27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

How to Explore Desirability, Feasibility and Viability of Business and System Design under Uncertainty

THE VALXPLORE METHOD

About me

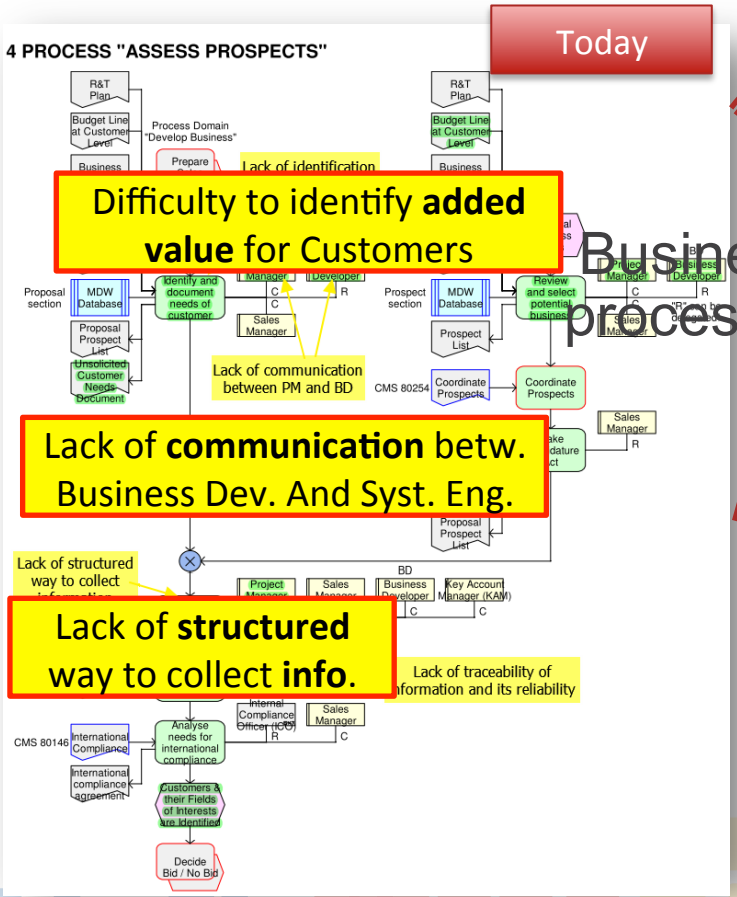
I am a system engineer at Airbus Safran Launchers.

Since 2014, I am doing a Ph.D. on system design

2011-2013: I took part in the Single European Sky Air traffic management Research (SESAR) program.

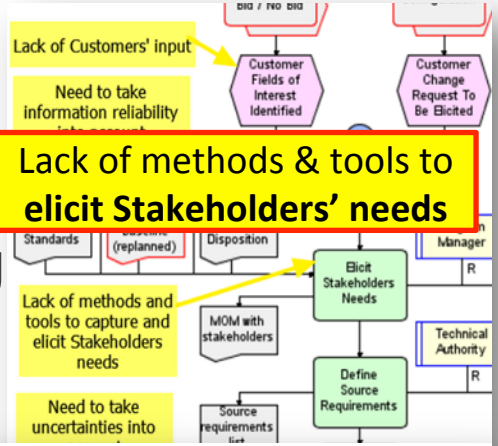
Linking Business & System design in early stages

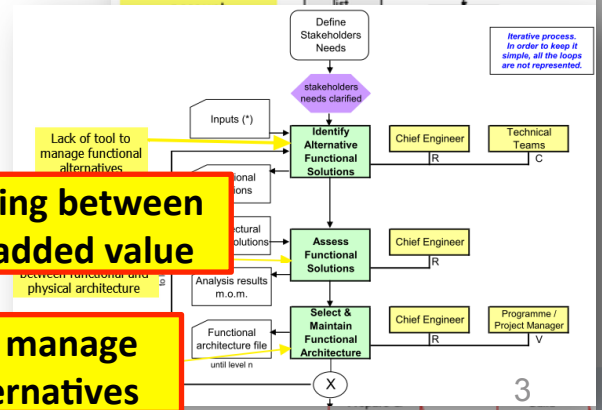
Today



Business processes

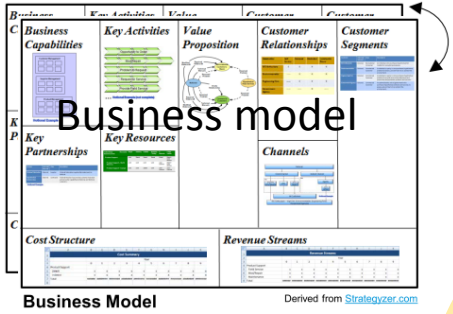
System Architecting processes



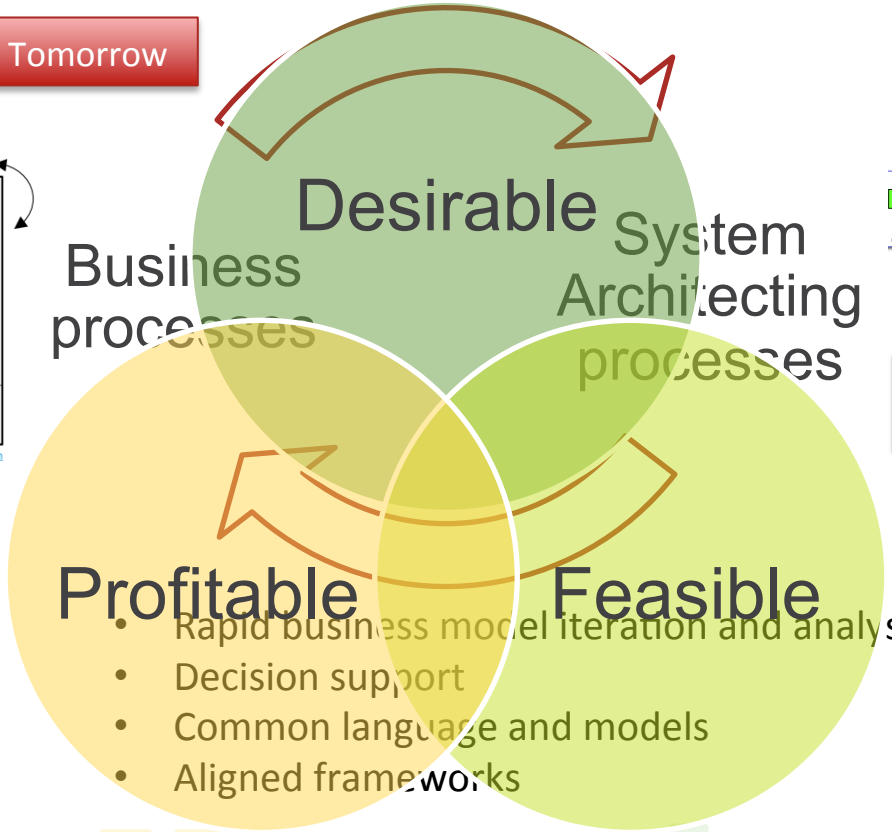


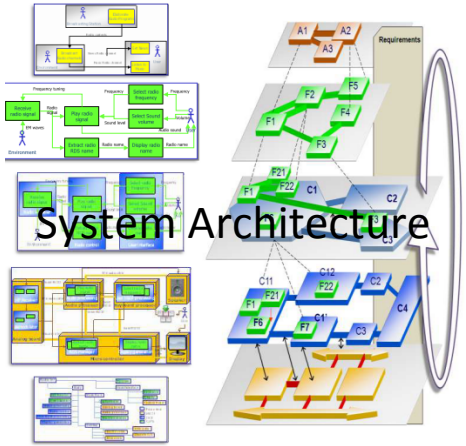
Linking Business & System design in early stages

Tomorrow



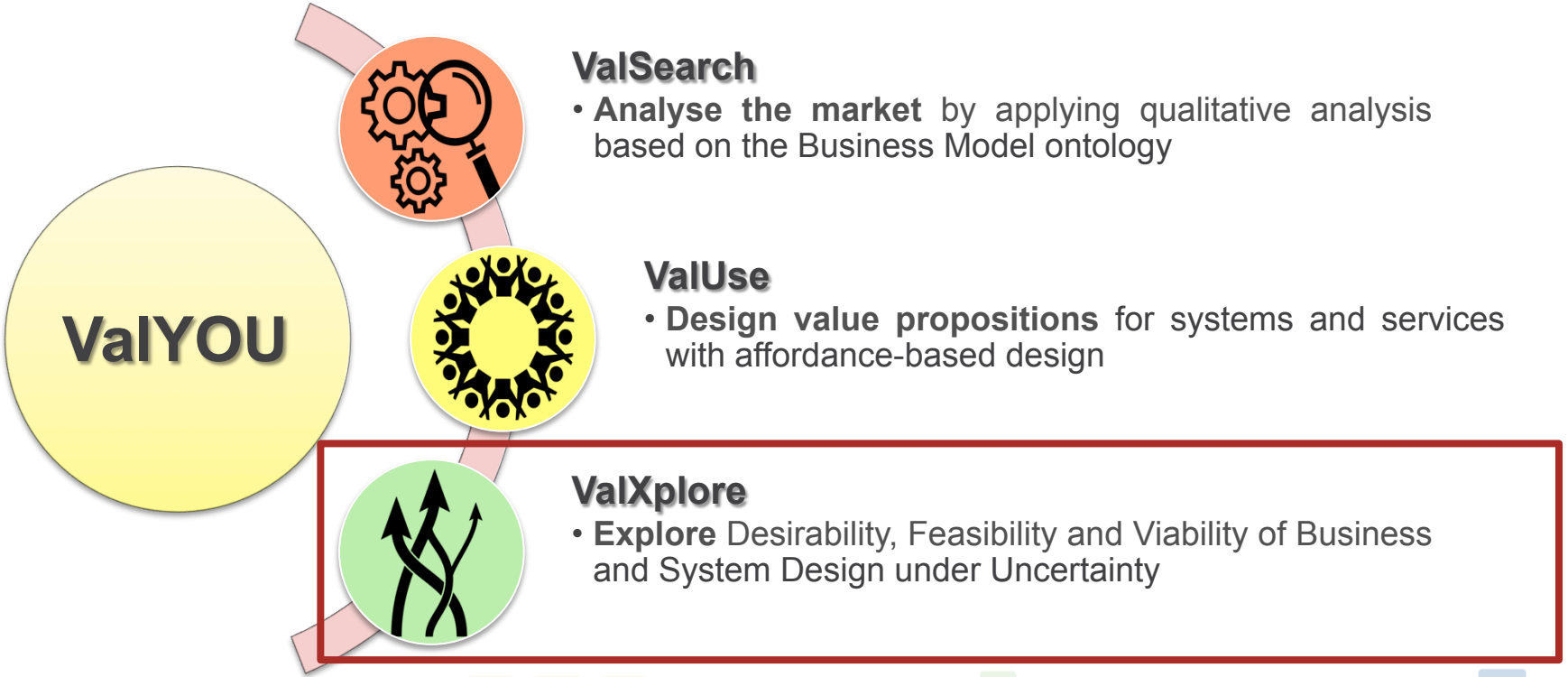
Business scenarios





CAPELLA

Proposed 3-step Design-to-Value methodology



ValSearch

- **Analyse the market** by applying qualitative analysis based on the Business Model ontology

ValUse

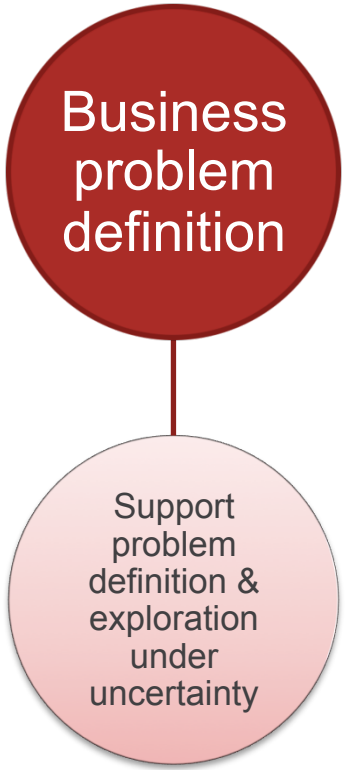
- **Design value propositions** for systems and services with affordance-based design

ValXplore

- **Explore** Desirability, Feasibility and Viability of Business and System Design under Uncertainty

