A Few Words First

Courtesy – Please mute your phone (*6 toggle).

Upcoming Chapter Meetings:

- **Jul 6, Summer Social, Chama River Brewing Company,**
  Robert Taylor will give a virtual tour of Friedman Recycling
  Free registration is open (and necessary) – see Chapter website events, or go direct:
  www.eventbrite.com/e/going-green-saves-the-planet-tickets-34954866948
- **Aug 9, Agile Systems and Processes 106 – Risk Management and Mitigation**
  Rick Dove, Paradigm Shift International
- **Sep 13, Beyond Biomimicry to Systems Mimicry**
  Len Troncale, Professor Emeritus California State Polytechnic University

Aug 21-25, International Systems Safety Conference, Albuquerque, NM
http://issc2017.system-safety.org

Oct 06-07, 2017 Socorro Systems Summit at NM Tech.

CSEP Courses by *Certification Training International:*
Course details | Course brochure
2017 Course Schedule (close by, but many more locations and dates):
Oct 30-Nov 3 | Las Vegas, NV
Feb 26-Mar 2 | Las Vegas, NV
Apr 02-Apr 5 | Denver

First slide, not recorded but retained in pdf presentation.

And Now - Introductions

Enchantment Chapter Monthly Meeting

14 June 2017 – 4:45-6:00 pm:

Defining "System" – a Comprehensive Approach

Regina Griego, Sandia National Labs, Distinguished R&D Systems Engineer, griegor@sandia.gov

Abstract: Over the past decades, a common definition of the term system has eluded researchers and practitioners alike. We reviewed over 100 current and historical definitions of system in an effort to understand perspectives and to propose the most comprehensive definition of this term. There is much common ground in different families of definition of system, but there are also important and significant differences. Some stem from different belief systems and worldviews, while others are due to a pragmatic desire to establish a clear definition for system within a particular community, disregarding wider considerations. In either case, it limits the effectiveness of various system communities' efforts to communicate, collaborate, and learn from the experience of other communities. We discovered that by considering a wide typology of systems, Bertalanffy's General Systems Theory provides a basis for a general, self-consistent sensible framework, capable of accommodating and showing the relationships amongst the variety of different definitions of and belief systems pertaining to system. Emergence, the appearance of a new phenomenon or capability as a result of relation or interaction between objects, is key in differentiating between objects that are systems and those that are not. Hence we propose a family of definitions, related by the common theme of emergence, which is in line with both the realist and constructivist worldviews and covers real and conceptual systems, which we believe can impact the scope of systems engineering and support the aspirations expressed in INCOSE SE Vision 2025.

Download slides today-only from GlobalMeetSeven file library or
anytime from the Library at www.incose.org/enchantment

NOTE: This meeting will be recorded

Today’s Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Speaker Bio

Regina M. Griego, Ph.D. is a Distinguished R&D Systems Engineer at Sandia National Laboratories working on systems strategy.

She has over 30 years of experience leading multi-agency and multidisciplinary teams in various domains to deliver systems and developing organizational capability.

She is a teacher, mentor, and coach and recognized for her research and ability to elicit a common conceptual basis for realizing solutions.

Regina is an INCOSE Fellow, past INCOSE Technical Director, and the Enchantment Chapter Founding President.

27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

The INCOSE Fellows Team:
Hillary Sillitto, CEng (**leader**)
Regina Griego, Ph.D.; Dov Dori, Ph.D.; Scott Jackson, Ph.D.; Daniel Krob, Ph.D.;
Patrick Godfrey, DEng; Eileen Arnold; James Martin, Ph.D.; Dorothy McKinney

Defining “System”: a Comprehensive Approach

Presentation Agenda

Background and analysis of existing definitions

You Are Here

Different perspectives and worldviews

Developing an integrative model

Summary and next steps

Charter/ Approach/ Vision

- CHARTER – Dorothy McKinney (Fellows Chair) in May 2016 chartered the team after discussions among Fellows and follow-on discussion with INCOSE President

- APPROACH
  - Review accepted definitions
  - Apply Soft System Methods to analyzing stakeholders and worldviews
  - Propose one or a set of definitions that facilitate communication and engagement

- VISION – A well-conceived definition should enable the following objectives:
  - Communicate the meaning of system more effectively across communities of research and practice to achieve common goals
  - Allow systems engineers to learn and adopt techniques from other communities
  - Improve systems engineering (SE) stakeholder communities' understanding of worldviews associated with different categories of definition of system, relevant to INCOSE's current activities and scope and to the aspirations set out in and implied by Vision 2025 (INCOSE 2014).

Executive summary

- Key Discovery
  - Many valid and different worldviews about systems
  - At least five distinctively different worldviews, within which many shades of nuance, among the 23 Fellows who responded to survey
- Implication
  - No possibility of developing a single, agreed, useful definition of “system”
  - No benefit to INCOSE in doing so
- What we have done so far: looked at
  - Framework: Typology of systems
  - Concepts: Key concepts associated with different types of system
  - Language: 270,000 different ways of saying the same thing?

Current INCOSE definition (SE Hdbk V4)

Excludes:
Naturally occurring systems
Systems including naturally occurring elements
Systems in non deterministic environments
Systems that "emerge" without defined users or prior purpose
Conceptual systems

- *…an integrated set of elements, subsystems and assemblies that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements. (INCOSE)*
- *…combination of interacting elements organized to achieve one or more stated purposes (ISO/IEC/IEEE 15288)*
- *…[these definitions are based on] the fundamental idea that a system is a purposeful whole that consists of interacting parts.*

Context for these definitions:

- *"The systems considered in this handbook are **human-made**, created and utilized to provide products or services **in defined environments** for the benefit of **users and other stakeholders**.*
- *The definitions cited here … refer to systems in the real world.*
- *A system concept should be regarded as a shared "mental representation" of the actual system.*
- *The systems engineer must continually distinguish between systems in the real world and system representations."*

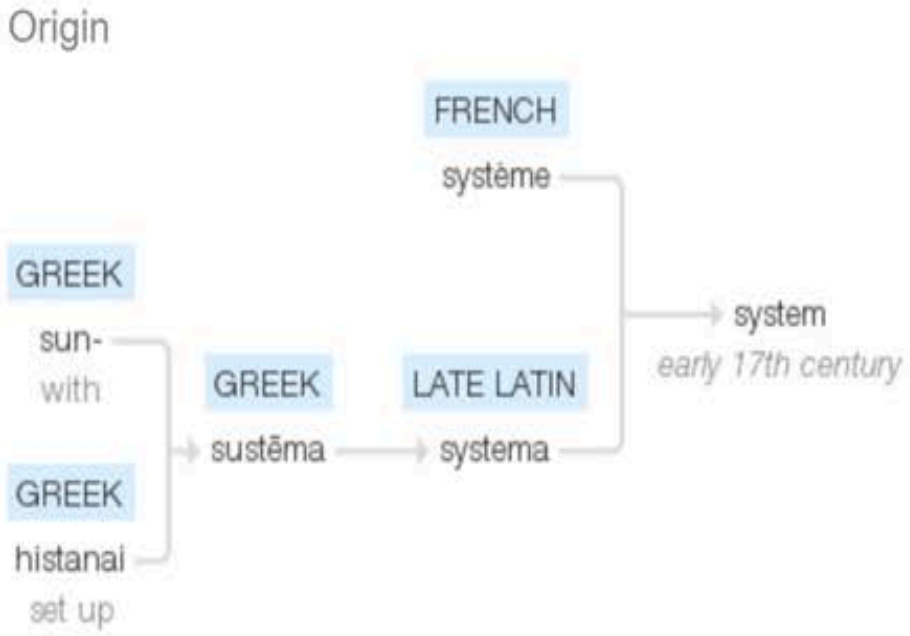
But the SE Vision 2025 suggests we need to address a wider scope

