Abstract: We explored developing “common language for systems praxis” to help systems theorists and systems practitioners deal with the major cross-discipline, cross-domain problems facing human society in the 21st Century. For the first three days, we explored a broad range of issues, from previous efforts at standardization; to the nature of language, culture, and praxis; to the relationship between systems science, systems thinking, and systems approaches to practice. On day 4, we used Checkland’s CATWOE approach to understand the usage, context, and constraints for any common language for systems praxis. On day 5, this checklist helped us develop a diagram showing how an integrated approach to Systems Praxis could put theories from Systems Science and Systems Thinking into action through technical Systems Engineering and social Systems Intervention.

We learned that the best medium for communication across different ‘tribes’ is patterns, and that a common language for systems praxis could use system patterns and praxis patterns to relate core concepts, principles, and paradigms, allowing stakeholder ‘silos’ to more effectively work together. We captured this vision in a diagram that provided a neutral ‘map’ each tribe can use to explain its own narrative, worldview, and belief system, as well as to appreciate how the various worldviews and belief systems complement and reinforce each other within systems praxis. Further development of the diagram post-conversation led to the Systems Praxis Framework (in the Addenda to this report).

Keywords: systems praxis, common language, systems thinking, systems science, systems engineering
This paper is one of several reports from the 16th IFSR Conversation held in Linz, Austria in April 2012, event entitled “Systems and Science at Crossroads.” The full proceedings can be found at: http://www.ifsr.org/conversations-proceedings. © 2012 the International Federation for Systems Research (IFSR) unless otherwise indicated. (Reprinted with permission)

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1. Introduction

There are many theories and approaches for recognizing and creating systems. Systems praxis, as a human activity system, prescribes competencies and processes for organizing various technologies into responsive systems. This activity is greatly complicated by varieties of systems types and the lack of common language among systems theories and practices. This conversation sought to clarify attributes of language for collaboration, co-learning and co-evolving in system praxis. It was also hoped that outcomes from the week might inform design of a set of domain-oriented but interoperable ontologies that could markedly increase the coherence of knowledge exchange and choice-making during systems praxis without constraining invention and innovation.

Team 4 exchanged discussion papers and other reference material and began weekly teleconferences in advance of the conversation. One issue that emerged early on was the difficulty of setting a goal for the conversation week given the level of abstraction and ambitious scope of the topic. A summary of team concerns and possible goals for the week included:

- Goal of group 4 is not clear or is not consistent among group members;
- A single common language is historically problematic (but single common ontology is also historically problematic);
- Contrast a single common language with domain specific languages; systems praxis is multi-lingual, multi-domain (even within a given system);
- Focus on concepts or ontology, not language?
- Focus on shared understanding, shared knowledge, shared vision?
- Importance of views and models throughout.

<table>
<thead>
<tr>
<th>Ultimate goal</th>
<th>Conversation goal this week</th>
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<tbody>
<tr>
<td>Define and adopt one common language</td>
<td>Clarify attributes of one common language</td>
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<tr>
<td>Define and adopt one common ontology</td>
<td>Clarify attributes of one common ontology</td>
</tr>
<tr>
<td>Define and adopt a small core common language</td>
<td>Clarify attributes of a small core common language</td>
</tr>
<tr>
<td>Define and adopt a small core common ontology</td>
<td>Clarify attributes of a small core common ontology</td>
</tr>
<tr>
<td>Define and adopt a set of common ontology views</td>
<td>Clarify attributes of a set of common ontology views</td>
</tr>
</tbody>
</table>

Given the breadth of possible tasks for the week, we spent several days in wide-ranging discussion before using Peter Checkland’s CATWOE approach to concretize a vision for the project.

This report presents 1) some of the issues raised during initial explorations; 2) the results of the CATWOE analysis on day four; and 3) some of the material that went into our successful completion of the “Unifying Systems Praxis” diagram on day five. A comparison of concepts and themes from participants’ position papers; some short position papers from participants; and the Systems Praxis Framework, an evolution of the diagram from work subsequent to the conversation, appear in the Addenda to this report. Longer contributed materials, together with team meeting notes in outline form, can be found in the Supplement at [http://ifsr.ocg.at/world/files/$12f$Magdalena-2012-supp.pdf](http://ifsr.ocg.at/world/files/$12f$Magdalena-2012-supp.pdf).

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1 Preliminary Systems Science Working Group material on this topic is available at [http://sites.google.com/site/syssciwg/meetings/workshop-2012-january](http://sites.google.com/site/syssciwg/meetings/workshop-2012-january)

2 See D. Hybertson’s “Comparison of Team 4 position paper themes and concepts” in the Addenda to this report.
2. Issues considered during initial explorations

2.1. Challenges of standardizing languages

What can we learn from prior efforts to standardize language? One participant, having reviewed three major efforts to identify and standardize appropriate ‘term use’ in particular contexts, found that

Two aspects of these three efforts are revealing: 1) none appear to be used by authors or editors of new works to actually reuse definitions across domains with few providing reuse even within domains; and, 2) most terms have several, sometimes conflicting, definitions. Given these observations, why might we expect that an effort to understand "the attributes of language that most interested parties could adopt and employ and that proves necessary and sufficient for collaboration, co-learning and co-evolving in the system praxis field" may yield substantive results?3

As further evidence of challenges in communicating with specific terms, the graphic depiction (below) of relationships found in WordNet synsets emphasizing "system", "environment" and "context" reveals a wide range of possible interpretations of these terms and their relationships to each other.

synset links from WordNet Search 3.1

Source: R. Martin (2012); reprinted with permission

2.2. The meaning of “system”

There is no clear agreement on the definition of the term “system”. One broadly adaptable approach holds that a system might be composed of things that are real, but this does not necessarily mean the system itself has a reality of its own. The system is a particular set of attributes of a collection of things that interact or relate to each other in some manner. Since there are an infinite number of variables and constants associated with any one thing or collection of things, then it does not make sense that the “system” is all of these attributes. One must choose which attributes are of interest, which is another way of saying that we have a “system of interest.”

3 See R. Martin “Obstacles to a unified praxis ontology” in the Addenda to this report.
The choice of appropriate attributes to consider in the SOI entails the use of systems thinking. The PICARD theory (or systems thinking framework) is a way to characterize the different categories of ‘stuff’ that can make up a certain system of interest. PICARD stands for parts, interactions, context, actions, relationships, and destiny, as illustrated in the figure.

2.3. The meaning of “systems praxis”

Our intent was to clarify the attributes of a language that most interested parties could adopt and employ for collaboration, co-learning, and co-evolving in the “systems praxis” fields. A concept map drawn the previous year by Jack Ring gave one approach to explicating the meaning of “praxis”:

Source: Ring (2011); reprinted with permission

From literature searches, we found uses of “praxis” as “putting theories into action” or “theory-informed practice”. We came up with working definitions of “systems praxis” as:
• Translating theory into action by thinking and acting in terms of systems.
• The act of engaging, applying, exercising, realizing, or practicing ideas about systems.

Systems praxis also includes the appreciation of systems by recognizing the quality, value, magnitude, or significance of, e.g., things or people as they contribute to system behaviors that lead to desirable outcomes.

2.4. Differences separating systems communities

We discussed at length the explicit and implicit differences that separated the various communities of systems theory and practice.

The IIGSS “Streams of Systemic Thought” diagram identifies lines of influence among those who have contributed to systems thinking from the early days of philosophy (e.g., Lao Tzu, Heraclitus, Plato, Aristotle) to more recent work (e.g., Peirce, von Bertalanffy, Ashby, Warfield). In addition to identifying lines of influence, the diagram is color-coded according to category of major work:

• General Systems
• Cybernetics
• Physical sciences
• Mathematics
• Computers & informatics
• Biology & medicine
• Symbolic systems
• Social systems
• Ecology
• Philosophy
• Systems analysis
• Engineering.

