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# Providing Tailored Heuristic Advice to Systems Engineers

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# Introduction

# Motivation

- The purpose of the Complex Systems Working Group is to enhance the ability of the systems engineering community to deal with complexity.
- But what do we mean by Complex Systems

# Motivation

- A **complicated system** has elements, the relationship between the states of which can be unfolded and ***comprehended***, leading to ***sufficient certainty between cause and effect***.
- A **complex system** has elements, the relationship between the states of which are weaved together so that they are ***not fully comprehended***, leading to ***insufficient certainty between cause and effect***.
- Understanding the difference means understanding the need to change everything
- How can we help?

# Leveraging INCOSE Expertise

- INCOSE Heuristics team have created 600+ Heuristics on how to handle Difficult Problems.

Heuristics Definition: *“Enabling one to discover or learn something for themselves base on the experience of others”*

To be useful they need to be **memorable, simplified** difficult concepts that can **change** your normal **response**.

But how do we make 600+ useful

Code	Group 1 Heuristics
A	Compelling Community Vision; Establish a Common Compelling Community Vision that aligns distributed stakeholders
B	Continuous Learning; Have a learning organization that accumulates and uses new insight
C	Proactive Feedback; Have a proactive feedback mechanism to sense change in the system or environment early
D	Living Systems; Have a living system that is able to adapt to new knowledge or insight
E	Generous Leadership; Have generous leaders that protect and enable the expertise to lead decision-making, rather than seniority
F	Equality Mindset; Have an Equality mindset, treating others' views and visions as equal to your own
G	Robust Relationships; Develop robust relationships between the organizational elements.

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#	Group 2 Heuristics
1	Iterate to evolve complex systems
2	Multiple perspectives identifies complexity
3	Complex systems are not wholly complex
4	Do not assume complicated pegs fit in complex holes
5	For every complex problem, there is an answer that is clear, simple, and wrong
6	Complexity understanding should precede action
7	Iterate and/or aggregate with stable system steps
8	Culture mismatch kills complex systems
9	Think big, evolve from small
10	Complexity necessitates continuous organizational learning and adaptation
11	Deprioritize optimization, prioritize multiple perspectives.
12	Keep options open to evolve
13	Complex Systems: As simple as possible, but no simpler!
14	Reuse with extreme care
15	Focus on holistic utility
16	Complex problems call for strategic thinking
17	Holistic system health avoids complex system failures
18	Manage emergence holistically



Code	Group 3 Heuristics
19	Successful communication requires an understanding of the listeners' mental models
20	Complex system failures enable accelerated learning
21	It is better to be roughly right than precisely wrong
22	The unrecognized assumptions are the most dangerous
23	Good solutions emerge through creative environments
24	Manage adverse consequences with proactive feedback structures or mechanisms
25	Every attempted fix of a complex problem, changes the problem
26	Identify a compelling community vision to address complex problems
27	In introducing complex solutions, "how" trumps "what"
28	It is easier to ignore complexity – and fail
29	Maintain a compelling community Vision through respectful collaboration
30	Evolving is the complex system's superpower
31	Minimizing harmful element interactions supports resilient complex systems
32	Complex systems should allow and enable human flexibility
33	Bear-hug complex problem unknowns
34	For complex systems, being useful is more important than being right

Code	Systems Engineering Principles
P1	Systems engineering in application is specific to stakeholder needs, solution space, resulting system solution(s), and context through the system life cycle
P2	Systems engineering has a holistic system view that includes the system elements and the interactions amongst themselves, the enabling systems and the system environment
P3	Systems engineering influences and is influenced by internal and external resource, political, economic, social, technological, environmental and legal factors
P4	Both Policy and Law must be properly understood to not overly constrain or under constrain the system implementation
P5	The real physical system is the only perfect representation of the system
P6	A focus of systems engineering is a progressively deeper understanding of the interactions, sensitivities and behaviors of the system, stakeholder needs and its operational environment
P7	Stakeholder needs change and must be accounted for over the system life cycle
P8	Systems engineering addresses stakeholder needs taking into consideration budget, schedule, technical, and other expectations and constraints
P9	Systems engineering decisions are made under uncertainty accounting for risk
P10	Decision quality depends on knowledge of the system, enabling system(s), and interoperating system(s) present in the decision-making process

