PROCEEDING

Two Essential Sources for Application of Systems Engineering to a Science of Laws

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ABSTRACT

To increase systems engineering potential for contributing substantially to law, legislation and public policy (LL&PP), two fundamental and indispensible knowledge bases, not yet present in SE practice, must be learned. First, SE would need to study the long history of precedent for science influencing lawmaking and Congress and the practical lessons those early experiences provide. This new attempt should learn from this pertinent past. Second, SE would need to incorporate a rigorous, evidence-based natural systems science in its education, post-graduate training, praxis, and certification programs. Regarding the first, this paper will describe the build-up of influences in the '60's that led to legislation establishing the Office of Technology Assessment (OTA, Public Law 92-484) [this author participated in those deliberations], recap its reports and their influence, outline forces that caused its demise, and concisely summarize some of the lessons learned. It will also describe some of the experiences of the institutions that attempted to substitute for the dissolution of OTA in terms of science counseling legislation. Regarding the second, this paper will describe a new natural systems science (Systems Processes Theory) that provides a very detailed list of 100+ isomorphic (patterns) that describe how systems work and also provide a spin-off of how systems don't work (Systems Pathology). Development of this research framework is one of the official projects of INCOSE's SSWG (Systems Science Working Group). This thorough list of desirable features of workable systems would be essential to evaluating models of proposed legislation or public policy positions.

Keywords: science and the law, Office of Technology Assessment, OTA, natural systems science, systems processes theory, modeling & simulation, checklists for modeling

INTRODUCTION

A selection of systems engineers and medical doctors who are members of INCOSE have decided that since laws, legislation and public policy (hereafter LL&PP) literally result in new social systems, they should be consulted to ensure that these new social systems are fair, efficient and sustainable. They would like to apply what they have learned in engineering complex systems to the complex systems problems faced by our nation. The INCOSE San Diego Chapter's annual Mini-Conference kindly dedicated an afternoon to this topic. The central objective would be to evaluate the potential of Systems Engineering (SE) to inform LL&PP.

This laudable and sensible objective is not new to history. Scientists, in general, have been trying to influence laws, legislation and public policy (LL&PP) for generations.

One objective of this paper is to raise questions about the readiness of SE as currently practiced to influence LL&PP. Some of these questions include the following: Is there a fundamental knowledge base in systems science (SS) underlying SE that describes how systems work and don't work to use in advising Congress? Is there sufficient understanding in SE of complex, hybrid (nature + human) systems to use to advise specifically how laws and public policy could be improved? Are there exemplars of successful application of SE to LL&PP? Do systems engineers generally have a good sense of how to influence LL&PP, the obstacles and possibilities involved, and have they studied past attempts and the lessons that could be learned from those past attempts? This last question is the main focus for this paper.

First, it may be important to note that historically the strongest effort by science for influencing public policy was in its own interests. Each year the budget proposed by the U.S. administration includes funding for many science research institutions. At the present time, the amounts of this funding are very significant, ~140 billions of dollars (~2.8% of GDP). So it is understandable that scientists and engineers,

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their corporations and universities, and their professional societies invested great energy in ensuring that Congress approved and authorized (two different steps) this funding at adequate levels. A short list of the research entities involved indicates how influential the research they conduct is to the health of our economy and the health of our people. The list also demonstrates the depth and breadth of involvement of science in our society.

- National Institutes of Health (NIH): ~$30 billion per year
- National Science Foundation (NSF): ~$7 billion per year
- National Aerospace and Space Administration (NASA): ~$17 billion per year
- National Oceanic and Atmospheric Administration (NOAA): ~$6 billion per year
- Center for Disease Control (CDC): ~$7 billion per year

But a second task soon emerged that was equally important to the health of our society and its individuals. Increasing numbers of laws concerned problems, topics, and issues that involved sophisticated science and technological components. The elected politicians and administrators had little preparation for understanding these new sci-tech components that they were obliged to vote upon and decide. So this paper focuses on the role of science and engineering in advising LL&PP rather than securing its own funding for research.

REDUCED COVERAGE OF SOURCES: THIS PAPER ONLY ON OTA HISTORY & LESSONS

Reviewers of the original version of this paper and presentation stated that both sources explained in the abstract would be useful information for this new SE initiative. However, time and length limitations required coverage of only the history and lessons portions. So this paper and presentation now only cover the first source. A handout of seven "posters" covered the second source, a science of systems and a general theory of how systems work and do not work. Some references also contain information on this candidate science of systems that would serve both as a foundation for systems engineering and for its advice to LL&PP. A brief overview of this theory and its spin-off Systems Pathology is given in the last section of this paper.

CURRENT STATUS OF SCIENCE REPRESENTATION IN CONGRESS

A first step in considering the history of science advising LL&PP would be to outline how many current politicians have a STEM (Science, Technology, Engineering and Mathematics) background. Representatives and Senators are elected to Congress for a multitude of reasons, but rarely for scientific expertise. There are only 3 conventional scientists (2 physicists; 1 microbiologist) in the current 535 members of the 113th Congress. All are in the House, none in the Senate. This is not counting the 6 engineers and 19 M.D.'s in Congress because if I have learned anything in my current research in INCOSE, it is that engineering feels itself to be quite uniquely different from science. I would praise the double blind control studies of medicine as an ideal of the scientific method, but it too is an applied science field with many objectives different from science. Science research M.D.'s are ony a small percentage of all M.D.s. Both of these specialties have a particular perspective and knowledge base useful for a subset of problems our nation faces. Neither has the breadth of systems-oriented studies because the crisis problems we face are complex systems problems.

