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hybrid event

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The INCOSE Systems Engineering Heuristics: What Are They Telling Us About the Discipline?

Outline of Presentation

- Introduction
- Methods
- Results
- Discussion
- Acknowledgments
- References
- The INCOSE Heuristics
- Details for Nominated Cluster Names

Introduction

Research Background

- INCOSE Heuristics team chartered in 2020 containing mainly INCOSE Fellows
  - Collected over 600 candidate heuristics from published sources, personal experiences, and colleagues.
  - Rolls Royce was a primary contributor
- An INCOSE Online Heuristics Resource prototype containing 164 heuristics was assembled.

Visualization in Bibliometric Networks

- Visualization is a powerful tool for analysis
  - Citation relationship network between publications or journals
  - Co-authoring relationship network between researchers
  - Co-occurrence relationship network between words
- Visualizing bibliometric networks has become larger, more advanced, and more widely used
- Bibliometric mapping has become increasingly important in the field of bibliometrics
  - Construction of bibliometric maps
  - Graphical representation of maps
- Can be used to represent trends in research and industry

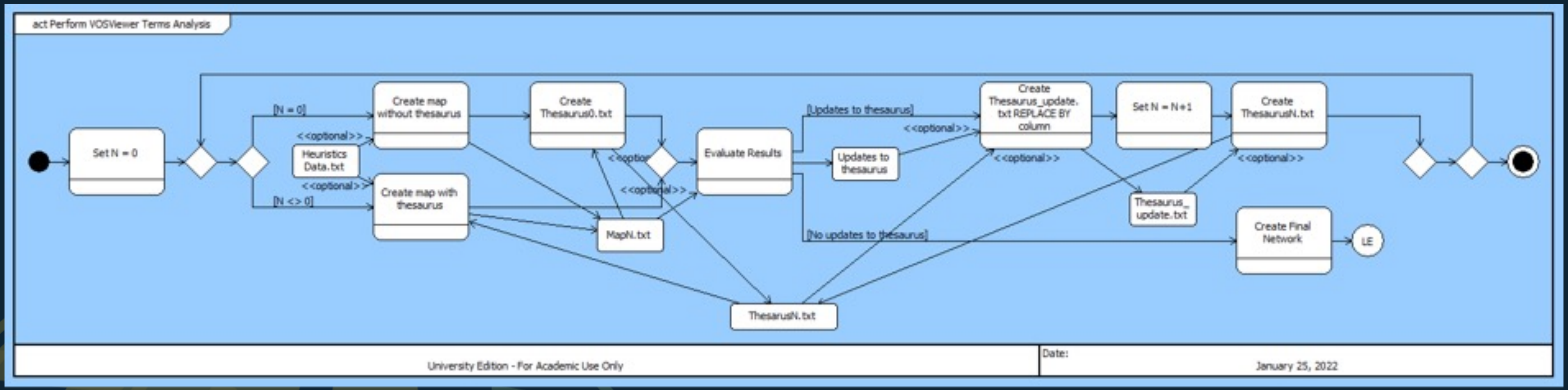
Bibliometric Analysis Using VOSviewer

- VOSviewer is a software tool for constructing and visualizing bibliometric networks
- Input data to VOSviewer for each of the 164 candidate heuristics
  - Unique identifier for the heuristic
  - Text (or corpus) of the heuristic
  - Sources cited by the heuristic
- Analyses Planned Using Three Different Methods
  - Co-Occurrence
    - Two terms occur together across multiple heuristics
    - The terms are identified by applying natural language processing algorithms to the text (or corpus) of the heuristics
    - A thesaurus file is used to merge common terms and to ignore terms that are immaterial–A human subject matter expert must create the thesaurus
  - Bibliographic Coupling
    - A bibliographic coupling link is a link between two heuristics that both cite the same source
  - Co-citation
    - A co-citation link is a link between two sources that are both cited by the same heuristic

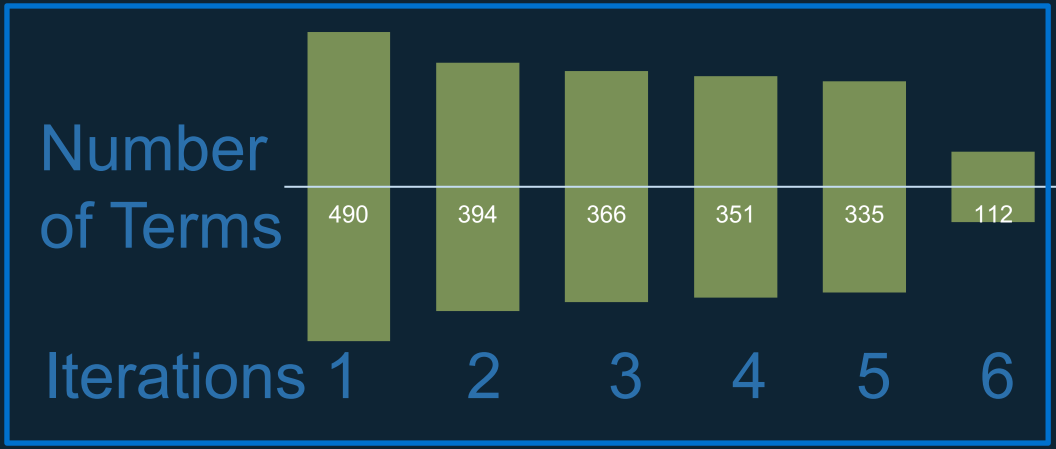
Methods

Co-Occurrence Followed up by a Fellows' Survey and a Member Ballot

VOSviewer Co-Occurrence Iterations



- Final network converged to 112 terms after six iterations (N=6)
- Sixth iteration eliminated all terms that occur only once



Details for Each Iteration

- Input to iteration
  - Collection of the text (or corpus) for the heuristics
  - A thesaurus file
- Output from iteration
  - Count of the number of occurrences of a term across all heuristics
  - Network mapping of the co-occurrences of pairs of terms
    - Link weights between each pair of terms in map is number of co-occurrences of the two terms
    - Clustering of the terms that maximizes a function based on association strength normalization of the link weights
- VOSviewer automatically identifies terms from heuristics database using four-step process
  1. Part-of-speech tagging (i.e., identification of verbs, nouns, adjectives, etc.)
     - Apache OpenNLP toolkit (http://incubator.apache.org/opennlp/)
     - Linguistic filter to identify noun phrases.
  2. Selects most relevant noun phrases using the Kullback-Leibler distance between distribution of (second order) co-occurrences over all noun phrases and the overall distribution of co-occurrences over noun phrases.
  3. Mapping and clustering the terms
  4. Produces visualizations of the results

Example of Thesaurus Substitutions

Original Heuristic Statement	Heuristic Statement with Thesaurus Substitutions
In ***managing***, try to ensure that all use of people's time contributes to achieving project ***objectives.***	In ***managerial structure***, try to ensure that all use of people's time contributes to achieving project ***objectives.***
Manage the details through focus on high-level measurable ***objectives***, not through bureaucracy.	***Managerial structure*** the details through focus on high-level measurable ***objectives***, not through bureaucracy.

