Natural Systems Working Group

Natural Systems–A Missing Element in Systems Engineering — NSWG White Paper 1

George Studor, NSWG Chair

INCOSE International Council on Systems Engineering

Problem: Intentional consideration of Natural Systems (NS) is largely missing from Systems Engineering (SE) and Technology Strategy (TS) standard processes and practices.

Why Natural Systems? All things, relationships, processes, and forces that are not man-made are a potential part of the SE solution space. Looking to Nature for innovation has been commonplace for 1,000s of years. We may benefit by routinely using this perspective in an era focused on man-made solutions.

Opportunity: The time is right to include NS considerations in SE—due to simultaneous ***increases*** in:

1. Challenging Problems. Demand is increasing for systems that are multi-functional, miniature, low size, weight and power (SWAP), high performance, adaptable, and resilient—and that include unprecedented functions, and that take advantage of both advances in materials and miniaturization (e.g., nano-structures).

2. NS-Based Success Stories. Beyond Velcro, there are gecko feet adhesives, spider silk armor, whale tubercle flow benefits, bird-like morphing wings, cognitive computing, bio-mimetic solar power**,** and spacecraft antennas from mutation algorithms—and many other examples of looking to nature for solutions.

3. Natural Systems Talent and Experience. There are NS-related programs at many major universities, institutes, consortiums, and government research and development (R&D) organizations.

4. The NS Knowledge Base. Scientists know more than ever about Nature, and there have been significant increases in NS-related publications of all types.

5. Mimicry of Natural Systems. Types of mimicry success include, but are not limited to nano-fabrication, computing, architecture, mechanisms, and materials.

6. Link and Search. While still limited, we are seeing advances in documentation/retrieval of NS data, concepts and success stories (e.g., www.asknature.org).

7. Interest in SE Change. INCOSE, AIAA, NASA and other government agencies and several industries expressed interest in considering NS in SE processes.

General Solution: Make integration of NS considerations into SE ***a <u>way of doing business</u>***..

1. Add NS Discipline to SE and Technology Teams. Ask the question: "Is there something in Nature we could use to help address our problem?" Assign team members or contract experts to answer NS questions.

2. Add SE and TS Discipline to NS Teams. Similarly, for teams engaged in NS-related R&D, ask "Are there customers in SE and/or TS that have needs that NS considerations could or should be applied to?" Assign team members or contract expert services to answer the SE/TS questions.

3. Promote Customer-Supplier Relationships. Develop/provide supporting search, communication, and networking tools. Require NS considerations in RFIs and RFPs. Provide R&D budgets for NS, TS, and SE. Educate SE, NS, and TS communities on each other's respective concepts, languages, and practices,.

4. Promote Opportunities for Dialog and Education. Establish communities of practice, workshops, and other communication forums/repositories to share information. Influence Education and Training programs.

5. Suggest Process Changes. Assess established processes and documentation. Identify, document, and promote NS-consideration best practices. Participate in addressing and establishing process change.

6. Grow SE/TS/NS Search and Integration Capabilities. Develop an on-line search tool that matches SE and TS requirement/capability needs with Natural Systems R&D and mimicry state of the art.

7. Exercise SE Process Changes in Prototype/Demonstration Projects. Use prototype/demonstration projects to exercise and refine NS-consideration-in-SE-processes—both from process technical and organizational perspectives. [e.g. a NASA robotic snake-like inspector] Seek to answer questions such as " How do we best include NS expertise on project teams? Document lessons learned and recommendations from SE, TS, NS, and application's domain perspectives**.**

The INCOSE Natural Systems Working Group: The NSWG was founded in early 2013 to address this **Opportunity** by incrementally promoting and implementing elements of this **General Solution**. Come and learn with us, have some fun, and make a difference.

Additional Information: The following pages present three types of additional information:

- A **"What's It All About?"** description of the Natural Systems Working Group - including a preliminary agenda for the January International Workshop
- A description of **Candidate Support Activities** that summarizes ways to get involved in the NSWG.
- An example of a biomimicry success story from an SE perspective: **Influencing Bullet Train Design.**

Join with us to influence SE processes to routinely consider: "What can we learn from Natural Systems?"

nswg-info@incose.org ***https://sites.google.com/site/incosenswg/***

Natural Systems Working Group

Natural Systems Working Group
What's It All About?

INCOSE International Council on Systems Engineering

NSWG Purpose: To influence SE processes and communications to consider and take advantage of Natural Systems concepts, data, and approaches.

