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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).

Current INCOSE definition (SE Hdbk V4)

- *…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.*

Excludes:

- Naturally occurring systems and systems that include naturally occurring elements
- Systems in non deterministic environments
- Systems that “emerge” without defined users or prior purpose
- Conceptual systems

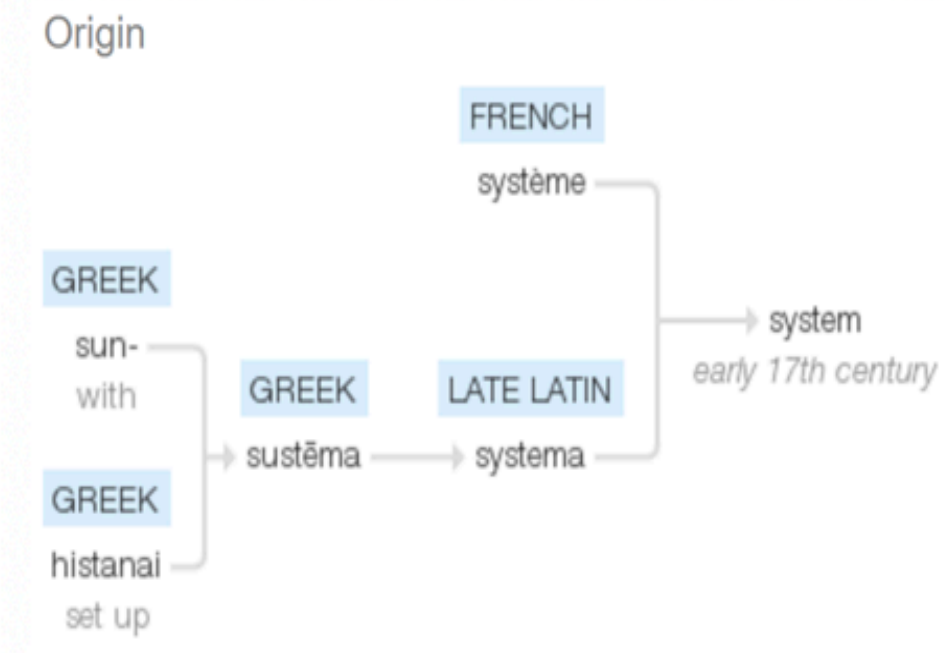
SE Vision 2025 suggests we need to address a wider scope

- The wider scope of future SE 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

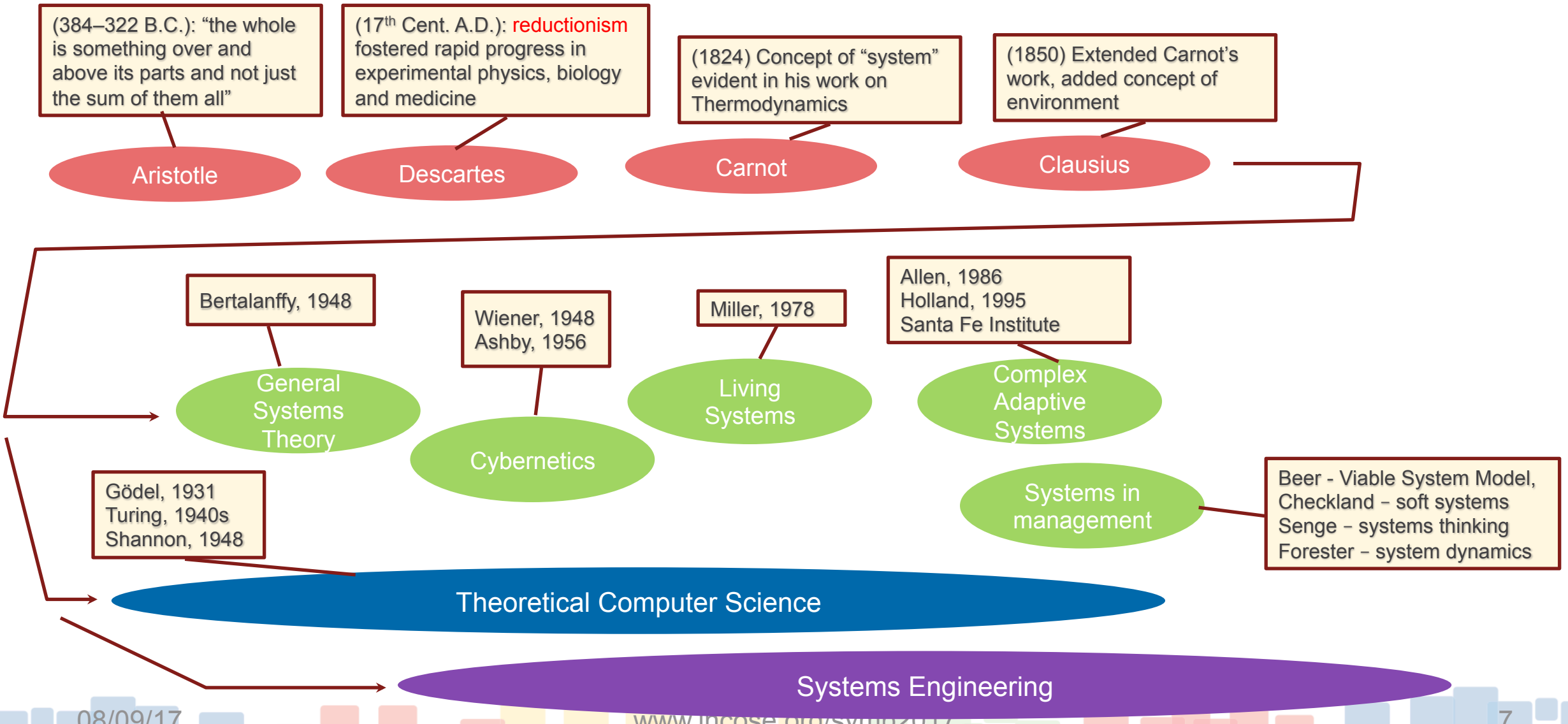
- It is not sufficient to design these kinds of systems to work in “a defined environment.” They also need to:
  - Cope with unforeseen events in a non deterministic environment
  - Degrade gracefully and restore service after disruption

