The Nature of Systems

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This article introduces The Nature of Systems knowledge area (KA). Systems cannot be separated from their environment and human conceptions of system are contingent upon relations within specific (constrained) situations. Whilst the previous sections are concerned with the Introduction to System Fundamentals, or "The Engineering of Useful Artifacts" (Mobus, Kalton 2014); This section aims to illustrate the nature of systems, a compact description of essential themes relevant to a 'systems science' approach to this understanding, and to recognizing interdependencies between systems science and practices of systems engineering.

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Contents

Topics

This KA contains the following topics:

- Types of Systems
- Cycles and the Cyclic Nature of Systems

Additional articles illustrating general concepts, theories and principles universal to all systems shall be added over time

System World Views

While a broad spectrum of perspectives on concrete systems derives from practices of Systems Engineering (Sillitto, et al 2018) and other systems-centered disciplines, the discipline of Systems Science seeks abstract, generalized, and universally applicable concepts, principles, and theories of systems. The overarching concept ‘system’ applies to any physical or conceptual subject of interest - including abstract domains of knowledge.

A system is a set of interrelated components. The components are variously linked to one another, and the system itself is connected to its surroundings. All systems have a boundary. In the case of designed or physical systems, the boundary is clear. In social and metaphysical systems, the boundary is typically more dynamic, less obvious, and more open to interpretation. In other words, observers are likely to perceive the boundary of a social or metaphysical system differently. According to Bogdanov (Bogdanov 1996), a system (or complex) is not simply a collection, aggregate (or vector) of components and their relationships. A system is a process, or continuous flux of independent granular processes, concatenated in self-triggering circles of buildup and degradation. Bogdanov's system cannot be separated from its environment, because it does not simply exist or interact with its environment: it is structurally coupled with its environment and thus evolves its own environment while co-evolving with it.

A common observation about systems is that they display properties which are not apparent from the properties of the components themselves. This is sometimes referred to as synergy, or as emergence.

While a system is often perceived as a structure, the unique properties come from the relations between the components within this structure. For example, trees provide shade from the sun and so can function as a refuge from heat. In the practice of systems engineering, a system is often identified with its functions. Designed systems exhibit one or more functions. Functions are useful properties in the context of a higher level system. The functions being an emergent property of the desired system's behavior, and the system’s behavior enabled by the structure of the system.

Systems can be both 'physical' and / or 'conceptual' things. Conceptual things, mental processes, often correlate with physical causes (eg, events observed in brains) and may be considered to 'constitute' a separate class of relational processes. If 'conceptual' things can be grounded in relational processes correlated with physical causes, it stands to reason that communicating meaningfully about physical causes at various spatial and temporal scales provides a theoretical basis for including conceptual and physical things in the domain of 'concrete' systems.

In this narrow sense it may be said that all subjects of interest take part in a 'unitary' system of 'concrete' (physical) nature. That is, as an irreducible physical unity, the universe is composed of conceptual and physical things existing in interlocking and subsuming processes of interrelation that may be described in subjectively relatable terms, in other words, 'understood'.

This 'systemness' (existing understandably in relational processes) is a general characteristic of all things. System Science provides useful frames of reference for meaningful approaches to both realms generally (eg, physical and social).

Definitions and Problems of terminology

In this overview article we recognize the (apparent) huge body of literature (a google scholar search on "nature of systems" returns 13,000 results) on the nature of systems. While a few basic definitions of systems (Sillitto, et al. 2018) are widely accepted in practice, significant differences in specialized usage exist.

Thus, here we try to use commonly understood terms meaningful to both both practitioners and scientists. While potentially useful to consider this diversity in terms of a more broadly organized taxonomy, it's helpful to appreciate that terminology is unlikely to be permanently 'fixed' or fully normalized; this contingent relation with human expression is a feature of the universe and dynamic interactions within it.

The dual nature of such contingency is notably paradoxical. On one hand, incommensurate terminology can present problems. On the other: opportunity. Together, in the open-ended relation between 'problem' and 'opportunity', interesting things can occur.

