

Engineering, Systems & Design

NAMIG

March 31, 2011

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Outline

- What is Engineering?
- Engineering Specialisations & Systems Engineering.
- Conceptual Design.



What is Engineering?

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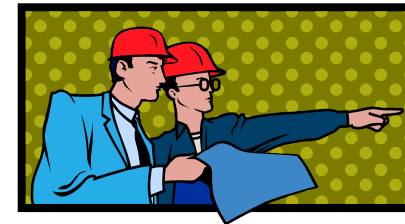
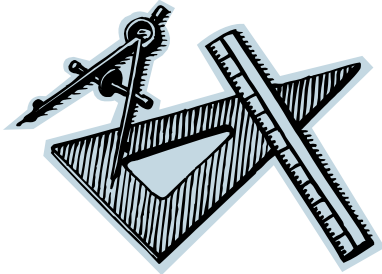
Defence and
Systems Institute

Outline

- What is it?
- What is it not?
- Why is it important?
- What do Engineers do?
- What responsibilities go with the job?
- What skills do you need?
- Famous Engineers?



What is it?



Engineering

“Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgement to develop ways to utilise economically, the materials and forces of nature *for the benefit of mankind.*”

(US Accreditation Board for Engineering and Technology)



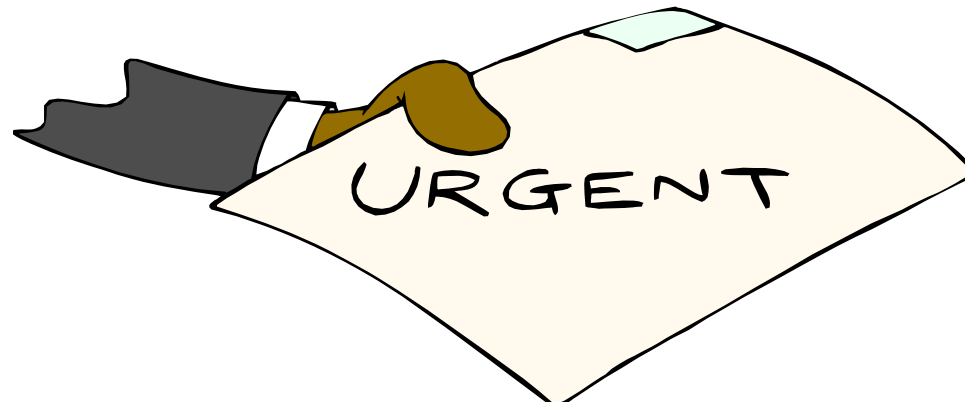
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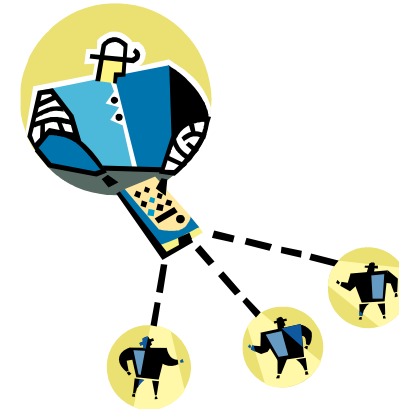
What is it not?



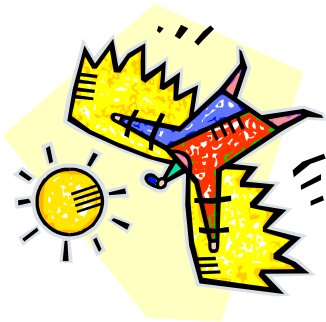
Why is it important?



What do Engineers do?



Responsibilities?



What skills do you need?





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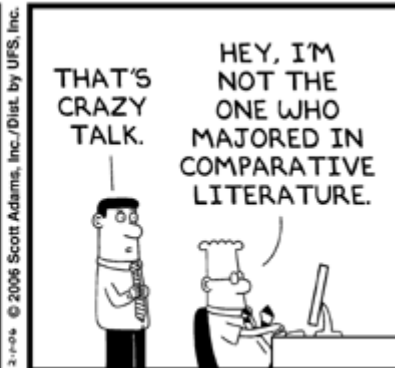
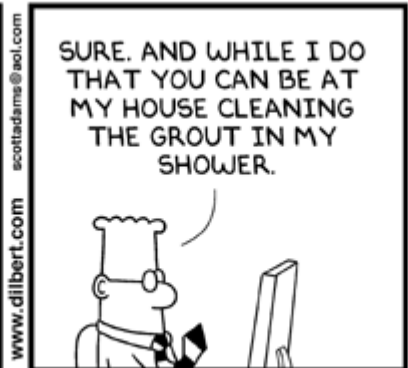


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Famous Engineers

- Yasser Arafat (Former Terrorist, Former Palestinian Leader, Nobel Peace Laureate)
- Rowan Atkinson (Mr Bean, “Blackadder”)
- Alfred Hitchcock (Film Director – ‘The Birds’, ‘North by Northwest’, etc.)
- Hedy Lamarr (Actress and inventor of a torpedo guidance system, in early 1940’s, considered 20 years ahead of its time)
- Scott Adams (Dilbert)
- Usama Bin Laden (Current Terrorist!!)





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<http://www.inventions.org/culture/female/lamarr.html>

<http://www.makeitso.org.au/>



Engineering Specialisations & Systems Engineering

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Engineering Specialisations

- Aeronautical
- Agricultural
- Architectural
- Automotive
- Biomedical
- Ceramic
- Chemical
- Civil
- Computer
- Electrical
- Electronic
- Environmental
- Industrial
- Manufacturing
- Marine
- Materials
- Mechanical
- Mining
- Nuclear
- Petroleum



Common Factor?

- “Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgement to develop ways to utilise economically, the materials and forces of nature for the benefit of mankind.”
- Solving problems by creating products:
- Aeronautical Engineering:
 - Fuel Efficient Engines, Aircraft Safety, Winglets.
- Biomedical Engineering:
 - Pacemakers, X-Ray Machines, Ultrasound.
- Environmental Engineering:
 - Wind Power Generators, Solar Cells, Water-Saving Devices.

Winglets



Winglets are a good example of specialist engineering solving a problem. The little turned-up bits were developed a few years ago. They reduce drag by about 7%, and that means Qantas uses 7% less fuel!



Products → Systems

- Engineering Specialisations tend to focus on their particular technology:
 - Mechanical, electronic, etc
- Nowadays, however, a lot of the technology that we use is a complex combination of different technologies.
- Modern cars are one example:
 - Engines, gears, body, wheels: mechanical
 - Engine computer, ABS control, stereo, alarm: electronic



Complex Systems

- An increasing amount of modern technology is what we call a “system”.
- Consists of a number of sub-systems, which themselves may be very sophisticated, and which may be designed by different engineering specialisations.
- Who makes sure that the overall “system”, and not just the specialist parts (sub-systems), all work together to solve the customer’s problem?



Systems Engineers!

- In the 1940s technology was reaching a state where it was possible to combine different specialist products into increasingly complex “systems”.
- Around that time people realised that someone needed to be responsible for making sure that all the sub-systems would actually work together.
- That’s how systems engineering was born.

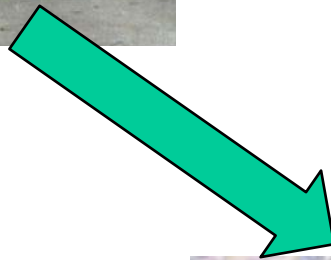
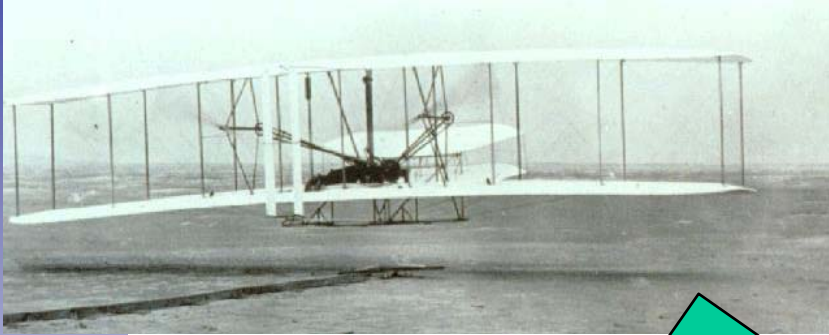


Complexity

- Complexity seems to be a common factor in modern problems that defy solution by conventional means.
- That complexity manifests itself in a number of ways.
- We can see the outward signs of this if we compare the Wright Flyer (B-Model) with a Boeing 777.



Increasing Complexity



Relative Complexity

Platform Complexity Metrics	Family Sedan	Battle Tank	Boeing 777	Frigate	Collins Class Submarine	Air Warfare Destroyer
Weight/Displacement (tonnes)	1.6	30	250	3,600	3,000	6,000
Length (metres)	4	7	60	118	78	130
Number of systems	20	25	40	60	108	120
Number of suppliers	500	600	550	600	1,600	1,500
Crew size	1	4	10	163	43	180
Patrol duration (hours)	7	24	8-14	340	1,700	430
Number of parts to assemble	17,000	14,000	100,000	170,000	500,000	600,000
Number of person hours to assemble	36	5,500	50,000	1,200,000	2,500,000	3,800,000
Construction time (month)	0.05	7	14	22	60	42
Price (AUD \$M)	0.04	4	300	600	1,000	1,500

Systems Engineering

- Systems engineers take a “big picture” view of the system.
- They worry about how to combine all the different sub-systems (mechanical, electronic, computer, human) into one, big, complex working system.
- They start by finding out what the customer wants, and then designing a solution to meet that need.
- They “integrate” all the different sub-systems, and make sure that they all work together efficiently to satisfy the customer’s need.



Systems Engineering

- Some of the most complex systems that get created are defence systems
 - Jet fighters, submarines, ships
- Systems engineering is most commonly associated with defence systems.
- Systems engineering is also important because these defence systems usually cost a lot, and the Government has to show that they aren't wasting our money.
- Systems Engineering makes sure that the system is built on-time, on-budget and does what it's supposed to do.



Air Warfare Destroyers

- The AWDs are a good example of a complex defence system.
- They will be built here in Adelaide.
- They will cost about \$6,000,000,000!
- If they take too long to build – that costs more money!
- If they sub-systems don't work together properly, that takes more time and costs more!
- If they ships don't do what the Navy wants, they have to be fixed, and that costs more money!
- Systems Engineering has an important job!

Air Warfare Destroyers

- The AWDs will take years to design and build.
- The companies making them employ thousands of people.
- They are an important part of our country's defence.
- We can't afford to get it wrong!
- Watch this short video...



Summary

- Systems Engineers are the coordinators.
- They work out what the customer needs.
- They design the overall solution (the system).
- They make sure all the specialist engineering gets done.
- They plug all the sub-systems together and make sure the whole system works.
- They make sure the system is delivered on-time and at the right price.



Design

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Outline

- **Simplified Conceptual Design Process.**
- This translates a customer need into a high-level design for a system.
- First cycle through a systems engineering process.
- Similar to design process for any stage of engineering.
- We'll design an Intelligent Washing Machine (IWM) as an exercise.



What is a “System”

- The Collins Concise Dictionary, 5th Edn (2001):
 - 1. “a group or combination of interrelated, interdependent or interacting elements forming a collective entity” – *a railroad system, the digestive system, a business information system, an exploration system, a cleaning system;*
 - 2. “any assembly of electronic, mechanical, etc., components with interdependent functions, usually forming a self-contained unit” – *a communication system, a telemetry system.*



NASA Mars Exploration Rover System

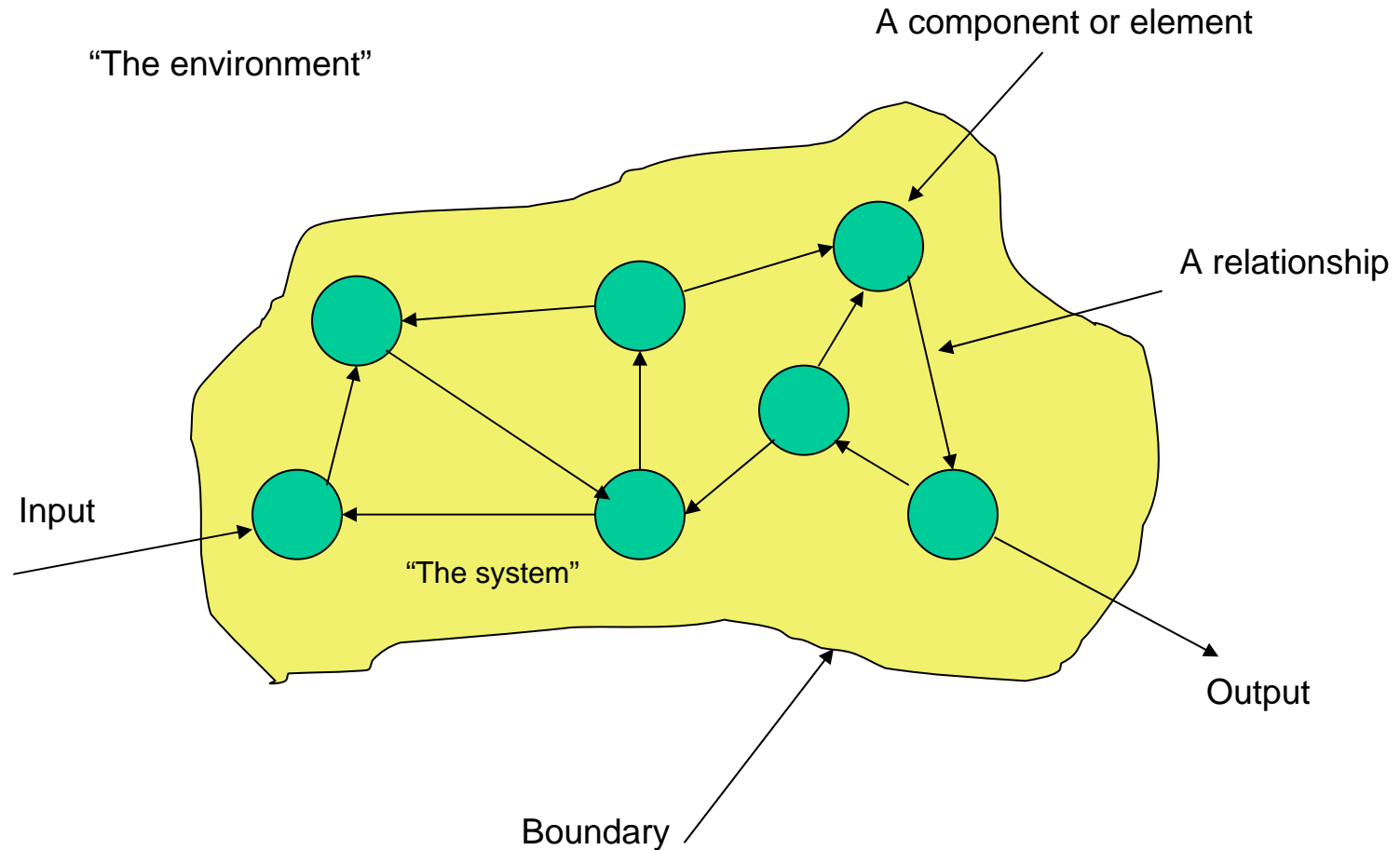
- Watch this video simulation of the recent Mars Exploration Rover (9 mins)
- While you watch, think about the “system”
- Is it a group of interrelated, interdependent and/or interacting elements forming a collective entity?
- If you were “designing” this system, what sort of things would you need to think about?