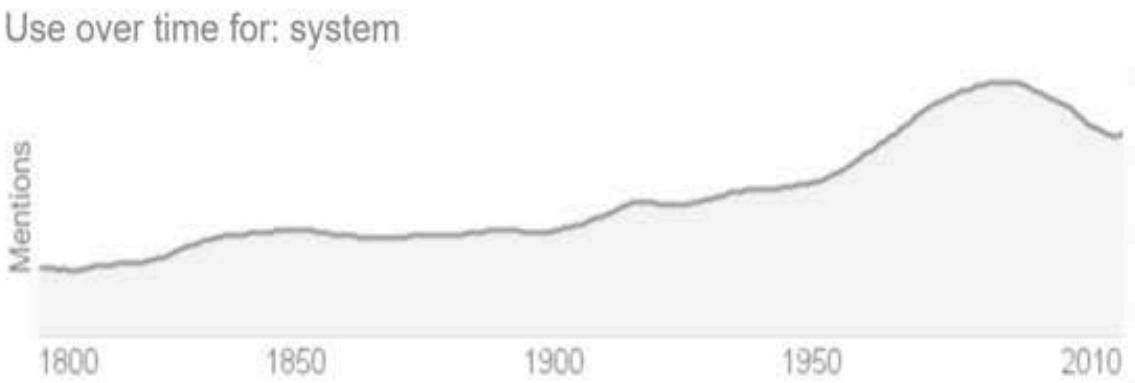
- The wider scope of future systems engineering may include
  - Natural Resource Management Systems
  - Financial and Insurance Systems
  - Ecological Systems
  - Social systems
  - Energy and Transport Systems
  - Agriculture and Food Management Systems
  - Information Systems

- Not all parts of these systems are human-made or human-specified
  - They include, or interact with, naturally occurring systems - which are clearly “systems”
  - Any use of “purpose” in system definition implies restriction to human-made systems

- It is not sufficient design these kinds of systems to work in “a defined environment”. They also need to:
  - Cope with unforeseen events in a non deterministic environment
  - Degrade gracefully and restore service after disruption

System: Origins and Use over Time





- Greek combination of sustēma, from *sun*, meaning *with*, and *histanai*, meaning *set up* or *cause to stand*.
- Together, the resulting semantics of *standing together*, *standing in relation*, or *togetherness* seems to be the essence of the original etymological root.
- In turn, the Greek may come from the Sanskrit *saṃsthāna*, which also means *standing together* (Sanskrit Dictionary, 2016).

Some schools of thought in systems

Reductionism: the practice of analyzing and describing a complex phenomenon in terms of its simple or fundamental constituents

(384–322 B.C.): "the whole is something over and above its parts and not just the sum of them all"

Artistotle

(17th Cent. A.D.): reductionism fostered rapid progress in experimental physics, biology and medicine

Descartes

(1824) Concept of "system" evident in his work on Thermodynamics

Carnot

(1850) Extended Carnot's work, added concept of environment

Clausius

Bertalanffy, 1948

General Systems Theory

Wiener, 1948
Ashby, 1956

Cybernetics

Miller, 1978

Living Systems

Allen, 1986
Holland, 1995
Santa Fe Institute

Complex Adaptive Systems

Gödel, 1931
Turing, 1940s
Shannon, 1948

Theoretical Computer Science

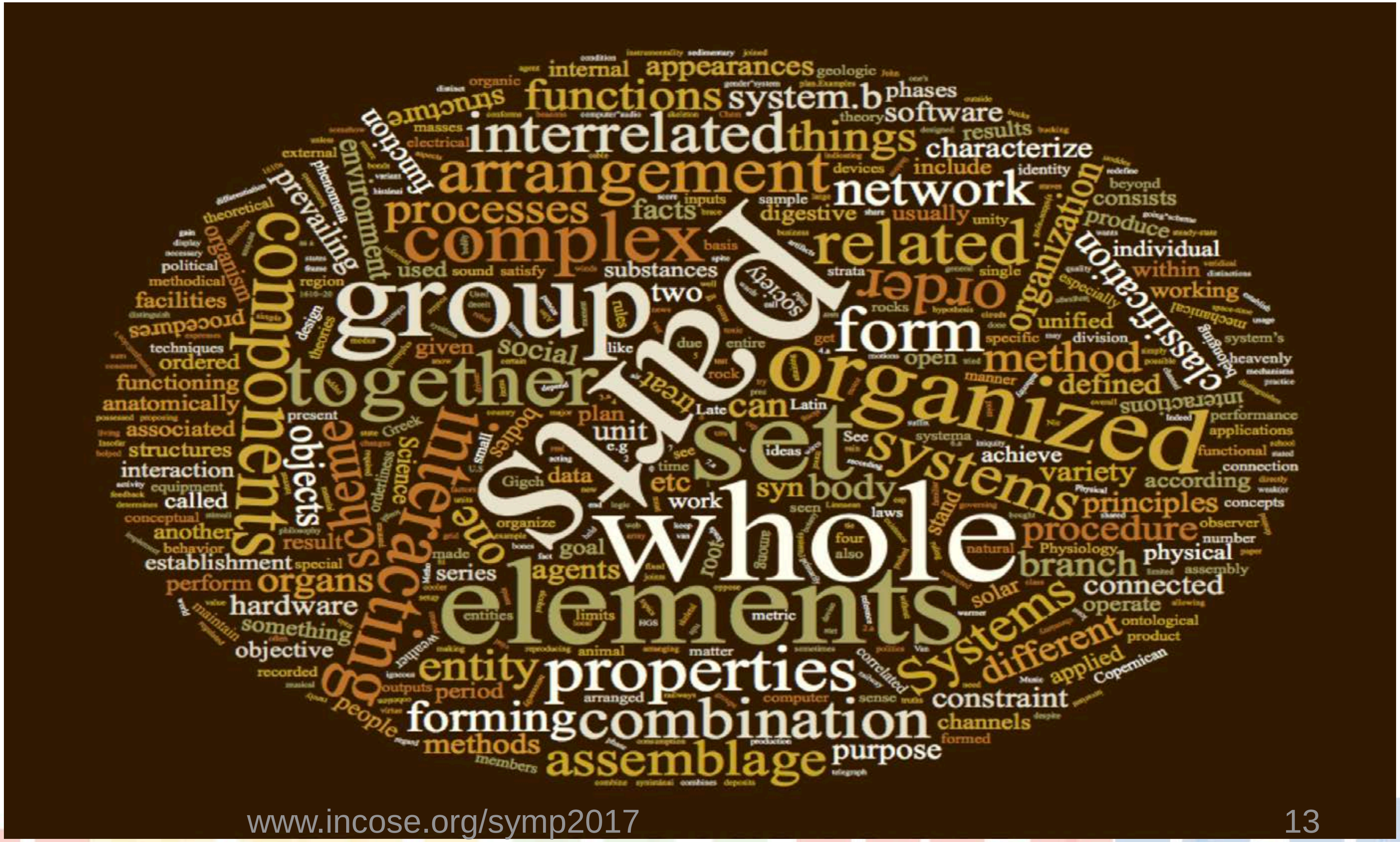
Systems in management

Beer - Viable System Model,
Checkland – soft systems
Senge – systems thinking
Forester – system dynamics

Systems Engineering

100 System Definitions Word Cloud

Compiled from approximately 100 definitions of “system” extracted from the literature.



Some dichotomies

- Systemic versus Systematic
- Artificial versus Natural (and hybrid of the two)
- Real world and corresponding Formal Systems
- Real world versus Mental models/constructs
- Whole versus (/and) Parts
- Structural versus (/and) Behavioral
- Purpose or not
- Fitness for purpose (designed)
- Persistence/resilience (naturally occurring and designed)
- Holistic vs Reductionist
- General vs Domain Specific

Language: so you thought it was simple?!

A system is a

<*set, combination, group, collection, configuration, arrangement, organization, assemblage, assembly, ensemble [10]*>

of

<*parts, components, elements, objects, subsystems, entities [6]*>

<*combined, integrated, organised, configured, arranged [5]*>

in a way that

<*creates, enables, motivates [3]*>

<*properties, functions, processes, capabilities, behaviors, dimensions [6]*>

not

<*possessed, exhibited, presented [3]*>

by the

<*separate, individual, single [3]*>

<*parts, components, elements, objects, subsystems, entities [6]*>.