“Name That Cluster” Fellows Survey

- For each co-occurrence cluster, Fellows were asked to
  - Name that cluster
  - Create a narrative that provides a rationale for the name and why it makes sense for the terms to belong to the cluster
- Seven Fellows participated
- Many thanks to the Fellows for contributing their intellectual horsepower and to the education of two Purdue undergraduate researchers

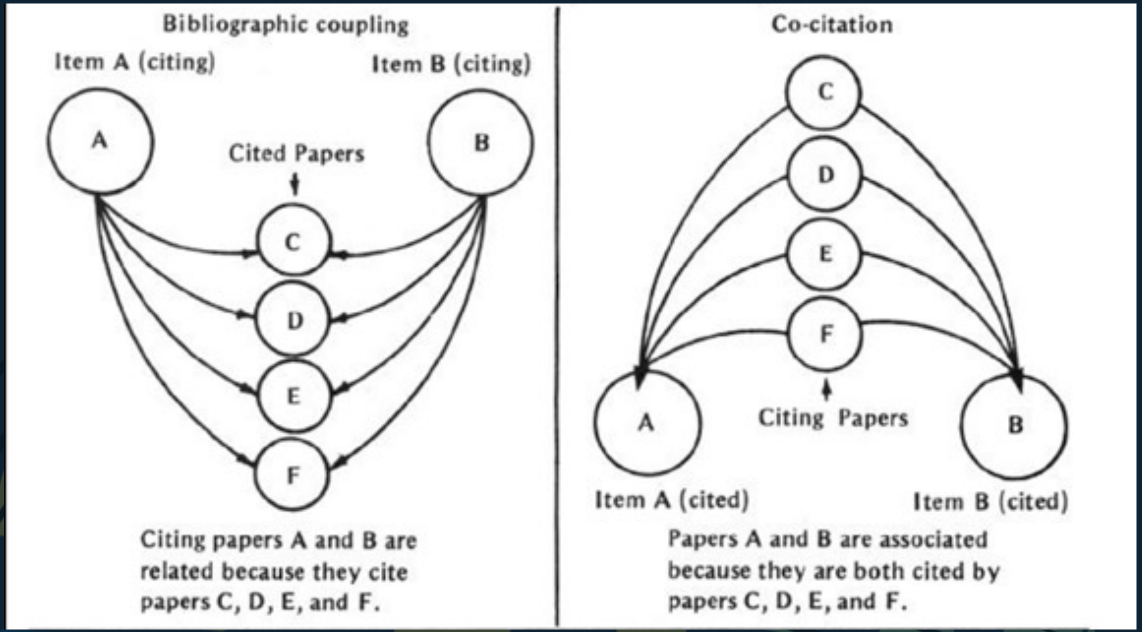
"Name That Cluster" Ballot

- For each cluster "nominated" by the Fellows, a ballot was distributed to 841 INCOSE members
- The ballots listed the cluster terms, cluster names, and the rationale for the names
- Names of the nominating Fellows were not revealed to the voters
- The voters were asked to
  - Vote for the cluster name that they believe best suits each cluster
  - Provide a rationale for the name that they voted for

Bibliographic Coupling and Co-Citation

Bibliographic Coupling and Co-Citation Using VOSviewer

Visual Explanation of Bibliographic Coupling and Co-Citation (Garfield 2001)



Bibliographic Coupling

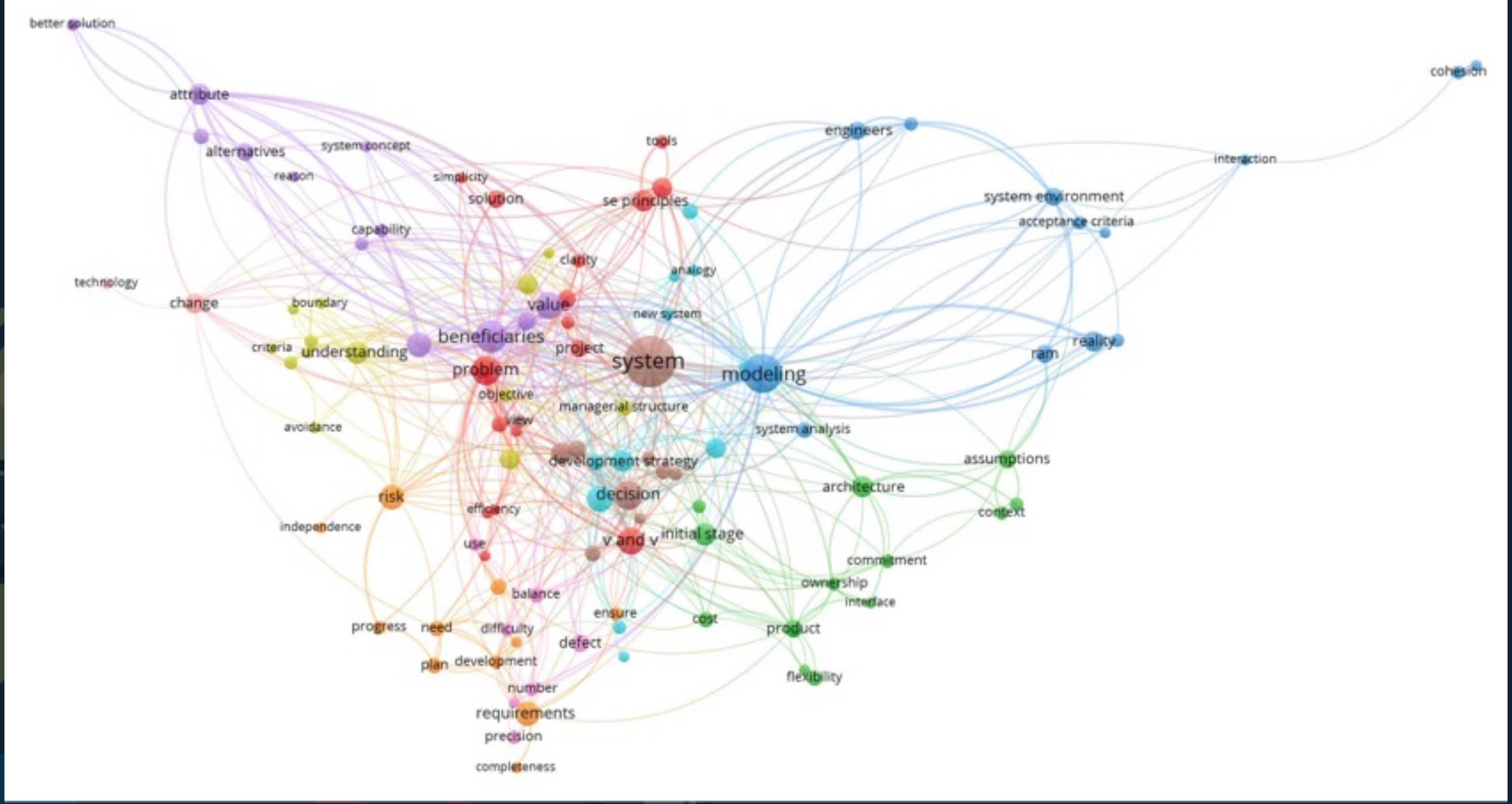
- Strength of links attributed to the number of cited references two heuristics have in common
- Similar to co-occurrence, uses a thesaurus file for organization
- Expected results to not be informative