Key System Concepts

- **Holism** - the need to consider the whole entity when reasoning, designing, analysing.
- **Hierarchy** - a system comprises identifiable parts which are in turn often composed of identifiable parts.
- **Complexity** - systems are inherently complex.
- **Emergence** - systems are more than the sum of their parts.
- **Synergy** - requires interaction between the parts.
- **Interdependence** - the value added by the system is created by the relationships among the parts; i.e. how they are interconnected.
- Can you recognise these in the Mars Rover?

A General Concept of a System

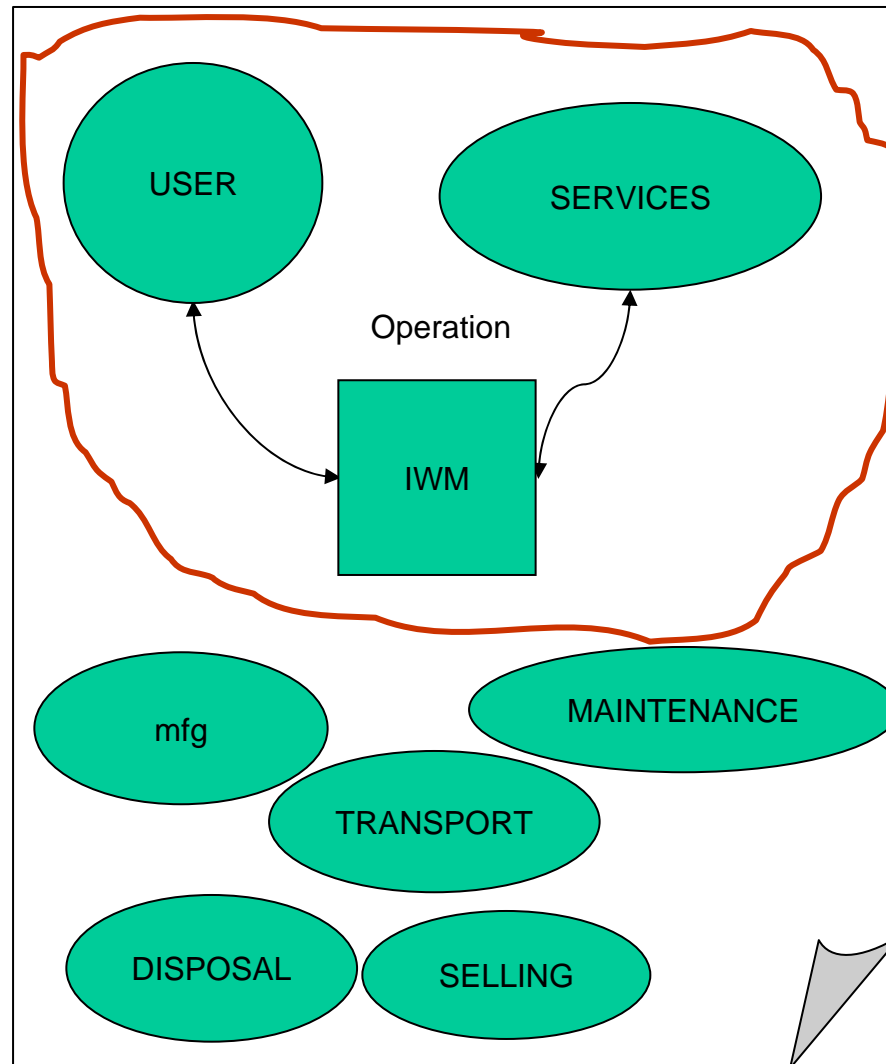


Exercise: IWM Context Diagram

- Let's draw a diagram for a hypothetical washing machine.
- What is part of the “system”?
- What is outside of the system boundary?
- How will all of these things impact on the design?



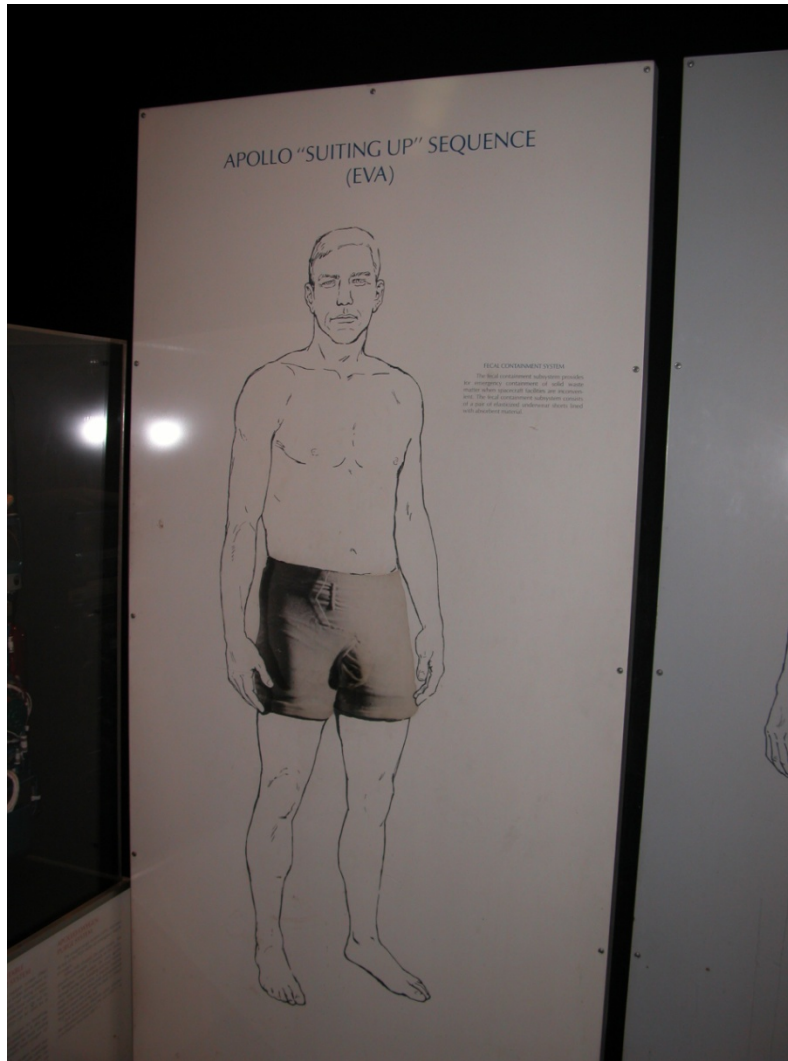
IWM Context Diagram



Is the IWM a System?

- Will it exist within an external environment?
- Will it receive inputs from that environment?
- Will it send outputs to that environment?
- Will it consist of components (sub-systems) that interact in some way?
- Will those components (sub-systems) themselves consist of smaller, interacting parts?
- Will it do things that the sub-systems on their own can't do?
- Is it a “system”?

Non-Systems!



The **Faecal Containment System**,
is what APOLLO Astronauts
had to wear on missions
in the late 1960's.

“System” is probably the wrong
word.

Non-Systems



Here we find a more appropriate term for this kind of structure. This is the

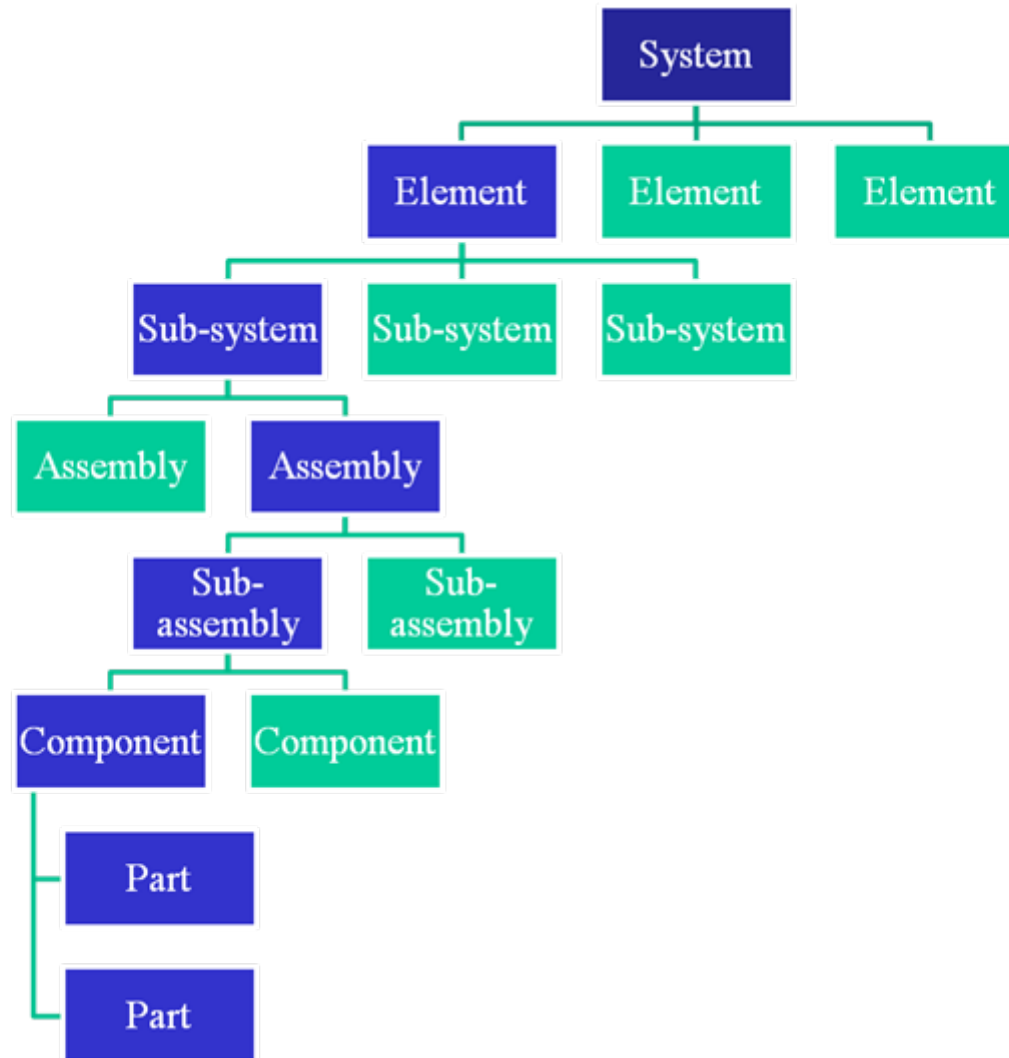
“Urinary Collection Sub-Assembly”

which gives a better indication of its place in the overall hierarchy of a system.

The System Hierarchy

- System
 - Information System
- Element/Segment
 - Computers, Network, Printers, Data Storage, Personnel
- Sub-system
 - Data Processor, Operating System, Software
- Assembly
- Subassembly
- Component
 - I/O, CPU, RAM, ROM
- Part

System Hierarchy



Creating a System

- First step in developing a system:
 - Rush off and start building?
 - Find out more?
 - Mistakes are much cheaper to fix now, before we've built anything, than later, when we've constructed an expensive prototype.
- What does the customer really want?
- IWM System???
 - Yes, but is that all there is to it?
- **Who** is the customer(s)?

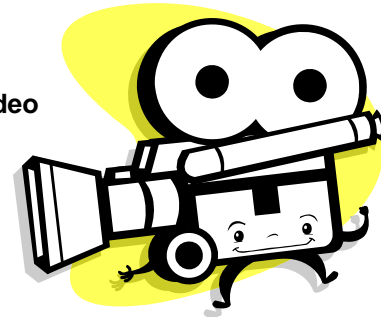
Needs Analysis - OCD

- Typically start with Operational Concept Definition (OCD):
 - **what** will the operational (working) system do?
 - **why** does it need to do it (rationale)?
 - **how well** does it need to do it (performance)?
- But **NOT**: **how** (no solutions yet)
- Briefing Paper. ✓
- Talking to customer?
- Thinking, looking, etc.?



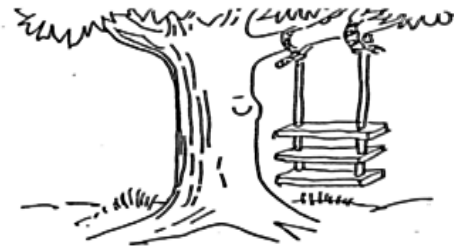
Understanding what the customer wants isn't always straightforward. It's easy to make assumptions, but you may be wrong!

Car-Breakdown Video

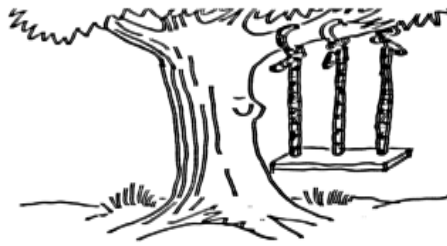


Step 1 - Communicate with the customer, and find out, very clearly, what they need to solve their problem

