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

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Abstract. Among the several official projects of the INCOSE Systems Science Working Group, one focuses on integrating the plethora of systems theories, sources, approaches, and tools developed over the past half-century with the purpose of enabling a new and unified "science" of systems as a fundamental basis for SE. Another seeks to develop a much more SE-usable Systems Pathology also grounded in a "science" of systems. This paper introduces the wider SE community to the current status of this unique knowledge base produced over the past three years by an INCOSE-ISSS alliance summarizing the current output of 7 Workshops, 12 Papers, >24 Presentations or Webinars, and 5 Reports.

It describes the need for integration of systems knowledge by demonstrating the extensive fragmentation of numerous contributing fields. It presents the current 12-step "protocol" used by the current group to guide its efforts at synthesis across systems domains, disciplines, tools, and scales asking for feedback to improve the approach. It introduces 15 Working Assumptions or Hypotheses that form the foundation for this attempt at unification citing why these could be used as working principles but why it may be undesirable to call them "principles" as others often do. The paper presents working frameworks for integration and criteria used to judge whether results are a "science" of systems or not with reminders that these early guidelines are being subjected to constant testing and revision.

The paper ends with images of the resulting "system" of systems processes theory (SoSPT) and its major spin-off, the new top-down Systems Pathology. Fifty-five key Systems Processes are listed that are dynamically and causally joined by more than 200 Linkage Propositions resulting in a much more detailed general theory of how systems work than previously known. The paper argues these products and the networked community of scholars working on them could prove very useful to future SE design, testing, modeling/simulation, and gradual evolution of better SE understanding of the sustainability, maintenance, and repair of systems of all kinds, far beyond those currently served by SE.

Statement of the Problem

Introduction. Discussions at previous INCOSE-IW's exposed a potentially serious gap in preparation and practice of systems engineers as well as self-named systems scientists. Chemical engineers take core courses in chemistry, and most other engineers take core courses in physics and mathematics. However, systems engineers do not take core courses in systems science. Why not? The irony and essence of the problem is that the field of systems science, though itself predicated on synthesis, actually is rapidly fragmenting with many variants. So many partial alternative approaches exist that a consensus systems science core course has failed to emerge. Further there were convincing arguments that although the parent field had now been named 'systems science' there was good evidence that these approaches were not scientific at all and many so-called theories only used a small part of available systems knowledge with virtually no documentation from the natural sciences. How could they even be called systems science?

The combined INCOSE-ISSS participants at the first Workshop in this series (INCOSE IW'10, Arizona) decided that a broad review and synthesis of systems theories, tools, approaches and thinking was needed and if accomplished could inform and improve SE performance. Several of the SE participants also noted that the field of SE had a currently under developed knowledge of actual breadth of systems approaches. This was demonstrated in the most recent of Workshops co-sponsored by INCOSE and ISSS (International Society for the Systems Sciences) this summer (ISSS Workshop, 2012, San Jose, California). A group of 28 participants were asked to brainstorm and write on index cards the names of systems theories they had studied. The composite list of 104 (see Table One to Three, described more in detail later in the paper) included a very mixed listing of types of systems approaches including many items that were not developed theories, were tools without theories, were theories without tools, were systems thinkers but not scientists, were systems managers, were popularizers but not original workers, and more.

Evidence was also accumulated that SE as currently practiced was too reliant on a few tools and theories that covered only a small part of the potentially wider spectrum of systems knowledge. Discussions at the first IW also demonstrated that there were potentially new fields, such as Systems Pathology, that could inform SE but that were either not known at all in SE circles, or were neglected in circles of systems scientists. Perhaps most important of all, the lack of a foundational and detailed systems science was recognized as restricting the practice of SE to only a small set of the much wider set of systems that could be served by SE. The market for SE professionals in the future was portrayed as much richer and diverse than that at present. INCOSE decided to form two projects to directly answer these shortcomings and ISSS indicated that it had three existing Special Integration Groups that shared these objectives. The need for a dedicated team focused not only on critical analysis, but on integration, unification, and synthesis was clear.

Documenting the Fragmentation of Systems Sources

SE Needs & Project Goals. If one is attracted to the possibility of a core course on the systems sciences as a required preparation for SEs, then which course should be adopted? At present there are a multitude of partial systems theories and systems tools that capture only a small part of the wealth of the systems literature. There are not many totally variant KBs (knowledge bases) in chemistry or physics to serve as a basis for their respective types of engineering. A large core of consensual knowledge exists in each of those disciplines. Until an adequate synthesis of universals or principles is identified and proven across the very diverse domains of systems approach listed below, there cannot be a core course for SEs from systems science. This presumes that there is a definable and distinct need in SE for a core of systems science.

For example, Charts One to Three show in graphic mode three different mappings of the systems arena by three different workers from three different perspectives. Taken separately much less together they indicate the magnitude of the task of integration. Which or what parts of these many should be covered or adopted in the synthesis?

Chart One is a modification by Jeffrey Li, IIGSS, of an original work by Schwarz. In Chart One, each small white card in the inner two-thirds cites a name of a systems worker and usually a text or lifework of products in the area of systems thinking. This inner oval contains at least 100 such names with those of systems significance mixed with others that we would not describe as systems oriented. That would mean the necessity of studying >50 sources for a unification of systems. The outer fringe, in our opinion, diverges to the philosophical and basic science underpinnings of some of the theorists and so leaves the arena of pure systems science that needs to be integrated. Still, the diversity workers cited from disciplines as seemingly separated and different as philosophy, history, economics, operations research, ecology, biological systems, geology, physics, information theory, computer science, management, mathematics and semantics is indicative of the fragmentation of systems approaches.

Chart Two is by Brian Castellani and surveys developmental lineages in complex adaptive systems work from the 1940's to 2000's. It cites the work of ~70 authors and texts in 29 categories. Many of these are from the more scientific arenas and recent developments and do not overlap much with the IIGSS chart. Chart Three is based on connections between some of the tools useful to systems studies in six categories of systems application from environmental science/ecology to cognitive science to AI. It cites such systems approaches as Bayesian statistics, neural networks, non-linear control, simulation, and network theory. Each Chart has some systems approach not found in the others with some overlap also visible. But taken together they show that diversity, not synthesis, has characterized the history of spreading systems awareness. All three of these Charts were originally intended as large posters and so are difficult to read in a paper format. The author will bring two of the three to IS'13 as posters to improve readability.

An exercise performed in a Pre-Conference workshop sponsored by INCOSE at the 56th Annual ISSS Conference exposed the extent of the problem of even recognizing the full set of possible theories to integrate. Individuals at five tables of from 5 to 7 individuals were asked to independently write down (brainstorm/list) the names of potential theorists and their lifeworks or texts that should be integrated to get a unified systems theory. They were given only half an hour to make their lists so time would be left to discuss the products.

Tables One to Four summarize the results. 28 participants submitted 59 index cards with 129 total entries. Because of redundancies, this came to 106 unique entries. Some individuals or tables submitted as many as 24 candidates while others submitted only one. We here describe the results in four Tables because we detect four different classes of submission although only one type was included in the instructions. Table One (n=54) represents lifeworks that this author designates as good candidates as systems science knowledge base sources. Table Two (n=26) has names that are questionable as direct inputs to systems science. Table Three (n=24) has names that provide merely philosophical background or precedents that the author judges are not directly on "how systems work" and so are not appropriate for the intended synthesis. Finally, Table Four (n=14) includes names of "fields" that are indeed expected to be part of the synthesis, but "fields" were not included in the instructions – only lifework of individuals.

This diversity indicates a very wide range of personal knowledge of the breadth of the field of system science sources and a potential source of problems for unification. A further indication is shown in Table Five that is a listing by this author in a recent review of persons he considers important to the synthesis of a knowledge base for how systems work. It contains a list of 60 names independently derived from those of the Pre-Conference workshop just described and partially reported in a recent SyEng Newsletter issue. It contains 33 names not found in Table One. The diversity also indicates that a truly comprehensive synthesis will not be accomplished unless the team working at the synthesis is sufficiently large and spends considerable time on the difficult task of reaching consensus.

Discussion of the submissions indicated that many of the participants had never even heard of candidates submitted by other participants. There were some submissions that had only one supporter. Some submissions were by the person submitting their own name. This indicates that even a sample of INCOSE SE and ISSS members self-selected for their interest in this project do not share a common idea of what can or must be synthesized, much less how to synthesize.

Documenting the Sources for Systems Science Synthesis. Our current efforts recognize the following "super domains" of systems thinking are co-extent and often competing in today's marketplace of systems ideas. The main problem we have encountered is that any one of these domains seems to be competing with instead of integrating their products. People experienced in one tend to resist even learning about the other. In some cases, the purposes, expectations, and methods of one domain are quite in contrast with the other domains. The worst-case scenario is that members of one domain cannot even see the relevance of another (e.g. across the human system vs. natural system chasm; or physical complex systems vs. engineered systems). In the most dramatic cases, the sources are not even considered sources of systems knowledge.

- Human or Social systems
- Artefact or Engineered systems
- Management systems
- Systems Philosophy and Theory
- Soft Systems Methodologies
- Hard Systems Methodologies
- Natural systems sciences (systems & synthetic biology, earth systems science, etc.)
- Hybrid Human-Natural Systems (the most pressing SoS problems facing society)
- Information systems
- Quantum physics
- Cosmology

Take for example the last two as case studies. In our work we have found abstracts for recent articles in quantum physics that cited no less than seven of the systems processes we are using to make a unified theory of how systems work. A similar trend is seen in recent science articles on earth systems science, systems biology, synthetic biology, and systems neuroscience. These types of articles are rigorous and often involve testing and experiments. The scientific articles may be reductionist in intent; but it is impossible for the natural sciences to study a natural system without learning something about how systems work because most all natural phenomena studied are ultimately systems based.

