrial Innovation Process 2006 | Mission statement | Market research | Ideas phase | Concept phase | Feasibility Phase | Pre production |

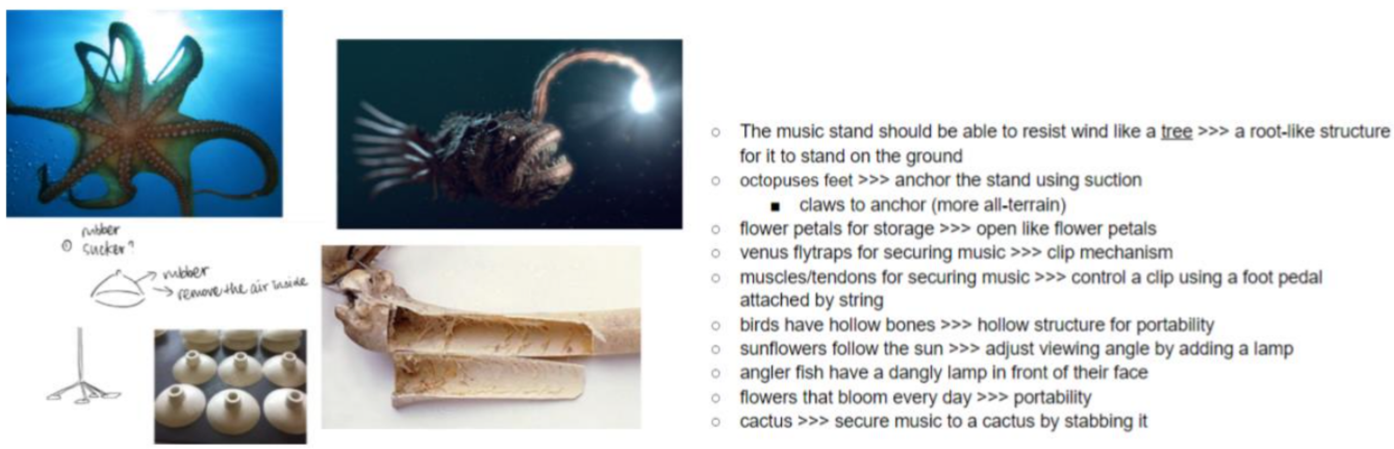
Slides from Synchronous 02 in Praxis II

## 4.2. Divergence Tools

### 4.2.1. Biomimicry

Biomimicry is a tool that is most helpful when designing for structural or functional requirements. It also requires the overall team to have a profound understanding and knowledge of organisms such as plants and animals in nature in terms of their biological functions and to be able to relate these functions with the features of potential designs.

The successful engineering practice of using biomimicry was to diverge on designs for outdoor music stands that give music performers better methods to display music sheets in windy outdoor environments. There were some ideas that inspired active follow-up discussions. For example, octopuses have suction cups on their feet that could grab and grip easily, which inspired the team to consider implementing rubber suckers on the bottom of the music stand so that it could resist wind gusts by holding the ground tightly. Another requirement was that the structure should allow users to carry around easily, then hollow structures were brought up by a teammate who was familiar with how birds have hollow bones that reduce self-weight and make it better for flying. Last but not least, when we were diverging upon ways that could display paper in front of someone's face, we came across angular fish which hangs a part of its body with support connecting to its head instead of any vertical support.




Candidates and Tools Critique, Praxis I

#### 4.2.2. Wishing

Wishing is a tool that I recommend using at the beginning of the divergence process. To use this tool, the users are asked by prompts such as "wouldn't it be nice if…" along with any constraint you wish could disappear. This tool explores creative potentials as if there were no constraints that could limit the scope of the designs. When the team is diverging on potential designs, of course, there can be a lot of realistic factors that restrain our creative ideas from bursting out due to the nature of an opportunity. However, what if some of the conceptual constraints do not necessarily need to exist if we think out of the box? Using wishing, the team gets to generate a broader range of possible ideas than before. Even though some of them might not be realistic, the team gets more options to develop upon and choose from.

An example also comes from the engineering practise of designing for music stands during Candidate and Tools Critique. In the image below, one of the high-quality takeaway ideas was replacing paper sheets with digital display devices to avoid letting the wind blow away the paper.

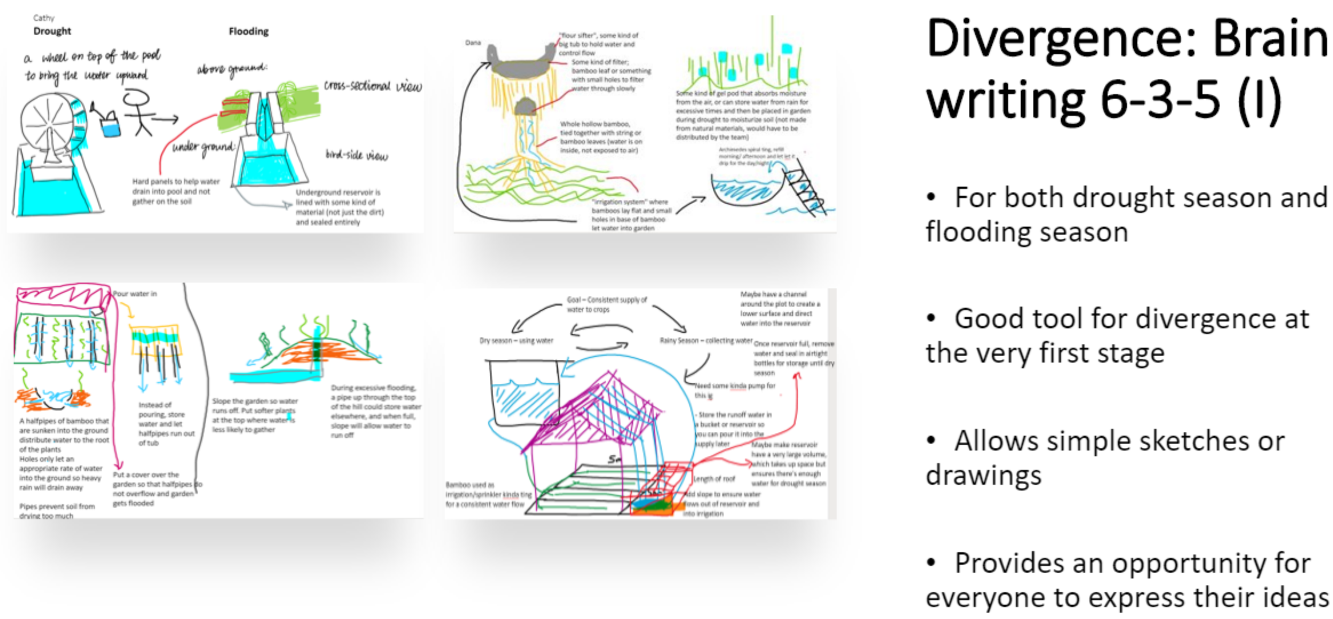
- No cost associated with materials
  - expensive, lightweight and sturdy materials
- Don't need actual paper sheets
  - digital sheet music (ipad, tablet, etc.)
- No technological constraints
  - project music onto the particles in the air
  - the music sheet that can float or be projected in the midair
- I wish the musicians were all the same height
  - music stand doesn't have to be adjustable
  - the viewing angles don't have to be adjustable
- I wish we didn't have to consider the musician's comfort
  - have everyone wear their stand around their neck so it's always at the right height; add cushioning for comfort

Google docs notes from Candidates and Tools Critique, Praxis I

### 4.2.3. Brainwriting 6-3-5

Brainwriting is a tool that my teams found really powerful in terms of giving everybody space to think as well as communicating and exchanging ideas through drawing and sketching. To begin, we need a small amount of space for each person either on slides virtually or on paper in person. We usually give each round about 10-15 minute and switch to the next person's work and leave some feedback at the blank regions. The process is over when the team finishes a full cycle.