It would be misleading to point out that scientists comprise only 0.5%, engineers only 1.1% and medical doctors only 3.5% of Congress - 5.2% all together. Scientists and engineers are less than 5% of the U.S. population. Percentages are irrelevant. We are concerned here about providing studies and research that inform all Representatives and Senators about the science and engineering background for a wide range of issues, not direct representation of the sci-tech population. In addition, the range of topics in sci-tech related legislation is far greater than the range of expertise of even the few scientists, engineers, and medical doctors in Congress.

CASE STUDY: OFFICE OF TECHNOLOGY ASSESSMENT

If INCOSE in particular, and systems engineers and systems scientists in general, seek to provide their expertise for improving LL&PP, then it would be useful for them to become savvy about the pitfalls and potentials of that intervention space. In this paper, we use the experience of the Office of Technology Assessment as a case study that contains many of the key features of such an endeavor. The case study approach is characterized by deep study of a single instantiation of a particular problematique with the hope that it will provide guidelines for similar situations. The OTA story is rich in detail and occurred at the very highest levels of science and technology studies in the service of LL&PP. It is also well documented, archived, and about to become an issue in current politics. So here we use OTA as a stand-in for the general class of activities involving science and engineering advising LL&PP.

Pre-OTA Debate; Development of Awareness of Need: Around the sixties, the politicians of Congress realized that they were voting on very specific legislation that far exceeded their knowledge base. Sworn to provide for the security and stability of our civilization, they were increasingly called on to make decisions about technical advances. They became sensitive to the need to anticipate negative consequences of their decisions and to various technological developments. Weisner, science advisor to President Kennedy, emphasized the need for the "early warning" function that science could provide on many issues. Congress recognized that we suffered a lack of deep, intense research on the crisis societal problems we were facing. Our country benefited from becoming the most accomplished innovation engine internationally, but this achievement simultaneously required that we vetted the innovations produced.

Ironically, one of the main needs that became apparent was an imbalance between the separate powers in our nation. The executive branch moved quickly to increase the availability of science and engineering advice (President's Science Advisor; President's Science Advisory Committee; PSAC since

Truman and Eisenhower) but the Legislative Branch of government was falling behind. Consider the allocations to the various science agencies listed above in each annual budget request. Such issues a anti-ballistic missile systems or not, Environmental Protection Agency or not, supersonic transportation or not put Nixon administration initiatives on the table. PSAC made requests according to reports from experts. But how was the Congress to decide on these requests without advice of its own? While we in science and engineering might see expert advice as leading to something like truth and accuracy, the Congress was actually more focused on power and making sure the power was balanced by equal, but independent technical studies. Another purely political aspect was the growing awareness that Congressional Committee Chairs needed to expand their control over sci-tech matters. LL&PP derives from Congressional Committee hearings and draft legislation. Congress also needed to consider the international dimension of competition with other nations over new sci-tech developments.

As a result of the above growing awareness and specifically because of the shock of Sputnik and Russian space science advances in 1957, Congress created the SRD, Committee on Science Research and Development, its first exercise at influencing science and hearing from science directly. In 1963, the House named E.Q. Daddario (D-Conn) as the Chair of the House SubCommittee on SRD. At first, its main role was running hearings on funding authorization for the National Science Foundation. Then hearings migrated to government-science relations in general. At these hearings, Yaeger introduced the name "technology assessment" which became standard internationally. Using three reports from the Library of Congress, the National Academy of Sciences and the National Academy of Engineering, Daddario's Committee proposed foundation of a Technology Assessment Board (TAB) in 1966 to identify new technology potentials, possible undesirable consequences, and transfer of basic research to applications. TAB was to be "neutral and detached" from political influence, "insulated from policy making," and "reflect both public and private interests." But TAB was altered significantly by Congressional hearings in 1969. It was refined to be serving Congress solely, and the feature of Presidential appointees was eliminated. Later other features, such as appointment of seven members of the public, and Directors of other science advisory organizations, was lost. Still no action was taken. Later Senator Bartlett (D-AL) proposed founding an Office of Science and Technology like the organization serving the executive branch. That proposal died in committee. It is really important in the context of this paper to recognize that all these changes were made for reasons of pure politics and power, not for improving how science influenced LL&PP

