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FEEG-2001

Systems Design and Computing:

Formal Systems Design 2 2020/2021

Mech and Aero Theme

Summary of last lecture

- Idea of Stakeholders rather than “customers”
- Objective tree to capture requirement “Leaves” (lowest level requirements)
- Solution neutral language
- “Discriminators” and “Eliminators”
- Relative importance of requirements
- Advantages (and expense) of binary weighting matrix

Spreadsheet implementation of binary weighting matrix

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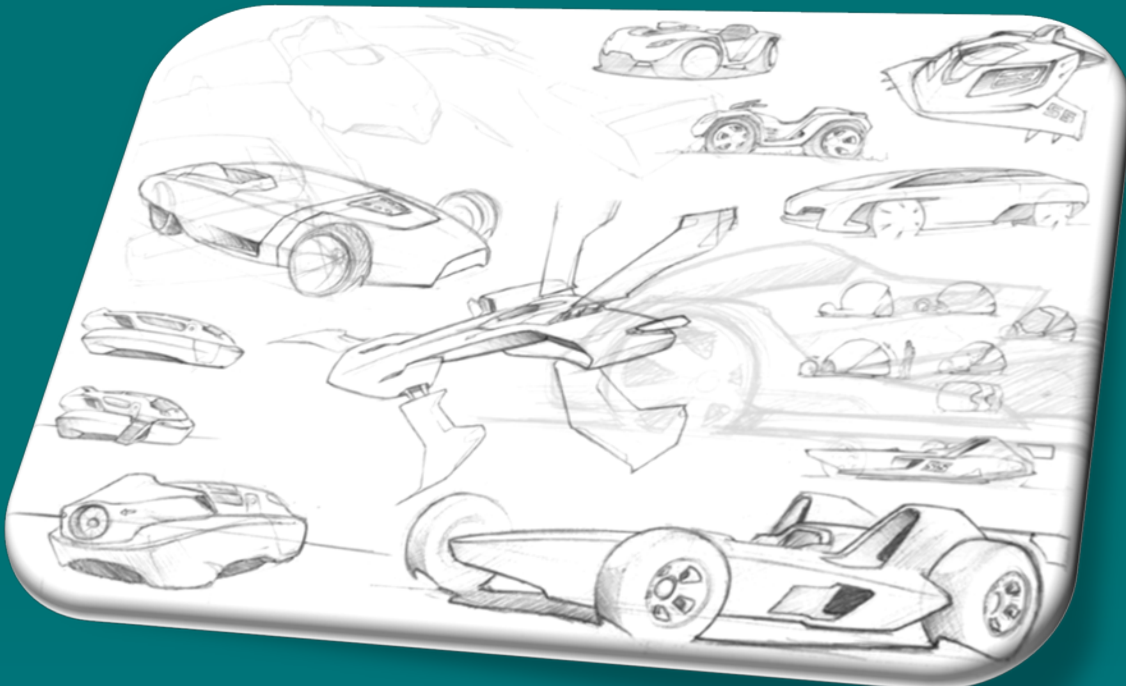
	Light weight	Impact resistance	Good visibility	Low noise	Easy to put on/remove	Comfortable			**Total score**	**biased score**	**Normalised score**
Light weight	X	0	0	1	0	0	1	0	1	2	9.5%
Impact resistance		X	1	1	1	1	4	1	5	6	28.6%
Good visibility			X	1	0	0	1	1	2	3	14.3%
Low noise				X	1	1	2	0	2	3	14.3%
Easy to put on/remove					X	0	0	2	2	3	14.3%
Comfortable						X	0	3	3	4	19.0%
	0	1	1	0	2	3				21	



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Concept Generation

Roadmap

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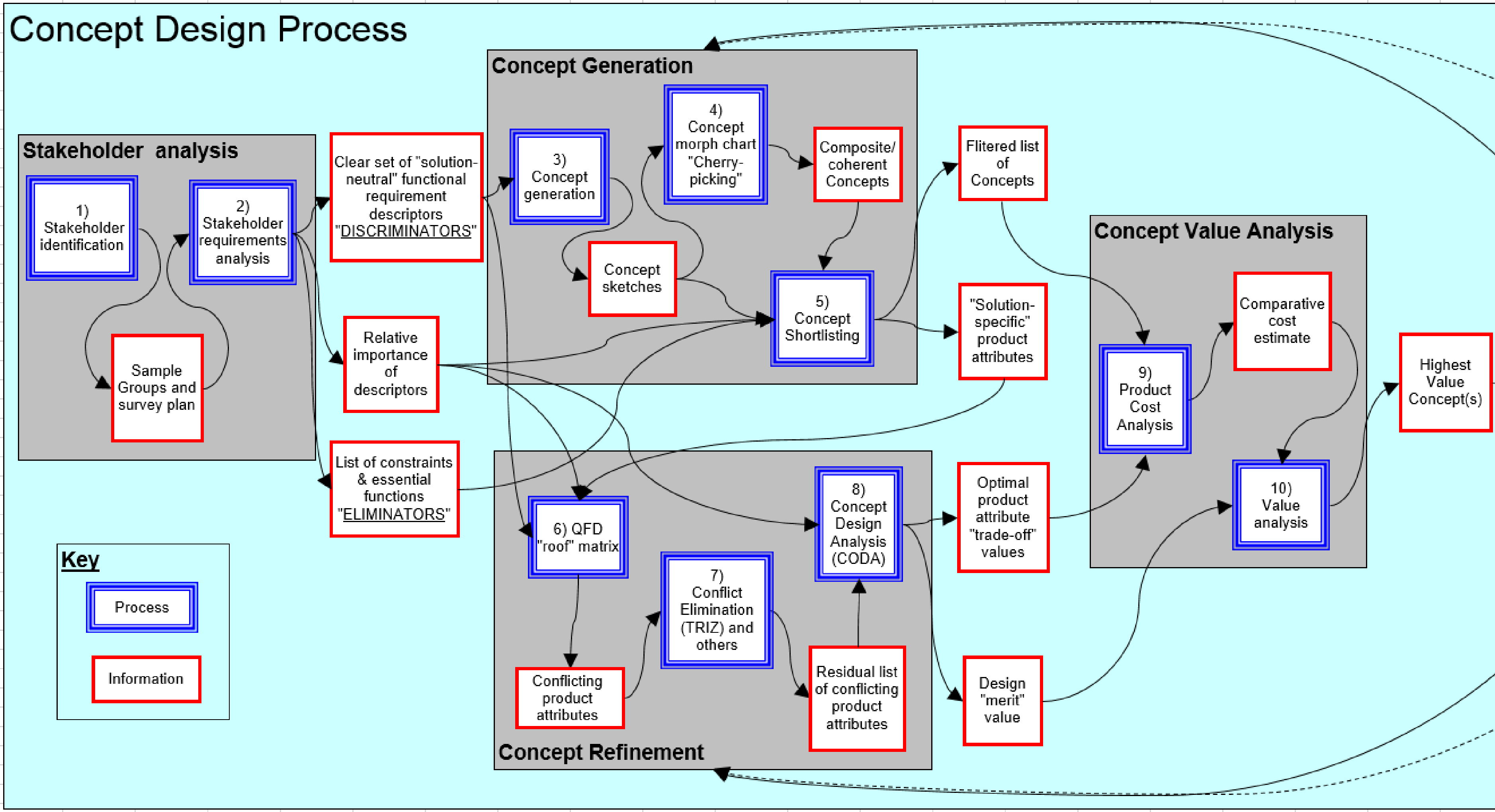

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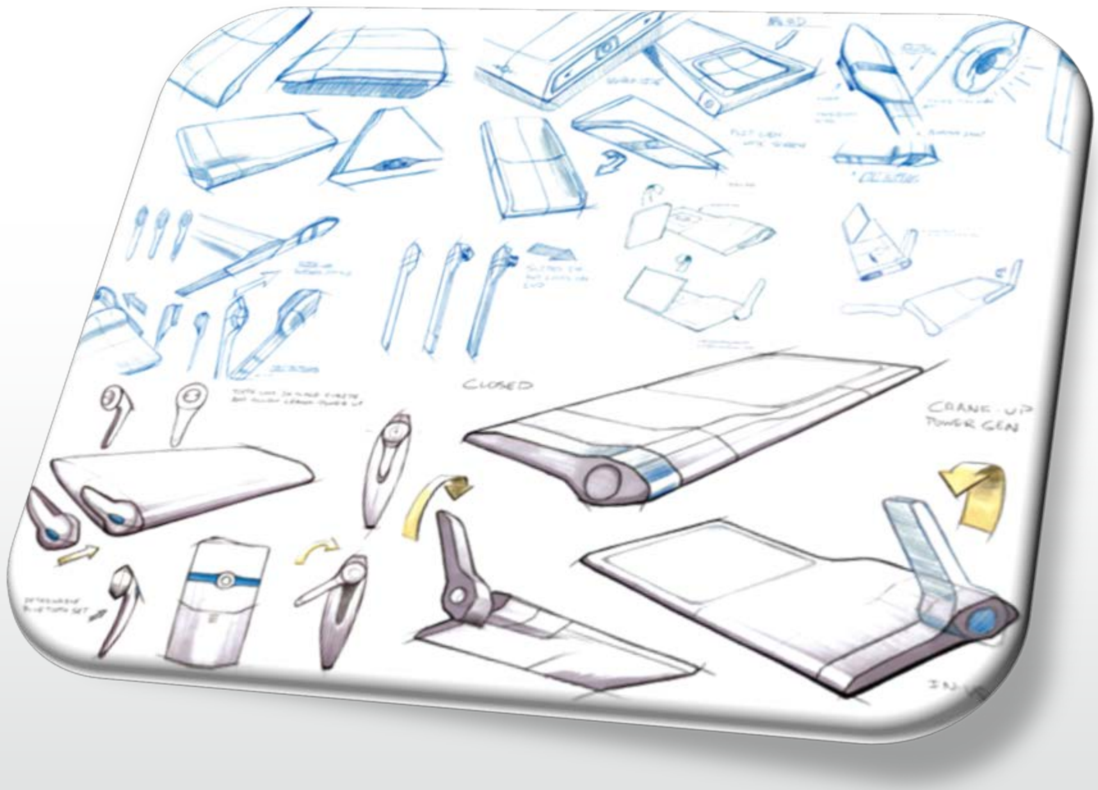
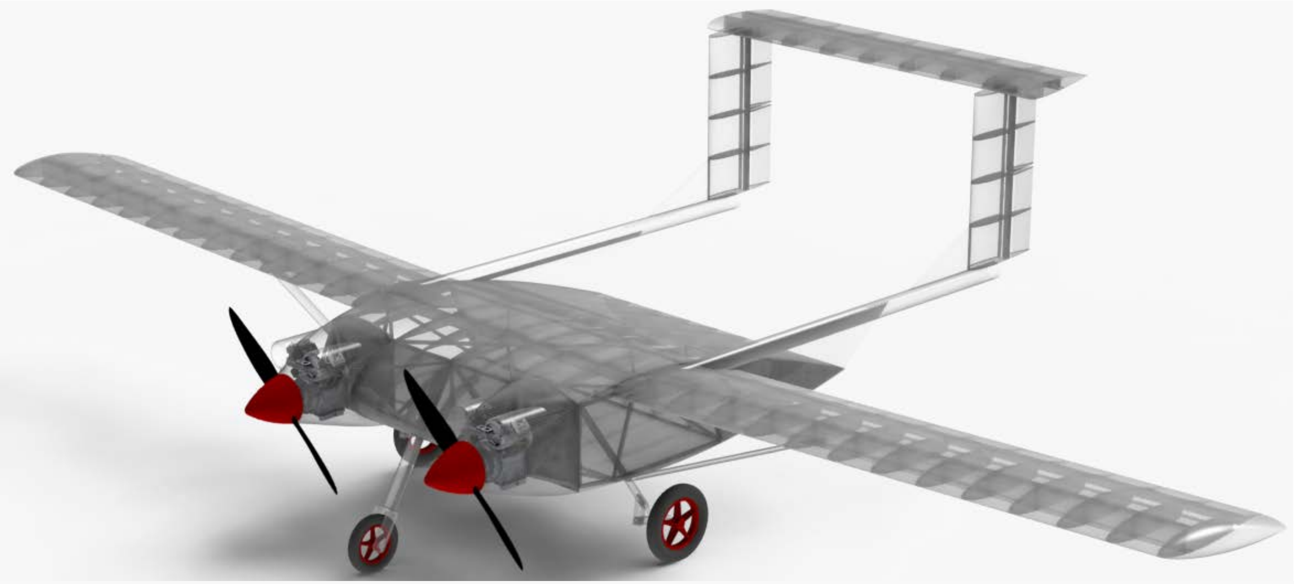
Early design phase

