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Morphological Analysis of Defence Procurement

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Defence Procurement

- What is defence procurement and why is it wicked?
  - We can't buy our way out of problems
    - How to get better by taking non-financial approaches
    - A lot of the change is in the social space

- A defence procurement problem:
  - Always has to be considered on its own merits, simply copying is not effective
  - Is owned by a range of stakeholders (e.g. military users, civilian users, legal, commercial)
    - Each stakeholder has different understandings/interpretations of the problem
  - The solution is procured as a performance, but required as an effectiveness
  - Solutions are typically good or bad rather than right or wrong

Outline

- Introduction to General Morphological Analysis (GMA)
- Extending General Morphological Analysis
  - SERAPH
  - Stakeholder confidence indicator
  - Finding representative combinations (solutions)
- Using SERAPH in the Defence Domain
- Summary

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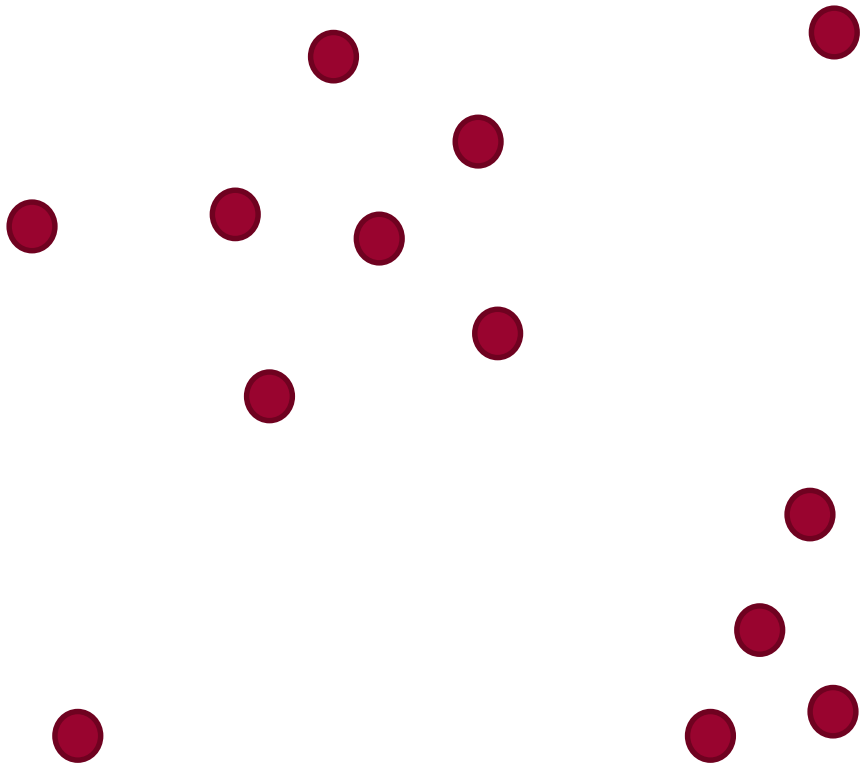
Introduction to General Morphological Analysis (GMA)

Morphology

The study of *form* and *structure (options)*



General Morphological Analysis (GMA)

- History:
  - Generalised by Fritz Zwicky in 1948;
  - Computational advancements by Tom Ritchey from 1995 to present day.

- **Can tame *wicked problems*.**

- Applicable domains include:
  - Engineering and Product Design;
  - Design Theory and Architecture;
  - Scenario Development;
  - Management Science, Policy Analysis and Organisational Design;
  - Security, Safety and **Defence**.

Structuring a Complex Problem Space

Morphological Field

The representation of the problem by the parameter dimensions and specified values (points in dimension).

Example: the procurement of a new ISTAR airplane

	Parameter A	Parameter B	Parameter C	Parameter D	Parameter E	Parameter F	Parameter G	Parameter H
	Platform	**Mission Range (nm)**	**Sensor Type**	**Target Type**	**Crewing**	**Data Processing**	**Training of operators**	**Tactical Requirement**
Value 1	Small TurboProp	up to 1000	IR	People	0	Onboard	No additional training for operators	Routine Reconaissance with full local support
Value 2	Large Turboprop	1000-2000	EO	Building	2-4 crew	Mixed	The Operators will need to attend a short uplift course.	Reconaissance with limited footprint
Value 3	Small Jet	2000-3000	GMTI	Vehicles	5-8 crew	Ground based	The Operators will need to attend a completely new Operator course.	Covert Operation
Value 4	Large Jet	>3000	SAR	Maritime	9-12 crew			
Value 5	Small UAV							
Value 6	Large UAV							

Structuring a Complex Problem Space

Let M_n represent the number of values for the nth parameter where $n = 1, \ldots, N$.

