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School of Engineering Sciences

FEEG-2001

Systems Design and Computing:

Formal Systems Design 1

Jim Scanlan

Mech, Aero and Acoustic Theme

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Introduction

Fixed Wing Aircraft Project

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My design experience

- This module is essentially about showing you how to design systems.
- I have some experience in systems design..
  - Small cog in a large machine (BAE/ Airbus)
  - Large cog in small machine (Unmanned aircraft)

Industry Experience

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46/month

Current Design Activity

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Span: 4m
Power: 2 x OS GF40 (3.75HP)
Endurance/range: 6 hours/600km
Maximum take-off weight: 35kg
Payload: 5kg
Stall speed (flaps down/up): 33knots/23knots

https://www.sotonuav.uk/

Farnborough

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Windracers Video

Founder of spin out BOXARR (http://www.boxarr.com/)

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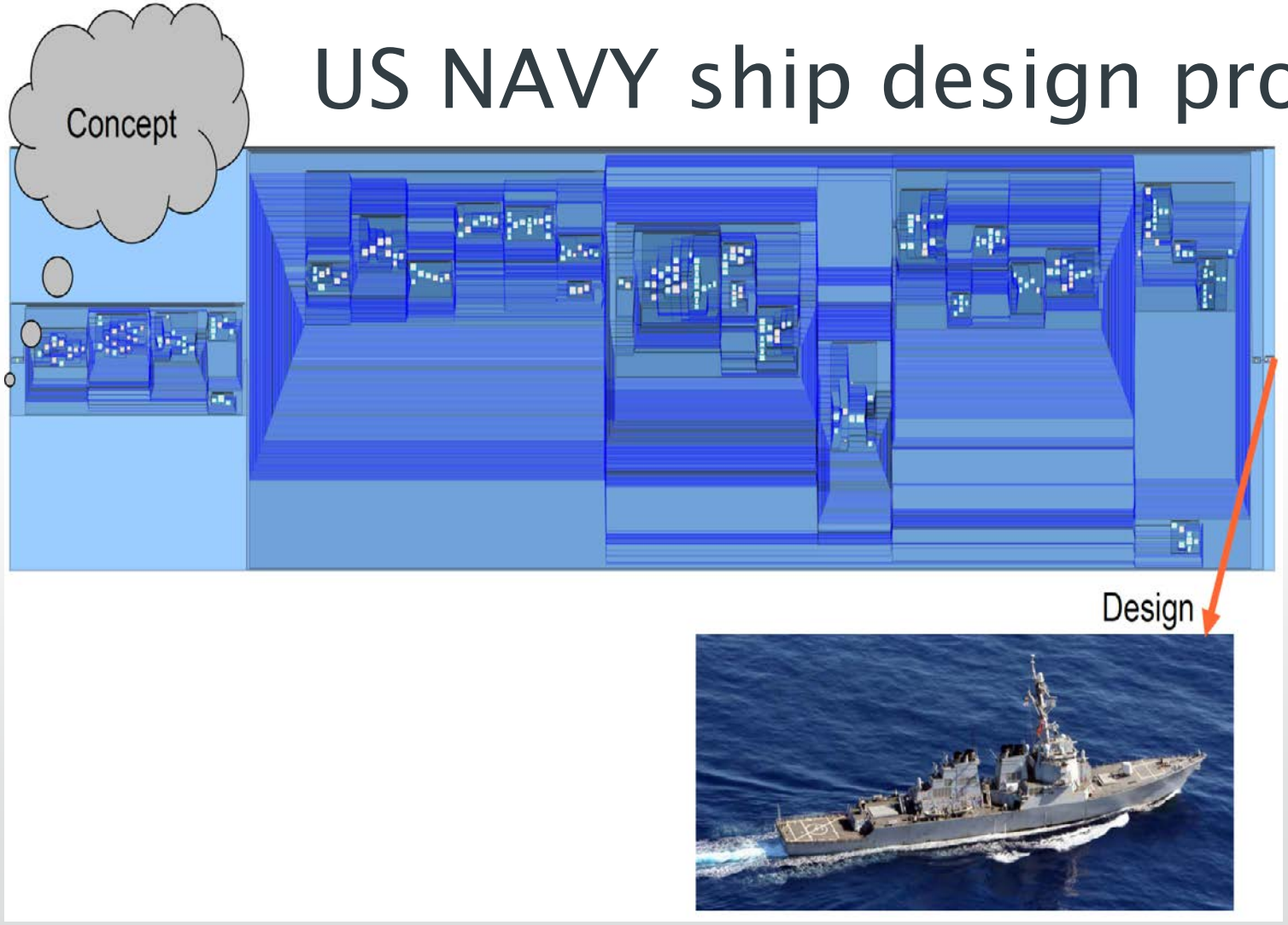
US NAVY ship design process