Co-Citation Analysis

- Networks constructed by analyzing references cited in support of each heuristic
- Extracts source titles and author names
- Three iterations: Author, Reference, Source

Results

Network Map – Co-Occurrence



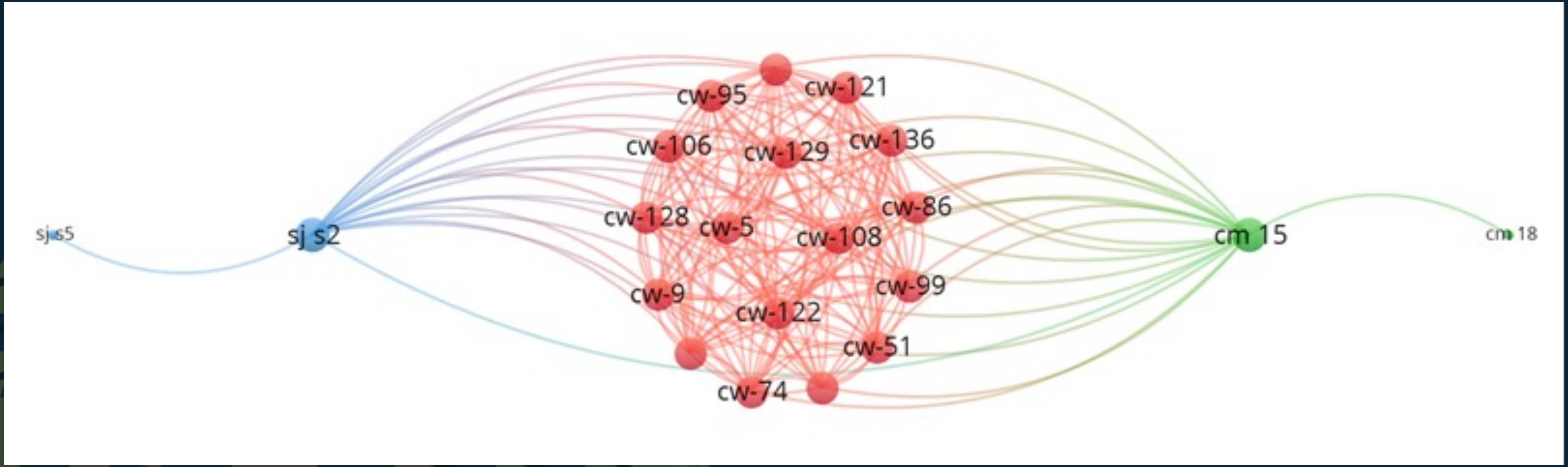
And the winners are… (Page 1 of 2)

Cluster	Winning cluster name(s)	Category for Winning Names	Related Category in INCOSE Handbook	Nominated by	Number of votes / number of votes cast	Runner-up cluster name (votes)
1	Systems Approach	Philosophy	Generic Life Cycle Stages	Fellow #5	20 / 51	Begin with the end in mind (8)
2	System Architecting Concept Exploration	Activity	Technical Processes	Fellow #2	14 / 51 14 / 51	Initial Lifecycle Stage (10)
3	Systems Modeling	Activity	Cross-Cutting Systems Engineering Methods	Fellow #2	21 / 51	Modeling Systems (7) MBSE (7)
4	System Complexity	Attribute	Emerging Knowledge (per SEBoK)	Fellow #2	21 / 50	Ontologies of a system (9)
5	Stakeholder Analysis	Activity	Technical Processes	Fellow #2	20 / 52	Value Analysis (15)

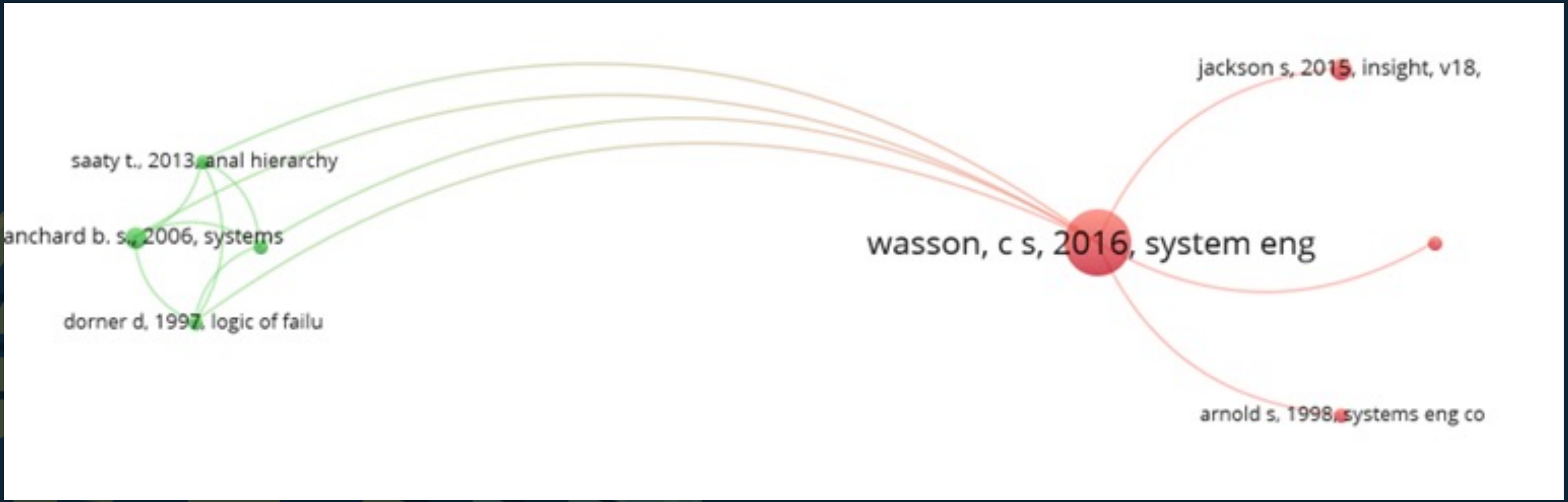
And the winners are… (Page 2 of 2)