So, all of the natural sciences literature is examined in our approach for proven knowledge of how systems work. We find that they are good sources for understanding how interaction between systems processes mediate fulfillment of systems functions. Yet they are at present completely ignored in SE-based discussions on systems thinking. Proof of this was well demonstrated at the recent Mini-Conference of the INCOSE-LA Chapter. One of its streams was a series of sessions on Systems Thinking. Not a single talk addressed anything more than the oldest work on systems management typical of Checkland and Warfield. In this modern day, such shallow coverage cannot be judged as representative of best practices or state-of-the-art of systems science.

Rendering the Sources Usable for SE. The SysInformatics Lab Project for the core Introduction to Systems Science course in the upcoming Master Degree Curriculum for the new Systems Engineering Program at California State Polytechnic University (Cal Poly Pomona) [start date circa Winter, 2014] will have students cooperate in producing a massive bibliography of texts, research papers, reports, and editorials on each of the 55 or more systems processes described for our current system of systems processes theory synthesis. It will harvest, document, and attempt to integrate some 25 specific categories of information on each of the 55 systems processes.

This will create nearly 1,500 data bases, each with thousands of entries – clearly enough beyond easy human comprehension to require a new specialty of SysInformatics like that of BioInformatics to handle and apply the data efficiently. It is intended that these student workers will join with others doing their graduate M.S. or Ph.D. theses in Systems Engineering through the existing INCOSE SEANET program and other cooperating agreements between international SE educational programs. We are hoping the result will be a much wider knowledge base for new SEs of the future and the new SE discipline of the future as informed by systems science.

Proposed Protocol for Integrating the Systems Literatures

A Shared Method. At present the following dozen steps have been identified as the rubric or algorithm to get a unified systems science from the unconnected theories and wider range of sources just described. These headings are those intended for use in the online discussions and for the face-to-face Workshops sponsored by INCOSE, ISSS, or possibly IEEE-Systems. Some of the first steps here are the logical first steps but not the one's we jumped to do first. At the ISSS Workshop in San Jose we tried steps 6 and 7 to get a feel for how wide the experience base of participants was in that group. Steps 1 to 5 are logical precursors to the task, but they would likely generate so much preliminary and mainly philosophical debate that interest might wane before the meat of the matter was engaged.

At present, we anticipate that Steps #7 (what stuff shall we integrate), #8 (systems processes as the unifying framework), #9 (how those interact to make a system work), & #11 (how to identify when they don't work, why they don't work). Certainly each of these steps deserves full research paper coverage in the perspective of the overall task. The terms listed under each step are intended to help users imagine what might be addressed in that step. Compare #7 with the results of the lists obtained from participants in the ISSS'12 INCOSE Workshop (Table One).

(1) TYPES OF ARGUMENTS FOR/AGAINST UNIFYING SYSTEMS THEORIES (should we even attempt this task; advantages vs. disadvantages; strengths vs. weaknesses?)

• *Example Positions:* diversification is good; consensus is needed; utility for improved education; utility for improved communication/translation; advantages of discrimination, disambiguation; awareness of discinyms/nyms; excessive focus on personal synthesis; as a core knowledge base for SE, Sustainability, SS, SB, SN, ESS communities; cannot apply to all domains

(2) TYPES OF UNIFICATION or SYNTHESIS (make a general image of the product sought?)

• *Example Terms:* isomorphic; isomorphism; isomorph; homomorphism; discipline independent; domain independent; scale independent; tool independent;

(3) TYPES OF SIMILARITY (how get to the unification?)

• *Example Terms:* correlation, correspondence, metaphor, simile, allegory, analogy, homology, parable, story, symbol, we choose isomorphy;

(4) TYPES OF THEORY (what are we unifying?)

• *Example Terms:* evidence-based; experimental-based; mathematical-based; laws; abstraction levels; universal patterns; de-abstraction guidelines; solely logic-based;

(5) IDENTIFY ALL DOMAINS OF SYSTEMS WORK (across what categories are we unifying?)

• *Example Terms:* single isomorph; multiple isomorph; single domain/discipline; multiple domain/discipline; general; mathematical; method-based; tool-based; natural systems; science-based; social systems;

(6) TYPES OF SYSTEMS (across what taxonomy are we unifying? Are the taxonomies orthogonal?)

• *Example Terms:* open; closed; mature; immature; natural; social; human; physical; living; non-living; mechanical; biological; geological; astronomical; chemical; computer; symbolic; semantic;

manifest; cognitive; neural;

(7) IDENTIFY ALL CANDIDATE SYSTEMS THEORIES /or/ WORKS (what will be unified/synthesized?)

• *Example Terms:* Odum; Miller; Klir; Forrester; von Foerster; Auyang; Rosen-Kineman; Simon; Wakeland; Iberall; Warfield; Churchman; Beer; Boulding; Checkland; Weiner; Gel Mann; Troncale; etc. etc. the 75+ in Charts One to Three.

(8) TYPES OF SYSTEMS PROCESSES (or MECHANISMS) (evaluating this synthesis framework?)

• *Example Terms:* clusters of SoSPT 55 systems processes; or individual SPs in list; general systems lifecycle stage clusters; must be isomorphic

(9) TYPES OF META-RELATIONS (INFLUENCES BETWEEN SYSTEMS PROCESSES) (evaluating this synthesis framework?)

• *Example Terms:* linkage propositions; cross-level hypotheses; entailments;

(10) TYPES (or CHARACTERISTICS) OF HEALTHY SYSTEMS (crucial to defining dysfunction?)

• *Example Terms:* sustainability; dynamic equilibrium; adaptability; integrity; evolvability; emergent behaviors; dynamic behaviors; responsiveness; normal range of parameters; transtemporality-comparative temporality;

<u>(11) TYPES OF SYSTEMS DISEASES</u> (categories of dysfunction at systems level?)

• *Example Terms:* dysfunctions such as these cyberpathologies; rheopathologies; nexopathologies; heteropathologies; cyclopathologies; (see dedicated section below)

<u>(12) TYPES OF SYSTEMS TOOLS/METHODS vis a vis SYSTEMS PROCESSES</u> (how are tools or methods so important to SE & SS related to knowledge of systems processes?)

• *Example Terms:* include all in ISSS, IEEE, & SE listings; include all from I. Tibor's list; etc. Relate each tool to the underlying systems processes it represents.

Call for Alternative Protocols & Tactics. At any moment in the procedure, this group could change its algorithm given good arguments for a better protocol. We are actively debating the procedure we are using and expect it to change even while we are implementing it. We hope this report will stimulate feedback and suggestions. A shortened version, for example, would be:

- ✓ Document Need for & Utility of (presumably for both SS and SE)
- ✓ Decide Strategy & Framework
- ✓ Decide Criteria for (Sources of; Science of; a general theory; a SE core curriculum)
- ✓ Identify Systems Domains and Relationship of Domains
- ✓ Identify Candidate Systems theories to be integrated
- ✓ Identify broadest Sources of knowledge to be integrated
- ✓ Describe images of products and delivery systems

There are also alternative tactics to consider and decide. For example, would it be better or more efficient to focus on <u>one Systems Process</u> and review all the many sources of Table One and Four for info on that process, /or/ would it be better to focus on <u>one Systems Source</u> in depth harvesting pertinent info for all the Systems Processes simultaneously. Or both may occur because different SSWG participants choose their preference. In any case, the availability of a standard, consensual framework will bring the work together in a unified whole.

Relationship with Other SSWG Projects. Jack Ring has a community of scholars engaged in discussions toward finding a fundamental "ontology" of systems for SE. Most of their debate also contributes to the task of unifying systems theories. If they can find an inherent, self-organizing ontology in the systems science database, it could be directly used in protocol steps 3 to 6 above. Some of the SEs and SSs involved in Ring's project are also contributing to this project. There is also a natural relation between the results of these two SSWG projects and its new efforts on Systems Education. A detailed consensus on a unified systems science would directly contribute to a curriculum for training systems engineers. Cross-fertilization between the projects gives rise to greater consistency in use of terminology which is a central goal of the Praxis Project of SSWG.

Guiding Tenets for the Project of Unifying Systems Sources

Principles or Working Assumptions? One of the needs identified by our workshops is putting the many results of various systems authors in some standardized, "atomic" form. By "atomic" we mean in the form of unit statements that can be learned, taught, tested, improved. Too much of systems authorship consists of very long descriptions and too little of nuggets for easy communication and application. We would strive to be more like the natural sciences. In the harder sciences, like physics and chemistry, there are formulae and laws that crystallize a large amount of supporting data on how things work. In still rather rigorous sciences like geology and biology, there are word statements that describe how phenomena work.

These word statements are concise, describe how their systems work, and are supported by a wide range of experiments. In fact, in cell and molecular biology entire recent texts of 1,000 pages are organized into numerous small sections titled by statements that capture the knowledge units about a phenomenon. They describe how it works. Thus some workers present Checkland or Warfields (2006) work in terms of "insights" or principles to apply to SE problems. In these projects we reject the temptation to call our "atoms" of knowledge, principles for the following reason.

Systems science has long had such terms as Deutsch's Law or Ashby's Law. But when one examines the origin of such laws, one does not find a large body of testing and support for the relation embodied in the law, but rather an intuitive appeal for the relation that gave it wide acceptance. They become almost urban legends. This is not science. In fact, these putative "laws" should not be called laws at all, but rather "conjectures" after the culture of mathematics.

