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SPT V:
ASSESSMENT OF A SOCIO-TECHNICAL SYSTEM USING SYSTEMS PROCESS THEORY AND SYSTEMS PATHOLOGY

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ABSTRACT

This paper begins with a dramatically expanded concept of systems engineering and the very large-scale systems problems to which it must be applied in the future. It describes an application of the current state of the Systems Process Theory-Systems Pathologies Framework (SPT/SP) to a real-life socio- technical system. This exploratory investigation attempts to see what can be learned about: (a) the usefulness of the SPT/SP to systems practitioners (what it says about bridging theory and praxis in general); b) the system of interest (improving praxis); and (c) how attempts at praxis can feedback and improve theory.

An aspiration of the SPT/SP framework is to provide a theoretically rigorous approach for Systems Engineers to use in evaluating system designs and interventions. The widely-held view that there is currently an un-met need for a rigorous framework such as this is exemplified by the support currently expended for development of the SPT/SP framework by the ISSS and INCOSE via their joint Systems Sciences Working Group. The System of Interest (SOI) chosen for this investigation is the technical project and process review System within one of the Thales UK operating domains. The SOI reviews the technical development of a portfolio of engineering projects, covering the work of around 700 engineers. The SOI evaluates the developing designs for numerous technical systems, and determines what interventions are necessary, and is therefore thought to provide a relevant case study.

We will be using the strategy-metaphor that many engineers use to construct bridges across separated chasms (in this case metaphorically theory separated from practice). We image this attempt as an island between land masses separated by water. We will start simultaneously from both sides and try to construct bridges from each side to the island nearer the middle. In this way each land mass retains its integrity, but flows of ideas and insights become possible via the bridges. From the theory side, we select only a few promising specific processes (how systems work) from 110 candidate systems processes, hundreds of linkage propositions defining their mutual influences, and from specific systems pathologies of the SPT/SP framework to apply to the Thales problematique. On the application side, we construct a list of some of the observed or anticipated problems faced by the company. In both cases we are looking for exemplar insights and understanding from the general SPT/SP that might improve/inform SOI practice.

The SPT/SP framework is rooted in the evidence-based natural sciences yet the SOI is socio-technical. But the SPT/SP has numerous examples of processes and pathologies that are common to BOTH the natural (technical) world and the human-social-business world. Subjectivity is likely unavoidable in the observation and analysis of the SOI, regardless of the evaluation framework that is applied. So this study leads to many questions. Are we as systems scientists and systems engineers suitably prepared to recognise when mixed-methods investigations are necessary? Are we equipped to carry them out while maintaining theoretical rigour? Can the SPT/SP framework provide a much-needed common terminology to improve communication between these domains?

As a development of SPT/SP from reflection upon this case study, we present a list of criteria for assessing theory → praxis "translation" relating SE to widespread attempts in modern medicine. We will also list practical goals and limits for applying systems theoretical findings to improving systems-level design and engineering. We will suggest a general protocol for "translating" abstract theoretical findings into workbench practices, for assessing reliability and ranges of applicability for theoretical findings, and for communicating across the growing chasm between theoreticians and practitioners. Final lists will include strengths and weaknesses of this approach and the possibilities and/or limits of "transferability" from this case study to other case studies. We end with insights into how the framework can simultaneously inform BOTH the (human-based) systems management of how a workforce PRODUCES a system as well as improves the PRODUCT system thus produced.

Keywords: systems processes theory; systems processes; isomorphies; linkage propositions; systems applications; systems of interest (SOI); systems pathologies; cyberpathologies

Capsule Outline:

- Expanded Vision of Systems Engineering and Systems Science
- The Need for Theory "Translation" to Practice; Searching for Exemplars
- Criteria for Judging Successful Translation
- Current State of Systems Processes Theory (SPT) and the new Systems Pathology (SysPath)
- Overview Description of Application System of Interest (SOI)
- Methodology for the Case Study
- How to Use SPT/SP in this Context
- SOI (system of interest) Data Collection
- Narrowing the Focus for A Manageable Case Study
- Results and Reflections to Date
- Applications of Cyberpathology to Thales Projects: Special Relevance to SE
- Further Results and Reflections
- The Industrial Perspective
- Observations on the General Task of Applying SS Theory to SE Practice
- Can Attempts at Application to Improve Practice Also Improve Theory?

Expanded Vision of Systems Engineering and Systems Science

The target for applying Systems Processes Theory (SPT) and its spin-off, Systems Pathology (SP) to Systems Engineering (SE) is not just the current practice of SE or of Systems Science (SS). While we intend to explore how the more detailed understanding of how systems work (SPT) and how systems don't work (SP) could inform current practices in a SE corporation, we want to emphasize up front that we foresee a much more extensive use of SE & SS in the future. It is to these expanded disciplines that we feel SPT/SP will be most applicable. The expanded work span for SE&SS comes from two specific and inexorable developments. First, our international civilizations are increasingly facing crisis problems that have one thing in common. They are all variants on very complex systems. Can anyone deny that climate changes, computer security challenges, pandemic threats, integration of subsystems into ever more complex supersystems, international economics, diminishing resources, increasing energy needs in the face of resource depletion or transitions, refugee movements, and political conflicts are fundamentally complex systems? We suggest the current practice of systems engineering is not up to solving these problems and needs the addition of the greater understanding and intervention ideas enabled by a true science of systems. We envision systems engineers becoming "physicians" to complex systems who fix, heal, and curate large complex systems and design them better in the first place to avoid recurring problems and dysfunctions.