One successful example in using this tool was during the divergence process of the water-regulation opportunity in Praxis II:




Slide from Beta Release, Praxis II

### 4.2.4. Attribute Listing

Attribute listing is an effective tool that decomposes the opportunity requirements into several pieces of features. In general, it requires three steps. Examples from designing for the music stand will be given.

Step 1: The opportunity is divided into detailed attributes that the candidate designs are expected to meet. In the context of the music stand, my team broke the music stand up into sections including the sheet holder, the stand, and the base. Each section was then conceptualized into attributes that it was expected to possess. For example, the sheet holder has to secure sheet music, the stand has to stay upright, and the base has to be stable.

Step 2: Each attribute is assessed by its effectiveness in improving the design. The ones that are not enhancing the performance of meeting the requirements are weeded out.

Step 3: Each attribute is scrutinized and weighted based on its importance for the design. The degree of value is adjusted accordingly.

This tool is recommended to be used in conjunction with other divergence tools for best performance. I also recommend using it towards the end of our divergence since it allows the team to collect all ideas and systematically categorize them. In designing for music stands, my team used it together with a morph chart (shown below) to better link expectations and detailed design concepts together.

| Attributes | Designs | | | | |
|---|---|---|---|---|---|
| hold music |  |  (foldable) |  | pleated | |
| secure music sheet/protect from wind |  wooden clip | magnets | metal flaps around sheets | foot pedal to control opening and closing of the clip | clipboard clip (suited for one-handed use) |
| stay upright | stand attached to neck | | | | |
| be anchored | person's weight >>heavy weights | suction cups | strings and pegs stabbed into the ground | | |
| adjustable height | hollow tubes nested within each other that can be extended | hollow tubes that snap onto each other  | truss structure | tripod | accordion  (portable, lightweight) |
| easy to transport | truss structure | hollow tubes | | tripod | accordion  (portable, lightweight) |
| handle | carrying bag/strap | | | | |

Google docs notes from Candidate and Tool Critique in Praxis I

### 4.2.5. Reverse Brainstorming

Reverse brainstorming is a diverging tool that enables the team to make sufficient consideration in terms of risk management and factor of safety. It starts with brainstorming all the possible aspects that could go wrong, and address each aspect with corresponding solutions.

This is a valuable tool that I recommend the team using towards the end of a diverging process. It is all known that the factor of safety is an important aspect to consider, but teams often have a lack of consideration for one or more scenarios of risks after finishing a whole engineering design process. As one example, my team in Praxis II did not use this tool to conduct risk management. During the showcase, we were asked a lot of questions about the failing point of the material and the factor of safety of some vulnerable regions of the structure, which is something we totally did not expect to get and did not have good answers to respond to. However, my team in Praxis I did manage several possible risks using this tool and found it helpful in coming up with thoughtful features to add to the candidate designs.

Reverse brainstorming

- music falls over
  - wind
    - clips or pins (see secure music section from morph charts)
  - structure collapses
    - sturdy materials (metal)
    - rigid joints
  - sheets fly out/slip off
    - see *secure music* from morph chart
- Stand doesn't fit in the space given
  - foldable (from biomimicry)
- stand falls over
  - see *be anchored* from morph chart
  - spikes-stab the stand into the ground

Google docs notes from Candidate and Tool Critique in Praxis I

### 4.2.6. SCAMPER

It is always good to use SCAMPER when the team already has some valuable ideas and tries to improve upon previous ideas instead of coming up with something entirely new. Specifically, SCAMPER stands for

- Substitute: What aspect of the design can you substitute in order to improve the design?
- Combine: What could you combine with to maximize the performance of the design?
- Adapt: How would you adjust the design to make it serve another purpose? What other context could you think of?
- Modify: What aspect of the design can you change or strengthen?
- Put to another use: Can you use this design somewhere else?
- Eliminate: How would you simplify this design?
- Reverse: What if you want the design to behave like the exact opposite of what it is right now?

Bamboo Irrigation (slide 17 and 18)

| Substitute | Substitute a half pipe for a pipe |
| --- | --- |
| Combine | Combine irrigation system with a water storage system |
| Adapt | Adapt the pipes to control the flow of water |
| Modify | |
| Put to other Purposes | Use bamboo as a roof |
| Eliminate | Eliminate bamboo and use a channel in the ground |
| Reverse | |

Ancient Egyptian Irrigation

| Substitute | Substitute ground reservoir (dirt) with half-pipe of different material (half bamboo) |
| --- | --- |
| Combine | Add a roof or something floating (a plant?) over the channels to prevent evaporation |
| Adapt | Adapt canals to be small-scale for small garden |
| Modify | Make channels thin and deep to prevent evaporation |
| Put to other Purposes | Use the channels to divert water in the rainy season |
| Eliminate | Eliminate soil and plant plants in the water |
| Reverse | |

**Divergence: SCAMPER**

on reference designs and current ideas

Slide from Beta Release, Praxis II

### 4.2.7. Functional Decomposition

Functional Decomposition is one of my favourite tools, especially when using it with ?. It requires the team to break down the requirements into conceptual functions or components so that the team can further identify possible means to achieve corresponding functions. The chart below is a slide from Mar 15 synchronous lecture in Praxis II. On the left are the main verbs about "what do you want the design to do", and on the right are mainly adjectives or nouns that describe your "object of interest".

| *Class (Primary)* | *Secondary* | *Tertiary* | *Correspondents* |
| --- | --- | --- | --- |
| **Branch** | Separate | | Isolate, sever, disjoin |
| | | Divide | Detach, *isolate*, release, sort, split, disconnect, subtract |
| | | Extract | Refine, filter, purify, percolate, strain, *clear* |
| | | Remove | Cut, drill, lathe, polish, sand |
| | Distribute | | Diffuse, dispel, disperse, dissipate, diverge, scatter |
| **Channel** | Import | | Form entrance, *allow*, input, *capture* |
| | Export | | Dispose, eject, *emit*, empty, *remove*, destroy, eliminate |
| | Transfer | | Carry, deliver |
| | | Transport | Advance, lift, move |
| | | Transmit | Conduct, convey |
| | Guide | | Direct, shift, steer, straighten, switch |
| | | Translate | Move, relocate |
| | | Rotate | Spin, turn |
| | | Allow DOF | *Constrain*, unfasten, unlock |
| **Connect** | Couple | | Associate, connect |
| | | Join | Assemble, fasten |
| | | Link | Attach |
| | Mix | | Add, blend, coalesce, combine, pack |
| **Control Magnitude** | Actuate | | Enable, initiate, start, turn-on |
| | Regulate | | Control, equalize, limit, maintain |
| | | Increase | *Allow*, open |
| | | Decrease | Close, delay, interrupt |
| | Change | | Adjust, modulate, *clear*, demodulate, invert, normalize, rectify, reset, scale, vary, modify |
| | | Increment | Amplify, enhance, magnify, multiply |
| | | Decrement | Attenuate, dampen, reduce |
| | | Shape | Compact, compress, crush, pierce, deform, form |
| | | Condition | Prepare, adapt, treat |
| | Stop | | End, halt, pause, interrupt, restrain |
| | | Prevent | Disable, turn-off |
| | | Inhibit | Shield, insulate, protect, resist |
| **Convert** | Convert | | Condense, create, decode, differentiate, digitize, encode, evaporate, generate, integrate, liquefy, *process*, solidify, transform |
| **Provision** | Store | | Accumulate |
| | | Contain | *Capture*, enclose |
| | | Collect | Absorb, consume, fill, reserve |
| | Supply | | Provide, replenish, retrieve |
| **Signal** | Sense | | Feel, determine |
| | | Detect | Discern, perceive, recognize |
| | | Measure | Identify, *locate* |
| | Indicate | | Announce, show, denote, record, register |
| | | Track | Mark, time |
| | | Display | *Emit*, expose, select |
| | Process | | Compare, calculate, check |
| **Support** | Stabilize | | Steady |
| | Secure | | *Constrain*, hold, place, fix |
| | Position | | Align, *locate*, orient |

