



34th Annual **INCOSE**
international symposium
hybrid event
Dublin, Ireland
July 2 - 6, 2024



Providing Tailored Heuristic Advice to Systems Engineers

E. Arnold, D. Beale, K. Cureton, D McKinney, R. Oosthuizen, A. Pickard, D. Stewart.

Contents

1. Introduction
 - a) Motivation
 - b) Leveraging INCOSE Expertise
 - c) Prior Work
2. Methodology
3. Results
4. Discussion/Summary
5. Next Steps



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.

#	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

Crown Copyright © 2024

Organisation Difficulty Scoring

Save 

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

Intricacy	Unpredictability	Unfamiliarity	Constraints / Enablers
1.1 How complicated are the relevant organisations, stakeholders or communities?	1.2 How changeable beyond your control are the relevant organisations, stakeholders or communities, within the task duration?	1.3 How unfamiliar/unsigned are the relevant organisations, stakeholders or communities?	1.4 How constrained are the relevant organisations, stakeholders or communities by processes, resources, information, facilities etc.
There are no inter-dependent interfaces. <input type="radio"/> 0	Very confident that change is unlikely to affect the task. <input type="radio"/> 0	All relevant elements are aligned or familiar with each aspect of the task. <input type="radio"/> 0	No constraints. <input type="radio"/> 0
There are several inter-dependent interfaces and some of these need to be managed. <input type="radio"/> 1	Minimal change could affect the task. Significant confidence that there are no unknowns. <input type="radio"/> 1	Some aspects are not aligned or familiar which may require resolution. <input type="radio"/> 1	Minor constraints involving process. <input type="radio"/> 1
There are many interfaces or a task which have caused significant interface issues. <input type="radio"/> 2	Some change likely to affect delivery that may cause disruption. <input type="radio"/> 2	Major aspects are not aligned or familiar with resources available. <input type="radio"/> 2	Multiple constraints across many aspects of the task. <input type="radio"/> 2
There are a large number of interfaces most of which have caused significant issues. <input type="radio"/> 3	Many changes are expected which is likely to cause significant delivery disruption. <input type="radio"/> 3	Major aspects are not known and will require significant effort to resolve. <input type="radio"/> 3	Major constraints reducing the likelihood of an acceptable outcome. <input type="radio"/> 3
Currently unable to ascertain or bound the number of interfaces which are causing significant issues. <input type="radio"/> 4	Significant change are expected which will cause significant delivery disruption. <input type="radio"/> 4	Major aspects are not known within or outside the team and will require research / development to resolve. <input type="radio"/> 4	Major constraints that mean the probability of an acceptable outcome is low. <input type="radio"/> 4
Comment	Comment	Comment	Comment
Although the number of interfaces is limited, there can be significant complexity, and the LCM not using some supplier interfaces. There are many more not here. Supplier interface complexity.			

Overview  Organization  Technology  Process  Information  Benefit  Environment  Evaluation  Back  Next  Log Out 

RB and AP Supplier Relationship Case Study

Export  Save 

ALL HEURISTICS - MOST IMPORTANT FIRST - PROCESS STEP SPECIFIC Score Used? New?

• C1 Complex Systems: As simple as possible, but no simpler	26.1988
• Principle 1: Systems engineering in application is specific to stakeholder needs, solution space, resulting system(s), and context throughout the system life cycle	25.2145
• Principle 10: Decision quality depends on knowledge of the system, enabling systems(s) and incorporating systems(s) 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 one is influenced by internal and external resources, political, economic, social, technological, environmental, and legal factors	25.2145
• Principle 6: Assess of systems engineering is a progressively deeper understanding of the interactions, sensitivities,	25.2145
• Principle 7: Stakeholder needs can change and must be accounted for over the system life cycle	25.2145

ALL HEURISTICS - MOST IMPORTANT FIRST - PROCESS STEP AGNOSTIC Score

• C1 Complex Systems: Have processes leading that prevent and enable the supplier to lead the system	6.41
• C11 Minimizing formal element interactions supports robust complex systems	6.39
• C13: Complex Systems: As simple as possible, but no simpler	6.38
• C14: Do the last parts first, not the few or frontier parts first	6.38
• Principle 1: Systems engineering in application is specific to stakeholder needs, solution space, resulting system(s), and context throughout the system life cycle	6.38
• Principle 10: Decision quality depends on knowledge of the system, enabling systems(s), and incorporating systems(s) present in the decision-making process	6.38
• Principle 2: Systems engineering has a holistic system view that includes the system elements and the interactions amongst the elements	6.38
• Principle 3: Systems engineering influences one is influenced by internal and external resources, political, economic, social, technological, environmental, and legal factors	6.38
• Principle 4: Both Policy and Law must be properly understood to not overly constrain or under constrain the system	6.38
• Principle 5: The real physical system is the only perfect representation of the system	6.38
• Principle 6: Assess of systems engineering is a progressively deeper understanding of the interactions, sensitivities,	6.38