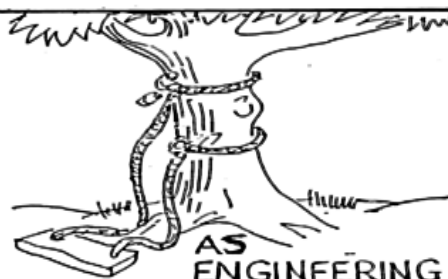




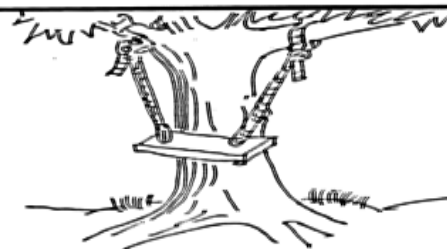
AS MARKETING REQUESTED IT



AS SALES ORDERED IT



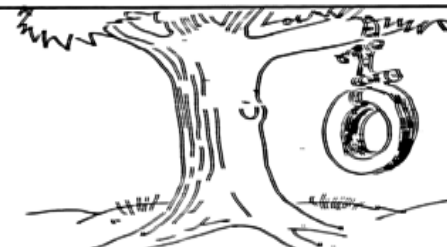
AS ENGINEERING DESIGNED IT



AS PRODUCTION MANUFACTURED IT

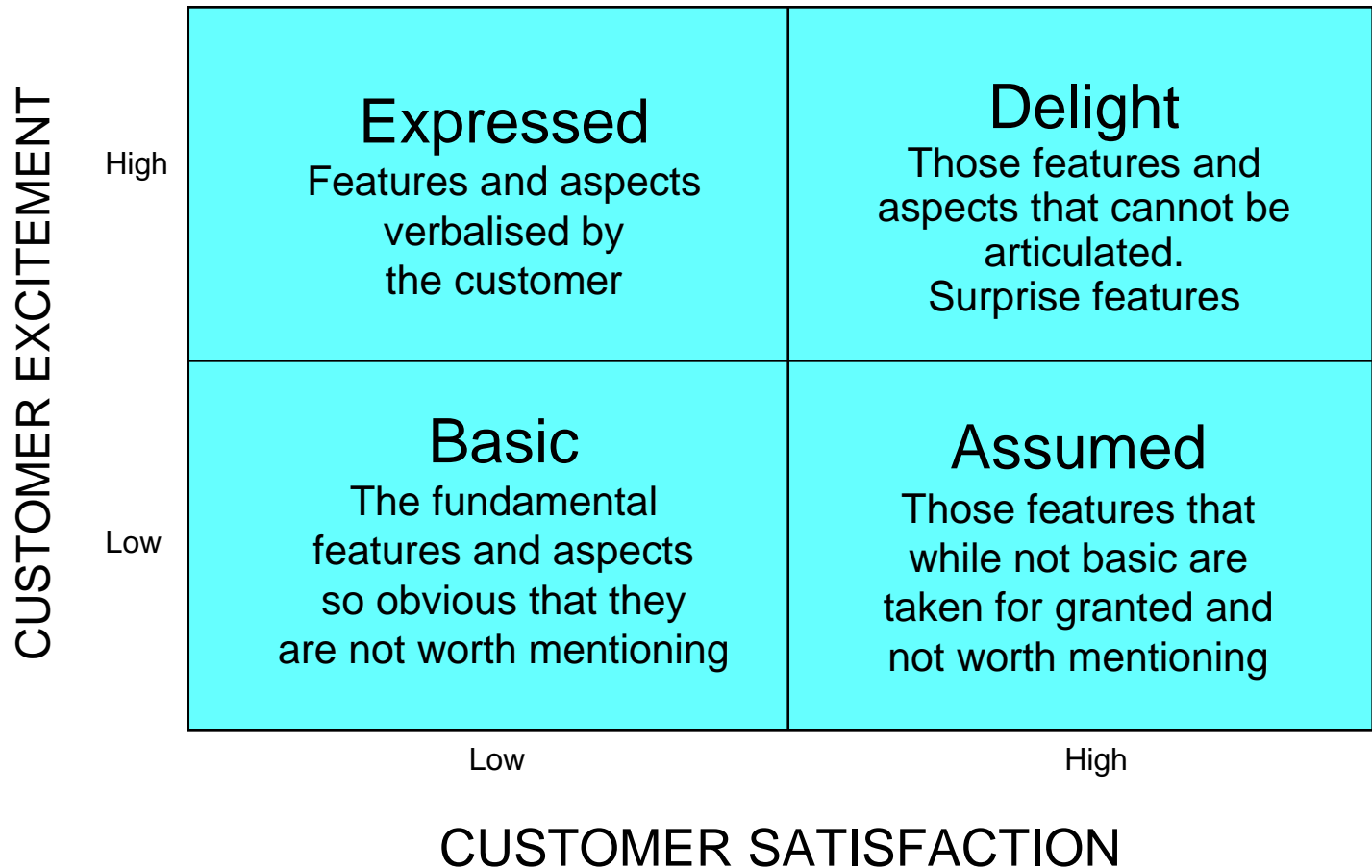


AS FIELD ENGINEERING INSTALLED IT



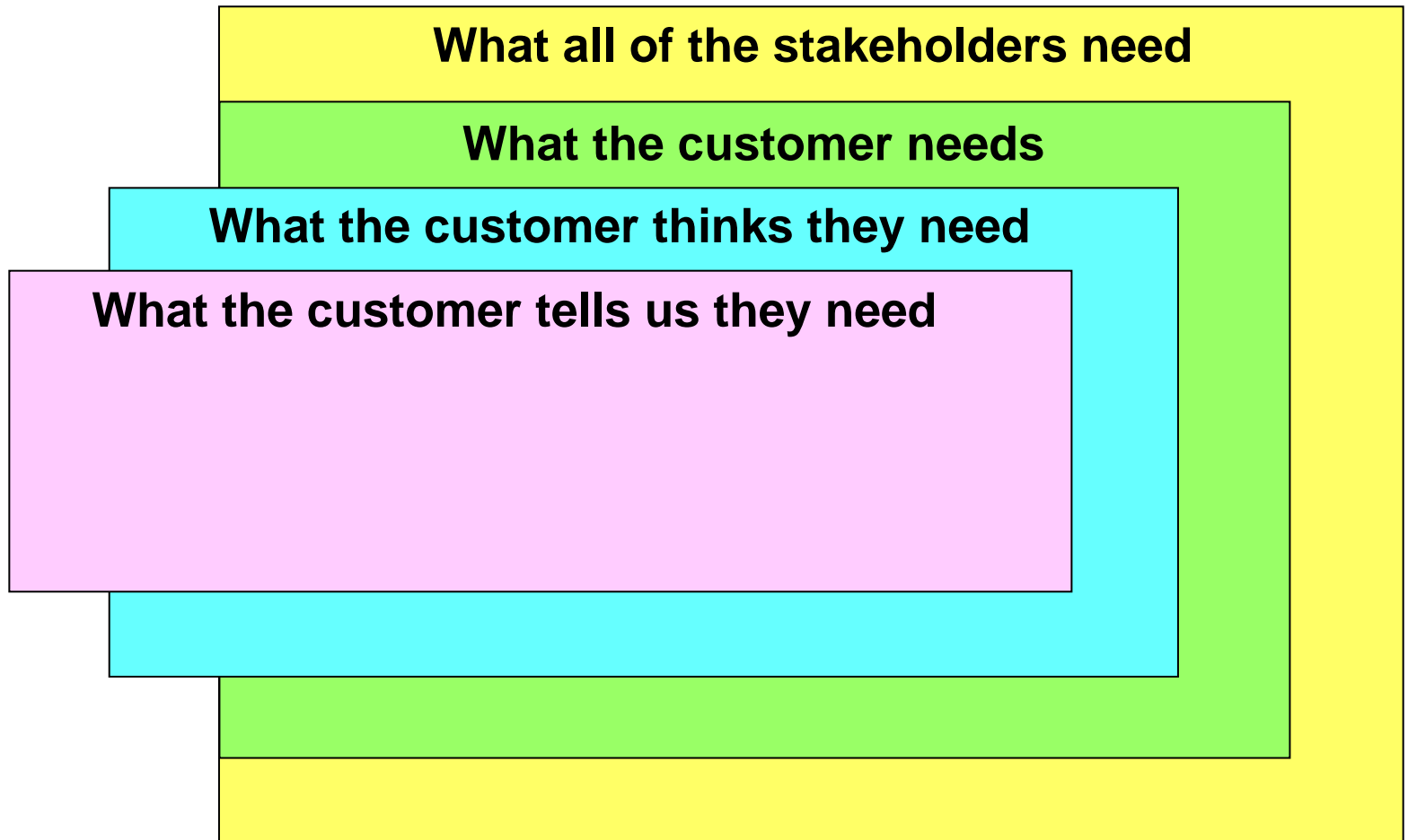
WHAT THE CUSTOMER WANTED

Customers can't get no Satisfaction



Customers require more than satisfaction; Customers only tell us their expressed requirements; Typically only 20% - 30% of the full set of requirements.

The Challenge

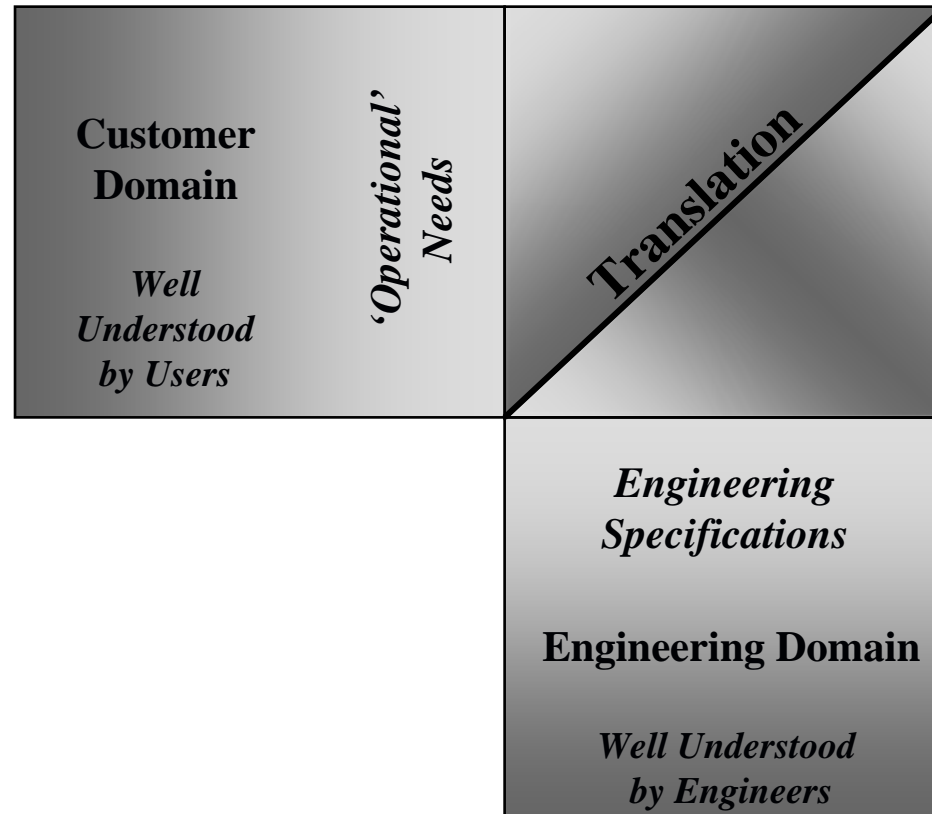


The Right Need

- Engineers: difficult job of translating customer need into formal, technical language (**specification**).
- Specifications: technical plan for system.
- Key step for engineers: make sure understand what customer wants, give customer a system that solves their problem.
- If customer can't state their *real* need, or the engineers misinterpret the need, the solution (system) will be wrong.



Translating the Need into “Engineer Speak”



Objectives of Customer Needs Identification



- To ensure that the system definition is driven by, and focused on, the customers' **real** needs
- To identify the hidden needs as well as the known needs
- To create a baseline to justify the system specification
- To verify that no critical need will be forgotten
- To develop a common understanding and common language of the customers' needs in the system development team

Exercise: IWM Customer Need

- Read the handout that outlines the “need” for the Intelligent Washing Machine.
- Ask questions.



What? - Requirements Types

- Requirements can be classified as:
 - Operational
 - Functional
 - Non-functional
 - performance requirements
 - system requirements
 - implementation requirements



Operational Requirements

- Operational requirements define the major purpose of a product/system (i.e. what it fundamentally does - its capability) together with the key overarching constraints.

System	Operational Requirement
Dish Washer	To clean eating and cooking utensils without damage
Civil Aircraft	To transfer passengers and their Baggage from one point to another safely



Functional Requirements

- Functional requirements specify **what** the product/system has to do in order to satisfy the operational requirement.
- For example some of the functional requirements of a civil aircraft are:
 - navigate
 - control flight
 - stow passengers
 - control cabin environment
 - communicate with other aircraft and ATC
 - etc
- Note that functional requirements contain a verb.

Non-functional Requirements

- Non-functional requirements are constraints on the system/product.
- They fall into three categories:
 - Non-functional Performance
 - Non-functional System
 - Non-functional Implementation.



Non-functional Performance Requirements

- Non-functional performance requirements are associated with corresponding functional requirements and define **how well** a particular function has to perform.

System	Function	Performance Requirement
Aircraft	Navigate	Accuracy = +/- 1mile in 3,000
Dish washer	Heat Water	+/- 1°C of set value



Non-functional System Requirements

- Non-functional system requirements define modifying influences/**constraints** that affect the whole system and include:

- safety
- cost
- size
- Weight
- reliability
- maintainability
- Deployability
- etc

} This group is often referred to as the “illities” – note there are many illities

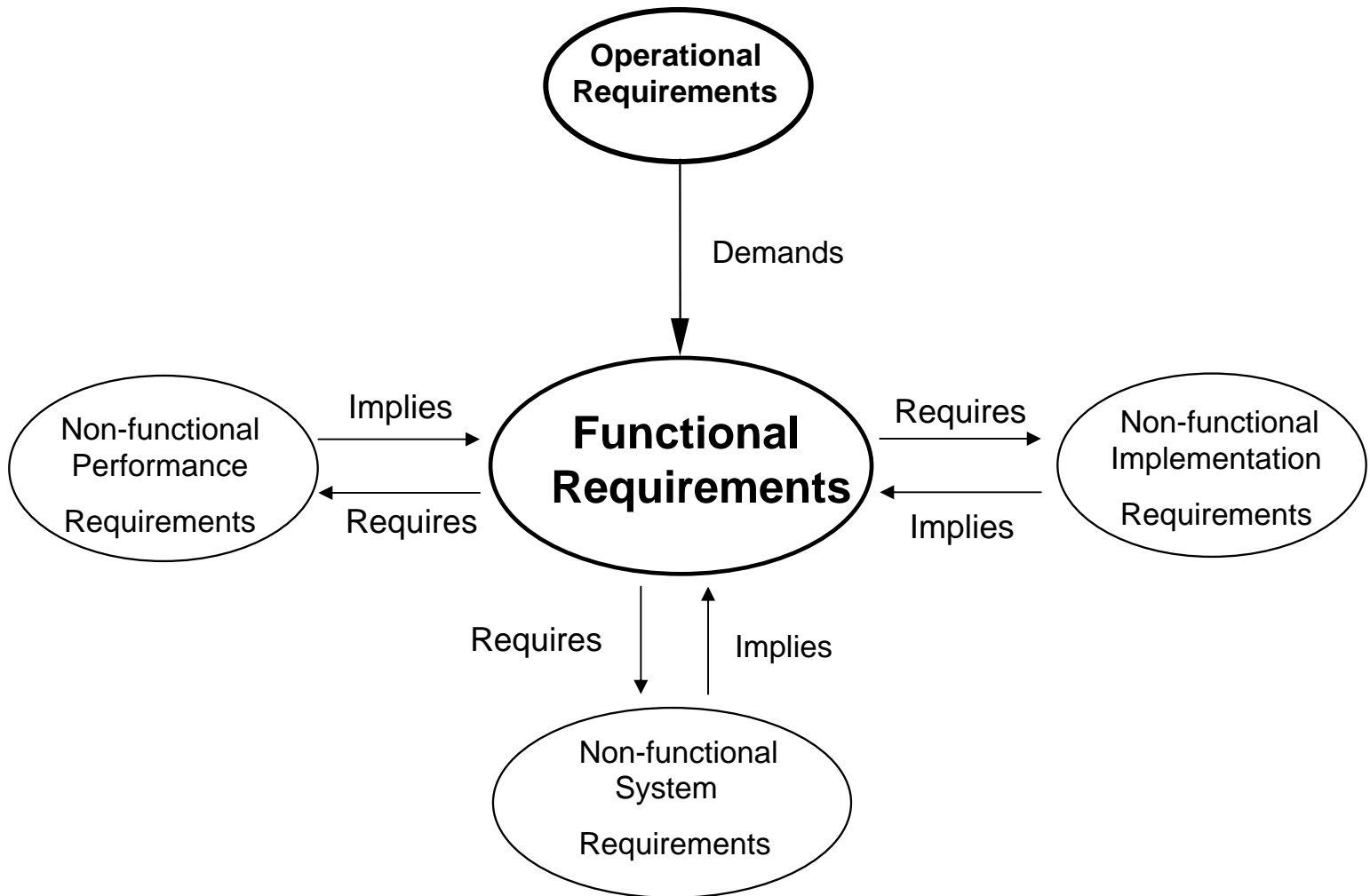


Non-functional Implementation Requirements

- Non-functional implementation requirements define **how** a system is to be built in terms of specific technology. They are specific requirements from the customer about a solution they require or legislative requirements.

