Systems Processes and Pathologies: Creating An Integrated Framework for Systems Science for SE

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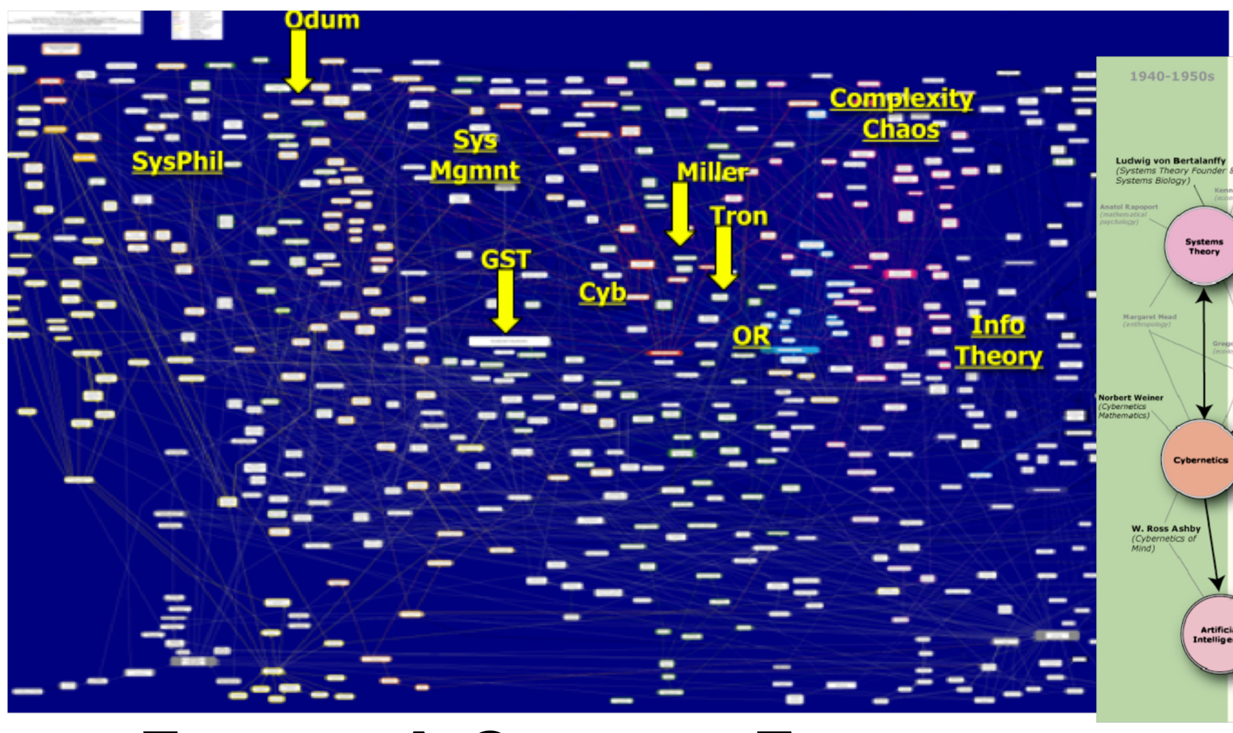
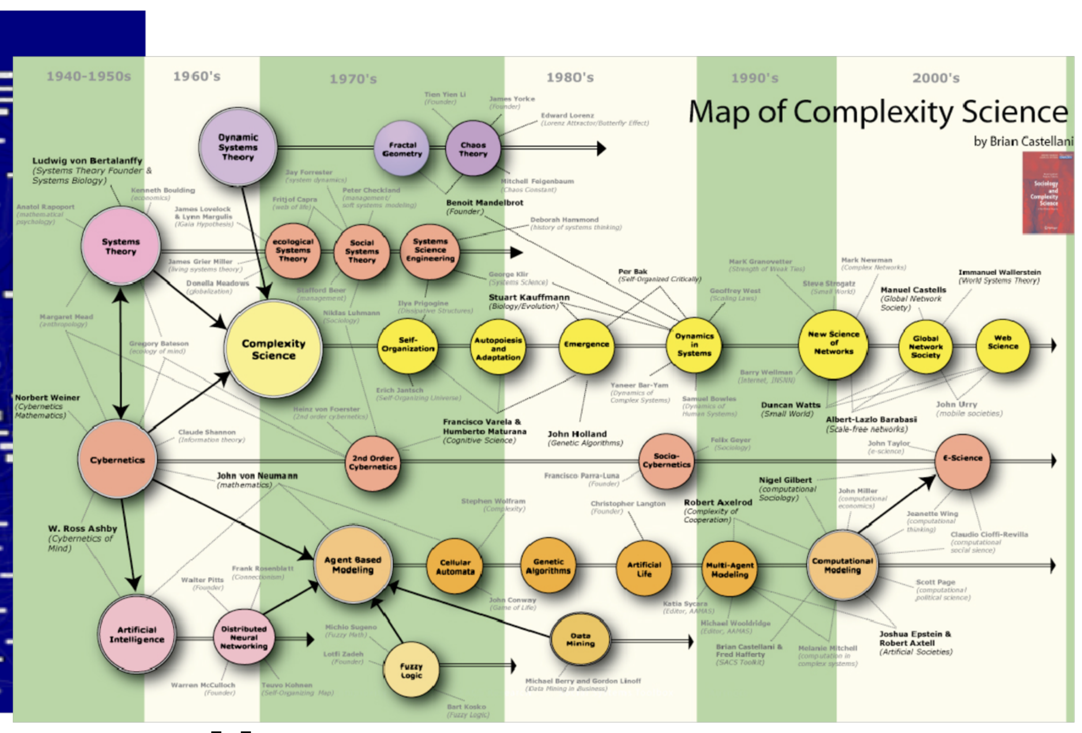
Purpose/Problem: Unintegrated Sources