If integration between all these systems-related fields is possible, what would it require in terms of language, epistemology, ontology, culture, …?

We considered the “three cultures” of science, humanities, and design identified by Cross (1982):

In most cases, it is easier to contrast the sciences and the humanities (e.g., objectivity versus subjectivity, experiment versus analogy) than it is to identify the relevant comparable concepts in design. This is perhaps an indication of the paucity of our language and concepts in the ‘third culture’, rather than any acknowledgement that it does not really exist in its own right. But we are certainly faced with the problem of being more articulate about what it means to be ‘designerly’ rather than to be ‘scientific’ or ‘artistic’.

Perhaps it would be better to regard the ‘third culture’ as technology, rather than design. This ‘material culture’ of design is, after all, the culture of the technologist—of the designer, doer and maker. Technology involves a synthesis of knowledge and skills from both the sciences and the humanities, in the pursuit of practical tasks; it is not simply ‘applied science’, but ‘the application of scientific and other organised knowledge to practical tasks’.

According to Cross, the three cultures are distinguishable by how education in that culture entails ‘enculturation’ in the three aspects:

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5 Cross, 1982. pp. 221-223
• transmission of knowledge about a phenomenon of study
• training in appropriate methods of enquiry
• initiation into the belief systems and values of the ‘culture’.

<table>
<thead>
<tr>
<th>Culture</th>
<th>Phenomena</th>
<th>Methods</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>Natural world</td>
<td>• Controlled experiment</td>
<td>• Objectivity</td>
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<tr>
<td></td>
<td></td>
<td>• Classification</td>
<td>• Rationality</td>
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<td>• Analysis</td>
<td>• Neutrality</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Concern for ‘truth’</td>
</tr>
<tr>
<td>Design</td>
<td>Man-made world</td>
<td>• Modeling</td>
<td>• Practicality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pattern-formation</td>
<td>• Ingenuity</td>
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<td></td>
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<td>• Synthesis</td>
<td>• Empathy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Concern for ‘appropriateness’</td>
</tr>
<tr>
<td>Humanities</td>
<td>Human experience</td>
<td>• Analogy</td>
<td>• Subjectivity</td>
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<td></td>
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<td>• Metaphor</td>
<td>• Imagination</td>
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<td></td>
<td></td>
<td>• Criticism</td>
<td>• Commitment</td>
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<tr>
<td></td>
<td></td>
<td>• Evaluation</td>
<td>• Concern for ‘justice’</td>
</tr>
</tbody>
</table>

Elements of the Three Cultures (after Cross, 1982)

2.5. Relationships between Systems Science, Systems Engineering, & Systems Thinking

We discussed how the reality of systems praxis always contains some degree of each of our three main areas of focus: systems science (SS), systems thinking (ST), and systems engineering (SE). In the past, when 80% of systems engineering projects arguably involved few problem dimensions requiring systems science and systems thinking, it was possible to ignore the need to communicate with those other fields, let alone integrate them into a unified systems approach or systems praxis.

This no longer seems to be the case.

SE seeks solutions to the world’s problems but must consider the wide range of factors and scopes that this solution could entail. Hitchins (1993) describes the scope of a system as dependent on which layer it principally resides in: product, project, business, industry, or society. SE also needs to consider more than merely the technical aspects of a problem or solution, which can be represented by the PESTEL factors: Political, Economic, Social, Technological, Ecological, and Legal. This has been expanded by some to STEEPLED by adding the factors of “Ethics” and “Demographics”.

Science seeks ‘truth’ whereas engineering is seeking solutions to the world’s problems using the truth found by science. As shown in the figure at right, science seeks to understand and describe properties and relationships of things in the world while engineering strives...
to understand these properties and relationships in order to apply them to solutions to engineering problems. Engineering then will create new properties and relationships in their designed artifacts, properties including such things as behavior, functionality, performance, structure, economy, practicality, and so on.

These complementary roles for science and engineering can also be seen in the system coupling diagram paradigm below. (Lawson, 2010)

A situation can be examined as a “system” (the so-called Situation System) and, from an understanding of this Situation System, a Respondent System can be devised that seeks to either exploit an opportunity identified therein or solve a problem caused by that situation. The Respondent System can be composed of system assets, either preexisting or needing to be designed and developed.⁶

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⁶ See B. Lawson’s “Paradigms to promote thinking and acting in terms of systems” available in [http://ifsr.ogc.at/world/files/$12f$Magdalena-2012-supp.pdf](http://ifsr.ogc.at/world/files/$12f$Magdalena-2012-supp.pdf)
The systems coupling diagram is among the system concepts, principles and paradigms that Bud Lawson has successfully used for several years to convey the essence of systems thinking, change management and systems engineering to interdisciplinary course participants. These elements have contributed to “learning to think and act in terms of systems”—key components of systems praxis.

2.6. Systems praxis and Jack Ring’s “Value Cycle”

We also found that the concept of systems praxis was embodied in the Value Cycle developed by Jack Ring. The cycle starts with an understanding of value, i.e., what the community of stakeholders believes is important to them individually and collectively in the community situation. A problem is discerned from this focus on value and this can lead to an understanding of the “problem system”. The effect a solution might bring to bear on the problem is envisioned and an intervention strategy is devised. This strategy is translated into solution elements in the form of a problem suppression system (PSS). The specific attributes of the PSS are defined and the total solution is envisioned, architected, and designed. The PSS components are specified, developed, and assembled into the complete PSS, and finally tested to determine its fitness for purpose. The effect on operations is determined and these effects on the problem situation are noted, and then the cycle repeats.

2.7. Key concepts that came up repeatedly in discussions

- Recursion
- Emergence
- Boundaries (especially purpose-dependent selection of boundaries), …
- Patterns and Affordances
- Dualities
  - Hard/Soft
  - Product/Process
  - Holistic/Reductionist
  - Positivist/Constructivist
  - Subjective/Objective
  - Potential/Actual
  - Hierarchy/Holarchy.
3. CATWOE analysis for the “Common Language for Systems Praxis” project

On the fourth day, we used Checkland’s CATWOE\(^7\) approach (customers, actors, transformation, worldview, owners, environment) to synthesize our insights into an overview of the usage, context and constraints for any common language for systems praxis. (The elements are presented below in a “TACWOE” sequence since we found that order to be more helpful in developing understanding.)

- **Transformation:** We want practitioners to be able to use a “common language” (core concepts, principles, patterns, and paradigms) in an integrated systems approach in order to work with stakeholders to achieve a successful and sustainable transformation of a problem situation into an improved situation through an appropriate set of interventions.

- **Actors/Stakeholders:** Primary actors and stakeholders are those who work in the fields of Systems Science, Systems Thinking, and Systems Engineering, and the stakeholders who are critical to their success. Benefits: Practitioners, systems integrators, consultants, and their employers will find it easier and faster to work successfully across multiple communities of practice to achieve common purpose. Students will find it easier to integrate a systems perspective into their learning and discipline practice. And policy makers will benefit from clarity of exposition of complex systems issues.

- **Customers:** We think primary customers for this work are system practitioners, and possibly tool developers.

- **Worldview:** We want the “common language” to be useful to practitioners and other stakeholders concerned with problem situations that call for solutions involving hybrid systems including Social, Technical, Economic, Environmental, Political, Legal, Ethical, Demographic (STEEPLED) aspects.

- **Owner(s):** We want the common “language” to be adopted and owned by “The Systems Community” (practitioners, researchers, and educators). Initially it will be owned and curated on their behalf by the group that started this work at the IFSR workshop in Linz in 2012.