Code	Complicated System Heuristics applicable to Complex Systems
C1	Seek external subject-matter experts when in-house knowledge is lacking
C2	Weakest links fail first – reliably and predictably
C3	Simplify, combine and eliminate, or simplify with smarter elements
C4	Do the hard parts first, not the fun or familiar parts first
C5	If in difficulty, re-formulate the problem and re-allocate the system functions and interfaces
C6	Periodically, pause and reflect!
C7	For suitability, such as safety and each other relevant “ility”, it is important to articulate what the minimal acceptable level is, as well as the level beyond which little added value is added or is feasible
C8	Each interface requires an owner
C9	Only insist on requirements which are essential
C10	Testing is expensive – make it efficient
C11	Delve beneath the symptoms
C12	Developing the system design in stages can reduce risk if the critical system behaviors are designed first
C13	<u>Change is inevitable – plan to deal with it</u>
C14	Minimize effort by focusing on the main mission objective first
C15	Ensure that the culture can support the strategy
C16	Bring solutions, not just problems

# Prior Work

- Look at identifying a memorable set of heuristics. This was challenging because:
  1. There are too many to boil down
  2. Good heuristics constantly being developed and identified
  3. Heuristic's meaning context specific
  4. Heuristic wording never quite right

Never ending – Alternative approach required



		Difficulty Elements			
		Intricacy	Unpredictability	Unfamiliarity	Constraints/Enablers
System Elements	Organization	0	1	4	0
	Technology	0	3	4	0
	Process	0	3	4	0
	Information	0	2	4	0
	Benefits	0	3	4	0
	Environment	0	4	4	0

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### Organisation Difficulty Scoring

Organisation: A group of people who work together in an organized way for a shared purpose

#### Intricacy

1.1 How complicated are the relevant organisations, stakeholders or communities?

There are no inter-dependent interfaces 0

There are several interdependent interfaces and some of these need to be managed 1

There are many interfaces or a few which have caused significant interface issues 2

There are a large number of interfaces most of which have known significant issues 3

Currently unable to ascertain or bound the number of interfaces which are causing significant issues 4

Comment: Although the number of stakeholders is limited, there are an endogenous relationship, with the OGD not using agreed supplier interface templates there are many more ad hoc. Suppliers have no template

#### Unpredictability

1.2 How changeable beyond your control are the relevant organisations, stakeholders or communities, within the task duration?

Very confident that change is unlikely to affect the task 0

Minimal change could affect the task. Significant confidence that there are no unknowns 1

Some change likely to affect delivery but may cause disruption 2

Many changes are expected which is likely to cause significant delivery disruption 3

Significant change is expected which will cause significant delivery disruption 4

Comment: Lack of change notice the problem period. Change needed to Partnering before and supplier response - that needs

#### Unfamiliarity

1.3 How unfamiliar/unaligned are the relevant organisations, stakeholders or communities?

All capability elements are aligned or familiar with each aspect of the task 0

Some aspects are not aligned or familiar which may require resolution 1

Major aspects are not aligned or familiar which will require resolution 2

Major aspects are not known and will require significant effort to resolve 3

Major aspects are not known within or outside the team and will require research/development to resolve 4

Comment: The task is not "known" but "known about"

#### Constraints / Enablers

1.4 How constrained are the relevant organisations, stakeholders or communities by processes, resources, information, facilities etc.