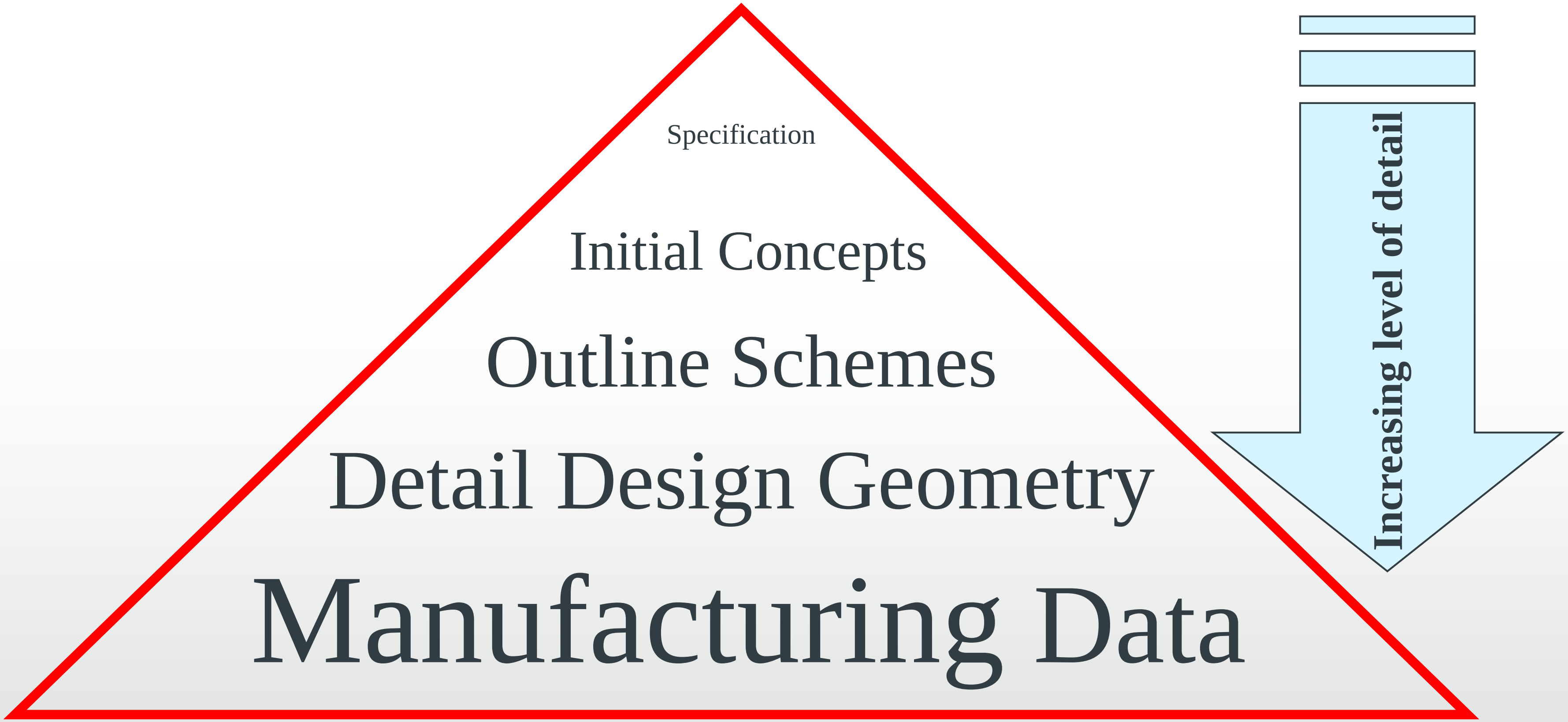
- Where most innovation potential lies
- Where designer has most freedom
- Where critical decisions are made
- Creativity, lateral/ unconventional thinking, rule breaking, important



ULTRA (Unmanned, Low-cost TRAnsport)



Search space



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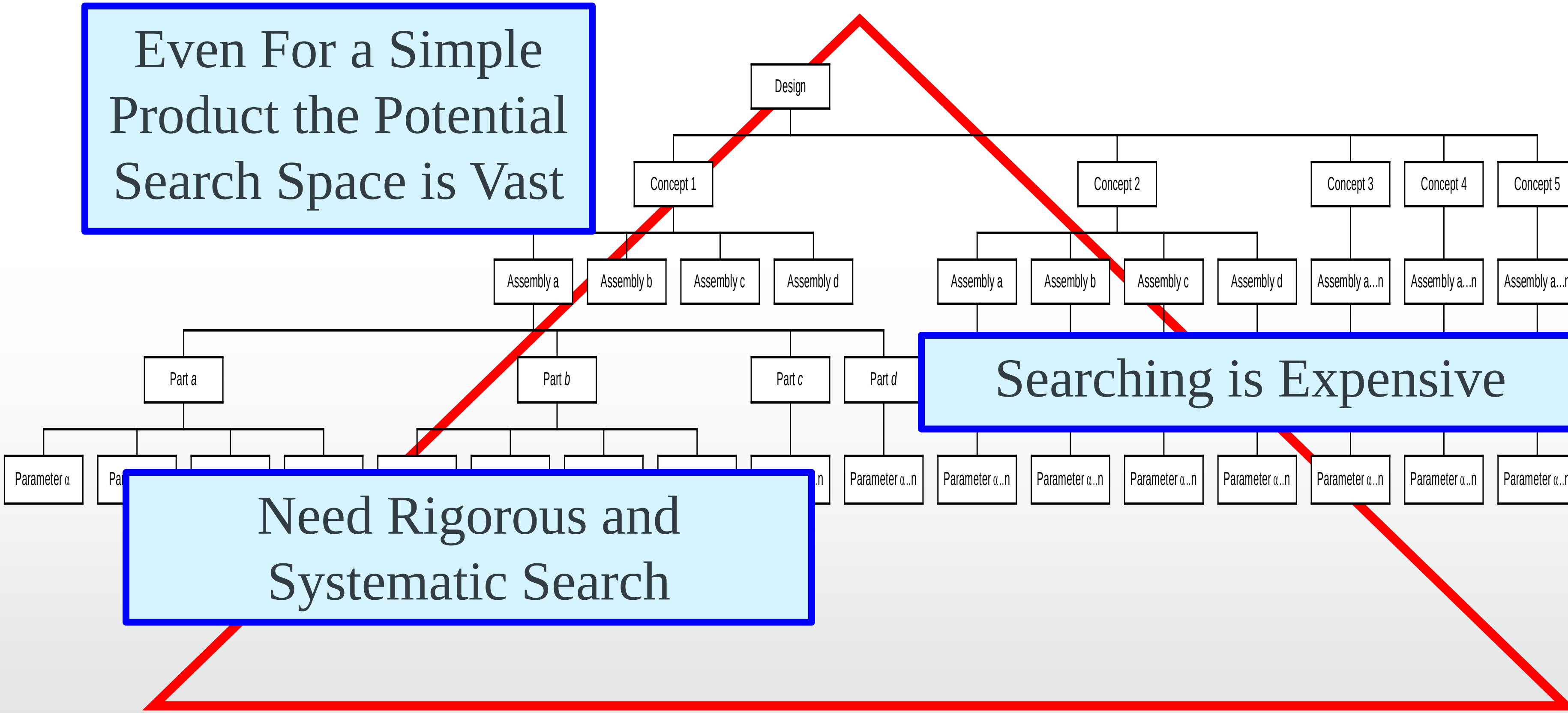
Search space



Aircraft Design Search Space

*MSc thesis "DEVELOPMENT OF A TAXONOMY OF UNMANNED AIRCRAFT CONFIGURATIONS" Steve Mace

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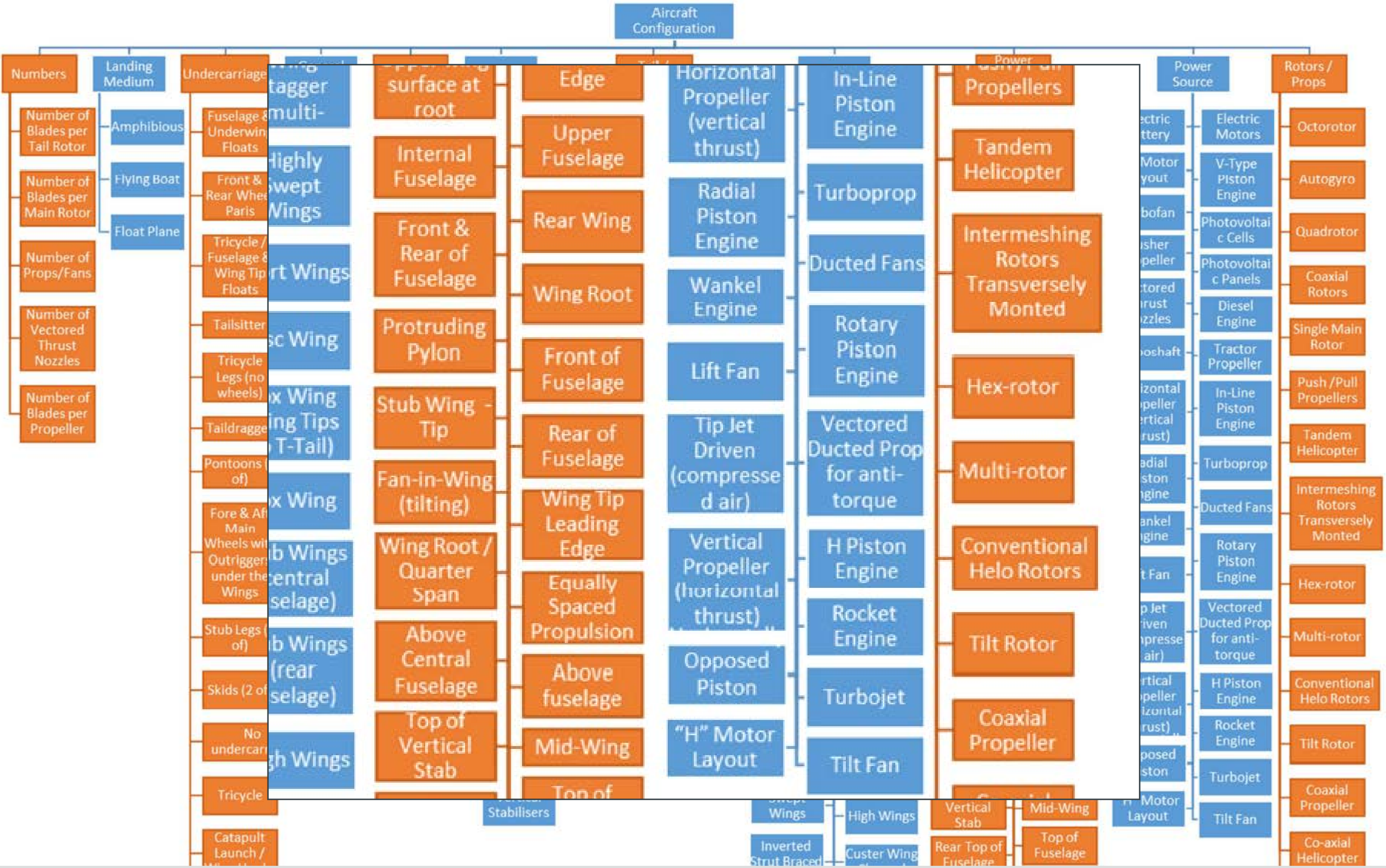

Design search space*

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Component	Total Descriptors	Total Options
Fuselage	7	12124
Power	18	31176
Lift	3237	5606484
Thrust	27	46764
Pitch	69	119508
Roll	33	57156
Yaw	66	114312
Undercarriage	13	22516