System	Function	Implementation Requirement
Aircraft	Communicate	Phillips A/C 1267 VHF Radio
Dish washer	Remove Waste	Danfoss 123 Electric Pump

Using Structured Requirements

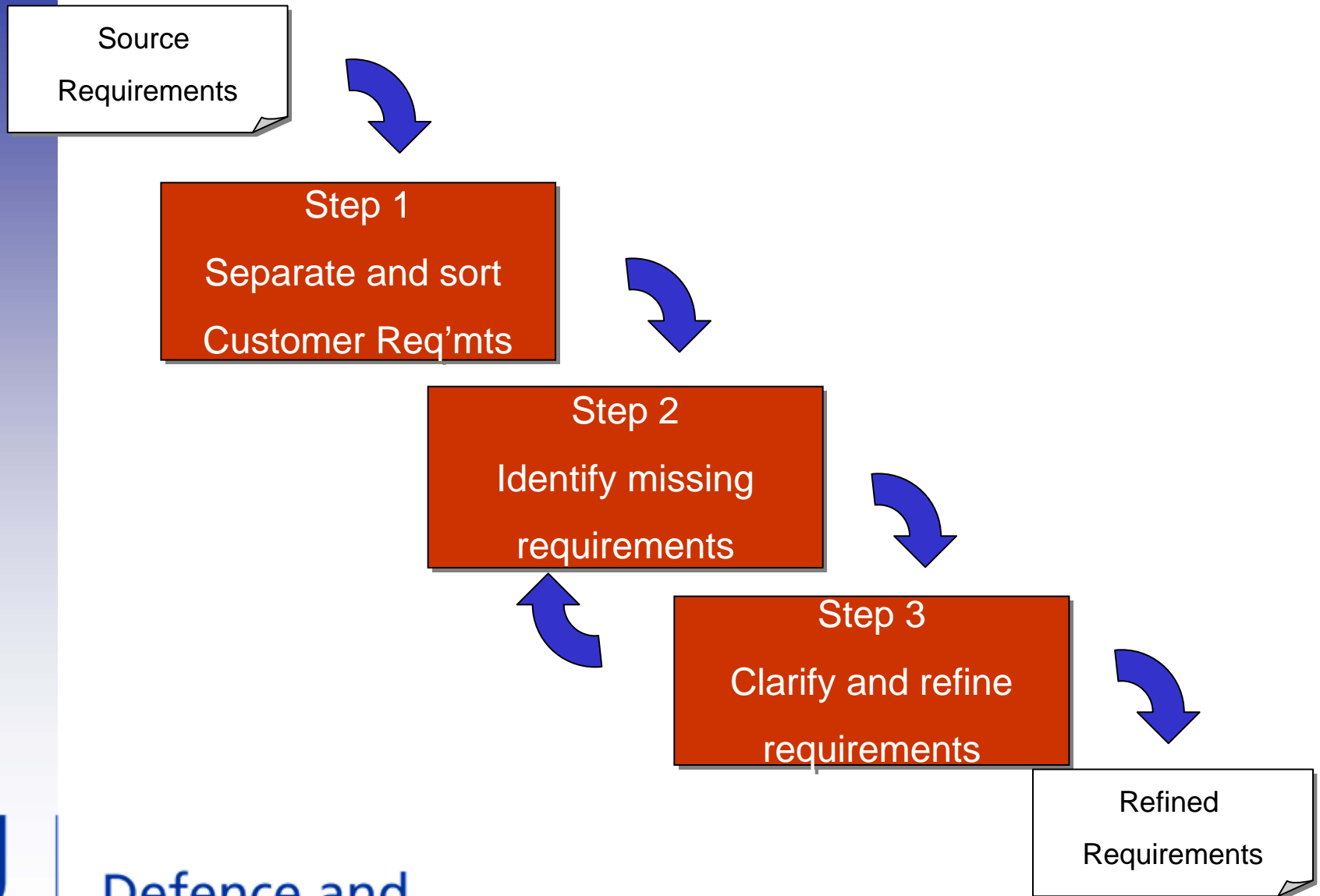


Exercise: IWM Requirements Analysis

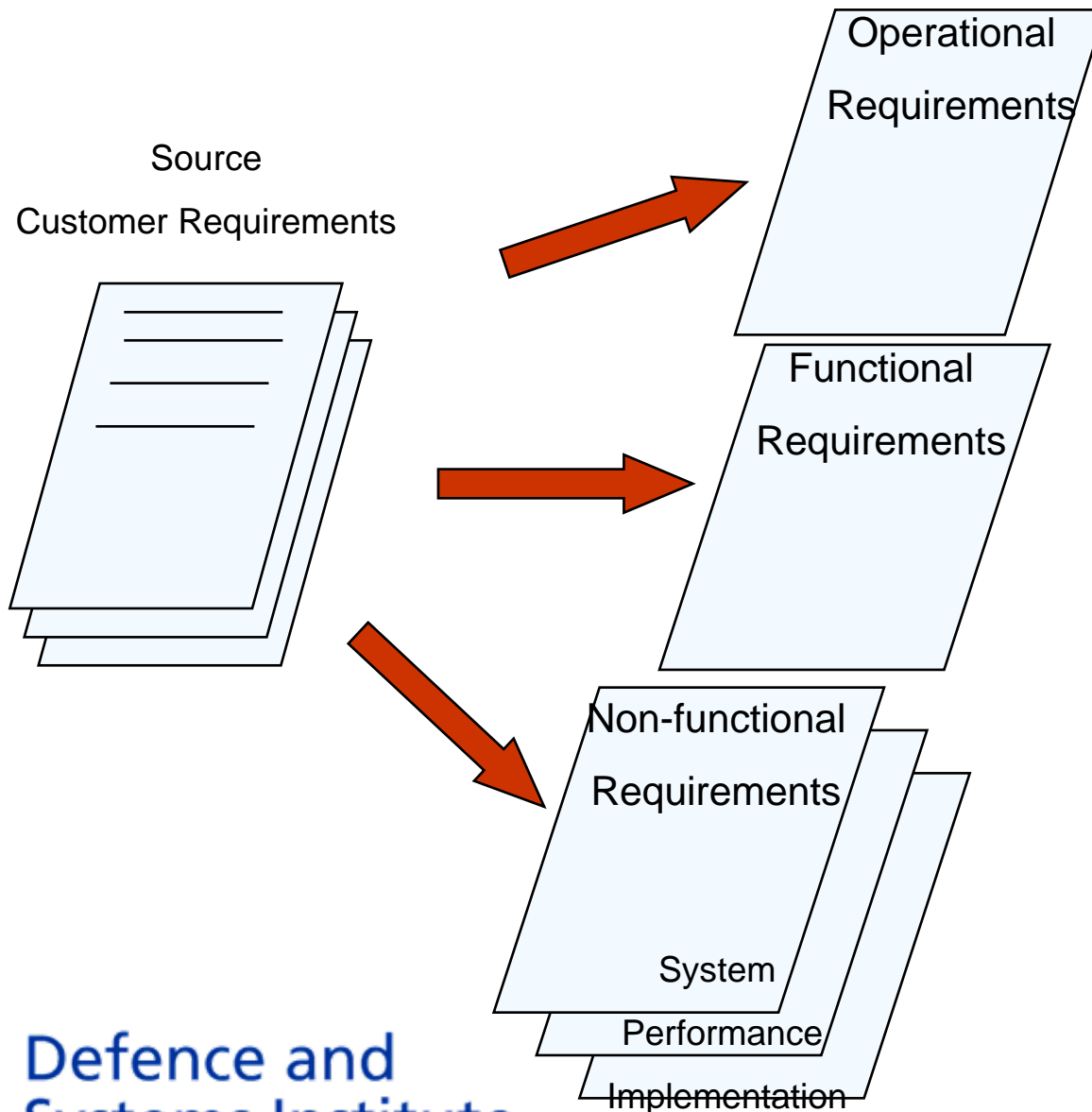
- Perform a textual analysis on the customer need statement.
- Determine the different types of requirements for the IWM.



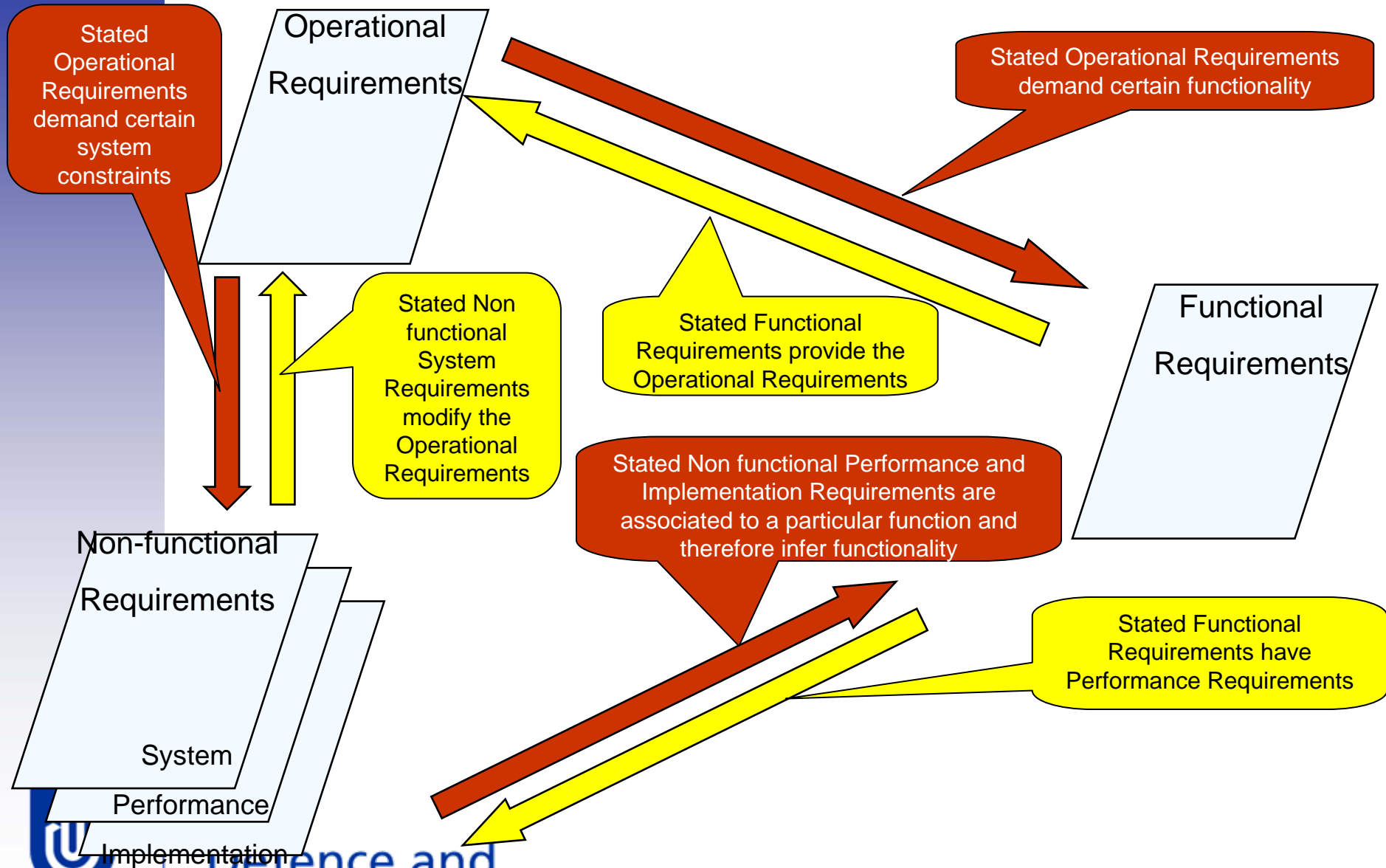
Structured Textual Analysis Process



Step 1: Separate and Sort Customer Requirements



Step 2: Identify Missing Requirements



Step 3: Clarify and Refine?

- A good requirement should be:
 - Clear and Unambiguous
 - Consistent
 - Complete
 - Verifiable
- This means wherever possible:
 - A requirement should be a complete and correct sentence.



Comments: IWM Requirements Analysis

- There is no simple clear Operational Requirement.
- Remember the operational requirement(s) should give the fundamental purpose of the system (to wash clothes and other items) together with any overarching constraints (automatically – without damage).



Comments: IWM RA

- The requirements to use “domestic water” and “electricity supplies” are Non Functional Implementation Requirements
 - items can be cleaned using fluids and processes other than water.
 - electricity is not the only power source.
- Fix the cleaning fluid as water?
 - There is, of course, no right answer. Indeed, the whole problem can be elevated a level as to whether a customer actually needs a washing machine? They do not, they need clean clothes and there are (potentially) other ways of doing this.
- “Spin” as a function? Not a true function but a way of “extracting water” (which is the function).
 - Spin is therefore a Non Functional Implementation Requirement.
- Similar arguments can be applied to “Wash” and “Rinse” since they imply the use of water.

INTELLIGENT WASHING MACHINE

OPERATIONAL REQUIREMENT

"To Automatically clean clothes without damage"

FUNCTIONAL REQUIREMENTS

- DETERMINE LOAD MAKEUP
- DETERMINE MIXED LOADS
- DETERMINE BEST CLEANING CYCLE
- INFORM USER OF EXTREME LOADS
- INFORM USER OF CURRENT STATUS
- INFORM USER OF WASH CYCLE
- OVERRIDE WASH CYCLE
- WASH CLOTHES
- RINSE CLOTHES
- REMOVE EXCESS WATER (SPIN)

NON FUNCTIONAL REQUIREMENTS

NF SYSTEM.

- MINIMISE DOMESTIC CHORES
- COMPLEMENT EXISTING TOP OF RANGE MODEL
- SHOULD BE A LIFESTYLE STATEMENT
- ATTRACTIVE & DISTINCTIVE

NF SYSTEM (CONT.)

- SALES OF 50K TO 75K PER ANNUM
- SELLING PRICE £550 TO £650 (INCLUDING VAT)
- STANDARD SIZE
- STANDARD 5kg LOAD
- EASY TO USE
- AVERAGE USEFUL LIFE 7 YEARS
- FIRST YEAR FAILURE RATE < 10%
- NOISE LEVEL < 91.5 dB
- VIBRATION < 0.5g RMS & 3.2g PEAK
- ENERGY EFFICIENT GRADE A
- COMPLIES WITH UK & EU SAFETY STANDARDS

NF PERFORMANCE REQUIREMENTS

- APPROPRIATE TEMPERATURES TO FABRIC TYPE
- 1600 RPM SPIN SPEED

NF IMPLEMENTATION REQUIREMENTS

- SINGLE PHASE 230V 50Hz SUPPLY
- DOMESTIC WATER
- CURRENTLY AVAILABLE DETERGENTS
- SPIN DRY
- (COULD ALSO INCLUDE WASH → CLEAN
RINSE → REMOVE CLEANING AGENTS)

View Point Analysis

- Textual Analysis is just one way to tease out the requirements for a system.
- Another good one, that both fills in some gaps, and helps to establish the functions required of the system is View Point Analysis.
- There are two basic “viewpoints”:
 - Functional
 - Non-functional.



Functional Viewpoints

- A functional viewpoint is defined as:
 - A logical partitioning of the system into the functions that are necessary for the system to achieve its operational requirement/capability
- There are two types of functional viewpoint:
 - **BOUNDING**: A bounding viewpoint is a view of the product/system from the outside – this highlights external functionality of the system of interest particularly life-cycle factors.
 - **DEFINING**: A defining viewpoint is a view of the product/system from the inside and is used to describe the internal function.