| *Class (Primary)* | *Secondary* | *Tertiary* | *Correspondents* |
| --- | --- | --- | --- |
| **Material** | Human | | Hand, foot, head |
| | Gas | | Homogeneous |
| | Liquid | | Incompressible, compressible, homogeneous, |
| | Solid | Object | Rigid-body, elastic-body, widget |
| | | Particulate | |
| | | Composite | |
| | Plasma | | |
| | Mixture | Gas-gas | |
| | | Liquid-liquid | |
| | | Solid-solid | Aggregate |
| | | Solid-Liquid | |
| | | Liquid-Gas | |
| | | Solid-Gas | |
| | | Solid-Liquid-Gas | |
| | | Colloidal | Aerosol |
| **Signal** | Status | Auditory | Tone, word |
| | | Olfactory | |
| | | Tactile | Temperature, pressure, roughness |
| | | Taste | |
| | | Visual | Position, displacement |
| | Control | Analog | Oscillatory |
| | | Discrete | Binary |
| **Energy** | Human | | |
| | Acoustic | | |
| | Biological | | |
| | Chemical | | |
| | Electrical | | |
| | Electromagnetic | Optical | |
| | | Solar | |
| | Hydraulic | | |
| | Magnetic | | |
| | Mechanical | Rotational | |
| | | Translational | |
| | Pneumatic | | |
| | Radioactive/Nuclear | | |
| | Thermal | | |

Overall increasing degree of specification →

There are many examples of using Functional Decomposition. If we want to design for a vacuum cleaner, functions can be broken down into the following:

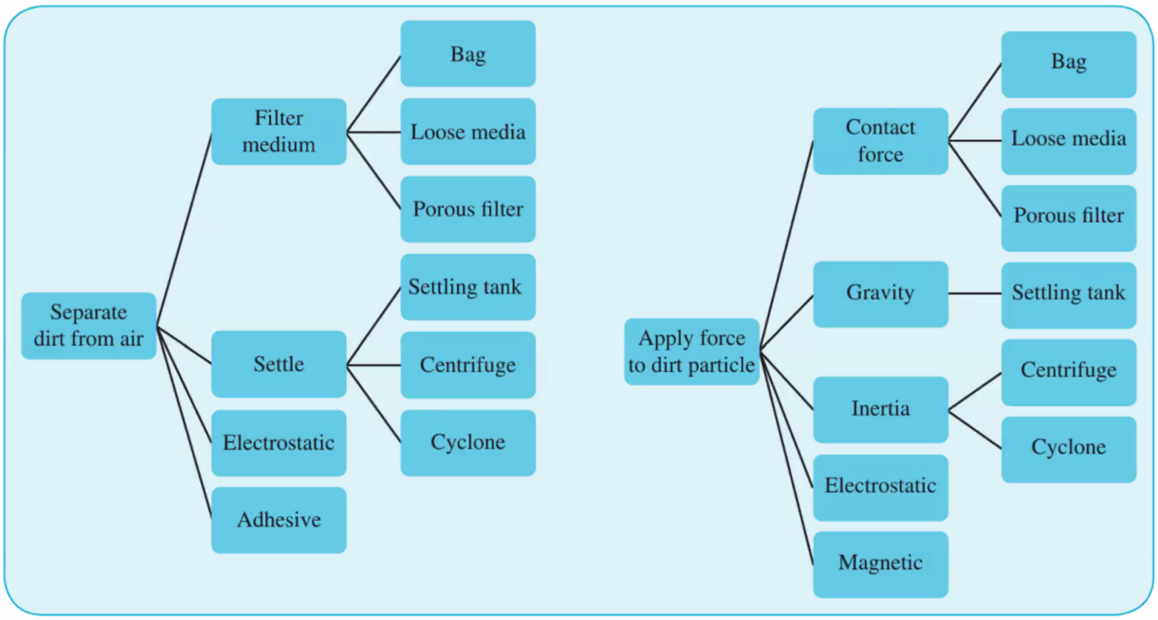



**FIGURE 2** **Two alternatives for the functional decomposition of the function "separate dirt from air."**

McCahan et. al., *Designing Engineers an Introductory Text*, Wiley, 2015.

My team in Praxis II also use this tool when designing for means to collect and transport water:

**Water Collection: Functional Decomposition**

Channel --> Transfer --> Carry, Deliver
--> Guide --> Direct
Provision --> Store --> Accumulate
--> Collect --> Reserve
--> Supply --> Provide, Replenish
Support --> Secure --> Constrain
--> Stabilize --> Steady
Energy --> Mechanical --> Rotational

After breaking down the functions, TRIZ Comparison Table is used to lookup methods that resolve corresponding contradictions. I normally like to use the website: http://triz40.com/TRIZ_GB.php.