No constraints 0

Minor constraints impeding progress 1

Possible constraints across many aspects of the task 2

Major constraints reducing the likelihood of an acceptable outcome 3

Major constraints that mean the probability of an acceptable outcome is low 4

Comment: Culture change is very difficult and complex - need to be able to see two word more at once than they have to

Overview → Organisation → Technology → Process → Information → Benefits → Environment → Evaluation

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### RB and AP Supplier Relationship Case Study

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#### ALL HEURISTICS - MOST IMPORTANT FIRST - PROCESS STEP SPECIFIC

Heuristic	Score	Used?	New?
13. Complex Systems: As simple as possible, but no simpler	26.1558		
Principle 1: Systems engineering in application is specific to stakeholder needs, solution space, resulting system relationships, and context throughout the system life cycle	25.2145		
Principle 10: Decision quality depends on knowledge of the system, enabling systems (and inter-enabling systems) present in the decision-making process	25.2145		
Principle 2: Systems engineering has a holistic system view that includes the system elements and the interactions amongst the elements	25.2145		
Principle 3: Systems engineering influences and is influenced by internal and external resources, political, economic, social, technological, environmental, and legal factors	25.2145		
Principle 6: A focus of systems engineering is a progressively deeper understanding of the interactions, constraints,	25.2145		
Principle 7: Stakeholder needs can change and must be accommodated over the system lifecycle	25.2145		

#### ALL HEURISTICS - MOST IMPORTANT FIRST - PROCESS STEP AGNOSTIC

Heuristic	Score
F. Governance leadership: Have governance leaders that protect and enable the perspective to lead the decision making	6.84
31. Minimizing harmful element interactions supports resilient complex systems	6.75
13. Complex Systems: As simple as possible, but no simpler	6.64
cd. Do the hard parts first, not the less familiar parts first	6.30
Principle 1: Systems engineering in application is specific to stakeholder needs, solution space, resulting system	6.30
Principle 10: Decision quality depends on knowledge of the system, enabling systems (and inter-enabling systems)	6.30
Principle 2: Systems engineering has a holistic system view that includes the system elements and the interactions	6.30
Principle 3: Systems engineering influences and is influenced by internal and external resources, political, social	6.30
Principle 6: Both Policy and Law must be properly understood to not overly constrain or under constrain the system	6.30
Principle 5: The real physical system is the only perfect representation of the system	6.30
Principle 6: A focus of systems engineering is a progressively deeper understanding of the interactions, constraints,	6.30

#### LEAST IMPORTANT HEURISTICS - PROCESS STEP SPECIFIC

Heuristic	Score
3. Complex systems are not wholly complex	0
31. Minimizing harmful element interactions supports resilient complex systems	0
4. Do not overuse complicated page 8 in complex tables	0
5. For every complex problem, there is an answer that is clear, simple, and wrong	0
7. Breaks and/or aggregate with stable system steps	0

#### LEAST IMPORTANT HEURISTICS - PROCESS STEP AGNOSTIC

Heuristic	Score
C14. Minimize effort by focusing on the main mission objective first	2.8188
C10. Scaling is expensive - make it efficient	4.6744
C8. Only build on requirements which are essential	4.1389
C7. For reliability, reduce redundancy and each other relevant "Do". It is important to articulate what the critical is	4.1967
C11. Deliver benefits the requirements	4.6312

	Intricacy	Unpredictability	Unfamiliarity	Constraints/Enablers
Organization	3	3	3	4
Technology	4	3	3	2
Process	4	3	3	4
Information	3	3	3	4
Benefits	0	1	2	2
Environment	3	3	3	4

#### Process Step: Stakeholder and System Requirements

# Benefits

## Approach:

**E**nvironment

**L**eadership style

**M**anage Methodology

**G**overnance Structure

**and**

**T**eam Mix

*And the Discussion!!!*



# Methodology



# Methodology

Q. Can we use the indicate which heuristics are useful?

- Selected quality heuristics from 600+
  - 41 Complexity 10 Complicated
- Scored what type of problems they are suitable for (Using DAT)
- Used matching algorithm to identify what Heuristics most applicable to problem