This author played a tiny role in the spread of awareness of the need for Congressional science advising at this time. (See the handout article distributed during the talk.) I was a graduate student in Cell and Molecular Biology at Catholic University just a short distance from the Capital. I had kept a personal file on Science and Public Policy debates as a side interest from my wetlab and theoretical systems science research. I decided to volunteer to help the key funding committee for NSF chaired by Daddario. So I walked into his office and was assigned to ghostwriting short floor statements -- some that made it into the Congressional Record. Rep. Daddario had been asked to give a speech at the dedication of the new Science Center at Wesleyan University. Apparently he liked my writing so he gave me the title, "Academic Science and the Federal Government" and entrusted writing the speech to me. From my personal file I spontaneously dictated a speech to his amazing secretary who typed as I talked. He adopted and very effectively delivered that speech and it yielded unexpected results. In the speech, I "outline(d) the characteristics of a structure that is needed to promote this partnership" (between academic science and government). It sounded much like what the OTA came to be. Those scientists attending the dedication thought the speech should be published as a feature article in Science (the most-widely-read journal of multidisciplinary natural science worldwide). The editors accepted the exact words I had written for the article – I had composed all but the title words. Clearly it was because Daddario, an authority of such influence, was saying those words that they were listened to at all. But it is ironic that as a mere graduate science student I was influencing national policy (if even by stealth). (Daddario passed away in 2010 after successfully founding OTA, becoming its first Director as well as President of the AAAS otherwise I would not disclose this ghostwriting, nor should you beyond these notes. My words, in any case, were derived from his past official positions as reported in the press, both scientific and public.)

Although Daddario led debate in the House for the predecessors and build-up to the proposed law that resulted in foundation of the OTA, he had decided in 1970 to leave Congress and run (unsuccessfully) for Governor of Connecticut.

Bi-Partisan Legislation (PL 92-484): Harvey Brooks, chair of the original National Academy of Science study requested by Daddario in 1968 wrote most of the bill. Rep Davis (D-Ga), who succeeded Daddario as Chair of the SRD introduced it as independent legislation, not a rider on other legislation as before. The bill simplified OTA administration; eliminated Presidential appointments so it was Congress's own agency; removed the outside public representatives; and perhaps most importantly limited referrals (requests for reports) to standing Congressional Committee Chairs only. It also contained unique bipartisan compromises. The TAB Chair and Vice Chair were to alternate between the political parties (Dem/Rep) and also between the House and Senate. The foundation of OTA finally passed Congress in 1972 and was signed by President Nixon. Unlike today, it was an era of bipartisan cooperation.

Relevance to Science & the Law: It is important to emphasize how key these changes were to the success of the legislation and how they are signals to any current effort to influence LL&PP. All six changes cited above secured start of OTA as a creature of the legislative branch exclusively, balanced between parties and houses, and coupled tightly to the direct concerns of Congress and its committee-chair-dominated system. Similar influences will effect INCOSE/SE.

ACTIVITIES OF THE OFFICE OF TECHNOLOGY ASSESSMENT

Despite his absence from Congress when OTA was initiated, Daddario became its first Director. OTA had an annual budget of ~$22M and 143 full time staff at its maximum, more than half Ph.D.'s, with a temporary ad hoc, part time staff approaching 200 at its peak in the 80's. A 12-member governing Board (the aforementioned TAB) of 6 Democrats and 6 Republicans each,, 3 from the House and 3 from the Senate, administered OTA. TAB appointed the OTA Director, approved the budget, approved and delivered reports after they were produced, and chose the individual projects from a list provided by congressional committee chairs, and only those chairs. No other individuals, agencies, or units could suggest projects. Any input from scientists or the public was relegated to the external Technology Assessment Advisory Committee (TAAC). Both the informal nature of OTA and its empowering legislation enabled and required it to seek to fulfill the following characteristics, "tuned carefully to language and context of Congress," "no recommendation of specific policies," "stakeholder bias minimized." For most of its lifespan, OTA appeared to succeed in achieving these ideals of "objectivity" and "neutrality." An advisory panel of experts, a core OTA team, stakeholders, and a dedicated, individual Project Director usually produced each of the OTA assessments. Many involved outside contracts for major analytical tasks as well as an in-house research team. Many also convened workshops, extensive external peer reviews, and continual rewriting as well as dissemination tasks.

Measures of Productivity: OTA conducted its studies for 24 years, 1972 to 1995. In this period it completed more than 755 studies on a very wide range of topics. These included such problem areas as health systems; assessment of polygraph reliability; space; defense; global climate change; acid rain; energy systems; information technology; environment; the textile industry; nuclear systems; weapons of mass destruction; biopest control; global telecommunications, etc. Some of these studies were massive. For example, one study alone consisted of 2 volumes, another 3 volumes, and still another 12 volumes. The average time taken to produce a study was 18 months at an average cost of $500,000. Notice the topics. Many of these studies have "staying power" and are as significant today as when they were completed.

The trends documented across the lifespan of the OTA indicate that reports increased steadily rising six-fold from the beginning to the end. The increase was from 10 per year at the onset to ~60 per year at the end with an average of 32 reports per year. The average doubled in the first two decades. But the official large-scale studies were only the tip of the iceberg. Many more interim reports, summaries, special reports, background papers were also produced. The inside joke around OTA was that the most often produced items were "senator-sized" (2-page) briefs. One way to evaluate OTA productivity is to compare it with Congress itself by noting that OTA used up $20M compared to Congress's $3,200M or half of one percent of its parents budget. A scientists'/engineers' conclusion would be, "sci-tech advising pays off with much value-added."