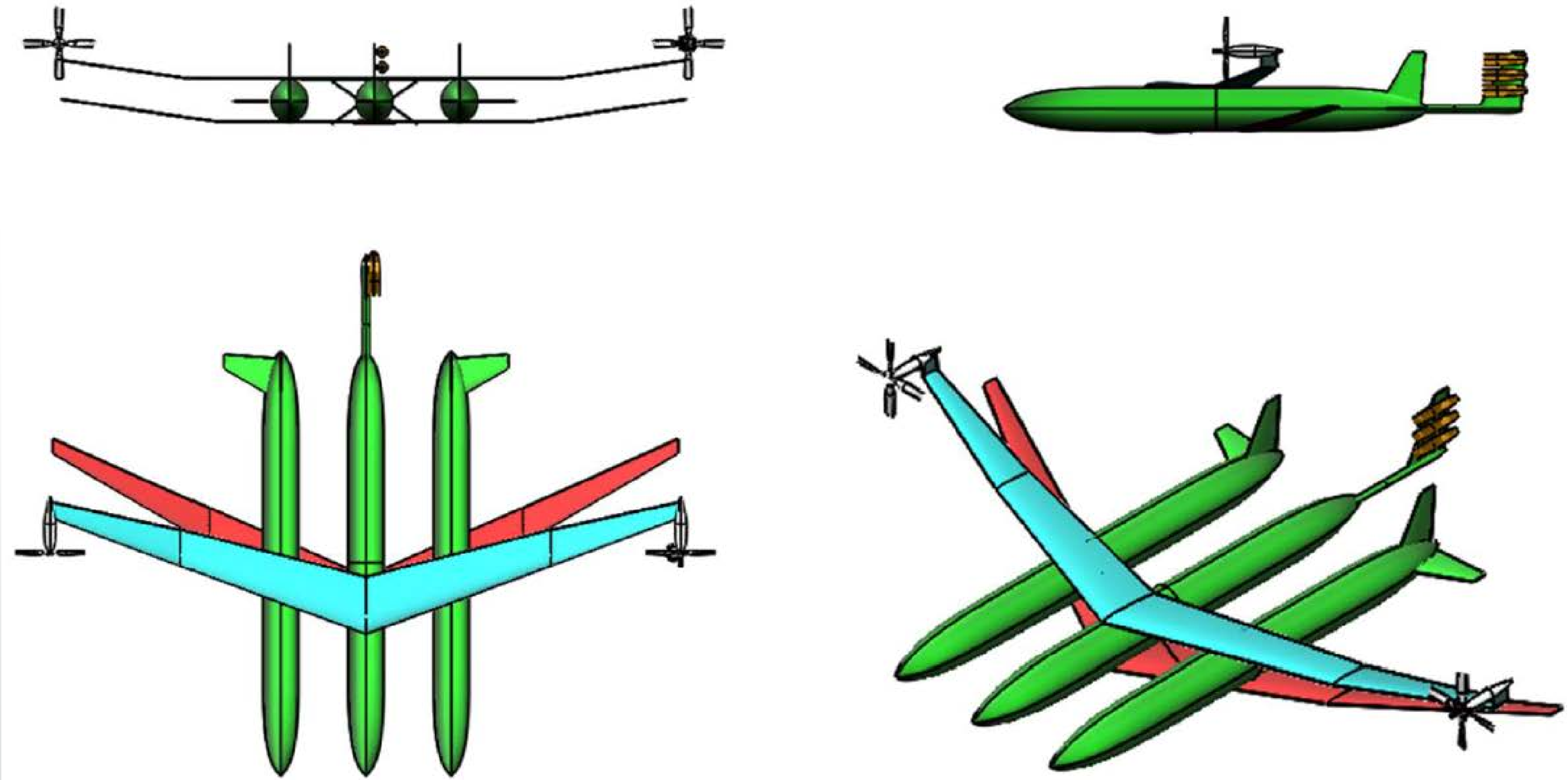
Table 31: Basic Total Possible Configurations

- $=2.577 \times 10^{61}$

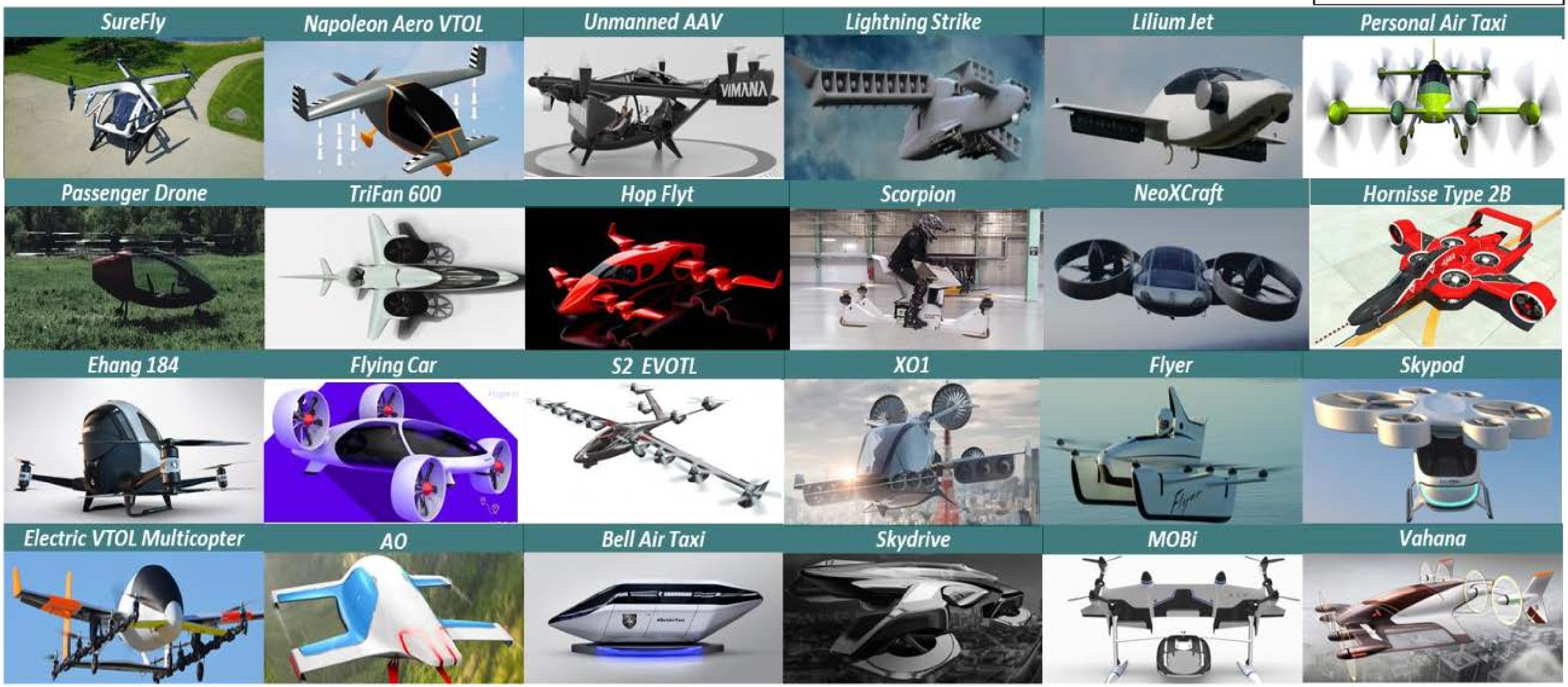
*MSc thesis "DEVELOPMENT OF A TAXONOMY OF UNMANNED AIRCRAFT CONFIGURATIONS" Steve Mace

Garbage…

A3/B1(051)-NA(0CL)/K3(0XP)-A154(005)/C75H(00X)-I3A1(0XP)/A104(0G1)-FA13(01X)/FA13(03H)-AA00(0CZ)-A101(0O5)/FA10(01X)/FA10(03H)-B(02J)/B(043)/D(05H)……..

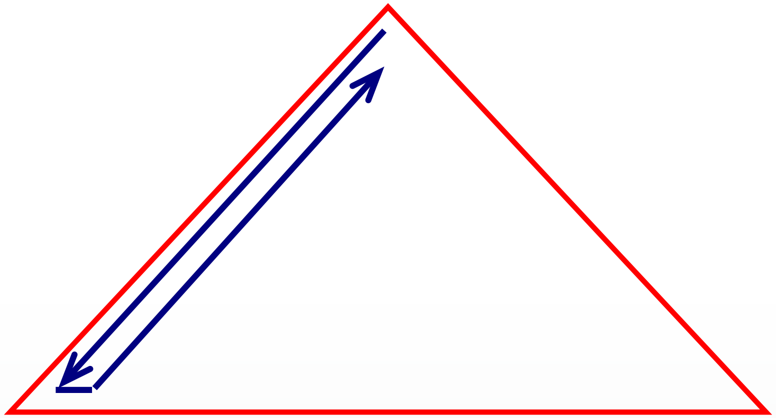


Urban Air Mobility

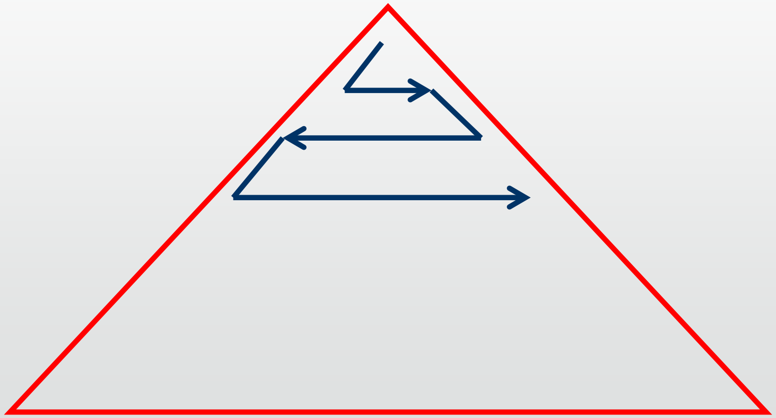


Search strategy

- Depth first



- Breadth first



ULTRA Concepts (fixed wing, prop)

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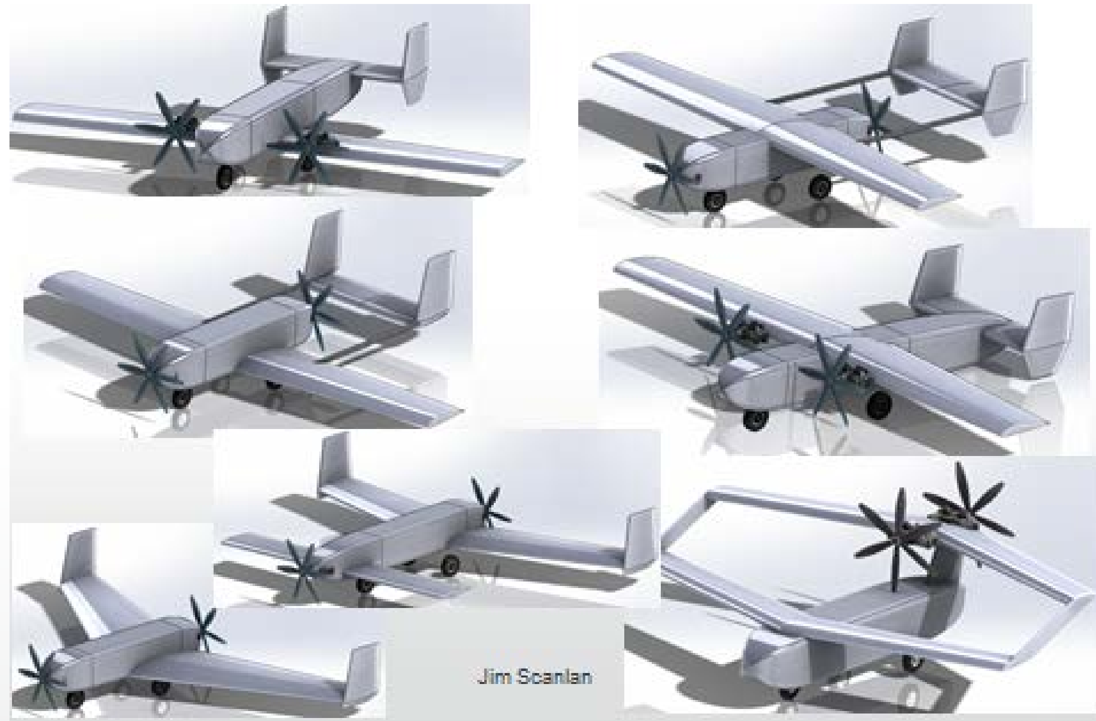
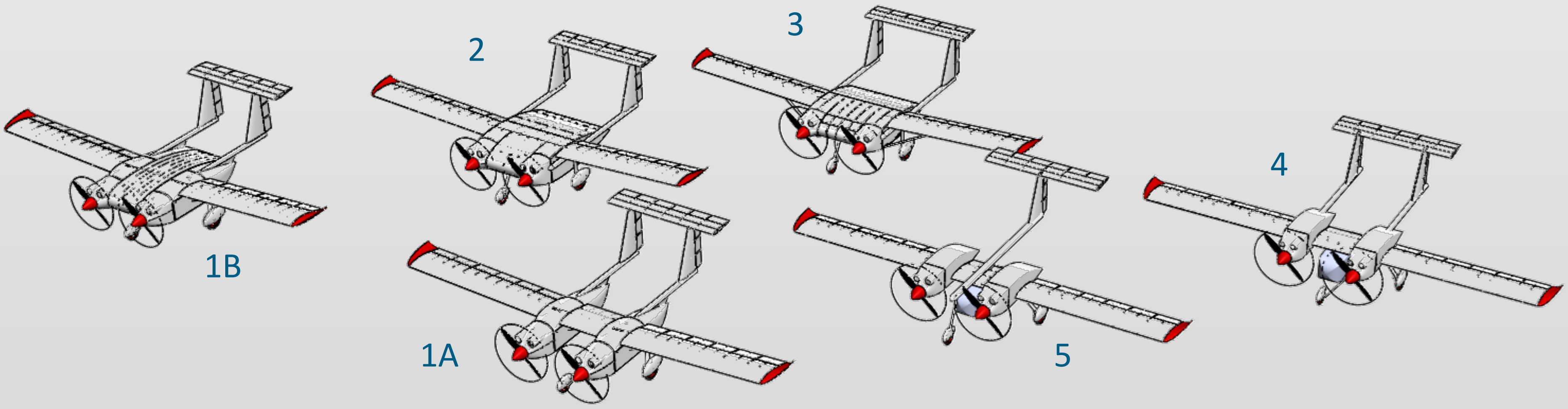
Single Engine configurations