Systems design

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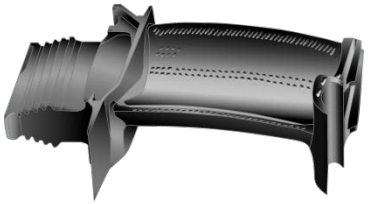
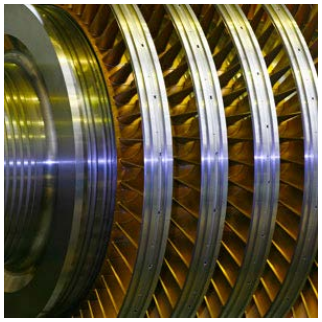
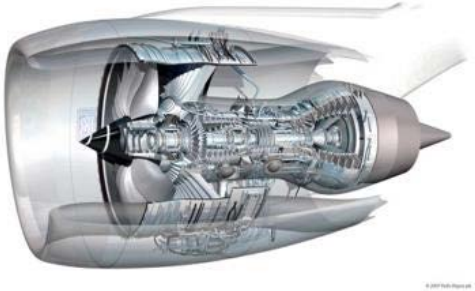
- Single part





- Sub system



- System

- Super system

Our “Super-System”

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- Aircraft
- Ground station
- Communications

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Formal systems design process

Rolls-Royce

Contents

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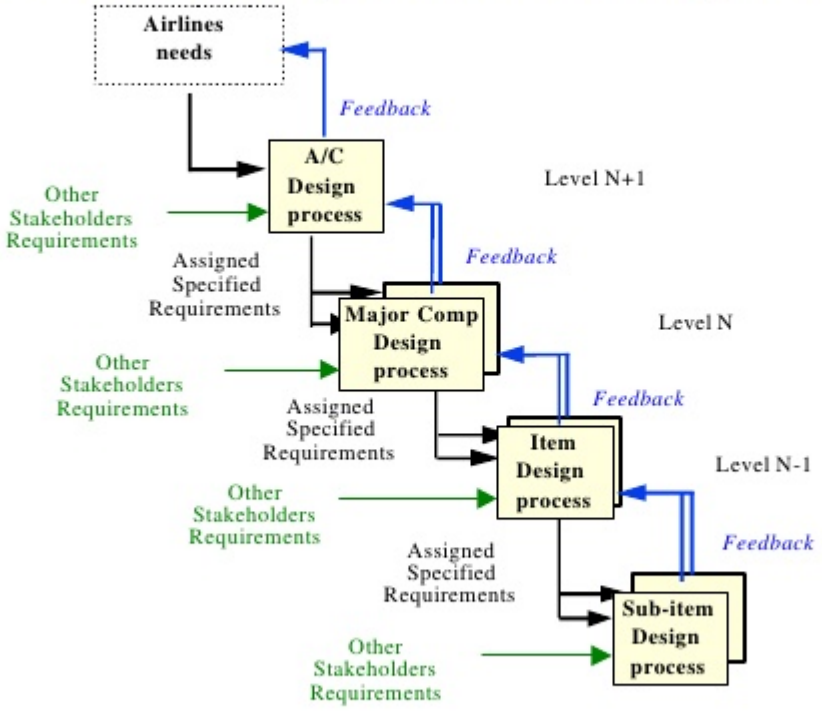
- Introduction 4
- Simplified Engineering Design Process Diagram 5