So hereafter in this paper and our work, we will respect the need for "statements" of fact in the knowledge base, but will identify ours as "working assumptions" or perhaps "working hypotheses" to emphasize that while some support for these have been documented, we advise and allow only conditional acceptance until more testing is completed and a greater consensus has evolved. A list of these provides something of a list of "tenets" for the project of unifying systems sources. For example, we recognize…

Working Hypothesis 1: [UNITS] Both a "science" of systems and SE need a systems theory made up of a series of unit statements that are testable, teachable, correctable, improvable, and tightly coupled.

Working Hypothesis 2: [PROVEN] These unit statements can and must be documented or proven in the source literature. This project has the goal of providing a rigorously "evidence-based" systems thinking as a step toward a more usable "science" of systems (next section).

Working Hypothesis 3: [PROCESSES] General theories of systems should be based fundamentally on systems processes (SP) /or/ mechanisms as their fundamental constituent or basic units. It should be noted that is through the understanding of "transformations," "mechanisms" or "processes" that the natural sciences have succeeded so well and are so useful. Likewise, a systems theory based on processes may well be the most usable by systems engineers and other users of systems theory.

Working Hypothesis 4: [COMPLETE SET] A full set of systems processes are both necessary and sufficient. Using all of them, rather than just concentrating on one. Some people attempt to define all systems by their favorite or most understood process, say, synergy (Corning, Haken) or feedback (Forrester, Meadows). All the systems processes mutually impacting.

Working Hypothesis 5: [AXIOMATIC] Systems processes are axiomatic. This means that they are so fundamental that they precede their manifestations in real systems. This working hypothesis presents two difficulties to many workers. How could they precede their manifestations? And if they are axiomatic, why do we need to provide evidence for them? Explanations of these work assumptions are beyond the scope of this paper and will be tested by discussions and testing.

Working Hypothesis 6: [MINIMAL] Systems processes are minimal states requiring the least resources to accomplish systems survival for all significant Newtonian and Informational parameters (such as least energy, least material, least space, least numbers, least information, especially regarding their combination as a whole gestalt)

Working Hypothesis 7: [EQUAL] All systems processes are equal. Some may precede others; others may be dependent. But for the purposes of the interactions within the set, none are dominant or exhibit a state of absolute control over the others.

Working Hypothesis 8: [INTERACTIVE] All systems processes interact with each other in non-trivial and definable ways forming a network. It is this network that creates the SYSTEM of systems processes (SoSP). It is the network that describes how systems work. No individual systems process is sufficient to describe how a system works. Interactions and mutual influences between systems processes can be expressed as language-based units we call Linkage Propositions.

Working Hypothesis 9: [ISOMORPHIC] Both systems processes and their Linkage Propositions must be proven to be isomorphic or present in every key phenomena of the several natural sciences, physical to living (demands concept of non-anthropocentric systems).

Working Hypothesis 10: [CONCURRENT] Systems processes exhibit “simultaneity” in their action; that is, all are available to each other and influencing each other at the same moment, immediate, parallel, concomitant in their influence.

Working Hypothesis 11: [STRUCTURPROCESS] The common, usual human distinction between “structure” and “process” does not obtain in SoSPT; structures indicators of process; structures are “slow” process; structures are enablers of process; there are no structure except through their role in enabling process; structures are an approximate illusion.

Working Hypothesis 12: [DISCRIMINATION] Although they intimately impact each other, systems processes can be distinguished from each other by their particular Identifying Features & Identifying Functions. Features and Functions commonly overlap to some degree; it is the gestalt for each systems process that accomplishes the differentiation despite overlap. The overlap that does exist indicates that the SPs are a set in network relations.

Working Hypothesis 13: [EXAGGERATED FUNCTION] Due to “exaggerated function,” similar to that found in the biological sciences, sometimes one systems process is much more recognizable or traceable in one disciplinary domain (one natural phenomena) than another (requires us to look at all systems everywhere, comparing and summing across them, to derive general theory).

Working Hypothesis 14: [PATHS] Although independent, there are certain motifs in the system of systems processes network such as “dependencies” or “prerequisites” that suggest chains of systems processes acting to perform certain super functions.

Working Hypothesis 15: [CLUSTERING] Differing sub-sets of associated systems processes are possible due to their cooperation in achieving necessary functions typical of systems that are visible and so sustainable. Organizing the systems processes in these clusters reduces the complexity of the long list of candidate processes.

Working Hypothesis 16: [CLASSIFICATION] The SoSPT can yield both a new “*taxonomy*” and "*ontology*" of systems across both manifest (natural) and engineered human systems. The above clustering may be a step in that direction.

Working Hypothesis 19: [DISCRIMINATION] By using the natural mutual influences of the system processes, SoSPT can help make better definitions of controversial, systems-based terms such as complexity and emergence as well as makes key discriminations between such conflated terms as growth, evolution, and development.

Working Hypothesis 17: [CORRESPONDENCE] The SoSPT has capability for development of both "translatability" and/or "correspondence" from the most general abstractions to most specific manifestations and back without losing place. Recognition of the SoSPT discinyms helps fulfill this feature. It is possible to establish both abstraction and de-abstraction protocols or methods for moving between manifest systems and scales of systems

Working Hypothesis 18: [NON-LINEAR CAUSALITY] The connected network of systems processes interacting via the linkage propositions provides many examples of non-linear causality and leads to recognition of several different types and their consequences.

Working Hypothesis 19: [IRRESOLVABILITY] Paradox and unresolvable, opposing dualities are welcome in SoSPT; they give dynamics to 45 levels of emergence of manifest systems at different scales. Paradox is natural. This conflicts with human expectation that all The same general system becomes discernable at different scales at different times as spin-offs of potential arising spontaneously from the previous scale of systems. (see Troncale, 1985)

Working Hypothesis 20: [LIMIT STATEMENT] There is not one, single general theory, but rather a hierarchy of related, ever more inclusive theories with defined ranges of validity relative to types or classes of systems.

So these tenets provide an overall image of the nature of the System of Systems Processes approach. It is one of the frameworks we are using to integrate systems sources. But it is important to emphasize that our team is not defending these tenets as much as further investigating each. We expect the list will be altered by future work. The intent is to improve these statements and possibly extend them.

Criteria for Identifying A True "Science" of Systems

Much of what is titled Science, Isn't. The word science is appended easily to any new discipline. Advocates of the new discipline want to imbue it with the sense of rigor, societal acceptance and funding opportunities that the physical and natural sciences have earned. As the person who suggested the "systems science" part of the title for the ISSS and guided it to a successful vote when I was ISSS Managing Director during the 80's, I am guilty of this hubris. But my intent was that we adopt some of the techniques to make it so, particularly the use of the scientific method. Instead, the term has been adopted very widely without incorporation of the scientific method. But not using the method that is successful in reductionist lab or fieldwork does not mean the products of such research should be ignored or rejected by those doing serious systems synthesis. To wit…..

Working Hypothesis 21: The natural sciences literature, even though produced by reductionist methods can yield important information and insights and facts that could be used in a theory of systems. We will prove the value of this in our work and have already in proving isomorphy (Troncale, 2012).

List of Criteria for Defining Science in the context of "science" of systems. Much of engineering is based on clever use of proven facts or math from the sciences. If we are to build a synthesis that leads to a true "science" of systems for use in SE, then our first step is to distinguish what we will accept as science and what is not. This becomes a particular thorny problem in SE because a great subset of SE is managing very large projects. And there are wide differences between what mangement science calls science and what the natural sciences call science. Here are some of the criteria we are studying in this thread of presentations and papers that might be used to ensure that the product is more a "science" of how systems work than merely systems thinking.

- Provides a self-consistent theory of past proven facts
- Has theories that enable asking answerable questions
- Enables predictions and relations that are testable
- Provides methods and suggested measurables to determine causation
- Provides reliable methods to address non-linear causation
- Yields results that constrain possible theories
- Enables building and testing of models and simulations of systems

The Systems Process-Based Synthesis to-date is SoSPT

This SSWG project team has initially been evaluating the System of Systems Processes Theory (SoSPT) as a framework for advancing unification of systems sources. It is anticipated that workers will harvest the "atoms" or "units" of many different theories, approaches, and applications under the umbrella of systems thinking attaching them to the SoSPT framework. Past work (Troncale, 1978, 1985) identified as many as 105 candidate systems processes. These are mechanisms of change that are found common or universal across large numbers and types of systems at many different scales of nature.

Most transcend the usual separated distinctions between physical, living, and social/human systems. They are thought to be common because they enable systems to work. In a sense they have been "tested" for us over 12 billion years by nature for their efficacy in making systems work. We detect them post facto by comparing systems now. We use focus on systems process to eliminate a plethora of terms used in systems thinking and philosophy that do not directly contribute to describing how systems work. The criteria for deciding what is a systems process and what is not include the following.