	Intracacy	Unpredictability	Unfamiliarity	Constraints/Enablers
Organisation	0	4	4	0
Technology	0	2	3	0
Process	0	4	4	0
Information	0	4	4	0
Benefits	0	2	3	0
Environment	0	2	3	0

## The Problem characterization

	Intracacy	Unpredictability	Unfamiliarity	Constraints/Enablers
Organisation	3	1	1	3
Technology	0	0	0	0
Process	2	0	0	1
Information	2	2	1	2
Benefits	2	2	1	3
Environment	2	1	1	1

## The Heuristic characterization

# Methodology

- Are these heuristics useful
  - Useful= Relevant to problem\* Newness
    - 0= Not
    - 1= A bit
    - 2= Somewhat
    - 3= A lot
    - 4= Significant
- How useful is this compared to discussion and Delivery Advice ELMGaTe. (already proven)
- Small number of responses (19)



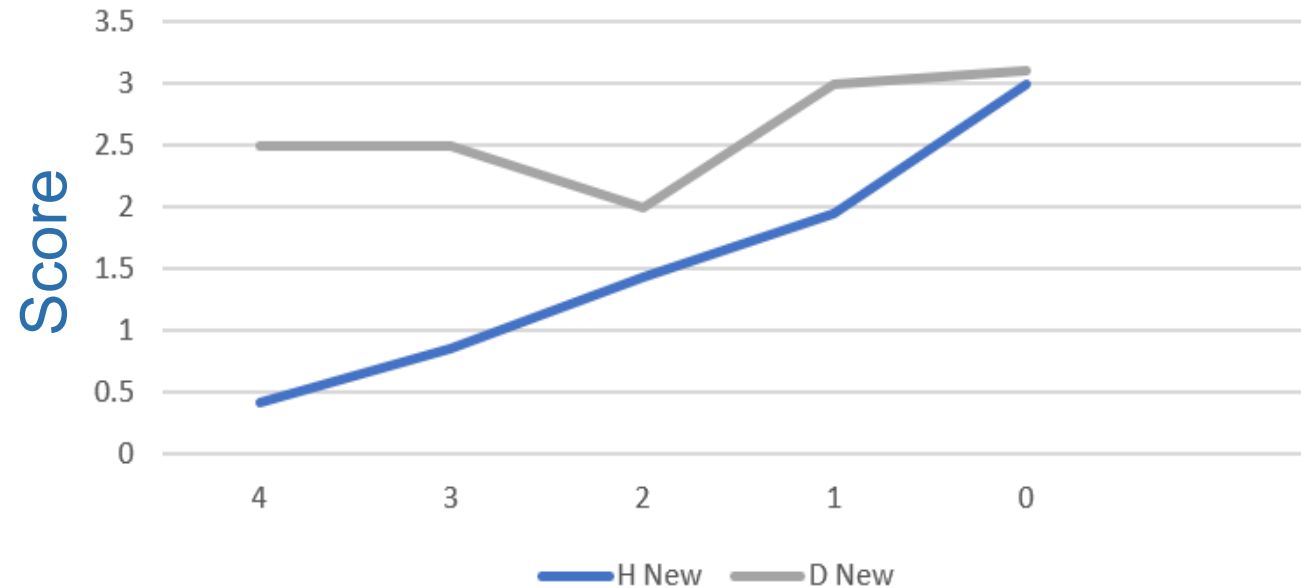
# Results

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# Newness

- Discussion always Valuable
- Heuristics value dependent on unfamiliarity with task
- ELMGaTe scored 1.65 on newness

Newness of discussion & heuristics wrt the teams familiarity with the task (0=being newest)