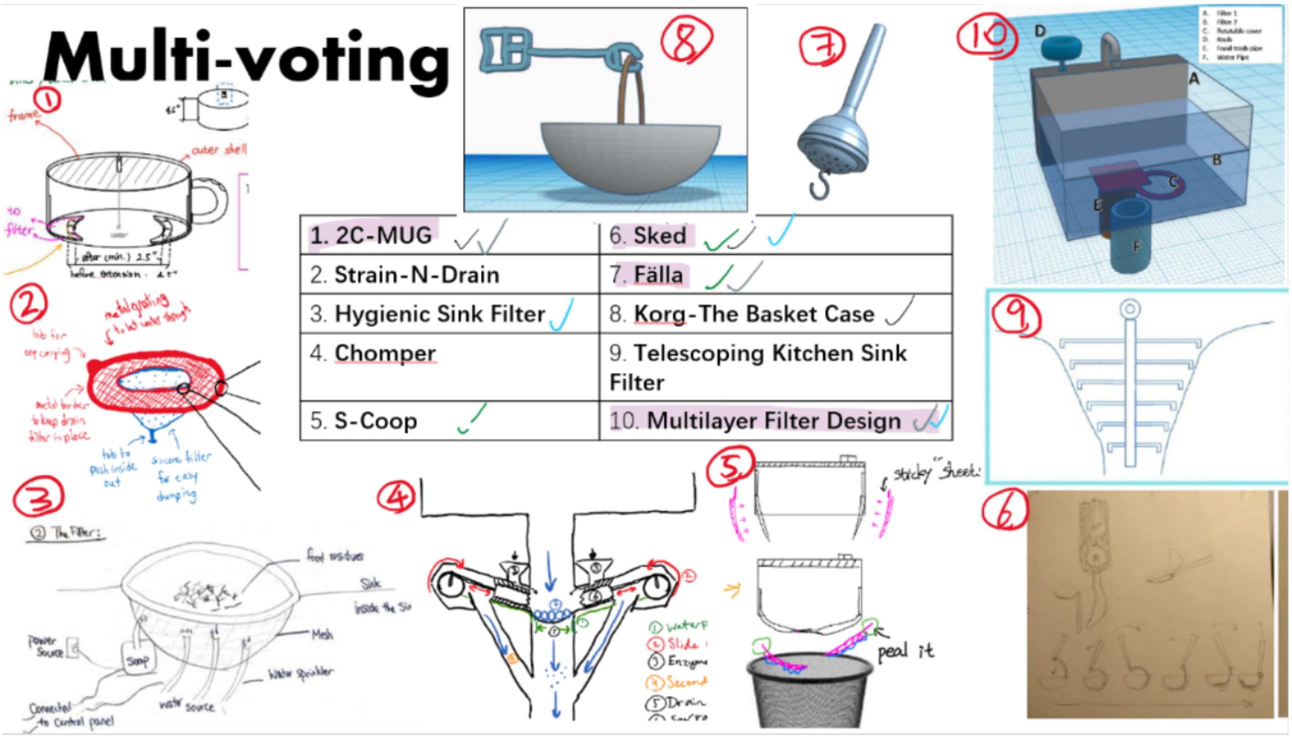
| | | Worsening Feature → / Improving Feature ↓ | Physical | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Weight of Moving object | Weight of Stationary Object | Length/Angle of Moving Object | Length/Angle of Stationary Object | Area of Moving Object | Area of Stationary Object | Volume of Moving Object | Volume of Stationary Object | Shape | Amount of Substance | Amount of Information | Duration of Action of Moving Object | Duration of Action of Stationary Object | Speed |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Physical | 1 | Weight of Moving Object | | 3 19 35 40 1 26 2 | 17 15 8 35 34 28 29 30 40 | 15 17 28 12 35 29 30 | 28 17 29 35 1 31 4 | 17 28 1 29 35 15 31 4 | 28 29 7 40 35 31 2 | 40 35 2 4 7 | 3 35 14 17 4 7 | 31 28 26 7 2 3 5 40 | 2 5 7 4 34 10 | 10 5 34 16 2 | 10 5 28 35 16 2 | 15 2 25 19 38 18 |
| Physical | 2 | Weight of Stationary Object | 35 3 40 2 31 1 26 | | 17 4 30 35 3 5 | 17 35 9 31 13 3 5 | 17 3 30 7 35 4 14 | 17 14 3 35 30 4 9 40 13 | 14 13 3 40 35 5 30 | 31 35 7 3 13 30 | 13 7 3 30 35 31 29 10 | 35 31 5 18 25 2 | 28 13 7 26 2 17 | 3 35 10 12 4 17 14 | 40 35 31 6 19 27 2 | 3 35 17 3 36 2 |
| Physical | 3 | Length/Angle of Moving Object | 31 4 17 15 34 8 29 30 1 | 1 2 17 15 30 4 5 | | 1 17 15 24 13 30 | 15 17 4 14 1 3 29 30 35 | 17 3 7 15 3 1 4 29 | 17 14 7 4 3 35 13 1 30 2 | 17 31 3 19 14 4 30 | 1 35 29 3 30 10 17 14 12 | 35 3 4 1 40 30 31 | 28 1 10 32 17 13 15 | 19 17 10 1 2 3 28 | 10 35 1 3 19 2 | 14 1 13 4 17 12 4 3 |
| Physical | 4 | Length/Angle of Stationary Object | 35 30 31 8 28 29 40 1 | 35 31 40 2 28 29 4 3 | 3 1 4 19 17 35 | | 3 4 19 17 35 1 | 17 40 35 10 31 14 4 7 | 35 30 14 7 15 17 | 14 35 17 2 4 7 3 | 13 14 15 7 17 3 30 | 4 3 31 25 17 14 | 7 17 2 22 28 13 | 35 3 29 2 31 7 19 | 35 10 1 3 2 25 4 5 | 3 14 4 13 18 31 9 |
| Physical | 5 | Area of Moving Object | 31 17 3 4 1 18 40 14 30 | 17 15 3 31 2 4 29 1 | 14 15 4 18 1 17 30 13 | 14 17 15 4 13 | | 17 1 4 3 24 5 2 | 14 17 7 4 13 1 31 3 18 | 14 17 7 13 4 31 3 1 18 | 35 4 14 17 15 34 29 13 1 | 31 30 3 13 6 29 1 5 19 | 17 15 14 32 1 3 | 3 19 18 1 6 5 2 | 1 3 19 2 6 5 | 14 3 34 29 28 30 13 |
| Physical | 6 | Area of Stationary Object | 14 31 17 19 4 13 3 12 | 35 14 31 30 17 4 18 | 17 19 3 13 1 14 | 17 14 3 4 7 9 24 13 26 | 4 31 7 19 15 14 3 13 | | 17 18 14 7 30 13 26 | 14 28 26 13 4 35 17 | 17 5 4 7 28 26 14 | 35 26 1 4 17 18 40 | 26 17 2 13 30 35 7 24 | 13 19 37 10 35 14 5 | 10 2 30 25 13 37 26 5 | 26 28 17 13 14 5 2 35 3 |
| Physical | 7 | Volume of Moving Object | 31 35 40 2 30 29 26 19 | 31 40 35 26 2 13 30 | 1 7 4 35 3 29 15 13 30 | 7 15 4 3 1 35 19 10 | 17 4 71 31 5 24 36 35 | 17 14 4 3 31 7 35 | | 35 14 28 2 3 24 13 | 15 1 14 19 29 14 38 25 | 30 31 7 4 29 36 | 10 2 28 7 32 3 15 26 | 4 36 35 31 6 1 30 28 5 | 30 31 1 35 4 28 38 5 | 29 4 28 1 35 38 3 13 14 |
| Physical | 8 | Volume of Stationary Object | 31 30 40 35 3 2 4 19 | 35 40 31 9 14 13 3 4 26 | 14 30 15 3 4 35 2 19 | 35 2 30 4 14 8 19 28 26 | 15 14 4 30 13 3 7 28 | 14 3 7 4 30 13 15 26 17 | 14 35 3 13 28 2 30 7 | | 7 35 2 30 31 13 | 35 3 31 40 5 13 17 | 10 7 24 28 3 26 2 | 35 19 1 38 15 34 28 | 35 38 15 31 3 1 34 | 35 40 2 38 28 |
| Physical | 9 | Shape | 29 30 3 10 40 8 31 35 | 15 3 10 31 26 35 40 | 4 14 29 5 15 13 2 7 | 17 14 4 13 5 7 31 | 4 17 5 2 14 32 | 17 14 5 28 2 32 4 | 14 4 15 3 7 29 5 13 | 14 4 7 1 2 35 5 32 | | 3 31 30 36 5 4 22 | 17 7 3 32 24 1 | 14 28 25 30 26 31 9 | 3 30 28 35 13 5 22 | 15 35 10 3 18 4 1 |
| Physical | 10 | Amount of Substance | 35 40 6 18 9 2 31 18 | 35 40 18 5 2 8 | 29 3 17 35 14 2 18 36 31 | 35 31 3 17 14 2 40 | 15 14 17 31 35 4 30 29 18 | 17 31 4 18 14 2 40 | 2 15 28 18 38 24 | 35 2 38 25 30 31 1 | 35 7 14 3 31 38 | | 17 37 4 31 13 | 35 40 34 10 3 7 18 19 | 35 30 31 3 12 2 | 28 35 29 24 34 3 38 |
| Physical | 11 | Amount of Information | 28 17 13 7 1 35 2 | 28 26 35 3 2 | 7 32 13 17 2 3 14 | 7 32 17 3 2 14 | 7 17 32 2 24 3 28 | 32 2 3 24 17 28 | 7 19 26 3 32 24 28 2 | 26 32 3 2 24 28 | 7 17 3 32 26 28 13 | 17 7 32 3 13 28 35 | | 7 3 2 10 13 12 24 19 | 7 3 10 12 2 13 24 | 10 7 13 37 3 28 12 5 |