Engineering Process Flow in support of A/C Product Development according to EIA 632



My formal design process

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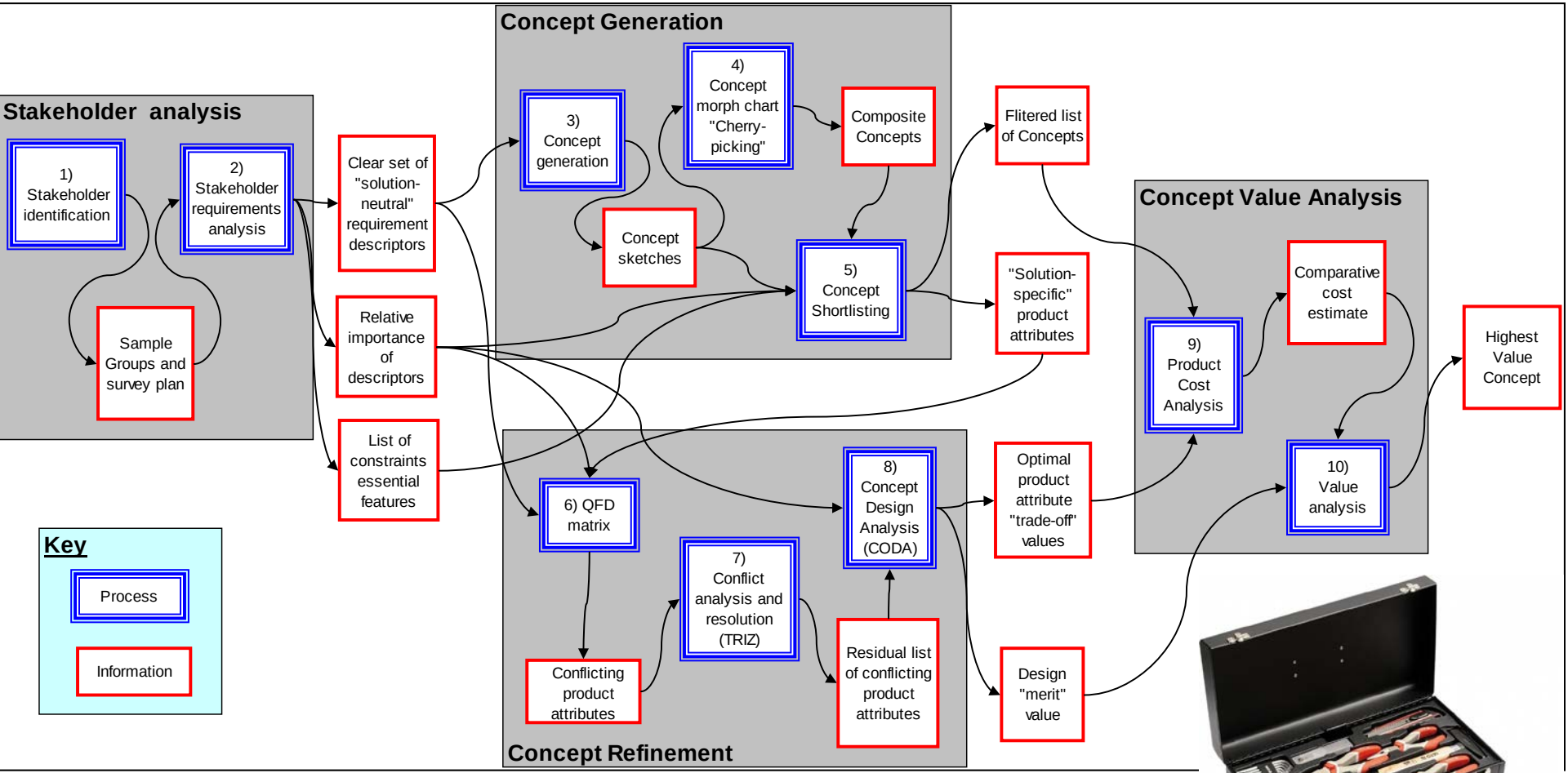