The available knowledge about systems is very rich indeed but it is yet chaotic (the system of system knowledge often yields more questions than answers) and the domain of system science relates variously with many knowledge domains (specializations) in the broader culture. One of the goals of system science, therefore, is to purposively help reconcile such 'geographical' concerns - literally and figuratively. This leads to validating questions of valuation and realization for systems knowledge and systems science pursuits.

Value of systems knowledge

The nature of systems, as one of the most powerful and widely used paradigmatic conceptions is a common thread across human existence. Generally, systems in the universe do not embody human agency - humans and system scientists do. The validation, legitimation, and valuation of systems knowledge generally occurs in its relation between human situations. More specifically, system science in the service of systems engineering (or vice versa) recognizes and is capable of anticipating and delivering value for system stakeholders - who are typically situated in systems of other derivation (cultures that do not necessarily share a common system language).

Systems science (as an activity system) adds value by organizing and tailoring concepts, theories, principles and assets which render useful expressions of fact, concern, effect or degree pertaining to forms, functions, and fitness of systems in the landscape of systems competencies.

These patterns of expression help stakeholders anticipate complex dynamic situations and compose descriptions and sequences of action (eg, plans) in multiple relatable - and reliable - ways. System scientists must communicate with a range of stakeholders in order for systems to be engineered to operate predictably well. In turn, stakeholders must be conversant in the 'local' language(s) of their systemic interest; often this takes priority and the value of system science is in expressing knowledge in terms stakeholders understand rather than the other way around.

Clearly, the nature of systems can be elusive and pursuit of systems knowledge a great challenge. Future articles in this KA are continually being developed to complement (and also improve upon) existing articles. The concepts in the titles of the articles can always be improved upon but the essence of the content should be consistent with this compact description, as it captures foundational themes in our understanding of the relation between human minds and the universe we are present to.

A Set of Systems Concerns

One of the aims of this section is to illustrate the wide array of concerns in systems science literature. Looking across the literature, there is a a notable variety of useful categorical mappings and taxonomies. Here we introduce ten representative concerns of systems science; the list is intended to be illustrative rather than definitive.

1. Identity: Bounded networks of relations among simplified elements constitute a nominal and semantically meaningful unit, pragmatically speaking. This 'systemness' is a general characteristic of all things and can often be represented (expressed) as a non-random (informative) network of symbols.
2. Processes: layers, levels, and dimensions of dynamically *changing structure and function.*
3. Networks of relations between elements: connectivity, structure, and holistic properties such as resilience, criticality, efficiency.
4. Dynamics on multiple time scales: states and sequences of change such as growth, collapse, cycling, pattern-formation, criticality.
5. Complexity : variability in number of elements and dimensions of element relations including additivity, connectivity, and inter-adaptability (contingency, dependency).
6. Evolution: progression of qualitative, quantitative, and/or semantic change over time.
7. Information: matter and energy 'encoded' within

network(s) of relation or exchange between senders and receivers.

8. Governance: modes of mutual regulation and adaptation between elements, typically involving synergetic co-operation or competitive interference.
9. Contingency: degrees of freedom within a network of constraints which the system is subject to.
10. Methods of interaction. Profoundly, every system has a kind of signature; a unique way of showing up to human cognition, through which it reveals or exchanges information and yields knowledge about its state and identity; Practically, this involves (human) stakeholders and their respective processes of attention. In regard to system science and engineering - attention to specific exchanges of energies *through* bounded interfaces (eg, scientific instrumentation; sensing/measuring systems), rather than narrowing-in on surface experience *of* limitations and boundaries. In other words, system science is a process of open ended learning.

Gaining a 'feel' for systems

Systems are an ordinary occurrence; we are immersed in systems. It is a challenge, however, to discover the unity in the immense diversity of ways systems manifest in experience. Considering the far-ranging Body of Knowledge underlying Systems Engineering, 'natural kinds of value' are foundational. All systems exist in our natural context and can be experienced as values. These values relate to utilities stemming from systems knowledge and its application, ranging from guiding personal day-to-day actions to addressing global challenges.

Within the structure of this section of the SEBOK we shall be giving presentation to interwoven concepts of Togetherness, Character/Behavior, Cycles, Purpose, Value, and Learning/Experience (Rousseau, et al. 2018) as a way of providing a cognitive system of values, and a holistic perspective on situated systems - systems in practice - that can deeply align theoretical and practical efficiencies of the systems engineering discipline.

