INCOSE SEANET – Systems Engineering & Architecting Doctoral Research Network

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Abstract

This paper introduces the INCOSE SEANET, a new strategic activity of the *International Council on Systems Engineering*[1] (INCOSE), aimed at fostering doctoral level research in systems engineering and contributing to the evolving intellectual agenda for systems engineering research. SEANET (Systems Engineering & Architecting Research Network) is an INCOSE sponsored organizational network of doctoral students working in the field of systems engineering and architecting. The 2005 program is an experimental program intended to explore the merits of the research network concept, and to determine how we can evolve to a program to serve the larger community of doctoral students at universities worldwide. The discussion that follows describes the need and concept for the SEANET; describes outcomes of the initial workshop event; and highlights the vision for the future of the network.

Need for Systems Research

Systems engineering and architecting are evolving to meet the challenges of increasingly complex systems and systems-of-systems. At the same time, the advancement of technology opens new possibilities for how we can perform engineering analysis, modeling, simulation and design. With these changes in systems and environment, we have an urgent need for more systems research in order to advance the state of the art and practice. Yet, our traditional research structures and educational institutions do not easily accommodate systems research. As a systems community, we lack a shared understanding of what constitutes good systems engineering research, and do not yet have the well-defined intellectual agenda which underlies this field.

INCOSE has set strategic objectives and policy to encourage doctoral level research in systems engineering, and the SEANET has been constructed as one key enabler for transforming this vision to reality. This network has the potential to bring together researchers and mentors to create a global, cross-university research community. We believe the network can be invaluable in many ways, for example defining the nature of systems engineering research, aiding the formulation of good research hypotheses, and "right sizing" of dissertation topics. The potential for this research network is significant, and realizing it will depend upon the energy and commitments that can be brought to this effort from the members of the systems engineering community.

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[1] For further information on INCOSE, refer to www.incose.org

SEANET Concept and Initialization

SEANET has been launched in 2005 as a pilot program to evolve into a full inter-university network of students/mentors working on systems engineering research. It is supported by collaboration of universities and the INCOSE organization. INCOSE is providing an expanded mentoring network. INCOSE will also allocate time in workshop and conference venues for structured dialogue and presentation of research progress and findings. For the 2005 pilot program, the Conference on Systems Engineering Research (March 2005 at Stevens Institute) has dedicated paper and discussion segments for INCOSE SEANET.

INCOSE wishes to foster and accelerate doctoral research in the area of systems engineering, and one means to do this is by connecting students and providing broader mentorship through senior level INCOSE professionals via the network. The network brings together students from several universities with similar yet complementary interests; provides additional mentoring through INCOSE Fellows and technical leaders; and provides collaboration and publication venues, with funding assistance for workshops.

In 2005, we are running an experimental pilot program for the SEANET which will help to shape a full program for a research network. Four universities are participating in the 2005 pilot[2]; in future years the network will seek to involve all interested universities. The student/mentor leads for the 2005 SEANET pilot program are shown in Table 1. Student doctoral funding comes through the individual university; for the 2005 pilot program only INCOSE is funding student travel to two workshops.

SEANET 2005 Perspectives

The initial meeting of SEANET was held January 29-30, 2005 at the INCOSE International Workshop in Tampa, FL. The meetings were attended by seven doctoral students, SEANET mentors, and INCOSE senior leaders from industry, government, and academia. Participants provided perspectives and recommendations for SEANET, as highlighted below.

Mentor Perspectives. The mentors attending the initial meeting of SEANET were very favorable on the event itself and the outlook for SEANET. The program was perceived as very beneficial and demonstrating the wide range of topics being considered. The group felt there were many good topics presented at the session, and gave both students and mentors the ability to exchange ideas. The group confirmed that mentors learn a lot in the process and get exposed to new intellectual pursuits in the systems community, while being able to give ideas and valuable feedback to students in the network

The discussions served to highlight our present issues concerning "what is systems engineering research?" and "where are the boundaries?" It was observed that each student involved had some industry experience, and that this may really be a requirement for doing SE research. We noted the difficult challenge for students to go from the broad systems perspective to a specific dissertation-scope topic, and certainly may be one aspect of how SEANET can help shape the student's research program (although there is also a risk that exposure to a wider network and more ideas could expand their scope).