Then the total number of *formal combinations* (options) is a **product**: $\prod_{n=1}^{N} M_n = \mathbf{41472}$

$M_1 = 6$ $M_2 = 4$ $M_3 = 4$ $M_4 = 4$ $M_5 = 4$ $M_6 = 3$ $M_7 = 3$ $M_8 = 3$

	Parameter A	Parameter B	Parameter C	Parameter D	Parameter E	Parameter F	Parameter G	Parameter H
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Value 5	Small UAV							
Value 6	Large UAV							

Structuring a Complex Problem Space

Cross-Consistency Assessment Matrix (CCM)

The process of analysing whether all unique pairs of parameter values are inconsistent and to what degree stakeholders believe a relationship is (in)consistent given evidence generated by the stakeholders.

The possible pair-wise relationship types are:

		Broad relationship	
		Consistent	Inconsistent
Confidence given evidence	High	C-H	IC-H
	Medium	C-M	IC-M
	Low	C-L	IC-L

Structuring a Complex Problem Space

Cross-Consistency Assessment Matrix (CCM)

The process of analysing whether all unique pairs of parameter values are inconsistent and to what degree stakeholders believe a relationship is (in)consistent given evidence generated by the stakeholders.

The number of pair-wise relationships is a **quadratic polynomial**:

$$\sum_{n=1}^{N} M_n \times \left(\sum_{m=n}^{N} M_m \right) = \mathbf{417}$$

Structuring a Complex Problem Space

		Platform						Mission Range (nm)				Sensor Type				Target Type				Crewing				Data Processing			Training of operators		
		Small TurboProp	Large Turboprop	Small Jet	Large Jet	Small UAV	Large UAV	up to 1000	1000-2000	2000-3000	>3000	IR	EO	GMTI	SAR	People	Building	Vehicles	Maritime	0	2-4 crew	5-8 crew	9-12 crew	Onboard	Mixed	Ground based	No additional training for operators	The Operators will need to attend a short uplift course.	The Operators will need to attend a completely new Operator course.
Mission Range (nm)	up to 1000	C - H	C - H	C - H	C - H	C - H	C - H																						
	1000-2000	C - M	C - H	C - H	C - H	C - M	C - H																						
	2000-3000	C - L	C - H	C - L	C - H	IC - H	C - H																						
	>3000	IC - H	C - H	IC - H	C - H	IC - H	C - H																						
Sensor Type	IR	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H																		
	EO	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H																		
	GMTI	C - H	C - H	C - H	C - H	C - M	C - H	C - H	C - H	C - H	C - H																		
	SAR	C - M	C - H	C - H	C - H	IC - H	C - H	C - H	C - H	C - H	C - H																		
Target Type	People	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - M	C - H	IC - H	IC - H														
	Building	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - M	C - H	IC - H	C - H														
	Vehicles	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H														
	Maritime	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - M	C - M	C - M	C - H														
Crewing	0	IC - H	IC - H	IC - H	IC - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H										
	2-4 crew	C - H	C - H	C - H	C - L	IC - H	IC - H	C - H	C - H	C - M	C - L	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H										
	5-8 crew	C - M	C - H	C - H	C - H	IC - H	IC - H	C - H	C - H	C - H	C - M	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H										
	9-12 crew	IC - H	C - H	IC - H	C - H	IC - H	IC - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H										
Data Processing	Onboard	C - H	C - H	C - H	C - H	IC - H	C - M	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H						
	Mixed	C - H	C - H	C - H	C - M	C - M	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - M	C - M	C - H	C - H	C - H	C - L	C - M	C - H	C - M						
	Ground based	C - H	C - M	C - H	C - L	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - L	C - L	C - H	C - M	C - H	C - H	C - M	C - M	C - L						
Training of operators	No additional training for operators	IC - H	IC - H	IC - H	IC - H	C - M	C - L	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	IC - H	C - L	C - M	C - H	C - H	C - H	C - H			
	The Operators will need to attend a short uplift course.	C - H	C - M	C - H	C - M	C - H	C - M	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - M	C - M	C - H	C - H	C - H	C - H	C - H			
	The Operators will need to attend a completely new Operator course.	C - M	C - H	C - M	C - H	C - M	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H			
Tactical Requirement	Routine Reconnaissance with full local support	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H
	Reconnaissance with limited footprint	C - H	C - L	C - H	C - M	C - H	C - M	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - L	IC - H	C - H	C - H	C - H	C - H	C - H	C - H
	Covert Operation	IC - H	IC - H	C - H	C - H	C - H	C - H	IC - H	C - M	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	C - H	IC - H	IC - H	C - H	C - H	C - H	C - H	C - H	C - H