The above listing is just a sample of the many pressing problems we must find solutions too soon. There is also a wide range of opportunities for the human species not yet realized. The search for near-earth-like planets and asteroid resources suggest that we will need to learn how to do resource collection, planet alteration, synthetic biology, and guided, industrial evolution on an unforeseen scale in the near future if our species is to survive. Just as young people dream of becoming astronauts or astronomers when stimulated by broad visions of the cosmos, we must make it possible for them to see the possibilities of systems engineering in the future. They will be the ones to make it come true.

The kinds of people who are needed to deal with these issues and possibilities, will increasingly be people who use rigorous systems approaches with a much more detailed use and understanding of systemness than heretofore available ……. the 'Systems Engineers' and 'Systems Scientists' of the future. Here we assess SPT/SP as a source for education and training of such individuals and organizations.

Note that today's use of the term in common parlance 'systems engineer' may suggest in someone's mind a professional who makes use of established/generic SE tools and processes in a somewhat sterile and unimaginative way. Some SEs criticize their new field as too slavishly following available computer tools for systems management rather than seeking to meet the above-described demands of the near future. It may also evoke an image of someone who applies a plethora of systems approaches in highly creative, yet theoretically weak ways. These are not the 'systems engineers' we imagine will see immediate value in the SPT/SP as it is currently represented, even though they could derive great value from the completed framework. SPT/SP is still a work in progress. The aspiration to develop the fundamental theories that can be applied to address these vast and complex real-world problems leads us to test the framework as it currently stands, so we may raise the profile of the work itself, show whether the 'in-development' framework can already deliver benefits, and see if we can discover any currently un-planned refinements and/or extensions that may improve the usability and value of SPT/SP for systems engineering practitioners. So this study is a challenge to both the current state of systems science and systems engineering simultaneously.

The Need for Theory "Translation" to Practice; Searching for Exemplars

One of the new, well funded movements in the 2,000 year old field of biological medicine is aimed at fulfilling the urgent need for "translational studies." Biomedicine is funded at huge levels in current society, $120 billion for 2012 alone, but how much of this basic biomedical research reaches the patient? Funding has now been set aside specifically to stimulate the "translation" of lab bench results to the clinic where it can increase survival and quality of life. Similarly, we not only need far more comprehensive systems theories to help understand how systems work and don't work, we need "translation" of the theoretical advances as quickly and systematically as possible to those who produce and manage systems. One way to do this is to highlight clear examples of success which are called exemplars. Such examples are important to perception and progress, so we seek to apply one current systems theory to real world cases even though the theory itself is not complete.

It is interesting to note that despite the huge costs to individuals and to societies of the systems-based crisis human problems we just mentioned, little funding is available either to stimulate advances in systems theory or in translation of those advances to systems engineering. It is clear that society as a whole is unaware (or putting its collective head in the sand) regarding the costs hidden in its current practices. We are unwilling to specify and allocate the modest funding needed to avoid those much larger costs coming due in near future generations. One representative case study of this is the rising of sea levels due to climate change. We humans have concentrated vast populations, habitats, and industrial infrastructures at sea shores that simply may disappear under the advancing ocean at inestimable costs to future society.

Criteria for Judging Successful Translation

SPT endeavors to produce and work on the most parsimonious list of isomorphic systems processes, yet miss none that are relevant. We continue to use the seven criteria for limiting the Integrative Themes to Principal Systems Concepts (PSCs) of the original paper in this series (Troncale, 1978) or its educational applications (Troncale, 1993). But we have added additional criteria to include assessment of potential for the above-described "translation." The expanded current list includes the following (not in order of importance):

(1) fulfills the working definition of "process;"
(2) fulfills the working definition of "systems-level;"
(3) can be proven to be isomorphic; found in all 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 and functions for that process;
(7) rich in associated literature of empirical or experimental or formal data;
(8) is domain-independent, discipline-independent, tool-independent, and scale-independent;
(9) illustrates key disciplinary phenomena for each case study;
(10) understood in sufficient detail;
(11) recognized by workers in relevant specialties;
(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

Just as in systems engineering, it is beneficial to start a task with a clear set of "criteria" that can be used as one progresses to judge whether or not one is succeeding at the task. In one sense, the isomorphic processes of the SPT are the common successes for sustainable systemness found by comparing a wider range of natural systems so are criteria for success. Do we have an adequate image of these isomorphic systems processes to use to judge any systems design process? We must have in order to accomplish the "translation" we seek.

Current State of Systems Processes Theory (SPT) and Systems Pathology

To carry out this case study, the body of SPT and Systems Pathology (SPT/SP) literature was reviewed. Although the framework for the theory was first described in (Troncale, 1971 & 1978) and Systems Pathology was first presented at the annual conference of ISSS (International Society for the Systems Sciences) in 2001, there has been a recent series of papers both. SPT1 (Friendshuh and Troncale, 2012a) describes a minimal, reduced set of candidate Systems Processes (SPs)(from the original 110 candidates to 40) that may be present in sustainable systems. It also describes the origins of the list and why the reductions were attempted. SPT3 (Troncale, 2012c) focuses on just one of the systems processes and its discinyms (cycles, cycling, oscillations, waves, solitons, lifecycles, and possibly spin) anre purports to "prove isomorphy" for the first time in the GST literature by citing 50 cases across all levels of physical, living, and social systems. SPT2 (McNamara and Troncale, 2012b) outlines how to identify Linkage Propositions from academic literature. These Linkage Propositions (just >200 LPs in the current formulation) describe a dimension beyond most claims of isomorphic nature of processes by specifying how the various SPs influence each other resulting in a complex network of very specific common interactions. This feature is claimed to be a significant advance over past general theories of systems or dictums from systems thinking and systems management traditions. The combination of SPs and LPs in a network are claimed to describe in more detail how systems work than past work. A CSER paper (Troncale, 2011) and an INCOSE paper (Troncale 2013) make the case for, and conceptually introduce Systems Pathology for use in Systems Engineering (or how systems don't work).