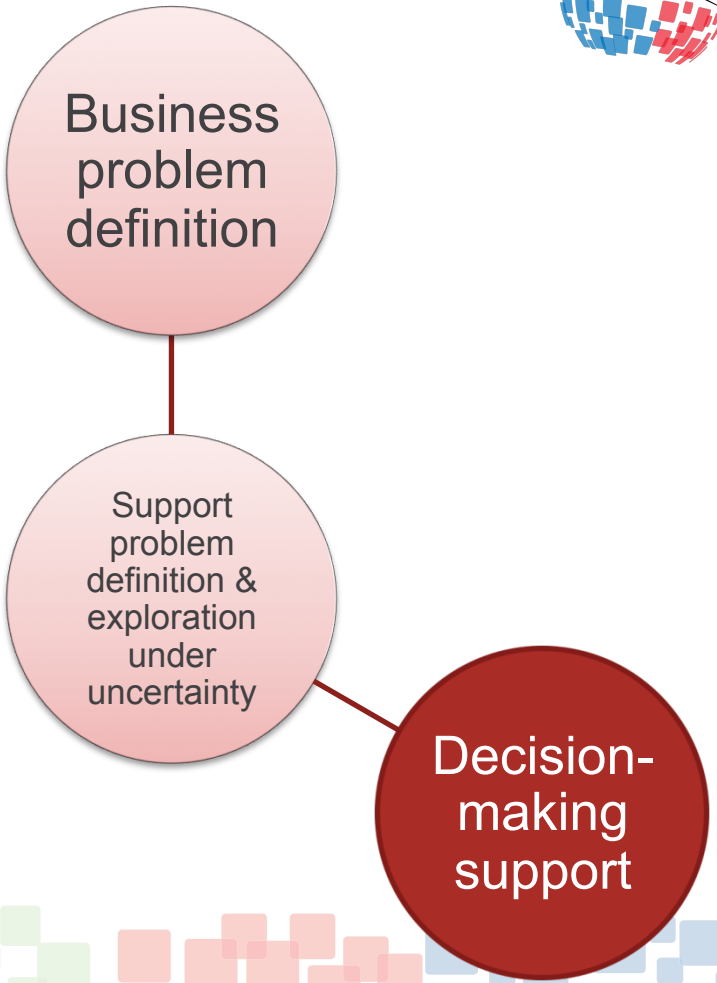
Background

- If not clearly defined, miss better alternatives *(Parnell 2016)*
- Sometimes most important step *(Blanchard and Fabrycky 2010)*
- Problem def. and solutions id. are highly concurrent activities
- Exploring solutions help understand problem; and vice versa

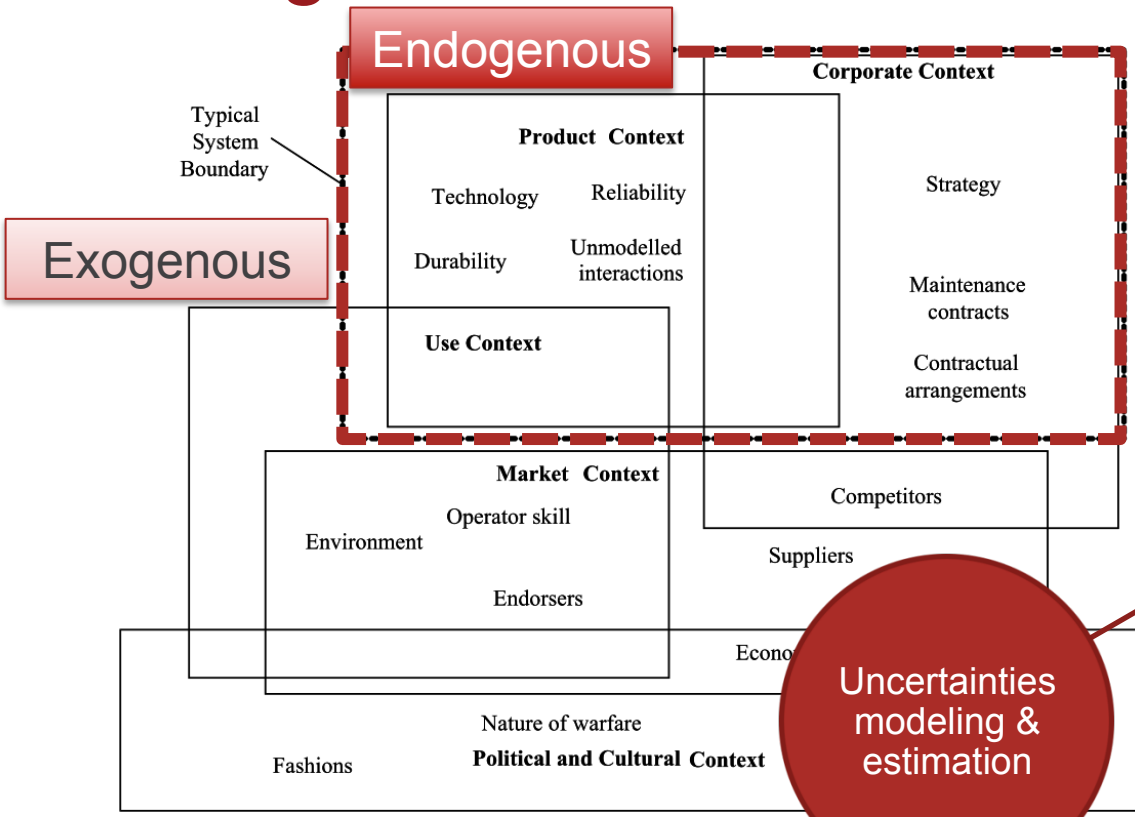


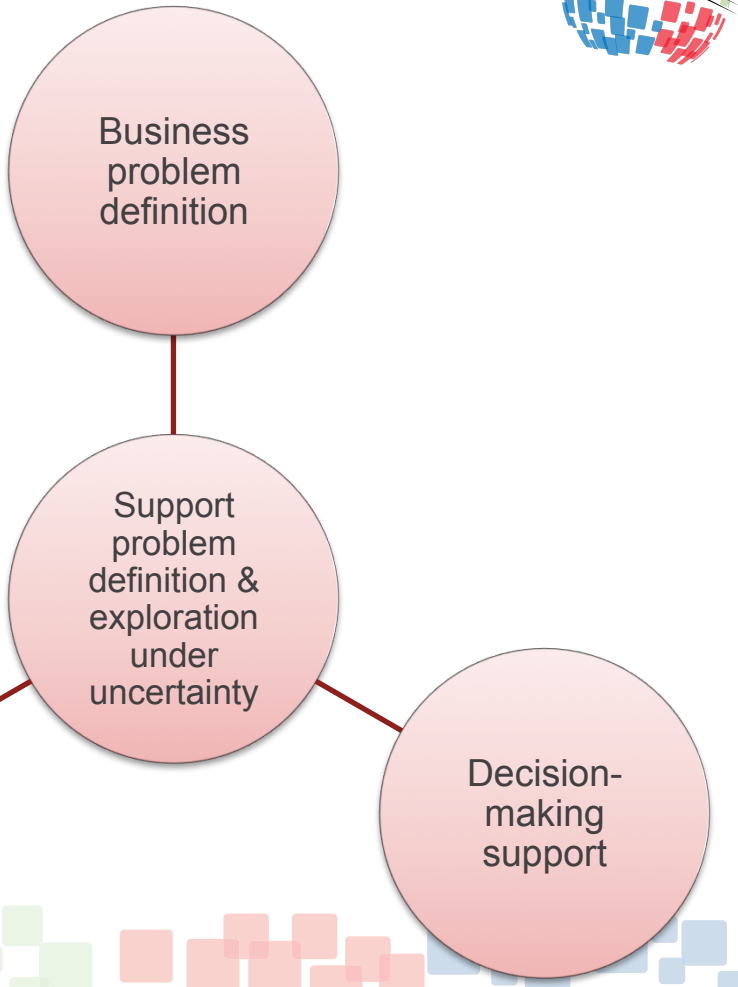
Background

- Increasing interest in the decision support **process** *(Tsoukiàs 2008)*
- MCDM focus on alternatives' exploration and evaluation, not **problem formulation** *(Belton and Stewart 2002)*
- Decision support **process** appears to be more important than the applied **method** *(French 1993; Keeney 2009; Roy 2013)*
- "a decision is not an act, but a process", *(Simon 1983)*