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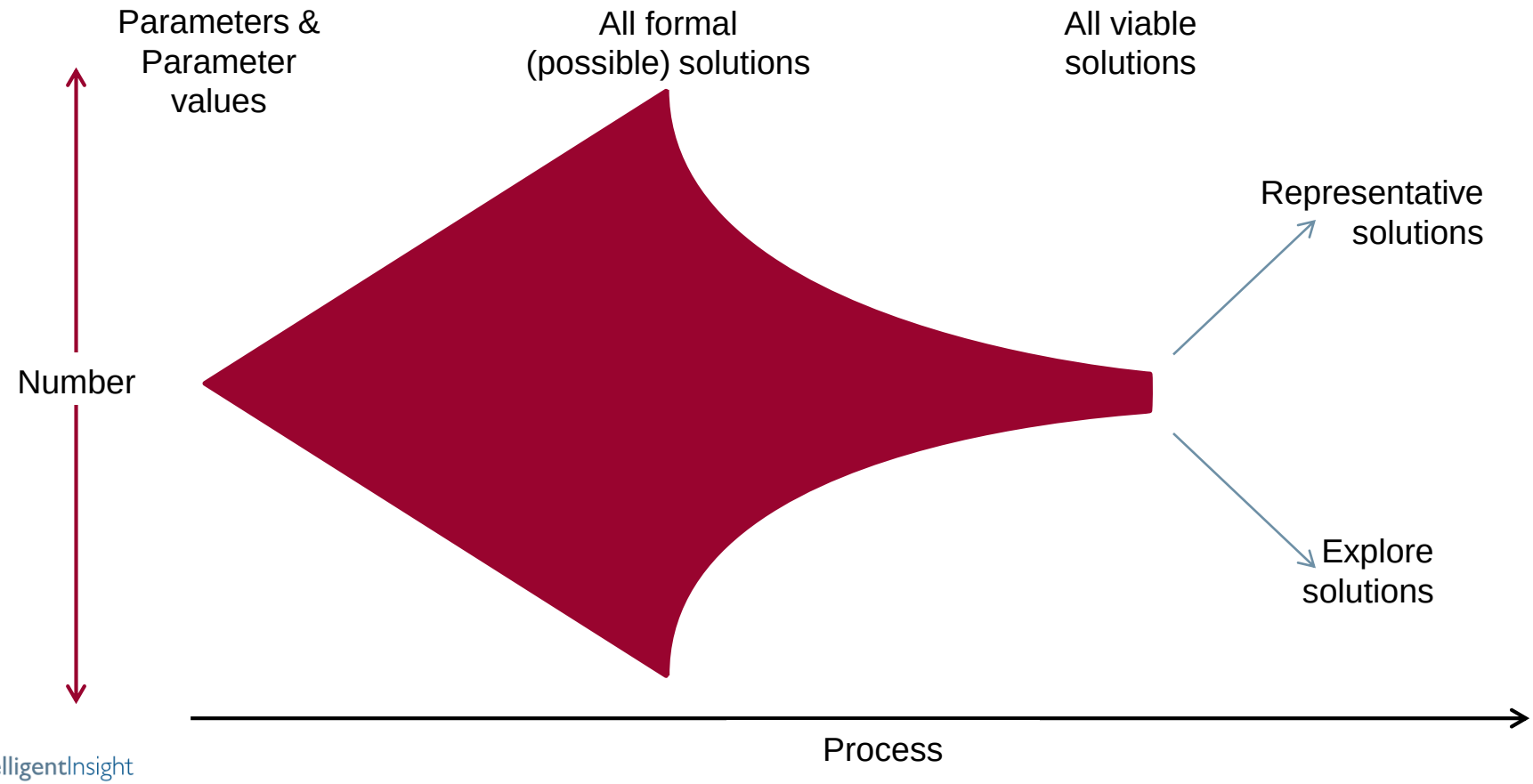
In Summary

- A method for the generation of a comprehensive and viable set of representative solutions from a multidimensional problem space with an auditable trail.



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Benefits of GMA

- Promotes understanding of **complex** and **fully/partially unquantifiable** problems
- Complete **transparency**
- Framework for characterisation of the problem space
- **Stakeholders own** the problem definition
- All defined aspects of the problem and solution spaces are explicitly considered
- Possible options are **exhaustive**ly generated in a rigorous and unbiased manner
- Provably considered **all possible options**