These papers represent the current state of SPT/SP for our purposes here of attempting to apply it to an industrial problem, i.e. a case study application. There is no suggestion that the combination of these papers should be expected to deliver a fully functional, rigorous and tested theory and user guide. Each paper takes care to describe what the contents are, and what they are not. The review of the literature did suggest that there is enough detail already there to make a case study application feasible, and that, given the 'in-development' status of the SPT/SP framework, valuable insights may be extracted from the exercise. Of course the SPT/SP literature is much wider, see (many refs), and while publication of SPT/SP literature continues, there is a lag between the development of ideas, refinement of theory in the minds of its developers, and the literature publication dates when the ideas are disseminated to the world. At least a dozen ongoing projects of the ISSS/INCOSE SSWG (Systems Science Working Group) provides a focal point to capture further development, with virtual forums, workshops, and tutorials also providing a platform for collaborators to actively discuss and debate developing thinking, prior to publication. The combined ISSS and INCOSE products to date total nearly 100 papers, posters, abstracts, workshop sessions and reports produced by a core research team of about 15 systems science and systems engineering collaborators.

Overview Description of the Application System of Interest (SOI)

Thales Group is an international engineering Company employing 65,000 people. It is headquartered in France, with a major presence in 17 countries spanning all continents. It delivers solutions for customers within 5 key sectors; aerospace, space, ground transportation, defense, and security. Its tag line is Faster, Safer, Everywhere. Thales UK has a substantial presence in 4 of the 5 Thales Group sectors. Thales UK splits its operation in to 5 main internal business units. This case study involves the entire engineering function of one of Thales UK's main internal business units. The work of around 700 engineers from disciplines including systems, software, hardware, firmware, electronics, etc. is covered by this case study.

Recent restructuring within Thales Group and Thales UK led to the creation of a new role (Internal Business Unit X Head of Engineering), with a scope and span that had never existed prior. The role of 'Head of Engineering' is clearly not new, rather, the responsibility of one person to grasp, understand, and be responsible for the engineering work across such a vast (in terms of the number of projects) and diverse (in terms of sector, size, customer-type, complexity, lifecycle, and technology) portfolio was new. The restructured Thales UK sought greater visibility of the technical progress of its engineering programs so emerging problems can be identified and dealt with earlier. Given the complexity and novelty of projects that Thales works on, problem identification and intervention may be as benign as a straight forward quality control check with feedback that is part and parcel of the normal 'way of working.' However status reviews, with judgments about suitability of progress within the project context, occur on a continuum. A suitable intervention may be to enact contractual clauses and withdraw from further work, or for R&D budgets to be reallocated away to other technologies, or on to a specific project in greater amounts. These more consequential decisions require information on the current state of project development that is interpreted from raw data, and highly contextualized. With every project being different, and every context different and dynamic, our problem of providing visibility of progress so that relevant decisions can be made is not straightforward.

Prior to the organizational restructuring, Thales UK leadership initially assumed that the implementation of a technical metrics program that would give visibility in to all UK projects and programs would require detailed effort, but that effort would deliver the insights that the organization sought. This view assumed the portfolio of projects could be managed using simple or complicated methods (see Snowden and Boone, year). In practice, Thales experience was similar to the efforts of the US DoD in response to calls from congress for a single set of metrics report card on defense acquisition. We like to measure programs quantitatively, but since all programs are unique, there is no 'summary' quantitative (and hence automatable) collapsible view of the state of a project portfolio. (Gilbert, Yearworth, and Oliver, 2013) (CSER 2014 Keynote, and 5000.02).

After the Thales restructure, the 'Internal Business Unit X Head of Engineering' (hereafter referred to as 'the SOI Owner'), brought together a number of Thales UK assets to develop a system that would monitor the technical progression of engineering within the Business Unit. This system is our SOI, for this case study. The system has purpose – to monitor the progression of engineering, such that the need for intervention can be detected early, and the impact of those interventions can be seen. As such, the purpose of this business unit was especially consistent with this paper's effort to review a broad range of engineering effort using a systems-based framework.

It is important to bear in mind that concrete evidence of a project or program's success or failure is only generated at the end of the project (i.e. when the scope, budget, or time allowed is completed). Judgments of the merits of mid-stage progression are always, to some degree, subjective, and are interpretations of 'likelihood of ultimate project/program success'. The SOI, like the engineering projects it monitors, is also in development. Currently, the SOI covers projects within 4 of the 6 business lines within the Business Unit, and 4 of the 6 UK sites where the Business Unit is present. There is an element of developing, maturing, and refining of elements of the system occurring in the areas where the system is more established. But even within its current area of coverage, the diversity of project types, number, scale, and complexity within one site, one business line, or one engineering discipline makes aggregating state-information and corresponding suitability judgments non-trivial, in a single big-picture view.

Methodology for the Case Study

This case study was exploratory. It sought to find out what could be learned. Inevitably, exploratory research develops scope, methodology, aims and findings in a somewhat iterative approach. This research activity was carried out as part of an EngD in Systems, which seeks to carry out doctoral level research that both contributes to knowledge and is also valuable to industry (Ref Godfrey et al). While origin of SPT/SP lies within the natural sciences where positivist philosophies dominate, the Systems EngD typically employs a critical realist paradigm in carrying out action research. Since this paradigm and the subject SOI were both socio-technical, they are fundamentally non-positivist domains. So to capture this "hybrid" situation, the specific research approach used to carry out this investigation was theoretical pluralism (Ref Midgley), driven primarily by the differing native, or preferred paradigms of the SPT/SP founders, the SOI owner, and the panel of academic supervisors that critique ongoing EngD research.