Cluster	Winning cluster name(s)	Category for Winning Name	Related Category in INCOSE Handbook	Nominated by	Number of votes / number of votes cast	Runner-up cluster name (votes)
6	System Design	Activity	Technical Processes	Fellow #2	34 / 52	System Design and its characteristics (8)
7	Requirements and risks and their potential applications	Attribute	Technical Processes / Technical Management Processes	Fellow #1	22 / 52	Requirements (16)
8	Decision Analysis	Activity	Technical Management Processes	Fellow #2	32 / 52	Human and Systems (7) Systems Approach (7)
9	System Assessment	Activity	Technical Management Processes	Fellow #2	22 / 49	Failure analysis (13)
10	Technology Forecasti ng	Activity	Specialty Engineering Activities	Fellow #2	18 / 50	Change (16)

Network Map – Bibliographic Coupling

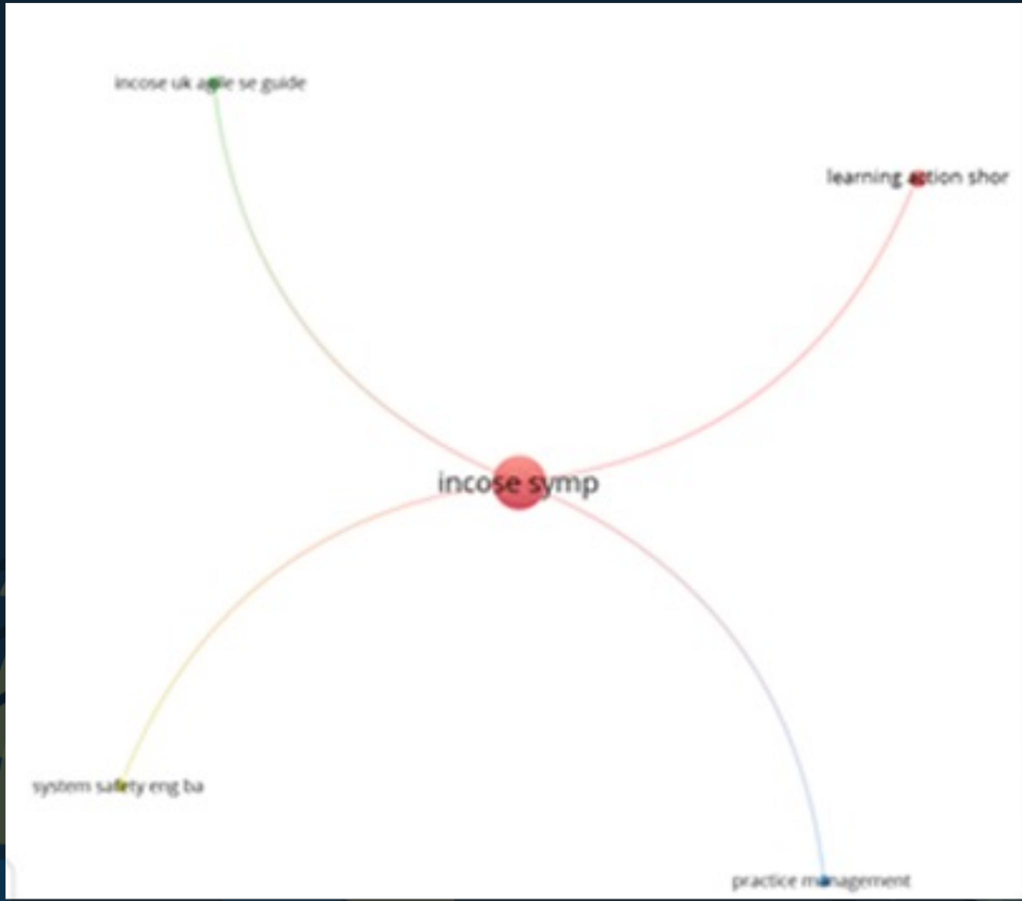


Network Maps – Co-Citation (1 of 2)

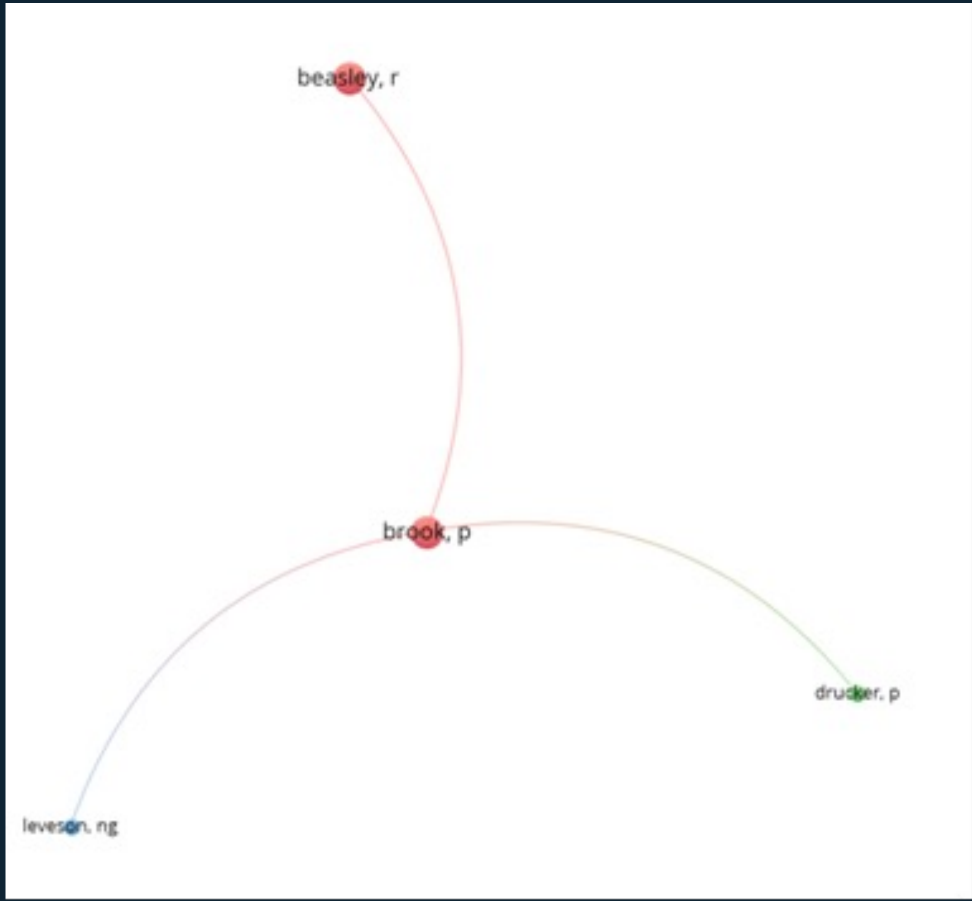


VOSviewer Co-Citation Map for References

Network Maps – Co-Citation (2 of 2)