- **Environmental Constraints:** The language will be used by humans and machines accustomed to different languages, “symbol systems”, standards, and with different mental models, culture, experience, roles, seniority, status (power relationships), learning styles, neuro-linguistic programming (NLP) modalities, gender, education (scope, discipline, level), belief systems, and paradigmatic silos. Teams using the common language will be multidisciplinary; multi-site; multi-organizational; multi-national; suffering from spread-think and group-think; working under management pressure and complex legal, infrastructure, institutional constraints; sharing (or not) narratives and success stories, inertia, not-invented-here, collaborative/competitive behaviours. Systems Praxis will use knowledge from diverse disciplines, including Thermodynamics, Informatics, Biomatics, Teleonomics, Human Social Dynamics, Economics, Ecology, and many more. Systems developed will need to satisfy constraints from the natural environment (hazards, pollutants, resources); social environment (social requirement, public acceptance, increase in population); and engineering and design environment (laws, specifications, codes, new built & maintenance, intended lifetime, transition strategies, …).

4. Developing a summary “systems praxis” diagram

With our CATWOE checklist as context, we turned to producing a summary diagram to capture insights we had gained into what might be involved in unifying systems praxis across ‘tribes’. We started from a preliminary version of the diagram below, which proposed an “Integrated Systems Approach” that incorporated 1) systems thinking for “understanding systems in a human context”; 2) systems science for the “theory of systems”; and 3) systems engineering for “making choices about how to create and adjust a new system or modify an existing one to better achieve a purpose”. \(^8\)

\(^7\)Checkland (1985). See also http://en.wikipedia.org/wiki/Soft_systems_methodology#CATWOE

We made a number of attempts to combine the above diagram with insights from the week’s conversation into a single framework, including, e.g., core systems concepts, principles, and patterns; the nature of systems praxis; the “three cultures”; the breadth of existing systems fields; and thinking and acting in terms of systems. At this point, we did not expect to be able to identify the specific attributes of common language that could be shared between SS, ST, and SE in an integrated systems approach. We wanted, at a minimum, to identify the outlines of a vision of systems praxis that could provide foundation and context for future work on questions of common language, ontology, etc.
When we took the step of adding a top-level category for social-systems-oriented “Systems Intervention” (SI in our diagram) to cover systems approaches to practice outside of Systems Engineering, we started to find useful dimensions and symmetries that illuminated the relationships we were interested in. These allowed us to develop a diagram showing how a “Unified Systems Praxis” could put theories from Systems Science and Systems Thinking into action through the approaches of technically-oriented Systems Engineering and socially-oriented Systems Intervention.
The culmination of the week’s effort is below. This diagram depicts Systems Praxis in terms of a cycle between Theory and Action, where Systems Science and Systems Thinking sources of theory feed into a “cloud” spanning System Engineering and Systems Intervention sources of action. Quantitative and qualitative evaluations of the outcomes from interventions feed back into the cloud. A continuum of systems approaches ranges from “Hard” (emphasizing control and performance, and tending toward quantitative and analytic methods) to “Soft” (emphasizing influence and values, and tending toward narrative and experiential methods). We did not reach a definitive conclusion regarding how to relate the Hard-Soft continuum to Systems Science and Systems Thinking. We did discuss how future systems praxis integration efforts—including work on common language, core concepts, etc.—could relate Systems Science and Systems Thinking via systems patterns, and Systems Engineering and Systems Intervention via praxis patterns.

We learned that the best medium for communication across different tribes is patterns, and that a common language for Unified Systems Praxis could use system patterns and praxis patterns to relate core concepts and principles across paradigms, allowing stakeholder silos to more effectively work together. By using a neutral language and not “boxing in” the domains, we were able to “separate the people from the problem.” The result was a step towards a common map that each tribe could use to explain its own narrative, worldview, and belief system, as well as to appreciate how the various worldviews and belief systems complement and reinforce each other within systems praxis.

Following the conclusion of the IFSR Conversation, some team members continued developing the above diagram to resolve issues not fully addressed during the week and further realize the integrative potential revealed in the original. The resulting Systems Praxis Framework, which is presented as an addendum to this report, is featured in the introduction to the “Part 2: Systems” in the INCOSE Guide to the Systems Engineering Body of Knowledge (SEBoK) at http://www.sebokwiki.org.
5. References (for the week)


Notes from the Team 4 Conversation: Towards A Common Language for Systems Praxis
H. Lawson: Paradigms to Promote Thinking and Acting in Terms of Systems
H. Sillitto: Integrating Systems Thinking, Systems Science and Systems Engineering
T. Tatsumasa: Experienced Theory and Praxis of Human Activity
T. Tatsumasa: Common Languages: Natural Languages and Invented Languages

Janet Singer is an independent systems researcher, VP for Research and Publications at the International Society for the Systems Sciences, and a BKCASE Author.

Hillary Sillitto is an INCOSE Fellow, ESEP, and BKCASE Author. He is the Systems Engineering Director for Thales UK.

Bud Lawson is an eminent computer systems engineer, INCOSE Fellow, BKCASE author and author, now lives in Sweden and works as an independent systems consultant.

Tamatsu Takaku is a systems researcher and civil engineer with a focus on bridge design. He is a member of the Japanese Society of Civil Engineers.

Gerhard Chroust is a professor emeritus of systems engineering with a specialization in development process models from the J. Kepler University Linz. He serves as the Secretary General of the IFSR, the mother organisation of the Conversation in Linz.

Duane Hybertson is a systems engineer and scientist who works with the MITRE Corporation. He wrote “Model-Oriented Systems Engineering Science—A Unifying Framework for Traditional and Complex Systems”.

Richard Martin is President of Tinwisle Corporation in Bloomington, Indiana, USA. He participates in an active research program to formalize the frameworks now in use for the management of model-based artefacts created in the course of enterprise operations. He is the INCOSE Delegate to the Federation of Enterprise Architecture Professional Organizations.

Johan Bendz is a systems engineering, enterprise architecting and standards expert working with the Swedish Ministry of Defence.

Michael Singer is a former systems engineer at NASA/JPL. He serves as chair of the Systems Engineering SIG and Board member for the International Society for the Systems Sciences.

James Martin is an INCOSE Fellow, textbook author, BKCASE author, standards committee chair for 6 years, and an enterprise architect working in the Aerospace Corporation.
6. Appendices

6.1. Systems Praxis Framework

The Systems Praxis Framework

building on the April 2012 Team 4 Conversation

(October 2012; credits below)

The challenges of complex systems require people to work together across disciplines. To work together, we must first communicate; and to communicate, we must first connect. Systems theorists and people who work with systems can connect through appreciating their synergistic roles in systems praxis.

Praxis is “integrating theory and practice”. Systems Praxis refers to the entire intellectual and practical endeavor of creating holistic solutions to complex system challenges. Systems concepts, principles, and methods are designed to be integrative across traditional domain boundaries. However, multiple dimensions of complexity (social, technical, environmental, etc.) may require a blend of approaches and techniques from disparate systems traditions. Terminology for the various systems domains, scales, and types may appear similar; but assumptions underpinning worldview, culture, and success criteria are not necessarily shared. The result is that systems practitioners and theorists are apt to find that, while they all are focused on “systems”, numerous subtle differences result in their being “divided by a common language”.

The following Systems Praxis Framework gives systems theorists and practitioners a common “map” wherein they can recognize and appreciate the complementary roles played by all participants and stakeholders in the complex process of systems praxis.
**Systems Thinking** is the core integrative element of the framework. It binds the foundations, theories and representations of systems science together with the pragmatic, “hard”, and “soft” approaches of systems practice. In systems praxis, there is a constant interplay of theory informing practice and outcomes from practice informing theory. Systems thinking guides this ongoing activity, reflecting on and appreciating systems and contexts, in order to choose appropriate adaptations.