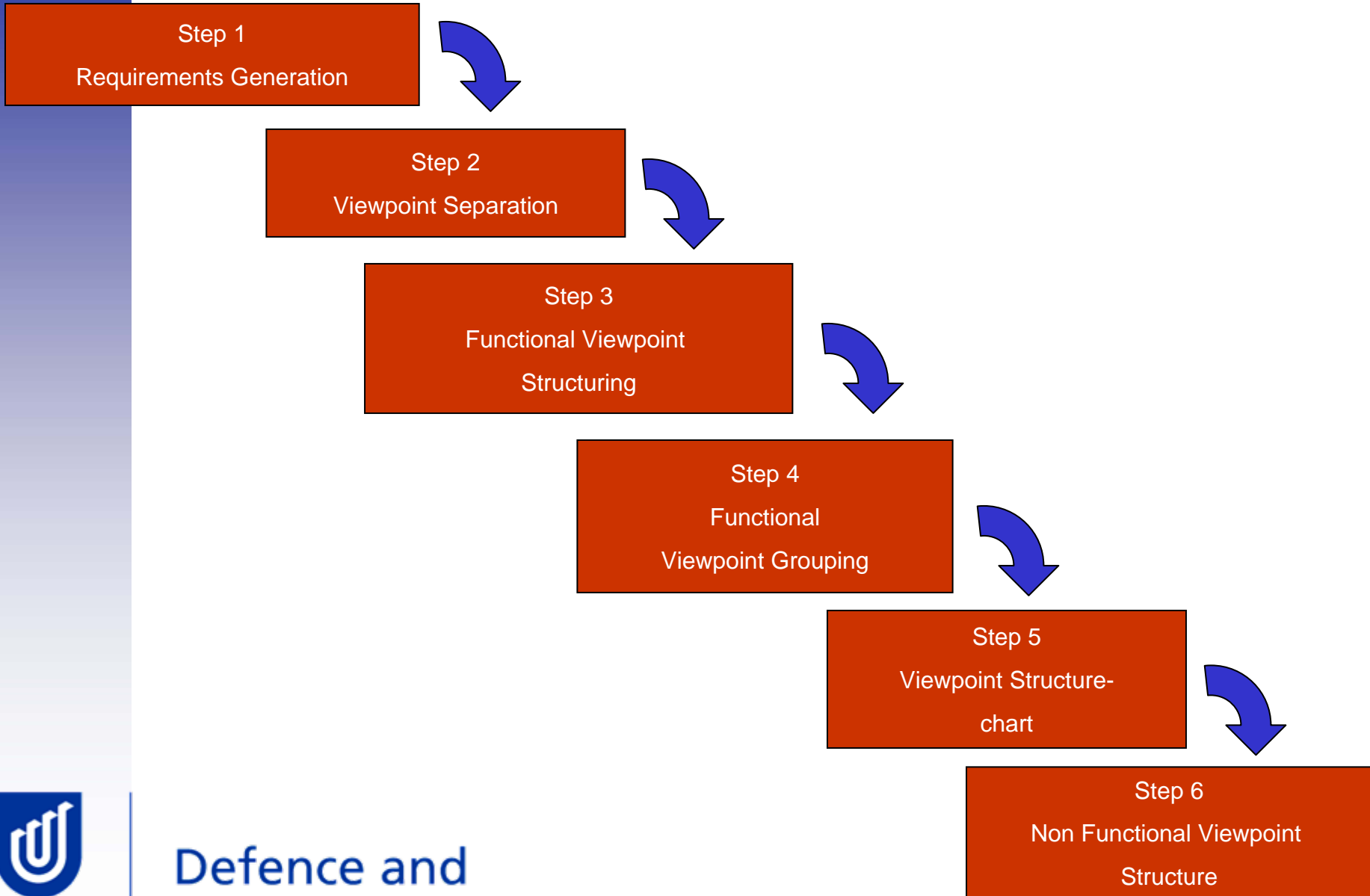


Non-Functional Viewpoints

- A non-functional viewpoint is defined as:
 - groups of requirements that modify or constrain the functional requirements of the product/system.
- Non-functional viewpoint requirements modify parts of the product/system.
- It is usual to consider them in small groups such as Safety, Reliability, Cost, Integrity, etc.



Viewpoint Analysis Process



Step 1: Requirements Generation

- The first stage is to determine the requirements that will make up the functional and non-functional viewpoints.
- It is important to remember that the customer requirements will not be complete and the team have to derive the ‘missing’ and ‘assumed’ requirements.
- The team “brainstorm” and write down all possible requirements on a **Viewpoint Bubble Diagram**, the sorting comes next.
- A key point to note here is that the requirements come from the customer requirements document, legislative documents **and** from the experience of the team.
- We should “brainstorm” requirements not solutions.

Example

Hovermo Ltd

Requirement for an Autonomous Lawn Mower

The Marketing department has identified a small but potentially profitable need for an intelligent lawn mower that is capable of autonomous operation.

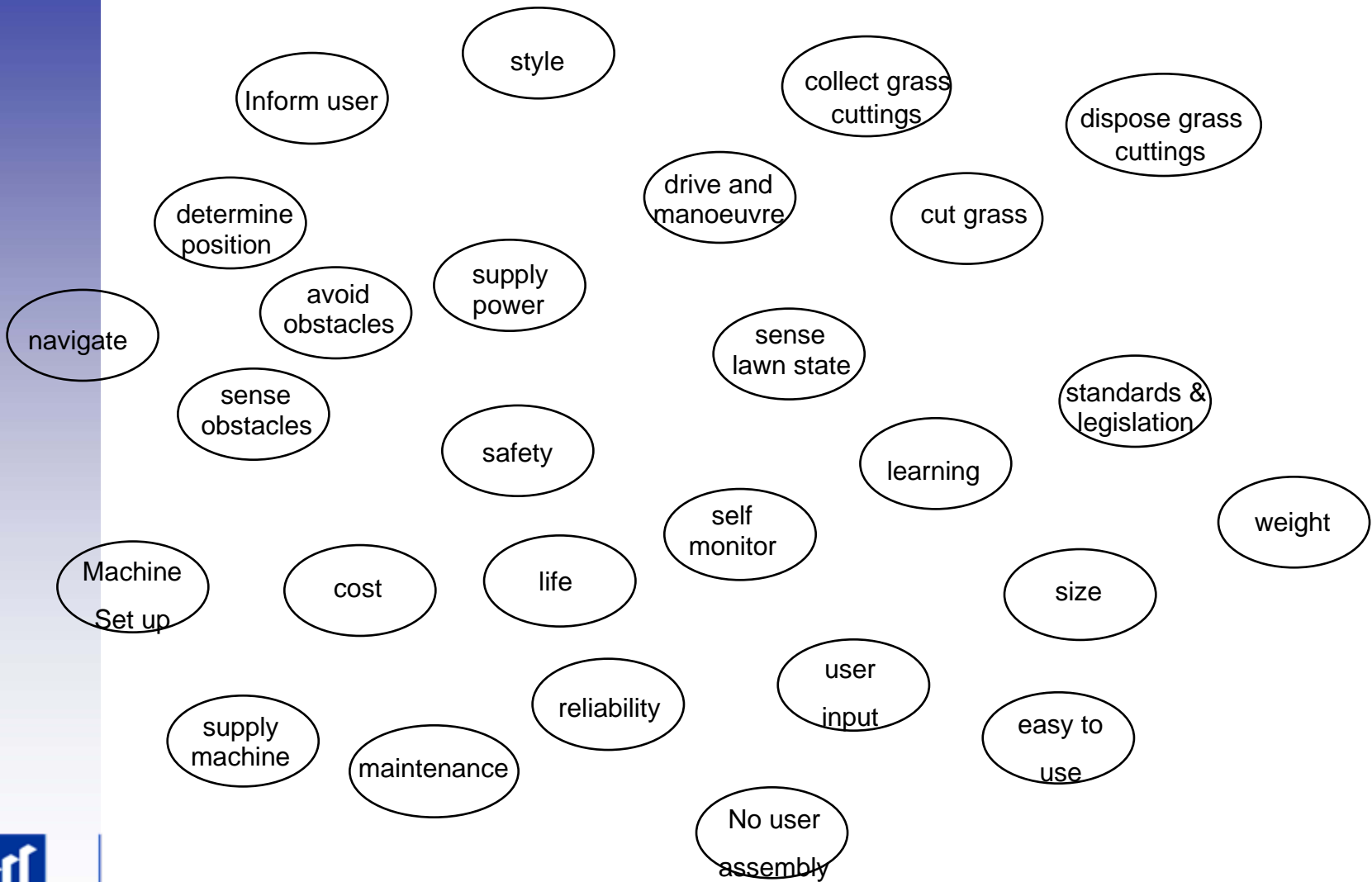
It should be able to autonomously cut grass lawns to the same standard as a conventional human operated hover mower. It should be able to cope with different grass conditions, types and lengths up to 100mm.

It should be able to navigate around a lawn avoiding permanent and moving obstacles. The mower should learn about the shape and position of fixed obstacles.

It must be able to mow a lawn of 300 square metres. The mower will have a self monitoring capability and inform the user of its current status. The machine must be safe. It must be easy to use and it will have a life of at least 10 years and require minimum maintenance.

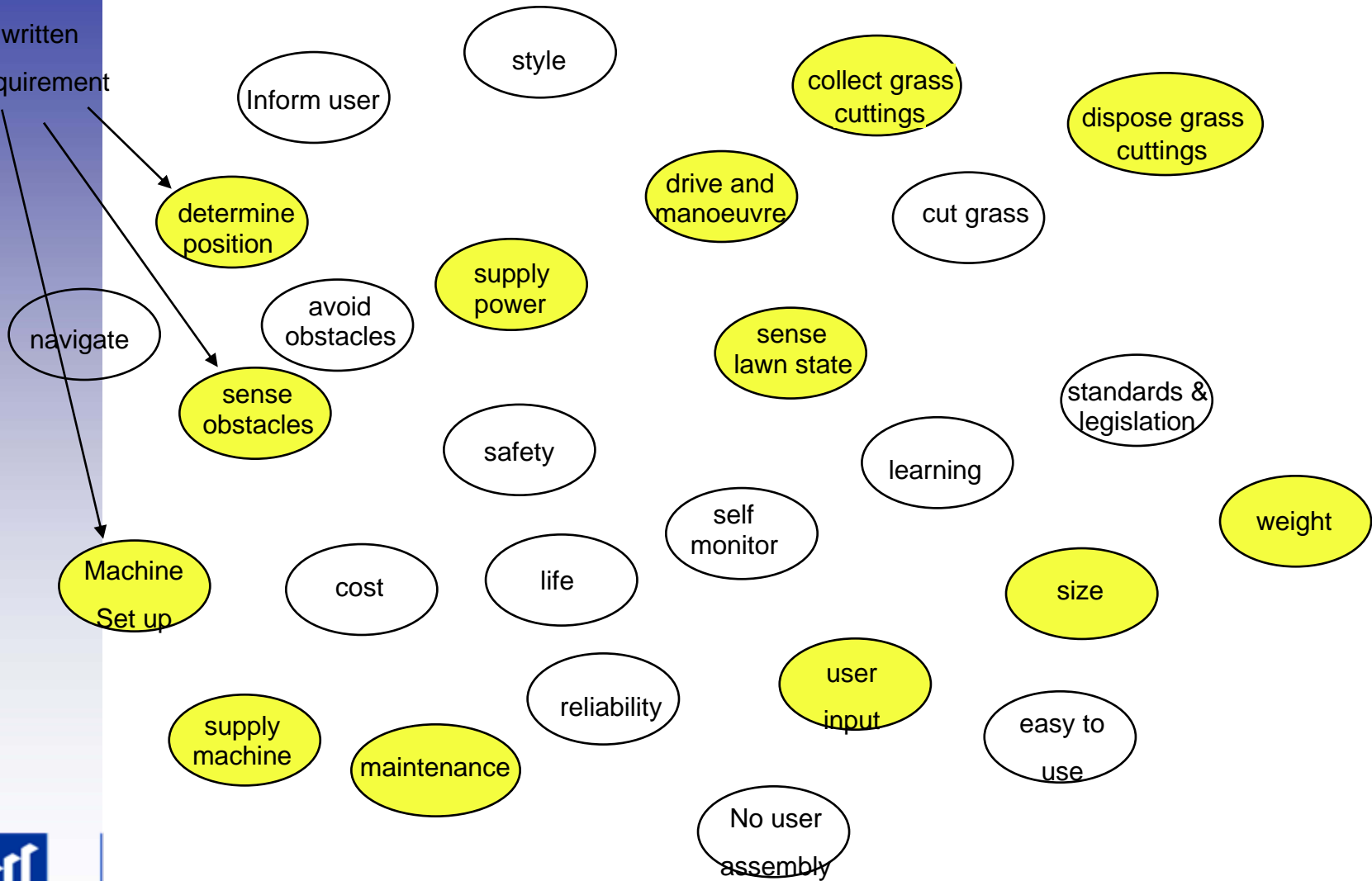
The style must be attractive and require no user assembly. The Purchase Price should be below \$4,000.

Example



The team introduce basic and assumed requirements

Not in written requirement



Step 2: Viewpoint Separation

- The next step in the approach is to partition the functional and non-functional requirements to provide the two basic viewpoints.
- Care should be exercised when identifying the functions that form the functional viewpoint:
 - Function descriptions contain a verb.
 - Functions transform inputs to outputs.
 - If you can't 'ing' it - it ain't a function! Sensing, loading, etc you can't 'safetying'.
 - Functional requirements should be implementation independent.
 - If it cannot be decided whether a requirement is functional or not, it should be put in the functional viewpoint.
- Remember customers tend to specify performance (non-functional), we should consider every bubble to see if it implies a function (which we should deduce and record on the bubble diagram).

System Functions

- When we define the functions that a system has to be able to perform, we also try to make them “solution-free”.
- A screwdriver can “screw (verb) screws (noun)”, but that implies that it can only do that one thing.
- If we say that it can “apply torque” then we realise that it can do more than just screw in screws. That gives us more options.