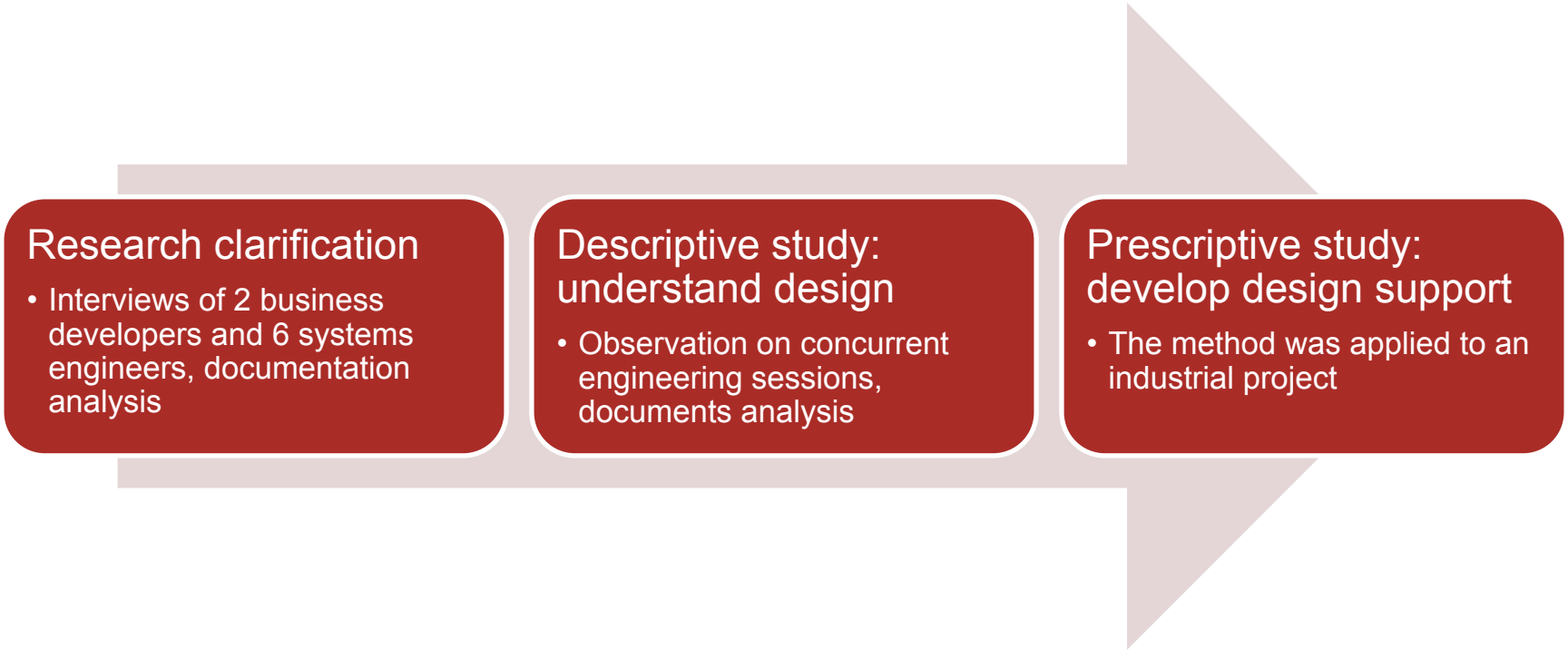
Background





Weck et al., 2007

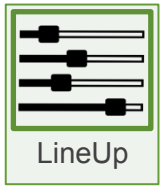
Research design



ValXplore is a two-stage decision support method

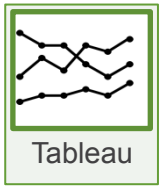
Design Business Problem

- Exploration based upon expert appraisal



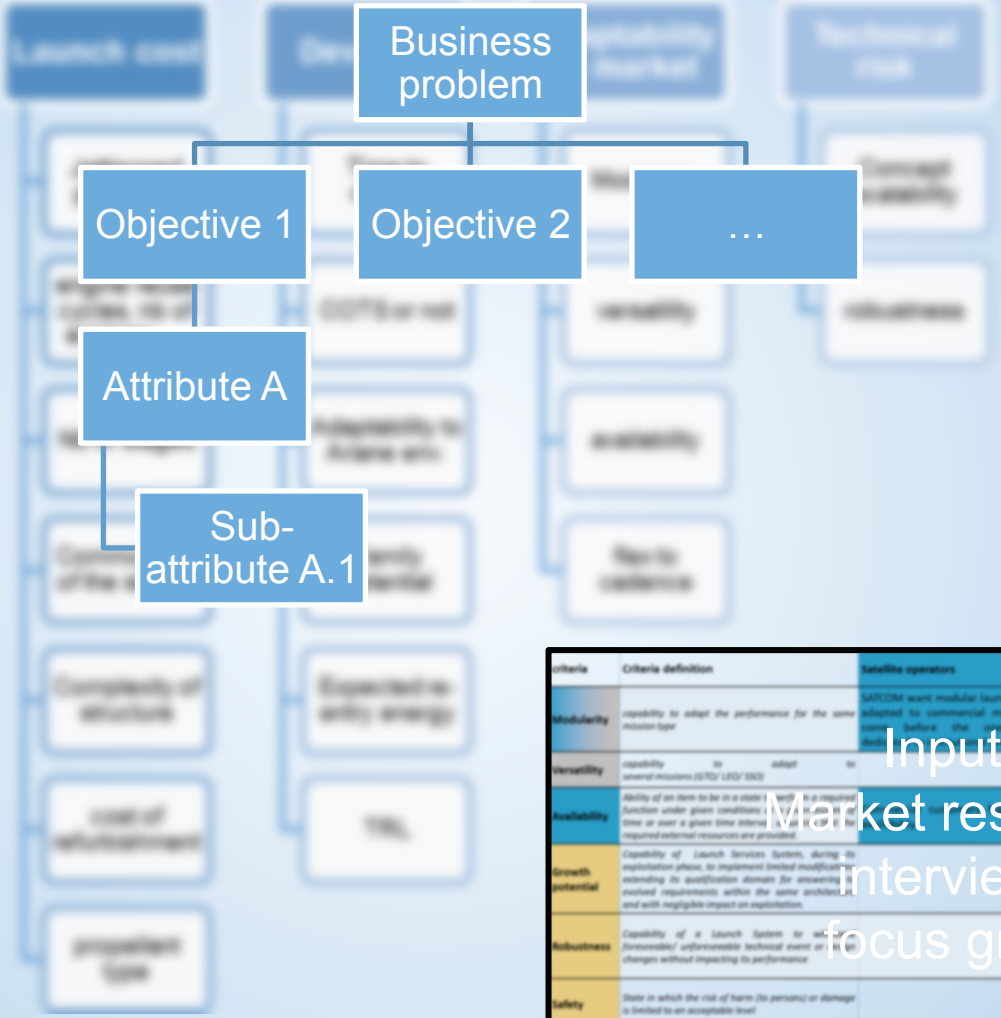
Explore Design alternatives

- Preliminary multi-disciplinary feasibility study



EXAMPLE:
WHAT ARE THE BENEFITS & LIMITS OF SEMI-REUSABLE LAUNCH VEHICLES?

Structure the Problem

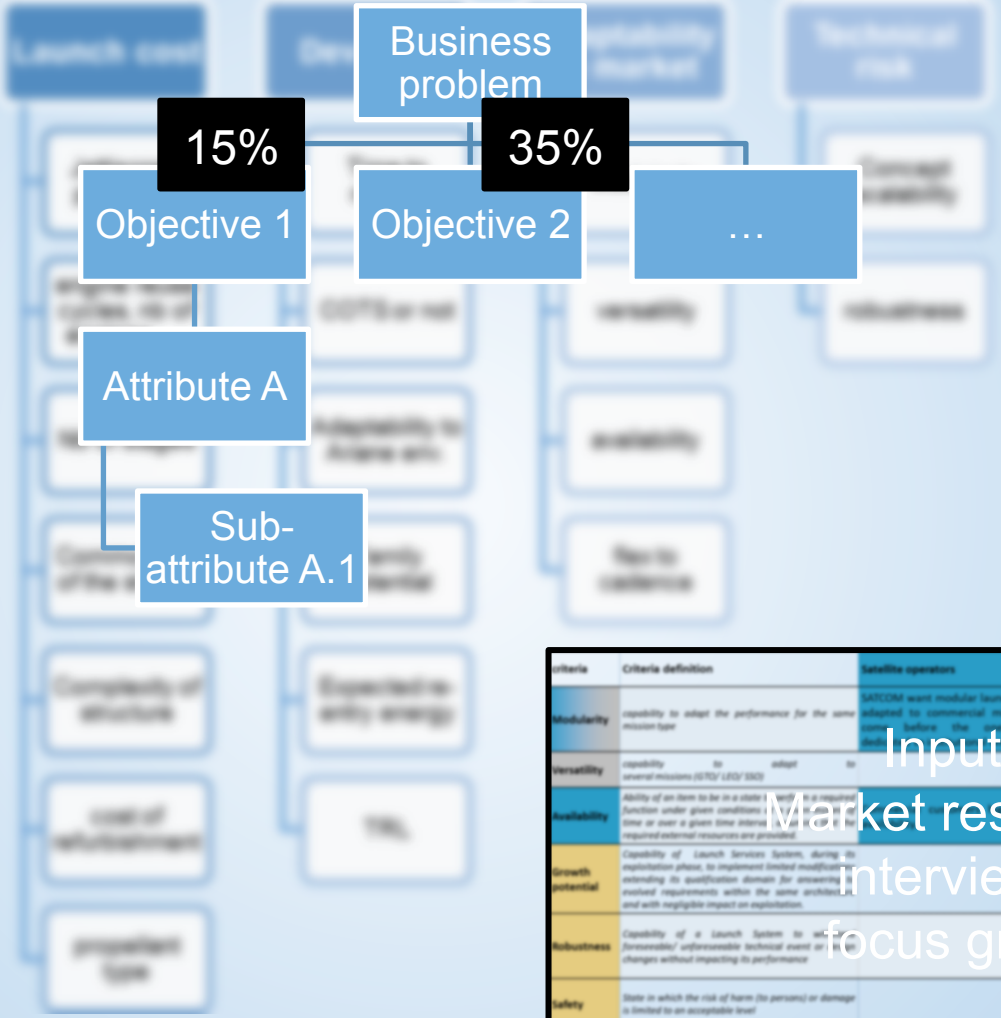


criteria	Criteria definition	Satellite operators	Institutions	European launcher industry	Population
Modularity	capability to adapt the performance for the same mission type	SATCOM want modular launcher most adapted to commercial missions to come before the ... mostly dedi...	La modularité doit pouvoi r être réactive et ne pas se faire au détriment de la di sponibilité		
Versatility	capability to adapt to several missions (GTO/ LEO/ SSO)		La versatilité n'intéresse q ue les vols institutionnels.		
Availability	Ability of an item to be in a state ... function under given conditions ... time or over a given time interv... required external resources are provided.				
Growth potential	Capability of Launch Services System, during its exploitation phase, to implement limited modifications extending its qualification domain for answering evolved requirements within the same architecture and with negligible impact on exploitation.			answer to evolved requirements	
Robustness	Capability of a Launch System to ... foreseeable/ unforeseeable technical event or ... changes without impacting its performance			Le manque de robust esse induit une perte de temps pour requ alification du lanceur	
Safety	State in which the risk of harm (to persons) or damage is limited to an acceptable level				Safety has a societal outcome

Inputs:
Market research,
interviews,
focus group

Structure the Problem

Model Preferences



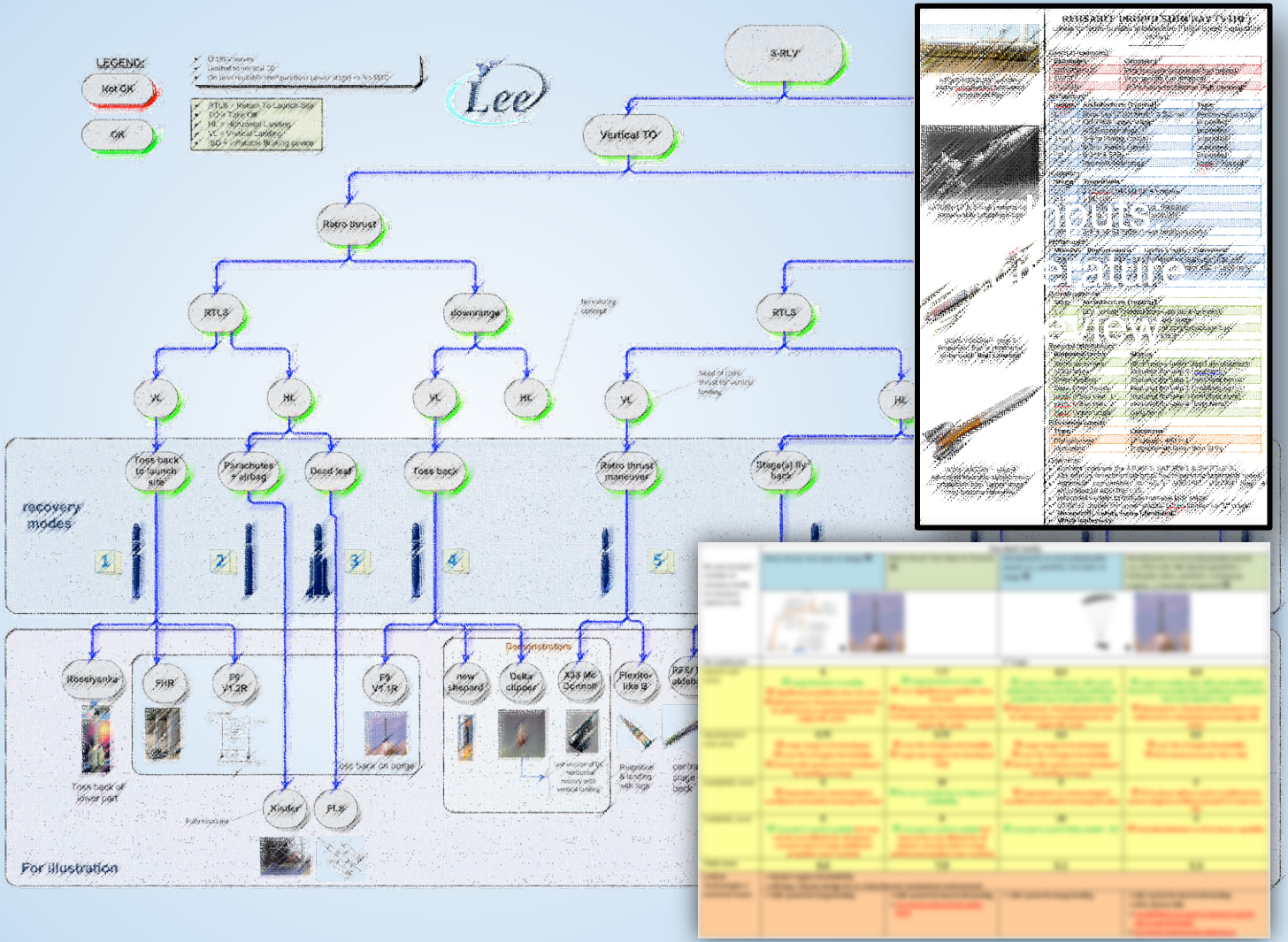
criteria	Criteria definition	Satellite operators	Institutions	European launcher industry	Population
Modularity	capability to adapt the performance for the same mission type	SATCOM want modular launcher most adapted to commercial missions to come before the ... mostly dedi...	La modularité doit pouvoi r être réactive et ne pas se faire au détriment de la di sponibilité		
Versatility	capability to adapt to several missions (GTO/ LEO/ SSO)		La versatilité n'intéresse q ue les vols institutionnels.		
Availability	Ability of an item to be in a state ... required function under given conditions ... time or over a given time interval ... required external resources are provided.				
Growth potential	Capability of Launch Services System, during its exploitation phase, to implement limited modifications ... extending its qualification domain for answering ... evolved requirements within the same architecture ... and with negligible impact on exploitation.			answer to evolved requirements	
Robustness	Capability of a Launch System to ... foreseeable/ unforeseeable technical event or ... changes without impacting its performance			Le manque de robust esse induit une perte de temps pour requ alification du lanceur	
Safety	State in which the risk of harm (to persons) or damage is limited to an acceptable level				Safety has a societal outcome

Inputs:
Market research,
interviews,
focus group

Structure the Problem

Model Preferences

Evaluate Alternatives



Structure the Problem

Model Preferences

Evaluate Alternatives

Formulate Recommendations

- *The higher the score, the better the alternative*
- *Quotation is performed on a range 0 to 10*

Challenges in defining the business problem

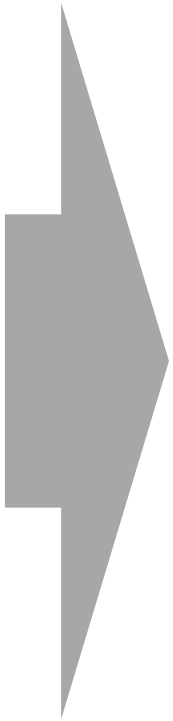
Define Objectives	• “Not thinking broadly enough, • not thinking deeply enough” *(Bond, et al. 2010)*
Model Preferences	•Fuzzy and evolving preferences •Conflicting preferences •Aggregated preferences difficult to interpret by decision-makers
Evaluate Alternatives	•Evaluate the alternatives with regard to the attributes •Interpret ranking
Formulate Recommendations	•Not clear identification of uncertainties, and their impact •Decision makers lack of confidence on selected alternatives