**Integrative Systems Science** has a very wide scope and is grouped into three broad areas:
1. **Foundations**, which help us to organize knowledge, learning, and discovery;
2. **Theories** about systems, identifying patterns abstracted from and applicable across domains and specialties;
3. **Representations** that allow insight into, and communication about, systems and their contexts, by describing, exploring, analyzing, making predictions, etc.

**Systems Approaches to Practice** aim to produce desired outcomes while being mindful of unintended consequences. No one branch of systems science or practice provides a satisfactory explanation for all aspects of a typical system “problematique”, so practice needs to involve the range of knowledge appropriate to the system of interest and its wider context.

4. A **Pragmatic** (also called Pluralist, Critical, or multi-methodological) approach judiciously selects a mix of “hard”, “soft”, and custom methods, tools and patterns, drawing from different foundations and systems-specific and domain-specific traditions as appropriate to the situation. The approach is open to whatever is useful for gaining sufficient insights to address the issues at hand and achieve desired combinations of emergent properties. Heuristics, “boundary critiques”, “model unfolding”, etc., allow assumptions, contexts, and constraints to be challenged and understood, uncovering hidden sources of complexity, such as from different stakeholders’ values and valuations. Systems may be viewed as hierarchies, networks, societies of agents, organisms, ecosystems, rhizomes, discourses, machines, etc.

5. “**Hard**” methods are suited to solving well-defined problems with reliable data and clear goals, using analytical methods and quantitative techniques. Strongly influenced by “machine” metaphors, they focus on technical systems, objective complexity, and optimization. They are based on “realist”, “functionalist”, and “positivist” foundations.

6. “**Soft**” methods are suited to resolving or structuring problems and opportunities involving incomplete data, unclear goals, or open inquiries using a “learning system” metaphor. They focus on communication, subjective and intersubjective complexity, interpretations, and roles. They are based on “constructivist”, “interpretivist”, and “humanist” foundations.

**Systems Praxis** is part of a wider ecosystem of knowledge, learning, and action. Successful integration with this wider ecosystem is the key to success with “real-world” systems. Systems science draws on and integrates insights regarding complex problems from the differentiated disciplines, including “hard” scientific disciplines such as physics and neuroscience; formal disciplines such as mathematics, logic, and computation; humanistic disciplines such as psychology, culture, and rhetoric; and pragmatic disciplines, such as accounting, design, and law. Systems approaches to practice depend on: measured data and specified metrics relevant to the problem or opportunity situation and domain; understanding of local values and knowledge; and pragmatic integration of experience, legacy practices, and discipline knowledge.

In summary: **Integrative Systems Science** allows us to identify, explore, and understand patterns of complexity relevant to a problematique; **Systems Approaches to Practice** draw on integrative systems science to address complex problems and opportunities; **Systems Thinking** binds the two together through appreciative and reflective practice using systems-paradigm concepts, principles, and patterns; and, finally, observing the results of systems practice enhances both practice and theory.
6.2 Contributed Papers

6.2.1 Comparison of Team 4 Position Paper Themes and Concepts - Duane Hybertson

Themes that emerged from the Team 4 position papers submitted pre-conference:

- Goal of Team 4 not clear or not consistent among group members
- Single common language is historically problematic [but single common ontology is also historically problematic]
- Contrast single common language with domain specific languages; systems praxis is multi-lingual, multi-domain (even within a given system)
- Suggest focus on concepts or ontology, not language
- Suggest shared understanding, shared knowledge, shared vision
- Importance of views; models

From these themes we can pose possible goals for the Conversation:

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<tr>
<th>No.</th>
<th>Ultimate goal</th>
<th>Conversation goal this week</th>
</tr>
</thead>
<tbody>
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<td>1.</td>
<td>Define and adopt one common language</td>
<td>Clarify the attributes of one common language</td>
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<tr>
<td>2.</td>
<td>Define and adopt one common ontology</td>
<td>Clarify the attributes of one common ontology</td>
</tr>
<tr>
<td>3.</td>
<td>Define and adopt a small core common language</td>
<td>Clarify the attributes of a small core common language</td>
</tr>
<tr>
<td>4.</td>
<td>Define and adopt a small core common ontology</td>
<td>Clarify the attributes of a small core common ontology</td>
</tr>
<tr>
<td>5.</td>
<td>Define and adopt a set of common ontology views</td>
<td>Clarify the attributes of a set of common ontology views</td>
</tr>
</tbody>
</table>

The table below selects excerpts from position papers of Team 4 members and relates them to a common set of systems science and systems engineering concepts described in the book *Model-Oriented Systems Engineering Science*[^9^], referred to here as MOSES. The purpose of the book is to define a science foundation for an envisioned systems engineering of the future that expands beyond its traditional scope of application domains to include more complex problem areas such as social systems and public policy issues. This science foundation is built substantially from general systems science and complex systems theory, but also from other disciplines including physics, biology, psychology, sociology, economics, law, and organizational theory. The book describes the general relation between science and engineering, and then focuses on the elements of the sciences that are useful for the practice of systems engineering. The model-oriented treatment of these topics in the book revolves around the position that it is useful and clarifying to regard the artifacts of science (such as theories) and engineering (such as requirements and design) as forms of models, and that these models can be organized in a multi-dimensional model space. The model space not only facilitates the understanding of the models and their relations and interactions, but also in a larger sense serves as a large virtual structured container of the body of knowledge of the relevant systems science and engineering disciplines.

This Team 4 Conversation, and the mapping table below, focused less on the model-oriented aspects of the book and more on the basic concepts of the sciences and systems engineering, and the relations between them. The first two columns of the table represent a selective synopsis of the position papers, while the third column provides a MOSES perspective on each position concept.