It should be mentioned that although the SPT/SP has as it sources mostly positivist natural science experimental results (and so is rigorously evidence-based), it does include and compare many results from human individuals and human societies. SPT/SP argues that the candidate processes, structures and mediators are isomorphic across physical, living, and social systems equally. Thus hierarchies, cycles, feedback, symmetry, boundaries, self-organization, etc. are as potent on social system levels as natural system levels.

The use of theoretical pluralism allowed the investigation to proceed through a number of strands – positivist (by attempting to apply the natural science-based theory, using a pathology-style methodology), interpretivist (by discussion and description of social processes), and critical realist (by employing multiple methodologies to draw out additional insights). We regarded this pluralistic approach as superior to any of the three taken alone.

How to use SPT/SP

While an aspiration of SPT/SP is to provide an approach for Systems Engineering practitioners to use, a methodology is always needed to put theory in to practice. In some instances, selecting the methodology best suited to applying a certain theory to practice may be trivial, indeed within the sciences, methodology is often not discussed. The scientific tradition itself is deeply intertwined with positivist approaches, this allows theorists to proceed simply assuming the relatively narrow group of supporting methodologies and methods will be applied.

The difficult conundrum that Systems Engineers face more and more is that more traditional systems engineering tools and methods are less well suited to address or include complexity, structural dynamism, and the increasing influence of individuals behavior, which so often manifests through unpredictability and subjectivity. We make no apology for selecting a SOI for this case study that encompases all these particularly difficult elements. In some respects, this case study is a process by which the 'what else is needed' elements of SPT/SP can be identified, rather than a critique of the need for or usefulness of what SPT/SP aspires to be.

To use SPT/SP to help evaluate a design or guide a generic SE intervention, options still remain. A sample of questions that an SE may reasonably (if aspirations are delivered) ask SPT/SP to answer include:

1. Is there behavior in my man-made system that I am unaware of that could lead to the systems' ultimate demise, or dysfunction, or reduced effectiveness?
2. If I changed component X for Component Y, how can I be sure I've understood all the implications of doing that?
3. I am trying to understand relevant (to me) aspects of a man-made system – how can I capture what I need to know?
4. In developing a system, if the behavior of a sub-system is not where we ultimately need it to be, how can we work out what to do next?
5. Can SPT/SP tell me something I didn't already know? Or make me aware of important processes I am not currently measuring or considering.

Each of these questions ask a different thing of SPT/SP, and imply different application methods. Perhaps the most benign is the last question – it doesn't require SPT/SP to identify best actions, and it doesn't require SPT/SP to be comprehensive (i.e. to 'catch-all') as the first three questions imply. Each of these questions also have methodological implications, for example question 5 compares the original understanding of an individual with the resultant understanding of that same individual and looks for a difference. Question 3 includes a partitioning of relevant and irrelevant, and necessary and unnecessary. Question 1 and 2 may well involve a method of dealing with unknown unknowns. Importantly, all of these questions involve some level of subjectivity.

The case study, from the industry perspective, proceeded seeking to answer Question 5 – Can

SPT/SP tell the SOI owner something they didn't already know. If the answer to this is yes (and that knowledge is somehow useful to the SOI owner), then industrial value of SPT/SP as it currently stands will have been realized.

The case study from an academic perspective explored 'what ifs'. What if the industrial stakeholder had asked a different question (for example, one of questions 1-4 above). Is the framework ready to answer these questions? What else would be needed?

SOI Data Collection

I was invited to observe the SOI, compare theory to what was observed, then present any insights drawn from the exercise back to the SOI owner. The response from the owner to these insights would demonstrate whether the exercise had been valuable to industry. Within Thales UK, monitoring of progress occurs on projects, and within projects, and disciplines on a cyclical basis. Some of the faster-moving, more detailed elements are monitored more frequently, but the cycle at the top level of the SOI is monthly. The SOI owner and a selection of engineering managers bring together objective and subjective evidence of project status, critiquing both the progress of the projects, and the methods by which the progress has been evidenced and judged. Interventions are discussed, both the effectiveness of recent interventions, and the need for new interventions. The engineering managers attending this top-level monthly meeting have responsibilities that may span one or a number of business lines, one or a number of engineering disciplines, and cover between 4 and 50 projects, the majority of which run for multiple years. Each of the engineering managers who report to the SOI owner typically also, on a monthly basis, take a comprehensive status review of the work they are responsible for. This review typically occurs in the week before the top-level review with the SOI owner, and also involves them discussing project status and relevant context with staff who report to them. A third monthly review layer exists in some locations and within some disciplines. Each of these reviews brings together objective and subjective evidence of project status, and creates evidence (records) of decisions made, and actions taken determined across a cluster of projects. All of these evidence sources could be viable data to use in the investigation.

The top-level monthly review is usually held by conference call, since attendees are spread across the country. During the meeting attendees refer to and discuss electronic files that are accessible to all attendees via the intranet. An audio recording of one of these meetings, along with the electronic files that were discussed were captured as the dataset to examine for this case study. The suitability of this selection could be reflected upon as part of the critique of the findings. This approach to data collection was minimally invasive, and required nothing extraordinary from the meeting attendees. All attendees were aware of the research being carried out, and the recording and files are protected under a University/Thales Non-Disclosure Agreement.