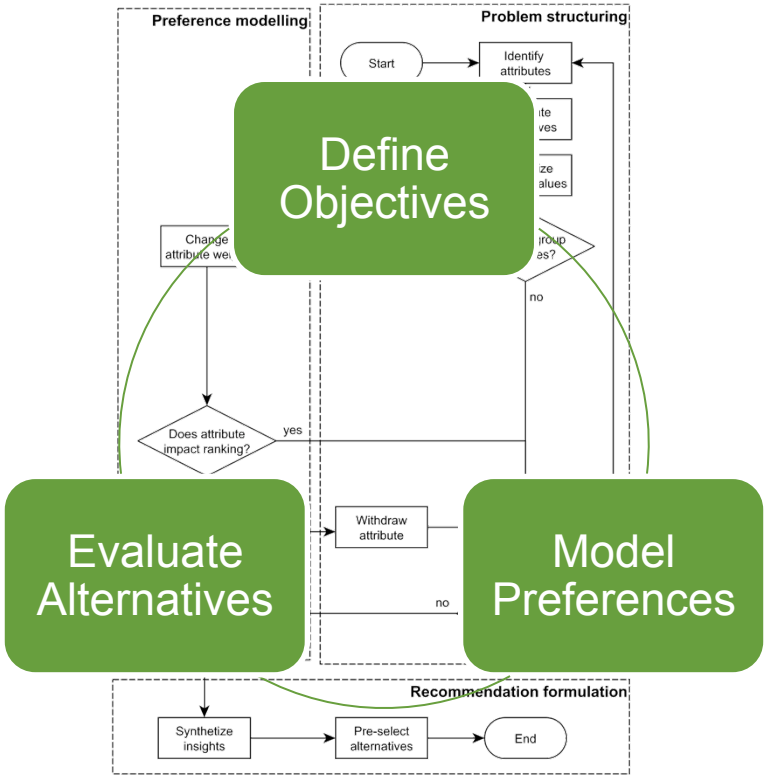
Framing the Business Problem

Define Objectives

Model Preferences

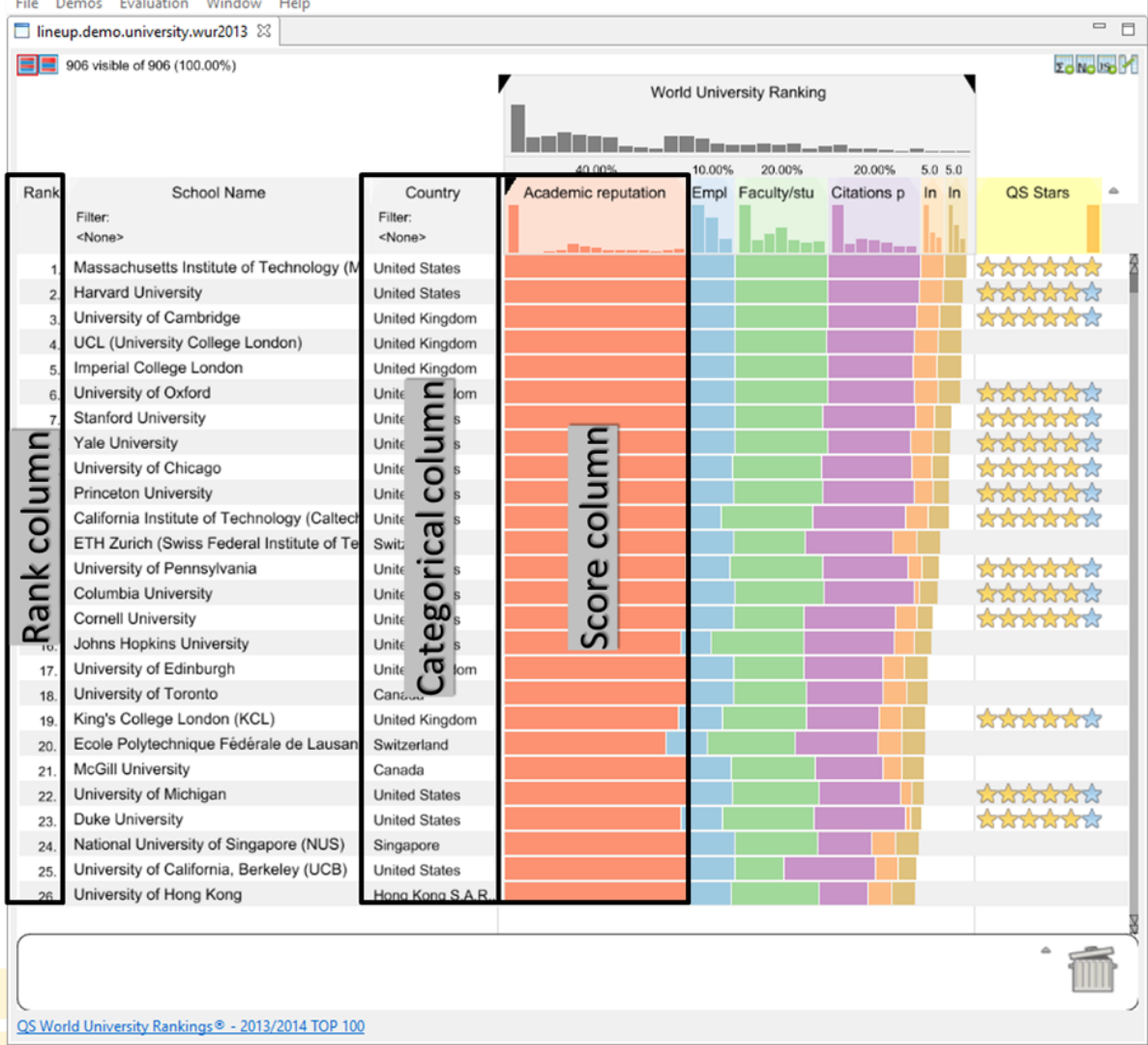
Evaluate Alternatives





Visual analysis with LineUp

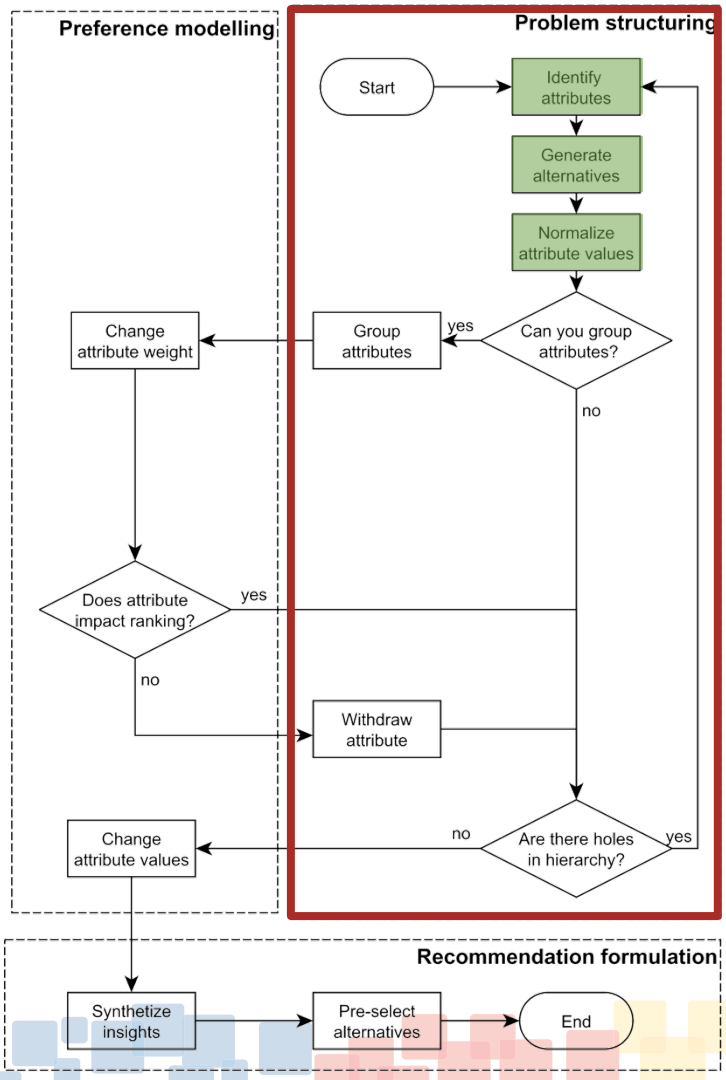
- Create, visualize and explore ranking
- columns that can be freely re-ordered using drag-and-drop



LineUp (Gratzl et al. 2013)

Problem definition characterization

Term	Notation	Definition and equation
Alternatives	$\vec{x}$	$\vec{x} = \begin{pmatrix} x_1 \\ x_i \\ x_m \end{pmatrix}$
Attribute values	A	$A = (a_{ij})_{1 \le i \le m, 1 \le j \le n}$
Filter range	$[f_{j\,min}, f_{j\,max}]$	Filters $f_{j\,min}$ and $f_{j\,max}$ on the attribute vector $\vec{a_j}$ to remove alternatives with attribute value a_{ij} outside the filter range $[f_{j\,min}, f_{j\,max}]$ from the ranking.
Mapping function	m_j	$m_j : a_{ij} \to [m_{j\,min}, m_{j\,max}] \mid 0 \le m_{j\,min} \le m_{j\,max} \le 1$
Mapped attribute values	A'	$A' = m(A) = (a'_{ij})_{1 \le i \le m, 1 \le j \le n}$
Hierarchy level	l	Number of levels in the hierarchy
Hierarchy level weights	W_k	W_k is the weight assigned to the aggregated attributes of level k: $W_k = (w_{ij})_{1 \le i \le m, 1 \le j \le g_{k-1}} \mid 0 \le w_{ij} \le 1 \wedge \sum w_{ij} = 1$ Where g_{k-1} is the number of groups at level $(k-1)$
Alternative score	s	$\vec{s}(\vec{x}) = A' \prod_{k=0}^{l-1} W_{l-k}$



Identify attributes

Objective: indicates the direction to go

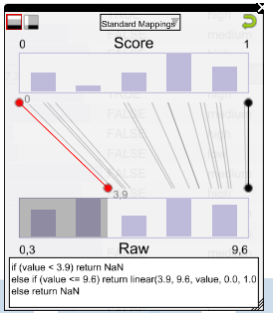
Attribute: measures achievement of the objective.

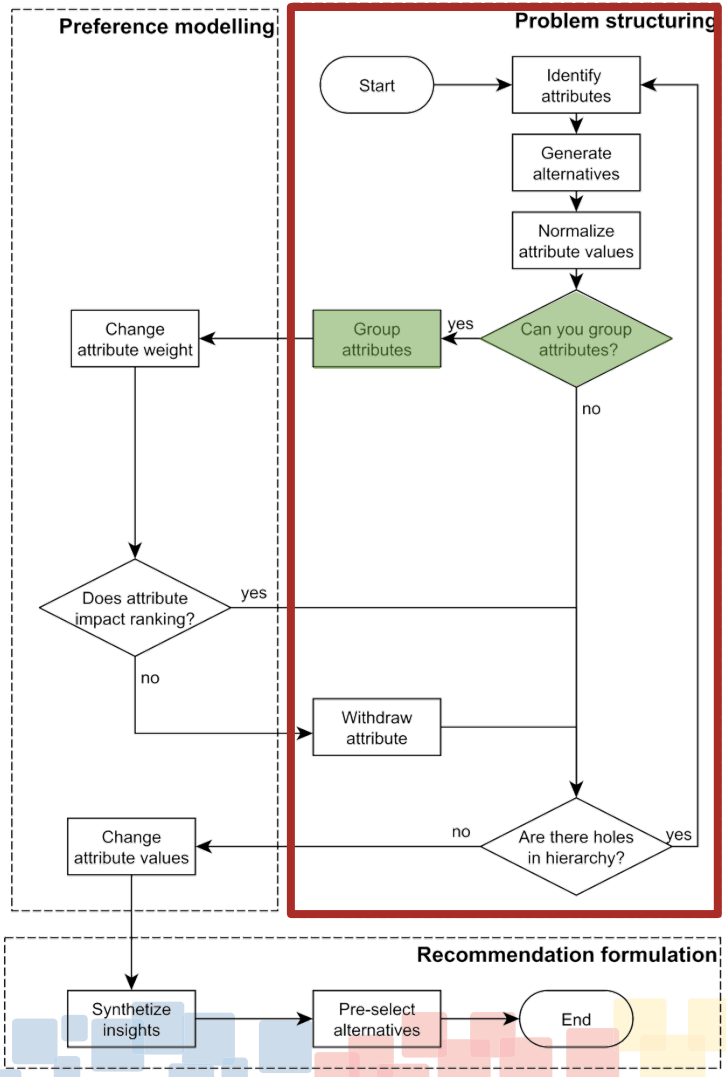
Generate alternatives

Alternative	a01	a02	a03	a04	a05	a06	a07	a08
x01	0.2		TRUE	high	risus	1.34 €	1	21.4
x02	0.2	2.5	TRUE	high		5.53 €	0	78.7
x03	0.7	7.6	FALSE	medium		5.67 €	1	99.1