Goals: Our goals include address six basic areas:
- State of the Discipline - Assessments, References
- Community of Practice: Webinars, Web-based info
- Success Stories and Best Practices
- BKCASE and SE Handbook Inputs
- Inter-relationships with other SE WGs
- System Engineering Process Enhancements

Organizers:
Chair: George Studor – Retired NASA, Consultant
Co-Chair: Curt McNamara/Logic Project Dev
Sponsor: Steve Else – Assoc. Dir. for Knowledge
Member Advisor: Larry Pohlmann, Consultant

Websites: We have presence in three locations
- INCOSE public site**:** **www.incose.org**
- INCOSE member only site (ID/password required.): **https://connect.incose.org/tb/knowledge/NaturalSystems/default.aspx**
- **Google** public site: **https://sites.google.com/site/incosenswg/**

History. The NSWG was chartered in February, 2013 at the prompting of now-retired NASA consultant and INCOSE member, George Studor. He sought to increase the routine consideration of Natural Systems (both living and non-living) approaches and solutions in the Systems Engineering process.

Activities. The NSWG seeks to encourage the application of the growing knowledge and ability to mimic natural systems to the standard SE methods of doing business. Primary activities include: (1) facilitating SE and NS dialog through Community of Practice (CoP) telecoms and webinars, on-going web-based NSWG participant dialogs, and INCOSE meetings, panels and associated papers and studies, and (2) documenting best practices from those dialogs and preparing written input for consideration into the INCOSE SE Handbook, BKCASE, and other publications.

Beyond simple materials and mechanisms, Systems Engineering of "Systems-of-Systems" and "Extremely Complex Systems" will also benefit by purposefully asking and answering the question "Is there anything in Nature that can help us with our current efforts?"

Why Participate? Active participation with the NSWG should increase your—
- Ability to consider natural systems approaches
- Problem solving skills/creative thinking
- Opportunities for improving SE and TS processes
- Networking with colleagues, customers, suppliers.
- Potential base of future interns/employees

Preliminary Plans:
- Continue monthly Community of Practice Webinars
- Increase NSWG participation
- Continue documentation of success stories
- Identify/document applicable best practices
- Identify SE Processes areas where consideration of natural systems concepts, data, and approaches are likely to be beneficial
- Propose prototype/demonstration/test projects with NASA and/ or other organizations

Join with us to influence SE processes to routinely consider: "What can we learn from Natural Systems?"

nswg-info@incose.org ***https://sites.google.com/site/incosenswg/***

Natural Systems Working Group

NSWG Candidate Support Activities

— Potential Areas of Participation —

The NSWG has multiple opportunities for you to participate. Activity types and task areas are listed below. Other task areas are possible. Consider working with us to find a task area that is of personal interest to you—and that contributes to the mission of the WG. We welcome your participation!

Types of participation include:

- **Contributor**—occasional participation by identifying and packaging information for a task area
- **Continuing Participant**—regular participation in a task area, e.g., some time each week; periodic coordination with the task lead
- **Lead**—typically devoting a few hours each week to meeting task area objectives; coordination of Contributor and Continuing Participant activities; coordination with the NSWG Chair and Co-chair
- **Liaison/Facilitator**—Working to establishing and maintaining relationships with other groups.

Bibliography Development

Help to identify natural systems related resources that are potentially of interest to the INCOSE membership — including web sites, on-line videos, papers / articles / panels, and books. Activities may include:

- Identification and submittal of resources
- Development of annotations for one or more resources (100 words max)
- Development of more detailed reviews where appropriate (1 page max), e.g., book reviews

Success Story Development

Help to identify and concisely document situations where the application of natural systems data or concepts contributed to the engineering solution. Emphasize situations likely to be of interest to the INCOSE membership. Focus on SE-related elements and approaches of the development process. Use the 'Bullet Train' example as the content and format prototype.

Research Program Summaries

Help to identify and briefly summarize natural systems applications research programs at university, government, and industry organizations that may be of interest to INCOSE members. Include development of bibliography-like citations and annotations.

Tool Identification and Development

Help to identify and briefly describe tools that can help with the consideration of natural systems data and concepts. Include tools that are at the various stages of development as well as tools that are mature and ready for practical use. Consider developments at university, government, and industry organizations.

Include special emphasis on the identification, collection, and/or development of simple, practical, easy-to-use guides and checklists that can facilitate the effective and efficient consideration of natural systems data and concepts in or across application domains.

Best Practices Definition and Documentation

Help to identify and document approaches for the consideration and application of natural systems data and concepts that have been repeatedly successful and are worthy of being considered as best practices.

Process Modification Suggestions

Help to suggest how SE processes (e.g., those in the INCOSE SE Handbook) can be modified/enhanced to routinely and appropriately consider natural systems data and concepts. Also address how natural systems community of practice processes can be modified to facilitate collaboration with the SE community.

Webinar Series Support

Assist with the management and administration of the NSWG webinar series. Include tracking suggestions and solicitations of webinar topics likely to be of interest to the NSWG. Consider offering to present.