| Performance | 12 | Duration of Action of Moving Object | 15 19 5 8 31 34 35 | 35 3 31 34 8 4 2 | 17 8 19 9 35 2 12 24 | 3 17 12 9 35 2 19 13 | 17 19 7 8 9 24 13 | 3 17 9 24 12 19 13 | 19 10 30 7 14 2 13 | 10 30 35 12 13 4 2 3 | 17 14 28 10 1 26 25 | 3 40 17 35 6 10 13 | 7 2 32 3 24 10 25 | | 10 2 24 20 13 4 17 6 | 3 35 5 13 17 4 37 9 |
| Performance | 13 | Duration of Action of Stationary Object | 35 31 8 19 4 15 34 | 35 6 2 31 19 3 34 | 17 40 19 2 35 3 8 | 40 35 1 9 17 2 13 | 3 35 18 19 14 2 | 35 17 3 30 7 14 | 35 19 18 3 13 17 4 | 35 40 31 3 34 38 19 13 | 17 3 40 14 33 13 10 7 | 35 31 3 40 17 13 6 | 24 7 10 25 3 2 32 | 35 24 28 4 3 25 29 34 | | 35 28 29 3 4 14 13 |
| Performance | 14 | Speed | 13 14 8 28 1 17 2 38 | 1 13 2 10 35 3 | 13 17 28 2 29 14 1 | 17 15 30 2 14 1 | 17 14 4 1 29 30 3 5 34 | 14 5 3 17 1 4 13 | 28 2 7 34 35 5 14 4 | 28 5 2 35 7 9 1 18 | 17 7 15 18 35 3 4 2 | 2 35 19 5 10 38 9 | 7 2 10 5 37 28 3 | 35 40 19 3 5 13 | 3 13 35 5 2 24 | |
| Performance | 15 | Force/Torque | 8 1 9 13 37 28 31 35 18 | 9 13 28 1 35 40 18 | 17 35 9 3 14 19 28 36 29 | 35 28 17 9 17 40 10 37 | 15 17 10 14 19 3 29 39 40 | 1 3 17 40 37 18 9 35 | 12 15 9 35 37 14 4 | 1 18 37 35 3 2 10 36 | 35 10 3 40 31 34 4 14 | 14 18 29 28 35 3 1 8 36 | 13 17 37 3 1 | 19 10 2 12 28 | 2 10 13 3 12 19 26 | 13 15 9 28 12 2 |
| Performance | 16 | Energy Used by Moving Object | 28 35 19 12 31 18 5 | 28 35 5 12 18 31 13 | 28 12 15 35 17 19 | 35 2 19 15 28 | 15 19 4 3 25 14 | 35 2 17 14 15 3 | 13 35 18 29 2 17 25 | 3 25 34 38 35 7 2 | 29 2 3 12 19 15 28 | 35 2 34 19 18 16 38 30 | 7 2 25 24 3 37 | 18 28 35 6 15 12 10 | 28 2 35 13 6 12 10 19 | 35 28 13 19 5 8 |
| Performance | 17 | Energy Used by Stationary Object | 35 28 13 8 3 19 | 19 13 35 9 28 6 | 17 4 12 3 24 14 | 4 17 9 19 3 16 | 3 4 13 5 12 24 | 4 17 3 14 16 19 | 2 35 13 19 13 18 28 4 | 35 39 19 2 18 28 4 9 | 7 35 24 30 13 5 10 36 | 35 31 3 24 28 13 4 9 | 2 19 17 20 7 | 40 35 3 19 4 28 24 | 40 35 3 17 28 26 24 | 1 3 28 19 13 25 |
| Performance | 18 | Power | 8 38 2 25 31 19 28 35 | 19 2 35 31 26 28 29 17 27 | 1 17 35 10 37 36 28 30 29 | 17 14 1 35 4 10 28 29 30 | 19 38 35 2 25 3 15 4 | 17 19 38 13 3 15 25 32 2 | 19 38 2 35 25 6 15 4 14 | 19 35 25 36 6 30 15 3 14 | 29 14 15 1 35 40 4 3 36 | 35 19 38 4 3 40 18 24 30 | 10 28 19 12 24 37 | 19 35 10 38 4 28 1 21 | 38 35 10 4 28 19 16 | 15 2 19 35 3 14 24 1 13 |
| Performance | 19 | Stress/Pressure | 40 35 31 10 36 37 2 17 | 35 10 13 31 29 40 2 17 | 35 9 40 17 3 14 4 13 | 3 14 17 35 40 4 9 1 | 10 35 40 14 17 28 15 3 | 40 14 35 10 37 17 3 | 35 10 40 3 15 14 4 17 | 35 17 4 40 3 30 24 14 | 35 4 40 3 30 14 31 15 | 35 10 25 31 14 13 12 5 | 28 2 26 7 24 | 19 3 35 4 13 14 2 | 3 14 35 9 2 5 12 | 35 17 24 13 6 14 29 36 |
| Performance | 20 | Strength | 40 31 17 8 1 35 3 4 | 40 31 2 1 17 26 35 3 | 17 35 40 1 4 15 8 | 17 35 9 37 14 4 40 15 | 14 17 3 7 19 4 40 5 | 14 17 9 40 3 4 13 | 4 7 17 14 35 10 15 31 | 14 9 17 4 31 13 35 | 40 4 9 35 7 17 30 25 | 30 17 31 9 13 29 3 | 17 2 32 3 28 26 | 35 40 3 26 17 4 13 | 35 3 5 24 26 4 13 40 | 14 28 8 13 12 26 2 |
| Performance | 21 | Stability | 40 35 31 5 2 39 17 24 8 | 40 35 31 17 39 1 24 4 | 17 1 35 13 15 28 4 25 | 17 4 35 37 13 1 40 | 31 13 35 17 4 3 2 12 | 35 31 4 3 39 13 17 | 24 5 39 35 10 19 28 25 | 35 40 24 31 25 14 5 | 1 4 35 17 7 3 18 21 | 5 24 31 40 35 15 39 13 | 2 7 10 35 24 5 | 10 13 5 35 4 19 7 40 | 10 40 3 39 23 6 13 7 | 40 28 25 13 24 10 33 15 18 |
| Performance | 22 | Temperature | 36 31 6 35 38 30 22 19 40 | 31 35 3 32 36 22 40 4 17 | 15 19 9 3 35 31 4 1 | 19 3 15 31 9 35 4 1 | 3 35 40 19 18 17 39 31 | 35 3 31 40 19 38 30 24 17 | 35 40 31 4 18 39 2 34 | 35 40 31 3 4 6 30 | 14 19 32 39 3 22 31 | 30 31 3 35 39 17 15 19 | 5 37 7 10 26 19 32 | 19 15 13 39 1 18 30 9 3 | 19 36 40 3 9 1 13 2 35 | 28 14 36 2 30 19 13 3 |
| Performance | 23 | Illumination Intensity | 19 1 24 32 31 39 35 | 35 32 2 19 31 1 5 30 | 14 19 32 35 17 24 1 | 14 17 32 35 24 19 1 | 14 17 24 35 19 32 26 4 1 | 14 17 4 35 24 32 19 1 26 | 14 24 13 10 19 2 32 35 4 | 14 13 24 35 10 19 2 32 | 3 30 13 24 32 35 5 14 1 | 1 19 35 14 24 28 3 | 2 25 19 32 7 6 3 | 19 2 6 35 28 4 25 | 2 6 10 35 28 4 | 19 10 13 28 35 4 5 |