Normalize attribute values

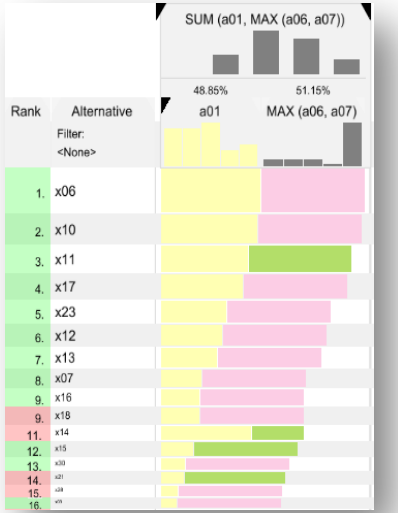
- **Enable to compare apples and oranges**
- Map attribute values to the interval [0,1]
- Exclude alternatives not compliant with constraints
- See the effect on ranking

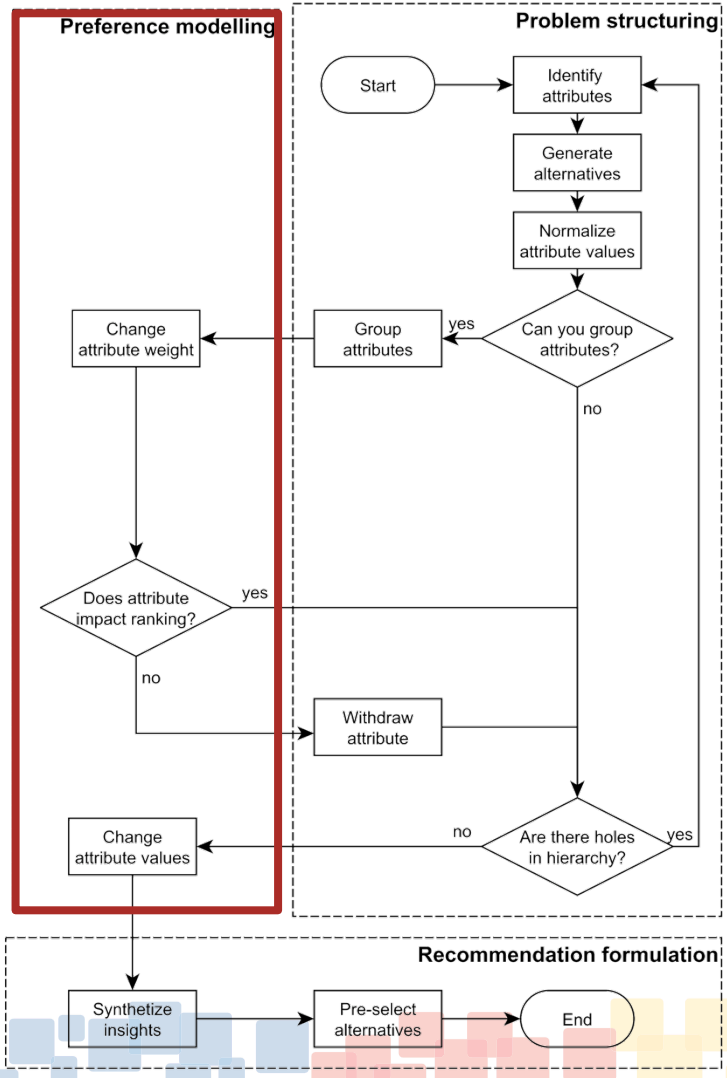




Investigate the impact of attribute relations and aggregation

- Try out different **hierarchies** to structure the list of identified attributes in a meaningful way
- Interactively combine criteria and flexibly refine parameters to explore the effect of changes in the criteria combination





Preference modelling

- Preferences can be captured through market, interviews, etc. However, conflicting preferences may exist making hard to aggregate preferences and maximize value, and preferences may be fuzzy for unarticulated needs.
- We explore changes in stakeholders' preferences that can occur in response to context shifts, like economic changes, market growth evolutions, threats, etc.

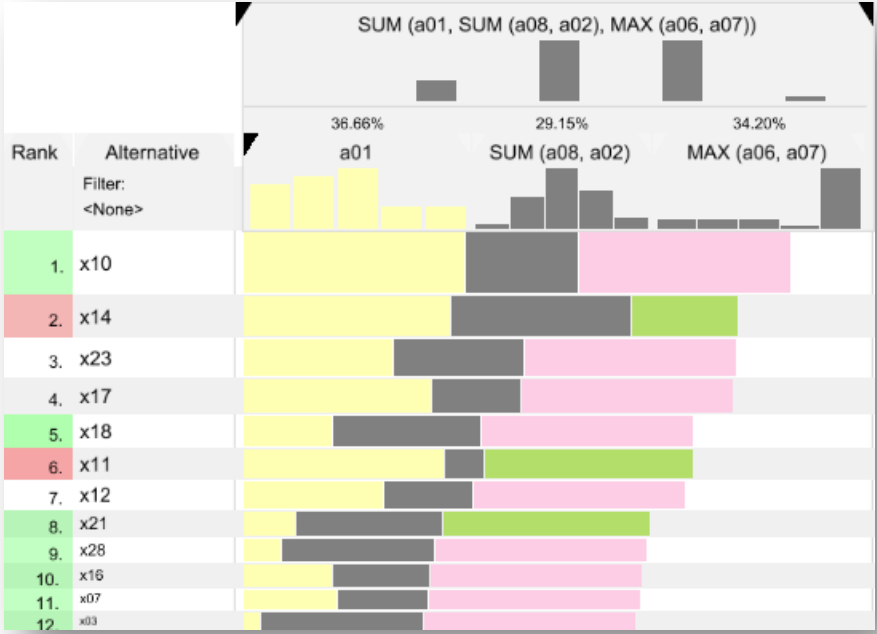
Investigation of attribute importance onto system architecture selection

- Preferences are defined by weights

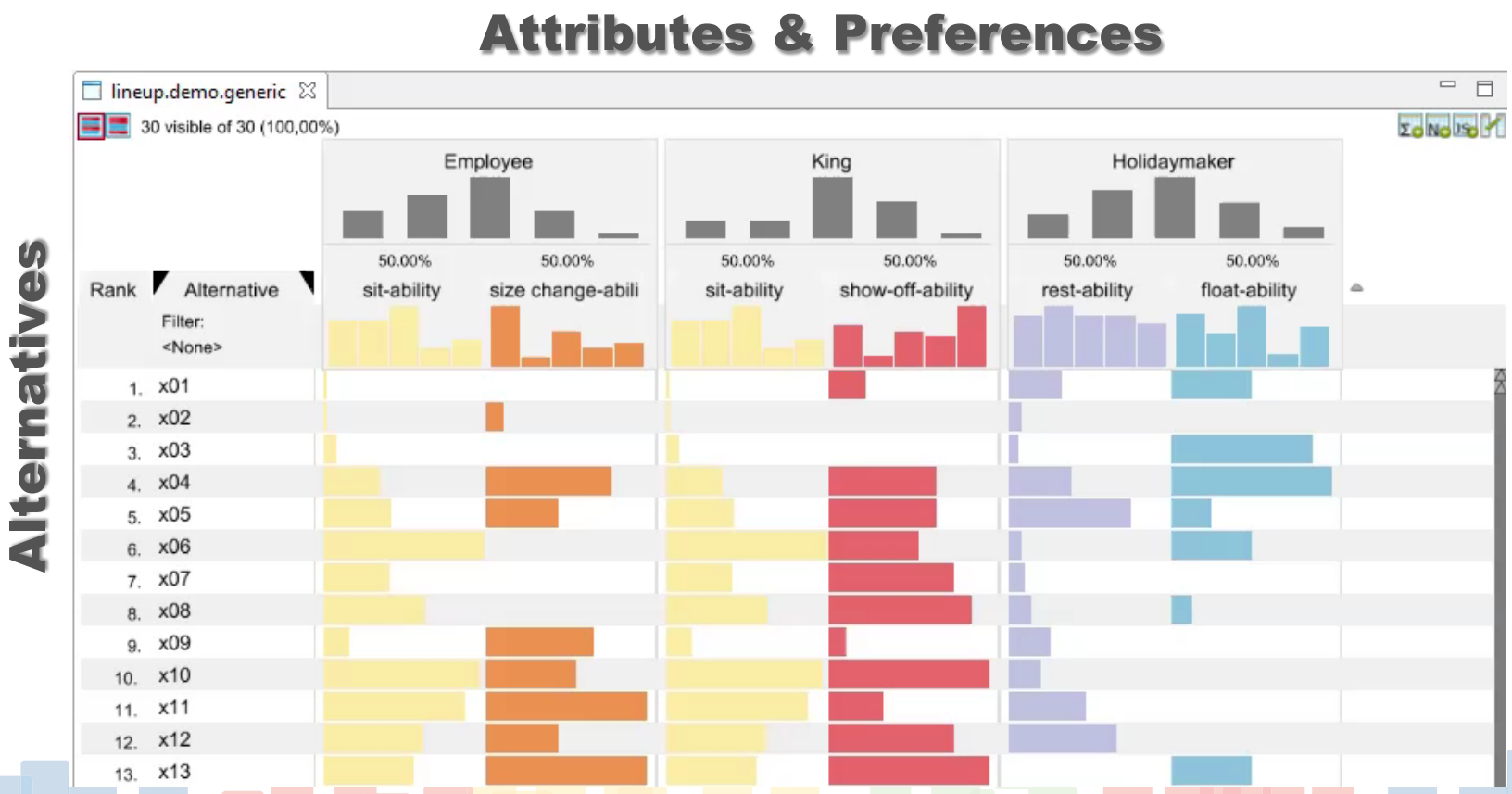
  associated to hierarchy level weights

  $W\downarrow k$

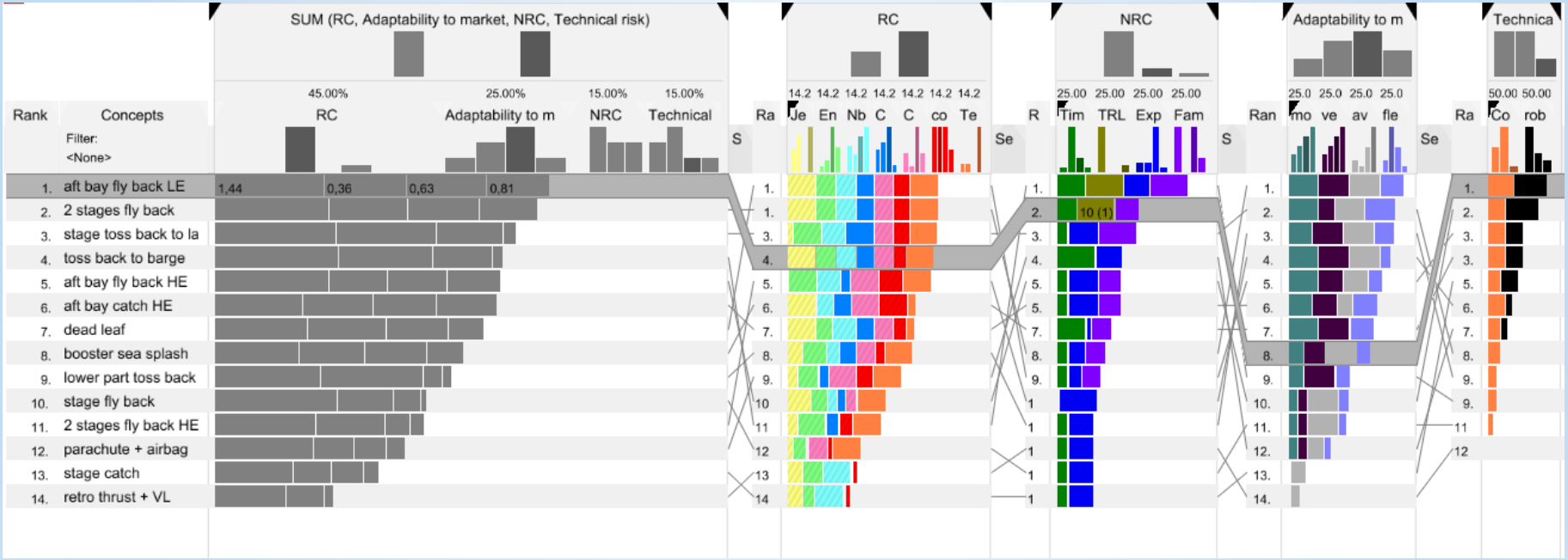
- To understand how the attributes influence the ranking of the alternatives, explore changes in:
  - stakeholders' preference
  - stakeholders' relative importance