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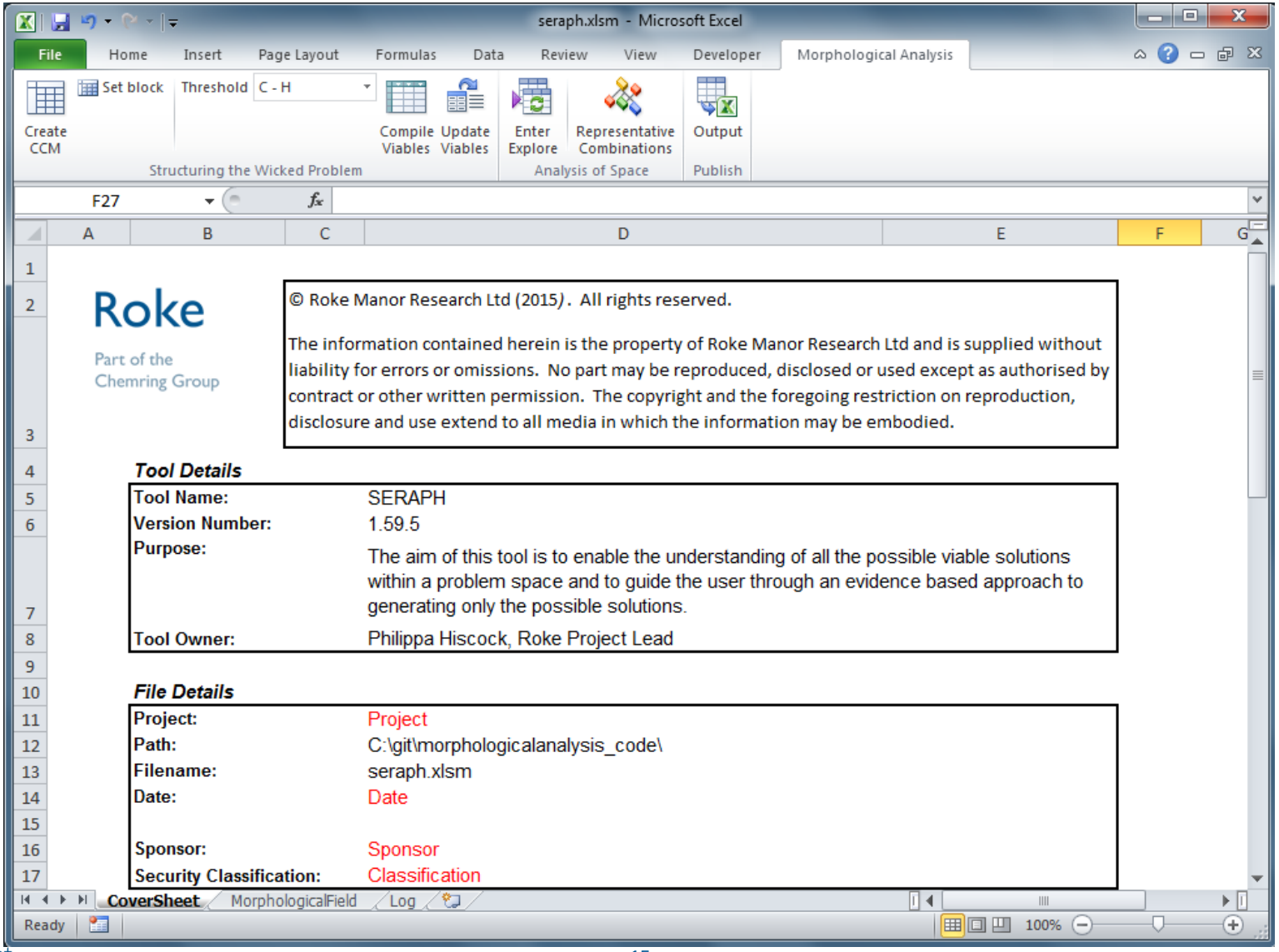
Extending General Morphological Analysis

SERAPH


seraph.xlsm - Microsoft Excel
File
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Data
Review
View
Developer
Morphological Analysis
Set block
Threshold
C - H
Create CCM
Compile Viables
Update Viables
Enter Explore
Representative Combinations
Output
Structuring the Wicked Problem
Analysis of Space
Publish
F27
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Tool Details
Tool Name: SERAPH
Version Number: 1.59.5
Purpose: The aim of this tool is to enable the understanding of all the possible viable solutions within a problem space and to guide the user through an evidence based approach to generating only the possible solutions.
Tool Owner: Philippa Hiscock, Roke Project Lead
File Details
Project: Project
Path: C:\git\morphologicalanalysis_code\
Filename: seraph.xlsm
Date: Date
Sponsor: Sponsor
Security Classification: Classification
CoverSheet
MorphologicalField
Log
Ready
100%

Stakeholder Confidence Indicator

		Broad relationship	
		Consistent	Inconsistent
Confidence given evidence	High	C-H	IC-H
	Medium	C-M	IC-M
	Low	C-L	IC-L

- T - set of pair-wise relationship types in combination
- w_t - weighting of pair-wise relationship type
- $J = \frac{1}{2}(N-1)N$ - number of unique pair-wise relationships given N parameters
- c_j - classification of jth relationship in combination c

- Stakeholder confidence achieved:

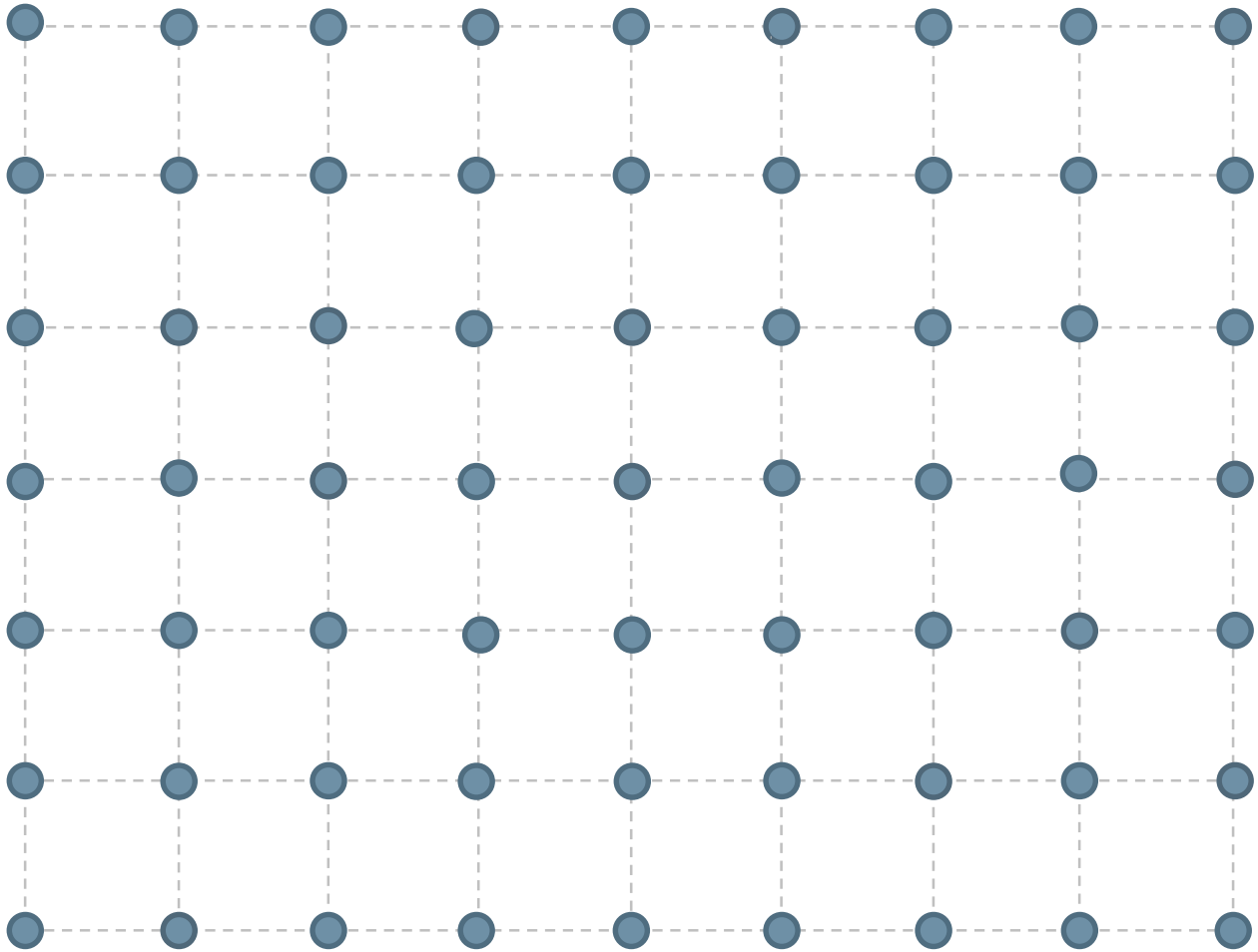
$$S_{\text{achieved}} = \frac{1}{\max\limits_{t \in T} w_t} \sum_{t \in T} w_t \left(\sum_{j=1}^{J} 1(c_j = t) \right)$$

Stakeholder Confidence Indicator

- Accept C-M and above gives **2526** *viable combinations* (options).

Combination Number	Platform	Mission Range (nm)	Sensor Type	Target Type	Crewing	Data Processing	Training of operators	Tactical Requirement	Viable Indicator	Number relationships C - H	Number relationships C - M	Stakeholder Confidence Achieved
5403	Small Jet	up to 1000	EO	People	5-8 crew	Onboard	The Operators will need to attend a short uplift course.	Routine Reconnaissance with full local support	TRUE	28	0	100%
5409	Small Jet	1000-2000	EO	People	5-8 crew	Onboard	The Operators will need to attend a short uplift course.	Routine Reconnaissance with full local support	TRUE	28	0	100%
40296	Large UAV	>3000	GMTI	Maritime	0	Ground based	The Operators will need to attend a completely new Operator course.	Covert Operation	TRUE	27	1	97%
4993	Small TurboProp	up to 1000	IR	People	2-4 crew	Onboard	The Operators will need to attend a short uplift course.	Routine Reconnaissance with full local support	TRUE	26	2	93%
40449	Small Jet	1000-2000	EO	Building	2-4 crew	Ground based	The Operators will need to attend a completely new Operator course.	Covert Operation	TRUE	25	3	89%
4614	Large UAV	up to 1000	IR	People	0	Onboard	The Operators will need to attend a short uplift course.	Routine Reconnaissance with full local support	TRUE	24	4	86%
40283	Small UAV	1000-2000	GMTI	Maritime	0	Ground based	The Operators will need to attend a completely new Operator course.	Covert Operation	TRUE	23	5	82%
6542	Large Turboprop	2000-3000	IR	People	2-4 crew	Mixed	The Operators will need to attend a short uplift course.	Routine Reconnaissance with full local support	TRUE	22	6	79%