Presentation Agenda

Background and analysis of existing definitions

Different perspectives and worldviews

You Are Here

Developing an integrative model

Summary and next steps

Five distinct worldviews or belief systems are revealed in the survey responses – just within our community

- Worldview S1: (S = System)
  - A formal minimalist view based on mathematics and logic
- Worldview S2:
  - Constructivist - systems are purely a mental construct
  - We include “system concept as a mode of description” within this category
- Worldview S3:
  - Moderate realist
- Worldview S4:
  - Strong and Extreme Realists
- Worldview S5 –
  - Complex, viable and living systems

Worldview S1: A formal minimalist view based on mathematics and logic

- Roots in theoretical computer science
  - Holds that the way to give a rigorous scientific basis to the concept of system is to define abstractly the concept of a “conceptual” system
  - Then a real system is anything that can be modeled by a conceptual system
- Complex systems built up from basic elements
- Seeks to improve mathematical and scientific tools for systems practice; consistent with an aim of generating real systems from mathematical models
- Focus very much on model based generation of artificial systems
- Implies if we can’t model it, we can’t call it a system
- Limiting case: considers systems to be abstracted systems based on formal models
  - These are then used to generate “artificial real” systems
  - Or, “the system is the model”, and the stuff in the real world is just stuff

Worldview S2: Constructivist - systems are purely a mental construct

- The concept of system is reserved for the conceptual world
- More conventional and less formal constructivist view: ~20% both survey groups
- Most agree that a system
  - Comprises more than one part, with relationships and interactions between the parts
  - Has a boundary - majority consider it to be a free choice of the observer
  - Exhibits emergent properties arising from the relationships and interactions between the parts
- Proponents are divided on whether systems must have a purpose or goal
- Some Conceptual Systems are considered to represent parts of the real world
  - Chose to call these “abstracted systems” – Bertalanffy
  - Abstracted system maps to those parts of the real world that the abstracted system represents
  - NOT IN THIS WORLDVIEW: The real world configurations represented by the abstracted system; considered to be “systems”

Worldview S3: Moderate realist

- The “consensus” holds that systems
  - Can exist as purely mental constructs, or in the real world, or both
  - And exist in both the natural and human-made worlds
- Many adherents do not consider that a boundary is an essential part of a system
  - Some adherents and some of the next category (strong and extreme realists) maintain that the system boundary can always be discovered and refined based on objective criteria
  - Intriguingly, there is no obvious correlation between this belief and the number of characteristics deemed “essential” for an entity to be a system
- A minority (<20%) don't consider emergent properties (as we defined them) to be a defining characteristic of systems

Worldview S4: Strong and Extreme Realists

- Systems only exist in the real world – Fellows'(1) & many SSWG

- No correlation between "systems only exist in the real world" and the attributes deemed necessary for an entity to be considered as a system

Worldview S5: Complex, viable and living systems

- Distinct in the Fellows' survey (10%) and larger but more diffuse in the SSWG responses
  - Complementary to and uncorrelated with Worldviews S2, S3 and S4,
  - Incompatible with the formal mathematics-based Worldview S1.
- Essential and defining attributes of systems include:

"homeostasis", the ability to maintain a condition of equilibrium within its internal environment, even when faced with external changes	***when deployed into their operational environment, systems both change and adapt to their environment***
viability, the ability to survive in a non-benign environment	***have dynamic and integrity limits***
internal communication between parts	***cohesiveness, the ability to or characteristic of clustering as a group***
internal decision-making processes	***the characteristic of being "whole" or "complete"***
resilience, the ability to absorb and recover from major disruption	***systems occur at multiple levels of integration with new properties emerging at each level***
adaptive control using internal feedback	

- By contrast, many other respondents recognized many of these as common but not essential characteristics of systems

Presentation Agenda

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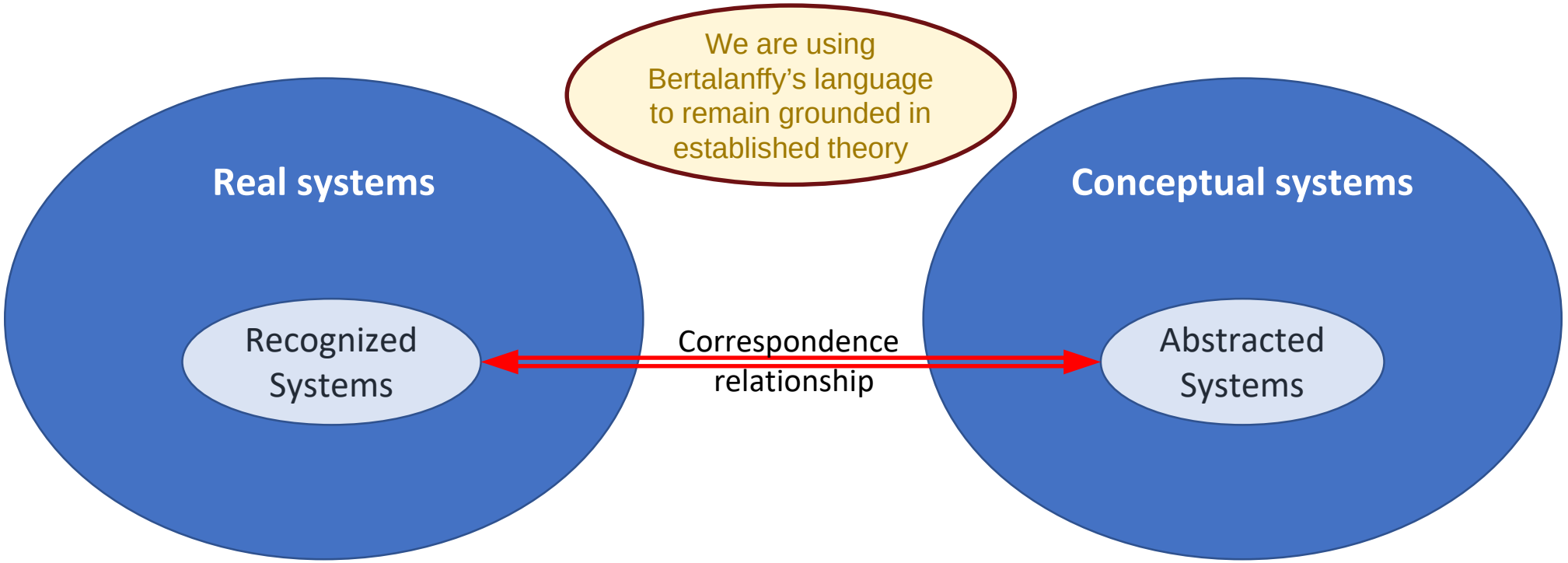
You Are Here

Bertalanffy's categories of "real" and "conceptual" systems form the basis of our conceptual model