<table>
<thead>
<tr>
<th>Person</th>
<th>Position concept or facet</th>
<th>Concept or response from MOSES view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bendz</td>
<td>a holistic approach to enterprise development and governance was required</td>
<td>Agree. Systems science; model space; collective actualization space</td>
</tr>
<tr>
<td>Bendz</td>
<td>poorly reflected notions of systems and architecture hamper the development of both technologies and skills</td>
<td>Agree. Concepts of system, mosaic, world; relation of architecture to internal model</td>
</tr>
<tr>
<td>Bendz</td>
<td>the way to go about achieving such an increase in the precision and formalism of the use of system concepts is through an ontological approach, ultimately shaping a consensus-based belief-system which would provide a 'lingua franca' for systems theorists and practitioners alike</td>
<td>Agree. system and connection concepts; shared understanding as specification; belief system as view or defined world</td>
</tr>
<tr>
<td>Bendz</td>
<td>there is a suboptimal understanding of the potentially important role of architecture … the core contribution of architecture is the understanding of the fundamental principles of the system … a.k.a the system concerns</td>
<td>Architecture as general internal model; concerns as views</td>
</tr>
<tr>
<td>Bendz</td>
<td>Incentives</td>
<td>Big factor in (purposeful) complex systems</td>
</tr>
<tr>
<td>Chroust</td>
<td>One of the keys to a successful systems engineering project is an orderly process to conceptualize, design and build the intended system. This process has to be defined, enacted and often even enforced.</td>
<td>Partially disagree. Agree that certain elements have to be controlled and enforced (e.g., configuration management). But it is important to distinguish between controlled aspects and the actual problem solving (design, engineering…)—which is opportunistic, messy, and disorderly. Keys to problem-solving are allowing the disorderly process and using knowledge of systems and system patterns acquired in a domain (as opposed to knowledge of processes and process patterns beyond the controlled aspects)</td>
</tr>
<tr>
<td>Chroust</td>
<td>Iterative, opportunistic, incremental; human aspects of process models</td>
<td>Yes, agree: these are more natural problem-solving concepts. But we need to allow them to happen, not prescribe them; the focus is still on the system and system artifacts and patterns</td>
</tr>
<tr>
<td>Chroust</td>
<td>Formal – exposed inconsistencies</td>
<td>Precise</td>
</tr>
<tr>
<td>Hybertson</td>
<td>The statement of the problem indicates a belief that a common language would improve systems praxis. Do we assume we need a common language or a common ontology? I suggest we need a common shared set of concepts, and we need to pay some attention to a common ontology as a basis for a common language.</td>
<td>Conceptualization of systems: language, ontology</td>
</tr>
<tr>
<td>Hybertson</td>
<td>The scope of the common language or ontology benefits from being limited to systems of interest to systems engineering (“SE systems”), not all systems. The field whose province is all systems is general systems science. I suggest the field whose province is all SE systems is SE science.</td>
<td>Scope of MOSES is systems engineering science</td>
</tr>
<tr>
<td>Hybertson</td>
<td>Position: Our IFSR Theme 4 group activity is supporting Systems Engineering Problem-Solving System (SE PSS, which is Systems praxis) by doing Systems Engineering Science Problem-Solving System (SES PSS) and producing—or at least working towards—a common language or ontology (the SE Science Solution System or SES SS) that is the language/ontology of SE Solution Systems (SE SS).</td>
<td>The SES PSS and SE PSS occur in the (MOSES) Collective Actualization Space, and the SE SS exists in the model space, solution space, and is ultimately deployed in the problem space.</td>
</tr>
<tr>
<td><strong>Hybertson</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Position:</strong> the language we are producing is (or should be) the language of SE solution systems, more than the language of SE PSS (systems praxis). Stated differently, the position is that the best way to help the SE process is not by focusing on (languaging) the SE process, but by focusing on (languaging) what that process produces, i.e., solution systems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Conceptualization of systems: language, ontology</strong></td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th><strong>Hybertson</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Position:</strong> we need to expand from the traditional mechanistic models of solution systems to include the organic models of complex solution systems. The language or ontology that we produce needs to reflect that expansion.</td>
</tr>
<tr>
<td><strong>The focus of MOSES is on defining a science that supports this expansion of SE.</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Hybertson</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I offer an interrelated collection of concepts and definitions [based substantially on concepts expressed in the book Model-Oriented Systems Engineering Science] that include the following:</strong></td>
</tr>
<tr>
<td><strong>Core system concepts; Collective actualization space</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>1. Core SE concepts in the form of an informal but reasonably precise set of terms and definitions for the language:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Primary concepts of things: world, system, mosaic, model, region…</td>
</tr>
<tr>
<td>b. Primary concepts of connections among things: interaction, action, party, activity, service, disservice, effect…</td>
</tr>
</tbody>
</table>

| **2. Concept of process and its environment: SE world, defined as collective actualization space (position paper Figure 2)** |

| **3. Organizing construct for capturing the most important knowledge for systems praxis: multidimensional model space of solution systems (Figure 2)** |

| **4. Characteristics of solution system models that go beyond mechanistic to organic** |

| **5. For those who need some process assistance:** |
| **Characteristics of SE process models that go beyond mechanistic to organic.** |

<table>
<thead>
<tr>
<th><strong>Lawson</strong></th>
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<tbody>
<tr>
<td><strong>one can question what is meant by “language”? Are we talking about an ontology of concepts expressed as terms and relationships?</strong></td>
</tr>
<tr>
<td><strong>I have the same question and suggestion</strong></td>
</tr>
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<tr>
<th><strong>Lawson</strong></th>
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<tbody>
<tr>
<td><strong>development of mental models and shared vision is related to the usage of paradigms (defining this as patterns based upon models) that express central concepts</strong></td>
</tr>
<tr>
<td><strong>Agree. Mental models and shared vision matches MOSES concept of shared understanding and relation between model, specification (p.67-70). Paradigm matches MOSES concepts of pattern and defined world</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Lawson</strong></th>
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<tbody>
<tr>
<td><strong>How are paradigms that relate concepts and principles expressed as models? Models have several forms (textual, mathematical or graphical). Every form of model is an abstraction of some part of portraying reality from a perspective as well indicated in the ISO/IEC 42010 standard. It is this plurality that establishes the basis for discussion and dialogue that leads to understanding (individually and collectively).</strong></td>
</tr>
<tr>
<td><strong>Agree. Plurality of perspective matches MOSES concept of view (Chapter 10 of book)</strong></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th><strong>Lawson</strong></th>
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<tbody>
<tr>
<td><strong>… the title of this Theme 4 … should be something like: Towards paradigms for improving systems praxis or Towards establishing a shared vision of systems praxis. … focus on multiple, but a small number of paradigms in the form of understandable and applicable system related models</strong></td>
</tr>
<tr>
<td><strong>Agree.</strong></td>
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<tr>
<th><strong>Lawson</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Complexity…</strong></td>
</tr>
<tr>
<td><strong>Essential vs accidental complexity</strong></td>
</tr>
</tbody>
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<table>
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<tr>
<th><strong>Martin J</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Since there are an infinite number of variables and constants associated with any one thing or collection of things, then it does not make sense</strong></td>
</tr>
<tr>
<td><strong>MOSES view: A system of interest to an observer is a system designated, and under consideration, by the observer. There are an</strong></td>
</tr>
<tr>
<td>Martin J</td>
</tr>
<tr>
<td>----------</td>
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<tr>
<td>Martin J</td>
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<tr>
<td>Martin J</td>
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<td>Martin J</td>
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<td>Martin J</td>
</tr>
<tr>
<td>Martin J</td>
</tr>
<tr>
<td>Martin, R</td>
</tr>
</tbody>
</table>
| Martin, R | However, we should be able to focus on those 'attributes of language' that do enable more productive communication and yet provide for suitable contextualization of use for specific terms and phrase. Toward that end, we have examined several efforts to formalize expressions of ontology associated with both an "upper level" for use across all domains and domain specific works. | 1. Agree – more focus on concepts and ontology 
2. Distinction between general ("upper level") and domain-specific concepts is important. Suggestion: We need a range of concepts from most general to narrowly defined domain-specific—perhaps a concept pyramid. |
<p>| Martin, R | Process Specification Language (PSL); Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE); ISO 15926 Industrial automation systems and integration; WordNet. … Are these taxonomies already over-specialized for the breadth of the SE domain? Does adding more terms and relations among them move us toward more general application of the terms to SE and SS or toward more specialized use of the terms | Agree. |</p>
<table>
<thead>
<tr>
<th>Martin, R</th>
<th>Process Specification Language (PSL); Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE); ISO 15926 Industrial automation systems and integration; WordNet. ... Are these taxonomies already over-specialized for the breadth of the SE domain? Does adding more terms and relations among them move us toward more general application of the terms to SE and SS or toward more specialized use of the terms where selected portions of the taxonomy can be applied to sub-domains? To move toward a Unified Ontology of any kind, we must focus not on the uses of terms common to our discourse but rather we must focus on the qualities we want those terms to bring to that discourse.</th>
<th>Agree.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring</td>
<td>Praxis prescribes system implementation from Day 1 and continual improvement through Year N. Praxis must provide for continual assessment and adaptation of praxis as knowledge occurs.</td>
<td>Both for an individual person, and for a community, improvement [maturation] dominates initially, then adaptation [evolution] dominates.</td>
</tr>
<tr>
<td>Ring</td>
<td>Praxis must be consistent with the extent, variety and ambiguity of both the problem system and the competencies of those who develop the intervention system. Praxis consists of a fusion of an algorithm and the human activities that execute it. Praxis must foster quality, parsimony and beauty in the resulting system.</td>
<td>Agree on desired qualities of an intervention system. But those qualities are achieved more by understanding and applying system patterns than by understanding and applying praxis algorithms.</td>
</tr>
<tr>
<td>Ring</td>
<td>Praxis produces errors both obvious and unobvious and unintended consequences.</td>
<td>Agree. But the errors and (negative) unintended consequences can be reduced significantly by understanding and applying system patterns (more than by improving and applying a praxis algorithm).</td>
</tr>
<tr>
<td>Ring</td>
<td>People are key. The language of praxis will consist of many local dialects whose users are both purposeful and adept at interoperability.</td>
<td>Agree. But again, a language of (intervention) systems is more useful for engineering intervention systems than is a language of praxis.</td>
</tr>
<tr>
<td>Sillitto</td>
<td>systems science as an objective “science of systems”</td>
<td>Yes, agree.</td>
</tr>
<tr>
<td>Sillitto</td>
<td>systems thinking as concerned with “understanding systems in a human context” – so ST establishes the “purpose” and “value” that drive systems engineering</td>
<td>Understanding is part of SS; all science is a human activity. Establishing purpose is part of SE.</td>
</tr>
<tr>
<td>Sillitto</td>
<td>systems engineering as “creating, adjusting and configuring systems for a purpose”</td>
<td>Yes, SE – assuming “creating” includes analyzing problem situations, defining capabilities, conducting tradeoffs, modeling, developing/applying architectures…</td>
</tr>
<tr>
<td>Sillitto</td>
<td>the “correct” choice of system boundary for a particular purpose depends on the property of interest. This choice seems to belong in the domain of “systems thinking”</td>
<td>Deciding the most useful boundary for a designated system of interest is part of SE; not necessarily an issue of “correct”</td>
</tr>
<tr>
<td>Singer J</td>
<td>gain insight into modeling as an activity that generates knowledge, and into models as the contexts within which knowledge is interpreted and used…. implications for the design and use of modeling tools and knowledge bases</td>
<td>Agree. Matches MOSES concept of model space as capturing and organizing the explicit aspects of a body of knowledge—in our case, the SE and SS body of knowledge.</td>
</tr>
<tr>
<td>Singer M</td>
<td>Caution: “System” can be hyped to where it comes to mean everything; we want to aim for a mature bounded concept/definition</td>
<td>… that is what happened to “architecture”. It is a pattern very much like the Gartner hype cycle.</td>
</tr>
<tr>
<td>Takaku</td>
<td>Zipf’s law, Pareto Principle: Applying power law distributions to language word usage</td>
<td>This analysis might be of interest in analyzing and comparing different system or praxis languages—for example, to find key terms</td>
</tr>
</tbody>
</table>
6.2.2 Systems Paradigms and Praxis - Harold “Bud” Lawson