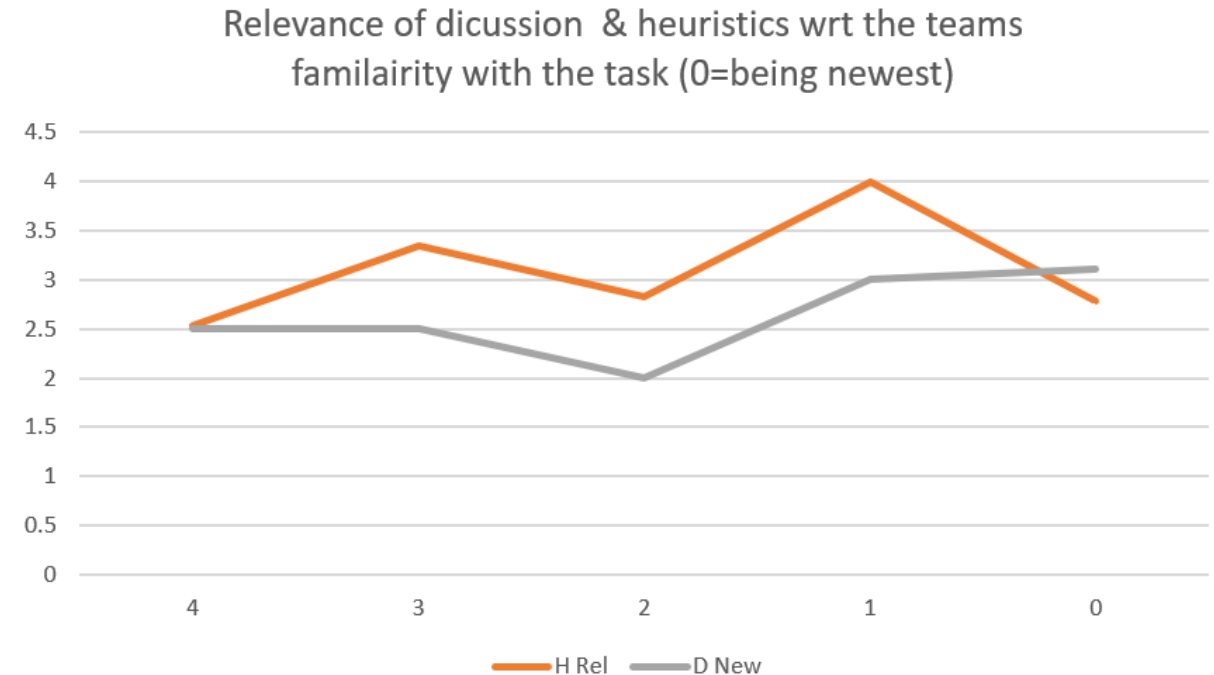
Team Unfamiliarity with Task →

0= Not  
1= A bit  
2= Somewhat  
3= A lot  
4= Significant

# Relevance

- Discussion value Valuable
- Heuristics value dependent on unfamiliarity with task
- ELMGaTe scored 3.5