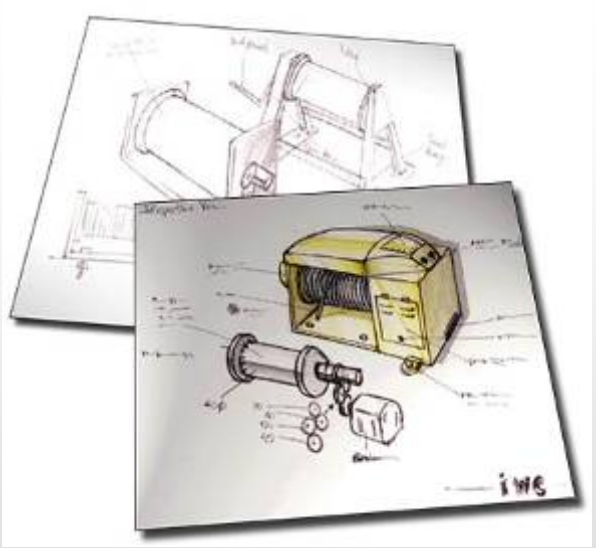
Log books

- Date stamped
- Electronic/Physical
- Hybrid; A4 bound notepad scanned and backed up
- Professionally documented process
- Intellectual property

What is ‘Design’?

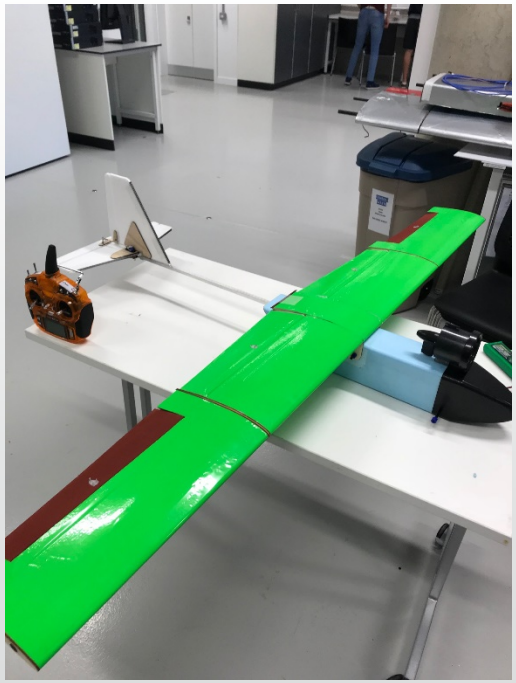
*'Design is the **conscious decision making process** by which information (an idea) is transformed into an outcome, be it tangible (product) or intangible (service).‘*

Dr Bettina von Stamm, Design Council



Conscious decision making process

- Case study; small product (~10^1 parts)
- Very large search space
- Structured methods introduce rigour and systematic search



Spectrum of design

$$\frac{\text{Function}}{\text{Form}}$$

Whimsical
Frivolous
Creative
Inspired
Aesthetic
Sensual

Rational
Logical
Austere
Lean
Purposeful

Aerospace/Mechanical

Decisions

- The principal role of a designer in, designing an artefact, is to ***make decisions*.**
- Rarely is all information available.
- Good designers need to interpret and make *engineering judgement*.

Second semester design decisions

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- Wing geometry
  - Section, Span, Chord, taper, twist
- Materials
- Structural architecture
- Control system
  - Bandwidth
  - Control response
  - Gains
- High lift Devices
- Control surfaces

Bad Decisions!