Measures of Influence: It is difficult to measure efficacy in an area so burdened with ideology and currently with partisan bias. Here are two measures, one from government staff observers and one from an external entity. The first involves assessment of the most political part of OTA, namely TAB consisting entirely of politicians. At the beginning of OTA it was predicted by some observers that the very busy, highly politicized members of TAB would inevitably become, "disinterested" and/or "dysfunctional." In most observers view, neither negative outcome happened. TAB continued to meet every six weeks and even more often as the workload increased. You would be surprised and pleased if you looked at a history of TAB members. It consisted of many well known and senior Congressional members of the House and Senate. Rather than opposing each other, they shared staff, and participated "vigorously." Important national topics were one of the stimulants for this performance. No member could ignore/avoid learning about ICBM information, or drug costs, or explosive agents. The analytical became an important extension of the conventional rhetorical arguments. In fact, sometimes both opposing sides in congressional debate used the same OTA report to support their positions.

The rigorously independent Union of Concerned Scientists conducted an external assessment of OTA. They pointed to four specific examples where OTA studies had resulted in a important service to the nation. First, in 1985 it warned about huge oil spills and our unpreparedness to handle them. This was four years before the Exxon-Valdez oil spill occurred in Alaska and much longer before the great Gulf disaster. We were still not ready. Second, compare the scientists stating that the missile defense system was costly and ineffective which was still deployed despite this advance warning yielding $9,000,000,000 to the providing industries. Third, OTA reports warned the newly formed Dept. of Homeland Security that its proposed radiation detection systems were defective but they were still purchased at a cost of billions. Fourth, OTA popularized the use of electronic distribution systems for government documents and that saved the taxpayer vast amounts of money. The UCS stated OTA saved or could have significantly saved taxpayers money while contributing to "better economic well-being, safety, and health."

DISSOLUTION OF THE OFFICE OF TECHNOLOGY ASSESSMENT

Evolution: The OTA changed across its history. Unexpectedly, both TAB members and their staffs became highly involved. Exactly oppositely, TAAC became marginalized. They had no vote and so direct public input disappeared. The vital and anticipated "early-warning" aspect was muted. The limitations of funding caused the OTA to spend more and more on pre-studies to ensure that they could do an adequate assessment of many topics. Focus changed from the "policy recommendations" of the first study (on drugs) to providing a range of positive and negative alternative policies. Some of these developments were good and some were not so good given the original objectives of the legislation.

History and Issues: About the time of the Reagan administration, voices were raised to criticize the OTA. For example, one book (*Fat City* by D. Lambro) tried to prove that OTA duplicated other existing agencies. Other more polemic criticisms were that: (i) OTA mission “was not fully integrated with well-established congressional processes;” (ii) accusation that Daddario favored liberal legislators; (iii) OTA staff harbored bias against some members; (iv) Ted Kennedy dominated OTA work; and (v) decried as a tool for Kennedy to attack the Nixon administration. Additionally the concentration of power of referral in Committee Chairs may have helped get the law passed, but in the end it meant that OTA provided very little contact or service to individual members and so it made it easier to find the votes to dissolve it.

As a matter of timing, these mounting criticisms occurred at the same time as the Gingrich “Contract with America” movement and a Republican resurgence gaining decisive control of power. The drumbeat that “government” must be scaled back arose and a “zero-sum” mentality proliferated. New power holders were looking for agencies to eliminate. They could not eliminate the Congressional Budget Office (it prepared their budgets), or the Congressional Research Service (it served all members; not just reports for Committee Chairs), or the GAO (mandated for audits and management), so they eliminated OTA that had a much smaller base of support. This earned the new powerbrokers a symbolic victory, some said only “brownie points,” yet they could say to the public that they had eliminated an entire agency and accomplished otherwise elusive budget austerity.

It is amazing to read the very close votes (sometimes by ruling that a couple of members enroute were absent) and extensive background maneuvering that led to OTA defunding. That is an important point. OTA was not completely eliminated – technically it still exists on the books. It was just stripped of funding and so of service. A more skeptical view has emerged in recent times. Politicians just found that analysis too often led to information that opposed their set ideological positions. Seeing our current stalemate on several issues like climate science, abortion, same sex marriages and raising children, on and on, such a skeptical view appears warranted to some. Generally it was not proved that OTA research reports were biased, inaccurate or imperfect. OTA fell from political partisanship, not research malfunction.

Reactions to Closing OTA: Reactions of the minority party of the time were predictable. G. Brown (D-Ca) described it as “shameful,” that it eliminated Congress’ “defense against the dumb,” that other agencies could not substitute for OTA reports (a conclusion that was later proven true in my opinion). But even the other side of the aisle had dissenters. Houghton (R-NY), though a part of the majority said this about dissolution of the OTA: “We are cutting off one of the most important arms of Congress when we cut off unbiased knowledge about science and technology.” Other observers claimed that this event was a case of “politics overriding science.” It would be useful for INCOSE and systems engineering to recognize this history because these obstacles remain in force and any ambition vis a vis science and the law must overcome them.