Score

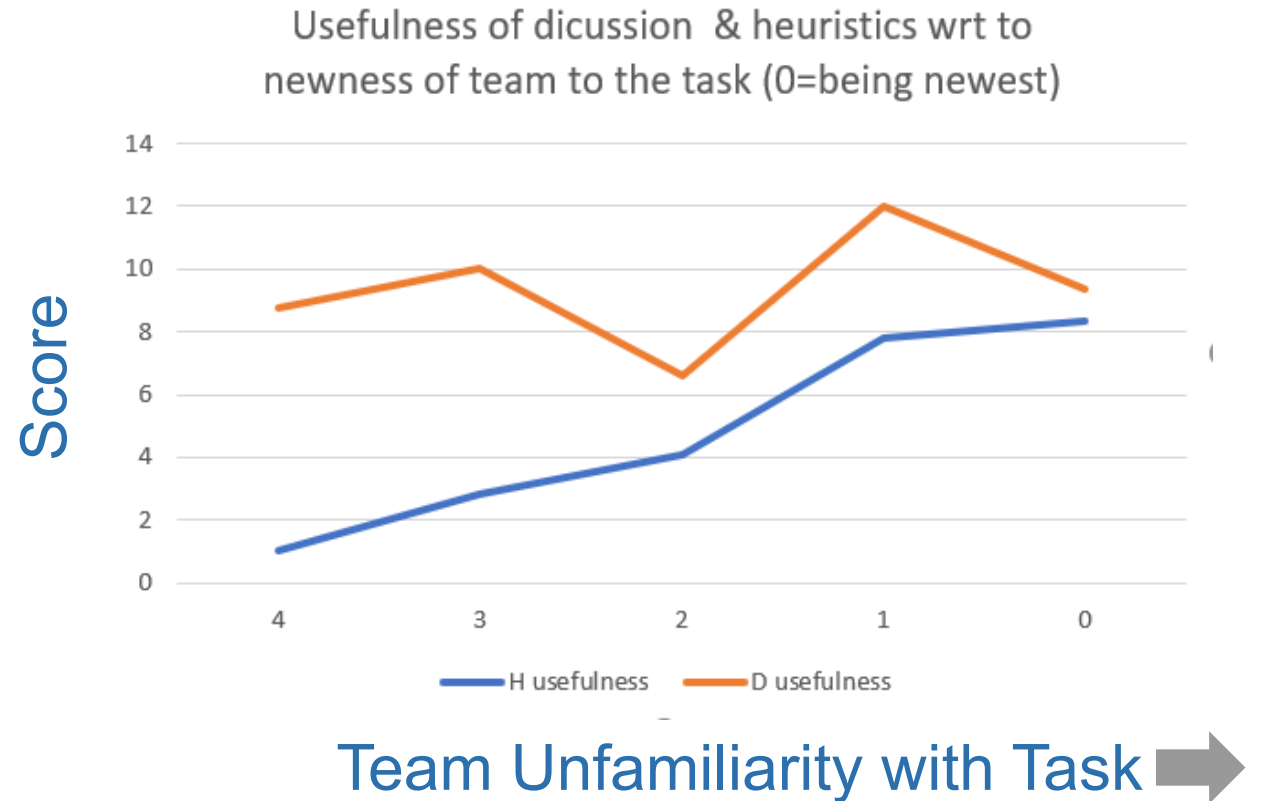


Team Unfamiliarity with Task →

0= Not  
1= A bit  
2= Somewhat  
3= A lot  
4= Significant

# Usefulness

- Relevance \* Newness
- Newness dominates usefulness curve



# Heuristic Mapping

The mapping worked effectively  
....according to the Engineers.

But test group scored all Heuristics  
provided highly.

Most likely as we pre-selected the  
best Heuristics from the 600.

Need to repeat without pre-  
selection

	Intracacy	Unpredictability	Unfamiliarity	Constraints/Enablers
Organisation	0	4	4	0
Technology	0	2	3	0
Process	0	4	4	0
Information	0	4	4	0
Benefits	0	2	3	0
Environment	0	2	3	0