(1) fulfills the working definition of "process;"
(2) fulfills the working definition of "systems-level;"
(3) can be proven to be isomorphic; found in many if not most mature systems; & all sciences;
(4) can be demonstrated to increase persistence or sustainability of manifest systems;
(5) has very rich associations or influences on the other systems processes;
(6) exhibits all of the identifying features for that process (does not overlap with other SPs);
(7) rich in associated literature of empirical or experimental or formal data;
(8) is domain-independent, discipline-independent, tool-independent, scale-independent, and phenomenon-independent;
(9) illustrates key disciplinary phenomena for each case study;
(10) understood in sufficient detail;
(11) recognized by workers in relevant specialties (or key enough to deserve future work);
(12) has exemplars of application to improve systems functions in defined contexts;
(13) enables citation of the range of systems for which it is present or valid;
(14) represents an intriguing advance in human knowledge in itself;
(15) can be used to teach or train others in detailed knowledge of how systems work;

As important as identifying the most comprehensive list of systems processes to date is the effort then to collect a huge database on each individual systems process from the systems source literature. This project is attempting to collect data in 25 categories for each systems process. Imagine the utility to future systems designers of such a database or set of workbooks. The categories of data sought from sources for unification that have been chosen to date include the following (in order of highest utility for presentation):

1. Introductory Examples
2. Identifying Features
3. Identifying Functions (strprocess relations & contexts)
4. Proof of Isomorphy /or/ Limits of Validity & Application
5. Linkage Propositions
6. Prerequisite & Dependency Relations
7. System’s Pathologies
8. Modeling Symbols & Logos; Use in Computer Modeling
9. Discinyms and Translational Tables
10. Comparative Word Definitions
11. Natural Science Phenomenological Case Studies
12. Types and Taxonomies
13. Measurables
14. Equations and Formalizations
15. Associated Tools and Techniques
16. Exemplars of Application
17. Brief History
18. Workers
19. Institutions
20. Funding Agencies
21. Bibliographies and Literature
22. FAQ’s (frequently asked questions about)
23. Current Consensus Findings (factoids; info bits)
24. Future Research Questions
25. Comparative Use in Established Systems Sources

The work of the SSWG participants has reduced the original list of 105 to about 55 recently and these are shown in Table Six. Since then, workers have discussed and evaluated several ways to aggregate or cluster the list of systems processes. Some of these clustering strategies include aggregation according to:

- ✓ Stages of the proposed general systems lifecycle (Troncale,)
- ✓ S*Pattern Hierarchy of the S*Metamodel (Schindel)
- ✓ Utility of Process in Enabling Key Systems Functions
- ✓ According to Pre-requisites and Dependencies
- ✓ According to the “operations” described by their Linkage Propositions

The most important contribution of the SoSPT may be the identification of the ways that systems processes influence each other in making systems work. Those multiple influences are discovered in the natural sciences literature and so have experiments supporting them. This leads more to a “science” of systems than was possible before. But more important, it drives theory to a new meta-level that elucidates the actual mechanisms by which systems of all kinds work. It is not just the processes but how the processes influence each other that achieves sustainable systems dynamics.

Table Six shows this by the many links (lines, edges) that are shown between a select number of processes (shown as boxes at periphery). Each line represents a specific Linkage Proposition found in the literature. The total set shows the network of connected systems processes as a network of interactions – i.e. a SYSTEM of systems processes.

The whole point of the SSWG unification exercise is to vastly increase the resolution or detail of what is known about how systems work. The SSWG suggests that this goal would result from the future availability of 25 important packets of data on 55 key systems processes with 100's of their mutual impacts included.

Discovery and Elucidation of A New Systems Pathology

SSWG workers argue that this theory accomplishes more than just dramatic increase in the specificity of statements and supporting data describing how systems work. It could also lead to better understanding of how systems don't work. Initial work () has suggested that one could extend the success of medicine and systems biology in elucidating human diseases to studying "top-down" systems-level diseases. Each of the key systems processes could be examined in case studies for not achieving the function they normally perform in making a system sustainable. That quickly would yield a "taxonomy" or "classification" of possible dysfunctions that is much more detailed than currently possible. Each systems process would then name an entire category of dysfunctions for SEs to be on the lookout for or avoid by design. For example,

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

Specific dysfunctions could then be named and clustered into each of these "classes" as shown in the expanded examples below. Consider how many more such specific dysfunctions could be added with large teams guided by these classifications.

- **Cyberpathologies** (abnormal delays of feedback loops relative to response needed; mismatch in increments or degree of change with needed magnitudes; mistake in or absence of coupling of negative and positive feedbacks; dysfunction due to feedback not present at all; missing feedback across hierarchical levels; feedback connect to wrong part of interacting net; dysfunctional change in output no longer calibrated to need in systems environment)
- **Cyclopathologies** (dyfunction due to mistimed cues or regulators for established states or stages; cycle stages occurring out of obligate sequence; absence of regulatory controls for phases in oscillations; imbalance of positive or negative feedbacks driving required oscillation; dysfunctions due to either hypercoherence, incoherence, or broken phase relations between two or more interlocked cycles or oscillations; loss of entrainment of population numbers sharing a cycle; loss of cycling at one scalar level needed at another)

- **Hapsopathologies** (too many or too few nodes or unstable connections between nodes; negative consequences of "degeneracy" or "equifinality" inherent in network structure; imbalance between diversity of connections or nodes to network function &/or dynamics; disintegration of key or central nodes; overload of interaction numbers & flows on a key or central node; incompatibility of subgroups or motifs of interlocked or interdependent nodes; errors in development of network structure or dynamics)
- **Rheopathologies** (deviating from fractal branching allometries& efficiencies at particular scales; dysfunction of boundaries and limits relative to flows; interrupted transitions between laminar & turbulent flows; disruption of "insulations" for flows; dysfunctional effects of inter-entity binding & interaction on flow continuity; neglecting or ignorance of opposing field effects on flows; disturbances in the asymmetries that cause flow or incompatibilities of coincident flows)

Once each of the specific dysfunctions has been recognized, this new Systems Pathology would provide a ready framework for studying each specific disease as medicine has done for 2000 years gradually accumulating an understanding of causes (etiology), a better way of detecting each dysfunction (diagnosis), and a tighter coupling of alternative treatments with outcomes (prognosis). The increased knowledge of how systems don't work could help avoid problems in the earliest stages of describing the requirements of a needed system, and in the design and maintenance of a system.

In a significant addition to the proposed Systems Processes provided a taxonomy and clues to how systems don't work, the Linkage Propositions of the SoSPT would be another fertile source of information on how a system could dysfunction. Disruption of any of these mutual influences between systems processes, either from absence of the coupling itself or dysfunction of the coupling would be a source of error. A third way that SoSPT would contribute to a greater understanding of systems dysfunction would be its exposition of a dozen of non-linear causalities and their impacts. This latter aspect would even be useful to modern medicine and Systems Biology; systems science and systems engineering would then return contributions to the rigorous fields contributing to it.

Posters introducing and describing the new, top-down Systems Pathology and listing nearly a hundred of the Linkage Propositions under study will be displayed at IS'13, especially in the pre-conference Tutorial-Workshop entitled "Systems Processes and Pathologies."

Beneficial Uses of These Products for Systems Engineering

It is too early in this project to prove that these products will be useful for the practice of systems engineering. But there are many suggestions for roles that greater knowledge of the systems processes, pathologies, and linkage propositions could perform for systems engineering. For example:

- New Knowledge Base & Tools for Improved *de novo* Engineering of SoS & Complex Sys
- New Knowledge Base & Tools for Detailed Diagnosis of Ailing SoS & Complex Sys's
- SE Education (distanced, on-line learning courses on SysSci & SysPath)
- Certification as a sub-specialty of SE
- Help satisfy huge need for improving our industrial & social use of natural systems
- Enables wider set of application areas for systems engineering (fixing natural systems)
- SOS Problems: Enable approaches or solutions to "system of systems" crises
- Sustainability: more rigorous approaches

References

Auyang, S.Y. (1995) *How is Quantum Field Theory Possible?* Oxford University Press, N.Y.

Auyang, S.Y. (1998) *Foundations of Complex Systems Theory: in Economics, Evolutionary Biology, and Statistical Physics.* Cambridge University Press, U.K., *404 pp.*

Beihoff, B. and W. Schindel. 2012. "Systems of Innovation I.: Summary Models of Their Health and Pathologies," in INCOSE Proceedings.

Friendshuh, L. & L. Troncale (2012) "SoSPT I.: "Identifying Fundamental Systems Processes for a General Theory of Systems (GTS)," in Proceedings of the 56th Annual Conference, International Society for the Systems Sciences (ISSS), July 15-20, San Jose State Univ. (electronic proceedings: Go to http://journals.isss.org), 22 pp.

Guimera, R. B. Uzzi, J. Spiro, & L. A. Amaral. 2005. "Team Assembly Mechanisms Determine Collaboration Network Structure and Team Performance," *Science,* 308: 697-702.

INCOSE, International Workshop. 2010. Phoenix, Arizona

INCOSE, International Workshop. 2011. Phoenix, Arizona

INCOSE, International Workshop. 2012. Jacksonville, Florida Beihoff and Schindel, presiding.

ISSS, Pre-Conference Workshop. 2012. San Jose, California, July 15th

McNamara, C. & L. Troncale (2012) "SoSPT II: ," in Proceedings of the 56th Annual Conference, International Society for the Systems Sciences (ISSS), July 15-20, San Jose State Univ. (electronic proceedings: Go to http://journals.isss.org), 20 pp.

Sparber, J. 2012. "

Troncale, L.1978 "Linkage Propositions Between Fifty Principal Systems Concepts," in *Applied General Systems Research: Recent Developments and Trends : N.A.T.O. Conference Series II. Systems Science* (G. J. Klir, Ed.) Plenum Press, N.Y., pp. 29-52.

———. 1982. "Linkage Propositions Between Systems Isomorphies" in *A General Survey of Systems Methodology: Vol. I. Conceptual and Mathematical Tools* (L.Troncale, Ed.) Intersystems Publ., Seaside, Ca., pp. 27-38.

———. 1985. "Duality/Complementarity As A General Systems Isomorphy." in *Systems Inquiring: Vol. I. Theory Philosophy Methodology* (B. Banathy, Ed.), Intersystems Publications, Seaside, Ca. pp. 186-199.

———.1986. "Knowing Natural Systems Enables Better Design of Man-Made Systems: The Linkage Proposition Model." in *Power, Utopia and Society: New Approaches to Complex Systems.* (R. Trappl, Ed.) Plenum Press, N.Y., pp. 43-80.