VOSviewer Co-Citation Map for Sources



VOSviewer Co-Citation Map for Authors

Discussion

The Importance of Co-Occurrence

- Clusters are based on a non-hierarchical, relational analysis
  - Identify emergent properties “in between” the heuristics
- Purpose is to discover the gestalt implied by a pile of information that has been collected by creating heuristics
- The winning names can be interpreted as emergent disciplines essential to the practice of systems engineering
  - Philosophical underpinnings, specific activities, attributes of system of interest
  - Heuristics heavily show themes of the “Technical Processes” sections of the INCOSE handbook

Recap of the Winning Cluster Names – the Emergent Disciplines

1. Systems Approach
2. System Architecting
3. Concept Exploration
4. Systems Modeling
5. System Complexity
6. Stakeholder Analysis
7. System Design
8. Requirements and risks and their potential applications
9. Decision Analysis
10. System Assessment
11. Technology Forecasting

Co-Occurrence Cluster Detailed Example

- "Requirements and risks and their potential applications"
  - Key attributes that must be considered in order to design a system that meets all objectives

Cluster 7

Term	Occurrences
requirements	9
risk	9
good solution	4
need	4
plan	4
development	3
ensure	3
progress	3
completeness	2
independence	2
insight	2

Bibliographic Coupling and Co-Citation Results

Bibliographic Coupling

- Many heuristics cited one of Wasson's sources
  - Indicating how impactful and universal his work might be

Co-Citation Analysis

- Again, shows Wasson's impact on the heuristics' references
- Sources map indicates the prevalence of the INCOSE Symposium as cited by the heuristics

The Importance of Bibliographic Coupling

- Gives an indication on topics that were and currently are important
  - Bibliographic coupling is a dynamic source of information
- Indicates communities of practice
  - Ex. Systems engineering, failure analysis, creative problem solving, resilience, human integration

The Importance of Co-Citation Analysis

- Indicates sources, references, and authors who may be becoming relevant
- Specifically showcases communities of theory and methodology used in the industry
  - Ex. Safety, business management, agile systems engineering
- References indicate topics relevant in systems engineering
  - Process used to analyze references can be used in other scenarios to identify emergent topics

The Importance of Co-Citation Analysis (cont'd)

- Sources show the importance of papers from the INCOSE symposium for defining heuristics as opposed to other sources
  - Journal articles unimportant in this context
- Co-citation author map displays authors that discuss enterprise systems engineering and effective systems engineering practices.

Looking Ahead

- Analysis process can be used to analyze other collections of documents:
  - Entire collection of INCOSE symposium papers
  - Abstracts from multiple papers
  - Using author co-citation, relating specific topics/subtopics to an author

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  - Scott Jackson
  - an anonymous Fellow who did not provide their name
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The INCOSE Heuristics

ID	Heuristic Statement
CM 8	Developing the system design in stages can reduce risk if the critical system behaviors are designed first.
CM 12	Use subject-matter experts when in-house knowledge is lacking
CM 15	Identifying the main objective for system design minimizes schedule and cost overruns and serves to validate the stake-holders' needs.
CM 18	If not considered as a viable trade-off options, alternate solutions cannot be adopted even if desirable
CM21	During system analysis, Model-Based System Design best captures the mission system behavior from collected information and drives consistency among the design team.
CM24	In modeling, configuration management of the model is paramount.
CM27	Design engineers need to represent the system concept in simple yet accurate model views that are created from respective stakeholder viewpoints to aid decision makers in ensuring stakeholder concerns are met to provide sufficient value.
cw	Test options against realistic scenarios
CW-1	Every system is perfectly designed to produce the results and outcomes you are observing
CW-5	Diagnose before treating: refrain from jumping to solutions before sufficiently understanding the problem.
CW-9	Every system exists for its stakeholders based on perceptions of their actual operational needs.
CW-29	Testing is expensive - make it efficient
CW-51	Only insist on requirements which are essential
CW-74	Make your assumptions explicit.
CW-86	Assign ownership and accountability for every interface within the system or product based on the highest-level architecture that identifies the interface.
CW-95	Tool users should be competent in the principles and processes that are supported by the tool.
CW-99	Multiplication of two 2-digit numbers does not produce four-digits of precision.
CW-106	Managers want to see prioritized solutions to a problem or issue, not problems for them to solve. Otherwise, your expertise has no value to them.
CW-108	Analysis results are only as valid as their underlying assumptions, models, and methodology.
CW-113	If you charter a trade study, be prepared to implement its conclusions unless there is a compelling reason(s) to do otherwise.
CW-118	Obtain and sustain stakeholder community “buy-in” through collaboration and implicit “ownership” of the system beginning with day 1.

ID	Heuristic Statement
CW-121	When diagnosing cause of failure, start with objective reconstruction of events and symptoms, then progressively eliminate possible causes using a sound methodology.
CW-122	Models and simulations are only as good as the algorithms that seek to represent the system and its interactions with its operating environment based on data from measurement or observation.
CW-128	Reliability, availability, and maintainability (RAM) estimates may be relied upon only if they identify the underlying math model, assumptions and constraints, component condition, and operating environment conditions.
CW-129	Every system should be designed with a strength design margin that exceeds its predicted operating environment stresses.
CW-136	Tell people what you need; otherwise don't complain about what they deliver.
CW-137	Make a decision "up front" concerning the % of project schedule time to be allocated for design risk mitigation testing and the System Test Phase; make a commitment to meet it!
DK-1	In defining a problem involving multiple stakeholders, try to ensure a common understanding of the problem boundary.
DK-2	For 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 extra value is added or is feasible.
DK-3	For all performance requirements, it is important to understand the difference between accuracy, precision and significance.
DK-4	Establish a lexicon of key SE subject matter terms to ensure a clear and concise understanding of terms among all participants.
DK-5	Although one must always be guided by official direction, circumstances are likely to change and it is wise to have a process for dealing with it should it arise.
DK-6	Implementing (a change towards) systems engineering is implementing a complex adaptive system (your organization/business). You need to probe, sense, and then adjust.
DK-7	A key SE success factor is ensuring the project culture is aligned and compatible with the development strategy.
DK-8	In developing a system, use the most appropriate development strategy, from waterfall; incremental; evolutionary (sometimes called incremental and iterative)- including agile, and spiral.
DK-9	Ensure that the requirements to make something reusable do not overwhelm the requirements needed to make something actually useful.
DK-10	Tailor your systems engineering information artifacts around the decisions they are intended to support, and the people who will be making the decisions.