DEMO

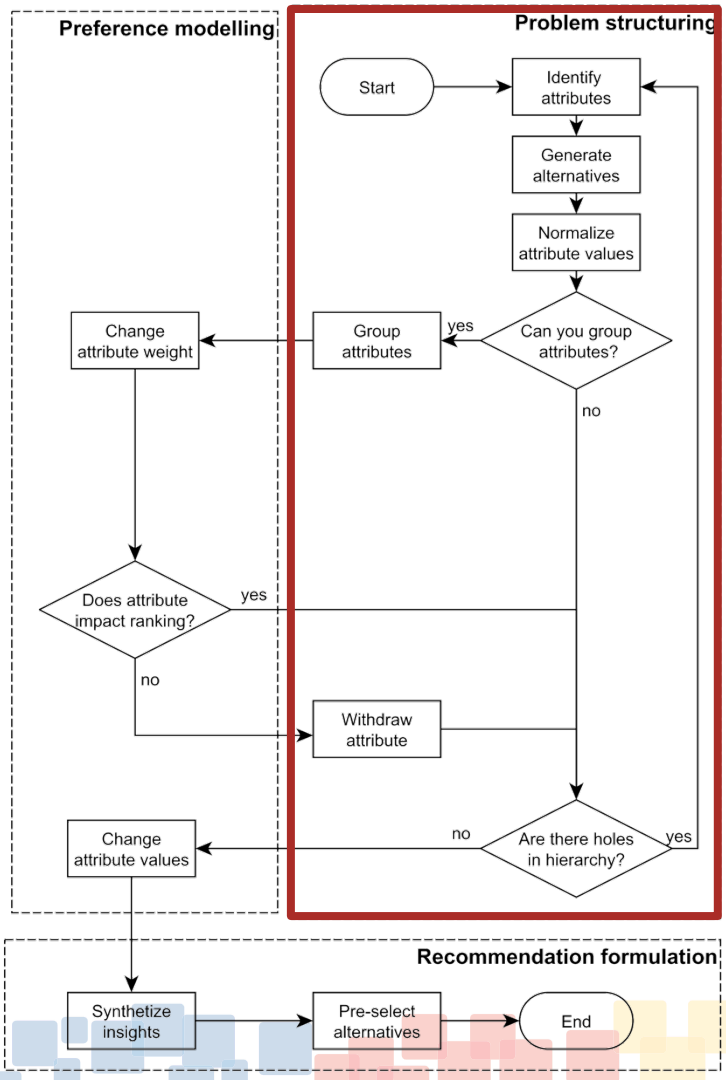

Attributes & Preferences
Alternatives
lineup.demo.generic
30 visible of 30 (100,00%)
Employee
King
Holidaymaker
50.00%
50.00%
50.00%
50.00%
50.00%
50.00%
Rank
Alternative
sit-ability
size change-abili
sit-ability
show-off-ability
rest-ability
float-ability
Filter:
<None>
1. x01
2. x02
3. x03
4. x04
5. x05
6. x06
7. x07
8. x08
9. x09
10. x10
11. x11
12. x12
13. x13

VISUALIZATION OF A CONCRETE CASE STUDY: INFORMATION PROPAGATION



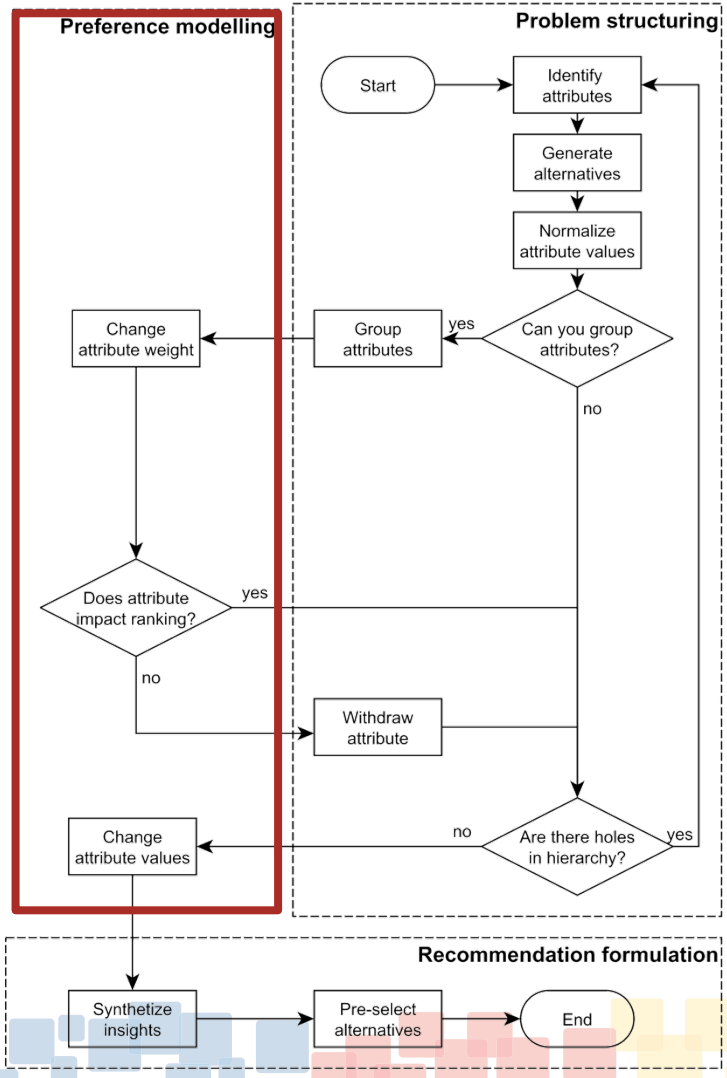
Does the attribute impact the ranking?

- Change attributes weight and check if the ranking is impacted.
- How far to decompose the attributes (vertical extension)? Change of the lowest attributes weight (leaves) to see if it impacts alternatives' ranking.
- For each attribute, does the selection of the alternative could be altered if the attribute was excluded? If not, withdraw the attribute.



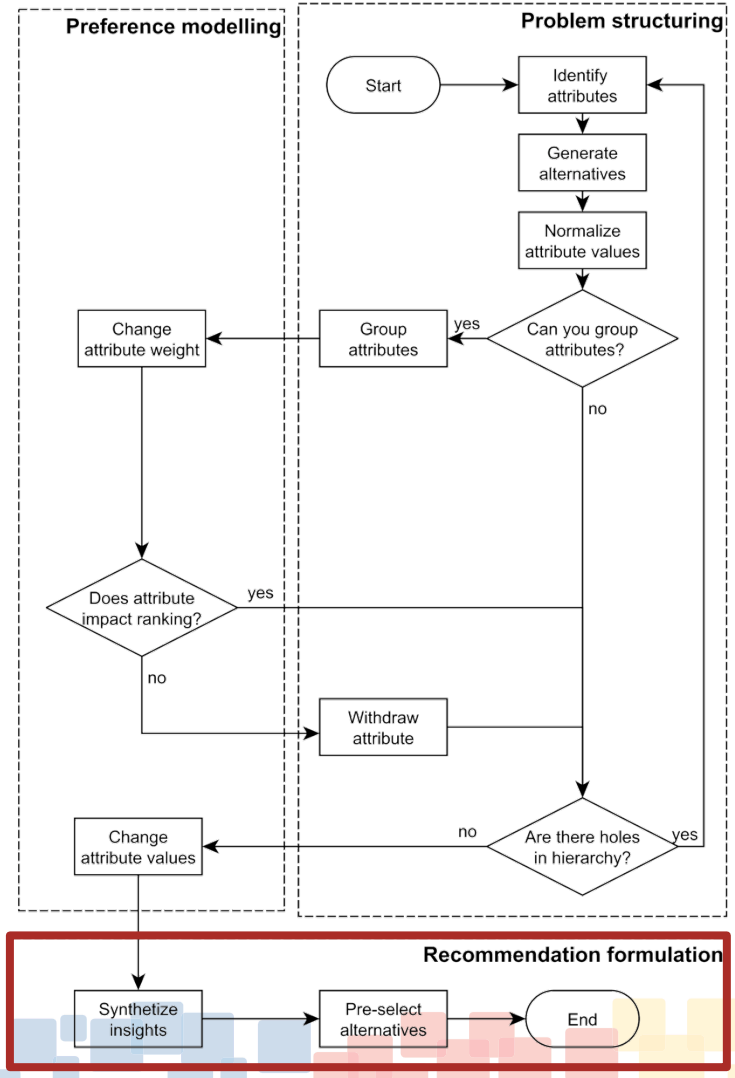
Are there holes in the hierarchy?

- What is good or bad about each alternative?
- Are the strengths and weaknesses of the alternatives captured through the identified attributes?
- If not, identify missing attributes and add them.



Change attribute values

- Adopt an alternative-focused thinking
- Look at the strengths and weaknesses of the relevant alternatives
- Explore the effect of changes in attribute values
- Optimize the values and weights to find the best possible ranking of a particular alternative



Synthesize insights

- What attributes combination and weighting affects the final ranking?
- What attribute values highly impact the ranking?
  - These values may require a more in depth evaluation of the alternatives' attribute values.

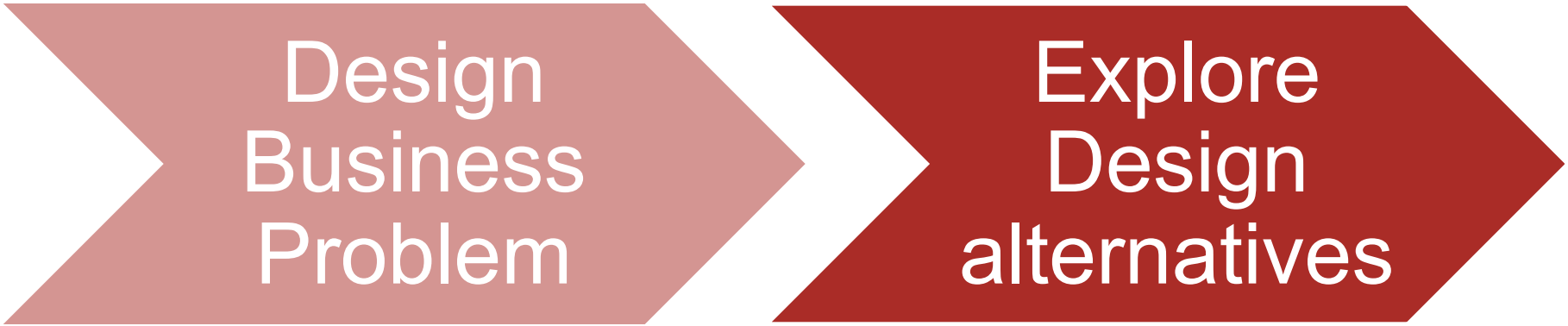
Pre-select alternatives

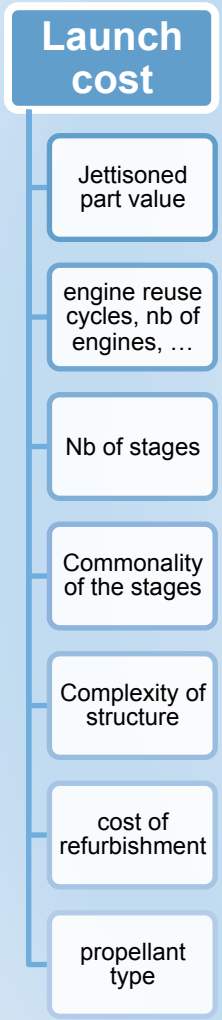
- Select a shortlist of the top-ranked alternatives

Benefits of ValXplore
Stage 1 – Problem Definition

Define Objectives	•Structure the problem iteratively •Understand the influence of attributes on ranking •Identify missing attributes
Model Preferences	•Gain insight on preferences' impact •Model preferences of multiple decision makers
Evaluate Alternatives	•Compare alternatives' ranking •Interpret ranking •Discuss attribute values
Formulate Recommendations	•Assess robustness of alternatives selection •Involved decision makers in the exploration of the problem definition

