Systems Engineering Capabilities

Purdue University
November 9, 2010

Integrated Deepwater System Concept – US Coast Guard / ICGS
Recent History of SE at Purdue

- 2003 Purdue College of Engineering initiates “Signature Areas”
  - “Systems of Systems” one of eight original areas
  - Hired five faculty members
  - Research and individual course development
- 2004 participated in first CESUN meeting as part of MIT ESD symposium
- 2006 School of Aeronautics and Astronautics added “Aerospace Systems” area along with disciplinary areas (e.g. aerodynamics, structures)
- 2007 Purdue NEXTRANS award Regional University Transportation Center from US DOT
  - Research has emphasis on systems and system of systems
- 2007 Purdue Engineering Professional Education offers “Introduction to Systems Engineering” course
- 2009 Purdue College of Engineering Strategic Plan (2009-2014) contains “System of Systems Institute
National Academy of Engineering
21st CENTURY CHALLENGES

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery
College of Engineering Schools

- Aeronautics and Astronautics (AAE)
- Agricultural and Biological Engineering (ABE)
- Biomedical Engineering (BME)
- Chemical Engineering (ChE)
- Civil engineering (CE)
- Construction Engineering and Management (CEM)
- Electrical and Computer Engineering (ECE)
- Engineering Education (ENE)
- Engineering Professional Education (EPE)
- Environmental and Ecological Engineering (EEE)
- Industrial Engineering (IE)
- Materials Engineering (MSE)
- Mechanical Engineering (ME)
- Nuclear Engineering (NE)
Purdue Engineering Signature Areas

Impact Areas

Purdue Competencies

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Purdue SE Signature Areas

Impact Areas

Energy
Production
Information
Defense/Aero
Healthcare

Purdue Competencies

EEE
AAE
ENE
ME
CE
ENE
EPE
ECE
CS
PSY
ABE
AME
CEM
MSE
NE
IE

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System of Systems Institute

Impact Areas

Domain Expertise

Organization and Integration

Enablers

SoS Institute

Purdue Competencies

- Energy
- Production
- Information
- Defense/Aero
- Healthcare

Enablers:
- AAE
- ECE
- ABE
- ENE
- STAT
- EEE
- PSY
- CE
- BME
- NE
- MSE
- CS
- ChE
- ME
- CEM
- IE
- EPE
- MSE
- IE
Purdue Discovery Park Centers

- **Bindley Bioscience Center** (*Bindley*)
- **Birck Nanotechnology Center** (*Birck*)
- **Burton Morgan Entrepreneurship Center**
- **Center for Advanced Manufacturing** (*CAM*)
- **Center for the Environment**
- **Cyber Center** (*Hub0*)
- **Discovery Learning Center**
- **E-Enterprise Center**
- **Energy Center** (*EC*)
- **Oncological Sciences Center**
- **Regenstrief Center for Healthcare Engineering** (*RCHE*)
Benefits of SoSI

- Facilitates multi-disciplinary approach to systems problems
- Encourages generalized thinking of systems issues
- Results in a larger pool of systems thinkers
- Speeds the introduction of proven systems concepts to diverse application areas
Purdue Engineering SoSI

Impact Areas

Enablers

SoS Institute

Purdue Competencies

Domain Expertise

Organization and Integration

Energy

EC

CE

ChE

IE

ME

ECE

AAE

ECE

ABE

ENE

ME

CEM

EEE

EPE

PSY

STAT

CS

BME

MSE

NE

IE

ChE

ME
Solar Energy Systems for Buildings

Development of a design platform for solar cooling and heating systems and solar power systems. Provide designers, engineers, vendors, and building investors the appropriate optimization method to assist them in decision making, system design, and system evaluation.

- Create architecture, design principles and tools to rapidly test designs and estimate costs
- Create flexibility in functionality & interfaces to support intersections in other SoS foci
• Standard terminal interfaces are non-sterile, not intuitive, and require attention and position shifts.
• Hand-gesture interaction is an alternative, for interaction that allows the environment to remain sterile.