- (1) Chemical, aerospace, & mechanical engineers take many science courses in their education; shouldn't systems engineers study & become adept at systems science?
- (2) Whose systems science? Current systems science is fragmented and very different between its many different domains. There is a great need for synthesis. Two mappings below show >100 workers in GST (left) and >70 workers in CAS (right) from 29 new fields whose work needs to be compared and/or unified. (see subposters for resolution)
- (3) There is also a great need for a "science" of systems; an evidence-based set of very detailed systems design principles that are proven for SE to use in praxis & training.



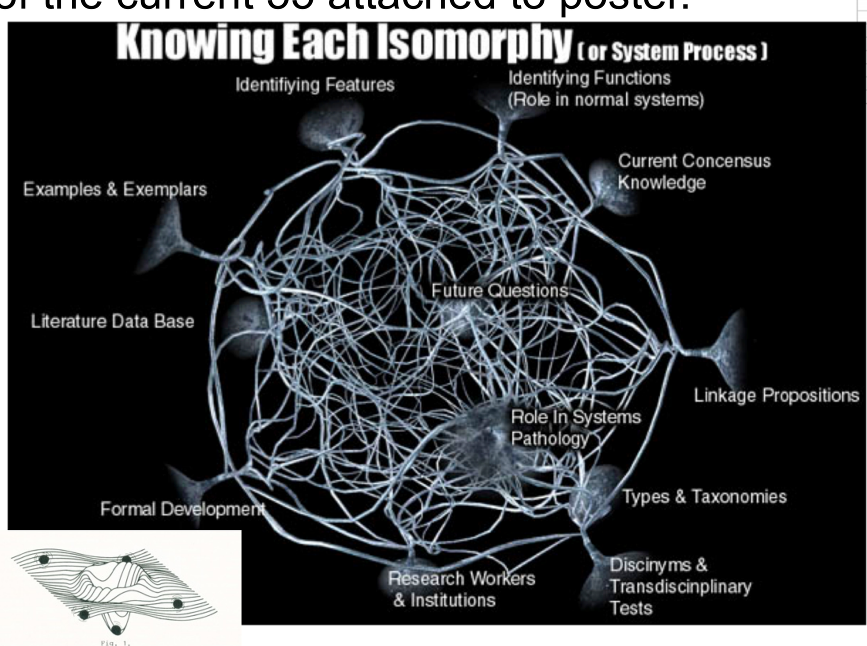


Finding A Common Framework for Unification

• The INCOSE Systems Science Working Group is seeking the most practical consensus framework to use for integrating & making usable all the diverse syssci knowledge base.
• Suggested steps for the unification protocol include identifying all possible: (1) domains of systems work; (2) types of synthesis; (3) types of similarity; (4) types of theory; (5) types of systems; (6) candidates for unification; (7) types of systems mechanisms; (8) types of influences between systems mechanisms; (9) arguments for & vs. unification.
• At present, our unifying theme is use of Systems Processes, Linkages and Pathologies
• Why systems processes? (1) processes are what engineers engineer; (2) processes are what scientists study when they study nature; (3) there exists a great deal of knowledge about processes; (4) processes can be mimicked & taught; (5) some processes have proven sustainable for billions of years. They are the essence of system
• For example see a comparison of six major systems lifeworks in at-a-glance format (right) showing their relative coverage of 100 systems processes (the darker the grey = more coverage); libraries of comparisons would be useful to students.
• At the IW'13 workshop, this SSWG project team identified nearly 90 names of systems workers as candidates for unification. Please see that listing attached to this poster.

How Systems Work: Systems Processes

• What we seek (what would be useful to SEs) is a more detailed explanation of how systems work in general to suggest better engineering of systems in particular.
• To better focus the syssci integration task and at the same time increase resolution of how systems work, we have chosen to explore past work on systems processes.
• ~100 candidate systems processes are shown at right; we have compacted this list to 55 for current work. See listing & definitions of the current 55 attached to poster.
• As shown in the comparison, even widely recognized workers in systems science only have produced findings on a few of the total list of our systems processes indicating the need for & efficacy of a synthesis approach.
• We are collecting and interconnecting (as partly shown at right) 25 categories of data for each systems process in workbooks for use in training. See list of these categories attached to this poster. Can you think of any more? (either systems processes or categories of needed knowledge for each?