———. 2001. "The Future of Systems Science – The Future of Natural Systems Science" in Wilby, J. and G. Gagsdell, Eds., Understanding Complexity, Kluwer Academic/Plenum Publishers, pp. 219-238.

———. 2006. "Towards A Science of Systems" *Systems Research and Behavioral Science*, Special Issue on J.G. Miller, Founding Editor (G.A. Swanson, Ed.) 23(3): 301-321.

———. 2011a. "Would A Rigorous Knowledge Base in Systems Pathology Add Significantly to the SE Portfolio," *CSER'11 Proceedings*, Conference on Systems Engineering Research, April 14-16, Redondo Beach, Ca., 11 pp. (electronic proceedings)

———. 2011b. "Can a Theory that Integrates the Natural Systems Sciences Help Systems Engineering of Defense Against Security Threats?" *ITNG'11 Proceedings*, Las Vegas, Nevada, 6 pp. (electronic proceedings).

———. 2012. "SoSPT V: Proving Isomorphy by 52 Case Studies: Testing for Cycles and Cycling Across Disciplines, Domains, and Scales" in ISSS Proceedings, 56th Annual Meeting in San Jose, CA. go to http:isss.journals.com (presented as a 68 slide ppt)

Warfield, J.N. 2006. *An Introduction to Systems.* World Scientific Publishing Co., Singapore.

Biography for L. Troncale

Dr. Len Troncale is Professor Emeritus of Cell and Molecular Biology, and past Chairman of the Biological Sciences Department at California State Polytechnic University. He served as Director of the Institute for Advanced Systems Studies, and Coordinator of its NSF-supported Systems-Integrated-Science General Education Program from 1972 to 2012. He has served as VP and Managing Director of the International Society for General Systems Research (SGSR), and President of the International Society for the Systems Sciences (ISSS). He has served as Visiting Professor at the University of Vienna, Austria, CSU Monterey Bay, and CSU Sonoma and as Research Associate at IIASA (the International Institute for Applied Systems Analysis). He was a member of the Board of Directors of IFSR (International Federation for Systems Research) and still serves on the Board of Trustees for ISSS.

Currently he has been presenting numerous talks at INCOSE and at Systems Biology conferences and serves as Lead for two official projects of the Systems Science Working Group of INCOSE (the International Council on Systems Engineering). Dr. Troncale has published 87 articles, abstracts, editorials and reports, 18 conference posters, served as Editor on 11 projects, delivered 115 invited and computerized presentations and demonstrations in 23 countries and served as P.I. on 52 grants and contracts for $5.3M from a variety of federal, state, and private organizations such as the NSF, DOE, ONR, HUD, the HHMI and the Keck Foundation, as well as the CSU System.

Supplemental Charts

Please find in this section five charts & six tables referred to & described further in the text…

Chart One: A mapping by the International Institute of General Systems Studies, Pennsylvania to show the diversity of systems approaches and their linneages. In our opinion the note cards include many things which are classical and clearly not systems-based, but the breadth of citation is well done.

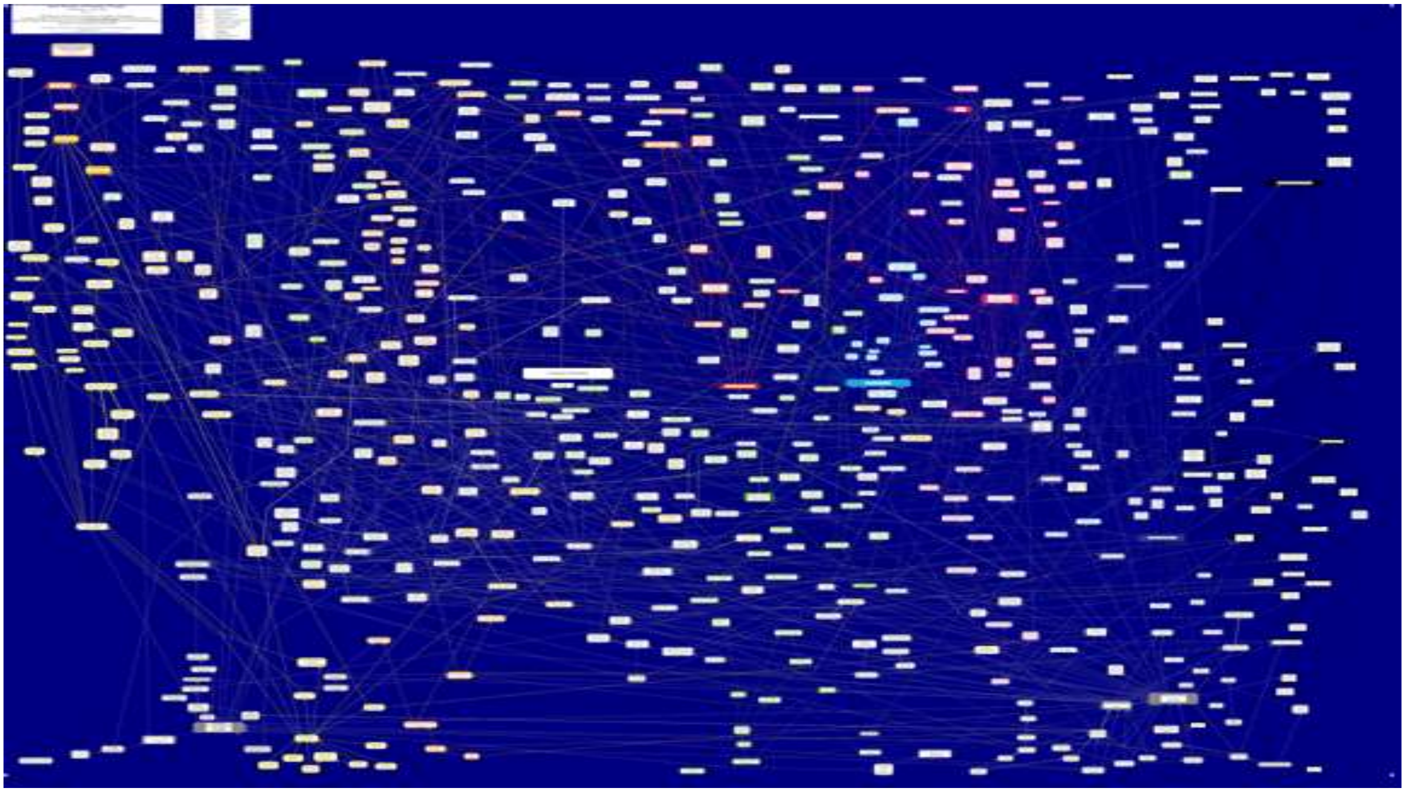


Chart Two: A mapping of the area of Complex Adaptive Systems (CAS) mostly studied by natural scientists and mathematicians. Produced by Brian Castellani. Some of these are in the IIGSS chart and some are additional workers to synthesize.

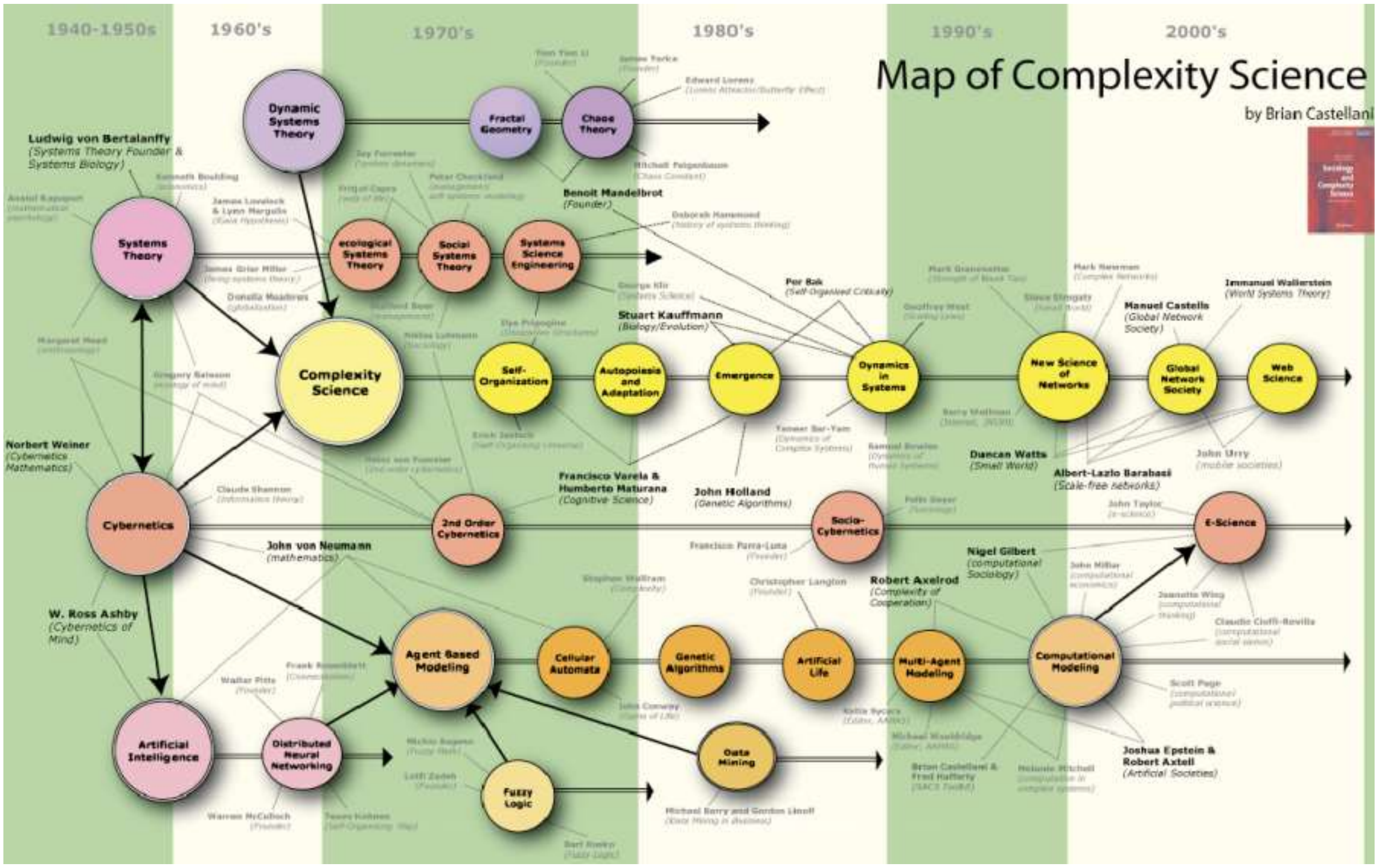


Chart Three: An interactive network of tools used to study some specific complex systems characteristic of different systems domains and application needs.