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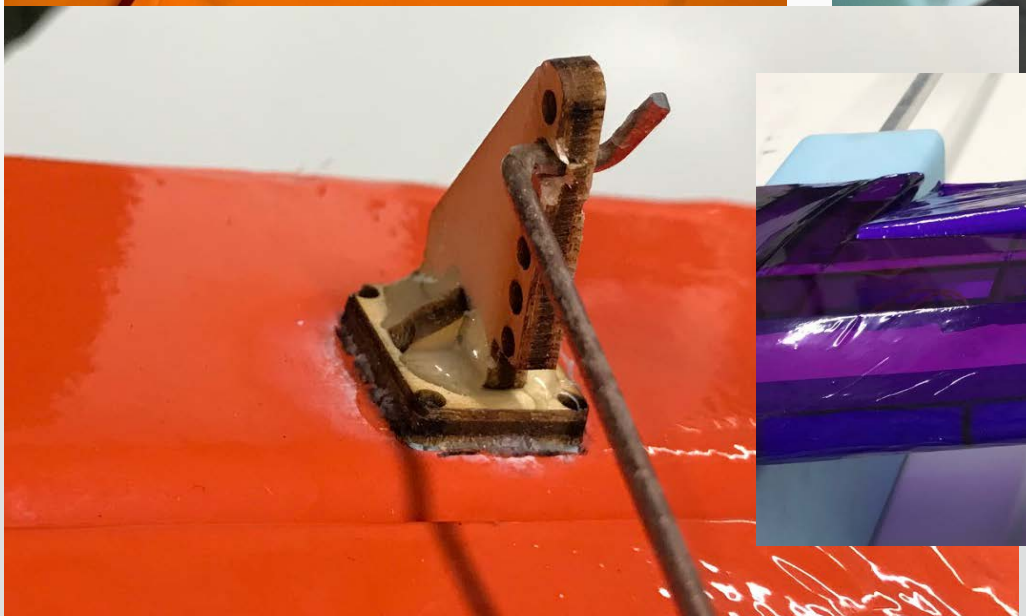


Multiple customers (stakeholders) and priorities

- Patient
- Nurse
- Community nurse
- Consultant
- Manufacturer
- Health trust
- Certification authority

Capturing customer requirements

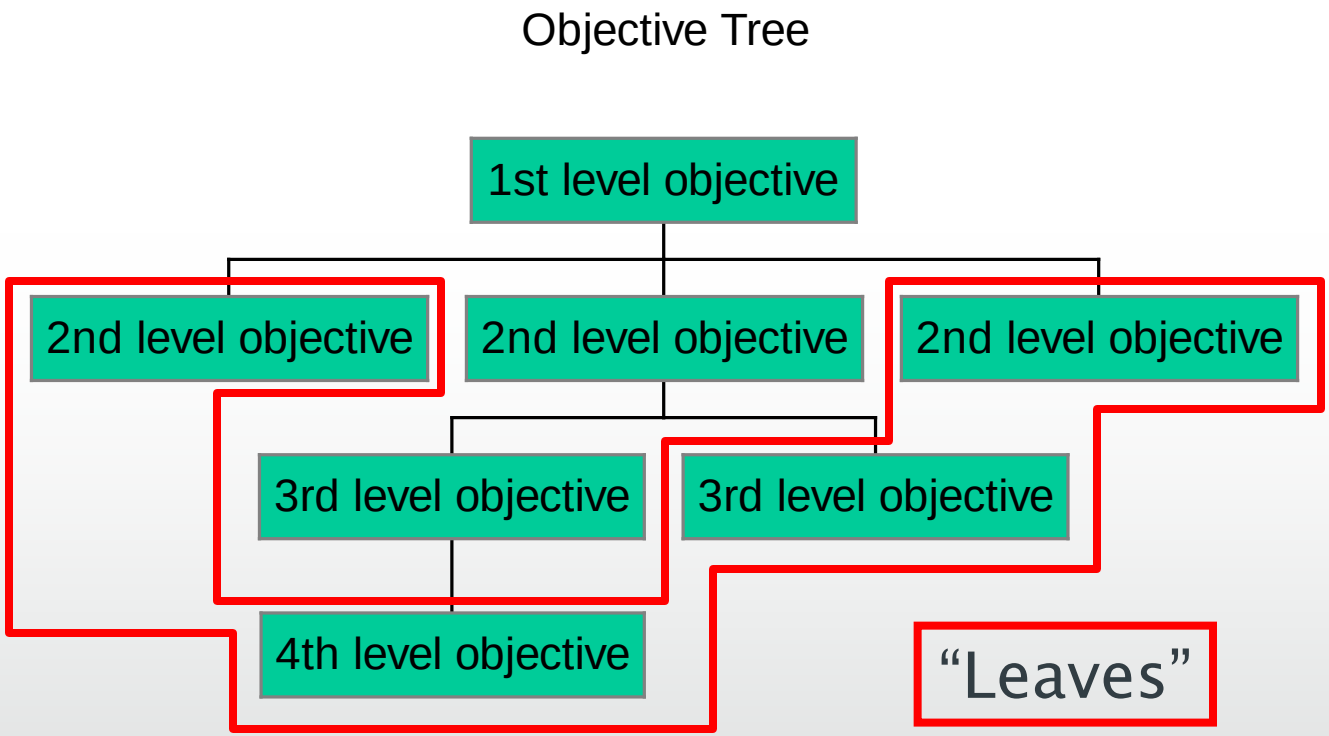
- "Solution Neutral"
- Unbiased
- Use customer terminology and language
- Interviews/surveys
- Very expensive
- Even more expensive if not done well!