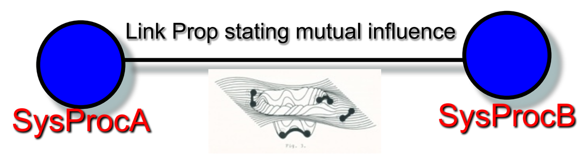


• Systems processes are hypothesized as isomorphic across all complex systems. The insert landscape shows that at system stabilization they are the lowest resource state. That is why they appear in many if not all mature systems in nature & should in human.
• Our working definition of systems process (SP) is: A finite, obligate sequence of steps or stages that results in a functional change in particulars increasing sustainability of that set of interactions (system) in a given environment. Like an algorithm in computer sci.
• This definition applies to the processes that drive all phenomena investigated by the natural sciences. That's what experiments explore – explanations of how things work. To graduate to the level of systems processes, one has to compare the processes across a wide range of disciplines, phenomena, domains, and scales & find them isomorphic.
• Nature is constantly changing &/or adapting; systems processes effect that change.
• We are attempting for the first time to actually demonstrate the presence of SPs (cite evidence for)(prove?) how they make "systemness" possible across many diverse systems. See the case studies at right that can provide multiple confirmations that each systems process is present in a wide range of domains, disciplines, or scales of reality.
• As one of our frameworks for integrating 50 yrs of systems science, & in addition the entire natural science literature, this approach yields several advantages:

- ✓ Knowing a process in detail gives many opportunities for intervention
- ✓ Wealth of data on processes makes teaching both SS & SE more effective
- ✓ Having a toolbox of processes enables SEs to evaluate their models/simulations
- ✓ Greater detail increases understanding of how systems work in many cases
- ✓ Greater detail enables understanding of why systems sometimes don't work
- ✓ A greater evidence-based knowledge could increase acceptance of both SS & SE
- ✓ Focus on Process helps leap barriers between physical, bio, & social systems
- ✓ Focus on Process helps trace systems dynamics at the most fundamental level
- ✓ Processes expressed at the most abstract level are neutral integrators.

Linkage Propositions → A System of SysProcesses

• The most important contribution of the SSP framework is its precise definition of the mutual influence of one isomorphic systems process on another. When many such unit influences are taken at the same time, a NETWORK of very specific interactions is defined…….
• A SSP Linkage Proposition is a language or computer-based description of the impact one systems process has on one or more other systems processes as observed in exp'ts on natural and human systems. As the systems processes are isomorphic and the lowest required resources state, so are the linkprop dyads. They "link" the SPs together to make a system possible, but are propositions until proven across many different systems.