Consequence of Closing OTA: Dissolution led to several effects: (i) Congress had to rely more on experts with a stake in the outcomes (lobbyists, industry); (ii) there was more centralization of power in the House of Representatives; (iii) influence from other government agencies was reduced because they did not have the OTA mechanism of producing extensive reports; (iv) the power of the Speaker of the House increased as power of committee chairs was reduced; (v) political party leaders influenced overall policy more than before; (vi) there was an immediate reduction in inclusivity; (vii) there was an immediate loss of systems-level interdisciplinary inquiry for complex systems problems. All of these effects are in play today.

Relevance to Intentions of INCOSE & SE: What does the ending of OTA say to the ambitions of INCOSE, scientists, and systems engineers to influence LL&PP? The objective of this special session of this mini-conference seems to be exactly what OTA was doing before disbanded. So every itemized problem above becomes either an obstacle or opportunity for future initiatives.

OTHER INSTITUTIONS ATTEMPTING TO FILL OTA ROLE POST-OTA

Where does the current Congress get science and engineering advice in the absence of OTA? That it still needs such advice, anticipation of problems years in advance, and accurate analysis is an argument against the original criticism that OTA was only providing services already available. Clearly the remaining advisory groups such as the Library of Congress (LOC) and the Congressional Research Service (CRS) were not authorized or set up to perform the intensive and extensive studies OTA performed. For a time (circa 2001) Congress requested the GAO (General Accounting Office) to experiment with Technology Assessment. It has a small TA unit producing only 1 report per year. But this attempt was short-lived, under funded, under staffed, and too narrow in focus. This inadequate response continues. GAO has no TAB to guide and focus referrals, no similar connection with Congress, no way to establish priorities, and no targeted funding for focused analyses on particular critical topics. The National Research Council (NRC), which is the research arm of the National Academies (NAS)(NAE) and the Institute for Medicine, more than doubled their reports to >50 per year from ~20 per year in the first year OTA was inoperable, but dropped back to the 20’s in 1 year. NRC services the executive branch more than the legislative and its reports are quite different in coverage than the OTA. The President’s Science Advisory Committee (PSAC) provides science advice for public policy but again it is a part of the executive branch leaving the legislative branch in the weakened position it was in before OTA. Some Think Tanks have objectives that sound similar to the OTA, but most are considered far from neutral. Most inhabit the extreme parts of the spectrum from liberal to conservative. After OTA some of its staffers formed the Institute for Technology Assessment (ITA) thinking there would be a market for it. But it never attracted sufficient funding, had no direct connection to Congress, and folded quickly. If INCOSE and SE want to influence LL&PP. then these several needs must still be fulfilled.

RE-ESTABLISH OTA? PLAYERS AND ODDS OF SUCCESS

What are the chances that a new OTA could be reinstituted? It would only require refunding since the enabling legislation is still in effect. There remains considerable documentation of the OTA. In its last year it produced 61 reports, the most ever. Archives have been maintained at Princeton University (OTA Legacy site) and the Federation of American Scientists (FAS) that have records of many interviews as well as the publications and reports. TA never took off in Europe possibly due to having the parliamentarian form of government rather than the balance of powers in three branches of the U.S. TA activities exist in Austria, Denmark, Great Britain, Sweden, the Netherlands, and the European Union as a whole (see EPTA). But TA never quite achieved the scale there as here. Ralph Nader has criticized Pelosi, minority leader of the House, on his blog for not pushing resurrection of the OTA. But this seems like grandstanding on his part given the current stalemate in Congress. Holt (D-NJ) has also called for the restart of OTA. It is very interesting that Hillary Clinton stated she would reinstate the OTA during her past presidential campaign. It will be even more interesting if she makes it one of her goals if she runs in 2016. The aforementioned Union of Concerned Scientists has called for OTA rebirth and its campaign for this has been backed by a significant coalition of >100 citizen, technical, and academic groups. Other allies for INCOSE and SE in formulating a science of laws might be the Woodrow Wilson International Center and its report on restarting OTA, the Science Cheerleader Blog, and the ECAST network (Expert & Citizen Assessment of Science and Technology). Overall, this author concludes that the INCOSE and SE effort to start a Science of Laws is a matter of timing and change of context. The environment is not strong at present for such an effort but preparations must be started now to capitalize on changes in the current situation.

POSSIBLE LESSONS LEARNED FROM OTA AND HISTORY

This section is the pièce de résistance of this paper. It briefly summarizes 30 lessons or insights taken from the above analysis and the considerable experience of the authors of the texts on TA found in the background references section. These are ideas, problems, obstacles, potentials, and pathways that INCOSE and SE might consider in increasing the influence of either systems engineering or systems science on laws or in initiating a foundation for a Science of Laws. The insights are not listed in any priority order and all may be regarded as equal in impact. In all of these "Pols" means all legislators and administrators who write and execute legislation and "SEs" means all external public citizens especially systems engineers and systems scientists.

Opposite Objectives: While attempting to influence LL&PP, SEs should keep in mind that everything written and said might be heard in entirely different ways. Experts studying TA, for example, have jokingly referred to a sarcastic twist on the medical Hippocratic Oath, "do no harm" as the political Hypocritical Oath, "do no harm to one's established interests." Pols seek results that agree with their positions, not necessarily scientific fact.

Role of Power: Experts advising Congress and the Administration likely have a self-image of having the truth on their side, and think the truth is powerful. The Pols who they advise, however, are the one's who have the power as invested in them by their election.