Solution neutral?

- “I need to get from A to B”

- “The engine size must be more than 2.0 litres”

Customer requirements



Objective tree example

Tape dispenser

- Dispense Tape
  - Pull to length
    - Stable
    - Pull one handed
    - Pull accurately
  - Cut tape
    - Clean edge
    - Safe
  - Easy refill
    - No parts to lose
    - # of tape types

Weighting

- Ranking
  - Simply list in order

Weighting

- Binary weighting matrix
  - Construct pair wise matrix
  - Make binary decision on importance of each pair of requirements
  - Sum

Weighting

- Ranking
  - Strength; easy, quick
  - Weakness; Linear
- Binary weighting
  - Strength; less subjective, non linear
  - Weakness; time consuming

Binary weighting matrix

Requirements

	a	b	c	d	e	f	g	
a	X	1	1	1	1	1	1	6
b		X	1	1	0	1	0	3
c			X	1	0	0	0	1
d				X	0	0	0	0
e					X	0	0	3
f						X	1	3
g							X	4

Relative Weighting

Weighting =
Σ(row units) +
Σ(column zeros)

Example

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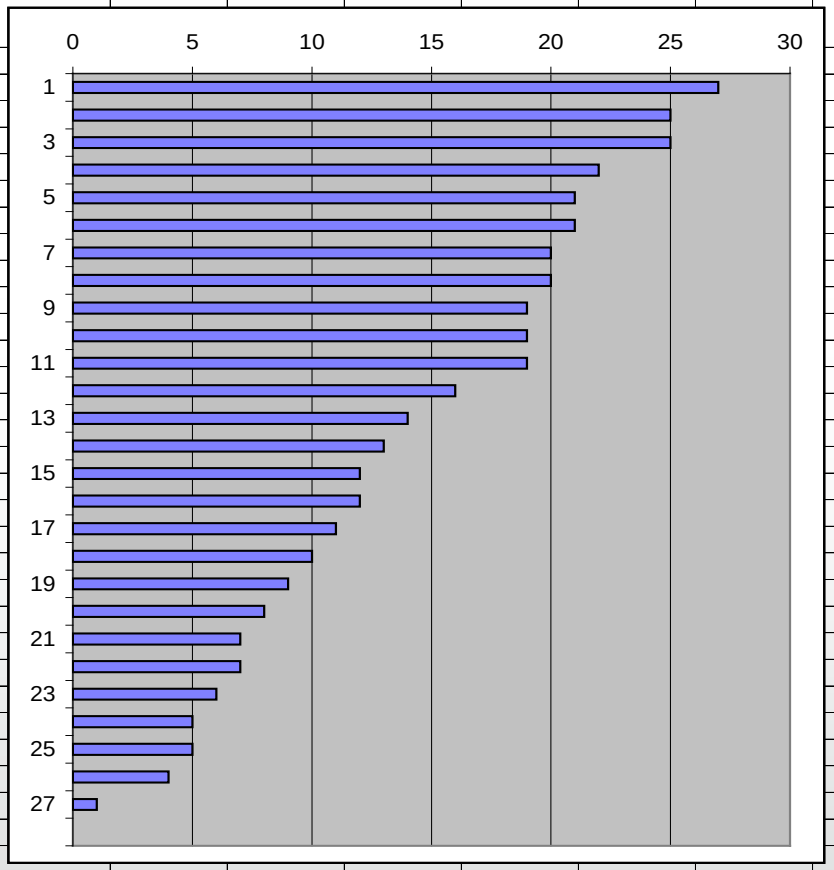
Second patient