ValXplore is a two-stage decision support method



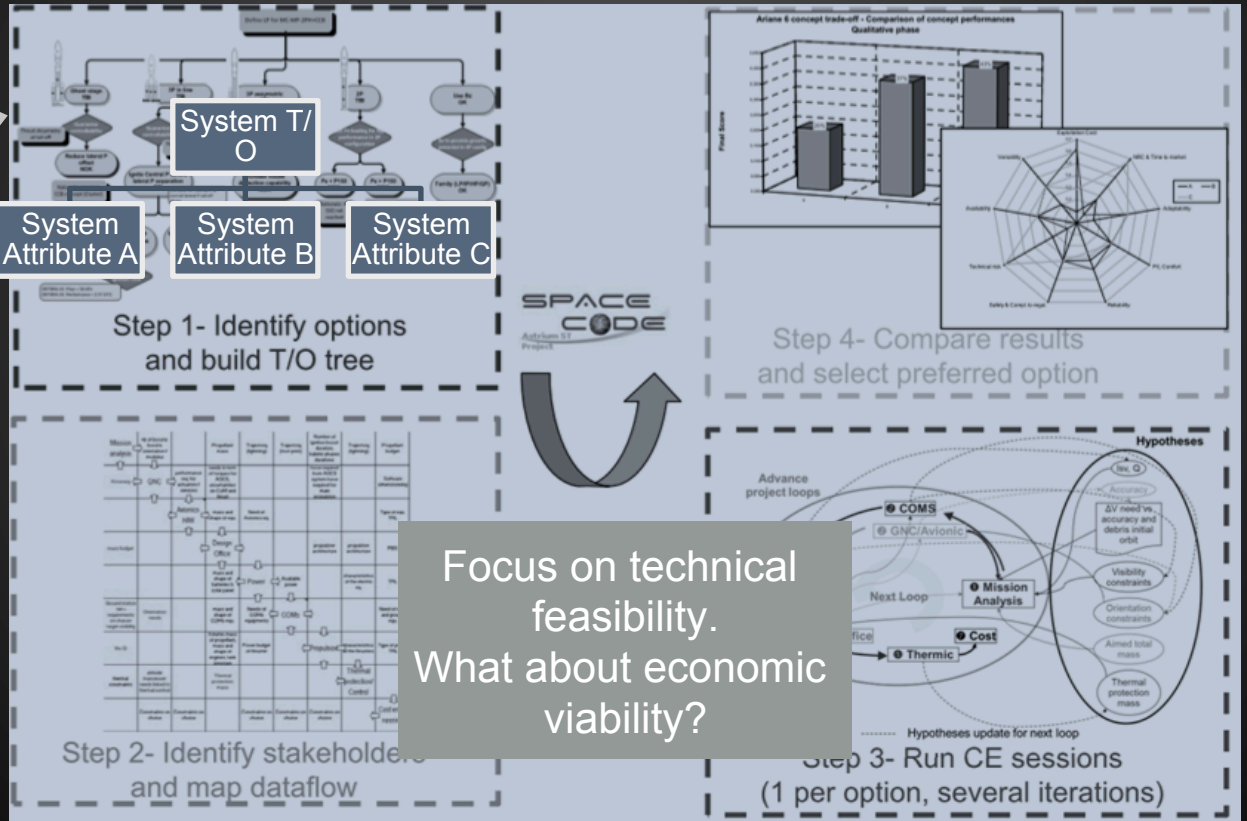


What is the launch of the fleet wrt market demand?

ALTERNATIVES EXPLORATION CHALLENGES

Difficult to make the link between market scenarios and alternatives

System design variables

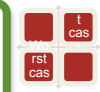


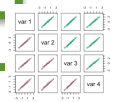
Focus on technical feasibility.
What about economic viability?

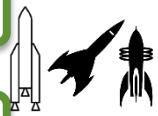
Missing link with exogeneous uncertainties
(market demand, etc.)

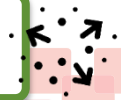
STAGE 2 - Exploration

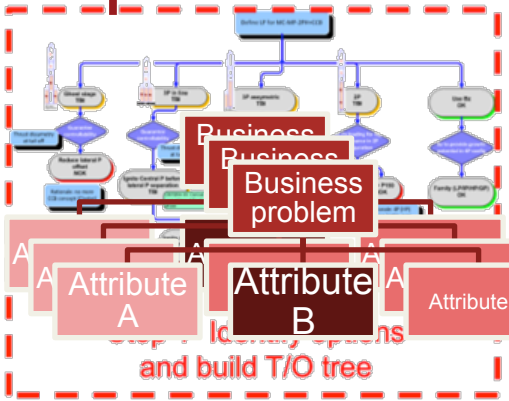
- Define possible futures
- Define the Business & System design variables
- Understand design variables correlations
- Identify the feasible design alternatives
- Evaluate design alternatives' performances
- Explore problem space
- Explore solution space



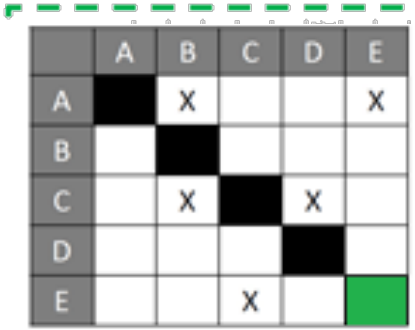




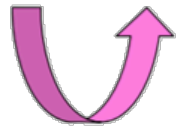


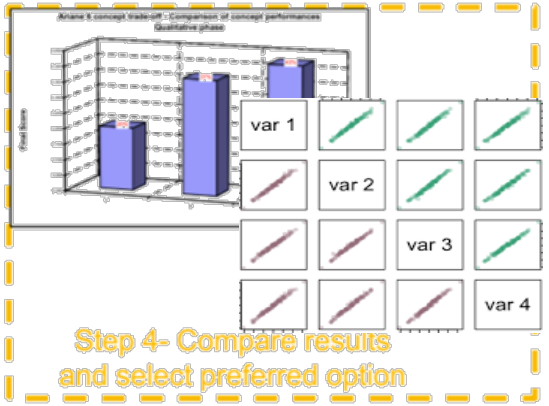


and build T/O tree

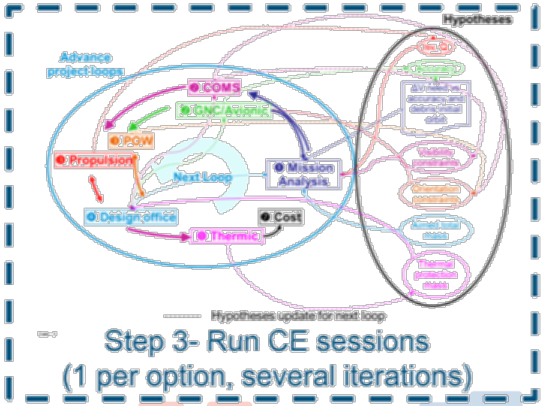


Business variables added





Step 4- Compare results and select preferred option

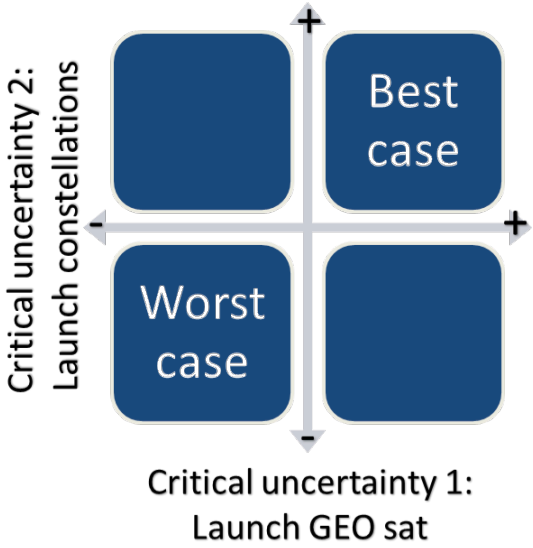


Step 3- Run CE sessions (1 per option, several iterations)

Define the possible futures

Purpose: Characterize exogenous uncertainties

- Define scenarios to explore critical future uncertainties. Identify most impactful factors
- What is assumed in this scenario?
- What assumptions need to be made to arrive to this scenario but are missing?
- How good are these assumptions?
- What-if an alternative assumption is made?



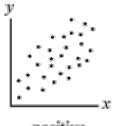
Define the Business & System design variables

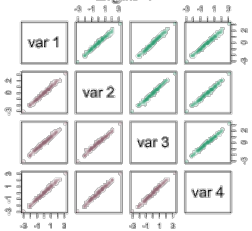
- Consider both business and system design variables:
  - value proposition,
  - customer segments
  - profit margin

Understand how the variables are correlated

Business	Market scenarios								
Fleet occupancy rate wrt market demand	**system**	target orbit flight scenario flight constraints atmospheric model lift-off & landing locations			architecture (concept): - nb étages - diamètre - fonds communs ? - target ou	Landing location nb of stages runway or landing pad	nb de boosts type de pression (He, Autogen...)		**cadence lanceur/an** cadence composant / an taille du batch TRL condition éco logique AIT nb de proto **nb réutilisation + coût refurbishment** PBS
	perfo mach @ separation	**Mission analysis**	traj key parameter : - altitude, - mission duration ...	trajectoire : - domaine de vol, - mach, - agt	trajectoire - Nlongi - Pdyn - lois débits - Masse CU max		masse ergols propu accélération à H0 accélération à H2	thermal flux stagnation pressure radiative equilibrium temperature (for TP assessment) Pdyn Mach Vrelative acceleration long/& lateral	thrust per stage
			SEL/Avionic		equipement masse (volumes/ description externe)			Power system mass in RM Launcher avionics weight in RM equipements réutilisés taux de rebus nb reutilisation	PBS avionics
		drag coef vs. Mach reference length/surface		**aéro**	drag coef vs mach: - globaux - répartis				
	TRL/ composants IRL nb refurbishment garanti (cycle) techno critique (for refurbish.)	fairing mass (jettisoning) SI per stage (staging) Inert mass per stage (dry + inert)		launcher géometry	**launcher D.O.**	diamètres hauteurs encombrement	diamètre réservoir longueur ligne d'alimentation hauteur ligne d'alimentation	launcher weight expendable part weight RM interface points position 1st stage diameter loads equipements réutilisés taux de rebus	mass budget / equipement nb eqt (matériaux) (techno)
	Synthese RC Synthese NRC moyens a mettre en oeuvre batiments, moyens sol, operation integration (including ressource), complexité, TRL				faisabilité moyens sol (p/r architecture lanceur)	**moyens sol**			coût NR des moyens sol coût R des moyens sol
	nb réutilisation garanti (cycle) techno critique pour refurbishment	vacuum Isp nozzle exit area vacuum thrust propulsive propellant mass inert propellant mass			Bilan masses ergols (masse chargée + decomposition) Volume ergols (volume reservoir) Pressions internes	strategie refurbishment (equipements réutilisés, hard or light maintenance)	**Liquid propu**	Dry & wet Propulsion mass in RM at take off maximum acceleration separation (broken down for main propulsion sub-sys: propellants, engine, pressu syst, feed syst ...) RM rocket engine thrust	
	nb réutilisation garanti (cycle) techno critique pour refurbishment	RM mass (dry, inert)	power need TM control need		RM mass: - PBS RM (mass, TRL per Eqt) - RM CAO	strategie refurbishment		**RM D.O.**	synthèse equipements réutilisés **taux de rebus** **nb reutilisation**
- Launched PL cost/kg wrt market demand **- SRLV cost reduct.**	**nb utilisation optimisé (objectif)** **RC & NRC**								**Costing**