## The Problem characterization

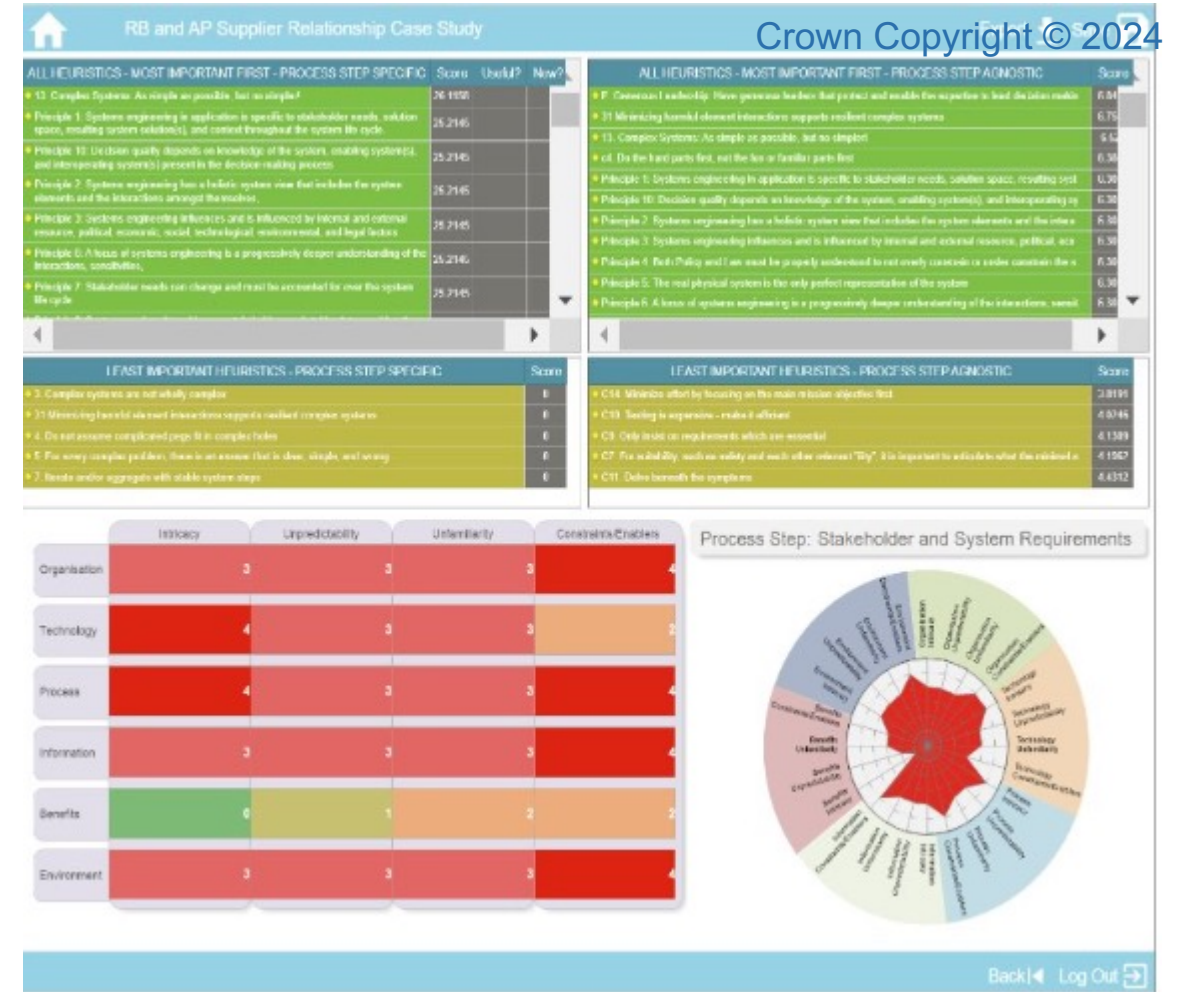
	Intracacy	Unpredictability	Unfamiliarity	Constraints/Enablers
Organisation	3	1	1	3
Technology	0	0	0	0
Process	2	0	0	1
Information	2	2	1	2
Benefits	2	2	1	3
Environment	2	1	1	1

## The Heuristic characterization



# Discussion/summary

- Discussion from using DAT always useful
- Heuristics really useful for new teams
- ELMGaTe results similarly useful if new
- 71% of practicing SE's found something significantly useful
- 100% of Trainee team got significant useful advice



# Next Steps

Can we simplify?

Can we create a field guide? to

1. Help new SE
2. Broaden experienced SE's
  1. Heuristics
  2. Tool/ Methods used

Advice types

- Heuristics
- Tactics
- Mindset – Leadership style
- Methodology
- .....

**Focused on understanding the situation:** Task and its ECO system:

Then mapping to the many advice types that might help that situation (referencing out advice)



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