Narrowing the Focus of SPT/SP - A Manageable Case Study

An initial approach to examine the SOI was attempted. The SPT/SP framework includes a comprehensive list of systems processes. Within an SOI, Systems Processes interact with one another via Linkage Propositions. The SOI, when represented as an image of systems processes and Linkage Propositions can be compared to the configurations that are called ‘Systems Pathologies’(which are assumed to represent configurations of systems which are unsustainable). It was supposed that this comparison would indicate if our SOI is less sustainable. As a further point, SPT/SP may be able to identify what aspect or element of an SOI is responsible for this ‘unsustainability’ (or this ‘illness’ or ‘dysfunction’) such that intervention cam be focused on remedying that point.

This approach is most closely linked to answering question 1 above, and as a researcher working within the Systems Engineering industry, on first reading the SPT/SP literature, I thought this approach was what SPT/SP implied could/should be done.

In practice, determining what was really meant by the each of the terms used to describe the minimal set of Systems Processes was difficult. The terms were not all defined in the initial literature. SPT1 (Friendshuh and Troncale, 2012) includes expanded descriptions of 16 of the minimal set of Systems Processes. Evidence of these 16 Systems Processes was then sought in the dataset (recognizing that, in not searching for all systems processes, we may miss one that is absent, when it should be present, or present but contributing to a pathology).

Early Results and Reflection

Evidence was easily found of 14 of the 16 Systems Processes (recognizing that, since practicing systems engineers don’t use ‘systems-process-speak’ but the conference call transcript did include fluent ‘Thales- speak’, some translation was required to match Systems Processes to the data gathered). The two systems processes that weren’t evident in the conference call snapshot of the system that I took were ‘Storage as a SysProcess’ and ‘Fractal Structure and Processes’.

It may well be that, for man-made systems, such as organizations, and engineering projects (and clusters thereof), fractal structures, as observed in nature wouldn’t exist, but its equivalent may. This is something for the SPT/SP theorists to consider discussing more directly in future literature if the natural-science based theory is to be applied to partially- of wholly-social, or man-made systems. There are, for example, two elements of fractal nature in SPT/SP not found in the basic fractal literature. One concerns a key “identifying function” of fractals. They seem in nature to be sufficing (if not optimal) organizations for flows and for occupying space efficiently. This key function has many possible counterparts in the SOI projects that were not examined. As such this is an example of question 5 above. Something the SOI knows nothing about and even does not measure or consider. The second concerns the process by which fractal structure is accomplished in nature. Very simple rules allow the elaboration of very complex results. This also may be an example of question 5 above. The SOI may likely not be using either of these isomorphic principles in its design, management, or judgment of projects which is not surprising because conventional approaches to social organization in general have no knowledge of the potential of application of these principles to its effectiveness.

While storage wasn’t explicitly evident in the snapshot view that I analyzed, some forms of storage were implicit, for example, files that were being discussed were accessed from a place of storage but this wasn't actually mentioned. Memories of what was discussed and concluded in last month's top-level review meeting did form part of the discussion. If I were looking for evidence of storage processes existing, I could persuade myself, through interpretation that they were there. But since they were not regarded as such, they may not have been as effectively utilized as SPT/SP says they must be. For example, where does conscious and explicit "storage" of "best practices" exist for very specific interactions among even the most common isomorphic processes. This is vital for any organization but humans are hardly even conscious of it (nor are human individuals). That is what the SPT/SP stores.

If I were a systems engineer, attempting to investigate my SOI to ensure that it is suitably rigorous and robust, I would not be comforted by what I observed. In man-made systems we satisfice, we need enough, but not more than is necessary. Observing presence or absence of systems processes in our SOI is not able to tell us if our SOI is satisficing. If the SPT/SP theory can be developed and supported with a suitable methodology, then satisficing could perhaps be understood by use of the theory. Without these enhancements, a practitioner would not be able to use the SPT/SP framework to ask questions of the form number 3 above.

Since some of the SPT systems processes described in SPT1 (Friendshuh and Troncale, 2012) include several possible types of manifestation of that process, if only one of the many is observed, what does that tell us about the sustainability of a system? Are all manifestations of the process necessary? If we find one, (two, or three, etc) instance (s) of a systems process within our SOI, as a practitioner, how do we know whether that one (two, or three, etc) instance(s) of that process is enough to support sustainability? This is one way that the attempt at applications can actually improve theory. SPT/SP is based on the assumption that the many SPs and LPs taken together as a network would enable and deliver sustainability. They have in natural systems. But as currently presented in the SPT/SP this is an assumption without clear coupling of any particular SP or LP and its contribution to sustainability. The theory must consider and answer this need, which as it is currently pursued has not been considered.

Some evidence of Systems Processes within the transcribed conference call were objective. Others were more implied. My understanding of Thales Jargon allowed me to understand what was meant on the occasions where acronyms of other systems within Thales were referred to, or when euphemisms were used. Similarly it may well be that there was meaning that participants took from the discussion that went over my head. My interpretation of the data collected was therefore personal to my understanding of the organization.

I mentioned the lack of evidence of storage processes to the SOI owner. I heard back that storage processes do exist, and are known to and used by those engaging with the system, it just wasn't explicitly discussed in the meeting. The data collection I had carried out had missed this aspect of the system. On reflection it is still not clear whether that was a bad thing or not. As a practitioner, is it better to take a quick, non-comprehensive view of a system, identify what is missing from that view, then look for it – or is it better to do a comprehensive data collection exercise before any analysis takes place? As an action researcher, this is an ongoing dilemma, and one that I can locate within the paradigm and methodology I am using at the time. To a practitioner who may attempt to use SPT/SP, the question of where to draw the system boundary, and how to observe the system that will be analyzed are important questions that may well be glossed over as issues belonging to theory rather than to practice. Methodological recommendations that address these issues as part of the SPT/SP package would benefit the user, and improve the value realized from the analysis.