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[2] Participants chosen for the 2005 experimental program are MIT (university of the pilot program leader); Stevens Institute of Technology and USC as co-sponsors of CSER 2005 (a primary venue for highlighting doctoral research and providing a venue to gather other university inputs); and Loughborough, to include a non-US university involved in significant SE doctoral research.

	University	Student	Research Topic	SEANET Mentor
US	MIT	Jason Bartolomei	*Complex Systems Engineering & Acquisitions: Coping with Dynamic Stakeholder Utility*	Dr. Donna Rhodes
		Heidi Davidz	*Enablers, Barriers, and Precursors to the Development of Systems Thinking*	
	Stevens Institute	Tom Herald	*Integration of Technology Assessment and Management Methodology for System Sustainment Determination*	Dr. Dinesh Verma
		Eirik Hole	*The Role of System Architectures and Architecting in a Dynamic Business and Technology Environment*	
	USC	Jo Ann Lane	*Constructive Cost Model for System-of-Systems Architecting and Integration*	Dr. Barry Boehm
		Ricardo Valerdi	*Constructive Systems Engineering Cost Model*	
UK	Loughborough University	John Cleveley	*Architecture Frameworks*	Dr. Carys Siemieniuch

Table 1. SEANET Pilot Program

An issue for systems engineering research and a specific INCOSE challenge is whether systems engineering in its present form is sufficient to address some of the difficult topics discussed during the SEANET session. It was noted that we generally are putting out "ideas" rather than "proofs", and that there may be some areas where proofs are not possible. The mentors noted that this meeting accentuated the question recently posed by INCOSE Academic Council Chair Dr. Daniel Hastings: "*What is the intellectual basis for systems engineering?*" Mentors suggested that students be encouraged to include in their dissertation some justification for their research in context of overall systems engineering state of the art and practice, and how it contributes to the intellectual basis.

Mentors and student thought that the network may provide a very good way to begin to build a composite picture of all of the diverse research that is going on in the field of systems engineering, and can help to characterize and give "validity" to PhD worthy research. It was also felt that the feedback to students (via mentors and others students) could accelerate the student progress perhaps in both time to completion (for students struggling with finding a research topic) and in knowledge building. Modern systems research involves new linkages into diverse areas of all sciences, including cognitive science, social science, and others. The network can potentially drive new synergies in this regard; participants noted that research is needed in the area of broad interface problems, to include diverse disciplines, and that new tools are urgently needed

The critical need to link the SEANET to other programs such as the INCOSE/Stevens Doctoral Award program was discussed. It was noted that we need to build collaboration in this network's mentors to gain support of involved universities, and that collaborations could occur in pairs of student/mentor to student/mentor. We have several issues to explore, for example would we involve students without involving a mentor from their home program, and how do we select mentors perhaps with different levels of involvement?

Student Perspectives. The students were very enthusiastic about the initial meeting of SEANET. They felt that it was an excellent forum to share research ideas, and very valuable feedback and advice was provided during the session. They noted they found it both interesting and encouraging to see the overlap in various research topics. The network was viewed as a means to understand what it takes to complete a PhD in systems engineering, and would help them understand when they have a good topic as perceived by a wider systems community as well as their

immediate committee and university. One of the students who is part-time noted that it hard to interact with other students, and the network will be very valuable to him in this regard. The network could provide greater student access to researchable ideas, as well as the opportunity to make contacts for doing field research.

Students confirmed that they would like a voice in the evolution of and management of the network, as well as in coalitions of universities and other initiatives focused on advancement of the field. It provides a good opportunity to articulate ideas in early phase and is great for building contacts and communication channels for future research. Students noted that there are different things on the student's mind at different times in their doctoral lifecycle – coursework, qualifying exams, and dissertation/defense, and there will be unique mentoring and support needs at each of these major phases.

One student noted that INCOSE can have significant influence on shaping the way students think about systems engineering. The SEANET provided benefits to the students regardless of phase of their work, and it was noted that it is valuable to dialogue with students in different phases of research. One of the students in the final semester of their studies noted "*I wish I had the opportunity to participate in this three years ago*".

The students discussed their desire to be able to get feedback via email and other informal channels between major events. They observed one gap in the initial meeting which was the absence of any assistant professors who would bring a different perspective. It was noted the junior faculty may be driving students toward their own research projects, while senior mentors tend to give advice that is not driven by a personal agenda; thus both junior and senior management should be involved.