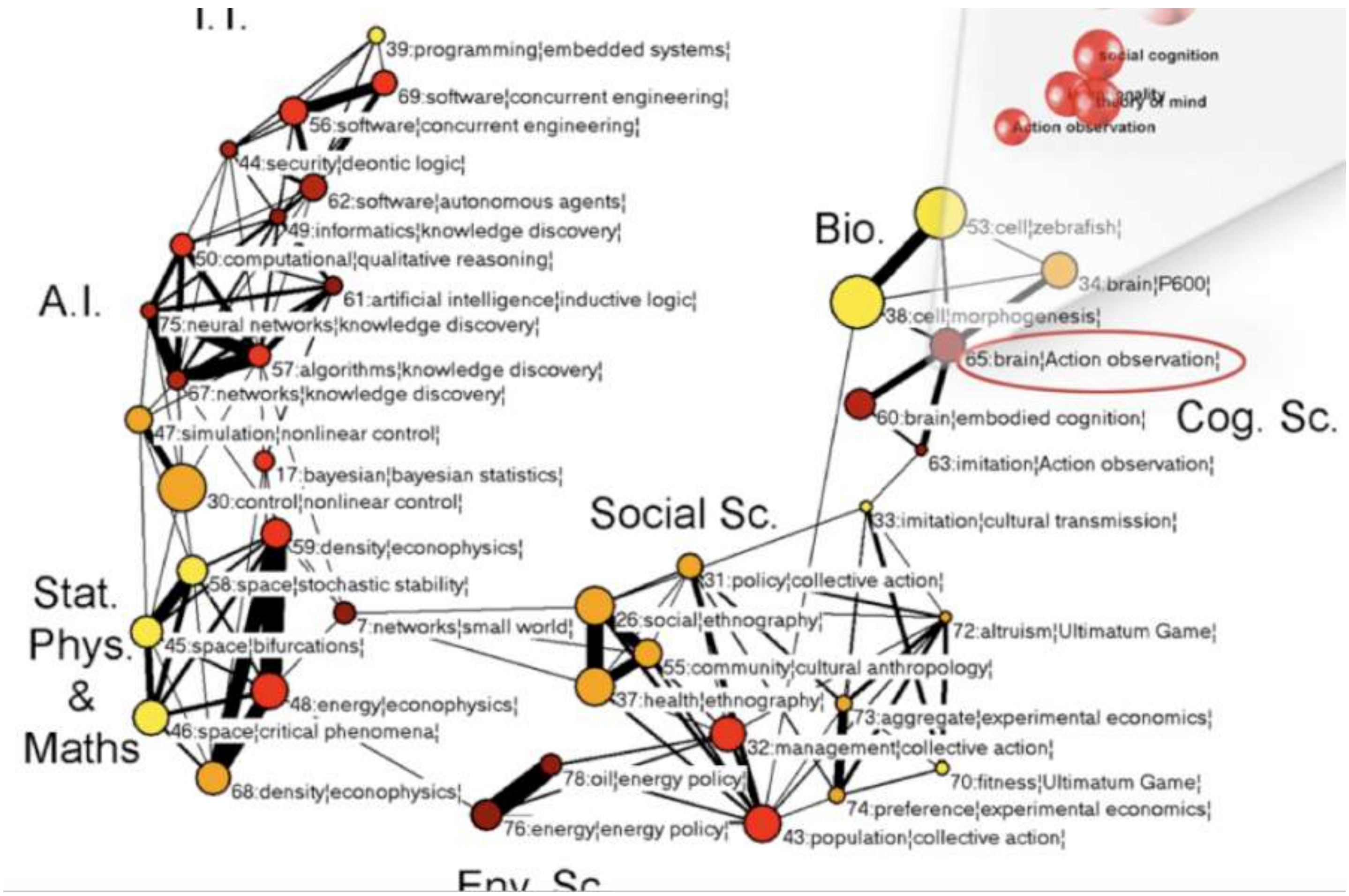
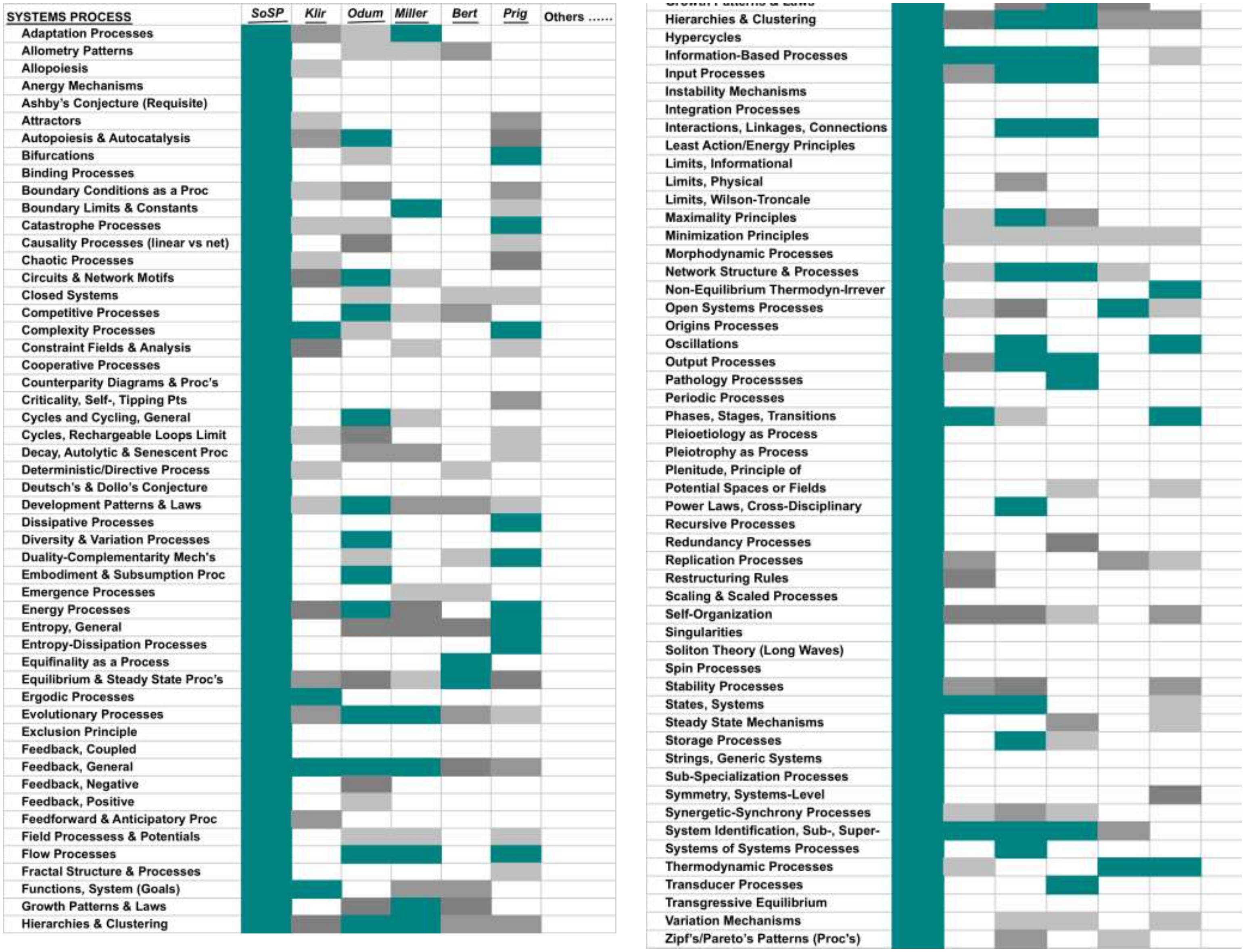


Chart Four: Representative example of comparative systems analysis of coverage of candidate systems processes across five key systems science texts. This is the original list of >100 candidate Systems Processes (SPs) to provide the greatest resolution for comparison across the five texts. Of course, the greatest coverage is in the first column which represents the build-out version of the SoSPT and of INCOSE's systems synthesis effort. Some of the SPs of our current synthesis are covered by all workers; many by none at all; some only a little by a selected few. Intensity of white (no coverage) to darker shades of grey (more coverage) shows coverage at a glance. Future work of this project will actually cite number of pages covered per worker, if any, and an electronic link will indicate specific pages.