Applications of Cyberpathology to Thales Projects; Special Relevance to SE

As the authors discussed and reflected on the methodology and findings discussed above, a second analytical approach was devised. The SOI is primarily one of judgment and feedback, and coincidentally one of the major Systems Pathologies (illnesses, dysfunctions) identified to date concerns systems-level errors in feedback architectures. SPT/SP calls these a class of dysfunction titled "cyberpathologies" (Troncale 2011). So this alternative approach examined the SOI observed data for all occurrences of feedback to ensure that the structure and operation of those feedbacks avoided knowable cyberpathologies. That is, did all observed instantiations avoid the known symptomologies of more than a dozen dysfunctional feedback architectures. Here the SPT/SP provides explicit and conscious specification and detail not usually encountered in conventional approaches.

This is a fundamentally different methodology of applying SPT/SP to an SOI, and doesn't fully address any of the five practitioner questions mentioned above, however, it's an interesting next step for this particular investigation which 'test-drives' the theory and sees what can be learned about the SOI.

Within systems research, causal loop diagrams and stock and flow diagrams are a well-known tool for representing feedback processes. The academic literature surrounding these methods covers the mechanics of how to represent stocks, flows and causal relations, as well as describing applications of the approach, insights drawn, supporting software, and the philosophical value of model-based representations of the real-world (see refs). In the workplace, practitioners frequently represent their mental understanding of cause and effect, stocks and flows, and feedback relationships using similar diagrams, regardless of their in-depth knowledge or otherwise their direct knowledge of the specific academic field of Systems Dynamics Modelling. Of note here is an established theoretical methodology that is suited to an aspect of SPT/SP theory that is also cognitively accessible to practitioners. The meeting transcript was examined for occurrences and structures that relate to feedback. While the vast majority of the meeting narrative discussed these concepts, they weren't explicitly identified (i.e. there was no statement of "lets now discuss the feedback structure within Business Line Y's software engineering discipline"). Further there was no conscious discussion of avoidance of known cyberpathologies.

Further Results and Reflection

Figures 1 and 2 illustrate diagrams that represent parts of the discussions held within the conference call.

INSERT FIGURE 1 - GET THALES CLEARANCE

INSERT FIGURE 2 – GET THALES CLEARANCE

Figure 1 and 2 show diagrams that illustrate aspects of feedback that were discussed in the meeting, they are not diagrams that strictly adhere to the notations of system dynamics models. The discussions observed via the meeting transcript showed that meeting contributors routinely query the feedback structures in place within the SOI to better understand its performance. They described assumptions, and discussed whether the data obtained tested and supported the assumptions, or whether this was not the case, and further investigations and interventions were required. To build feedback where there currently is none, or current feedback processes are weak, unreliable, slow, burdensome, or otherwise malfunctioning, various options were discussed amongst the group. In this respect ideas were put forward, and critiqued for the person responsible to consider, another form of feedback. Figure 1 and 2 therefore represent feedback within the system as it is known to occur, as it is assumed to occur, and where it could possibly be enhanced. Representing these three kinds of feedback in one diagram breaks conventions of systems dynamics modelling, but nonetheless captures the evolving and emerging understanding of the SOI.

In practice, the meeting narrative discussed some of the elements and links within these figures, then moved on to another topic, only to revisit and expand the discussion later. The specific discussions held described these structures, but also included discussions where others would challenge the suitability of the structure, and suggest potential variants. It was clear from the discussion, that even without this kind of diagrammatic aide, the participants shared an understanding of the feedback structures and processes. In this regard, providing these diagrams to the participants, or examining the SOI from a perspective of cyberpathology, would not tell them anything they didn't already know. (However, one of these co-authors questions emphatically if they considered all of the dozen cyberpathologies in this discussion. Clearly they did some, but not all). This is more a commentary of the developing maturity, the current structure, and the attention paid to this aspect of the SOI, than it is a commentary of the usefulness of the cyberpathology view. The system is, of course in development, and as mentioned above, storage processes aren't viewed as being so vital that they merit explicit discussion. As the SOI develops, ages, and inevitable role-changes occur, the lack of non-narrative representations of the SOI may become burdensome, and the value of a 'system audit' from the cyberpathology perspective could increase dramatically.

This case study also gives rise to the need to consider adaptive systems. For example, a cyberpathology view of the SOI may highlight areas where feedback is key to the ability of the SOI to serve its purpose, yet it does not currently exist. One view may suggest that this is a case where the SPT/SP evaluation has discovered a malady that causes the SOI to be unsustainable. However, the structure is adaptive, and growing, so it's appropriate that not everything is perfectly in place yet, and that with time, the system will grow and adapt to address these issues. The question remains, how do we determine whether an incomplete, yet adaptive system will adapt to become complete (i.e. has the characteristics to repair itself) or whether it will adapt in different ways and become unsustainable?

This gives evidence of the importance of just one of the Systems Processes (feedback) to SOI work; consider then the implied importance of giving equal time and consideration to some 40 or more other isomorphies. Many of these were not even considered in the discussions. Further, and beyond pathologies, SPT studies “circuits,” “modules,” “sub-graphs,” and “motifs” for some of the SPs that are not in common knowledge but have proved successful in a variety of natural systems for specific functions. Some of these involve feedbacks. Would a knowledge of these successful motif architectures not be useful to even SOI participants who are already knowledgeable about conventional feedback?