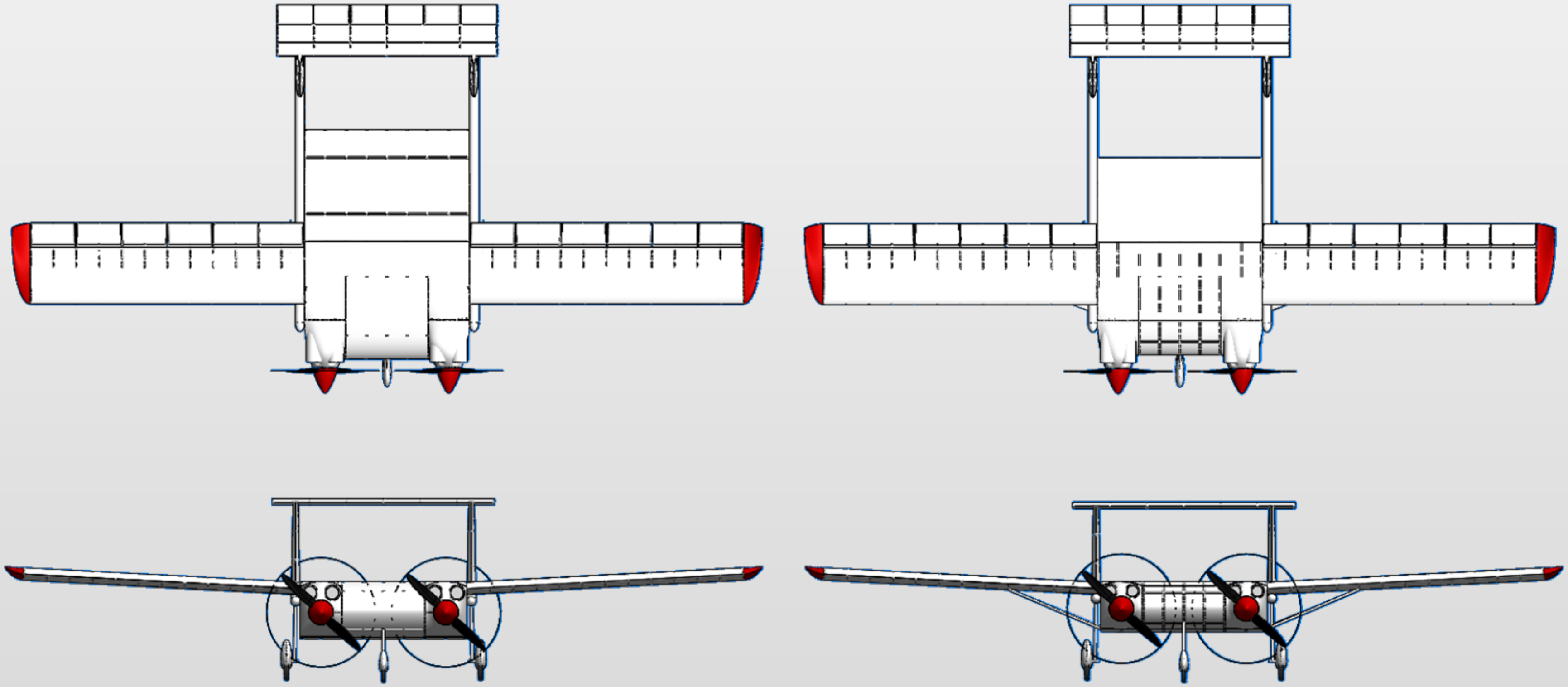
Twin Engine configuration

Concept selection (twin engine tractor)

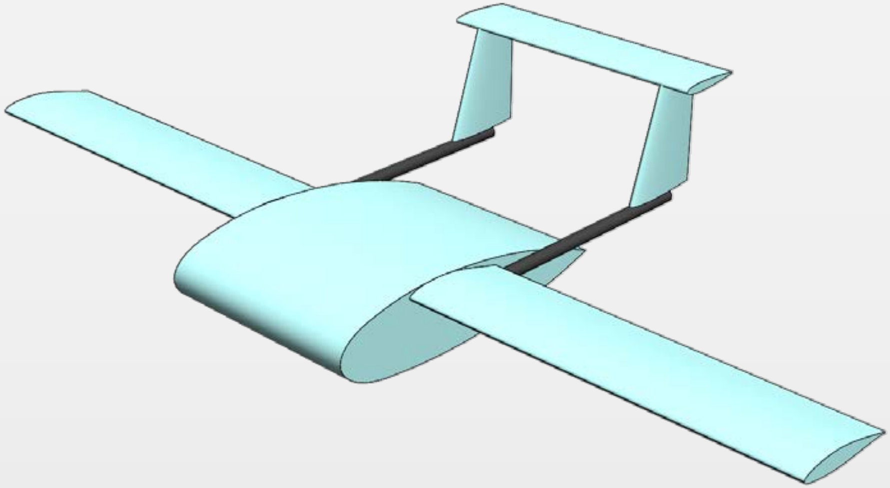
concept number	internal payload (l)	external payload (l)	acquisition cost	fuel cost	operator cost	versatility	engine out	hourly cost
1A (baseline)	256	256	£2.05	£6.10	£2.86	1	1	£18.52
1B	512	0	£2.15	£6.50	£2.86	1.1	1	£19.02
2	512	0	£2.11	£6.44	£2.57	1.15	1	£18.63
3	512	0	£2.13	£6.41	£2.57	1.15	1	£18.62
4	0	512	£1.98	£6.47	£2.71	1.1	1	£18.68
5	0	512	£1.96	£6.41	£2.71	1.2	0.95	£18.60



Cantilever or strut-braced Lifting body –



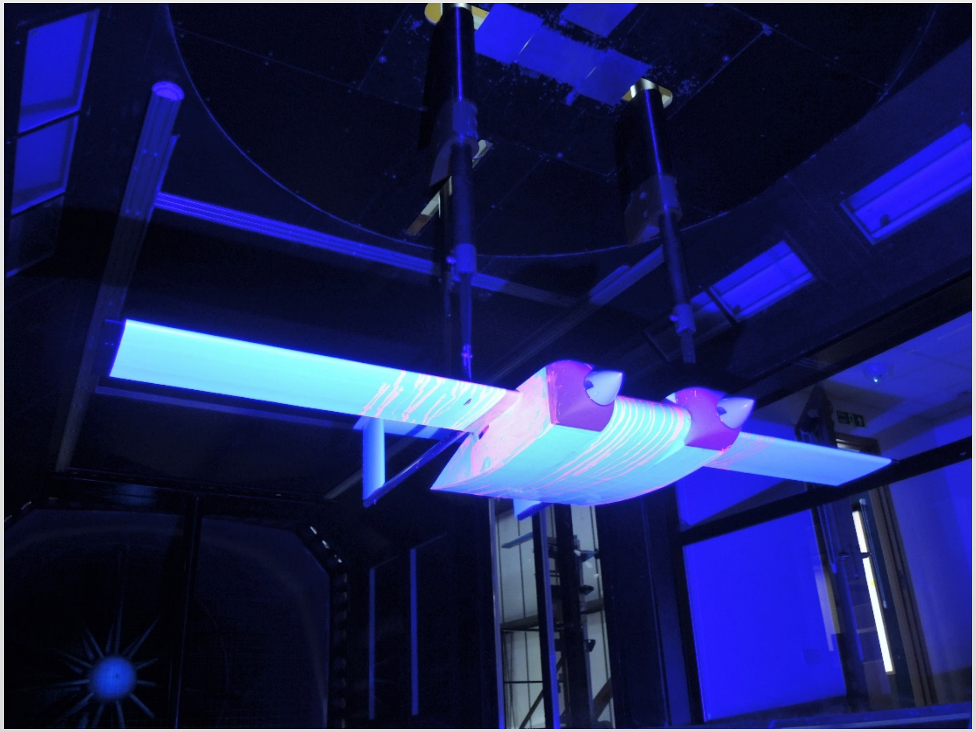
Wind tunnel model



- Flow around wing-body junction (visualisation). Experiment with fillets
- Lift/ drag. Modular centre section to allow comparison with conventional configuration
- Centre of pressure movement with angle of attack
- Impact of centre section on horizontal tail
- Optimum wing incidence with respect to lifting body
- Validation of CFD model

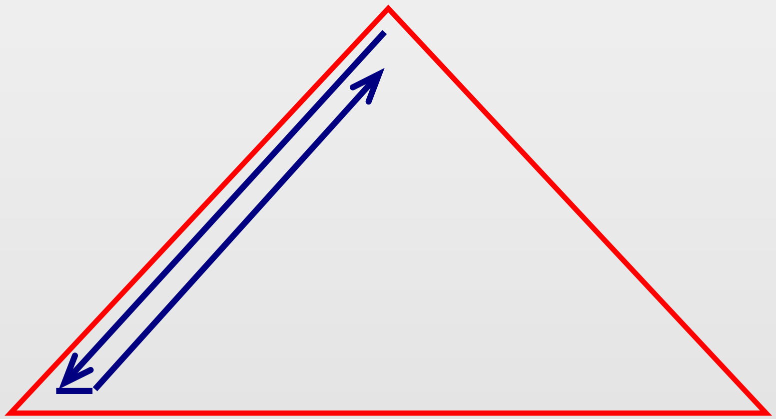
Aim to run in RJ Mitchell Tunnel (3.6 x 2.5 m working section, 40 m/s)

Flying scale model of value?

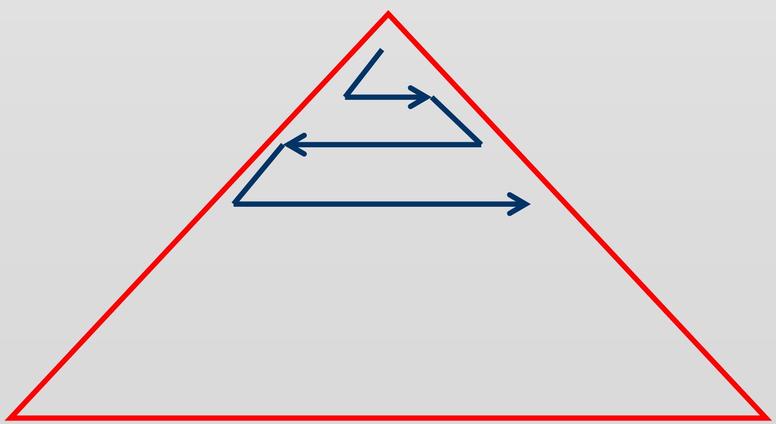


Search strategy

- Depth first



- Breadth first



Design Rationale and decision trees

Why did you design it like that?