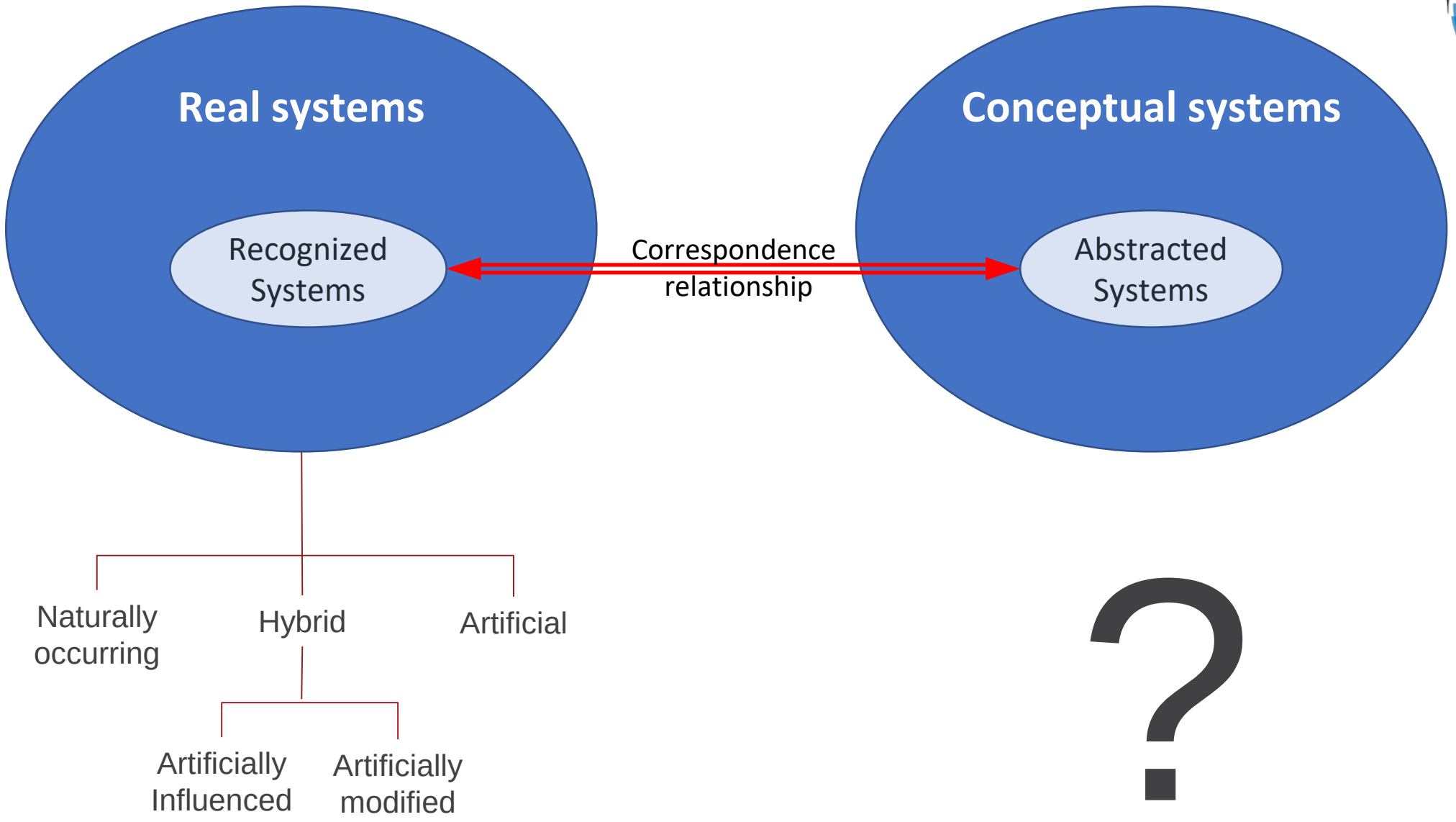


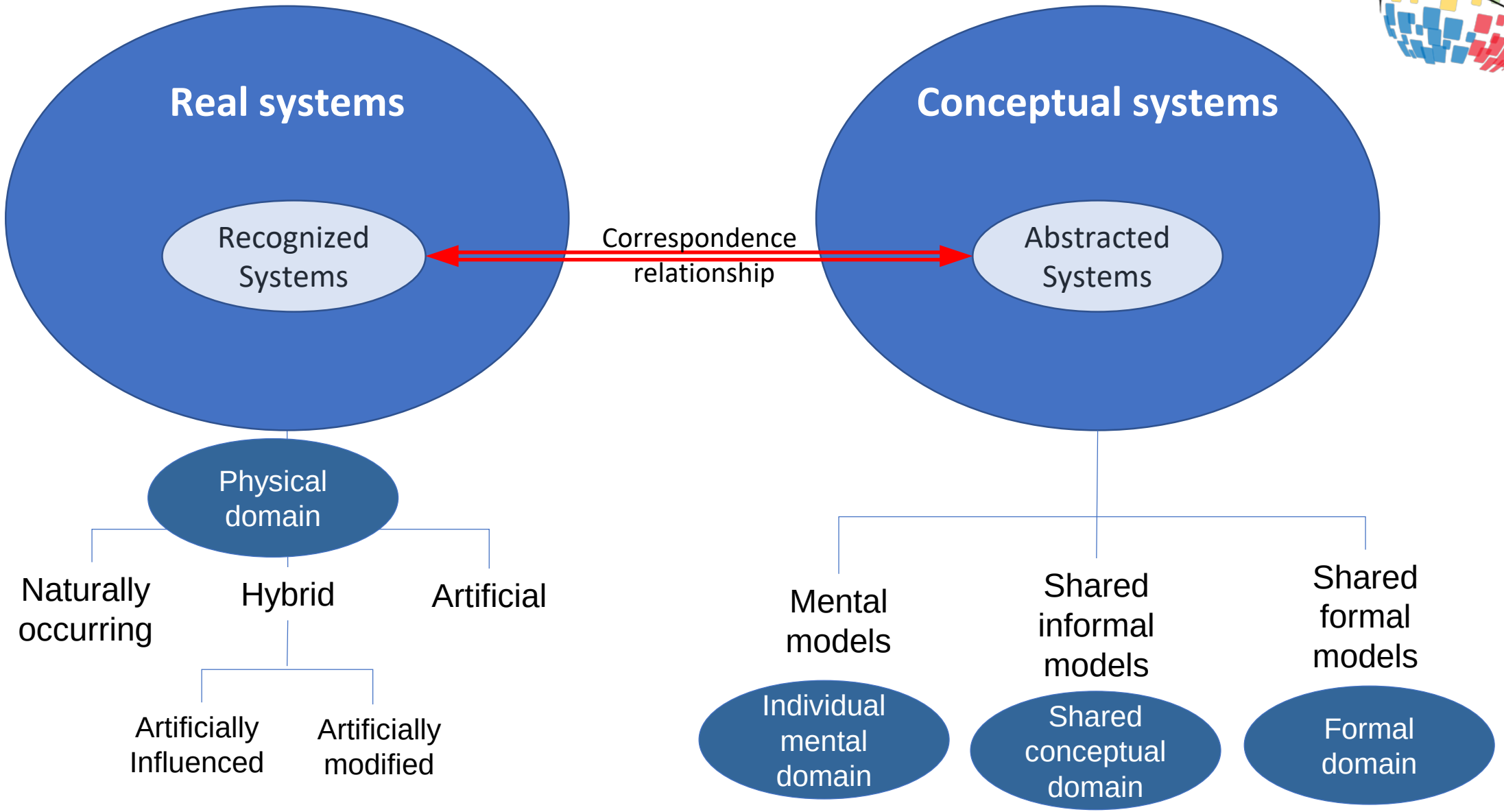
Synonyms for "real" system:

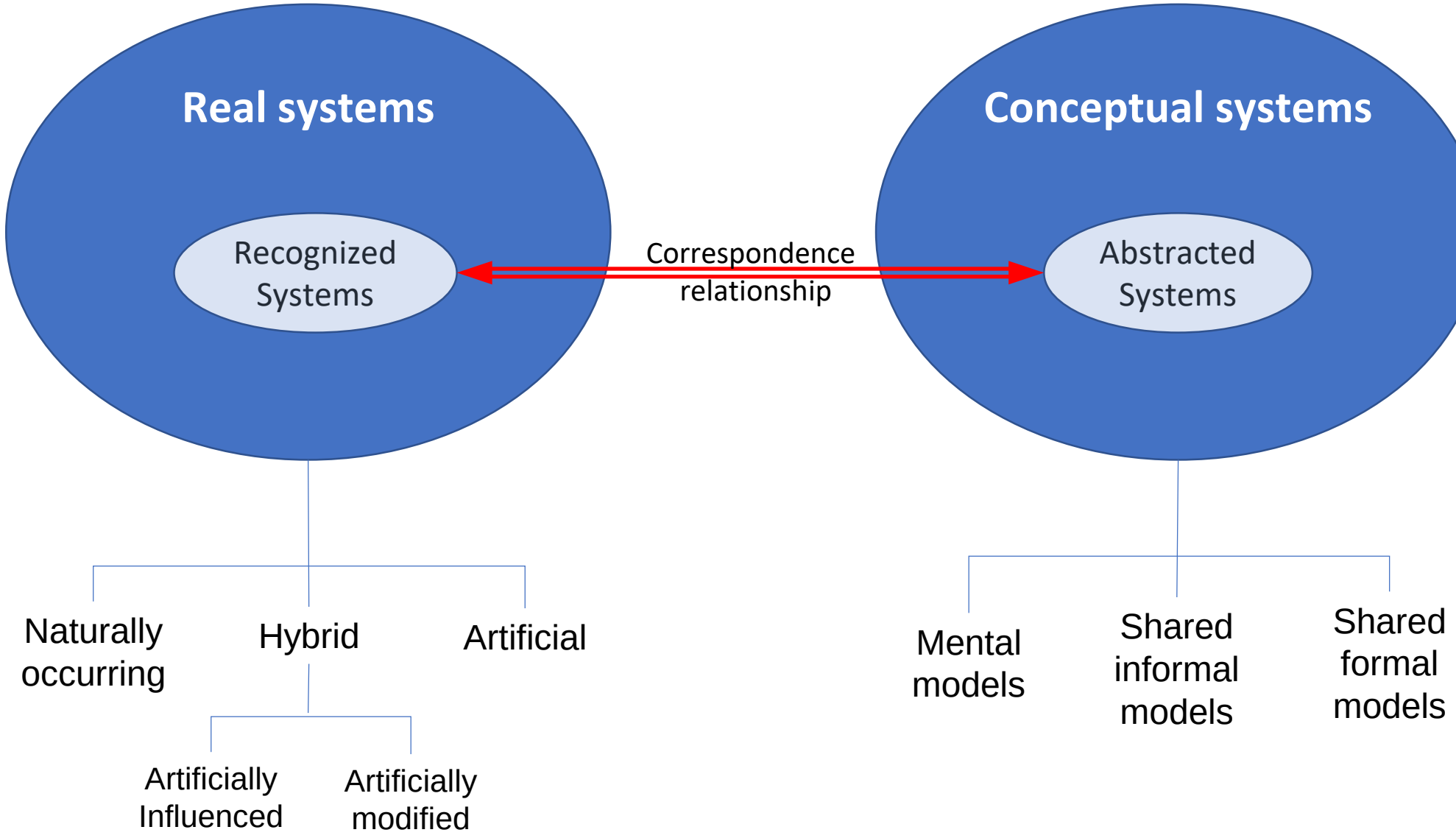
- "physical system"
- "concrete system" (Miller)
- "natural system" (Rosen)

Synonym for "conceptual" system:

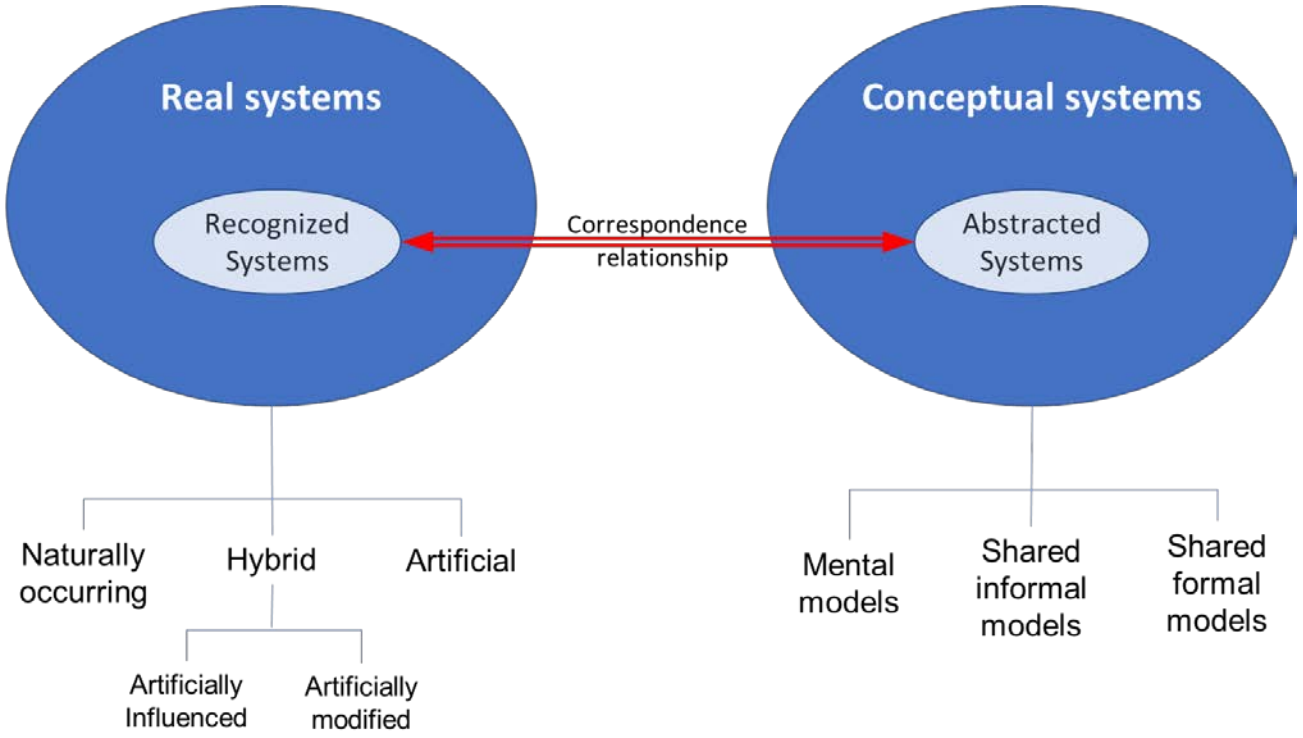
- "abstract system"


Real systems
Recognized Systems
Correspondence relationship
Conceptual systems
Abstracted Systems
Naturally occurring
Hybrid
Artificial
Artificially Influenced
Artificially modified
?


Real systems
Recognized Systems
Correspondence relationship
Conceptual systems
Abstracted Systems
Physical domain
Naturally occurring
Hybrid
Artificial
Artificially Influenced
Artificially modified
Mental models
Shared informal models
Shared formal models
Individual mental domain
Shared conceptual domain
Formal domain


Real systems
Recognized Systems
Correspondence relationship
Conceptual systems
Abstracted Systems
Naturally occurring
Hybrid
Artificial
Artificially Influenced
Artificially modified
Mental models
Shared informal models
Shared formal models