System: origins and use over time



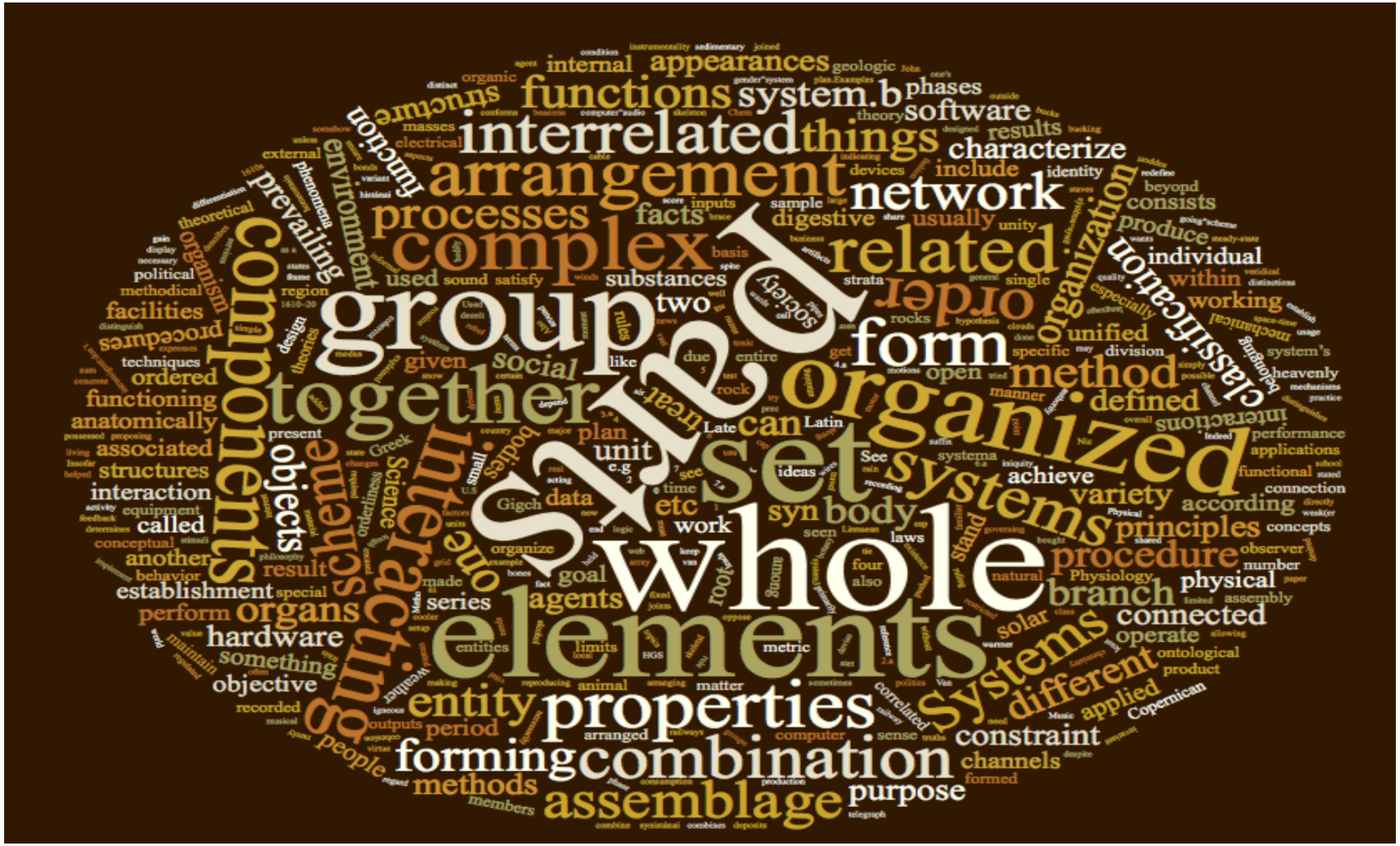
- Greek combination of sustēma, from *sun*, meaning *with*, and *histanai*, meaning *set up* or *cause to stand*.
- Together, the resulting semantics of *standing together*, *standing in relation*, or *togetherness* seems to be the essence of the original etymological root.
- In turn, the Greek may come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