Decision trees

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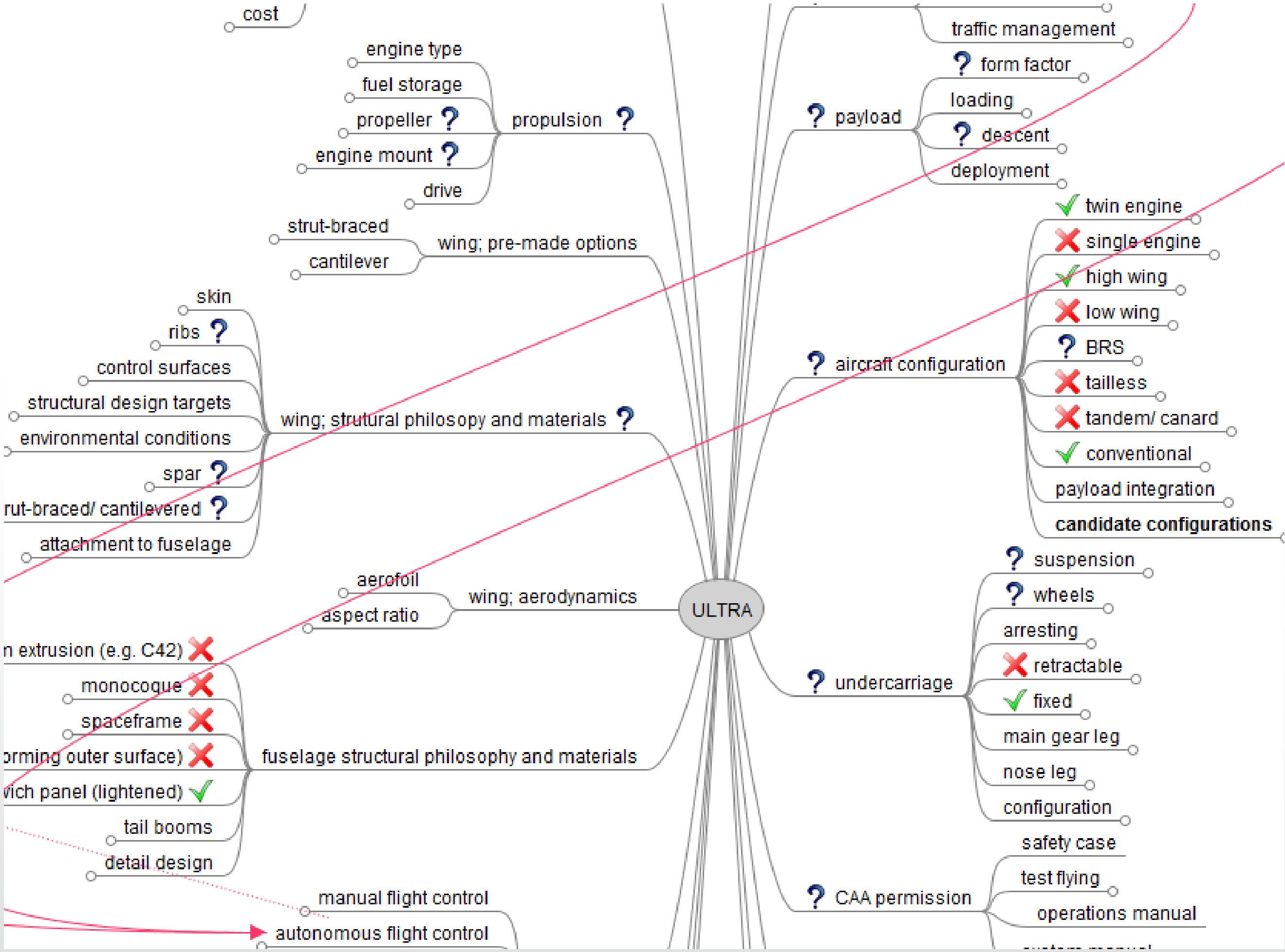
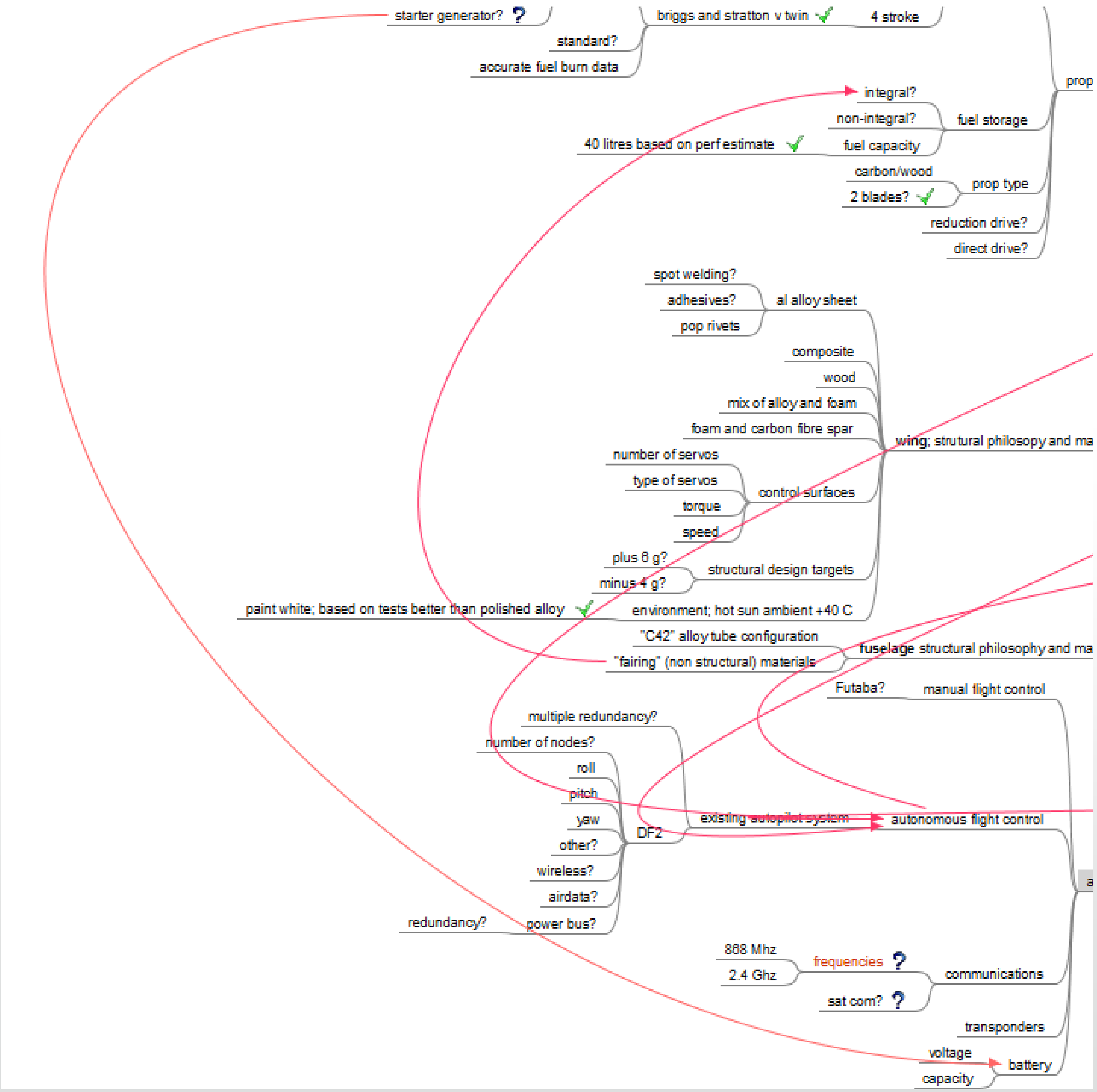
- Free mind software (Mindmup; multiuser capability)
- List decision options
- Annotate decisions;
  - ? Open decision, Cross eliminated, Tick option selected
- Advantages/ Notes etc
- Transclusion

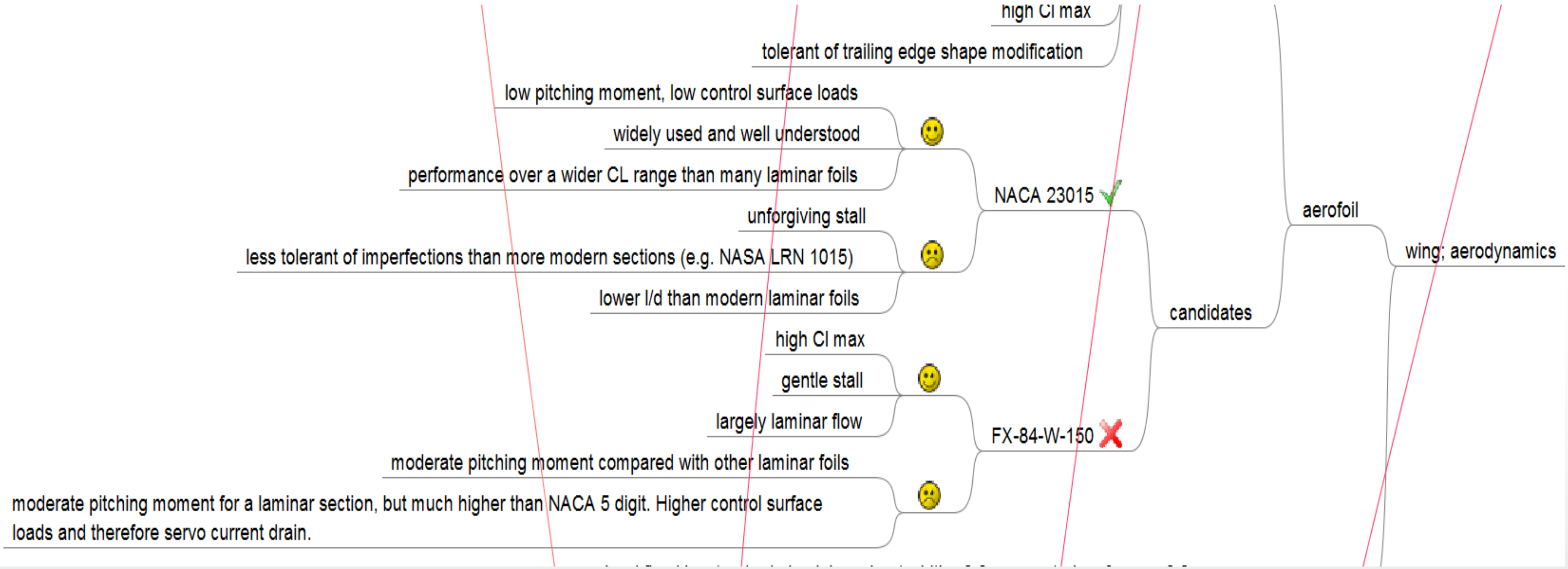


Transclusion

- Connections between decisions
- Engine starter generator decision
- Battery decision



Rationale


high Cl max
tolerant of trailing edge shape modification
low pitching moment, low control surface loads
widely used and well understood
performance over a wider CL range than many laminar foils
NACA 23015
unforgiving stall
less tolerant of imperfections than more modern sections (e.g. NASA LRN 1015)
lower l/d than modern laminar foils
aerofoil
wing; aerodynamics
candidates
high Cl max
gentle stall
largely laminar flow
FX-84-W-150
moderate pitching moment compared with other laminar foils
moderate pitching moment for a laminar section, but much higher than NACA 5 digit. Higher control surface loads and therefore servo current drain.

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Knowledge, external links

- adhesives
  - film
    - AF130-2
    - TecmanUK
      - DAAT
        - Thicknesses: 0.5mm, 1mm, plus others
        - High initial tack to hold assembly together
        - Cure 45 mins at 120C, 3 mins at 200C
        - Designed for cure in paint oven
        - Surface prep not critical - can absorb press oil if absolutely necessary (loss of tack 50C)
        - Cure pressure <0.1 MPa
        - Expect ~35 MPa shear for premared aluminium
        - Available as tape
        - Price £125/m2
        - Contact Kevin Porter - kevin.porter@tecmanuk.com
      - Quality control issues - delays
    - Hexcel
      - Adhesive selection guide
      - Redux 312
        - 100 degree service temp
        - Cure 30 mins at 120C
      - Redux 212-NA
        - 100C service temp
        - Cure 60 mins at 120C

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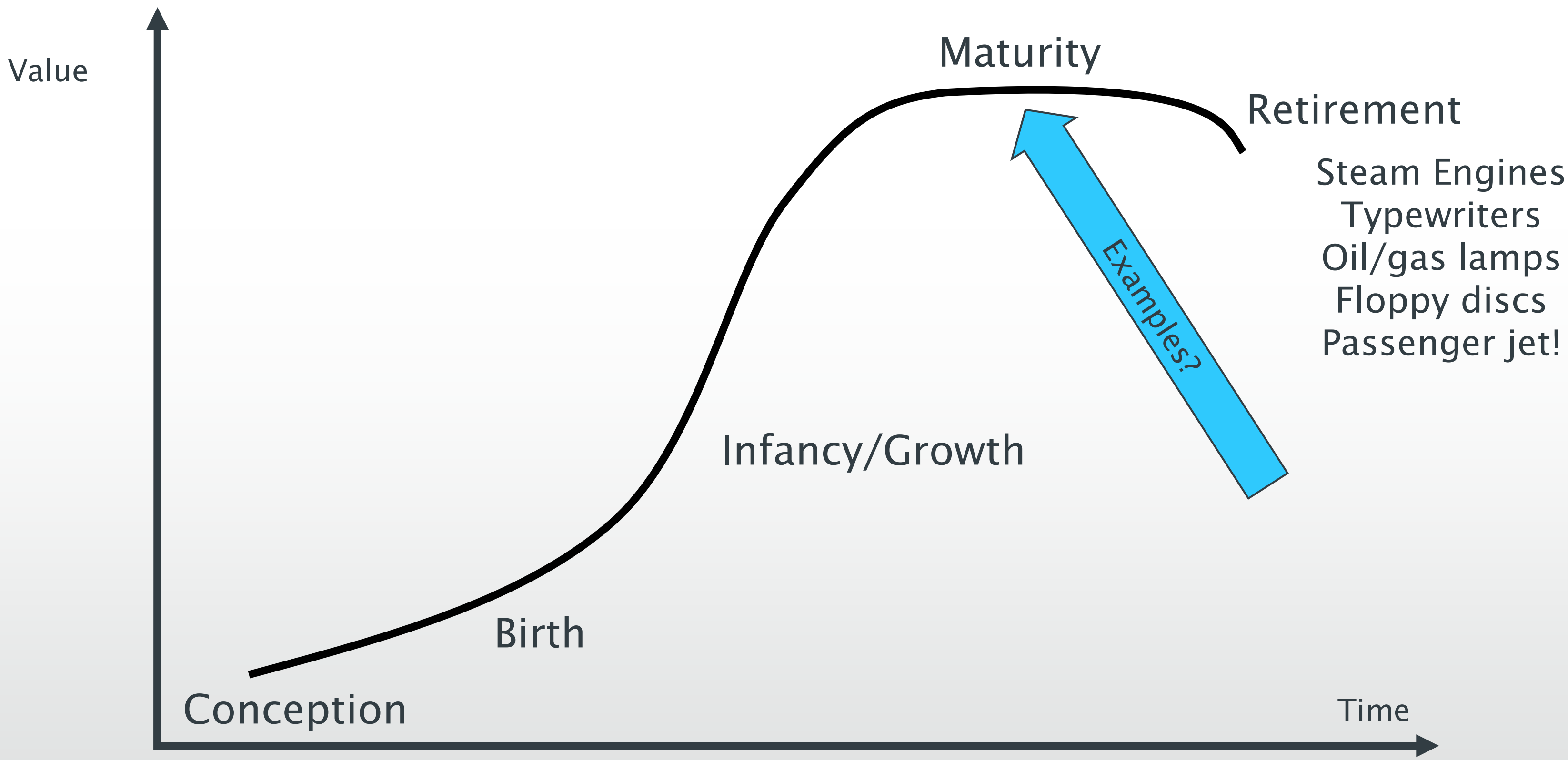
Conflicts and Design Evolution