Summary: Proposed Framework for System Definition and Classification

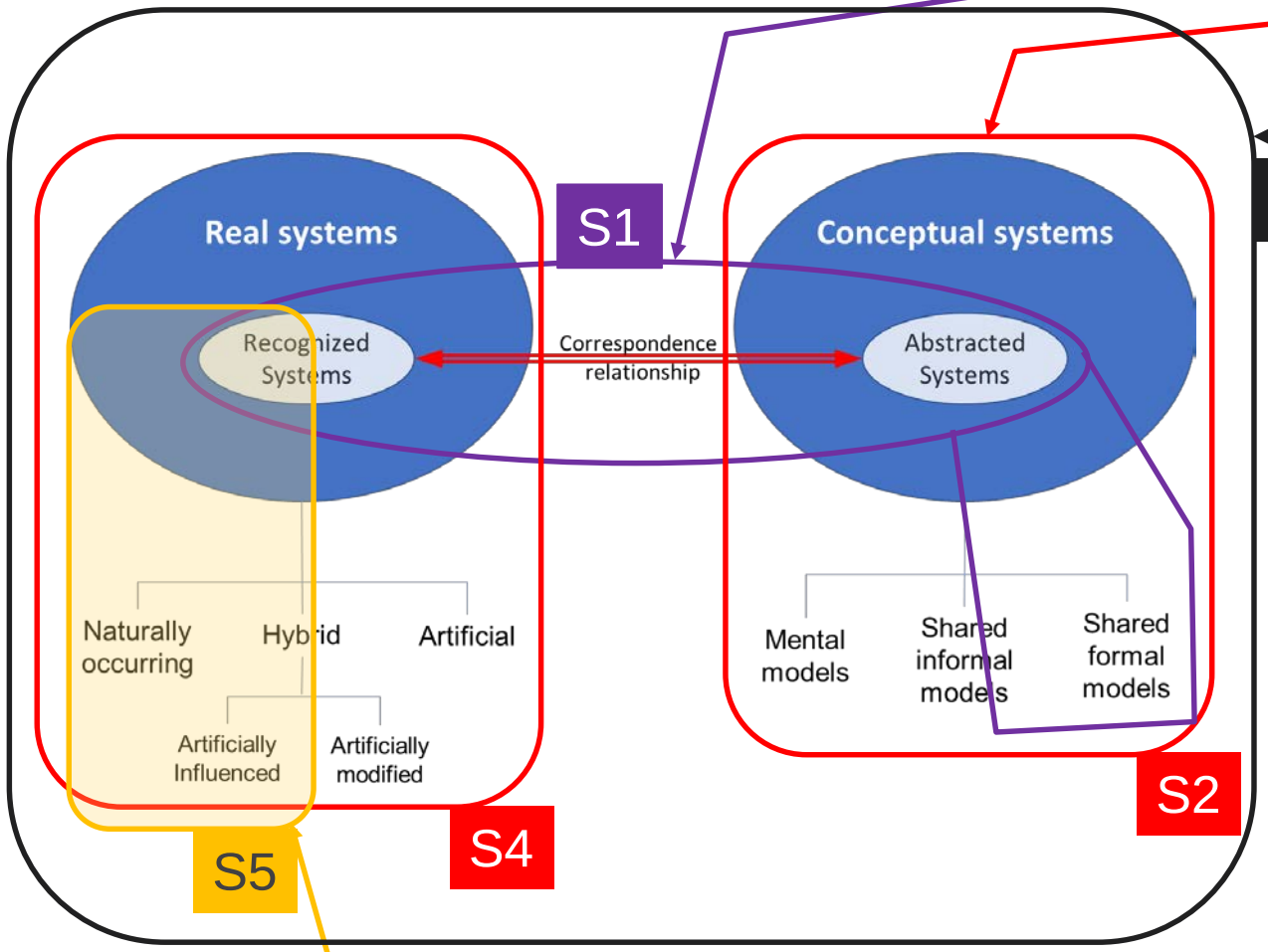


- **Real System** and **Conceptual System** are **Systems.**
- **Real systems** exist in the physical world.
- **Conceptual systems** are the product of human thought.
- **Conceptual Systems** may be: **mental models, informal shared models,** or **formal shared models.**
- **Abstracted Systems** are **conceptual systems** which represent ("are abstractions of", or "are abstracted from") **real systems**.
- **Real Systems** may be **Naturally-occurring, Artificial,** or **Hybrid** (containing both naturally-occurring and artificial elements)**.**
- **Hybrid systems** may be **Artificially Modified** or **Artificially Influenced.**
- **Hybrid Systems** and **Artificial Systems** may be **intended** or **unintended.**
- **Recognised Real Systems** are recognised to exist in the real world.
  - They may be recognised by their **structure**, **function** or **behaviour**.
- **Real Systems can be characterised by their internal capacity for communication, decision making, and adaptive control.**
- **Real Systems that share the characteristics of "viable systems" and "living Systems" exhibit homeostasis, resilience and ability to cope with unforeseen circumstances.**
- **Information systems are conceptual systems hosted in real systems.**

NB: Most belief systems only recognise some of these system types as valid.

We believe future SE practice needs to use a framework that includes all of them, and that practitioners will be more effective if willing to at least "suspend disbelief" about the elements they don't agree with!

Mapping of Worldviews to Conceptual Model



Five (possibly six) distinct worldviews or belief systems are revealed in the survey responses – just within our community

- Worldview S1: (S = System)
  - A formal minimalist view based on mathematics and logic
- Worldview S2:
  - Constructivist - systems are purely a mental construct
  - For now, we include "system concept as a mode of description" within this category
- Worldview S3:
  - Moderate realist
- Worldview S4:
  - Strong and Extreme Realists
- Worldview S5 –
  - Complex, viable and living systems

SO WHAT? We believe:

This conceptual model encompasses (more or less adequately) all belief systems and worldviews revealed by the Fellows' and SSWG surveys and discovered by literature review.

This conceptual model also spans all Systems Engineering activities we can imagine based on the SE 2025 vision.

It is grounded in widely recognised prior research and should therefore be acceptable across the range of systems communities.

A single definition encompassing all types of system in the conceptual model is possible, but may be too vague to be useful.

A family of definitions aligned to this conceptual model is possible and has the potential to be useful.

The best way of expressing these definitions is almost certainly natural language and will be contentious

Presentation Agenda

Background and analysis of existing definitions

Different perspectives and worldviews

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Summary and next steps

You Are Here

Summary and next steps

We Propose

- A robust framework of system types
  - Accommodates all identified definitions and worldviews
  - Covers scope of SE 2025 Vision
- Definitions for these types
  - Core definition is based on belief that “emergence” is the primary identifying characteristic of Systems
  - Use the word “emergence” or a longer explanation
  - Finding a choice of words that avoids triggering unintended reactions from any important stakeholders
  - Don’t lose sight of the practitioners who just want to “get on with the day job”

Next Steps

- Wrap up this work
- Agreeing that the set of definitions is still unfinished business
- Move on to review definition of Systems Engineering (SE)

FINDINGS:

- INCOSE definition of System is too narrow to cover scope of SE 2025 vision
- Wide variation of belief systems among Fellows and SSWG members
  5 fundamentally different categories of worldview identified and
  Many flavors and subtypes within each worldview category

Back-up material

WHAT THE TEAM THOUGHT:

Different members had a different intuitive feel for what they believed to be the threshold for “a proper system”.

- “The notion of emergence has to involve the creation of new property dimensions or attributes, not merely a different value of the same attribute.”
- “I regard a nutcracker or a hammer as a tool, a fridge and a plane as technical systems, whereas Hitchins holds that even the plane only becomes a system when the pilot steps in.
- “Every tool is a system.” [Which elicited disagreement, including this response:] “The nut cracker (and a hammer) cannot credibly or usefully be considered a system. It is merely a tool that in its normal embodiment has several parts. It can do nothing and has no intelligence or decision-making process independent of the operator.”
- “The refrigerator, once provided with power, can exercise internal decision processes, control, and state behaviour, so is qualitatively different from a nutcracker, or a hammer.”
- “So the level of control and internal decision processes makes the difference? If so, is a refrigerator a system but a cooling box supplied with ice not a system?”

Why don't we agree – different Worldviews: e.g. Constructivism vs. Scientific Realism (from David Rousseau)

- Constructivists maintain that a system is purely a mental construct
  - Social Constructivists – maintain that we cannot know the truth about anything, and hence whether there are mind-independent truths, because of our cultural conditioning
  - Philosophical Idealists – view that consciousness is the ultimate reality
  - Postmodernists – maintain that there are no absolutes, everything is relative and contingent

- Metaphysicians of science subscribe to Scientific Realism, having three commitments:
  - The world has a definite and mind-independent structure
  - Scientific theories are true or not because of the way the world is
  - Our best scientific theories are approximately true of the world

- Scientific Realists can be
  - Atomists – think that only fundamental particles are really "things"
  - Priority Monists – think that only one thing exists: the whole universe
  - Compositional Pluralists – think that parts can make up new kinds of things with new properties