Grant Support: By AHRQ (contract 1R03HS019837-01)
Purdue Engineering SoSI

Domain Expertise

Organization and Integration

Enablers

SoS Institute

Purdue Competencies

Impact Areas

Defense/Aero

SERC

AAE

IE

CS

ECE

ME

PSY

ENE

STAT

EPE

CE

ChE

ECE

AEE

EEE

BME

MSE

IE

ME

CEM
Selected Defense/Aerospace Research

- An Agent-based Concept for an Enhanced C2BMC Architecture (Missile Defense Agency)
- Complexity and Adaptability Metrics for DARPA META program (Boeing, for DARPA)
- Aerospace Systems Research in Support of Integration of Advanced Concepts into NextGen (NASA NRA via Raytheon)
- Acquisition Management for Systems-of-Systems: Exploratory Model Development and Experimentation (Naval Postgraduate School)
- Near-Term Operational Changes for Reducing Aviation’s Environmental Impact (FAA PARTNER Center of Excellence)
- Fractional Shares, Air Charter and Air Taxi Operations as a System of Systems Problem (Cessna and CitationShares)
Project Focus: Impact of Disruptions and Interdependence Structure in Capabilities Development

• **Sponsor:** Naval Postgraduate School Acquisition Research Program

• **Research Questions:** How do system-specific characteristics impact the successful development of systems of systems for capability-based acquisition?

  - How do disruptions propagate in complex networks of interdependent systems?
  - How can we quantify the cascading effects of development risk?
  - How can we compare network of systems in their ability to reduce the impact of risk?

• **Objective:** Answers to these questions can increase the probability of success in systems of systems development
Disruption Propagation in Capability-Based Acquisition

- Two-pronged approach:
  - Discrete event simulation of SE processes
  - Analytical model for risk propagation
- Investigate impact of system interdependencies and development risk on development time
  - Cascading effects of risk and disruptions
SoSI Also Focused on Education

- SE interdisciplinary concentration
  - Expected appeal to thesis seeking MS and PhD students as well as non-thesis MS students
  - 3-4 Courses + SE Project
  - Readily matches a “certificate” program, which is often desirable to distance-learning / professional students

- Example SE Course
  - Instructor: practicing SE
  - Principles of SE and their application across the system life cycle
  - On-campus and distance students
SoS Course

- Graduate (MS-level) offering, seeking students from all engineering departments (and beyond?)
- Application project emphasis across domains
- Methodological emphasis is on understanding dynamic system interactions and problem definition, and then mathematical modeling

Sp06 Semester = 27 Students
Sp07 Semester = 27 Students
Sp08 = 32 Students (10 Distance)
Sp09 = 30 Students (11 Distance)
Sp10 = 47 Students (17 Distance)

NEW COURSE
SPRING 2006
System-of-Systems Modeling & Analysis
A&AE 590K
(17th 12:00 - 1:15)

Course Instructor: Dr. Daniel DeLaurentis
Contact information: ddelaur@purdue.edu, *40694, ORIE-312

Course Description:
The primary focus of this course is on understanding, modeling, and analyzing an emerging class of problems called System-of-Systems. Large-scale, interdisciplinary problems with heterogeneous collections of independently operating systems. Team projects will be undertaken in which students will explore new methods for analyzing problems such as the National Transportation System, Space Exploration, Integrated Defense and other national priorities.

Topics:
- Distinguishing traits and behaviors of Sys-of-Sys problems
- Lexicon and abstraction methods
- Modeling approaches, such as:
  - State equations & control
  - Modern network theory
  - Probabilistic robust design
  - Artificial intelligence (especially multi-agent simulation)
- Methods for analysis of alternatives through simulation

Prerequisites:
- Graduate or Senior-level standing (letter with consent of instructor)
- Knowledge of probability & statistics is preferred
- Students from Engineering, Management, Computer Science, Physics, Economics, Mathematics and other majors are welcome!

For more information, please visit: http://web.ie.purdue.edu/~ddelaure/Course
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NextGen Air Transportation System - FAA