Personal over Written: Science experts have lived lives completely dedicated to doing work that resulted in written publications. To them power and influence comes from the written word, but study of OTA's history indicates that it was the personal interactions and loyalties of OTA staff with Congressional staff that over and over again proved the most influential. Oral and face-to-face methods were dominant in effecting change in LL&PP.

Objectivity Rejected: The SE expert's orientation and value lies in objectivity, but the Pols of the LL&PP audience have an orientation and value of subjectivity and special interest.

Winning over Neutrality: SE experts try to achieve neutrality to identify, discover, and develop facts; Pols gather "facts" to win. These unlike mindsets can inhibit communication. SE's & SS's try to start with neutrality; Pols try to end neutrality.

Consensus Difficult: Science is based on competition, challenge, self-correcting criticism. This is often misinterpreted by Pols who use any dissension as evidence for non-consensus and lack of factual basis. It is hard to communicate relative proportions to non-scientists.

Complexity of Problems: SE and systems science experts have to recognize that not all problems are soluble by application of the scientific method. Often societal crisis problems are beyond the reach of conventional science. Problems are "messy" in systems science jargon.

Variety over Truth: The search for consensus in science leads to a reduction of variety. Other branches of government focus decisions and so also reduce variety. But the whole goal of Congress is to increase variety through representational government. Variety dilutes factuality.

Alternatives over Conclusions: Science often continues experiments until it reaches a conclusion or set of facts. But Congress wants a range of alternatives, not a single conclusion.

Unexpected Influences: Pols in general have many competing pressures to balance (Committee Chairs; special interest groups; balance of powers of competing Branches) so experts have to be alert to a wider range of influences and consequences than they usually consider. Advising government is not like designing a "controlled" study.

From Political to Depolitical: OTA attempted to avoid politicization and even Orrin Hatch and Ted Stevens praised it as neutral. Expert advice has to be depoliticized to succeed.

Experts under Pols: History shows Pols want experts "on tap, not on top." Purporting to have the facts, experts easily appear to be dominant. This is counterproductive in this arena.

Need for Courage: Example, Hollings (D-SC) voted to authorize and release the OTA report on Textiles even though negative for his state. He later spoke out against its findings and recommendations; but he did not use his power to stop the study from being done or released.

Three Branches in U.S.: Experts must be sensitive while doing studies that the facts they compile might be seen and used differently by each of our three Branches of government in fulfilling their roles of checking and balancing the power of each other. Facts take on a different nature when viewed in this special light of competing power centers.

Other Key Issues: Experts tend to study isolated issues. It is very difficult to establish patterns and regularities without controlling the study area. But Congress has to consider a much wider range of influences including many trade-offs, value judgments, and public opinion.

Ideology over Science: Current studies show that most humans actually become more tied to their pre-existing errors when presented with facts rather than alter their original ideas. Pols are human. Expect established orthodoxies to compete well with facts whether true or not.

Inform don't Decide: OTA's experience showed that providing Pols with the maximum number of alternatives was more successful than providing them with a conclusion. Better to inform the debate than to resolve the debate or recommend a specific pathway or action.

Importance of Prioritization: With so many influences beyond the factual and always subject to very limited resources, experts must work hard to establish fact-vetted priorities.

Early Warning Critical: Experts must help government at all levels become much more proactive than its current state of being chiefly reactive. But dealing with problems not yet here is discounted by the public and so also by their representatives.

Expose Ideology: Experts have to be more aggressive in challenging faulty ideologies, immediately confronting faulty rhetoric as well as combating them not only in advising Pols but also in education and culture looking toward a generation less hobbled by limited thinking.

Reverse Anti-Science Positions: It is obvious that certain factions today are against any method or tool that results in unassailable facts. How to advise without a substantive change in this climate is a significant obstacle that any Science and the Law initiative must overcome.

Tightly Couple to Congress: It is an inherent paradox to improve the strength of external advising and yet have that advice be accepted as internal. But the OTA history indicates that for science to have any significant effect on LL&PP its counsel has to appear indigenous.

Lessen Time Delays: Many OTA reports took so long to produce, their effect on particular issues was lessened. At the other end of the process, advice often was implemented soon enough to resolve the problems. Perhaps exemplars would increase this recognition

Interdisciplinary Teams: Many of the complex problems faced by society are hybrids of natural and human systems that demand the broadest range of disciplines, but science appears to be virtually enslaved by disciplinary boundaries and isolated silo or stovepipe thinking. My experience with the current status of SE is that they are as hobbled by stovepipe thinking and reliance on tools as the disciplines, even though they criticize silo thinking.

External Peer Review: Pols are not accustomed to peer review, but SEs and science are built on the necessity of peer review. Advisors must reconcile these opposite worldviews.

Use Proven Features: OTA showed that it is important to (a) do studies highly relevant and tied to Congressional needs and concerns; (b) prove its neutrality in both experts and methods; (c) prove evidence-based rigor; (d) communicate in direct, simple, clear language; and (e) employ personal relations in addition to written reports. SE should employ these features.

Increase All Advisory Units: Any efforts of Science and the Law should involve and seek complementarity with other advising units, like the GAO, CRS, CBO, and any new OTA.