Survey of system characteristics: Fellows' (26) and SSWG (33) ranked

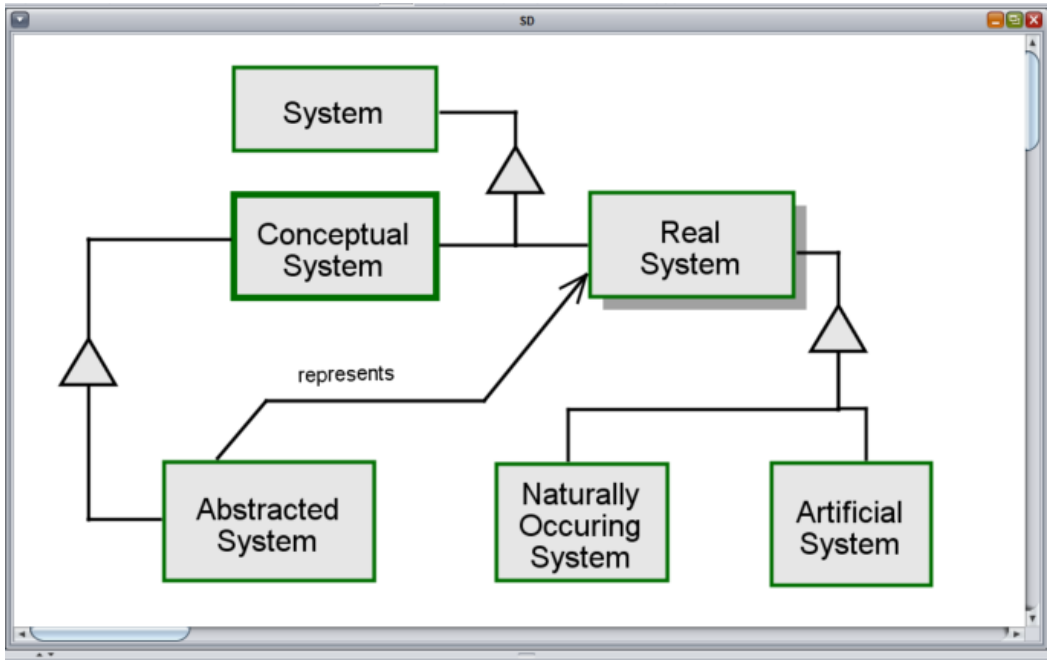
more than one part or element	24
relationships between the parts	24
interactions between the parts	22
"emergent properties", properties of the whole system not possessed by the individual parts	22
a boundary (physical or logical) separating the system from its environment	18
internal communication between parts	11
when deployed into their operational environment, systems both change and adapt	10
a defined "purpose" or "goal"	7
"homeostasis", the ability to maintain a condition of equilibrium within its internal environment, even when faced with external	6
viability, the ability to survive in a non-benign environment	6
adaptive control using internal feedback	5
resilience, the ability to absorb and recover from major disruption	4
internal decision making processes	3

relationships between the parts	29
interactions between the parts	28
more than one part	27
"emergent properties", properties of the whole system not possessed by the individual parts acting separately	27
a boundary separating or distinguishing the system from its environment	24
systems occur at multiple levels of integration with new properties emerging at each level	22
internal communication between parts	19
input / output behavior	19
have dynamic and integrity limits	16
The characteristic of being "whole" or "complete"	16
"homeostasis", the ability to maintain a condition of equilibrium within its internal environment, even when faced with external changes	15
adaptive control using internal feedback	14
internal decision making processes	13
cohesiveness, the ability to or characteristic of clustering as a group	13
when deployed into their operational environment, systems both change and adapt to their environment	12
a defined "purpose" or "goal"	10
viability, the ability to survive in a non-benign environment	10
resilience, the ability to absorb and recover from major disruption	10

Some choices were not offered in Fellows' questionnaire:

Roughly 1/3 of you do NOT think that boundary is a defining attribute of a system

OPM Model of System based on Bertalanffy's framework



Artificial System is a Real System.
Conceptual System is a System.
Real System is physical.
Real System is a System.
Naturally Occuring System is a Real System.
Abstracted System is a Conceptual System.
Abstracted System represents Real System.

In summary:

- **Real System** and **Conceptual System** are **Systems**;
  - **real systems** may be **naturally occurring** or **artificial** (man-made);
  - **abstracted systems** are **conceptual systems** which are intended to represent **real systems**.

- We see that specialization into two kinds of systems at the highest level is not between natural and artificial systems, as one might be tempted to think, but between real and conceptual ones.

Worldview S1: A formal minimalist view based on mathematics and logic

- Roots in theoretical computer science
  - Holds that the way to give a rigorous scientific basis to the concept of system is to define abstractly the concept of a “conceptual” system
  - Then a real system is anything that can be modeled by a conceptual system
- Complex systems built up from basic elements
- Seeks to improve mathematical and scientific tools for systems practice; consistent with an aim of generating real systems from mathematical models
- Focus very much on model based generation of artificial systems
- Implies if we can’t model it, we can’t call it a system
- Limiting case: considers systems to be abstracted systems based on formal models
  - These are then used to generate “artificial real” systems
  - Or, “the system is the model”, and the stuff in the real world is just stuff

Complex properties can be developed from even a minimalist definition, such as

Bertalanffy’s description of a system as an entity that can be mathematically modelled as a dynamical system

Wolfram’s Cellular Automata, which create complex emergent behaviour from simple interaction rules

Worldview S2: Constructivist - systems are purely a mental construct

- The concept of system is reserved for the conceptual world
- More conventional and less formal constructivist view: ~20% both survey groups
- Most agree that a system
  - Comprises more than one part, with relationships and interactions between the parts
  - Has a boundary - majority consider it to be a free choice of the observer
  - Exhibits emergent properties arising from the relationships and interactions between the parts
- Proponents are divided on whether systems must have a purpose or goal
- Some Conceptual Systems are considered to represent parts of the real world
  - Chose to call these “abstracted systems” – Bertalanffy
  - Abstracted system maps to those parts of the real world that the abstracted system represents
  - NOT IN THIS WORLDVIEW: The real world configurations represented by the abstracted system; considered to be “systems”

Hybertson (2009) articulates this distinction very clearly.

He describes the ensemble of relevant parts of the real world as “the mosaic”.

He defines systems in terms of a model of parts of the mosaic considered relevant to the purpose or of interest to the observer.

Consistent with Checkland’s (1981) view of Human Activity Systems which he describes as a notional system which expresses some purposeful human activity.

The systems are notional in the sense that they are intellectual constructs and not descriptions of actual real-world activity.

Worldview S3: Moderate realist

- The “consensus” holds that systems
  - Can exist as purely mental constructs, or in the real world, or both
  - And exist in both the natural and human-made worlds
- Many adherents do not consider that a boundary is an essential part of a system
  - Some adherents and some of the next category (strong and extreme realists) maintain that the system boundary can always be discovered and refined based on objective criteria
  - Intriguingly, there is no obvious correlation between this belief and the number of characteristics deemed “essential” for an entity to be a system
- A minority (<20%) don't consider emergent properties (as we defined them) to be a defining characteristic of systems

Rousseau et al (2016) suggest this worldview *(or one where we act as if this worldview applies)* seems to be the most appropriate for the practice of systems engineering

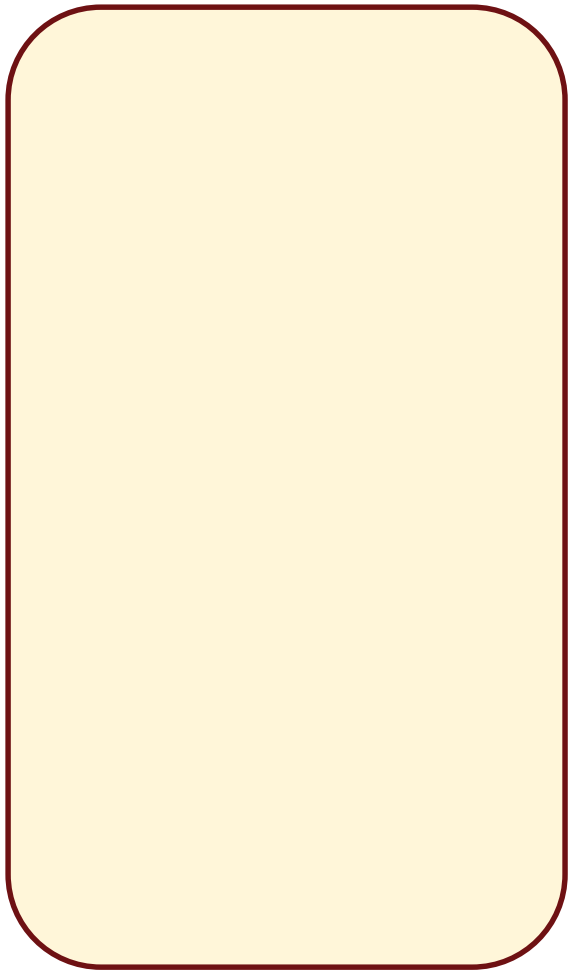
Reflected by the large majority of responses from the INCOSE Fellows that espouse some variant of this worldview