Some schools of thought in systems



100 System definitions word cloud

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



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, organized, 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]*>.

Some dichotomies

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

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Uncovered five distinct worldviews

MINIMALIST BASED
ON MATH AND LOGIC

CONSTRUCTIVIST

MODERATE REALIST

STRONG AND
EXTREME REALISTS

COMPLEX, VIABLE AND
LIVING SYSTEMS

Revealed in survey responses
by Fellows & System Science community

Worldview S1:

MINIMALIST BASED ON MATH 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…concept of system is reserved for the conceptual world
- “System concept as a mode of description” included within this category
- 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

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
  - 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

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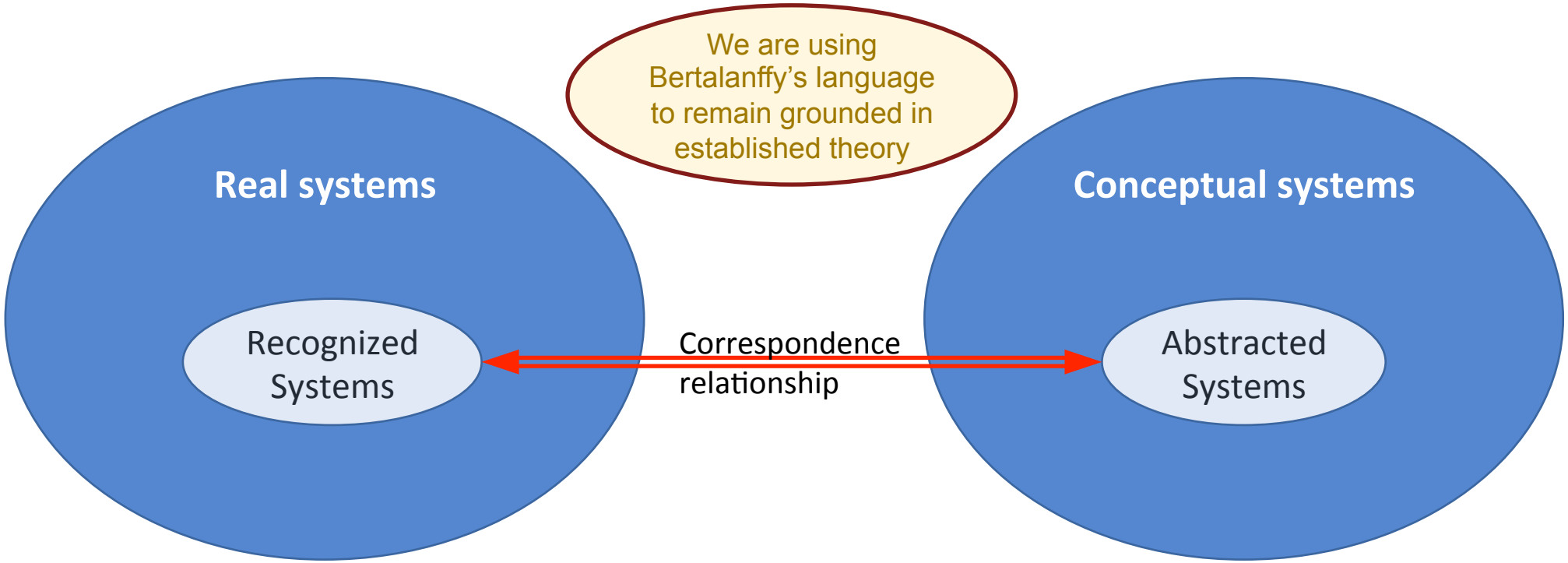
Bertalanffy's categories of "real" and "conceptual" systems form the basis of our definition framework