Mar 16 Synchronous Lecture in Praxis II

## 4.3. Convergence Tools

### 4.3.1. Multi-Voting

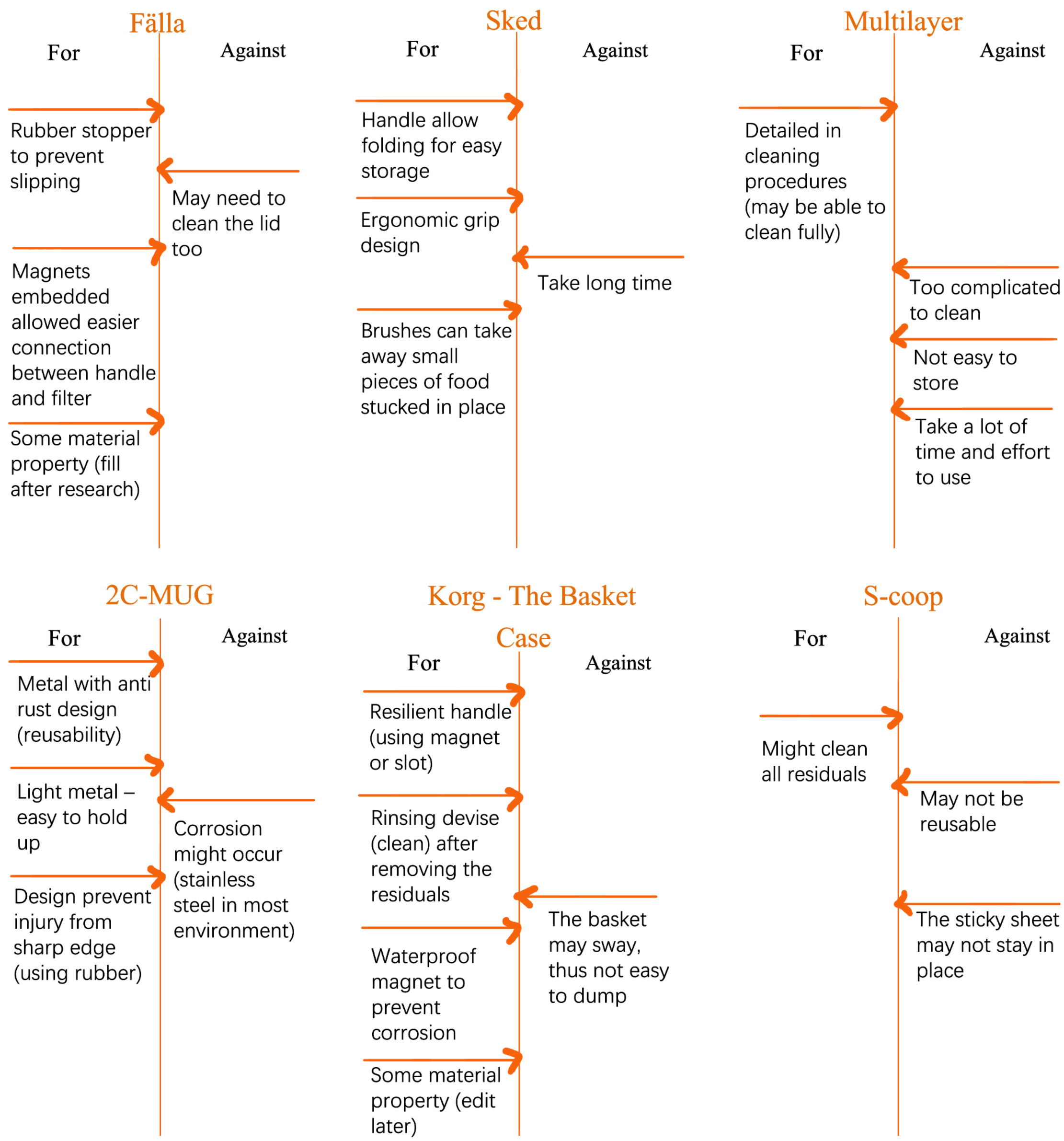
Who doesn't like some democracy? With multi-voting, the team can quickly decide on a smaller range of options than before. Thus, it is recommended to use this tool at the very beginning to filter out those designs that are relatively less qualified.




### 4.3.2. Force-Field Analysis

Force-Field Analysis is similar to “listing pros and cons”, but it requires the team to list them for every design. In the end, there will be a “free-body diagram” for each design and the team needs to examine whether the overall force is “for” or “against”. The team should also attempt to neutralize the forces against and increase the forces for.

An example can be given from the practice of recommending a kitchen sink filter:




### 4.3.3. Proxy Testing

Proxy-testing is a typical convergence step that no team wants to miss out on. It gives practical information about how well each design would perform in real life in a way that is more tangible than secondary research. In general, the closer to reality, the better the proxy test is. However, proxy tests do not have to be highly similar to reality. Instead, each test should be broken down to one purpose and target at testing one characteristic of the designs. Thus, it usually makes sense to me to conduct one test for each critical metric/objective. I can think of a couple of steps for a team to conduct proxy tests:

- Step 1: Design Proxy Tests based on Objectives

Critical Objective 1: Remove the food residue thoroughly with shorter cleaning time

- Test 1:
  - Measure 20ml of rice grain with a measuring cup and place it in the filter model.
  - Use the designed prototype of each design and perform the cleaning process in 10 seconds
  - Compare the amount of rice grains left by counting the number of grains.


Critical Objective 1: Remove the food residue thoroughly with shorter cleaning time

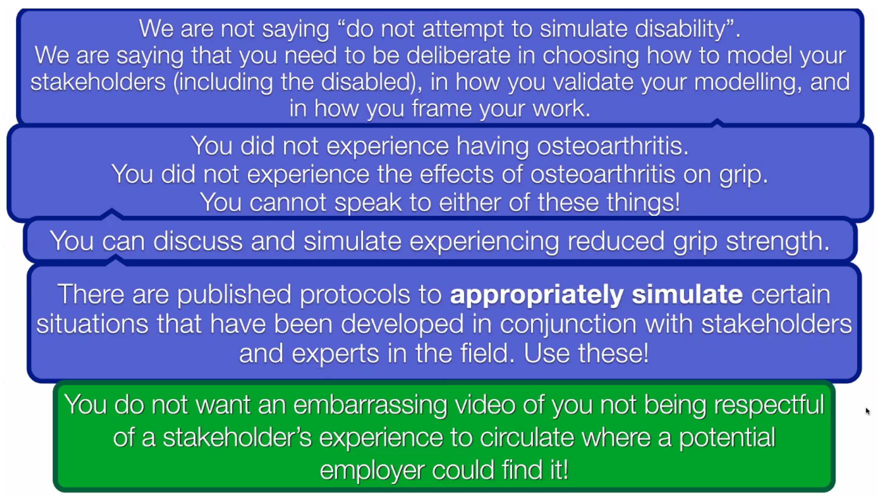
- Test 2:
  - Measure approximately 10ml of wet tea leaves and repeat the procedures of the previous test for 10 seconds.


- Step 2: Filling the Comparison Matrix with Test Results

# Measurement Matrix – Test Result

| Candidates | Modified Reference Design | Falla | Sked | 2C-MUG | Korg |
|---|---|---|---|---|---|
| Rice: Amount Left After 10 sec (grains) | 0 | 0 | Around 20 | 0 | 0 |
| Tea: Amount Left After 10 sec (leaves) | 3-4 | 3-4 | 10+ | 3-4 | 4-6 |
| Duration For cleaning (seconds) | 5 | 5 | 10 | 15 | 10 |

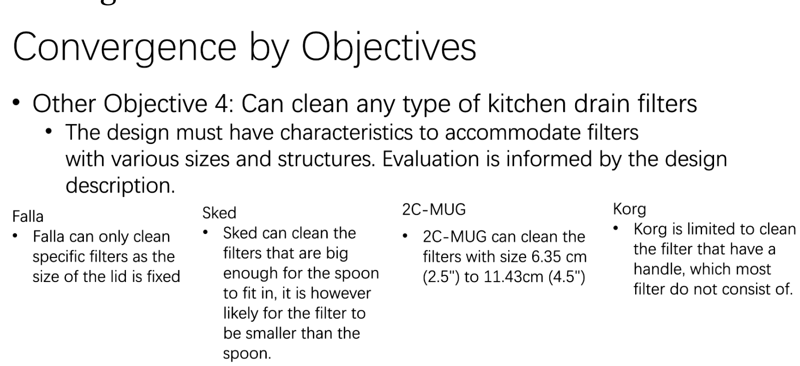
It should be noted that the example I am using is to design a household product which is the best and easiest scenario to conduct proxy testing. For some opportunities involving vulnerability or even double vulnerability, "generating inappropriate tests that can be disrespectful to your stakeholders will do a lot more harm than good" (Mar 19 lecture slide). For example, for an opportunity involving Parkinson patients, it is extremely disrespectful to conduct proxy tests by imitating behaviours with the disease. In fact, as Professor Sheridan said in one lecture, disability simulation is impractical because people with disability have a long time dealing with the experience and might undergo different levels of psychological frustrations that a test cannot simulate (Mar 22 lecture).