The students recommended we develop ideas for what is needed out of the mentoring process, as well as the case for the value in getting a doctoral degree in systems engineering. Also discussed were ideas for student collaboration, including:
1. Students from different universities co-authoring a paper on a theme;
2. Creating a categorized list of recommended readings;
3. Sharing research plans (including reading lists) so that new students can learn from these;
4. Having (via telecom) dry runs of dissertation defenses to help prepare students for actual defense;
5. Establishing SEANET webpage with what students are doing, what students need that INCOSE can help with (like subjects/sites for research studies), and resources; and
6. Developing the " business case" for individual/university involvement in the network.

Program Risks and Sensitivities

The SEANET program does have risks and issues we must be sensitive to. The first of these is scalability of the approach. It is one thing to have a meeting with seven students and an equal number of mentors; it is quite another challenge if the network becomes quite large. It will be important to take an incremental approach to this program, and develop effective strategies for involving increasing numbers of students and mentors. Similarly, as we do SEANET sessions a second and third time, we need to ensure that the structure will provide new intellectual dialogue rather than repeating past sessions. One student suggested that a small number of students be selected each year to present their ideas in a

forum similar to the January 2005 workshop event.

There could be some risk in a student receiving recommendations from multiple mentors, along the nature of a "too many cooks" dilemma. Also, the university advisor may see the SEANET as low in priority, and this can be mitigated to some extent by structuring differing levels of involvement (for both students and mentors) as this program matures. The student's faculty advisors may possibly disagree with recommendations the student gains from the network. The selection process needs to be established to provide equity for interested students, and a clear set of criteria for participation is necessary.

Although the INCOSE Fellows are a primary source for the mentors for SEANET, we need to ensure that other senior experts are involved, as they offer additional perspectives and specialized expertise. It was noted that the INCOSE working groups may be an excellent source for mentoring in regard to a specific topic area. The program must be organized, but we need to ensure that it is not overly structured or prescriptive. Research clusters should avoid being domain specific, and the concept of *dynamic clustering* for an event (or program year) may be used, so that the clusters are not fixed over time or too stovepiped in nature. Most importantly, the program must not conflict with or detract from the student's home university policies, academic practices, and intellectual agenda.

Supporting the SEANET Program

As the SEANET program grows, increased planning and resources will be required. In the pilot program, the seven doctoral students and four lead mentors are providing a planning function. As the program evolves, we will need to establish a formal management committee, and the role

must include planning, management, and ongoing evaluation of the program. This committee must involve students and network alumni, and some support from INCOSE may be needed to permit the participation of such individuals.

The Stevens/INCOSE Doctoral Award (and we need more awards of this nature) needs to be connected to SEANET, and one participant in the 2005 program, Tom Herald, is an award recipient. As the INCOSE Foundation grows, our hope is that the foundation will provide scholarships and perhaps support for students who want to participate in SEANET events, but can not obtain the funding. An alternative for needs-based funding may be through INCOSE corporate members. SEANET events can be structured to feature student poster sessions or papers which can help provide the justification for student to get funds from their university program for attending such events. As SEANET events grow, an incentive for university and corporate participation may be the opportunity to interview and recruit doctoral students for positions in their organization.

As SEANET evolves, the alumni of the program will play an important role in ensuring program support. We envision some active service on the part of each network alumnus with flexibility in post graduation contributions. This may include being a mentor; giving a tutorial; helping get new sponsors; taking information on the network or specific students back to company/university; serving as a reader for dissertations or papers, donating frequent flyer miles for travel, and other possibilities. Our expectation is that participating in SEANET as a student will create the natural desire to give back to this program, and continued participation will enable the new graduate to stay in touch with the next wave of systems research.

SEANET Program in 2005

The small group of SEANET 2005 students and mentors are gathering several times during 2005, including the initial January meeting held in Tampa, the Conference on Systems Engineering Research (CSER, Hoboken, NJ in March), and at the INCOSE International Symposium (Rochester, NY in July). Six of the seven SEANET students are presenting research papers at the March conference. The 2005 students will be working to evolve the SEANET program for 2006 and beyond. During the remainder of 2005, the group will be gathering additional inputs and ideas, especially during a special session on the SEANET at the CSER Conference. We also would like to develop student resources:

1. List of pitfalls and fatal flaws in research for doctoral students;
2. Assessment of variants in doctoral programs across the international community;
3. List of conferences and events of interest to doctoral students; and
4. List of preferred journals for publication of systems engineering research.