Finding Representative Combinations (Solutions)

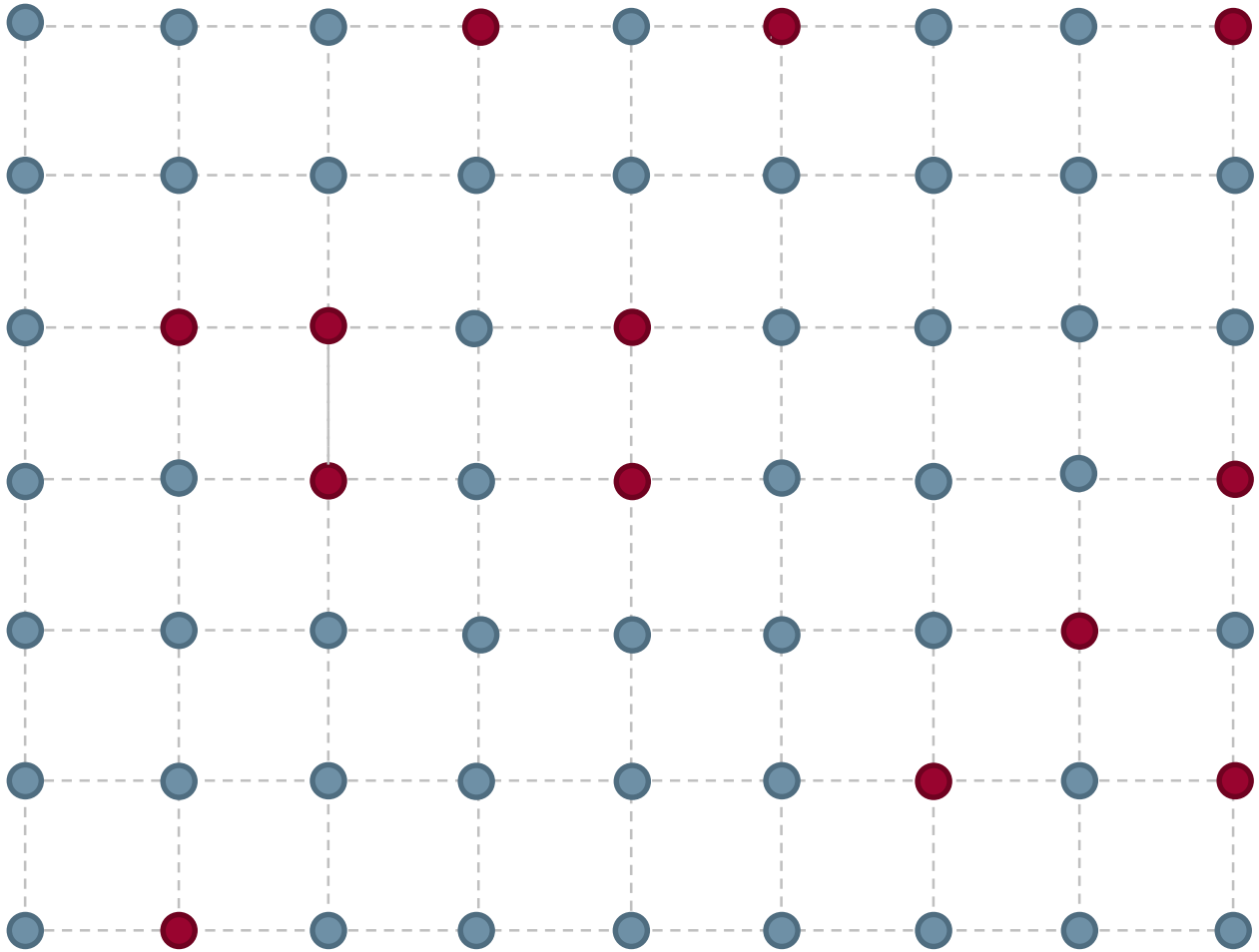


Viable combination

Formal combination

One degree of difference

Finding Representative Combinations (Solutions)