From a pathology perspective, this was an interesting case. It is recognized that the idea of ‘systems pathology’ is not yet thoroughly described in the SPT/SP literature. Systems Pathology is developed to date mostly as a call for elaborating and organizing an already available and vast taxonomy; as a framework for beneficial research. A pathology could be a description of an illness, or could be an entire methodological approach of determining health or illness, selecting appropriate interventions, applying those interventions and checking their effectiveness. Without more explicit descriptions of what is meant by the ‘Systems Pathology’ element of SPT/SP, it is not clear whether SPT/SP is ‘just’ theory, or whether is it ‘theory and methodology’. This is an area for upcoming SPT/SP literature to explore further, particularly with regards to the aspiration of making SPT a useable and valuable theoretical basis for SE practitioners to use.

The industrial case study examined in this paper involved the co-authors (one a theorist, one a systems researcher embedded in industry) and the cooperation of practitioners. The current framework is useable by a researcher, but not particularly accessible to practitioners. A survey of 6 Thales Systems Engineers who are engaged with the SOI, with between 3- and 37 years experience individually, but with 128 years’ experience collectively recognized what was meant by [Dawn to Update]X, Y, X, A, B, C of the 54 SPT Systems Processes from the named list used. SPT uses discipline agnostic terms to describe systems processes that occur in systems regardless of their discipline. In using discipline agnostic terms, the terms become unrecognizable to practitioners at home within one discipline. For SPT to be accessible to practitioners, it may be preferable to develop a thesaurus for use by, for example, systems engineers, which could ‘translate’ SPT language in to ‘Systems Engineers’ language. Otherwise, it is incumbent on practitioners to learn what is, for engineers, a quite impenetrable language, before the value of SPT/SP could start to be considered. Not accomplishing this would hamper the useability, and therefore industrial value of the SPT/SP framework. For example, all the practitioners who were surveyed understood the concept of ‘systems level malfunctions in feedback’, though none of them interpreted ‘cyberpathology’ this way. It would be interesting to measure their familiarity with all of the specific dysfunctions of feedback contained under the collecting term ‘cyberpathology’ or the feedback motif’s SPT has collected. Otherwise, this dilemma points out exactly the need for systems engineers to study systems science in their preparation. One of the co-authors maintains that no, zero, none of the current curricula preparing systems engineers internationally contains a stand-alone course on the deep findings of systems theory. He has examined the most popular textbook used to train systems engineers and found it explicitly cites only a tiny number of the systems processes, structures, and mediators of the SPT. If one compares the first and the latest (fifth) edition of this textbook, there virtually no difference in coverage or detail on systems science even though the field itself has exploded. INCOSE materials are embarrassing in their shallow coverage of only one or two of the several domains of systems science and even that in passing.

The Industrial Perspective

As mentioned above, the SPT/SP framework is currently inaccessible to practitioners. The SOI owner was surveyed regarding his familiarity with the minimal list of systems processes (n = 45 to 54).

> *"I understand some of the words, but could not be sure I understand the real meaning of ANY of them in the context that you have stated. E.g. I understand "competitive" but I could not be sure what you mean by "competitive process". Many of the words I have never come across e.g. exaptation, dysergy, metacrescence" (MM email may 23rd).*

In initiating this investigation I offered to observe the SOI, and provide the SOI owner with a 'theoretical' view of the System, which may provide insights of value, and if not, would provide valuable feedback on the applicability of theory to practice. I promised the SOI owner that the view would be thought-provoking, and would not exceed 4 pages.

As described above, the content of the discussion itself provided a great deal of evidence that the SOI owner and participants had a understanding of the structure and issues surrounding feedback which they personally believed to be thorough. Similarly it was clear they understood hierarchy, boundary, flow, cycling, cooperation, and networks. In selecting the SOI as one to test SPT/SP, I drew the system boundary around the outside of the system owner, and included the conference call participants within the System. The SOI I investigated was therefore socio-technical. The SOI owner had assumed I would draw the system boundary around the technical artifacts, i.e. selecting a smaller boundary that included only technical elements, perhaps mirroring his own assumption about where 'the system boundary' is. Actually the SPT/SP are just as much about the technical products that are produced than the human systems that produce those artifacts. So the co-author and the SOI owner are being pushed to consider more than they would before the exercise. And this is without the extended meaning of boundary conditions typical if they studied SPT and its consequent pathologies. Learning that there are a number of different credible boundary conditions is an important lesson in itself both for improving producing systems, products, and improving communications. (Non-explicit expression or awareness of different boundaries can lead to miscommunication and conflict).

But do they really know even these most common of a few systems isomorphies as well as they think they know them? General familiarity with a term does not equal adeptness in use of its potential, especially those isomorphic terms that are in common terminology. Since the key contribution of the SPT is that the Linkage Propositions explain how items like hierarchy, boundary, flow, cycling, and networks <u>influence each other</u>, it is not clear that the SOI owner has as detailed a knowledge as that provided by the more fully developed SPT without studying the LPs. Second, another key contribution of the SPT is its detailed description of the processes behind these widely experienced isomorphies which directly enables more detailed description of when they don't work in systems pathologies. Without the detail of the specific dysfunctions, it is likely SEs might feel they know these processes but still not know the many ways they can become dysfunctional. And that is just using the systems processes and not the added level of detail of the linkage propositions and their consequent pathologies. Third, SEs like the SOI owner may know a handful of the most common isomorphies, but that does not amount to knowledge of 40 of them or 110 of them in the longer listing of candidates.