LEAST IMPORTANT HEURISTICS - PROCESS STEP SPECIFIC Score

• C2 Complex systems are not really complex	0
• C11 Minimizing formal element interactions supports robust complex systems	0
• C4 Do not assume complicated things fit in simple holes	0
• C5 For many complex problems, there is an answer that is clear, simple, and obvious	0
• C7 Reuse and/or aggregate with stable system steps	0

LEAST IMPORTANT HEURISTICS - PROCESS STEP AGNOSTIC Score

• C14: Minimize effort by focusing on the main mission objective first	28.098
• C13: Testing is expensive - make it efficient	4.0345
• C3: Only focus on requirements which are essential	4.1389
• C7: For stability, reduce volatility and seek other interests ("Why"). It is important to understand what the customer needs	4.1957
• C11: Define benefits the right way	4.4312

Process Step: Stakeholder and System Requirements

	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



Benefits

Approach:

Environment

Leadership style

Manage Methodology

Governance Structure

and

Team 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

	Intricacy	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

	Intricacy	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)

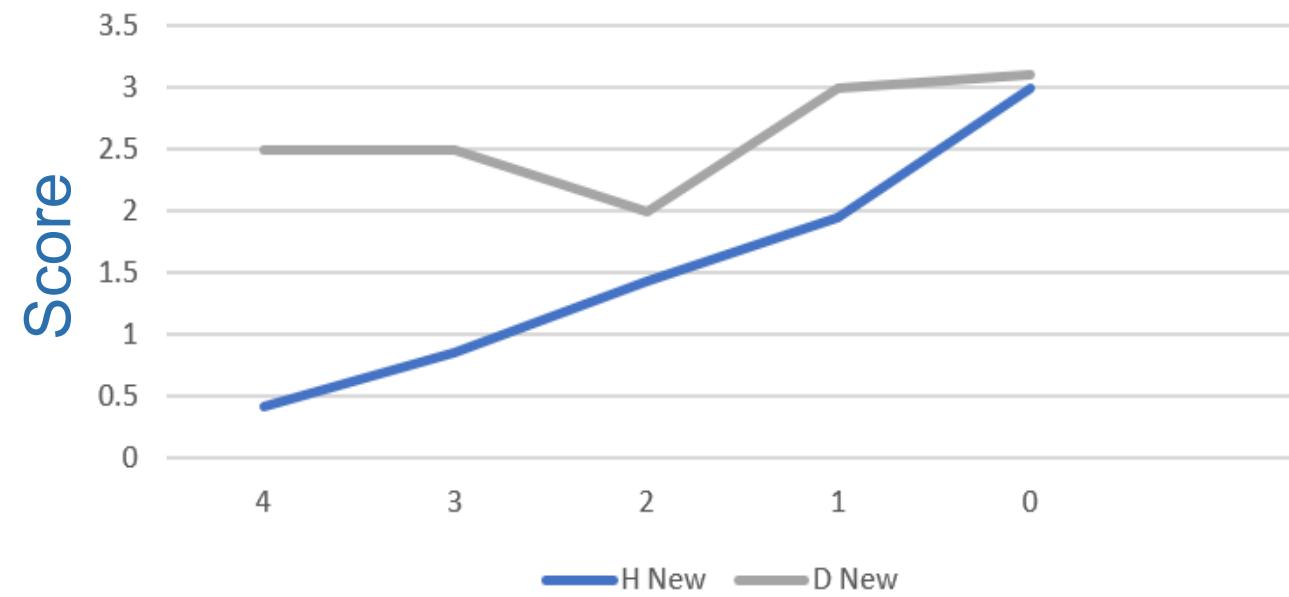


Results

Newness

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

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

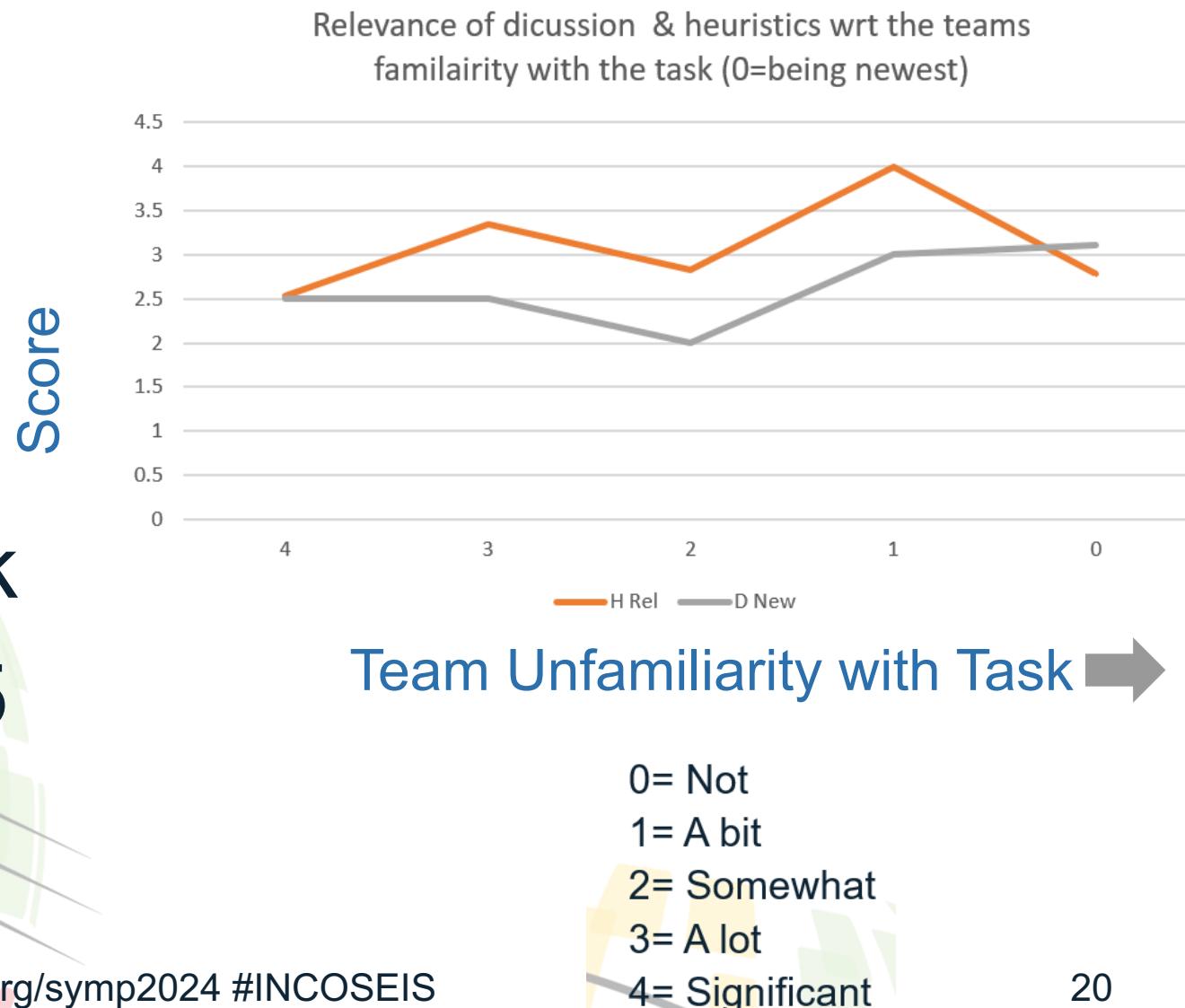


Team Unfamiliarity with Task →

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

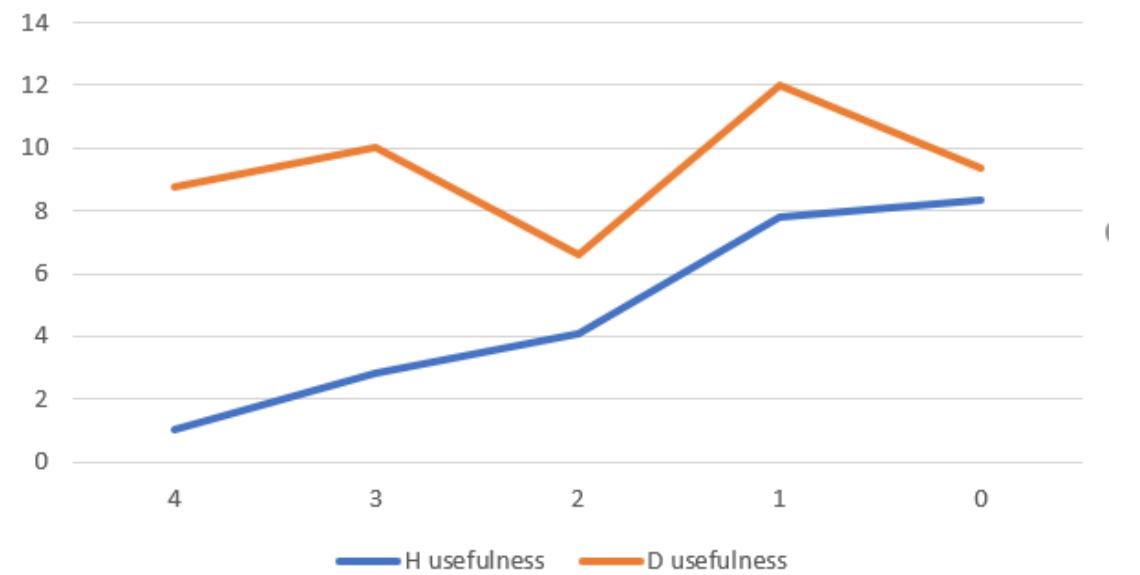


Usefulness

- Relevance * Newness
- Newness dominates usefulness curve



Usefulness of dicussion & heuristics wrt to newness of team to the task (0=being newest)