The form of things: Togetherness provides a framework for collaborative and integrated operations, emphasizing the indispensability of harmonious interrelations at the heart of successful systems. Behavior informs the adaptable and responsive dynamics that are essential for the resilience and robustness of engineered entities.

The function of things: Cycles highlight the recent and iterative nature of systems, underscoring the importance of feedback mechanisms in persistent operation and effectiveness. Purpose anchors systems with a definitive direction and intentionality, centering on outcomes that deliver meaningful impact.

The fitness of things: Value signifies the critical evaluation of a system's effects, ensuring that resource utilization and stakeholder interests are aligned. Experience centers the human-centric aspects of system concepts, definition, realization and operation, ensuring human appreciation, influence, and subsidiarity.

These six intertwined concepts provide a conceptual scaffolding upon which systems engineering may appreciate the nature of systems when fulfilling the requirements of Form, Fit and Function.

In practice, these general concepts and the theoretical models that build upon them translate through to the application of specific assets such as that utilized in our lifecycle management processes as discussed in the article on cycles.

Applications engendered by these assets play out in the creation and modification of systems artifacts and complex entities involving living systems. Here, the natural kinds of value are further actualized through the actions of embedded computational networks (themselves products of evolutionary refinement); continuous regeneration of self-sufficient organic systems, promotion of sustainable resource cycles, alignment of system functionalities within overarching frameworks of values, elevation of stakeholder value, and enhancement of user interaction with technology.

In general, guidance offered for practical use of systems knowledge spans various dimensions of human activity. It helps direct rationalizations taking place in personal decision-making through to the strategic considerations necessary for addressing complex global issues. By operationalizing the six concepts at every level—from nanotechnology to large-scale infrastructure— systems engineering integrates natural kinds of value with a complex of systems critical to technical, social and natural systems safety and well-being.

In summary, the six system concepts serve as theoretical keystones that, together with methods and applications (facilitated by relevant assets at hand), aim to deliver natural kinds of value at every scale of human enterprise. Integrating these theories, methods, and applications fosters an approach to systems engineering that thrives on adding net intrinsic value. Through such an approach engineered systems transcend mere functionality, endowing them with qualities that support and enrich the human experience in its broadest context.

This is by no means a complete landscape of systems concepts, rather it may help to scaffold a useful entry point into the diverse inspirations and instrumental concepts for systems engineering.

Value of a Systems Science Foundation for Systems Engineers

The urgency of understanding common foundations of systems for practicing SE's can be summarized in three points:

1. Civilization depends upon highly evolved physical and conceptual systems and recent evidence from planetary science https://www.ipcc.ch/reports indicates that planetary support systems are changing significantly and relatively quickly. Civilization is an ongoing co-evolutionary System of Systems with Humankinds' Planetary Support system, and recent evidence indicates that the rate of change is increasing; Civilization depends upon highly evolved planetary systems and recent evidence from planetary science (limits to growth update) indicates that these are changing significantly and relatively quickly;
2. The practice of Systems Engineering is embedded in and co-evolves with the proliferation of socio-technical systems that constitute modern civilization;
3. Designing, integrating, and evolving socio-technical systems becomes more complex and challenging as new technical specialists become involved in Systems Engineering processes. For instance, adding environmental, economic, social, and governance specialties in-creases workload for the key Systems Engineering role of System Integrator and Communicator.

The considerable value of Systems Science could be demonstrated in helping address these key Systems Engineering challenges by:

1. Framing common-view characteristics of all systems relevant to a given System of Interest and the environment of interacting System of Systems 's so that appropriate tools, techniques, and processes can be employed and/or developed for efficiently working across the system design and development community;
2. Facilitating effective cooperation between diverse technical specialists bringing unique concepts, models, and vocabularies and promoting inclusive equity for enhanced project/program/system success: it's essential for all stakeholders to appreciate their specific situational role(s) in systems of interest co-evolution with interacting systems of systems, to more effectively engage in realizing critical shared objectives.

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Additional References

None.

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