### 4.3.4. Pairwise Comparison

Pairwise Comparison along with a Pugh Chart is a common convergence tool being used when there is a smaller range of candidates. The team is required to fill the comparison matrix with details of how well each candidate meets the detailed objectives, and then fill the Pugh Chart with results comparing each candidate with the reference design: "+", "-", or "0".

- Step 1: Comparison against DOs



## Convergence by Objectives

- Other Objective 5: Should be safe and ergonomic
  - The design must not cause any physical injuries or allergies. Evaluation is informed by both the design mechanism and research.
  - The design must have at least one ergonomic feature based on the design description.

Falla
- Falla is designed with a rubber stopper on the handle, which prevent it to roll down the table
- However, Falla consist of a hook, which is dangerous

Sked
- No potential risk were found for sked

2C-MUG
- The rubber ring is designed to prevent injury from share metal edges

Korg
- The handle for the prototype is made of heavy material, and can cause severe injury if droped from the height of the sink to someone's feet.

- Step 2: Filling the Pugh Chart

## Pugh Chart

| | **Modified Reference Design** | **Falla** | **Sked** | **2C-MUG** | **Korg** |
|---|---|---|---|---|---|
| Rice: Amount Left After 10 sec | 0 | 0 | - | 0 | 0 |
| Tea: Amount Left After 10 sec | 0 | 0 | - | 0 | - |
| Duration For cleaning | 0 | 0 | - | - | - |
| Reactivity | 0 | 0 | 0 | - | - |
| Safety | 0 | - | 0 | 0 | - |
| Durability | 0 | - | - | - | - |

Note: This example Pugh Chart combines the results from proxy tests (first 3 rows) and the results from Pairwise Comparison (last 3 rows).

Another example of the Pugh Chart (the team communicated the reasons for each sign verbally):

Order of FDCR Activities:
1. Brainwriting 6-3-5
2. SCAMPER on reference designs and current ideas
3. Wishing
4. Biomimicry
5. Multi-voting
6. Brainwriting 6-3-5
7. Pairwise Comparison
8. Functional Decomposition

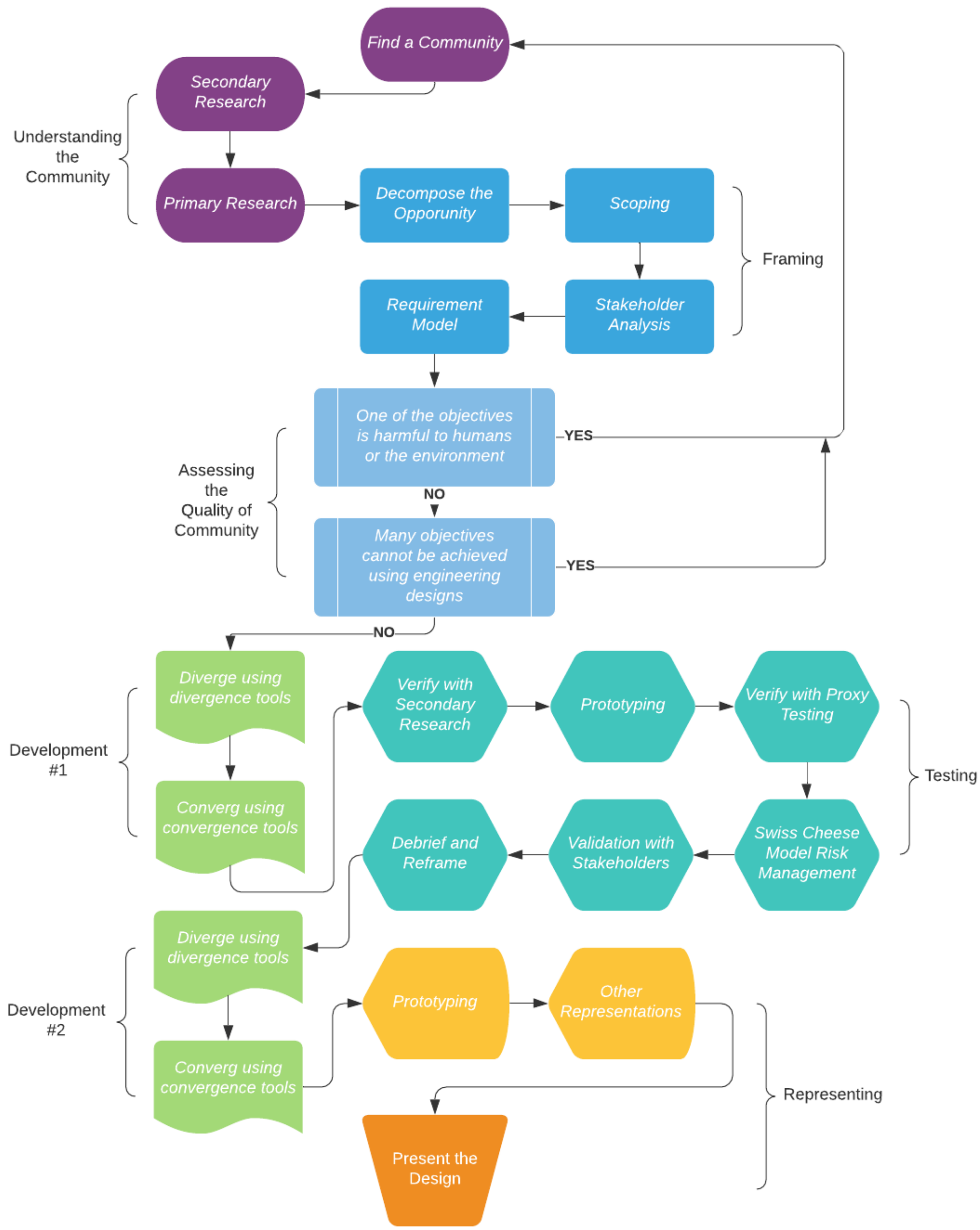
- Bicycle with water tank on back
- Tricycle with water tank
- Scooter with water tank
- Push barrel of water (with sticks connected to roll)
- Pull barrel of water, like suitcase
- Channel/Tunnels from water source to town
- Big barrel, rolled (possibly with track)
- Water wheelbarrow
- Water Jacket
- Water Backpack
- Roof to reservoir
- Condenser
- Balloon tank (use a balloon, wings, etc. to reduce the weight of the water)

| First Option | DO3: Water Storage Time | DO5: Time/Effort Collecting Water | DO6: Local Materials |
|---|---|---|---|
| **Reference Design:** Water Suitcase | 0 | 0 | 0 |
| Bicycle | + | + | - |
| Tricycle | + | + | - |
| Scooter | + | 0 | - |
| Push barrel of water | - | - | + |
| Channels from well | - | + | + |
| Water wheelbarrow | 0 | - | 0 |
| Water jacket | 0 | - | - |
| **Water backpack** | 0 | 0 | + |
| **Roof to reservoir** | - | + | + |
| **Condenser** | + | + | - |
| Barrel rolled with track | + | 0 | - |
| Balloon tank | 0 | 0 | - |

Pugh Chart from Beta Release, Praxis II

## 5. Personal Engineering Design Process

The purpose of this section is to compile a complete engineering design process that I find most helpful for myself based on experience in previous engineering design practices. It can potentially prevent the future me from forgetting the process and falling back to square one with no plan or idea to start with. Although the design process could be placed after the positionality section because of its high relevance to my characteristics and skills, it is placed after the TMFs section because I may refer back to some of the tools and models.