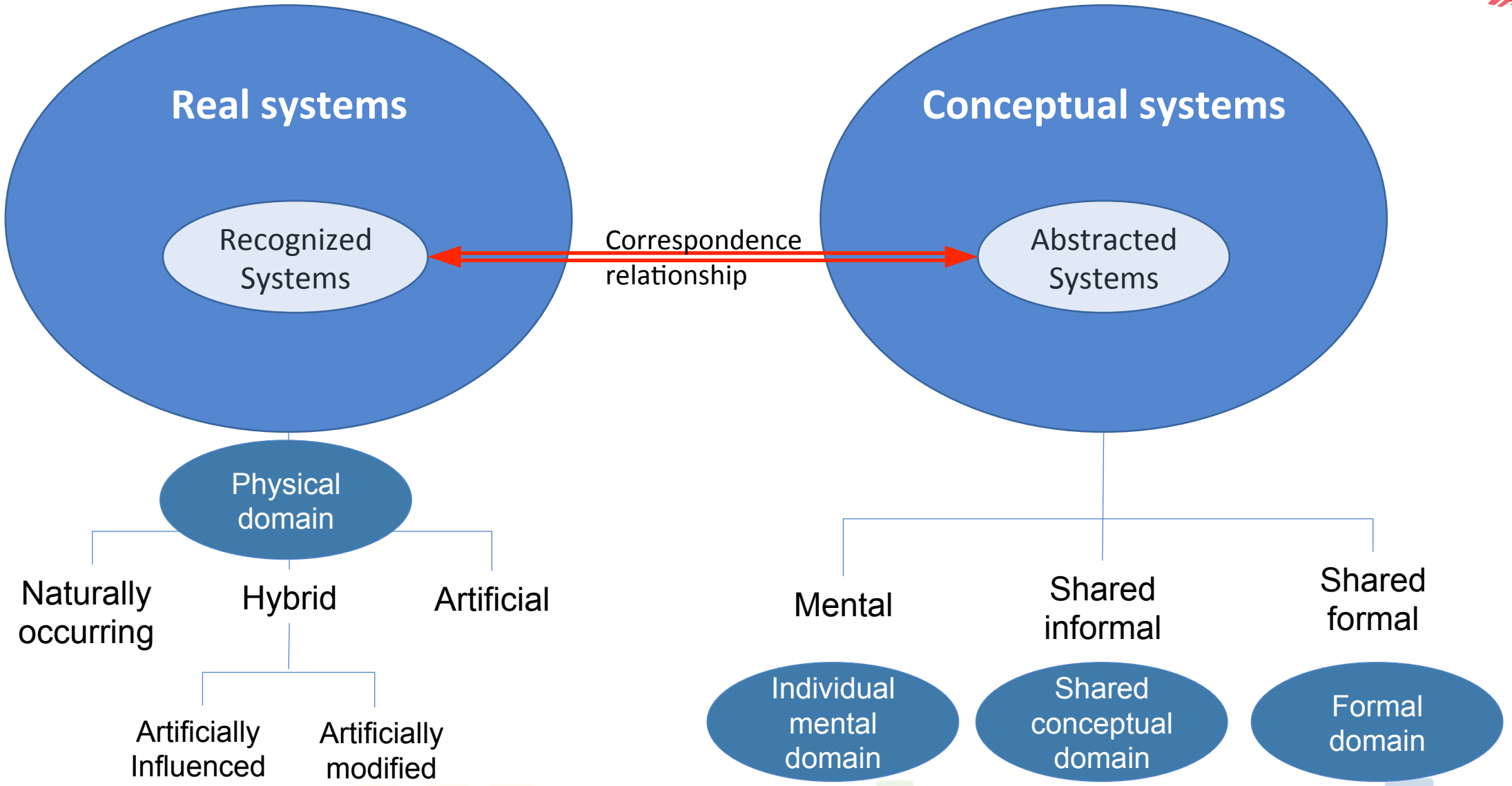
Synonyms for "real" system:

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

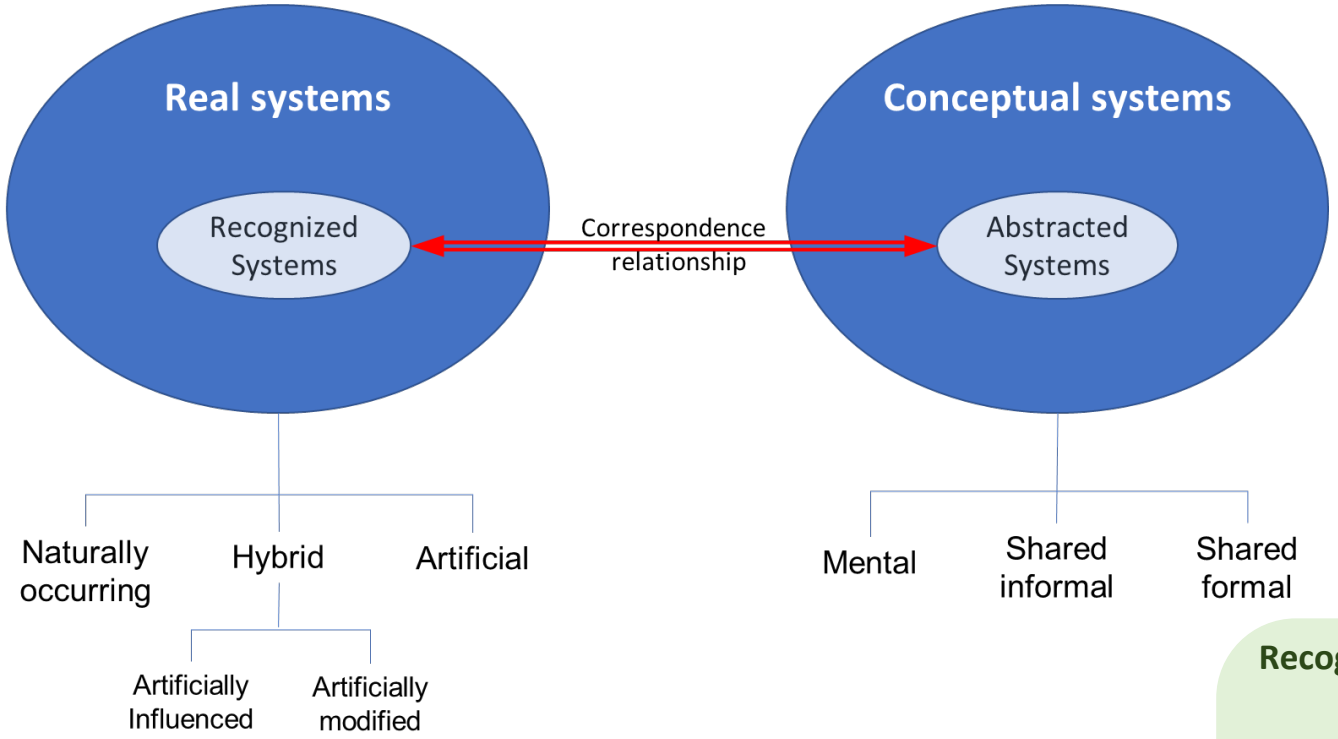
Synonym for "conceptual" system:

- "abstract system"

Popper & Lloyd – three worlds + 1



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, informal shared,** or **formal shared.**