Typical product life-cycle S-curve



Source; Darryl Mann http://function.creax.com/

Product/Process Trending: S-Curves

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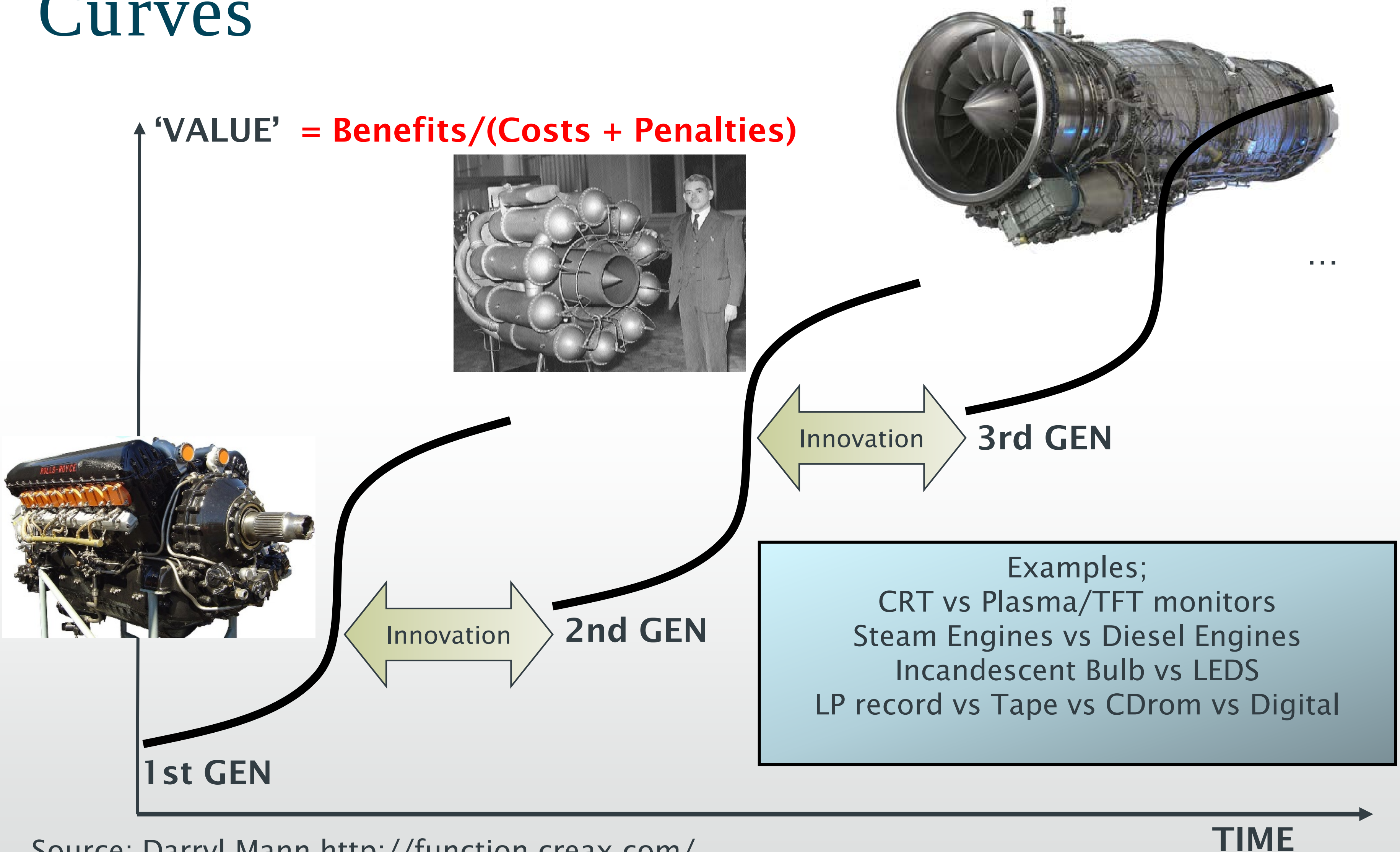

Examples;
CRT vs Plasma/TFT monitors
Steam Engines vs Diesel Engines
Incandescent Bulb vs LEDS
LP record vs Tape vs CDrom vs Digital

Source; Darryl Mann http://function.creax.com/

Perfect design

- Conflicts prevent perfect design solutions
- A designer should initially seek to eliminate conflicts through innovation
  - TRIZ (**T**eoriya **R**esheniya **I**zobretatelskikh **Z**adatch: The theory of solving inventor's problems)
- Unresolved conflicts lead to trade-offs and compromises

Breakthrough concept examples

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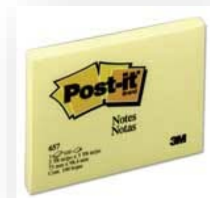
- Radar; use of cavity magnetron in microwave ovens (Percy Spencer, Raytheon); time vs volume
- Cyclone used in wood mills applied to vacuum cleaner (James Dyson) suction vs filtration
- Failed industrial adhesive used in stationery yellow “Post-it” notes (Dr Spencer Silver , 3M) stick vs reuse
- spring used in wind-up generator (Trevor Bayliss) Tensator portability vs endurance
- Semi-conductor laser used in data storage devices (CD/DVD) capacity vs reliability
- High strength magnetic fields led MRI scanners (Oxford Instruments) resolution vs safety
- Use of large prime numbers in data encryption security vs convenience
- Use of platinum catalyst in gas powered portable soldering irons convenience vs safety









Example: Aircraft gyroscopes

Mechanical Guidance Gyro (1950's)
~2 Kg
~40 W
~$ 10000

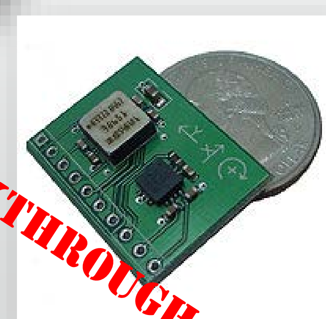
BREAKTHROUGH

Ring-laser Gyro (1960's)
~0.5 Kg
~5 W
~$ 5000

BREAKTHROUGH

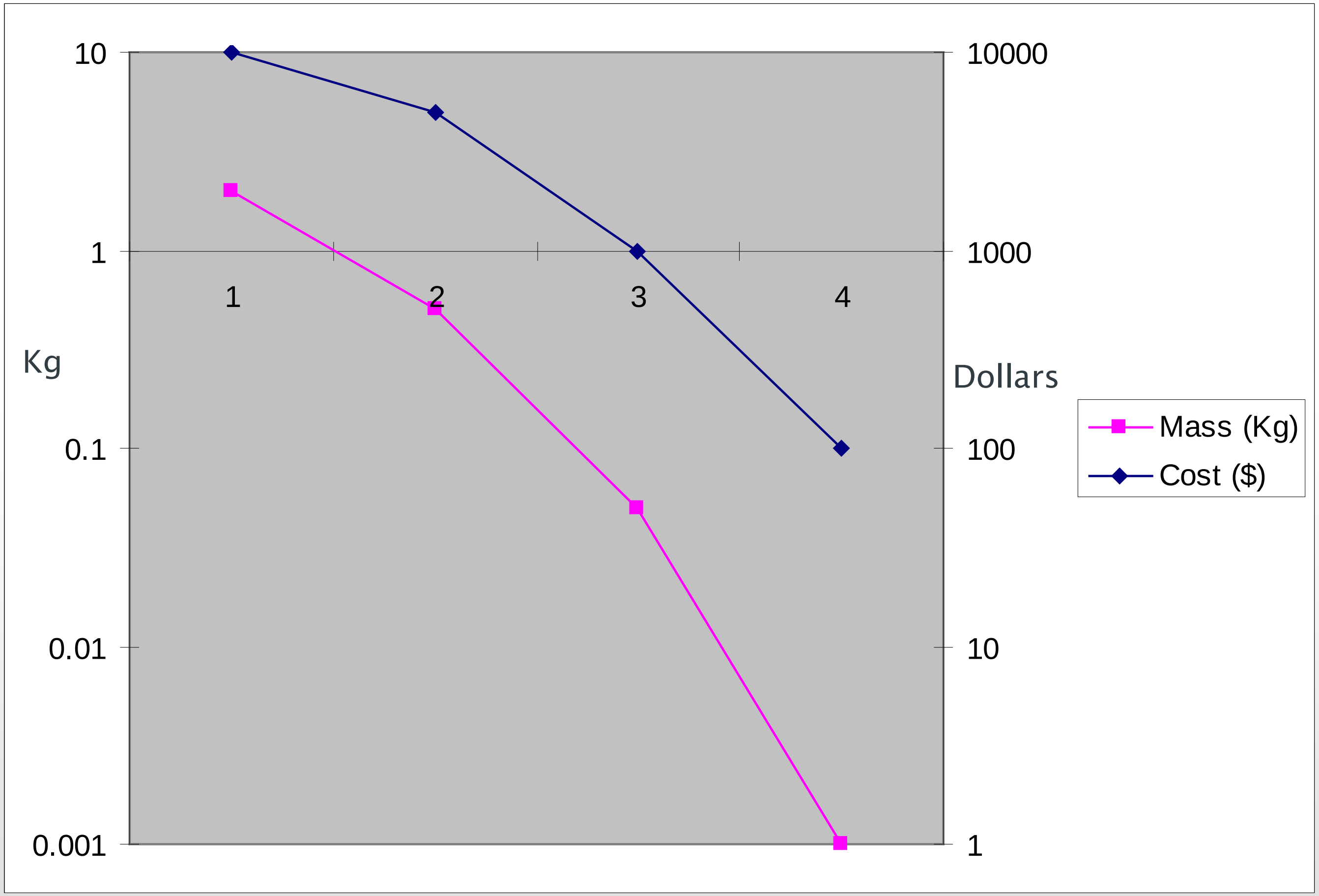
Fibre-optic Gyro (1980's)
~0.1 Kg
~1 W
~$ 1000