Flowchart of my personal engineering process

## 5.1. Find a Community

The team should first diverge on a range of different types of communities, rank them in terms of priority based on the team's positionality, and contact a proper amount of communities in a respectful way.

| |
|---|
| **High Priority** |
| **-Alzheimer's community - https://alzheimer.ca/peel/en/home** |
| **-Bob Anderson (choir teacher w/ Alzheimer)** |
| **-Refugees/donations (Fresh Start Project) - Nancy Milton** |
| Medium Priority |
| -Gym/fitness Community |
| -Music rehearsals/online learning |
| Low Priority |
| -Music recording/performance |
| -Homeless shelters |
| -Women's shelters> |

Process work of how my team in Praxis II started with finding communities

## 5.2. Understanding the Community

### 5.2.1. Secondary Research

Secondary Research is the main method that the team should depend on when trying to understand the community. Research can be found from credible websites, journals, books, and even the official website of the community if it exists. Doing sufficient secondary research can also smooth the interaction with the stakeholders which makes the team professional.

### 5.2.2. Primary Research

Primary Research comes from direct interactions with representatives of the community through face-to-face conversations, virtual meetings, phone calls, or emails. It should be noted that it is important for the team to use people-first language, and it is inappropriate for the team to go directly such as "What are your problems?". The team should enter the conversation in a respectful way without making any assumptions about the community. For example, it is appropriate for the team to ask the representatives about their experience in the community, what their daily life looks like, and showing interest in topics that they bring up. Also, keep in mind that the team should not make any promise about being able to improve the current situation.

## 5.3. Framing

### 5.3.1. Decompose the Opportunity

After gathering enough information about the community, the team should organize and categorize it in terms of different types of actions that a candidate design is expected to do. For example, if the community might potentially need a design that can store and transport, it helps if the team can decompose the opportunity separately in terms of "store" and "transport".

### 5.3.2. Scoping

Keeping the team's positionality in mind and also considering teammates' skills and interests, the opportunity is scoped into only one aspect so that the team can better handle it.

### 5.3.3. Stakeholder Analysis

Identify both primary stakeholders and secondary stakeholders. Then analyze their roles and relationships in the community along with what they do in the current situation.

### 5.3.4. Requirement Models

Identify all the requirements that a candidate design needs to meet and turn them into high-level objectives. Decompose each high-level objective into detailed objectives and identify their corresponding metrics, constraints, and criteria.

## 5.4. Assessing the Quality of the Community

### 5.4.1. Morality Check

My positionality requires the opportunity to be safe for humans and the environment. If it is not, the team should find another community.

### 5.4.2. Is this an Engineering Opportunity?

Some opportunities require solutions related to social changes or political science. Make sure the opportunity can be solved by an engineering solution.

Note: for me, other factors such as the level of engagement of the stakeholders or the size of the community do **not** matter so much that could make me change a community.

## 5.5. Development #1

### 5.5.1. Divergence

Use the tools that I commented to be suitable at the beginning of the divergence process.

### 5.5.2. Convergence

Use the tools that I commented to be suitable at the beginning of the convergence process, and converge into around 3-4 designs with different types.

## 5.6. Testing

### 5.6.1. Verify with Secondary Research

During verification, there are lots of uncertainties that can be answered by secondary research. For example, the tensile strength of a shoulder strap can be found online and the factor of safety can be found with calculation. As well, geographic information such as the local annual rainfall can also be obtained in this step.

### 5.6.2. Prototyping

At this stage, the goal of prototyping is to better represent at least one characteristic of the candidate designs in order to prepare for the following proxy testing.

### 5.6.3. Verify with Proxy Testing

Appropriate proxy tests are designed based on the section TMFs. Any results or feedback from testing the prototype could be potentially impactful for making a change. For example, some requirements such as comfort are hard to be measured or researched and could potentially be determined through testing.

### 5.6.4. Swiss Cheese Model Risk Management

Using the model to identify any potential risk that could fail the designs, diverge on solutions, and modify the designs.

### 5.6.5. Validation with Stakeholders

Validate the candidates with the stakeholders using deliverables such as the prototypes and take notes of their feedback.

### 5.6.6. Debrief and Reframe

Organize and interpret the feedback. Reframe the scoped opportunity if there is a discrepancy between the stakeholders' needs and the team's understanding.

## 5.7. Development #2

### 5.7.1. Divergence

Diverge on the candidates from the convergence last time to see if there is any way to improve their performance, based on the critical requirements of the reframed opportunity.

#### 5.7.2. Convergence

Compare the candidates and converge into one final design.

### 5.8. Representing

#### 5.8.1. Prototyping

Build a new prototype or refine the existing prototype for the design. Or build the actual design (code the software etc).

#### 5.8.2. Other Representations

Make other types of representations such as sketchings, drawings, 3D models, demo videos, and slide shows, if they can better convey design ideas.

#### 5.8.3. Present the Design

Launch the design, or present it in a showcase etc.

## Source Extracts

Note:

1. This section is for sources that have been used in the handbook without any picture.
2. All pictures from the course have been introduced with specific locations of where I found them, so they will not appear in this section.

[1]

## JIRA Waterfall Model

← Prev Next →

Before understanding the agile and JIRA, you must be aware of the waterfall model.

### What is a Waterfall model?

Waterfall model is the oldest model used by an IT industry to develop the software.

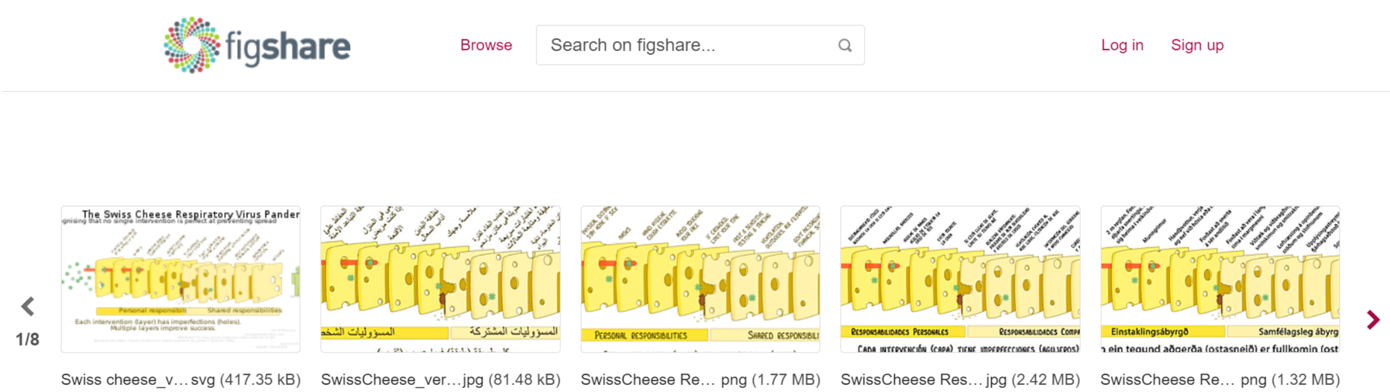
There are various models and processes which are used by different companies, but the waterfall model is the oldest, safest, and easy model in the IT industry.

It is the easiest model for building software that represents real life.

**Let's understand the Waterfall model.**

**Waterfall model is broken down into multiple phases:**

[2]




## Reference

Note: All pictures **not** from the course will be given corresponding citations in this section.

[1] “JIRA Waterfall Model - Javatpoint,” www.javatpoint.com. [Online]. Available: https://www.javatpoint.com/jira-waterfall-model.

[2] Mackay, Ian M. (2020): The Swiss Cheese Respiratory Virus Defence. figshare. Figure. https://doi.org/10.6084/m9.figshare.13082618.v22