SYSTEMS PROCESS	SoSP	Klir	Odum	Miller	Bert	Prig	Others ……
Adaptation Processes	■	▒	░	■			
Allometry Patterns	■		░	░	▒		
Allopoiesis	■	░					
Anergy Mechanisms	■						
Ashby's Conjecture (Requisite)	■						
Attractors	■	░				▒	
Autopoiesis & Autocatalysis	■	▒	■			▓	
Bifurcations	■		░			■	
Binding Processes	■						
Boundary Conditions as a Proc	■	░	▒			▒	
Boundary Limits & Constants	■			■		░	
Catastrophe Processes	■	░	░			■	
Causality Processes (linear vs net)	■		▓			░	
Chaotic Processes	■	░				▓	
Circuits & Network Motifs	■	▓	■	░			
Closed Systems	■		░		░	░	
Competitive Processes	■		■	░	▒		
Complexity Processes	■	■	░			■	
Constraint Fields & Analysis	■	▓		░		░	
Cooperative Processes	■						
Counterparity Diagrams & Proc's	■						
Criticality, Self-, Tipping Pts	■					▒	
Cycles and Cycling, General	■		■	░			
Cycles, Rechargeable Loops Limit	■	░	▓			░	
Decay, Autolytic & Senescent Proc	■		▒	▒		░	
Deterministic/Directive Process	■	░			░		
Deutsch's & Dollo's Conjecture	■						
Development Patterns & Laws	■	░	■	▒	▒	░	
Dissipative Processes	■					■	
Diversity & Variation Processes	■		■				
Duality-Complementarity Mech's	■		░		░	■	
Embodiment & Subsumption Proc	■		■				
Emergence Processes	■			░	░		
Energy Processes	■	▓	■	▓		■	
Entropy, General	■		▓	▓	▓	■	
Entropy-Dissipation Processes	■					■	
Equifinality as a Process	■				■		
Equilibrium & Steady State Proc's	■	▒	▓	░	■	▓	
Ergodic Processes	■	■					
Evolutionary Processes	■	▒	■	■	▒	░	
Exclusion Principle	■						
Feedback, Coupled	■						
Feedback, General	■	■	■	■	▓	▒	
Feedback, Negative	■		▓				
Feedback, Positive	■		░				
Feedforward & Anticipatory Proc	■	▒					
Field Processess & Potentials	■		░	░		░	
Flow Processes	■		■	■		■	
Fractal Structure & Processes	■					░	
Functions, System (Goals)	■	■		▒	▒		
Growth Patterns & Laws	■		▓	■	▓		
Hierarchies & Clustering	■	▓	■	■	▒	▒	
Hypercycles	■						
Information-Based Processes	■	■	■	■		░	
Input Processes	■	▒	■	■			
Instability Mechanisms	■						
Integration Processes	■						
Interactions, Linkages, Connections	■		■	■			
Least Action/Energy Principles	■						
Limits, Informational	■						
Limits, Physical	■		▒				
Limits, Wilson-Troncale	■						
Maximality Principles	■	░	■	▒			
Minimization Principles	■	░	░	░	░	░	
Morphodynamic Processes	■						
Network Structure & Processes	■	░	■	■	░		
Non-Equilibrium Thermodyn-Irrever	■					■	
Open Systems Processes	■	░	▓		■	░	
Origins Processes	■						
Oscillations	■		■			■	
Output Processes	■	▒	■	■			
Pathology Processses	■			■			
Periodic Processes	■						
Phases, Stages, Transitions	■	■	░			■	
Pleioetiology as Process	■						
Pleiotrophy as Process	■						
Plenitude, Principle of	■						
Potential Spaces or Fields	■			░		░	
Power Laws, Cross-Disciplinary	■		■				
Recursive Processes	■						
Redundancy Processes	■			▓			
Replication Processes	■	▒			▒	░	
Restructuring Rules	■	▓					
Scaling & Scaled Processes	■						
Self-Organization	■	▓	▓	░		▒	
Singularities	■						
Soliton Theory (Long Waves)	■						
Spin Processes	■						
Stability Processes	■	▒	▓			▒	
States, Systems	■	■	■			░	
Steady State Mechanisms	■			▒		░	
Storage Processes	■		■	░			
Strings, Generic Systems	■						
Sub-Specialization Processes	■						
Symmetry, Systems-Level	■					▓	
Synergetic-Synchrony Processes	■	░	▒	░			
System Identification, Sub-, Super-	■	■	■	■	▒		
Systems of Systems Processes	■		■				
Thermodynamic Processes	■	░			■	■	
Transducer Processes	■			■			
Transgressive Equilibrium	■						
Variation Mechanisms	■		░	░		░	
Zipf's/Pareto's Patterns (Proc's)	■		▒		░		

Chart Five: This diagram graphically shows 85 specific Linkage Propositions (lines or edges) as partial causes of (so non-linear causation) of 42 systems processes. Thus, this diagram is an early indication that our synthesis is a detailed depiction of how systemness in general works; it is a SYSTEM of SYSTEMS PROCESSES (SoSP).

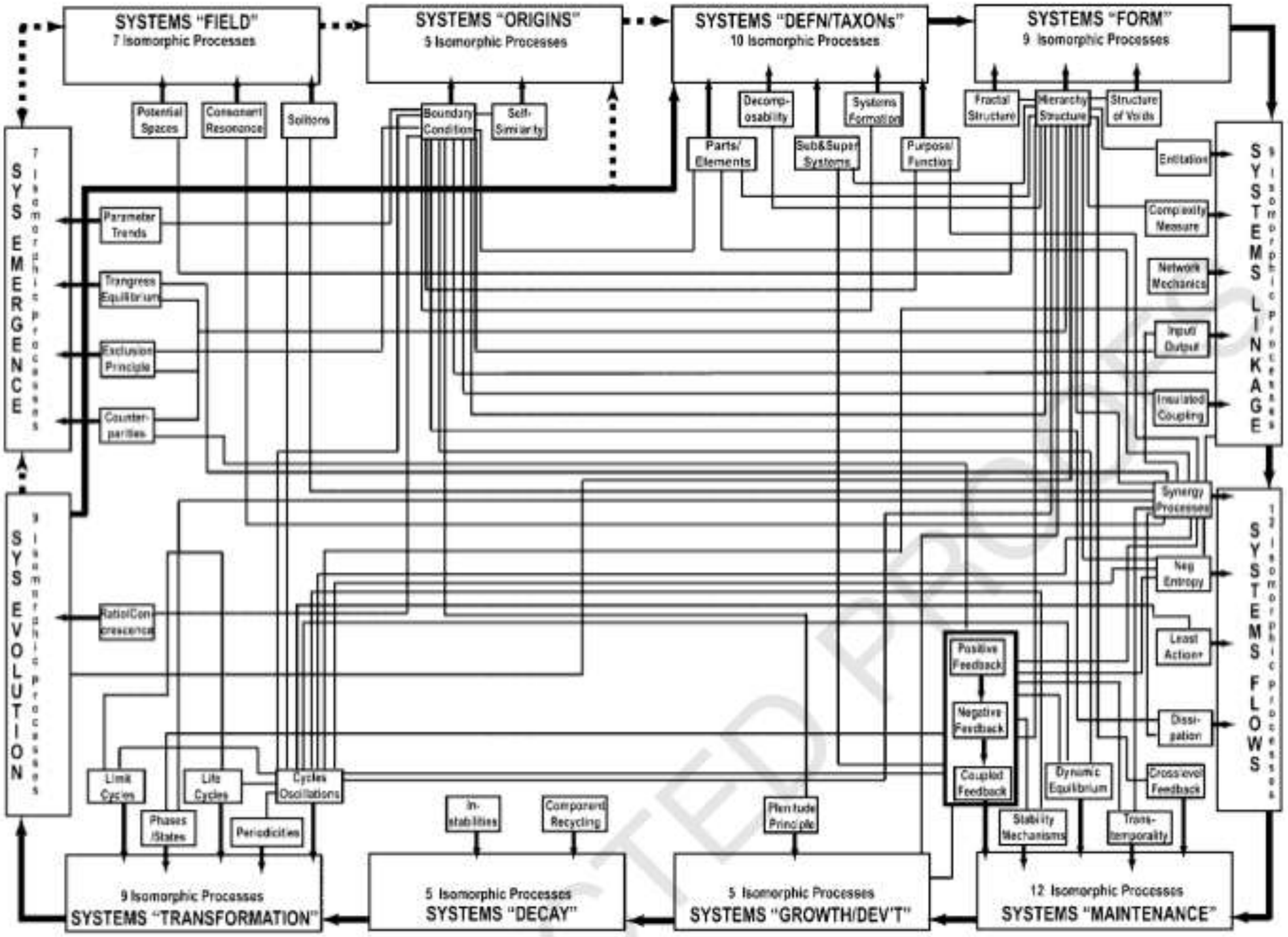


Figure 2. Network map showing ~ 85 linkage propositions between five isomorphic processes and the 42 systems processes with which they experience mutual influences

Tables One to Four: Products of Sunday, July 15th Pre-Conference Workshop at the 56th Annual Conference of the ISSS (International Society for the Systems Sciences), San Jose, Ca.

A mixture of 28 INCOSE systems engineers and systems thinkers were asked to list what products needed to be synthesized to attain a unified systems theory. Analysis and significance is discussed in text.

Table One: Alphabetical Listing of Systems Science Theory Makers, Lifeworks, Text Authors, As Sources of Information for Unification of Systems Theories

Number in parenthesis following name indicates "number of times that name was submitted independently" by workshop attendants. These lists were produced either by individuals or tables of individuals working separately. Goal was to produce a group listing that was more comprehensive than any one individual or table was capable of producing. The purpose of the exercise was to widen the minds of participants as regards work that should be included in the synthesis. Question marks indicate possible misspelling or person unknown to rapporteur.