One can question whether the development of a “language” is the right or only approach to improving systems praxis. Further, one can question what is meant by “language”? Are we talking about an ontology of concepts expressed as terms and relationships?

As Peter Senge (1990) points out in respect to a learning organization, it is personal mastery, mental models, shared vision and team learning based upon systems thinking that are routes to improvement.

In particular the development of mental models and shared vision is related to the usage of paradigms (defining this as patterns based upon models) that express central concepts.

An ontology identifying (labeling) concepts and relationships between concepts such as the Cmap portrayal being developed under the leadership of Jack Ring in the SSWG is one paradigm. While useful an ontology of this form needs to be complemented with additional paradigms that provide deeper insight into the concepts, collections of concepts as well as underlying principles.

If there are too many concepts as in many of the currently well-known architectural frameworks, the mind boggles. Individuals and teams have a hard time understanding and even agreeing upon what the framework provides.

In my personal experience finding a “limited” (perhaps 5 +/- 2) driving set of concepts that form mental models and provide a basis for shared vision has been a key to improvement of systems praxis.

I would suspect that this is why the ISO/IEC 15288 standard is attractive for systems engineers. It is based upon limited number of level-wise reusable concepts in a system breakdown that individuals and groups can get their mind around. Due to this fact, the concepts remain in the mind while the details are there when needed. The document describes system related processes in a mere 40 pages.

I have often point to what I call “The Arms Length Test”. That is if you take a printed copy of a standard (could also apply to other documents like architectural framework descriptions) and can hold it at arms length for one minute then it might be a useful document to read and to utilize. Is this a useful principle?

I suggest that the most important aspect of improving systems praxis is developing personal mastery and group (team) competence and capabilities in learning to think and act in terms of systems. I further suggest that this is best accomplished by multiple paradigms that not only portray an ontology of concepts that guide thinking but also convey concepts and underlying principles that guide action Lawson and Martin (2008).

How are paradigms that relate concepts and principles expressed as models? Models have several forms (textual, mathematical or graphical). Every form of model is an abstraction of some part of portraying reality from a perspective as well indicated in the ISO/IEC 42010 standard. It is this plurality that establishes the basis for discussion and dialogue that leads to understanding (individually and collectively).

So, I would suggest that the title of this Theme 4 is not correct. It should be something like:

- Towards paradigms for improving systems praxis, or
- Towards establishing a shared vision of systems praxis.
If we really want to revolutionize the perspective of systems praxis, it will require the use of multiple paradigms (not just a “language” based upon an ontology). This perspective that is applicable to science and is as well applicable to engineering was stated quite clearly by Kuhn (1962):

“a scientific revolution is defined by the appearance of new conceptual schemes or ‘paradigms.’ These bring to the fore aspects which previously were not seen or perceived, or even suppressed in “normal” science, i.e., science generally accepted and practiced at the time.”

My perspective in conveying multiple paradigms has been presented in the book “A Journey Through the Systems Landscape” Lawson (2010). My personal experience in conveying these paradigms have led to significant results for others in respect to collaboration, co-learning and co-evolving.

In conclusion I suggest that it is vital to focus on multiple, but a small number of paradigms in the form of understandable and applicable system related models in improving system praxis. This perspective will be supported during the discussions of this theme.

Reference

6.2.3 Four Thought Patterns in Support of the Systems Approach - James Martin

I have a strong interest in characterizing the “nature” of systems to facilitate the creation of systems for the betterment of mankind. I have developed four thought patterns (or frameworks, if you will) to assist in the characterization of systems:

1. PICARD Theory
2. 7 Samurai Framework
3. PMTE Paradigm
4. Knowledge Pyramid

Each of these is summarized below. These have been found helpful in creating more successful systems since they enable better systems thinking about the problem situation and corresponding potential interventions in the problem space.

1. **PICARD Theory.** Systems might be composed of things that are real, but this does not necessarily mean the system itself has a reality of its own. The system is a particular set of attributes of a collection of things that interact or relate to each other in some manner. Since there are an infinite number of variables and constants associated with any one thing or collection of things, then it does not make sense that the “system” is all of these attributes. You must choose which attributes are of interest, which is another way of saying that we have a “system of interest.”

   The choice of appropriate attributes to consider in the SOI entails the use of systems thinking. The PICARD theory (or systems thinking framework) is a way to characterize the different categories of “stuff” that can make up a certain system of interest. PICARD stands for parts, interactions, context, actions, relationships, and destiny, as illustrated above. (Martin 2007)

2. **The 7 Samurai Framework.** There are seven categories of systems that interact with each other as shown below. The main system to be engineered is the Intervention System (S2) that will be designed to solve a real or perceived problem. The Intervention System will be placed in a Context System (S1) and must be developed and deployed using a Realization System (S3). (Martin 2004)

   The Intervention, when installed in the Context, becomes the Deployed System (S4) which is often different in substantial ways from the original intent of the Intervention. This Deployed System will interact with Collaborating Systems (S5) to accomplish its own functions. A Sustainment System (S6) provides services and materials to keep the Deployed System operational. Finally, there is one or more Competing Systems (S7) that may also solve the original problem and will compete for resources with your Deployed System. All seven systems must be properly reckoned with when
3. PMTE Paradigm. There is an intimate, supporting relationship among the PMTE elements shown below. These elements must be consistent with each other, and must be well integrated and balanced to achieve the greatest benefit from systems engineering practice. A process is executed using methods suitable for each process step. In turn, each method can be supported by one or more tools. A tool must be supported within a particular environment.