ID	Heuristic Statement
DK-11	Understand that when you communicate to people, they will interpret what you communicate using their own mental models, which may result in their making unexpected decisions using the information you have given them.
DK-12	Be careful in using terms with subtle differences of meaning, to avoid misunderstanding.
DK-13	When a stakeholder characterizes something as "complex," recognize that this reflects their understanding (subjective complexity), not necessarily the inherent (objective) complexity (or complicatedness) of the topic or system being discussed. Make this assessment and act accordingly.
DK-14	Don't assume that a systems engineering technique that has worked well for you with complicated systems (e.g. static structural modeling or semantic modeling) will be helpful with complex systems.
DK-15	When you model a system, design the model for the questions you are trying to answer, and allow for iteration.
DMcK 1	Don't try to build it all at once -- evolve the system based on highest value early, and aim to rapidly learn from the realities
DMcK 3	In a high risk project, progress in reducing major risks and making stakeholders see that progress is being made are important.
DMcK-2	Systems should be designed for change, since change is inevitable.
DMcK3a	Employ independent authority to evaluate project risks.
Dov Dori-1	Start modeling of a contemplated engineered system by defining the function the system is expected to perform, this being a combination of the system's main process and the main object (operand) and its value-providing attribute which that process transforms, along with the beneficiary group (a person or a group of people) and benefit-providing attribute, i.e., the attribute the change of which provides value to the beneficiary group.
Dov Dori-2	Propose at least two, preferably more, alternative concepts by which the system's properties may be achieved, model at a conceptual level of detail, and compare them based on a predetermined, accepted weighing scheme.
Dov Dori-3	Make explicit in a system model the affiliation of things: which objects and processes are systemic (part of the system, over which the engineer has control) and which are environment (part of the system's environment, over which the engineer has no control).
GW-1	In designing, we must sacrifice the precision of the math in order to make it useful.
GW-2	We engineers don't get paid to do things right. We get paid to do things just right enough.
GW-5	Simplicity of solution is a virtue only if the solution solves the problem.
GW-6	The architect is principally an agent of the supplier, not the acquirer.
GW-8	In managing, try to ensure that all use of people's time contributes to achieving project objectives.
GW-9	Expect resistance to change. Plan accordingly.

ID	Heuristic Statement
IM 1	A plan against which progress is measured may be flawed; continually re-evaluate the plan.
IM 3	You don’t make a project cheaper by not doing things; you make it cheaper by doing more of the right things.
IM 4	The customer may well not be right, but their position is valid from their (current) point of view and should be respected.
IM-2	Recognizing uncertainty is the first step to certainty
JD2	Plan for the inevitable need to correct and change requirements as insight into the need and the "best" solution grows during development.
PB1	Keep options open as long as possible. Only down-select when there is good evidence it is feasible and affordable. Decide at the last responsible moment.
PB2	Align the system and responsibility boundaries to the extent that is possible
PB3	In the early stages of a project, unknowns are a bigger issue than known problems
PB4	Get to a straw man solution early, to allow for iterations and elaboration to a better solution
PB5	Aim first for the most efficient solution to the most difficult domain problem
PB6	Use multiple perspectives to understand the problem.
PB7	Front-load architectural design.
PB8	Coupling and cohesion: Structure elements to minimize the degree of inter-element coupling/ interdependency, and maximize internal element cohesion
PB19	Use the real world as a model of the system
PB23	Continually build on what already exists
PB31	The original problem statement is often incomplete or even incorrect.
PB32	In choosing subsystems, try to minimize interactions between subsystems, with high internal interactions.
PB34	In general, each system level provides a context for the level(s) below.
PB34b	Complex systems will evolve within an overall architecture more rapidly if there are stable intermediate forms.
PB36	Design tests to evaluate the success of the systems hand-in-hand with its design and development.
PB37	Success is defined by the beholder not by the architect

ID	Heuristic Statement
PB38	The most dangerous assumptions are the unrecognized ones. Draw out significant aspects of problem context before making commitments to architecture.
PB39	Firm commitments are best made after the prototype works.
PB40	The choice between architectures may well depend on which set of drawbacks the customer can handle best.
PB53	Collaborate
PB58	Things should be designed to be usable, without modification, by as many people as possible.
PB59	The level of control should be related to the proficiency and experience of the user
PB60	When creating a new system, include in your considerations the way the customer has used similar systems in the past. In other words: use crowd-sourced input.
PB61	Beware feature creep in design and development.
PB62	As the flexibility of a product increases, the usability and performance of the product decreases.
PB63	Systems should help people avoid errors and protect them from harm when they do occur.
PB64	Consider the use of prototyping to increase understanding.
PB66	Weakest links fail first - reliably and predictably
RJH-1	Every project should foster SE work environments that stimulate, not stifle, creativity.
RJH-2	In undertaking an engineering project, establish clear objectives, appoint competent people, create a supportive environment, and employ effective processes based on sound principles.
RJH-3	When there is significant risk or opportunity, especially with new systems in uncertain environments, apply spiral development to the targeted entity regardless of level of abstraction.
RJH-4	Always apply SE principles; in applying SE principles, use the SE process tools selectively, with a level of formality based on the specifics of the task at hand.
RJH-5	Make engineering decisions on the basis of maximizing the value that will be delivered by the engineering on the balance of probabilities, notwithstanding that any individual decision can produce a bad result.
RJH-6	Try to achieve a sufficient set of requirements, not a literally complete set of requirements.
RJH-7	Identify feasible solution alternatives. Pick the best.

ID	Heuristic Statement
RJH-8	The essence of systems engineering is problem understanding, efficient application of knowledge and creativity to solution development, verification that we have done the job right, and validation that we have done the right job.
RJH-9	The engineering management decision between Waterfall, Incremental, Evolutionary, and Spiral development strategies, for each design object, can lock in success or failure – decide based on predictable parameters.
RJH-11	In conducting trade-offs, never develop weights for attributes alone; only develop weights for improvements in attributes, each over a defined range of improvement.
RJH-13	Communicating your understanding (even if it is not what others believe, or want to hear) is critical to being an effective member of an engineering team.
RJH-14	The system that does the engineering is an enabling system to the system being engineered – engineer both concurrently, collaboratively and in balance.
RJH-15	Avoid confusing "never having defined the problem properly in the first place" with a genuine change of need
RJH-16	View and engineer the engineering system as being of the same criticality as the system it is to engineer.
RJH-17	Maintain a clear distinction between problem and solution, while maintaining traceability between the two.
RJH-18	Apply the principles of systems engineering to all engineering.
RJH-19	In order to manage risk effectively, achieve a thorough understanding the ingredients of risk: value, threat, vulnerability, and probability.
RJH-20	Apply systems engineering principles, heuristics and methods to project planning and assurance.
RJH-21	As an initial priority of any engineering project, Investigate and identify what is known and knowable about a problem.
RJH-22	Avoid usage of language in engineering that is in conflict with community usage as reflected in respected dictionaries.
RJH-24	In building an engineering workforce, aim for every engineer to possess and use at least a foundation level of skill in systems engineering principles and methods.
RJH-26	Ensure that the risk reduction benefit of each verification activity exceeds the cost of the activity.
RR-2	Manage the details through focus on high-level measurable objectives, not through bureaucracy.
RR-5	Frame each requirement to maximize the value it contributes for stakeholders, or "Everything must pay its way into the product."
RR-11	Performance, cost and schedule cannot be specified independently. At least one of the three must depend on the others.
RR-24	It is unlikely that a complex system can be optimum to all parties concerned.