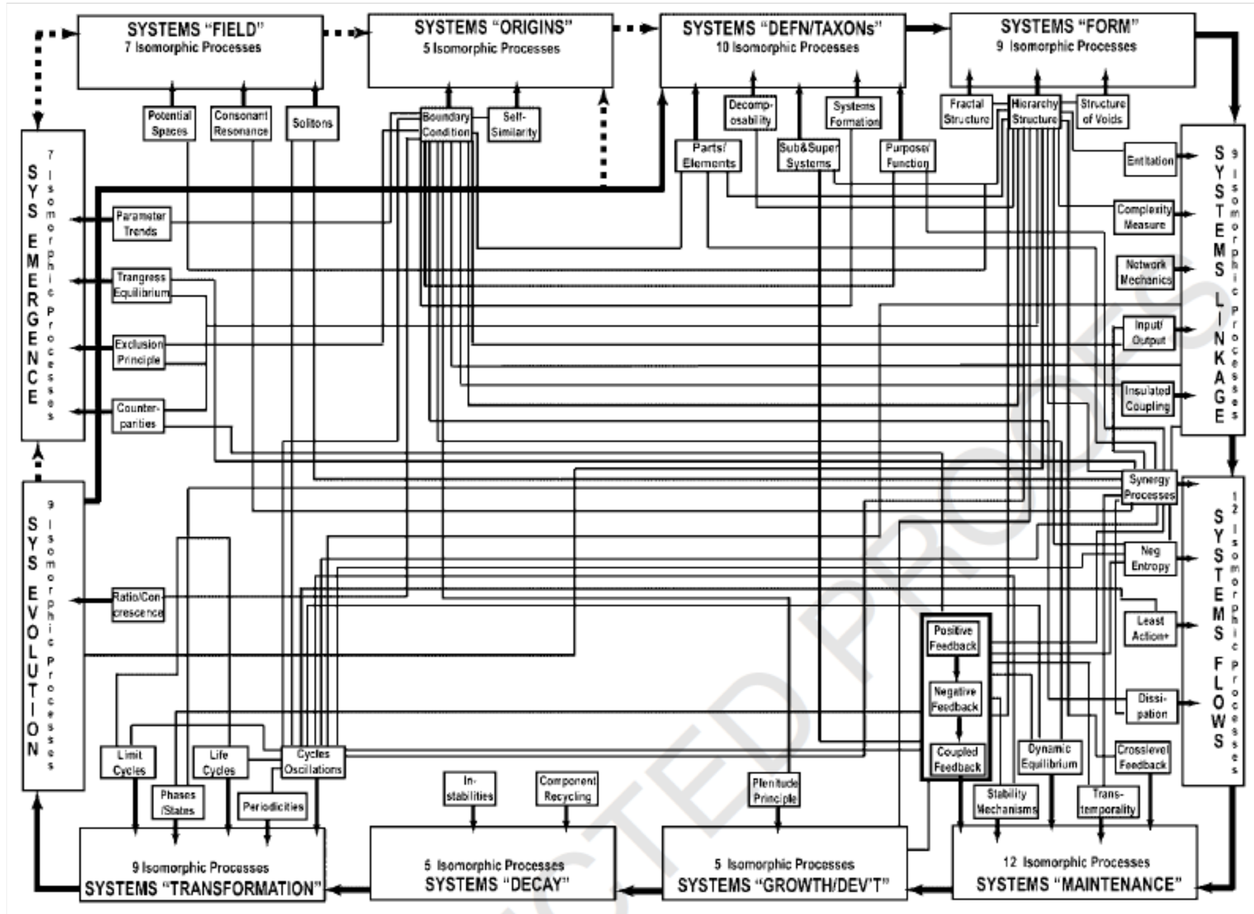


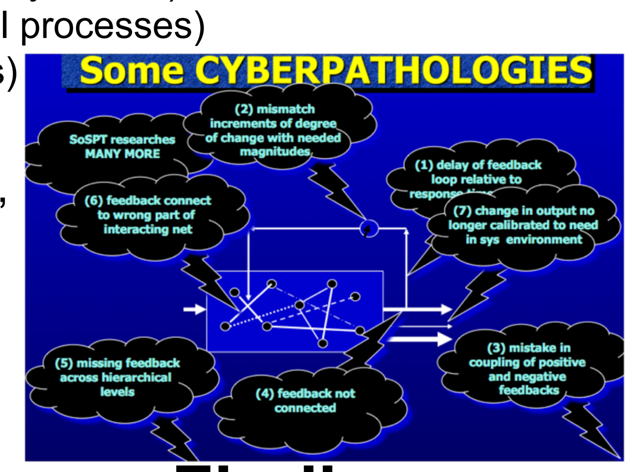
Figure 2. Network map showing ~85 linkage propositions between five isomorphic processes and the 42 systems processes with which they experience mutual influences

• So the goal of the network of propositions shown above is to explain our observations of "systemness" in more specific phenomenological detail than ever possible before at the most fundamental level.
• Simultaneously, SSWG is analyzing the vast systems science literature for evidence for and against such a theory, its statements and guidelines. Thus, we are integrating the fragmented literature into one >usable framework.