When the PMTE elements are not well balanced with each other this can often lead to “misfires” in the system creation effort. When introducing changes to any layer it is often necessary to make adjustments in the other layers of the PMTE stack.
4. Knowledge Pyramid. Many systems exist to help us increase our knowledge of the world in one way or another. Systems engineering needs a better way to understand how systems help or hinder the creation of knowledge. The Knowledge Pyramid was developed as a reference model to facilitate systems analysis with respect to signals, data, information and knowledge. (Martin 2006) Some systems do all their work at one level while other systems might span several levels. This pyramid has been especially helpful in understanding how to engineer enterprise systems since enterprises tend to operate in the upper half of pyramid. Technological systems usually operate in the lower half of the pyramid. (Martin 2006)

Summary. These four “thought constructs” have been found to be helpful in doing more complete, consistent and correct systems thinking. These are useful additions to any SE toolbox alongside other common tools and principles like the Zachman framework, GERAM (generalized enterprise reference architecture and methodology), STEEPLED (social, technological, economic, environmental, political, legal, ethical, and demographics), POSIWID (purpose of a system is what it does), IWKIWISI (I will know it when I see it), DOTMLPF (doctrine, organization, training, materiel, leadership, personnel, facilities), etc.

References


6.2.4 Obstacles to a Unified Systems Praxis Ontology - Richard Martin

In 2003, ISO TC184/SC5/WG1 began an effort to consolidate the formally defined terms from the International Standards adopted by TC184/SC5 related to automation systems interoperability and related works of other IEC and ISO groups. The purpose of this effort was to allow those involved in the drafting, adoption, and revision of International Standards an opportunity to examine existing term definitions before they created new definitions. That effort culminated in a glossary published by ISO TC184/SC5 as N994 in 2010 that contains 327 different terms from 29 documents including 15 TC184/SC5 International Standards.[1] Definitions are annotated with the usage context and reference, and preferred definitions are identified for reuse where possible. All of these standards are related to various system engineering aspects of industrial automation systems.

The authors of the TC184/SC5 work conducted a stakeholder survey and analysis of term use in an attempt to better understand the difficulty authors and editors have with technology term reuse. Two additional publications resulted. The first was the ISO/TC 184/SC 5 N895 Vocabulary Study Group Final Report (2006) and the second was an I KSO 2006 Conference paper titled The Integration of Standards for Knowledge Organization in the Domain of Manufacturing Enterprises.[4] Both of these describe analysis and survey efforts associated with the preparation of the final glossary.

In about the same time frame, the IEEE Computer Society in conjunction with ISO/IEC JTC1 conducted a similar activity for the work products related to Information Technology identifying a Software and Systems Engineering Vocabulary that now is included in the IEEE Standards Dictionary of 29,000 terms.[2] Some of these IEEE related standards are also included in the TC184/SC5 N994 document. A distinguishing feature of this effort is the automated search interface that is provided online, now a common feature for dictionaries.

Another effort by ISO for its entire catalog of defined terms from 18,000 International Standards was launched in 2009 as the ISO Concept Database.[3] This online database of defined terms is similar in function to the IEEE work product in that keyword-based inquiry yields term definitions but in this case it is all definitions containing the keyword.

Two aspects of these three efforts are revealing: 1) none appear to be used by authors or editors of new works to actually reuse definitions across domains with few providing reuse even within domains; and, 2) most terms have several, sometimes conflicting, definitions. Given these observations, why might we expect that an effort to understand "the attributes of language that most interested parties could adopt and employ and that proves necessary and sufficient for collaboration, co-learning and co-evolving in the system praxis field" may yield substantive results?

We can observe that the three efforts above are addressing specific term use in a particular context. A technical term is to be defined whenever the use in a particular context, like an International Standard specification, deviates from the 'common meaning' of the term. The fact that most terms have several 'common meanings' tends to exacerbate the proliferation of specialized definitions. Even
when pruning the potential meanings to the one chosen for use in the document, the tendency is to further embellish the term's definition and thereby specialize the specialization.

In addition, while the standard does specify a particular meaning for a term or phrase in the work, readers often re-interpret that same word or phrase when encountered in the text because there is no means for distinguishing the particular meaning when it appears – defined terms are not tagged in the text. After reviewing a technical specification for several hours and 70 pages or so deep into the specification, it is almost impossible to retain the special meaning intended for a particular word or phrase defined at the beginning of the document, especially if your practice ascribes a different meaning. We also note that writing style and translation idioms creep into the mix both for non-English speaking authors/editors and eventual users of the English or French text (most International Standards are published only in English unless they also are adopted as National Standards by a member Body of ISO or IEC).

The use of terminology in engineering disciplines is influenced by training, practice, and regional factors. The same can be said of terminology used in scientific disciplines. We are not going to 'standardize' term use precisely because of the need to communicate contextualized knowledge among people with very diverse backgrounds. Distinguishing terms in context is essential to knowledge transfer. However, we should be able to focus on those 'attributes of language' that do enable more productive communication and yet provide for suitable contextualization of use for specific terms and phrase.

Toward that end, we have examined several efforts to formalize expressions of ontology associated with both an "upper level" for use across all domains and domain specific works. An example of the later is the ISO 18629 series for a Process Specification Language (PSL). The underlying language used for PSL is KIF (Knowledge Interchange Format).

"ISO 18629 specifies a language and ontology for the specification of processes, that is focused on, but not limited to the realm of discrete processes related to manufacturing, including all processes in the design and manufacturing life cycle. Business processes and manufacturing engineering processes are included in this work both to ascertain common aspects for process specification and to acknowledge the current and future integration of business and engineering functions."

PSL servers as a precise interface specification language, which machines can process for the exchange of process relevant information between those machines. PSL is a meta-language for the processes that are communicated across the interface. The ontological aspect of its specification helps to assure that the language is complete with respect to the domain that it serves.

At the other end of the spectrum for formalized ontology are several works, beginning with the early Greeks and continuing today. Upper-level ontology, i.e. those intended to serve all or at least most domains of discourse, have seen extensive efforts over the past 40 years. Of particular interest in the manufacturing domain is the work centered on the DOLCE effort at the Laboratory For Applied Ontology in Trento, Italy.

"Developing foundational ontologies is not simple at all. We decided to describe first a core set of key ontological assumptions, focusing on the needs of other projects we were involved in, and reflecting our own choices and intuitions... This was the origin of DOLCE, whose acronym (Descriptive Ontology for Linguistic and Cognitive Engineering) reflects what we have called a cognitive bias. Since its first development, DOLCE was not intended as a candidate for a "universal" standard ontology, but rather as a reference module, to be adopted as a starting point for comparing and elucidating the relationships with other future modules of the library. Indeed, the public availability of DOLCE - since its first release – stimulated other research groups working on formal ontology to make their own ontologies available in the library as independent modules, although linked to DOLCE according to the WONDERWEB philosophy."
The attractiveness of this work is that it has focused on two domains of interest to system engineers. The initial DOLCE effort was sponsored by the WonderWeb research project funded by the IST Programme of the Commission of the European Communities with a focus on web services technologies.[5] The final project deliverable has an expression of DOLCE in KIF as well. An extension of the DOLCE effort focused on a series of workshops titled Formal Ontologies Meet Industry. These workshops examined the application of ontologies to a wide variety of industrial applications with an understanding that it is the domain specific use of an upper-level ontology that yields the value of that ontology. Like PSL, DOLCE identifies relationships among concepts with formal semantics suitable for application within domains, including inference.