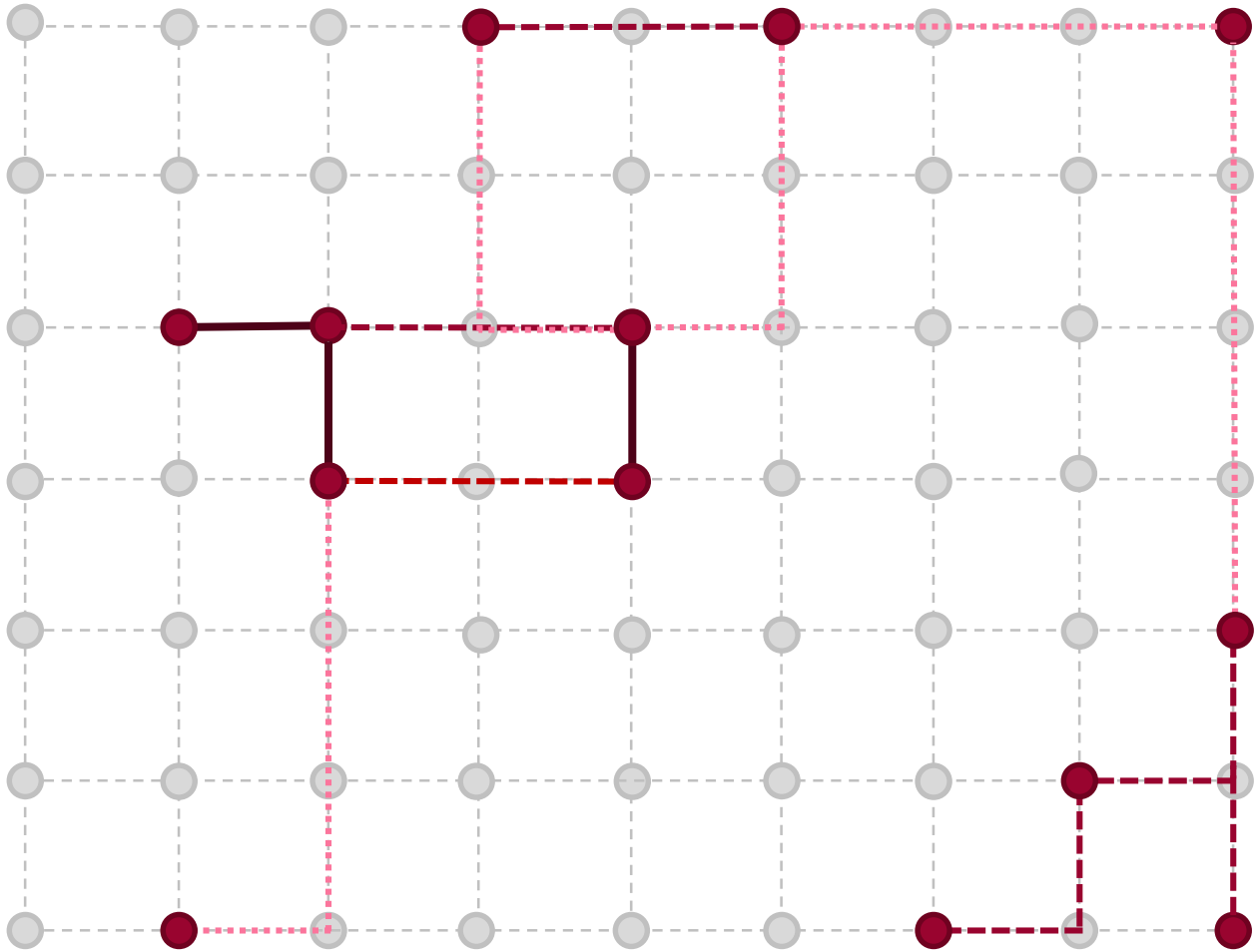


Viable combination

Formal combination

One degree of difference

Finding Representative Combinations (Solutions)