ID	Heuristic Statement
RR-26	When choices must be made with unavoidably inadequate information, choose the best available on the balance of probabilities and then watch to see whether future solution confirmations appear faster than future problems. If so, the choice was at least adequate. If not, go back and choose again.
RR-31	Challenge the process and solution, for surely someone else will do so.
RR-40	Use open architectures. You will need them once the market starts to respond.
RR-41	Assess previous studies for completeness, currency and correctness; don't just assume their validity.
RR-43	Once the architecture begins to take shape, the sooner contextual constraints and sanity checks are made on assumptions and requirements feasibility, the better.
RR-45	Place limits on element behavior to avoid unintended consequences in unanticipated scenarios.
RR-47	In engineering a system, any system that has the potential for doing harm should also contain the means for preventing that harm.
RR-54	Balance increased accuracy of a model from increasing the number of parameters in the model against the ease of use and difficulty of calibration of the model.
RR-59	Estimate development parameters using multiple methods (e.g. analogy, parametric, etc.)
RR-65	In any resource-limited situation, the true value of a given service or product is determined by what one is willing to give up to obtain it.
RR-66	Recognise the trade-off between reduced time to delivery and threat to functionality.
RR-71	Reuse is not free
RR-72	One insight is worth a thousand analyses.
RR-74	Mistakes are understandable, failing to report them is inexcusable.
RR-75	If you think your design is perfect, it's only because you haven't shown it to someone else
RR-78	There is no such thing as a purely technical problem.
RR-80	A model is not reality; a model is an approximate representation of the real system.
RR-81	The cost to find and fix an inadequate or failed part increases by an order of magnitude as it is successively incorporated into higher levels of the system
RR-82	Recovery from failure or flaw is not complete until a specific mechanism, and no other, has been shown to be the cause.
RR-86	In introducing technological change, we need to win the support of those affected; that the change is beneficial is not enough.

ID	Heuristic Statement
RR-89	The test setup for a system is itself a system and should be engineered as such.
RR-90	Don't do more analysis than the data are worth.
RR-91	Not all requirements are created equal
RR-92	Ensure that a process exists for deciding upon and implementing a course of action in response to failures of any nature that are reported.
RR-122	Define how an acceptance criterion is to be certified at the same time the criterion is established
RR-133	Identify the hard parts first and start them early
RR-154	Don't rely on tests or reviews to find all defects, as the number of undetected defects is proportional to those found.
RR-156	The essence of Toyota's "five why's" is to keep asking "why" from effect to cause until the true underlying cause is found
RR-160	The least expensive and most effective place to find and fix a problem is at its source.
RR-163	Clarify expectations for input needed from upstream and add value to provide downstream.
RR-182	In evaluating decision alternatives, recognise the tendency of people to over-estimate benefit and under-estimate risk.
RR-184	The team that created and built a presently successful product is often the best one for its evolution - but seldom for creating its replacement.
RR-188	The architecture of an enabling system must fit that of the system that it supports.
RR-191	Models are an approximation to reality; in modeling, aim to make the model useful.
RR-195	Before proceeding too far, pause and reflect! Cool off periodically and seek an independent review
RR-205	If being absolute is impossible in estimating some property of a system, then estimating relative to some other system may help.
S29	Most mistakes are made on the first day.
SJ M2	Design the system to minimize common-mode failures.
SJ M4	To avoid single-point failures, design the system so that critical elements, both physical and informatical, are redundant.
SJ S2	A resilient architecture can be used to allow a gradual reduction in capability when such an effect is preferable to losing total functionality.
SJ S5	A partially damaged system upon encountering an adversity should still be capable of functioning at the next level of degraded capability by design

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SJ1a	Flexible and dynamically adaptable systems should be designed using reconfigurable architectures.
SJ3ab	Design mission-critical systems with functional redundancy
SJ9	The system shall allow the human operator to be in command in order to overcome possibly critical unforeseeable design flaws.
SJ11	The human operator(s) must be informed of the status of the system.
SJ12	The system operator must be informed about automated systems behaviour, so the human knows what to expect, and how to use the system.
SJ14a	Whenever decisions are made, the possible harm due to the consequences of those decisions should be identified.
SJ15	Capabilities should be automated only when there is a good reason for doing so.
SJ15a	Employ an organizational and managerial structure that encourages cooperation between engineering disciplines.
SJ17	To be resilient a system should be reconfigurable.

Details for Nominated Cluster Names

Cluster 1

Term	Occurrences
problem	13
v and v	11
expertise	7
se principles	7
process	6
effectiveness	5
project	5
solution	5
systems engineering	4
clarity	3
culture	3
tools	3
creativity	2
efficiency	2
iteration	2
simplicity	2
solution development	2

Cluster Name	Rationale for Cluster Name
Problem solving abilities	Problem solving abilities include effective processes like SE and proper enablers like culture and specific competencies like creativity
General SE	In some respects, this seems like the least clear cluster. My sense is that this has gathered terms that relate to general issues, issues not tied to specific phases or problem types, or issues that arise almost all of the time (like understanding what "the problem" is.
SE Principles or SE Heuristics Categories	Unsure why these are considered a cluster. Each word perhaps is a cluster? Words used indicate cross-lifecycle, some skills, disparate what is done in SE, I don't see a consistent pattern or reason for these somewhat random SE generalizations, unless each word is a cluster.
state the problem	None given
Begin with the end in mind	When I start addressing a problem I assess context and culture of both the system of interest and the system that will produce and maintain the system. This requires assessing process, effectiveness, culture, tools, etc. to understand what solution best fits and develop the project plans based se principles and solution development. The efficacy, creativity, and simplicity of the solution will depend on the clarity of the problem and how the solution will be accepted through validation. For industry any solution that hits the market quickly may be the predominant criteria and iteration is the name of the game even after it enters the market. For high consequence systems there is a lengthy v and v process.
Common SysE terms and related issues	Systems Engineering uses a number of terms to identify elements and aspects of the work done in engineering systems, and has identified several factors important to the success of this work.
Systems approach	Words are in the same cluster because they reflect the many different aspects of the systems approach addressed in the heuristics. My name makes sense because it is the official purpose of INCOSE.

Cluster 2

Term	Occurrences
initial stage	8
architecture	7
assumptions	5
product	5
cost	4
flexibility	4
collaboration	3
commitment	3
context	3
feasibility	3
ownership	3
interface	2
performance	2
schedule	2

Cluster Name	Rationale for Cluster Name
System Characteristics	System characteristics include terms like architecture, assumptions, flexibility, collaboration, and more
"Systems architecting" or "Concept exploration"	This appears to be a cluster related to the issues encountered at the beginning of an effort. At this earliest phase assumptions have to be clarified (or changed), cost outlined, collaboration and commitment determined. "Initial" is directly suggested, and "architecture" is commonly associated with this phase.
Initial Lifecycle Stage	During the initial stages of the life cycle, assumptions, commitment, collaboration, and initial schedule are created with architecture concepts in mind. Then feasibility studies occur, performance measures are indicated, but performance occurs throughout. Devils in the details.
incipient design	None given
The system of interest is highly dependent on the development syste m.	The initial stage of development will likely lock in long-term costs, performance, schedule and major interfaces. It will determine the cost of ownership. An architecture and architectural concepts determine the flexibility, feasibility, and characteristics of the solution.
Considerations in SysE	Effective Systems Engineering requires a combination of factors, and attention to these factors increases the likelihood of success in systems engineering endeavors.
Systems approach	Words are in the same cluster because they reflect the many different aspects of the systems approach addressed in the heuristics. My name makes sense because it is the official purpose of INCOSE.