How Systems Don't Work: Systems Pathology

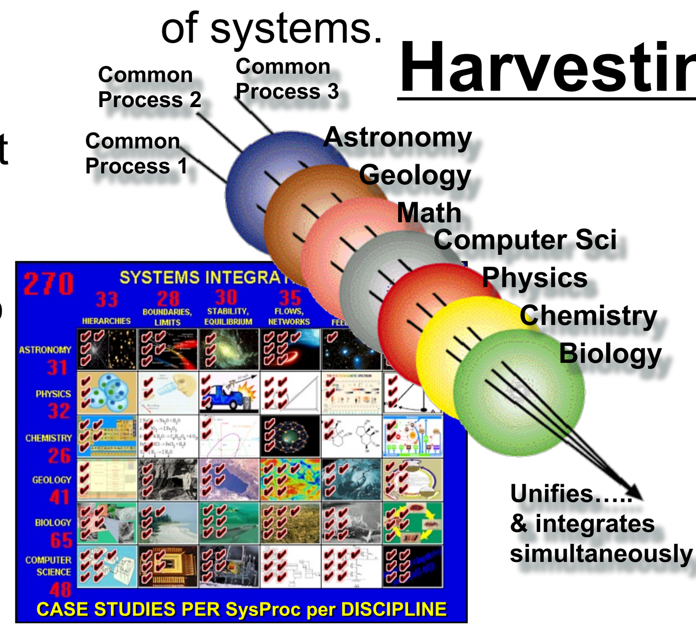
• Beyond explaining "systemness" in general this framework also enables much more specific recognition & treatment of systems malfunctions.
• We propose adopting the framework proven for medical science. Our focus on systems processes & their mutual influences enables faster recognition of a "taxonomy" or "ontology" of categories of how systems fail or malfunction
• Each systems process that is essential for systems sustainability also is a process that could function below needed parameters of normality, hence a namable group of problems to look out for before, during, and after their engineering. Would provide another framework for evolving data & measures.
• We now recognize some 55 major categories of top-down, systems-level diseases; each with its own set of problematic mechanisms (as shown below for just one) and its own set of possible remedies that practicing SEs must keep strict data records on as do some of our medical institutions…….

- **Cyberpathologies** (dysfunctions of feedbacks)
- **Rheopathologies** (dysfunctions of systems flows)
- **Cyclopathologies** (dysfunctions of cycling, oscillations)
- **Heteropathologies** (dysfunctions of hierarchy or modular str)
- **Hapsopathologies** (dysfunctions of network str or dynamics)
- **Teratopathologies** (dysfunctions in developmental processes)
- **Stathopathologies** (dysfunctions in stability states)



• SE could achieve a great leap forward by learning from > 2,000 years of medical experience. First, identify a disease, name and document its symptoms, provide protocols for its diagnosis, collect data that allows prognosis, collect data on outcomes of various treatments, study its etiology (cause of the dysfunction). Study normality across ranges of systems.

Harvesting Rich Natural Science Findings for SE Praxis



• Essentially all of the natural sciences and their vast numbers of workers & funds have, over the last three centuries, been doing expt's to understand in detail how their particular systems work.
• To date, this prodigious output has been used to engineer very particular human systems or to copy, as in biomimicry, evolved, natural solutions to problems.
• We are harvesting this data, again for the first time, to explain "systemness" in general and to guide the engineering of new systems and better predictive understanding of systems failures.

Dramatic New Vision of Systems Engineering

• Imagine systems engineers as doctors employed to diagnose and treat a very wide range of increasingly complex, but dysfunctional human & a wide range of natural systems.
• Imagine SE as the go-to discipline for understanding of why our human systems are not compatible with or are destroying the natural systems upon which we depend.
• Consider SE as using a science of systems, an evidence-based core, as design principles for designing ever more complex systems as nature has → Systems Mimicry & SysInformatics.

Citations

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