BREAKTHROUGH



MEMS Gyro (1990's)
~0.01 Kg
~.01 W
~$ 100

Example: Aircraft gyroscopes



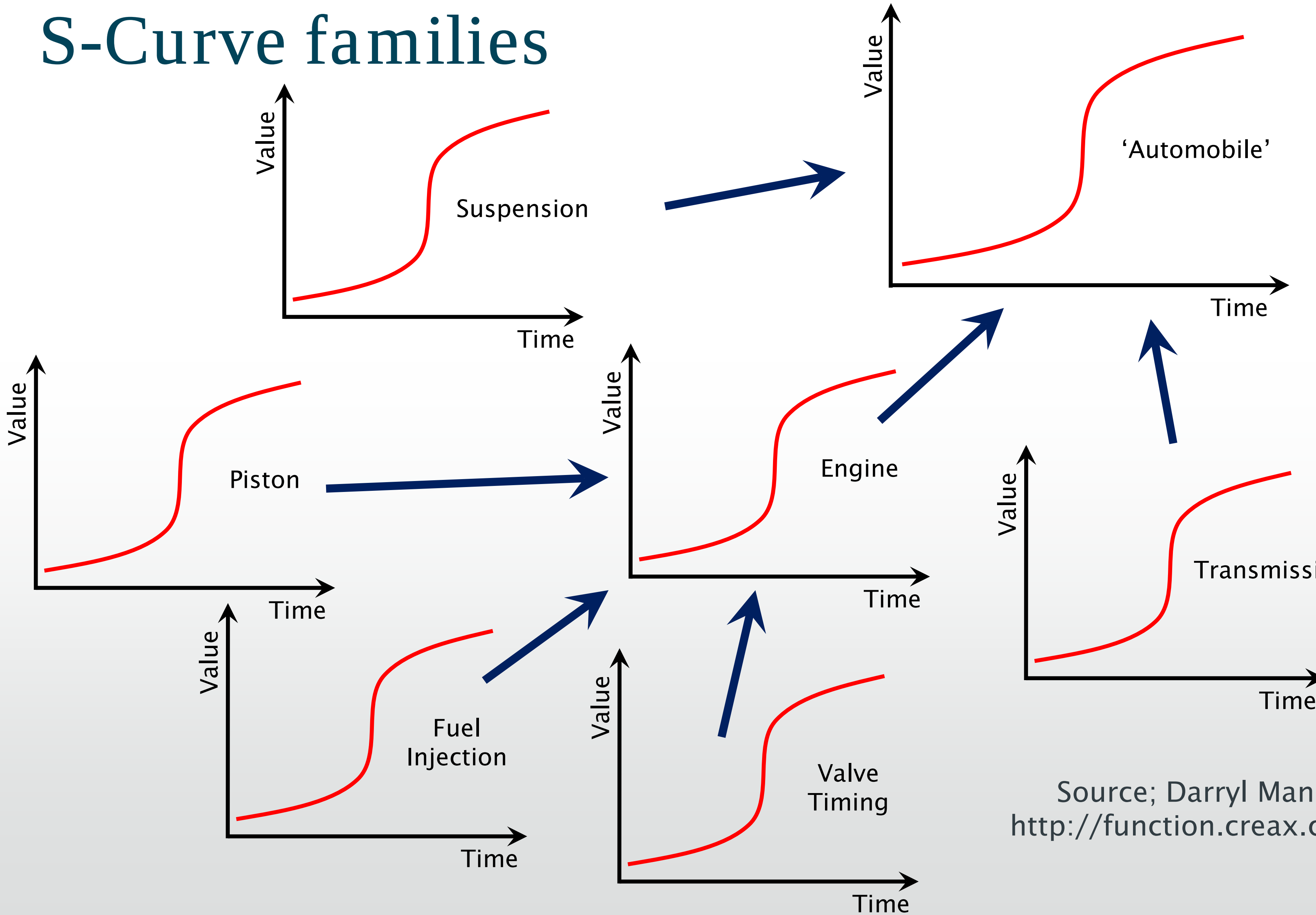
Note the logarithmic y-axes!

S-Curve families

- Every single component in the system has its own family of S-curves
- Every component's manufacturing process has its own family of S-curves
- At the lower hierarchy levels, it is more likely that the designer will design at the top right hand end of the family

Source; Darryl Mann http://function.creax.com/

S-Curve families



Source; Darryl Mann
http://function.creax.com/

Techniques

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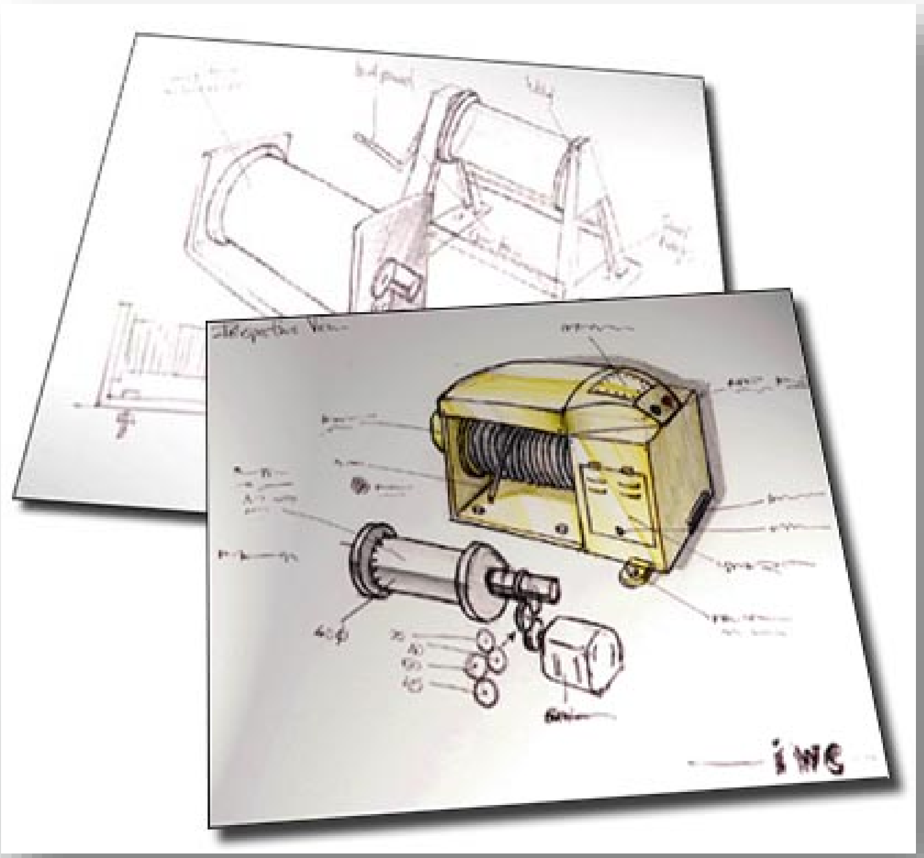
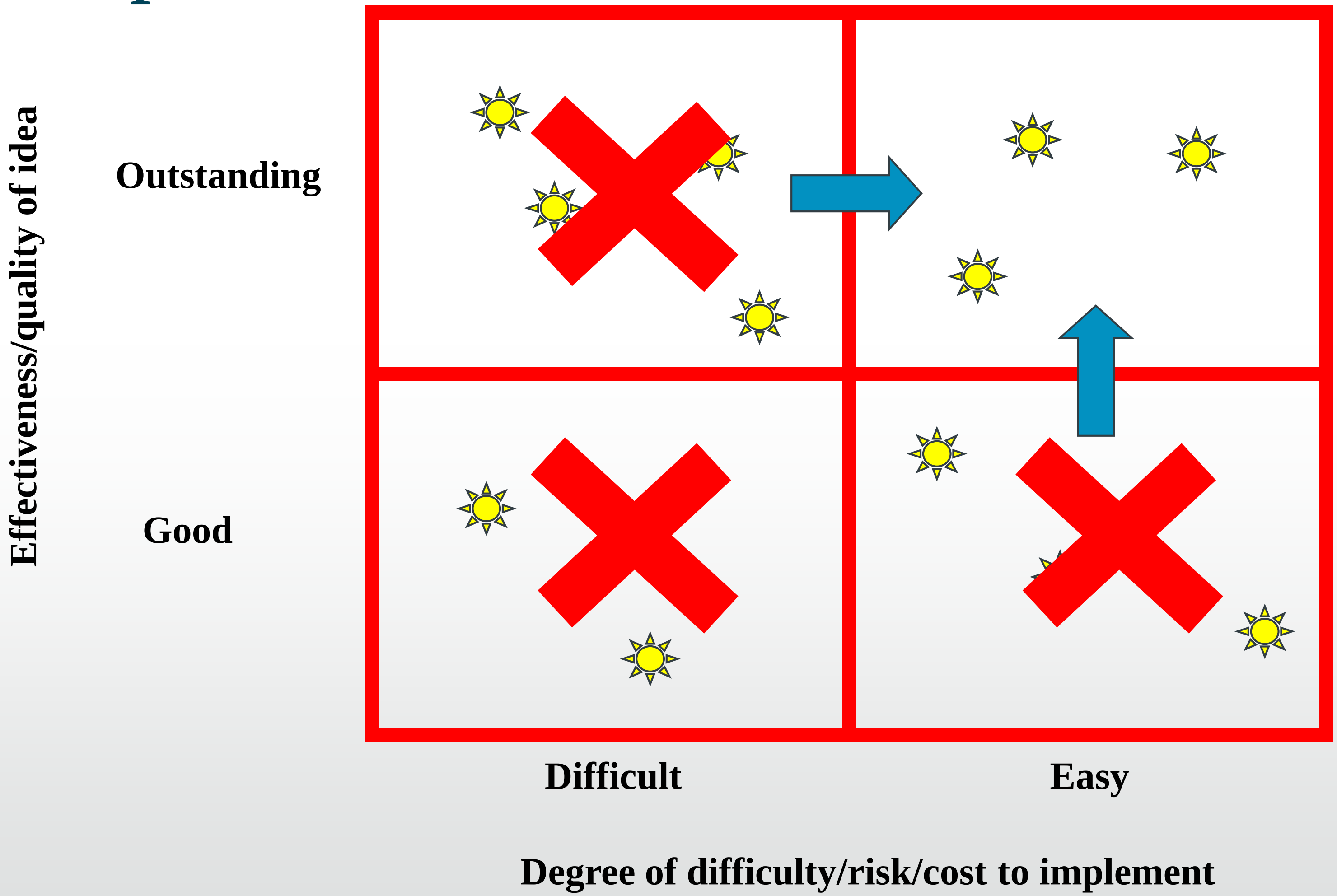
Concept generation

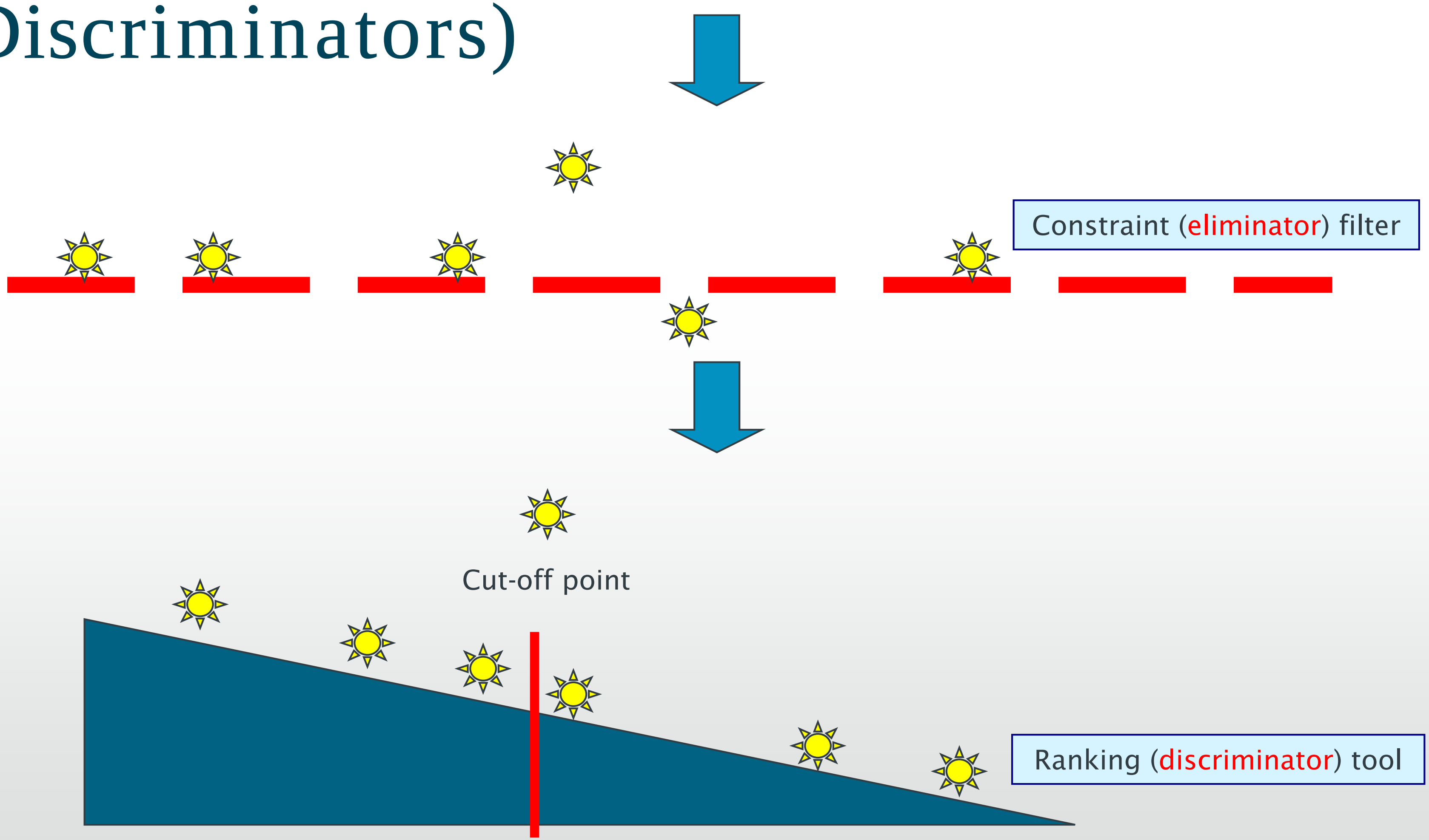
- Generate ideas and "cartoon" them one concept per page
- Use sketches and notes to illustrate key features of concepts



Concept classification



Concept selection (eliminators, Discriminators)