Cluster 3

Term	Occurrences
modeling	23
reality	6
engineers	5
RAM	5
system environment	5
system analysis	4
acceptance criteria	3
approximation	3
cohesion	3
control	3
coupling	2
data	2
interaction	2

Cluster Name	Rationale for Cluster Name
modeling and its application	Modeling is applied for demonstrating the reality, viewed by the engineers as the new language for system analysis and more
System Modeling, or "Modeling systems," or even Model Based Systems Engineering (MBSE)	Pretty obvious, since modeling is so strong at the top. The other elements, like reality (do the models correspond to reality?), engineering connection, analysis are commonly associated with modeling considerations.
Interaction modelling	All of these clusters lack context. I am unable to answer yes/know/maybe, to insight and confusion question. CONFUSION of what this survey is, reigns. Clustering by common word patterns isn't my preferred way to cluster.
model the system	None given
Modeling throughout development approximates reality	Modeling is critical to understanding architecture, performance, and eventual system environments as well as RAM. The degree to which a solid architecture is understood, including cohesion, coupling, control, interaction, data, and environmental limits is the degree that it reflects reality. Collecting data in environments reflective of reality is important to the system analysis process.
Design characteristics and influences	Characteristics of a design, and how it is represented, can make a significant difference in the ability of stakeholders to agree whether a design is appropriate.
Systems approach	Accepted INCOSE terminology

Cluster 4

Term	Occurrences
understanding	8
complexity	6
engineering	6
managerial structure	4
objective	3
ontology	3
time	3
avoidance	2
boundary	2
complicatedness	2
criteria	2
term	2
threat	2

Cluster Name	Rationale for Cluster Name
Ontologies of a system	System ontologies may include complexity, managerial structure, complicatedness and more
Complexity or system complexity	This one is unclear, but the link is probably associated with understanding complex systems and environments, unwinding complexity and complication, and related considerations.
model the system	None given
The soft stuff is the hard stuff	Establishing a shared understanding for a problem, potential solutions, and complexity of solution development is critical. It is dependent on managerial structure, shared ontology, clear objectives, engineering participation, and make or break criteria. Taking time to establish the shared understanding is never enough, but the degree to which everyone is shooting at the same target will determine the acceptability of a solution and limit the threat of cancelation or failure of the solution.
Difficulties of Systems Engineeri ng	There are a number of issues which make understanding problems and systems more challenging.
Systems approach	Accepted terminology

Cluster 5

Term	Occurrences
beneficiaries	16
value	11
person	9
attribute	7
alternatives	5
teams	5
trade offs	4
capability	3
functionality	3
better solution	2
reason	2
system concept	2
weight	2

Cluster Name	Rationale for Cluster Name
system beneficiaries	system beneficiaries include person and teams whom the system is serving
Stakeholder Analysis or Value Analysis	There is general acceptance of the idea that an essential SE elements is understanding how a system delivers value (hence "beneficiaries"), finding attributes and capabilities that delivery value, and making tradeoffs in the service of better delivering value. There is a connected set of considerations in doing this. I find it curious that "requirements" does not show up in this cluster at all.
tradeoff study	None given
There are always trades	In the solution concept stage all alternatives must be considered and weighed based on beneficiaries and value rather than simply technology. Sometimes a better solution is not important when the weight of what's important to the beneficiaries is considered fully. Being an honest broker of trade offs require reason as well as emotional distance from personal preference for functionality or attributes of a solution.
Influences on choices	There are many different influences on systems engineering choices, and it helps to explicitly recognize what all of these are likely to be.
Systems approach	Accepted terminology

Cluster 6

Term	Occurrences
system design	10
development strategy	7
failure	6
evolutionary	4
methodology	4
methods	4
root cause	4
success	3
analogy	2
architect	2
input	2
new system	2

Cluster Name	Rationale for Cluster Name
System Design and its characteristics	System design is a systematic approach and process with the mentioned characteristics
System Design	System Design is the primary term. The other terms are commonly associated with design processes and considerations.
design the system	None given
Precedence	A system can be unprecedented (in function or scale), or it can represent an evolution from a previous system. Understanding the precedents for a system can improve the likelihood of system development success.
Systems approach	Accepted terminology

Cluster 7

Term	Occurrences
requirements	9
risk	9
good solution	4
need	4
plan	4
development	3
ensure	3
progress	3
completeness	2
independence	2
insight	2

Cluster Name	Rationale for Cluster Name
requirements and risks and their potential applications	This is possible list of related terms for requirements & risks
Requirements	This is a weakly connected group, as I see it. It's distinctiveness from the Value cluster is very unclear.
discover requirements	None given
Understanding	A system design and the plan for its development and implementation is much more likely to success if these relevant factors are taken into account.
Systems approach	Accepted terminology

Cluster 8

Term	Occurrences
system	39
decision	13
uncertainty	7
criticality	5
information	4
victims	4
behavior	3
system operator	3
view	3
consequence	2

Cluster Name	Rationale for Cluster Name
system with related terms	In order to describe a system you may apply part of these terms
Decision Analysis	Decision analysis in the context of SE decision making is a well-established part of SE, and has a well-connected set of concepts and considerations. Many of them appear on the list.
define the system	None given
Humans and Systems	Human thinking underpins many of the choices and impacts on system design, development, and usage.
Systems approach	Accepted terminology

Cluster 9

Term	Occurrences
defect	5
balance	4
difficulty	3
number	3
precision	3
use	3
accuracy	2

Cluster Name	Rationale for Cluster Name
characteristics	It may serve as a list of characteristics of a product/process/system,
Failure Analysis or System Assessme nt	This grouping seems very weakly connected. Failure analysis perhaps, but failure does not appear. Nor does test.
defect detection	None given
Tradeoffs	Clarity in understanding both needs and choices is critical in systems engineering.
Systems approach	Accepted terminology

Cluster 10

Term	Occurrences
change	6
technology	2

Cluster Name	Rationale for Cluster Name
The change of technology	We are in the era of fast change of technology
Technology Forecast ing or Technical Change Analysis	Probably the connecting idea here is the need to understand how technology is changing and its impact on the system of interest. Confusingly, terms like "impact," and "value" do not appear at all.
monitor the marketplace	None given
Change	Envisioning change is very important in designing and implementing a system with a long expected life.
Systems approach	Accepted terminology

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