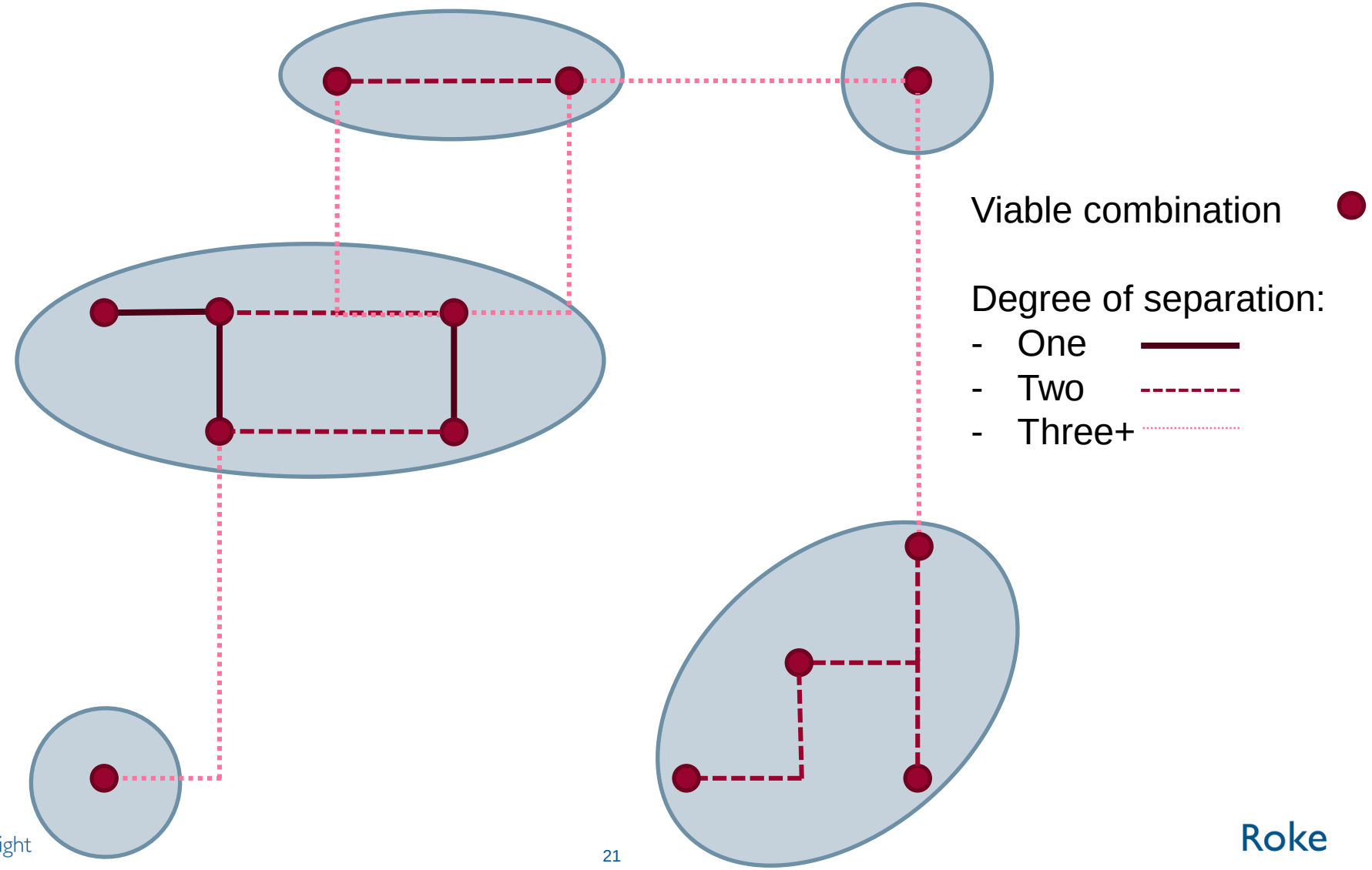
Viable combination

Unviable combination

One degree of separation (unviable)

Degree of separation:
- One
- Two
- Three+

Finding Representative Combinations (Solutions)



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Using SERAPH in the Defence Domain

Using SERAPH in the Defence Domain

- Applying GMA to a set of *wicked problems* within the Defence Analysis and Advice space.

- Defence enabler project:
  - Communications architectures considered as part of the wider procurement and implementation process.
  - Served to structure the thinking into combining independent building blocks to build solutions in an iterative process.
  - Use of the tool has allowed the project to demonstrate that all possible options have been unbiasedly considered before down-selecting.
    - Provided an auditable evidence base.
  - Significant potential for use in the policy analysis space.

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Summary

Summary

- We have taken a robust and proven process and developed it to include:
  - Stakeholder degree of confidence;
  - Clustering to find representative solutions that can be subjected to more detailed analysis.
- Motivated by how to “visualise” the solution space.
- Developments possible due to advances in modern computing.
- SERAPH represents a unique capability within the UK defence domain.

- Moving forwards:
  - Network analysis of combinations using L0 norm;
  - Working with The University of Southampton to develop the clustering algorithm;
  - D3 visualisation of viable combinations post clustering.

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Questions?

Wicked Problems

- Free for All (1967). Wicked Problems. *Management Science* **14** (4): B-141-B-146.
- Rittel, Horst W.J. and Webber, Melvin M. (1973). Dilemmas in a General Theory of Planning. *Policy Sciences* **4** (2): 55-169.
  - There is **no definitive formulation** of the problem
  - The problem is essentially **novel** and **unique**
  - There is **no stopping rule**
  - Every solution is a '**one-shot operation**'
  - Solutions are either **good or bad** (no right or wrong)
- Ritchey, Tom (2011). *Wicked Problems – Social Messes: Decision Support Modelling with Morphological Analysis.* Vol 17. Springer Science & Business Media.
  - **Wicked problems are all about people as Stakeholders.**

Back