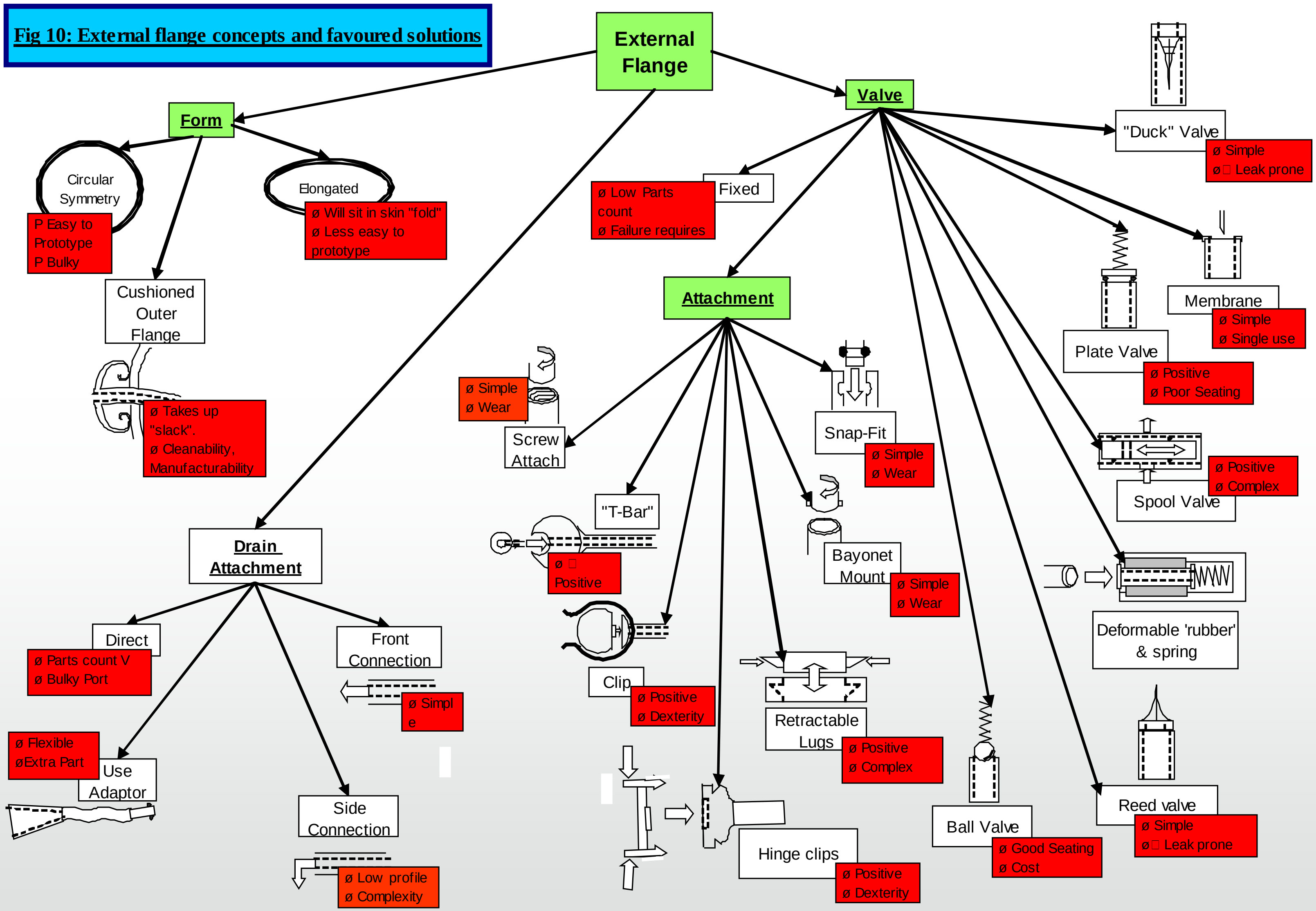


Using morphological charts to generate concepts‡

- A morphological chart is a table based on the function analysis.
- On the left side of the chart the functions are listed, while on the right side, different solutions which can be used to perform the functions listed are drawn.
- The idea generation is accomplished by creating single systems from different mechanisms illustrated in the morphological chart.

‡ http://www.eng.fsu.edu/~haik/design/idea_generation.htm

Morph Charts



Morph Charts

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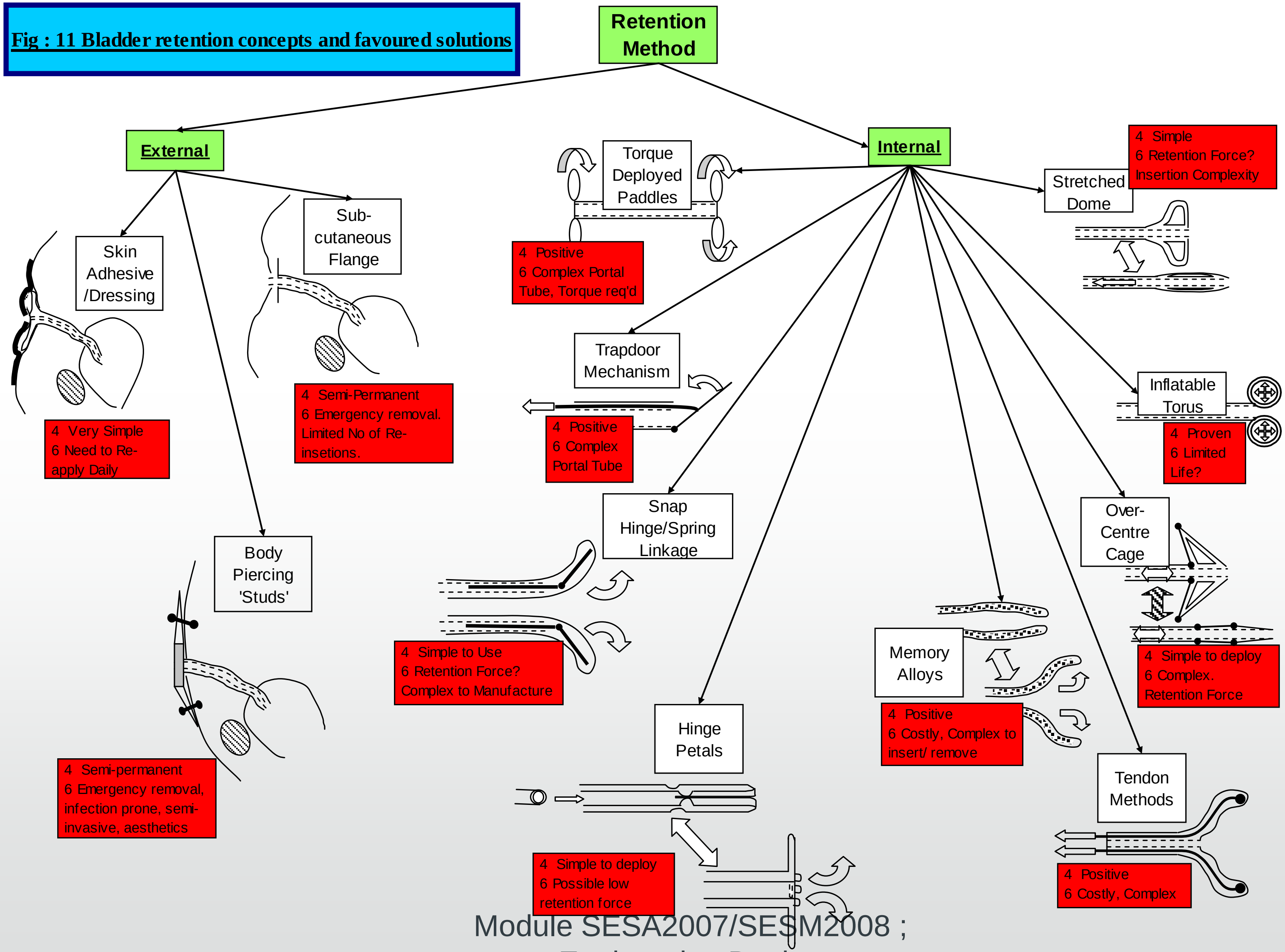

Fig : 11 Bladder retention concepts and favoured solutions

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Homework 2
Design Concept Selection

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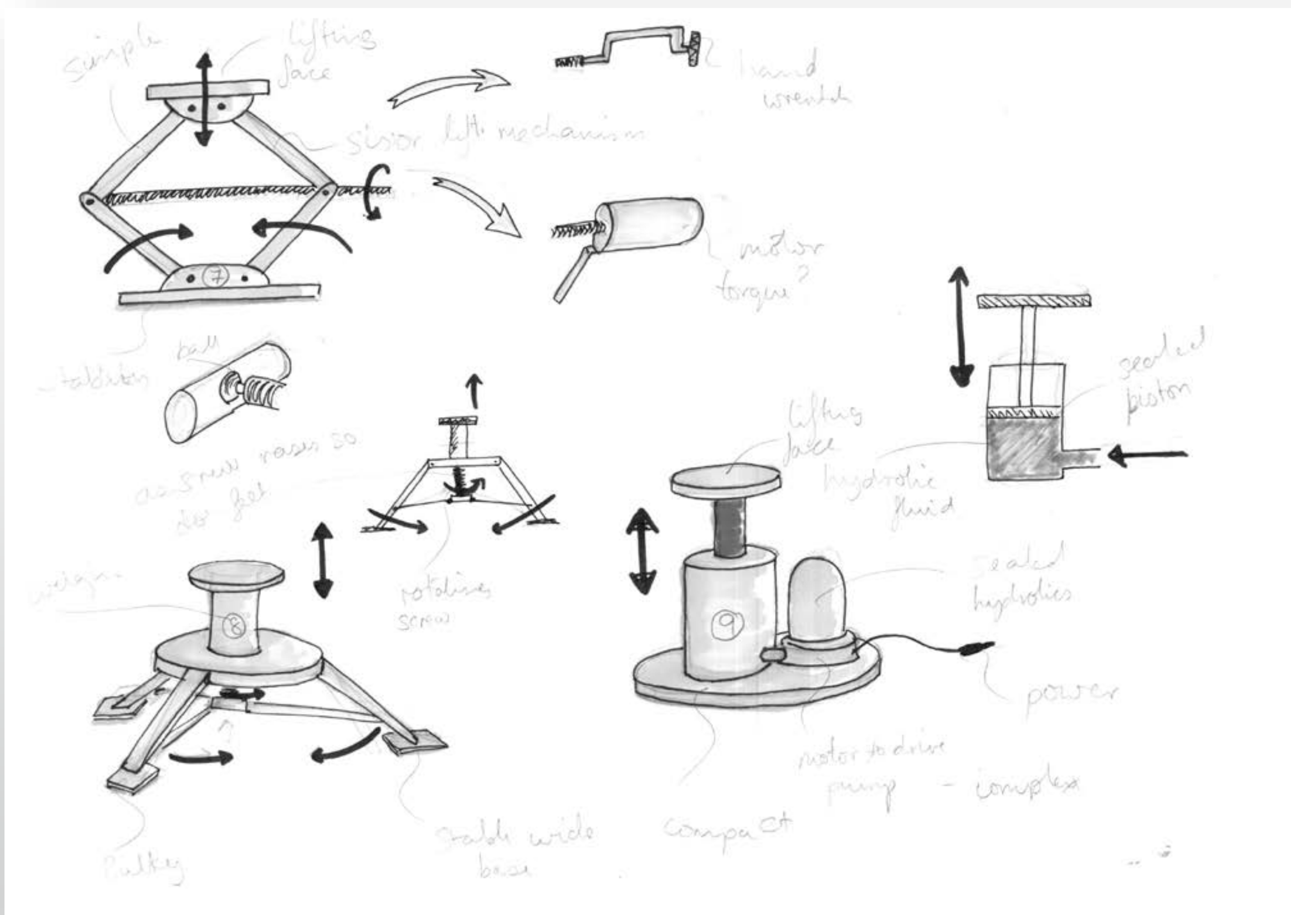
Background

- Continue working on the car jack project.

Objective

- Select a design concept as a candidate to evaluate in further detail.



Procedure

- The detail design phase of a project is expensive.
- In order to ensure that you invest effort in the right concept you need to
  - Generate a large range of candidate design concepts which adequately cover the scope of the design space
  - Document each concept as a distinct entity
  - Filter out concepts that clearly do not meet any hard constraints that you have identified
  - Rank the remaining concepts
  - Select most highly ranked concept

Techniques

An important consideration is the need to partition the concept analysis process:

- **Stage 1:** The objective of the first stage is to generate ideas. The success of this stage is measured in terms of the range, novelty and number of distinct ideas and concepts generated. This requires a constructive attitude/ mindset/ atmosphere.
- **Stage 2:** The second stage concerns selecting the best idea/concept in a structured and logical (auditable!) way. This needs critical appraisal and requires a judgemental and discriminative attitude/ mindset/ atmosphere.

In an industrial setting it is important to ensure that these two stages are divorced from each other as they are ***not*** complimentary activities. In many companies the two functions are undertaken by two separate parts of the organisation.