Web Presence Support

Help to develop and maintain NSWG web sites, including both public and limited access sites (e.g. on INCOSE Connect). Perform as webmaster.

Natural Systems Applications Theory

Help to investigate whether there is a 'theory of natural systems consideration and application.' If so, assist with development of this theory.

Liaison/Facilitator Activities

Help to establish and maintain mutual awareness and support among NSWG and other INCOSE WG's or related external WG's in other professional organizations, societies, or associations.

Closing Comments

Consider getting involved with one or more of the task areas above!

Contact us at: nswg-info@incose.org

Join with us to influence SE processes to routinely consider: "What can we learn from Natural Systems?"

Natural Systems Working Group

Influencing Bullet Train System Engineering

— Achieving Success by Considering Natural Systems —

Prepared by Dr. Lawrence D. Pohlmann, March, 2013

INCOSE International Council on Systems Engineering

Biomimicry: "the examination of nature, its models, systems, processes, and elements to emulate or take inspiration from [nature] in order to solve human problems" (from Wikipedia).

The Context. Japan has long been at the forefront of high-speed rail transportation. Their first ***Shinkansen*** (which literally means 'new trunk line') began operations in 1964 in time for the Tokyo Olympics. Because of the shape of the initial trains (**Figure 1**), the name 'bullet train' became the common label. Currently there are nearly 2400 km (~1500 mi) of line in the network.

Figure 1. "0" Series Bullet Train

The Problem. The mountainous countryside required passing through tunnels. Initial train speeds were 210 km/h (130 mph). As speeds increased, problems began to occur at speeds over 250 km/h:

- On entering tunnels, rapid pressure changes resulted in aural discomfort for passengers, severe vibrations that were also disturbing to passengers, and, occasionaly, damaged to the tunnel.
- On exiting tunnels, loud 'tunnel booms' shattered nearby windows and disturbed the nearby countryside for up to half a kilometer.

The Physics. Projectile-through-pipe simulations helped SEs to understand the physics (see **Figure 2)**.

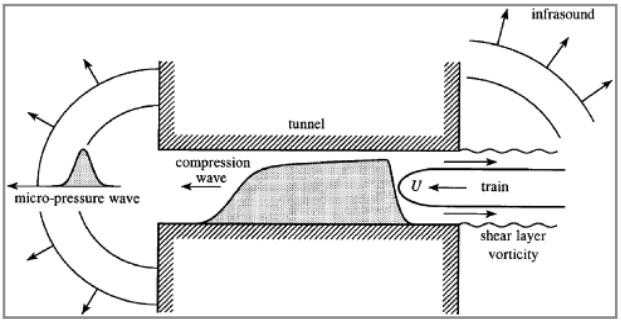

Figure 2. The Tunnel Boom Phenomenon

As a train entered a tunnel, a shear layer created both vibration and pressure changes in train cars—and a compression wave rapidly formed in front of the train. As the train exited the tunnel, the compression wave was instantly dissipated as a micro-pressure wave, which was heard and felt as a 'tunnel boom.'

Overview: Influencing Bullet Train Engineering & Design

Situation—*As Japan's bullet trains entered tunnels, severe vibration and pressure changes were disturbing to passengers. As trains exited tunnels, loud 'tunnel booms' disturbed the neighboring countryside*

Approach— *Find an analogy in nature. Design the nose of the bullet train to mimic the shape of the beak of the kingfisher bird*

Benefits—*Increased passenger comfort, reduced tunnel boom, increased speed, and 15% less energy use*

Looking to Nature. Eiji Nakatsu, Chief Designer of Japan's legendary bullet train, looked for a case where extensive changes in pressure were handled in nature. He remembered the kingfisher (**Figure 3**), which dives into water with almost no splash. His SE team studied the bird's sharp beak and head shape in detail.

Figure 3. The Kingfisher

Solution and Benefits. Nakatsu's team of SEs analyzed, did trade studies, modeled and simulated, and then applied the kingfisher's sharp beak concept to bullet train models—resulting in the current E5 series design, which has a nose that is over 49 ft. long, and that is nearly round in cross-section as (see **Figure 4**.)

Figure 4. E5 Series Bullet Train

The team's derivation of an advanced design that mimics nature helps to increase passenger comfort and greatly reduces tunnel boom—while meeting Japan's strict (70dB) noise restrictions—at speeds up to 320 km/h (~200 mph) on 15% less electricity.

Integration with other noise reduction methods (e.g., flared tunnel openings, sound absorbing tunnel materials, pantograph design, and other abatement methods) will allow even higher speeds in the future.

Join with us to influence SE processes to routinely consider: "What can we learn from Natural Systems?"

nswg-info@incose.org https://sites.google.com/site/incosenswg/