Understand variables correlation with scatter plot matrix

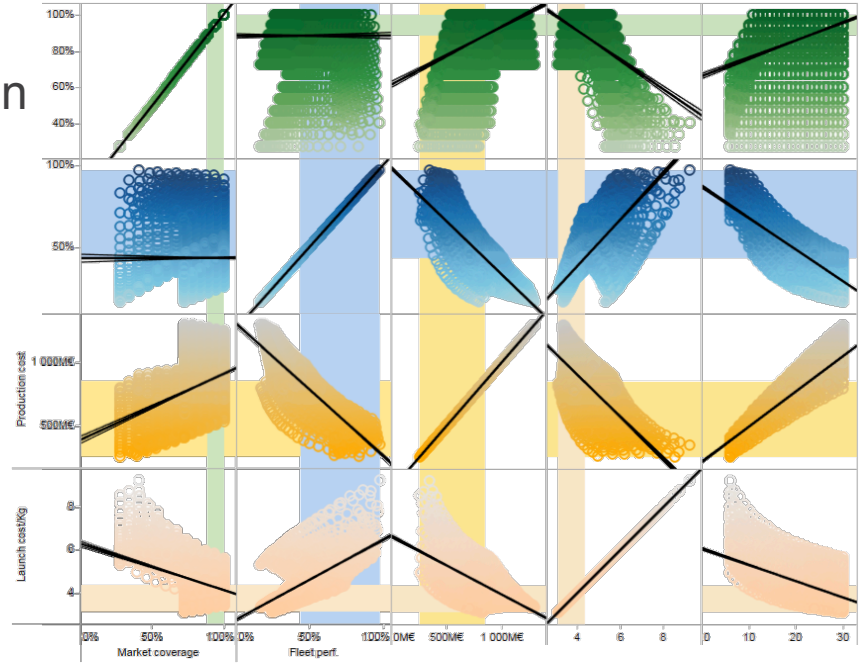




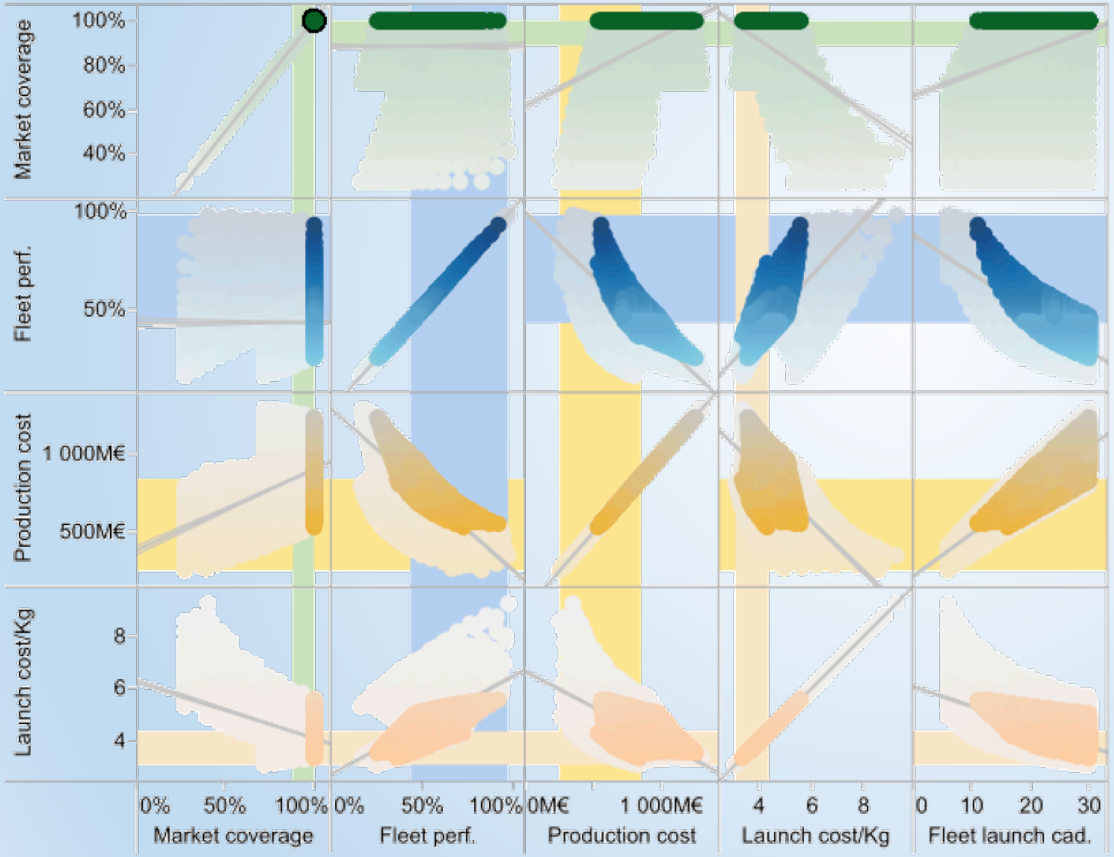
A scatter plot displays the correlation between a pair of variables.

- **Positive**: variables tend to move in the same direction
- **Negative**: variables tend to move in the opposite directions

The scatter plot matrix helps to **understand the correlation between several variables**.



SCREEN ALTERNATIVES



We select fleets launch cadence combinations that cover market demand: market coverage = 100%.

Fleet perf.
17% 97%

Market coverage
27% 100%

Production cost
256M€ 1 295M€

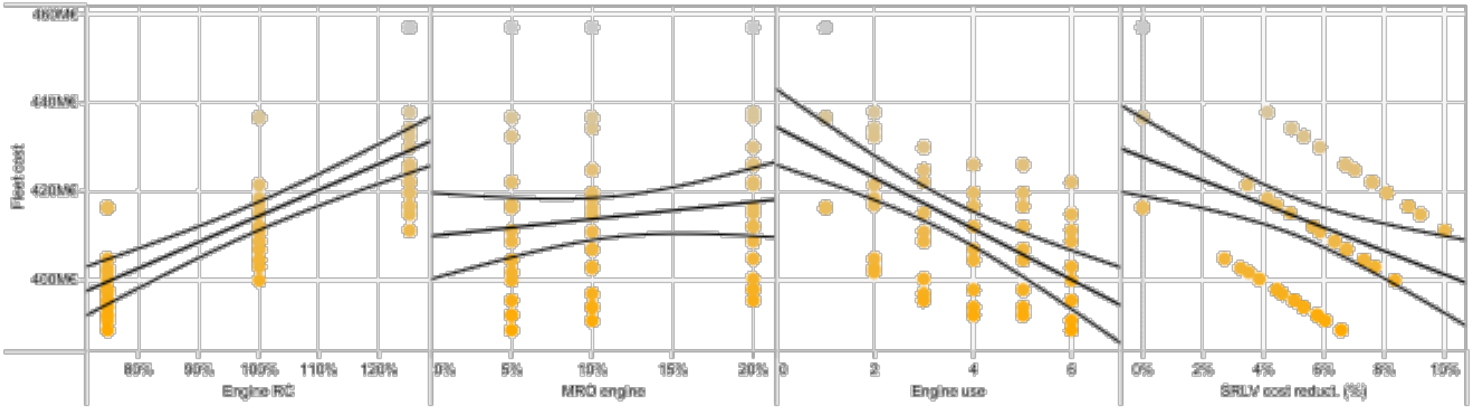
Launch cost/Kg
3,087 9,254

Evaluate performances

- Develop performance and cost models to evaluate the performances of the design alternatives

Investigate the uncertainties related to design parameters onto identified solutions

- Perform sensitivity analysis on the design variables

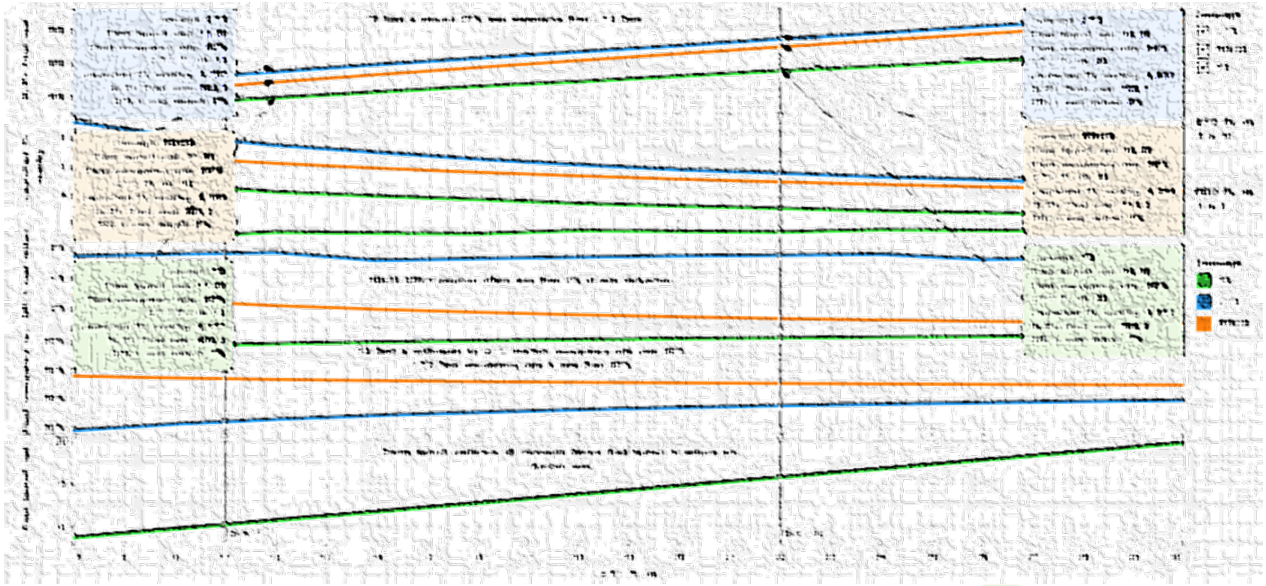


Engine RC influences the most fleet cost, then the engine use and finally the MRO engine.

Trend Lines Model
A linear trend model is computed for Fleet cost. The model may be significant at p <= 0,05.

Investigating the impact of combination of exogenous uncertainties onto solution space

Change the exogenous uncertainties to understand the impact on the design alternatives: value proposition, target customers, etc.



Provide recommendations

- Give recommendations to select the best design alternative with regard to changing contexts. E.g.:
  - Change the value proposition
  - Optimize A design alternative
  - Refine a performance or cost model.

Limitations

- Attribute interdependencies have not been considered (weighted sum)
- Data quality is a limitation factor with regard to results
- Data gathering took 6 months (increased time related to data gathering)
- Uncertainty types related to this decision have to be validated in additional case studies

Future work

- Collaborative decision-making process not yet considered and investigated

Conclusion: ValXplore helps to….

- Design Business Problem
- Investigate Business Scenarios
- Compare Concepts to Competing Offers
- Understand Design Variables Correlations
- Explore Problem Space
- Explore Solution Space
- Identify Most Valuable Design Alternatives

Thank you for your attention

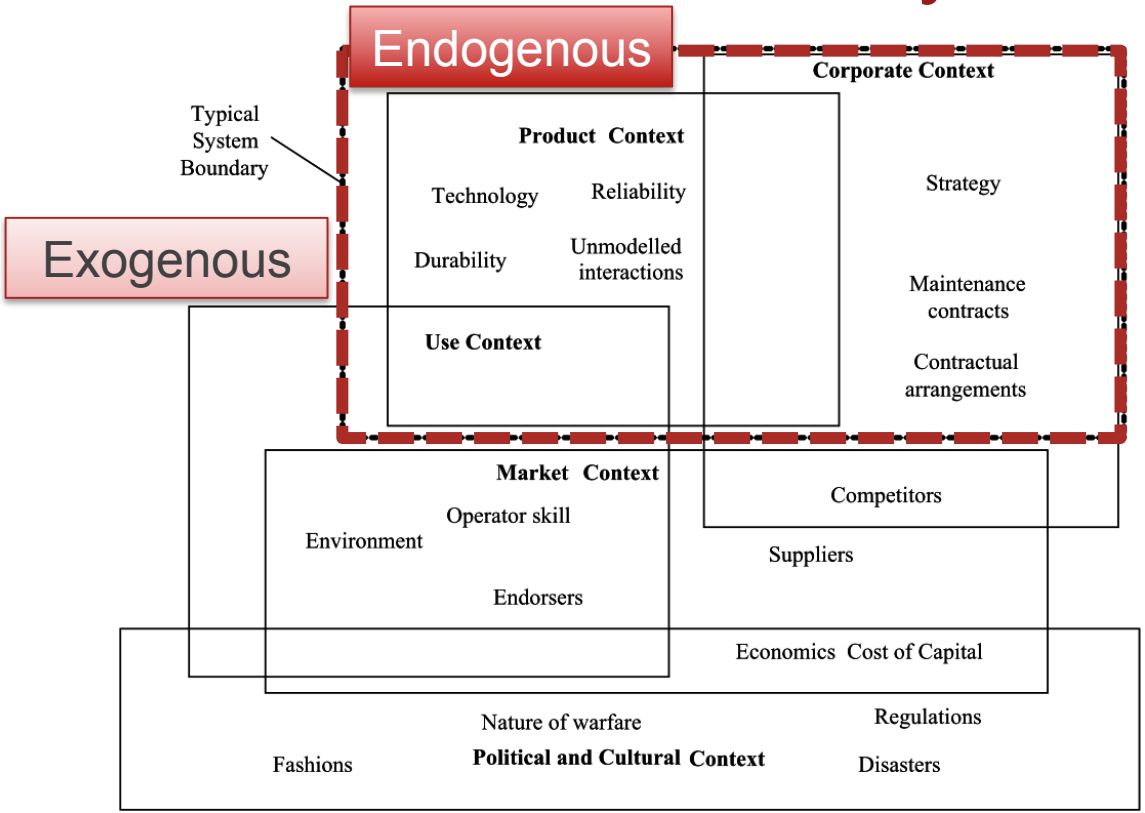
27th annual INCOSE international symposium

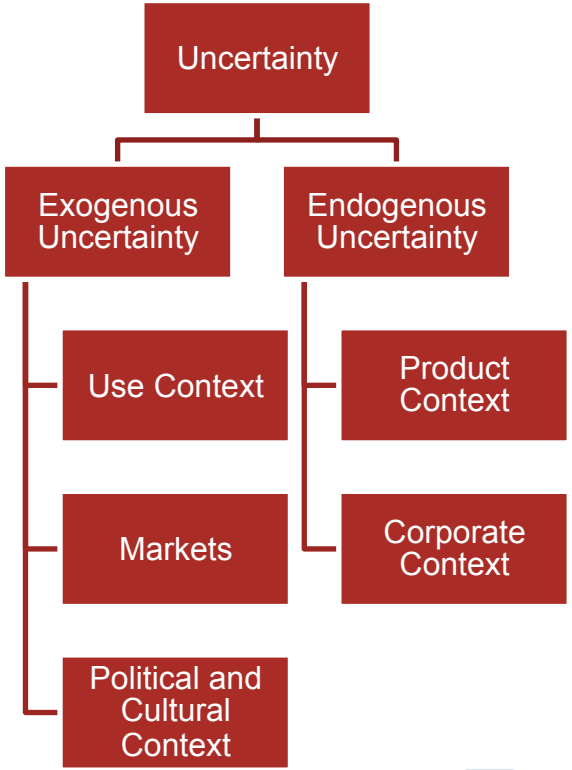
Adelaide, Australia

July 15 - 20, 2017

www.incose.org/symp2017

Sources of uncertainty in early stages





de Weck Olivier et al., 2011