The activity of observing a system and examining its systems processes, and how they interact, while developing a methodology to use required creativity, interpretation, and in some cases led to investigation of what turned out to be, dead ends. This style of research relies heavily on sense-making, and its findings therefore, are subject to my own background knowledge, and skills as a researcher. As mentioned above, systems dynamics modeling is an established methodology that could be used to link the SPT/SP theory to practice, and without 'translation', SPT may be somewhat meaningless to practitioners. In doing this work, I tended to pattern-match what I saw with other systems methodologies that I am familiar with which aren't founded upon the fundamental systems processes of the SPT, but do appear to have units based on interacting combinations of SPT elements.

My feedback to the system owner was a greatly truncated, and re-packaged selection of the detailed work that was carried out. It covered only the insights that I drew from the investigation that evidence suggested had not been noted or noticed by the SOI owner. It focused primarily on two aspects; problem- solving in the social-network, and expansion of the SOI to cover the remaining business lines and Thales UK sites.

The SPT/SP evaluation could give us a substantial description of what the technical system is, and to some degree how it works, however it could not describe why it works. SPT/SP is a 'component-level' diagnostic most suited to application in the physical (i.e not social) world. The applicability of systems processes to the social system is in some cases easily translatable as we have all received 'feedback' in a social setting, if we have acted in an 'unexpected way'. The ability of other systems processes to map, or translate from their natural science base to a more social-science arena is an important aspect of SPT/SP development to consider. The 'systems engineers' described at the beginning of this paper need to deal with social systems more and more. For SPT/SP to help them, a theory and methodology must cover social systems.

In providing feedback to the SOI owner, I attempted to 'translate' the systems processes from SPT/SP that appeared to be manifest in the social element of the socio-technical SOI. I combined this view with other established social-systems approaches to give a 'plain english' description. My summary stated that the forum of the conference call established a feedback loop where ideas were solicited from all, ideas were voiced, considered by all, critiqued, implemented, and reviewed on repeat. What results is a continually improving system that can adapt to changing external stimulus, and can employ methods suited to the complexity of the local context. The diversity and experience of the participants also mean the greatest minds who are familiar with the context and the problem are put to the new (emerging) problem very quickly. It is key that the leader of the meeting and the owner of the SOI establish this 'feedback loop' social norm to be repeated with every issue and at each meeting. It should be noted that it is not uncommon within engineering companies, including Thales, to run meetings that discuss a diverse portfolio, where members of one part of the company do not, and are not invited to critique the work and ideas of those in another part of the company. I recommended that this aspect of the SOI workings be considered when bringing in the remaining business lines and sites.*"I am very grateful for your observations about bringing in [new business line 1] and [new business line 2]. I do not think deeply about these things but clearly I should because I would probably have got things off to the wrong start! You have almost certainly saved me a lot of grief!" email mm 29th april*

Observations on the General Task of Applying SS Theory to SE Practice

The SPT/SP framework is in development, so an attempted application could only give early suggestions of its ultimate usefulness and usability. This particular application was carried out by a systems researcher embedded in industry, in collaboration with the founder of the theory. This particular combination is rare, and it may be fair to say that, prior to this paper being published, a systems engineering practitioner may not have attempted to apply the framework to an industry-based SOI and draw meaningful insights. A number of undergrad and graduate students have tried application of SPT to broad disciplinary domains such as marine conservation, computer memory devices, transportation systems and several more, but these were very broad attempts and not as focused as this attempt.

The combination of skills, background, motivation, time, and access that led to this investigation being carried out was clearly rare, but did result in useful insights being drawn out and taken on board by practicing Systems Engineers. The aspiration of the SPT/SP framework in terms of its usefulness to practitioners is (as of March 2014) somewhat vague. While the framework aspires to help, it is not clear to the SE co-author what industry-based questions it could be used to answer (for example, is it unreasonable that practitoners ask the 5 questions listed above? What other questions could they ask? What developments are needed to SPT to allow it to answer those questions?

This application has clarified the need for a methodology, and highlighted difficulties in 'translating' theory from natural sciences to other domains. Questions clearly remain about the validity of claims that a theory from natural science can be useful in a social domain if the methodology to make that translation is not supplied. Put in direct terms, the SE co-author feels that the 'translation' of SPs from natural science to social contexts should be described explicitly within literature, rather than leaving individual users to 'imagine' how flow in the physical world maps to 'flow' in a social world.

Can Attempts at Application to Improve Practice Also Improve Theory?

So what about the reverse flow of advice and information? Can attempts to apply the theory lead to improvement of the theory. Both co-authors feel that there are several lessons from this first tentative application that suggest theory must listen carefully to attempts at application. First, there is a sine qua non need for discussions about methodology or protocols, how they are different for the natural systems and social systems domain, and even more different in the engineering domains. Translation will require bridges for all three. Second, there is a need for more specific descriptions of many of the systems processes, especially the dozens that are entirely new to practicing systems engineers (and even many systems scientists). The ongoing collection by collaborators of data on 26 categories of info for each systems process (sysinformatics) may help satisfy this need. Also, the preparation of a comprehensive semester course on Introduction to Systems Science for the new Master's Program at California State Polytechnic University and the Workbooks and MOOCs associated with this course will help. Third, there is a need for more exact description of exactly what the SPT or Systems Pathology can (or will be able to) do for practitioners, since these specific descriptions impact what the theory needs to cover and guides those who may attempt future applications. Fourth, attempts at communicating the theoretical abstractions to applied persons has led to deeper questions about the systems processes and the many systems pathologies in ways that have strengthened the theorists command of each.

It is ironic that the motto for the California State Polytechnic Universities (both Pomona and San Luis Obispo campuses) (where the SPT/SP originated) has always been "learn by doing." Indeed the rationale for the "polytechnic" emphasis is practical application and not isolated academic theorizing.

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