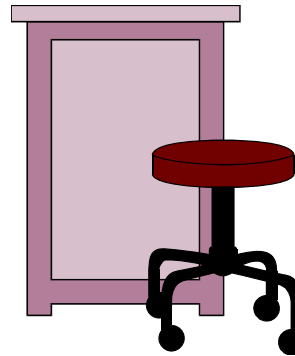
Examples of Functions

Screwdriver -



Apply
Torque

Chair -

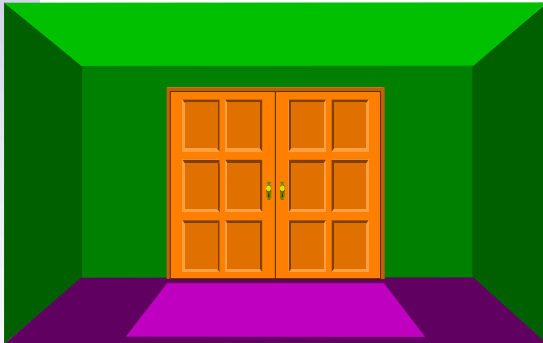


Carry
Weight

Paper clip -

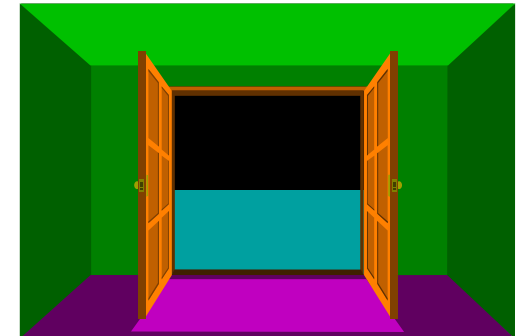


Prevent
Movement

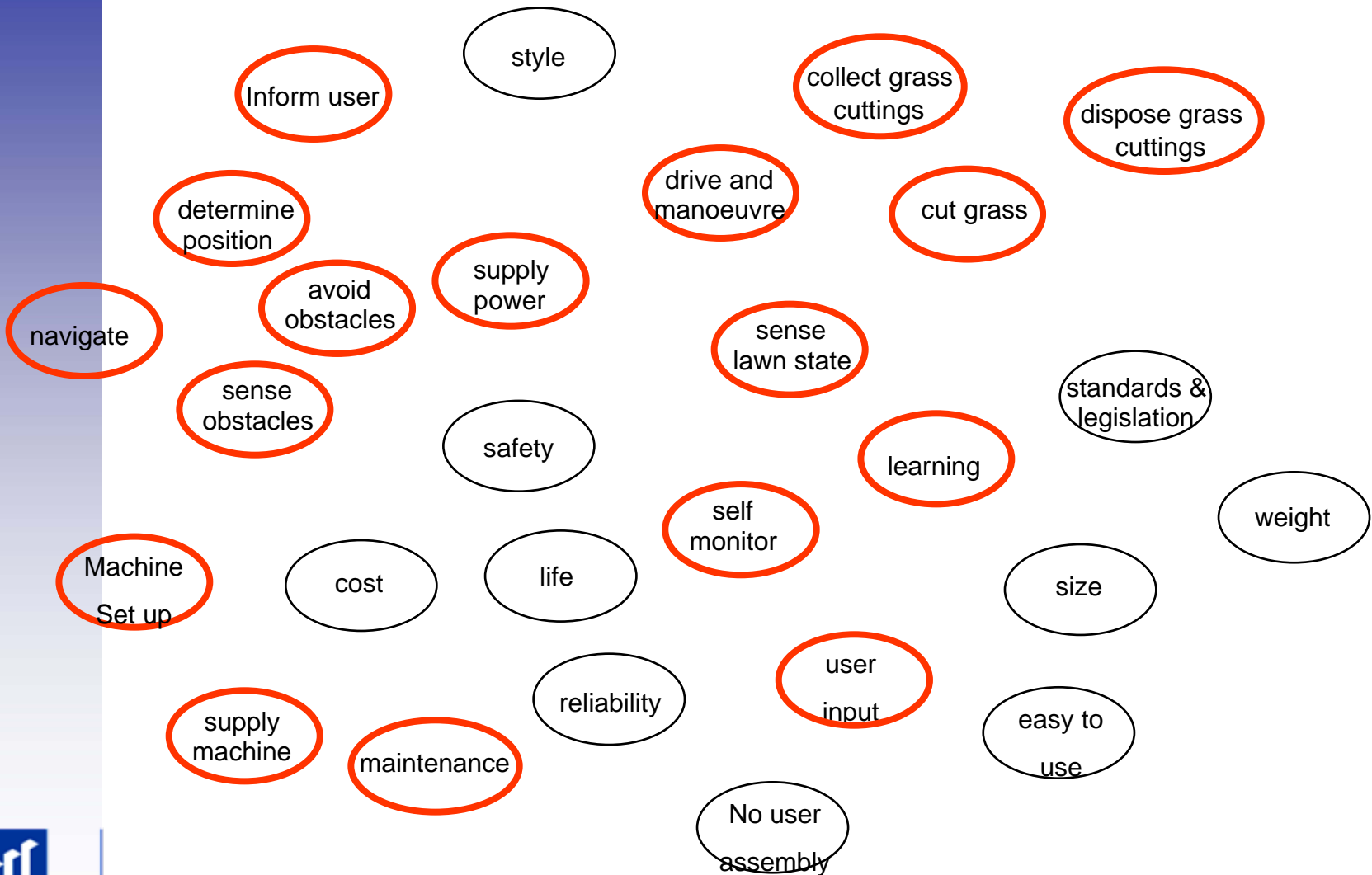


Door -

Control Entry



Functional Viewpoint Bubble Diagram

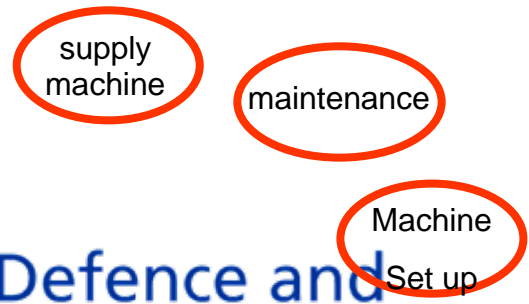
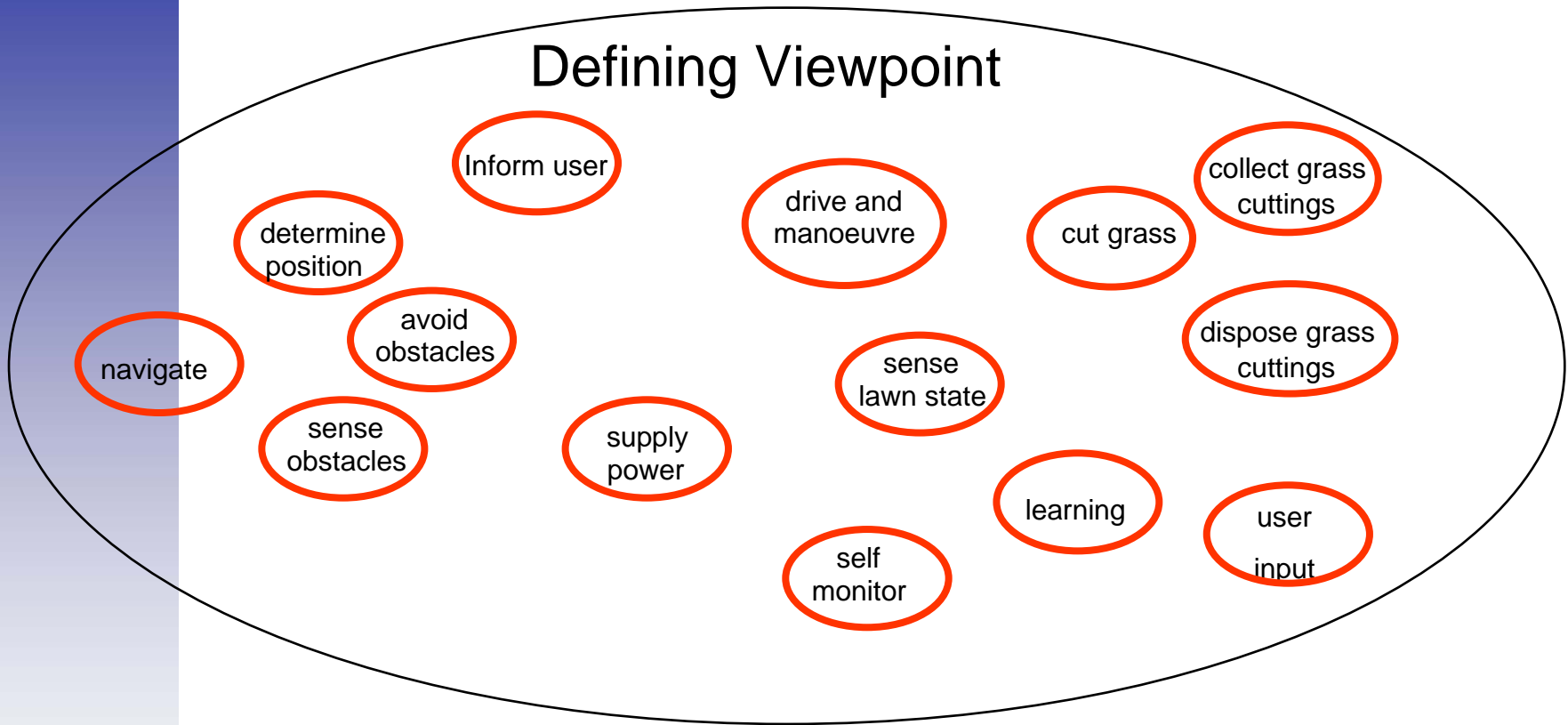


Step 3: Functional Viewpoint Structuring

- The non-functional viewpoint requirements are temporarily discarded and consideration is given to logically structuring the functional viewpoint requirements.
- The first step in structuring the functional viewpoint requirements is to identify the bounding and defining viewpoint requirements.
- This effectively defines the “system of interest” and those systems elements in its environment that it will have to interact with.



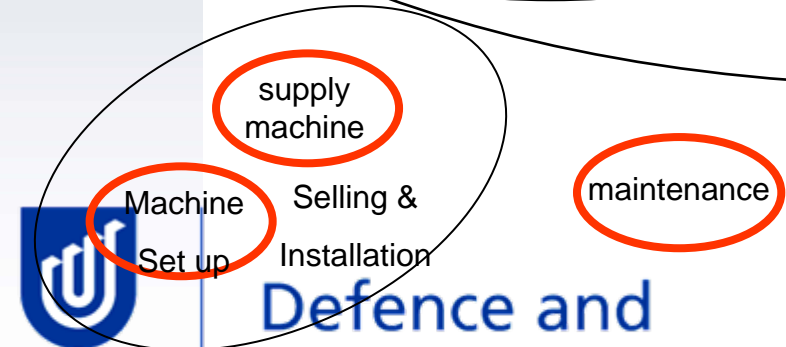
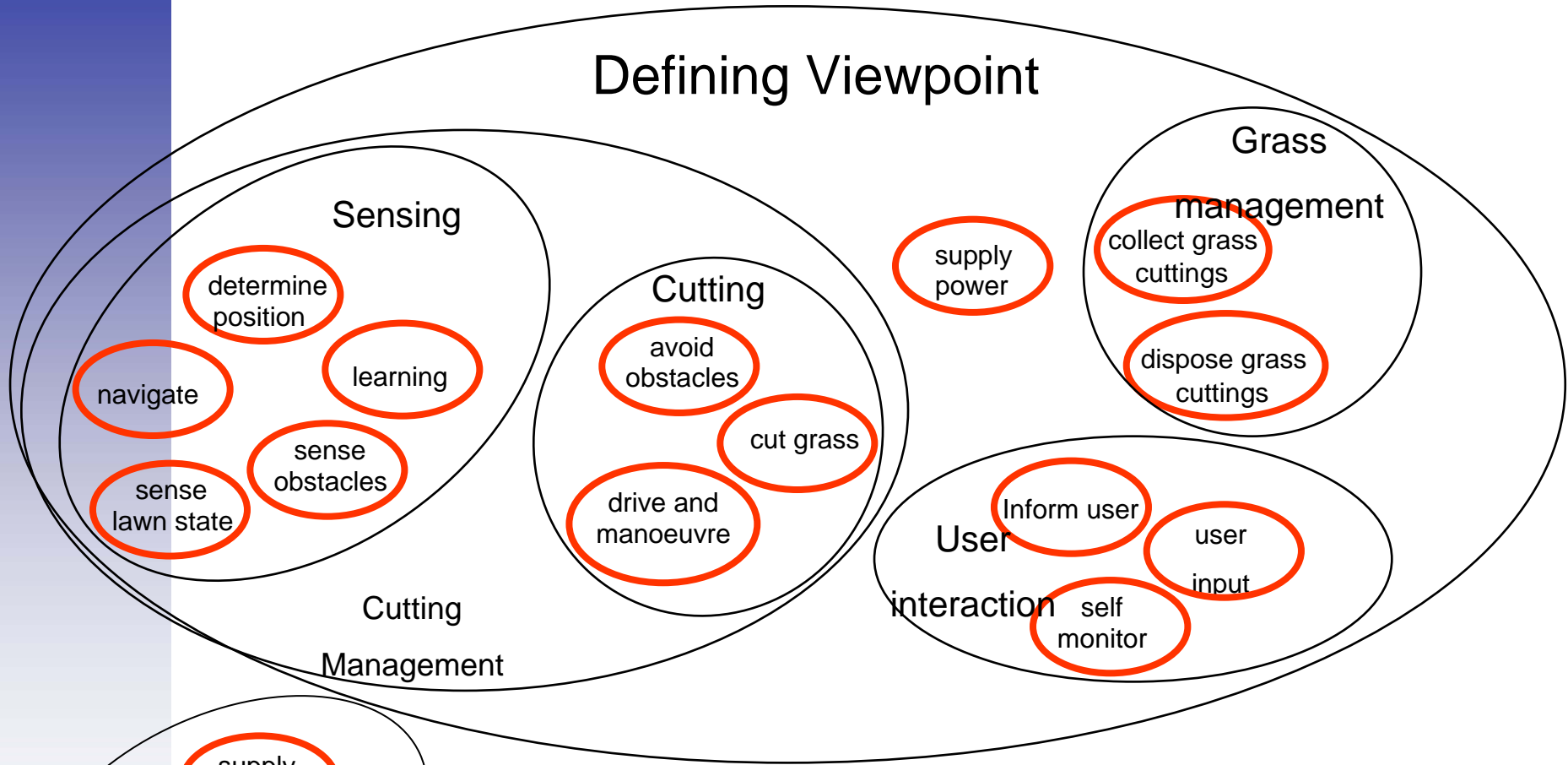
Example: Bounding & Defining



Step 4: Functional Viewpoint Grouping

- The next step is to logically group the functions together so that at any one level of grouping there is a maximum of 5 functions.
- The groups should be logical and named
 - If you have difficulty deciding a name the grouping is not logical – look for another grouping.

Grouping 'Bounding' & 'Defining'

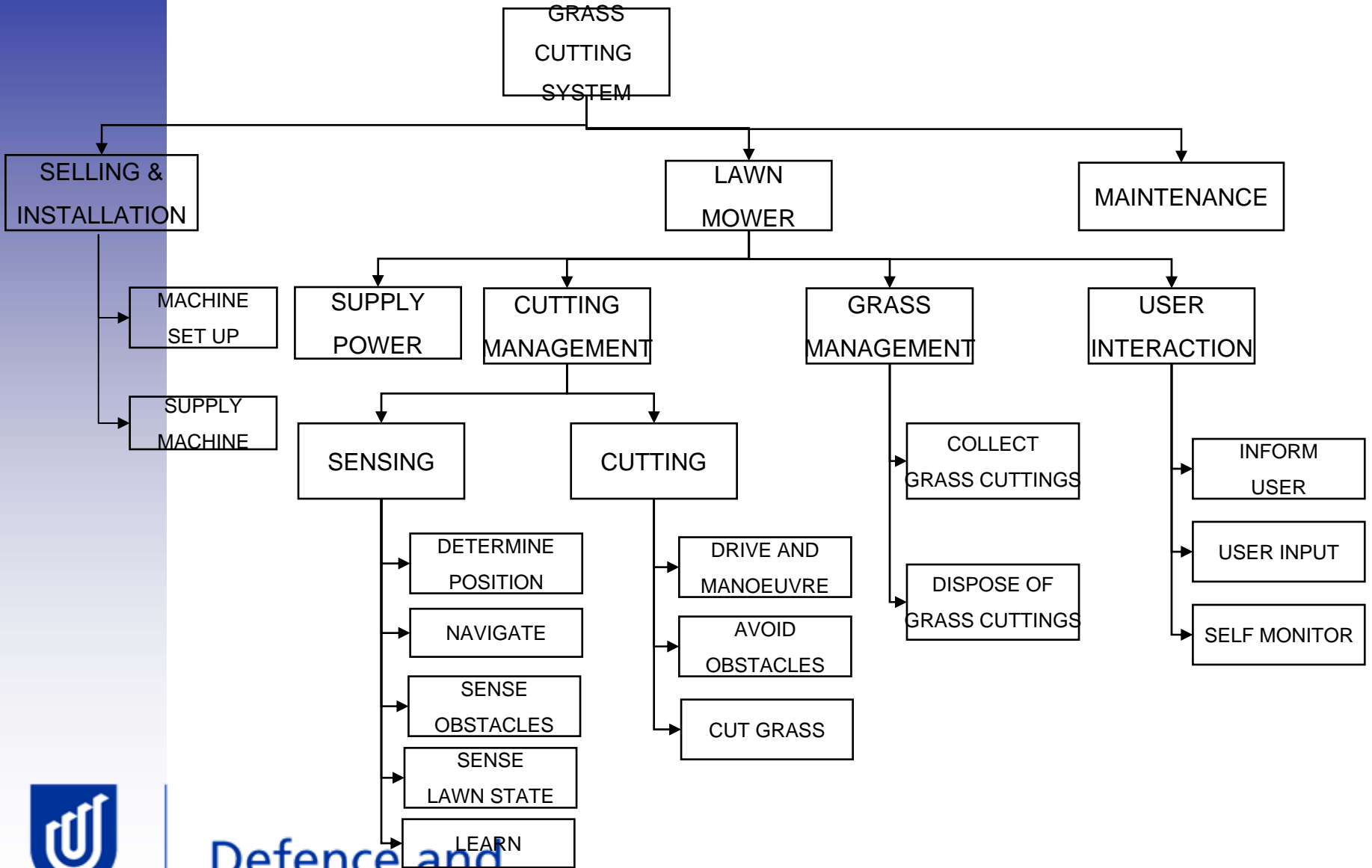


Step 5: Viewpoint Structure Chart

- The penultimate stage is to convert the structured viewpoint bubble diagram into a viewpoint structure chart.
- In practice it is found that the bounding viewpoint functions impact at the same level as the system of interest.
 - The method automatically elevates these aspects such that their importance is recognised early.