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.**

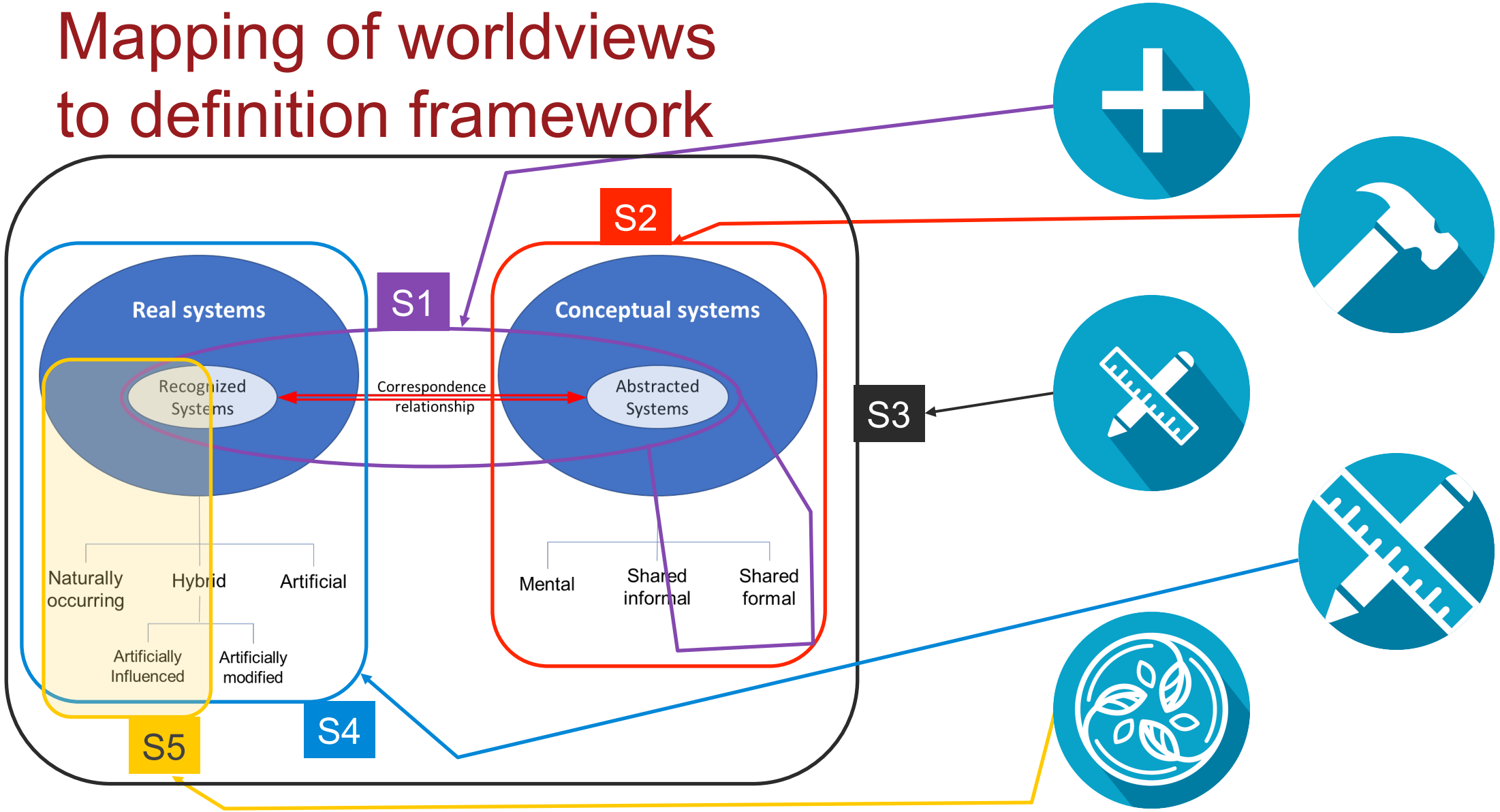
Recognized Real Systems are recognized to exist in the real world. They may be recognized by their **structure**, **function** or **behavior**.

Real Systems can be characterized 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.

Mapping of worldviews to definition framework



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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
  - Find words that avoid 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
- Agree that the set of definitions is still unfinished business
- Move on to propose definition(s) 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 category

WE WANT TO KNOW WHAT YOU THINK!

INCOSE leadership asked a team of Fellows to devise an updated definition of "systems engineering" to better support INCOSE's vision for the future. The team would very much appreciate your input to help in this effort -- specifically, we are asking INCOSE members to complete the survey at:

https://www.surveymonkey.co.uk/r/IS_2017