Team Unfamiliarity with Task 

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

	Intricacy	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

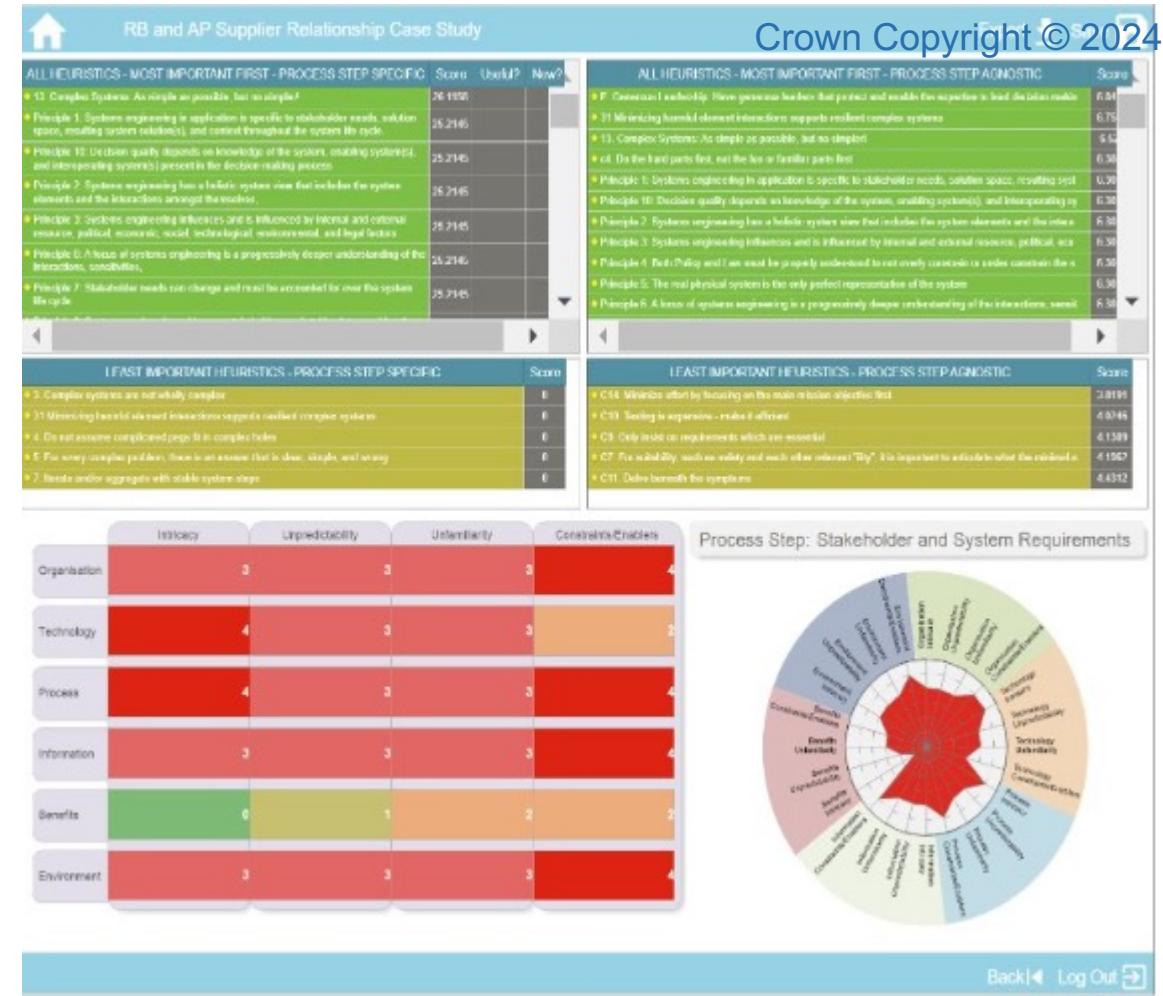
The Problem characterization

	Intricacy	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)



34th Annual **INCOSE**
international symposium

hybrid event

Dublin, Ireland
July 2 - 6, 2024

www.incos.org/symp2024
#INCOSEIS