		LEVEL OF SHORT TERM (POST OPERATIVE) PAIN & DISCOMFORT	LEVEL OF LONG TERM PAIN & DISCOMFORT	AMOUNT OF DISCHARGE AROUND DEVICE	INTERFRENCE WITH MOBILITY	INTERFERENCE WITH SLEEP	INTERFERENCE (CATCHING) WITH CLOTHING	SIZE	COLOUR	SHAPE	FEEL	SURFACE TEXTURE	REPLACEMENT FREQUENCY	LEAKAGE RISK	EASE OF REPLACEMENT	RESISTANCE TO BLOCKAGE/ENCRUSTATION	MINIMISATION OF INFECTION	RESISTANCE TO STONE FORMATION	PREVENTION OF BLEEDING	ABILITY TO GRIP DRAIN/IRRIGATION TUBE
COMFORT	LEVEL OF SHORT TERM (POST OPERATIVE) PAIN & DISCOMFORT	X	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1
	LEVEL OF LONG TERM PAIN & DISCOMFORT		X	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1
	AMOUNT OF DISCHARGE AROUND DEVICE			X	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1	1
	INTERFRENCE WITH MOBILITY				X	0	1	1	1	1	1	1	0	0	1	0	0	0	1	1
	INTERFERENCE WITH SLEEP					X	1	1	1	1	1	1	0	0	0	0	0	0	1	1
	INTERFERENCE (CATCHING) WITH CLOTHING						X	1	1	1	1	1	0	0	0	0	0	0	0	0
APPEARANCE	SIZE							X	1	1	0	1	0	0	0	0	0	0	0	0
	COLOUR								X	0	0	0	0	0	0	0	0	0	0	0
	SHAPE									X	0	1	0	0	0	0	0	0	0	0
	FEEL										X	1	0	0	0	0	0	0	0	0
	SURFACE TEXTURE											X	0	0	0	0	0	0	0	0
RELIABILITY	REPLACEMENT FREQUENCY												X	0	1	0	0	0	0	1
	LEAKAGE RISK													X	1	0	1	0	1	1
	EASE OF REPLACEMENT														X	0	1	0	1	1
COMPLICATIONS	RESISTANCE TO BLOCKAGE/ENCRUSTATION															X	1	1	1	1
	MINIMISATION OF INFECTION																X	0	1	1
	RESISTANCE TO STONE FORMATION																	X	1	1
	PREVENTION OF BLEEDING																		X	1
EASE OF USE	ABILITY TO GRIP DRAIN/IRRIGATION TUBE																			X
	ABILITY TO LOCATE DRAIN/IRRIGATION TUBE																			
	POSITIVE ENGAGEMENT OF DRAIN/IRRIGATION TUBE																			
	MINIMISATION OF DRIBBLES																			
	ABILITY TO CLEAN EASILY																			
	QUICK TO EMPTY																			