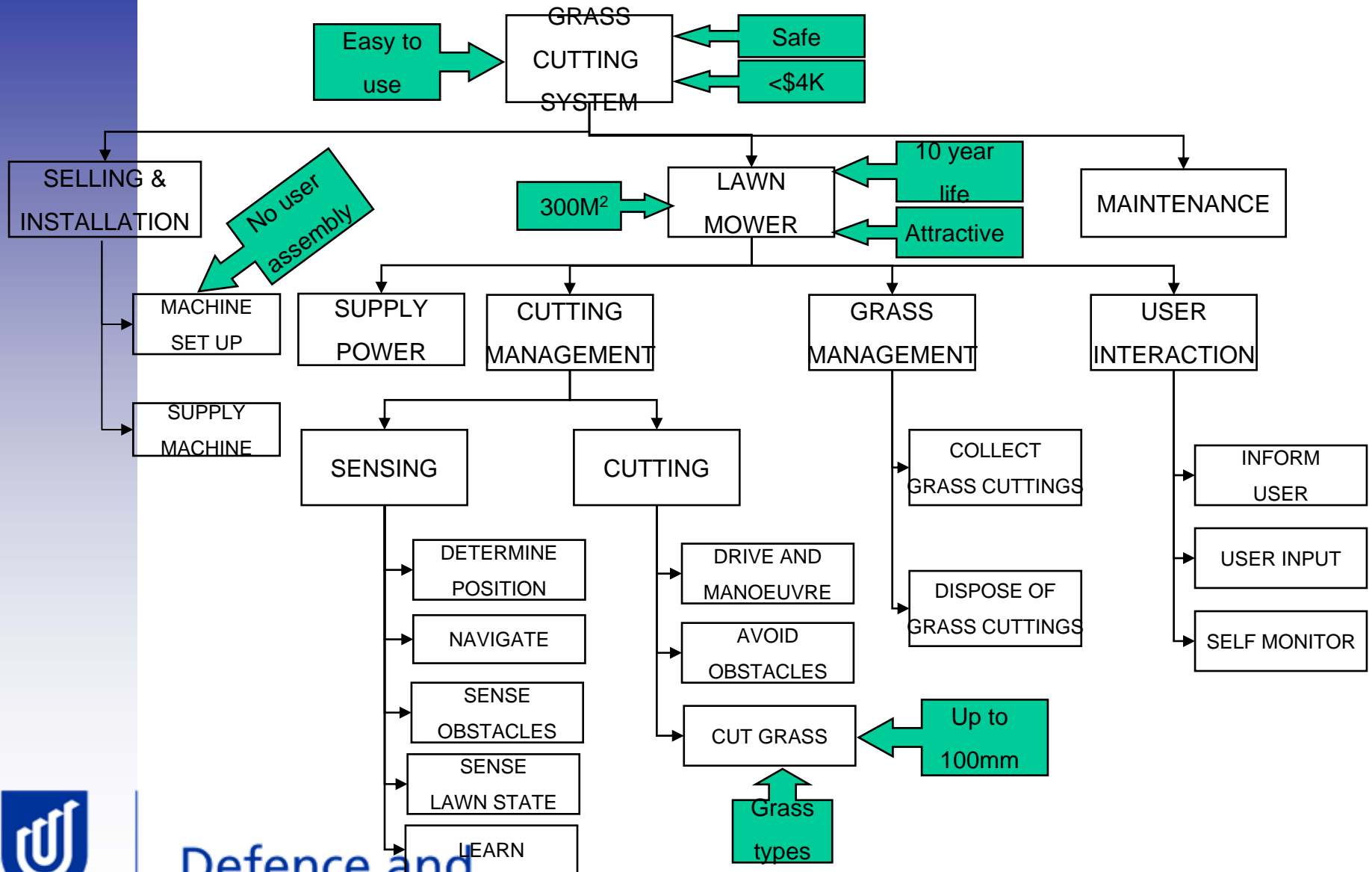
Viewpoint Structure Chart



Step 6: Non-functional Viewpoint Structure

- The final stage in viewpoint analysis is to structure the Non-functional Requirements.
- To satisfy this it is necessary to structure the non-functional as close as possible to the functional viewpoint structure.
- For each 'level' of non-functional viewpoint it is necessary to develop a specification of what the constraints are. These are developed from the customers' requirements document together with other sources of information such as national standards. It is common that customers will miss important non-functional requirements.

Including Non-functional Requirements

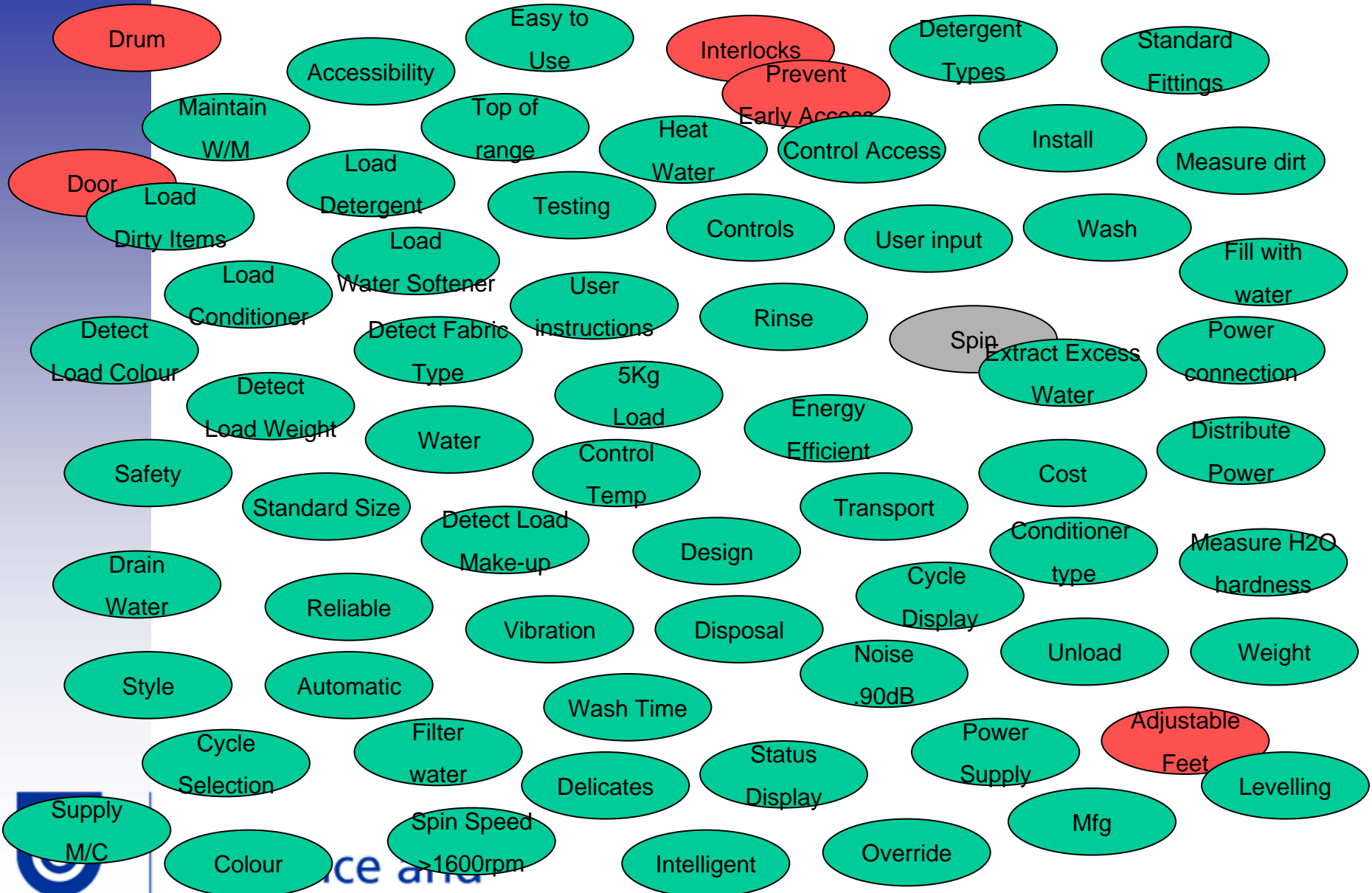


Exercise - VPA - IWM

- Follow the steps for the Viewpoint Analysis for the IWM.
- Your goal is to produce a diagram like the one is the previous slide, for the IWM.
- Remember that your Textual Analysis output provides a lot of the starting material for this exercise.



Typical Step 1 Output



Typical Step 2 Output

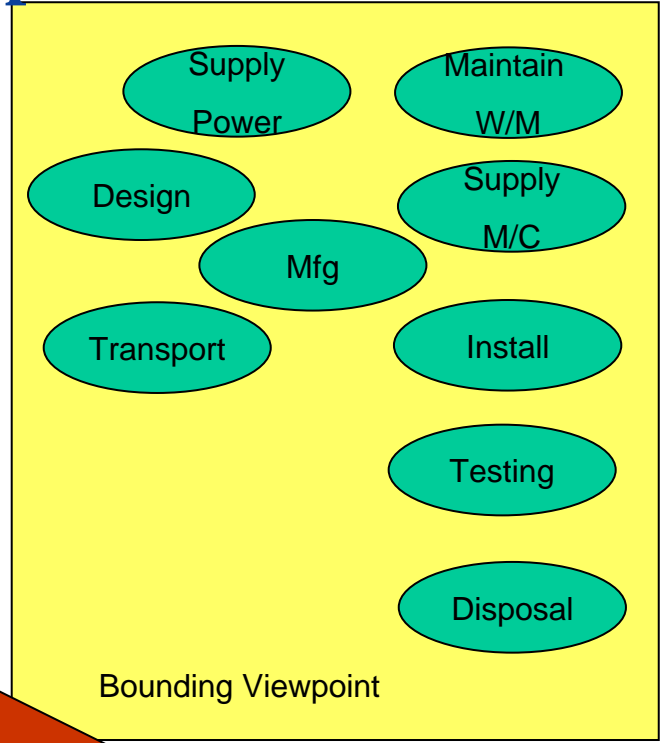
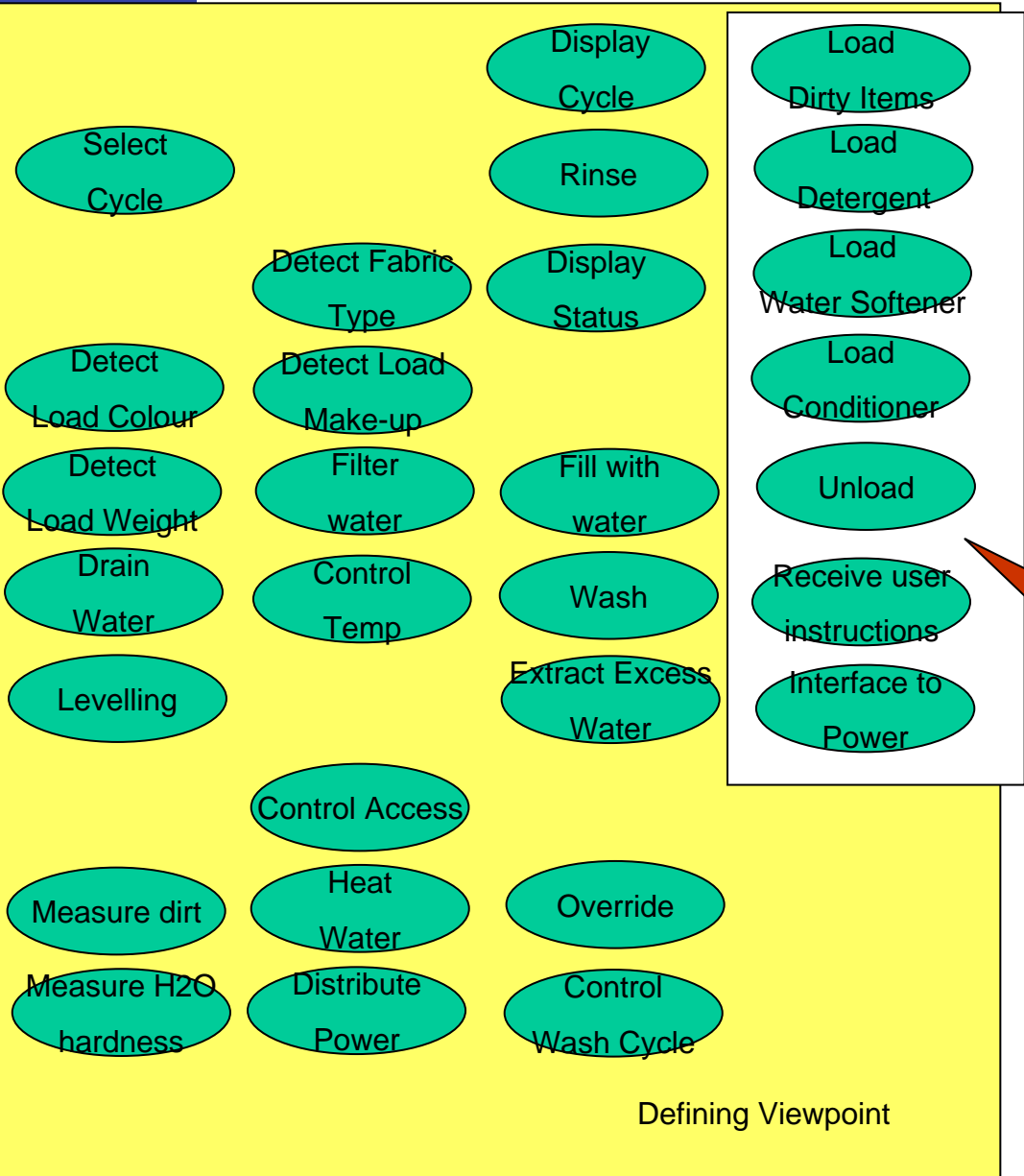
- Maintain W/M
- Load Dirty Items
- Load Conditioner
- Detect Load Colour
- Detect Load Weight
- Drain Water
- Levelling
- Supply M/C
- Measure dirt
- Measure H₂O hardness
- Install
- Load Detergent
- Load Water Softener
- Detect Fabric Type
- Detect Load Make-up
- Filter water
- Control Temp
- Testing
- Control Access
- Heat Water
- Distribute Power
- Disposal
- Supply Power
- Rinse
- Design
- Transport
- Fill with water
- Wash
- Extract Excess Water
- Unload
- Override
- Control Wash Cycle
- Interface to Power
- Display Cycle
- Display Status
- Select Cycle
- Receive user instructions
- Mfg

Functional

- Detergent Types
- Safety
- 230V 50Hz AC
- AS 3000 Plug & socket
- Accessibility
- Easy to Use
- Top of range
- Conditioner type
- Noise .90dB
- Delicates
- Intelligent
- Spin Speed >1600rpm
- Standard Size
- User instructions
- 5Kg Load
- Standard Fittings
- Water
- Reliable
- Energy Efficient
- Weight
- Colour
- Automatic
- Style
- Wash Time
- Vibration
- Cost