SEANET will also need to evaluate the success of the pilot, as well as the ongoing program. Preliminary ideas of assessing impact include: measuring web-hits if we have a webpage; tracking how many are inquiring about joining; direct feedback from each student (via a feedback form); tracking collaborations inspired by SEANET; measuring papers that students collaborate on; tracking level of contact between sessions; and exploring the use of metrics for social networks.

Vision for SEANET 2006

Our concept for the second year of the network is to expand to two dozen or more students from eight or more schools.

A key challenge beginning in this next phase will involve how to provide adequate mentor coverage for students. In part this will be mitigated by having the first alumni and more senior students providing some level of guidance to the newer student researchers. We envision offering a workshop for the involved students which will feature sessions such as:

- Methods and tools for research
- Developing a research plan
- How to collect data from industry
- Avoiding pitfalls and research flaws
- Narrowing research ideas to a topic
- Poster session on student research topics
- Writing and publishing a journal article
- Social event for informal interaction between students and with mentors

We may also use an approach such as *SEANET Speed Networking* where two students or a student and mentor will have 5 minutes of quick discussion on a research topic. This short interaction may result in recommendations for reading or someone to talk to about the research, and in some cases, scheduling of a follow-on time to talk.

Vision for SEANET 2007

Our concept for the third year of the network is to expand the program to an even larger set of students, in some equitable manner although we do not yet know what is a reasonable number to include. The ability to provide mentoring will be a significant challenge as we grow the network, as will the networking of students with one another. One possible approach may be to create clusters of students with similar research topics and have group mentoring sessions. A key challenge in this approach will be to cluster students with some common research interests but to retain some degree of diversity in topics to encourage interesting interaction and synergies. We envision having a major workshop event for the

involved students and possibly open to additional interested students who are not formally part of the network. We envision sessions as described for SEANET 2006, with the addition of topics like the following:

- Lessons learned from past network alumni (and perhaps from doctoral students who never finished the degree);
- Industry executives discussing career paths for doctoral candidates in industry;
- University deans or department chairs on academic careers; and
- Funding agency presentations.

We may also build a research map where students will post their topic on the wall (via a small poster) and different colored string will be used to show current and potential interrelationships between the research topics. This exercise will help students and advisors to see how the individual research fits in context of the growing body of research in the systems engineering field, and can serve to begin to identify some specific research threads.

Contributors

This paper includes contributions from the students and mentors involved in the first SEANET meeting which took place Jan 29-30, 2005 at the INCOSE International Workshop in Tampa, FL and was chaired by the author. The seven students involved in 2005 SEANET are: Jason Bartolomei (MIT); John Cleveley (Loughborough University); Heidi Davidz (MIT); Tom Herald (Stevens Institute); Eirik Hole (Stevens Institute); Jo Ann Lane (USC); and Ricardo Valerdi (USC).

The INCOSE mentors who participated in all or portions of the first meeting included (in alphabetic order): Dr. Elliot Axelband; Dr. Erik Aslaksen; Dr. John Boardman; Dr. Barry Boehm (SEANET Mentor), Dr. Cihan Dagli, Dr. Wolt Fabrycky; Dr. George Friedman; Mr. Eric Honour; Dr. Alex Levis; Ms. Dorothy McKinney; Dr. Donna Rhodes (SEANET Mentor and Program Lead); Dr. Stanley Weiss, and Mr. Mark Wilson.

Summary

SEANET gives INCOSE a practical means to have impact on doctoral research in systems engineering. The network is underway and key challenges face us in how to transform the pilot to a full scale program. There is considerable interest and energy directed at the SEANET program, and continued contributions from the systems community are essential to the successful development of this program. This paper seeks to stimulate additional interest in and support for the doctoral research network. Ideas and comments may be directed to the SEANET Program Leader, Donna Rhodes, rhodes@mit.edu.

Biography

Donna Rhodes is a Senior Lecturer in the Engineering Systems Division at Massachusetts Institute of Technology, where she is also a principal researcher for the Lean Aerospace Initiative. Dr. Rhodes has 20 years of experience in aerospace, defense systems, and commercial product development. She has been involved in the development of several systems engineering degree programs. She is a Past-President and Fellow of the International Council on Systems Engineering (INCOSE), and presently is INCOSE Director for Strategic Planning. She received her Ph.D. in Systems Science from the T.J. Watson School of Engineering at SUNY Binghamton.