Beyond Conventional Science: Most experts from the NAS and NAE are dedicated silo scientists of the reductionist orientation. But the crisis problems faced by society all are on the complex systems level. Advice must go beyond the conventional sciences represented so well in NAS and NAE. Thus the new role and importance of systems engineering & systems science.

Bridge Natural & Social Science: The conventional disciplines are generally clustered into these two super groups. But the crisis problems have major elements of both and involve all disciplines. So the studies need to have experts who can work across these usually separate super groups. SE and systems science potentially have that feature though not yet unified.

Bridge Linear & Non-Linear Causation: The two super groups, especially the natural sciences explain mechanisms mostly with linear causation. But our crisis problems are often complex systems based and characterized by non-linear effects. Conventional sciences need the systems sciences and systems engineering to study these special system problems.

Medical doctors serving patients in end-of-life situations often face unintended negative effects of competing treatments. The above many insights also often compete with each other. For example, in studying the OTA case we learned that having referrals come only from the powerful committee chairs helped get the original OTA legislation through Congress and promoted greater involvement of powerful Senators and Representatives. But it later had the negative effect of removing OTA popularity from the rank-and-file Congressmen and that helped get votes for dissolution. Likewise satisfying one of the needs above might inflame other needs.

PRACTICAL ADVICE TO INCOSE AND SE RE: SCIENCE AND THE LAW

So what can be accomplished? In the near term and without extensive resources the Systems of Law Institute could: (1) Initiate a long-term study group within INCOSE. These are already a tradition as Working Groups. Procedures exist for starting new WG's. They organize a self-selected set of the 9,000 INCOSE members, and conduct activities throughout the year studying a particular sub-topic under the umbrella of systems engineering. They hold international Webinars, organize four days of Workshops once per year, sponsor papers at a range of annual conferences, and invite outside speakers and experts. (2) Once established, this Systems Engineering and the Law WG should meet and share work with already well-established INCOSE WG's on related topics like the Systems Science WG, the Complex Systems WG, the Natural Systems WG, etc. (3) A section on Science and the Law might be written and submitted to the ongoing SE workbooks, SEBoK and courses developed for SE curricula. (4) Science and the Law Institute needs to make very specific alliances with key institutions with the same objectives such as ECAST, Union of Concerned Scientists, Federation of American Scientists, and the EPTA. (5) Science and the Law Institute could offer help in any capacity needed to the National Academy of Sciences and the National Academy of Engineering. (6) The Science and the Law Institute needs to identify and write proposals to funding agencies, both public and private, for support of its projects. (7) Write and publish a range of books, reports, editorials, and research articles to establish credentials in this new area and to disseminate Science and Law ideas.

PREVIEW OF A RIGOROUS SCIENCE OF SYSTEMS FOR SE AND LL&PP

This section was intended to be the new secret weapon in establishing a rigorous, evidence-based science of laws. My collaborators think of LL&PP application as a significant spin-off of our Systems Processes Theory (SPT). However, reviewers sensibly suggested that only one of the two sources described in the abstract could be developed within the limitations of length and time. So this section is now merely a teaser. It is based on three simple observations. Laws, legislation and public policy (LL&PP) build new systems. It would be best then to build these systems using the very best knowledge we have of how systems work (a science of systems = SPT) and don't work (a new Systems Pathology, another spin-off of SPT). These would provide a strong systems theory and universal patterns to guide formation and curation of sustainable systems. But these guidelines (it is presumption to call them either laws or principles) would have to be very detailed to add value to our current practices. At the talk, the following nine mini-posters were distributed to give an introduction to a Systems Processes Theory from systems science and a Systems Pathology that would be a strong candidate for the above strategy. They would be the basis not only for a stronger systems engineering, but also for sustainability studies, a medicine of systems, and for application to public policy formation. These posters were once presented at ISSS, NECSI, ICCS, NSF, and Education conferences. Here is a summary of topics covered.

Intro to Systems Processes Theory (SPT) (includes: SPT = GST, Identification of Isomorphic Processes, What are Linkage Propositions (LPs), Sample LPs, Classes of LPs, Tools to Use SPT, Applications)

Linkage Propositions (LPs) of the SPT (includes: Limits of GST, Defining LPs, Sample LPs, Dependency of LPs, LPs Better than Text Descriptions, LPs from Science, Outline of 134 LPs, Uses of LPs)

Systems Processes and Pathologies (includes Problem of Unintegrated Sources, Common Framework for Unifying, Systems Processes Theory, Classes of Systems Pathologies based on SPT Systems Processes)

Natural Sciences Test SPT (includes: Case Studies from Natural Sciences, Tests by Comparison, Types-Classes-Extent of Isomorphies, Listing of Discipline Case Studies, Empirical Base for Systems Science)

SPT Prerequisites, Discinyms, Discriminations, Mutuality (includes: SPT Tenets, Pre-requisite Chains of Processes, What is Mutuality, What are Discinyms, Discinym Examples, Key Discriminations)

Clustering of Systems Processes in SPT (includes: Clustering in Systems Biology, Clustering Systems Processes by Function, by Prerequisites, by Stages of Systems Life Cycle, by Stages of Development)