Within that group there are significant variations in the number of subsidiary characteristics that are considered “essential” aspects of being a system

Worldview S4: Strong and Extreme Realists

- Systems only exist in the real world – Fellows'(1) & many SSWG

- No correlation between "systems only exist in the real world" and the attributes deemed necessary for an entity to be considered as a system



Worldview S5: Complex, viable and living systems

- Distinct in the Fellows' survey (10%) and larger but more diffuse in the SSWG responses
  - Complementary to and uncorrelated with Worldviews S2, S3 and S4,
  - Incompatible with the formal mathematics-based Worldview S1.
- Essential and defining attributes of systems include:

"homeostasis", the ability to maintain a condition of equilibrium within its internal environment, even when faced with external changes	***when deployed into their operational environment, systems both change and adapt to their environment***
viability, the ability to survive in a non-benign environment	***have dynamic and integrity limits***
internal communication between parts	***cohesiveness, the ability to or characteristic of clustering as a group***
internal decision-making processes	***the characteristic of being "whole" or "complete"***
resilience, the ability to absorb and recover from major disruption	***systems occur at multiple levels of integration with new properties emerging at each level***
adaptive control using internal feedback	

- By contrast, many other respondents recognized many of these as common but not essential characteristics of systems

Described by Miller (1978), and "viable" organisational systems as described by Beer (1972).

This group includes, and may be limited to, those who are mainly interested in viable autonomous systems capable of reproducing themselves, such as "living" biological systems.

Many of these attributes (though not the ability to reproduce themselves!) are increasingly being expected of engineered systems.

Attempts to answer: *"What is a system?"*

	Draft Definition	Examples
All systems	A complex whole whose properties are due to the relationships between its constituent parts as well as to the parts themselves. Or: A collection of possibly interacting, related components that exhibits	

Or - A group of parts combined in a way that creates one or more emergent property or capability not possessed by the separate parts…

(Or – "that which is fit for purpose"...)
(or - "parts in Relation"…)

Key issues :

1. Start from the whole or the parts?
2. Is it "group", or "collection", or "set", or….?
3. Describe in terms of properties, and/or effects, and/or of composition…?
4. Use the term "emergence", or use a longer form of words that "spells it out"?

Emergence

	Draft Definition	Examples
Emergent property	A property of a whole that "emerges" from the relationships and interactions between the parts, that applies to the whole and not to the parts.	
Real Systems	Two or more elements interacting in physical space-time to create properties and effects not achievable by the elements in isolation.	Plane, planet, solar system, universe, atom, climate system, weather, flock of geese, bridge over an estuary, cat, herd of wildebeest, bacterium, mammal's cardiovascular system, ant colony…
Conceptual systems	Two or more related informatic elements which taken together have meaning not conveyed by the individual elements.	Relationships between letters to form words. Relationships between equations to form a mathematical model. Relationships between lines of code to form a computer programme. Relationship between elements of belief to form a belief system (religion, political philosophy, etc). - A model of a real system!!!

Emergence of effects due to interactions

Emergence of meaning due to relationships

System Type	Draft Definition	Examples
System	a group of parts combined in a way that creates one or more emergent property or capability not possessed by the separate parts	Everything listed below
Real System	two or more elements interacting in physical space-time to create emergent properties, capabilities, functions or effects that the elements in isolation cannot achieve	plane, planet, solar system, universe, atom, climate system, weather, flock of geese, bridge over an estuary, cat, herd of wildebeest, bacterium, mammal's cardiovascular system, an ant colony…
Conceptual System	a model, a product of human thought, with emergence through new meaning not conveyed by the individual elements, and boundary designated by the conceiver	relationships between letters to form words, relationships between axioms to form a theory, relationships between equations to form a mathematical model, relationships between lines of code to form a computer program, a matrix of numbers or mathematical expressions, a topological map, a model of a real system, a machine drawing, an electric circuit scheme, a UML or OPM conceptual model, relationship between elements of belief in religion, politics, philosophy, etc.
A particular class of conceptual system:		
Abstracted System	conceptual system that represents - is an abstraction of - a corresponding real system	a system architecture, an organization chart, design information for manufacturing a product, a mental or mathematical model of an observed or postulated physical phenomenon, a diagram or sketch of a real-world system

Types or Categories of Conceptual System

System Type	Draft Definition	Examples
Mental models	Concepts and ideas existing in the mind of an individual sentient being	How we think a computer or a car works, perception of how other people see us, an initial concept of a system design.
Informal shared models	Concepts and ideas shared with other sentient beings.	A book, drawings or sketches, photographs, a speech, a video recording, minutes of a meeting, a song or ballad or story or legend, a system of beliefs (religious or political) …
Formal shared models	Concepts and ideas shared with others as a set of formally related informatic objects.	Computer programme, mathematical proof, 3-D solid model of a physical artefact, executable simulation of an electronic circuit or a physical system, a system of equations (e.g. Maxwell's Equations)

Types or categories of Real System

System Type	Draft Definition	Examples
Naturally-occurring System	a real system that exists in nature	the universe, the solar system, planet earth, human being, ant, ant colony, atoms, systems in nature that we have not yet recognised.
Hybrid System	a system that combines natural and artificial sources, modifications, or influences	See below.
Human-made (Artificial) System	a real system created by human (or other sentient) beings	aeroplane, airline, air defence system, city, car, military, factory, ship, procurement system, camera, computer, transportation system, communication system

Existing INCOSE / 15288 definitions apply to artificial systems created for a purpose.

(NB: some human-made systems are created accidentally – for example when unintended coupling between simple systems results in a more complex one with unintended consequences – *unintended consequences are usually due to an unintended system*!

Types or categories of Real System

System Type	Draft Definition	Examples
Naturally-occurring System	a real system that exists in nature	the universe, the solar system, planet earth, human being, ant, ant colony, atoms, systems in nature that we have not yet recognised.
Hybrid System	a system that combines natural and artificial sources, modifications, or influences	See below.
Human-made (Artificial) System	a real system created by human (or other sentient) beings	aeroplane, airline, air defence system, city, car, military, factory, ship, procurement system, camera, computer, transportation system, communication system
Two types of Hybrid System:		
Artificially Modified naturally-occurring systems	Hybrid systems created by modifying elements of naturally-occurring systems	genetically modified crops and animals, engineered biological tissue, result of bypass surgery, agriculture
Artificially Influenced naturally-occurring systems	naturally-occurring systems influenced by actions of sentient beings and/or systems made by them	selectively bred crops and animals; the water flow downstream of a dam or flood prevention system

Recognized Systems

- **Recognized Real Systems** are systems that are recognized to exist in the real world.
- Their recognition can be through one or more of the three universal system aspects: **structure**, **behaviour**, **function**.

System type	Definition	Examples
Recognized Real Systems	systems that are known, recognized, intended, or perceived to exist in the real world	the universe, the solar system, planet Earth, human being, ant, ant colony, atom, the USA Federal highway system
The boundary of a recognized system is proposed by the observer based on objective criteria and is refined through successive approximations by empirical observation.		
Three basic types of recognized system according to the primary aspect that enables their recognition:		
Structurally - recognized Real Systems	systems that have a well-defined and easily agreed-on physical boundary	an ant, an aeroplane, a car, a bird, a ship, the Mediterranean Sea
Behaviourally - recognized Real Systems	systems that may be fleeting or transient, recognized by correlated or synchronised behaviour of the parts	a flock of geese, a crowd of soccer supporters, a dance group, The Red Army Choir, the Earth's climate
Functionally - recognized Real Systems	systems that are embedded in and distributed throughout other systems or their environment, but have a clear effect or function	a mammal's cardio vascular system, a road through a landscape, the global air-traffic control system

Today’s Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Please

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