1. Ackoff, Russell
2. Ashby, Ross
3. Axelrod, Robert M. (cooperation)
4. Banathy, Bela (systems education)
5. Bar-Yam, Yaneer (2X)
6. Barabasi, Albert-Laszlo
7. Bateson, Gregory (2X)
8. Beer, Stafford (3X)
9. Bertalanffy, Ludwig von (3X)
10. Boulding, Kenneth
11. Callon (actor net theory)
12. Capra, Fritiof
13. Checkland, Peter (3X)
14. Chomsky, Noam
15. Churchman, C.W.
16. Doxiadis (Ekistics)
17. Foerster, Heinz von (2X)
18. Forrester, Jay
19. Fuller, Buckminster
20. Hieronymi, Andreas
21. Holland, John
22. Jantsch, Erick
23. Kaufmann, Stuart
24. Klir, George (3X)
25. Latour (actor net theory)
26. Lazlo, Irwin
27. Leontiev (systems economics)
28. Luhmann (2X)
29. Mandelbrot, Benoit
30. Maturana, Humberto (3X)
31. McCuhan, Marshall
32. Mead, Margaret (2X)
33. Meadows, Donella
34. Metcalf, Gary
35. Miller, James (3X)
36. Mitchell, Melanie
37. Odum, Howard
38. Priogogine, Ilya
39. Rapoport, Anatol
40. Ring, Jack (2X)
41. Senge, Peter
42. Shannon, Claude
43. Simms
44. Simon, Herb
45. Sterman
46. Strogatz, Steven
47. Thom, Rene
48. Troncale, Len (3X)
49. Vesterby, Vince
50. Vickers, Geoffrey
51. Varela, Francisco (3X)
52. Warfield, John
53. Weiner, Norbert (2X)
54. Wolfram, Stephen

Table Two: Questionable entries?

Names submitted that need additional information provided to support inclusion as sources of significant info to integrate in the area of science of systems or systems thinking. Searches on Google or Wikipedia did not result in any information or so much information of a non-specific kind that no discrimination could be made. Question marks indicate possible misspelling (or inability to read long hand record) or unknown person.

1. Alter, Steven (Work System Theory?)
2. Alexander, Christopher
3. Angyal?
4. Arango, Juan
5. Berkhof
6. Beth?
7. Campbell, Joseph
8. Cohen
9. Darwin, Charles
10. Dossey?
11. Feylzberg, ????
12. Feyerman???
13. Gall, John
14. (Macullah) (????)
15. Macy ????
16. Nakamorai
17. Nardi & Kupelinen?
18. Nelson and Winter?
19. Newman
20. Newton, Isaac
21. Nonaka
22. Page, Scott E.
23. Taquish
24. Virella???
25. Wallace, Alfred Russell
26. Watts

Table Three: Alphabetical Listing of Philosophical Underpinnings of Systems Thinking

Names submitted that might qualify as holistic thinkers but not in the stricter sense of contributing to a science of systems or a modern day direct sense of systems. Nevertheless many of these philosophers or revered thinkers or futurists portrayed the sense of wholeness. Again question marks indicate possible miss-spellings.

1. Bergsan?
2. Black Elk
3. Buddha
4. Bunge, Mario
5. Christ
6. Compte, Auguste
7. Deleuze & Guattra Anizomes????
8. Feyerman? Feyerabend ?? 2X
9. Freud
10. Heidegger, M.
11. Husserl?
12. I Ching
13. Jung
14. Kant, I.
15. Lao-Tse
16. Linnaeus
17. McCuhan, Marshall
18. Namatesque ????
19. Polanyi, Michael (some emergence; anti-reductionism)
20. Popper, Karl
21. Russell, Bertrand
22. Sitting Bull
23. Truvious ????
24. Whitehead, Alfred North

Table Four: Alphabetical Listing of Fields, Classes or Types of Theory as Sources of Unification of Systems Science

Names submitted that did not follow original instructions of listing workers whose work should be included in the intended unification of systems theories. These do not identify lifeworks as much as identify categories for possible inclusion.

1. Activity Theory (Actor Network Theory)
2. Autopoiesis
3. Complex Adaptive Systems
4. Cybernetics
5. Ekistics
6. General Systems Theory
7. Living Systems
8. Operations Research
9. Semiotics, aspects of
10. Soft Systems Theory
11. Systems Dynamics
12. Systems Theory
13. Systems Thinking
14. Systems Science

Table Five: Author's own List of Lifeworkers that Should Be Included in the Unification of Systems Science

The author of this report was moderator of the Pre-Conference Workshop for Tables 1-4 so did not submit his candidate names. This would have been his submission from the "top of the head" memory and represents only a partial list of those he considers important. Note that there are 33 unique names on this list (shown in bold) not redundant with the Table One list above. Adding them to the Workshop products would have produced a total list 162 (in just half an hour of brainstorming) with 87 as primary sources for unification of systems theory.

1. **Abraham, Ralph (chaos theory)**
2. Ackoff, Russell (sys mgmnt)
3. **Allen, Tim (hierarchies)**
4. Ashby, Ross
5. **Auyung, Sunny (fdns complex systems)**
6. **Bak, Per (self-criticality)**
7. Bar Yam, Yaneer (NECSI products)
8. Barabasi, Albert-Laszlo (network theory)
9. **Barrow, John D. (theory of everything)**
10. Beer, Stafford
11. Bertalanffy, Ludwig von (GST)
12. **Bosch, Ockie (bayesian stats)**
13. Boulding, Kenneth (GST & economics)
14. Capra, Fritiof
15. Checkland's, Peter (soft systems meth)
16. Churchman's, C. West (sys mgmnt)
17. **Corning, Peter (synergy, biological)**
18. **Cowan's,**
19. **Earth systems science (as a field)**
20. **Eigen, Manfred (hypercycles)**
21. Forrester, Jay (feedback; syst dynamics)
22. **Francois, Charles (encyclopedia)**
23. **Garajidajeh, Jamshid**
24. **Gel Mann, Murray (flexion theory)**
25. **Gerard, Ralph (systems neurobiology)**
26. **Haken, Herbert (synergy, physical)**
27. **Hammond, Deborah (systems history)**
28. Holland's (agent-based modeling)
29. **Hood's systems biology,**
30. **Iberall, A.S. (viable systems)**
31. **Jackson, Michael (SSM)**
32. Kauffman, Stuart (emergence)
33. Klir, George (reconstructability Theory)
34. **Langton's (artificial life)**
35. Lazlos' systems philosophy,
36. **Lorenz, Konrad (chaos)**
37. Mandelbrot, Benoit (fractals)
38. Meadows, and more);
39. **Mesarovic, Mihalo (systems biology)**
40. Miller, James (living systems theory)
41. Odum, Howard (systems ecology) (ecological economics)
42. **Pattee, Howard (hierarchy theory)**
43. Prigogine, Ilya (thermodynamics)
44. Rapoport, Anatol (GST & game theory)
45. **Randall, Lisa (systems physics)**
46. **Salthe, Stan (hierarchies)**
47. Senge, Peter (systems management}
48. Shannon's (information theory)
49. **Skyttner, Lars (popularizer)**
50. Thom, Rene (catastrophe theory)
51. Troncale,Len (sys processes/pathology)
52. von Foerster, Heinz(self-organization)
53. Warfield's, John (ISM)
54. **Weinberg, Gerald (sys engineering)**
55. **West, Gregory (systems allometry)**
56. **Whiteside, George (sys chemistry)**
57. **Wilson, Albert G. (hierarchies)**
58. **Wymore's, Wayne (sys engineering)**
59. **Zadeh, Lofti (fuzzy math)**
60. **Zeeman (catastrophe theory)**

Table Six: Our Current Working List of Systems Processes: How Systems Work

These 55 Systems Process are those we have selected from a longer list of 104 candidates. They are the “universal isomorphic” algorithms we will look for in all the systems literature and the natural science literature to create a “science of systems, and a documented system of systems processes general theory. See Friendshuh & Troncale, 2012 for discussion of 15 of these as case studies of identification and unification.

1. Adaptation Processes
2. Allometry, Systems-Level
3. Allopoiesis
4. Binding Processes
5. Boundary Conditions as a Proc
6. Causality Processes (linear vs. non-)
7. Chaotic Processes
8. Competitive Processes
9. Constraint Fields & Analysis
10. Cycles/Oscillations/Hypercycles as Processes
11. Decay, Autolytic & Senescent Processes
12. Development Patterns & Laws
13. Duality/Complementarity/ Counterparity Mech's
14. Dysergy as a Process
15. Emergence Processes
16. Entropy, General (as a process)
17. Equilibrium & Steady State Proc’s
18. Evolutionary Processes
19. Exaptation, Cooption Processes
20. Feedback, General
21. Field Processess & Potentials
22. Flow Processes
23. Fractal Structure (as a Processes)
24. Functions, System (Purpose)
25. Growth Patterns & Laws
26. Hierarchies & Clustering as a Process
27. Information-Based Processes
28. Input Processes
29. Limits, Physical & General
30. Integration Processes
31. Metacrescence as a Process
32. Network Structure & Processes
33. Neutralization Processes
34. Non-Equilibrium Thermodyn-Irrever
35. Origins Processes
36. Output Processes
37. Phases, Stages, Transitions
38. Power Laws, Cross-Disciplinary as a P
39. Quantum Processes
40. Recursive Processes
41. Redundancy Processes
42. Replication Processes
43. Self-Criticality/Tipping Pts/ Catastrophes as Processes
44. Self-Organization/ Autopoiesis/ Autocatalysis
45. Spin Processes
46. Storage Processes
47. Structure as Process
48. Symmetry, Systems-Level (as a process)
49. Synergy/Synchrony/Cooperation as Processes
50. Thermodynamic Processes
51. Variation Processes
52. Minimality/Maximality Principle