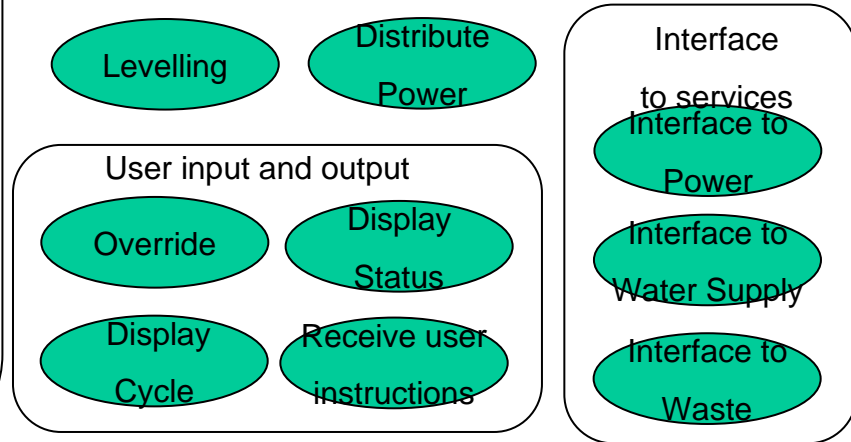
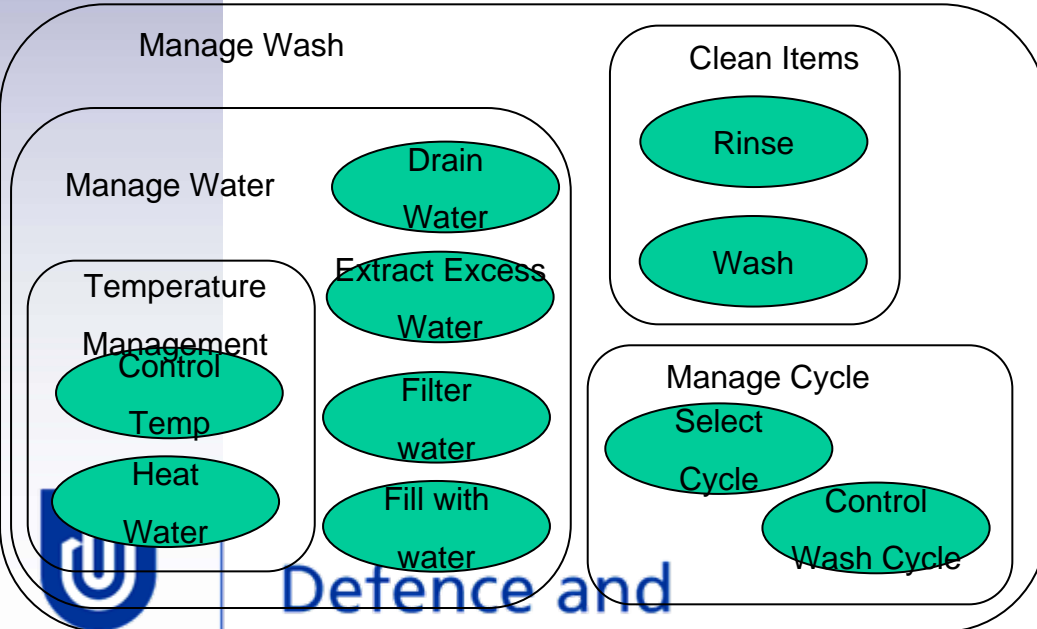
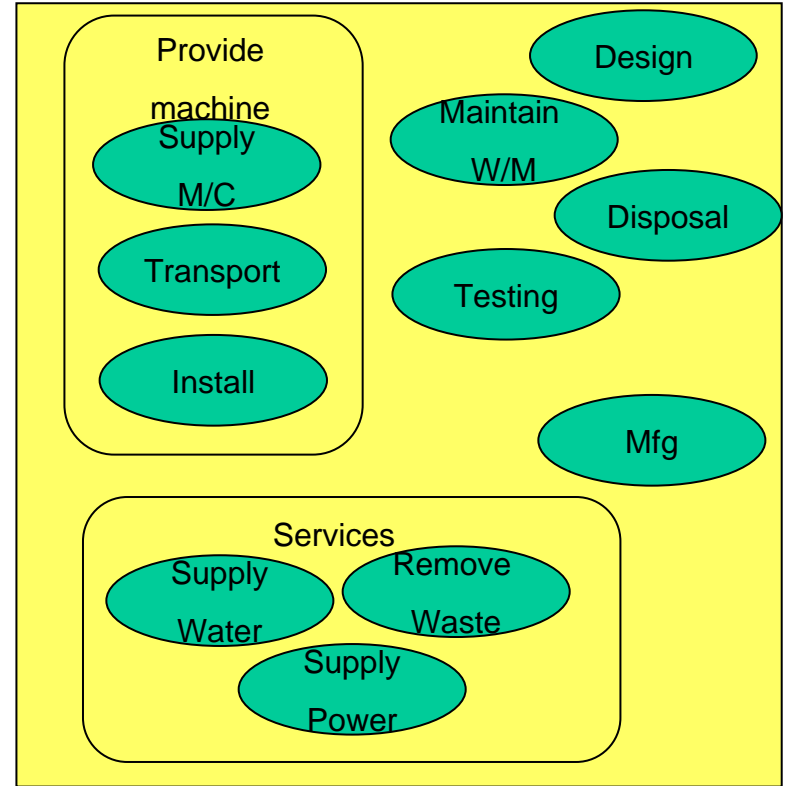
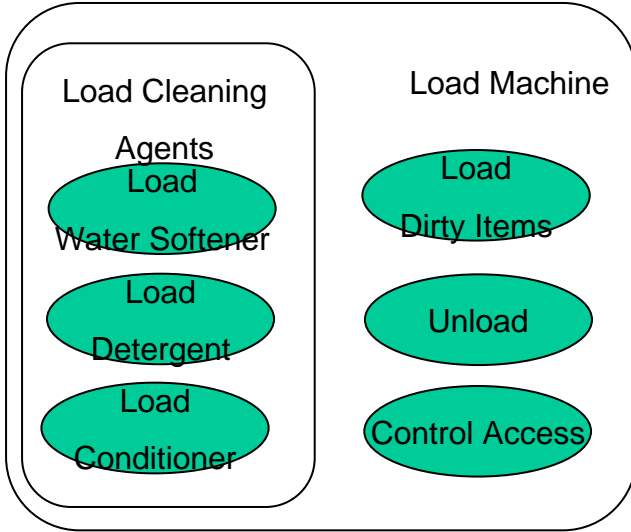
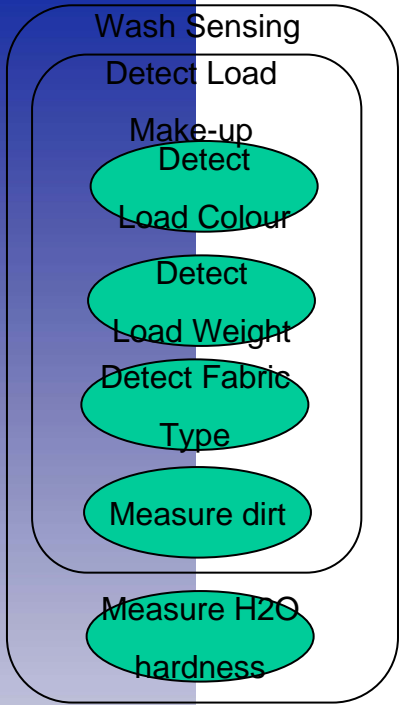
Non Functional

Typical Step 3 Output



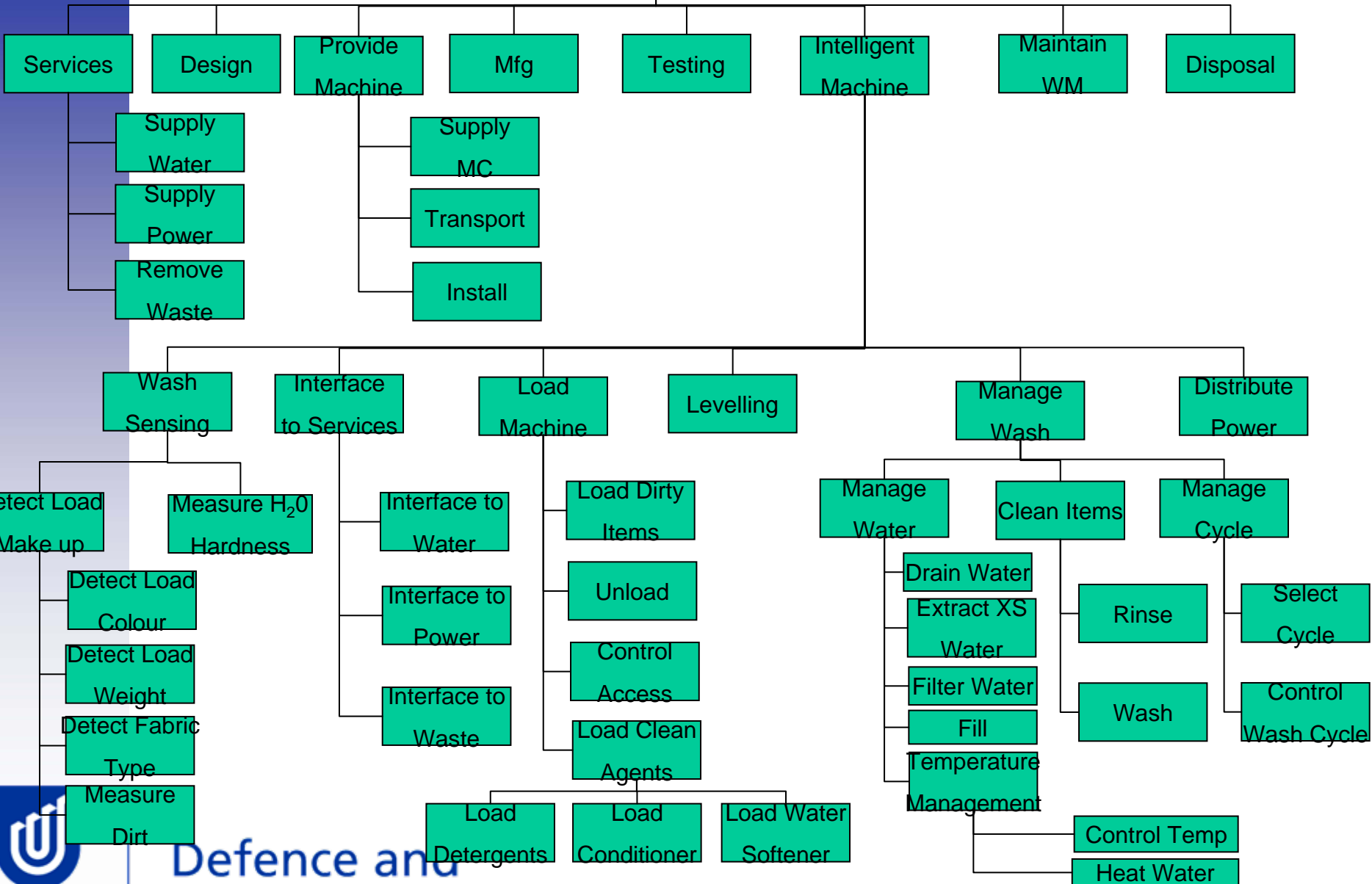
Some functions could be inside or outside the prime system. Were we decide to put them defines the system boundary. We need to think carefully about these. Will they lead to design solutions that will be part of the prime system

Typical Step 4 Output



Typical Step 5 Output

Washing System



Functional Architecture

- We now have a picture of the proposed system – the IWM – from the point of view of **what** it must do to satisfy the customer.
- We call this a functional architecture.
- We can also verify it by working backwards.
- Starting with a particular function, we can trace what customer need it is satisfying.
- Next step – **HOW?**

Solutions

- Now we have a list of system functions – “**what**” the IWM System must do to satisfy customer and solve their problem.
- We know “**why**” we are doing these things.
- We also know “**how well**” these have to be done.

- We now have to solve the riddle of **HOW?**
- How will we “Fn XXX”, “Fn YYY”, and so on?
- This is where some creative thinking comes in!



‘WHAT’ problems?

- Let’s agree that we have, say, 5 key functions that the IWM System must do. These can be written as 5 problems that we have to solve.
- E.g. Load machine, perform cleaning, sense load, communicate with user, etc.
- How will you:
 - Fn1 = load the IWM?
 - Fn2 = sense the load type?
 - Fn3 = clean the clothing?
 - Fn4 = etc
- These are your functions, now you have decide HOW you do each of these?



Design

- These 5 functions are, or should be, our Major System Functions.
- Later, you can, if you need, break these down into more detail.
- For now, we will stick to the top level of system design.



Brainstorming

- For each of your five key system functions, spend a few minutes brainstorming **HOW**.
- Try to list at least 10 HOWs for each function.
- Then give each HOW idea a score:
 - P = Performance – How well do you think that idea would be at performing the function?
 - 0 = no good at all, 5 = fantastically good
 - R = Risk – How difficult do you think that idea will be to make:
 - 0 = high risk, 5 = very low risk

Brainstorming Rules

- Go for lots of ideas.
- Don't analyse them until you have a set of ideas.
- Encourage any possible idea.
- Don't criticise other people's ideas.
- Build on other ideas.



Brainstorming – Warm-up

- What are possible uses of a paperclip?



Exercise: IWM Function ideas

- Brainstorm solution ideas for your IWM functions.



Morphological Tables

- Now we need to make sense of our possible solutions.
- A morphological table helps us to find the “feasible” combinations out of all our brainstorm ideas.
- Fill in the next table with your best five solutions (HOWs) for each WHAT. “Best” means, highest combined P+R score.
- See example...



Brainstorm Output

How? What?	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5
Function A (apply torque)	Screw driver (5:5)	Paper clip (3:4)	Knife (4:4)		
Function B					
Function C					
Function D					
Function E					



Exercise: IWM Morph Table

- After analysing your brainstormed ideas, select the most feasible and draw up a Morphological Table.



Morphological Table

- When you've filled in the Morphological Table, take a few minutes to find the best three overall system solutions for your IWM System.
- These will be the best combinations of HOWs for each WHAT.
- See example...



Solutions

How? What?	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5
Function A	Option A1 (5:5)				
Function B		Option B2 (4:3)			
Function C				Option C4 (4:4)	
Function D			Option D3 (4:5)		
Function E					Option E5 (3:3)

Solution = A1+B2+C4+D3+E5



Welcome to Your IWM System

- You've done it!
- You have 'designed' three possible solutions for the customer.
- Each represents a possible way of meeting the IWM System Needs.
- We also have information to help us determine HOW WELL each function needs to be performed.
- In other words, we have what engineers call a *Conceptual Design* for the system.

Last Step

- There is one more thing we need to do before we are finished our conceptual design.
- We need to evaluate each of your three solutions against the “reference product” (the current system).
- If none of your solutions is better than the current system, then the customer has wasted his time!
- If you can show him that at least one of your designs is better than the existing method, then he will probably pay you to build it.
- That final stage is what engineers are aiming for – a satisfied customer who is willing to pay for a system to be designed and developed.
- That’s what keep engineers employed.

Design Evaluation: Pugh Table

- Activity: fill in the next table.
- For your evaluation criteria use:
 - Speed
 - Weight
 - Range
 - Size
 - Duration
 - Coverage
- And then we move onto the next stage – repeating a lot of what we’ve done at progressively more detailed levels.