Example

Medical team requirements; ranked relative importance

REQUIREMENT	relative importance
ABILITY TO REMOVE IN EMERGENCY (DUE TO BLOCKAGE)	27
REDUCED REPLACEMENT FREQUENCY	25
POSITIVE FIXATION	25
EASE OF REPLACEMENT	22
INTIAL SURGICAL SKILLS REQUIRED	21
REMEDIAL CARE SKILLS REQUIRED	21
LOW RISK OF INTIAL SURGICAL INFECTION	20
IRRIGATION CAPABILITY	20
EASE OF SURGICAL INSERTION	19
EASY TO STERILISE	19
LOW RISK OF WALL PENETRATION	19
GOOD INTERNAL ACCESS TO BLADDER	16
URETHRAL LEAKAGE	14
PERI-PORTAL LEAKAGE	13
NON-RETURN VALVE LEAKAGE	12
FLEXIBILITY OF APPLICATION (ABDOMINAL WALL THICKNESS)	12
FLEXIBILITY OF APPLICATION (PHYSICAL SIZE RANGE)	11
FLEXIBILITY OF APPLICATION (PATIENT CONDITION RANGE)	10
FLEXIBILITY OF APPLICATION (BLADDER DIMENSIONS)	9
FLEXIBILITY OF APPLICATION (AGE RANGE)	8
INTIAL SURGICAL FACILITIES REQUIRED	7
VISUAL INSPECTION COVERAGE	7
VISUAL INSPECTION EASE OF MANIPULATION	6
MAINTENANCE FACILITIES REQUIRED	5
VISUAL INSPECTION RESOLUTION	5
VISUAL INSPECTION COLOUR FIDELITY	4
MAINTENANCE TIME REQUIRED	1
INTIAL SURGICAL TIME REQUIRED	0



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Homework... Customer Requirements

Background

- Design a car jack for changing car wheels
- Standard fit on a range of models
- The jack will be fitted internally within the car
- The scope of your design brief does not cover tools for removing wheel trim or wheel nuts

Objective

- Document and analyse customer requirements
- Key questions;
  - Who are the customers?
  - What are their objectives?
  - What problems might they face?
  - Are there any minorities that you need to take into account?
  - What are the extreme scenarios that you need consider?

Remember!

- You need to use language and terminology that the customer groups would understand and recognise.
- Ideally the requirements should be un-biased and “solution-neutral”.
- You will need to bias and normalise the relative importance of the customer requirements.

Deliverables

- Clear set of customer requirements (aim for at least 12 distinct requirements)
- Construct a binary weighting matrix to establish relative importance
- Enter binary decisions
- Construct a spreadsheet that can invert the lower triangular part of the matrix and summate
- Use Excel formulas for all calculated cells!

Method 1

Calculate the anti-symmetric lower triangular matrix

Binary Weighting Matrix - Method 1								
	Cust. Req. #1	Cust. Req. #2	Cust. Req. #3	Cust. Req. #4	Cust. Req. #5	Scores (Sum of rows)	Biased Scores (Scores+1)	Normalized Scores (Biased Scores/Total)
Cust. Req. #1	X	1	0	1	1	3	4	26.67%
Cust. Req. #2	0	X	1	0	0	1	2	13.33%
Cust. Req. #3	1	0	X	1	1	3	4	26.67%
Cust. Req. #4	0	1	0	X	0	1	2	13.33%
Cust. Req. #5	0	1	0	1	X	2	3	20.00%
						Total	15	100.00%

User Input
Calculation

Method 2

Sum 1's (rows) and 0's (columns) and transform

Binary Weighting Matrix - Method 2

	Cust. Req. #1	Cust. Req. #2	Cust. Req. #3	Cust. Req. #4	Cust. Req. #5	X Scores (Count ones in rows)	Y Scores (Transposed)	Scores (X Scores + Y Scores)	Biased Scores (Scores+1)	Normalized Scores (Biased Scores/Total)
Cust. Req. #1	x	1	0	1	1	3	0	3	4	26.67%
Cust. Req. #2		x	1	0	0	1	0	1	2	13.33%
Cust. Req. #3			x	1	1	2	1	3	4	26.67%
Cust. Req. #4				x	0	0	1	1	2	13.33%
Cust. Req. #5					x	0	2	2	3	20.00%
Y Scores (Count zeroes in columns)	0	0	1	1	2			Total	15	100.00%

User Input
Calculation