One other ISO effort is worth mentioning as an 'upper-level' formal ontology. The ISO 15926 Industrial automation systems and integration — Integration of life-cycle data for process plants series of International Standards specifies with formalization in the Express Language, standardized in ISO 10303-11, the ontology for use among a large industrial domain with a wide variety of sub-domains.

"ISO 15926 is an International Standard for the representation of process plant life-cycle information. This representation is specified by a generic, conceptual data model that is suitable as the basis for implementation in a shared database or data warehouse. The data model is designed to be used in conjunction with reference data, i.e. standard instances that represent information common to a number of users, process plants, or both. The support for a specific life-cycle activity depends on the use of appropriate reference data in conjunction with the data model."

While the work is characterized as a 'data model' it is in fact an 'upper-level' ontology for use in defining application level data models for use within the industrial domain. Of particular note is the ontic commitment to what is often called a 4D approach that explicitly considers all physical things in both space and time. This approach is consistent with the DOLCE foundational ontology as described below:

"In general a 3D option claims that objects are: a) extended in a three-dimensional space; b) wholly present at each instant of their life; c) changing entities, in the sense that at different times they can instantiate different properties (indeed, one could say When I was out in the balcony my hands were colder than now). On the contrary a four dimensional perspective states that objects are: a) space-time worms; b) only partially present at each instant; c) changing entities, in the sense that at different phases they can have different properties (My hands during the time spent out in the balcony, were colder than now)."

Finally I want to examine one last ontological effort that is helpful in making my closing cautionary comments. WordNet is a project maintained by Princeton University that is a lexical database of English with nouns, verbs, adjectives and adverbs grouped into sets of cognitive synonyms, which results in a network of meaningfully related words and concepts.[6] Below is one of those networks emphasizing the words 'system', 'environment', and 'context'. These words were chosen to relate because of their importance to system engineering and system science.

When we talk about the 'context of a system', to which of the 4 paths from 'system' are we referring or are we referring to a different path altogether? Or are we referring to one of the 5 paths from 'context' to 'system'? The triple depicted on the System Cmap is <System, bounded by, Context>. Notice that according to WordNet, context must be an abstract entity rather than a physical entity but I am certain that many system engineers consider 'context' to be a physical attribute of 'system' – a path not found in WordNet. Which of the terms above should we ascribe to the phrase 'bounded by' in our Cmap?

Each of these 'upper-level' examples does not specify the terminology of the domain but does specify likely classifiers and relationships among those terms that users should investigate. Most often the result of that investigation is not a formal domain specific ontology but rather a loose taxonomy of
terms and phrases with associated definitions that are domain relevant. It is in this direction that the System Sciences Working Group project Toward a Unified Ontology for Systemists has proceeded. The five conceptual maps (Cmaps) presented at the INCOSE IW2011 workshop represent the current state of our understanding of the five primary terms System, System_Engineering, Praxis, Model, and Fault_Detection_and_Correction.

Are these taxonomies already over-specialized for the breadth of the SE domain? Does adding more terms and relations among them move us toward more general application of the terms to SE and SS or toward more specialized use of the terms where selected portions of the taxonomy can be applied to sub-domains? To move toward a Unified Ontology of any kind, we must focus not on the uses of terms common to our discourse but rather we must focus on the qualities we want those terms to bring to that discourse.

References

People who work with models at the metalevel—whether to develop knowledge bases or to design tools that help people do modeling—require a systematic, unified framework within which they can operate. This framework should encompass informal as well as formal, and qualitative as well as quantitative, modeling approaches. It should facilitate the development of systems such as modeling resources that can support a user throughout the modeling process, from the earliest exploratory stages through the highest levels of specialized analytic techniques.

The use of knowledge requires the use of models, but we lack a coherent understanding of the relationship between the two. There is no general agreement on what a model is. To many scientists, the word “model” refers specifically to a computer simulation. To a mathematician, a model is a system of equations. To a logician, a model of a formula of a language is an interpretation of the language for which the formula comes out true. According to the O.E.D., a model is “a representation of structure” or “something that accurately resembles something else.”

Standards of terminology, method and evaluation criteria for modeling are well developed within certain narrow domains. These domains are determined by such factors as formal characteristics of the model (linear v. nonlinear, etc.), domain of application (econometric v. ecological, etc.), and techniques of analysis (regression v. linear programming, etc.). Yet there are no standards that hold across these domains, and there is no framework that indicates how the standards that do exist relate to one another.

It has not been possible to bridge the gulfs between these domains to construct a unified framework that showed the relationships between the formal, functional, structural and behavioral characteristics of models and modeling approaches.

A unifying framework can be provided by seeing models as the results of the modeling activities of situated rational agents. The formal characteristics of the models, their domains of application, and the techniques used to analyze them are then seen to be the results of decisions made by the agent during the modeling process (consciously or not). The presence or absence of these features is therefore dependent on the factors which influenced those modeling decisions. The fundamental basis of a comprehensive and unified taxonomy of modeling approaches across domains should be those features of situation, motivation, and resource constraints which influence modeling decisions.

Questions To Be Considered

Theoretical questions:
- What is a model?
- Are all representations models?
- Is a measurement a model?
- Is a metaphor a model?
- What are the syntax, semantics, and pragmatics of modeling?
- Are the syntax, semantics and pragmatics of modeling necessarily domain dependent, or can they be defined in a way that is (for all practical purposes) domain invariant?
- How are speech acts related to modeling acts?
- How is knowledge related to models?
Is it possible to use knowledge without relying on the context of one or more models (e.g., a “world” model)?
Does knowledge originate in any way other than through modeling?
Does a collection of facts and rules in a knowledge base somehow “induce” one or more models?
How are exact models related to fuzzy models?
How are formal models related to informal models?
How are implicit models related to explicit models?
Is an explicit model always understood within the context of one or more implicit models—within a hierarchy of nested models?

Empirical questions:

Under what conditions of situation, motivation and resource constraints do people generate and use models?
What phenomena do they model?
What are their motivations and objectives—implicit as well as explicit?
What kinds of tradeoffs do they make to meet their objectives?
What language do they use to discuss modeling?
What kinds of representations do they use?
What are their methods for model generation?
What are their methods for model transformation and analysis?
How do they use the results of their modeling activities?
What are the decisions/choices that they make during modeling and what are the criteria that they use to make these decisions?
What are the criteria they use to evaluate the results of their work?

Practical questions:

How do the evaluation criteria identified in the taxonomy (accuracy, reliability, maintainability, efficiency, usefulness, controllability, observability, robustness, stability, sensitivity, specificity, significance, etc.) relate to features of situation, motivation, and resource constraints?
How does the model of modeling behavior implicit in the taxonomy evaluate as a resource for designing modeling tools and knowledge bases according to the above evaluation criteria?
What are the consequences of different kinds of errors (sampling, sample design, biased measurement, non-conformable measurement, data handling, classification, formulation, logical, procedural, random, deliberate, etc.) for the types of models identified?
Under what conditions is it meaningful/useful to use the output of one model as the input to another?
Under what conditions is it meaningful/useful to use intermediate results from one model as the input to another?
What kinds of conditions/assumptions make models incompatible or compatible?
How do the results of this study relate to issues in statistical meta analysis?
If the design of a knowledge base entails the design of implicit models, what design criteria should be followed to ensure that these models are optimally suited to the intended uses (and users) of the knowledge base?
What information regarding the origin of a particular item of knowledge should be encoded in a knowledge base to ensure that if it is used in modeling, the kinds of errors for which that modeling activity has low tolerance are not compounded?
What information regarding the origin of a particular item of knowledge should be encoded in a knowledge base to allow for the optimal intelligent use of the knowledge base, and how should users be trained to this end?
When is knowledge most robust to variation in modeling conditions and how can knowledge representations be designed to enhance this robustness?
How can resources be developed to help users make good modeling decisions in all types of situations?