SOS in Engineering: An NSF Report (includes: NSF Challenge, What is SOS? Importance of SOS, Natural Science and SOS, Science of SOS? Development Needs of SOS, SPT and SOS, Conclusions)

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APPENDIX A: ACRONYMS USED IN THIS PAPER

AAAS = American Association for the Advancement of Science *[Public-Citizen]*
ABM = Anti-Ballistic Missile Systems
ASCB = American Society for Cell Biology *[Public-Citizen]*
CBO = Congressional Budget Office *[Congress]*
CDC = Center for Disease Control *[Executive]*
CEQ = Council on Environmental Quality *[Executive]*
CRS = Congressional Research Service *[Congress]*
CS = case study or studies
CSA = Committee for Science and Astronautics (→ CST, then CSST) *[House]*
CxSWG = Complex Systems Working Group of INCOSE *[Public-Citizen]*
DARPA = Defense Advanced Research Projects Agency *[Executive]*
DHS = Department of Homeland Security *[Executive]*
DOE = Department of Energy *[Executive]*
ECAST = Expert & Citizen Assessment of Science and Technology *[Public-Citizen]*
EPA = Environmental Protection Agency *[Executive]*
FAS = Federation of American Scientists *[Public-Citizen]*
GAO = General Accounting Office *[Congress]*
ICJ = International Court of Justice
ICRW = International Convention for Regulation of Whaling
INCOSE = International Council of Systems Engineers *[Public-Citizen]*
ITA = Institute for Technology Assessment *[Public-Citizen}*
IWC = International Whaling Commission (also Int'l Confederation of Wizards)
LL&PP = Law, Legislation and Public Policy
LOC = Library of Congress *[Congress]*
LP (LPs) = Linkage Propositions of SPT
MD = Medical Doctor *[Public-Citizen]*
NAE = National Academy of Engineering *[Public-Citizen]*
NAS = National Academy of Sciences *[Public-Citizen]*
NASA = National Aeronautics and Space Administration *[Executive]*
NIH = National Institutes of Health *[Executive]*
NOAA = National Oceanic and Aeronautics Administration *[Executive]*
NRC = National Research Council *[Public-Citizen]*
NSB = National Science Board *[both]*
NSF = National Science Foundation *[Executive]*
NSWG = Natural Systems Working Group of INCOSE *[Public-Citizen]*
OECD = Organization for Economic Cooperation and Development
OMB = Office of Management and the Budget
ONR = Office of Naval Research *[Executive]*
OST = Office of Science and Technology *[Executive]*
FDA = Food and Drug Administration *[Executive]*
OSTP = Office of Science and Technology Policy
OTA = Office of Technology Assessment *[Congress]*
PSAC = President's Science Advisory Committee *[Executive]*
S&T = Science and Technology *[Public-Citizen]*
SE = Systems Engineering *[Public-Citizen]*
SEBoK = Systems Engineering Body of Knowledge Library *[Public-Citizen]*
SP (SPs) = Systems Processes (Isomorphies of a general theory of systems)
SPT = Systems Processes Theory
SRD = Science Research & Development *[Congress-House]*
SS = Systems Science or systems sciences
SSWG = Systems Science Working Group of INCOSE
TA = Technology Assessment (or Technological)
TAAC = Technology Assessment Advisory Council *[Public-Citizen]*
TAB = Technology Assessment Board *[Congress-House]*
UCS = Union of Concerned Scientists *[Public-Citizen]*

Dr. Len Troncale is Professor Emeritus of Cell and Molecular Biology, and past Chair of the Biological Sciences Department at California State Polytechnic University (CPP/Cal Poly). He is also Past Founding Director of the Institute for Advanced Systems Studies, and Coordinator of its NSF-supported Systems-Integrated-Science General Education (ISGE) Program at CPP. He served as VP and Managing Director of the International Society for General Systems Research (SGSR) for six years, and President of the International Society for the Systems Sciences (ISSS) for the three-year cycle. He has served as Visiting Professor at the University of Vienna, Austria, CSU Monterey Bay, and CSU Sonoma and as Research Associate at IIASA Austria (the International Institute for Applied Systems Analysis). He was a member of the Board of Directors of IFSR (International Federation for Systems Research) for several years and still serves on the Board of Trustees for ISSS. He is on the editorial board of several systems publications, for example, Systems Research and Behavioral Science. Currently he has been presenting talks, research papers, posters, and webinars for INCOSE (the International Council on Systems Engineering) and at Systems Biology conferences and serves as Lead for two official projects of the Systems Science Working Group of INCOSE. Most recently, he has been named Lecturer for the new Master's in Systems Engineering of the College of Engineering at Cal Poly teaching the new core course Introduction to Natural Systems Science for systems engineers. Dr. Troncale has published over 137 research articles, abstracts, editorials and reports, 33 conference posters, served as Editor on 11 projects, delivered 125 invited and computerized presentations and demonstrations in 23 countries and served as P.I. on 52 grants and contracts for $5.3M from a variety of federal, state, and private organizations such as the NSF, DOE, ONR, HUD, the HHMI and the Keck Foundation, as well as the CSU System. A history of his contributions may be viewed at lentroncale.com, Wikipedia, and five other linked website/blogs.