School of Systems&Enterprises

Systems Engineering Masters

Candidate Project and Dissertation Topics

October 2007

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List of Topics

Topic	Advisor
Requirements networks and their role in expediting systems engineering	Boardman, Ramirez-Marquez, Sauser
Boundary constructors and their intended/unintended consequences	Boardman, Sauser
Systems of Systems – Distinguishing Characteristics	Boardman, Sauser
Accessing and Leveraging the Genius in Systems Engineering	Boardman, Sauser
Alignment between Organizational, Logical, and Physical System Boundaries and Interfaces	Verma
Requirements for Large Scale, Complex Systems	Verma
Value of Systems Engineering	Verma
Systems Engineering Education	Verma
Case Study on Integrating Software and Systems Engineering Processes, Governance, and Organization	Pyster
Infrastructure Resilience and the Impact of Natural and Human-Made Disasters on Transportation Systems	Nilchiani
Infrastructure Resilience and the Impact of Natural and Human-Made Disasters on Energy Systems	Nilchiani
The Impact of Modularity on Flexible Systems Design	Nilchiani
Product Portfolio Analysis	Farr
Complex System Modeling and Activity Monitoring	Jiang
Data Integration and Information Quality Management	Jiang
Literature Survey & Description of Distributed Detection Networks	Ramirez-Marquez
Modeling of Distributed Detection in Probabilistic Sensor Networks	Ramirez-Marquez
Optimization of Distributed Sensor Networks Under Design Constraints	Ramirez-Marquez
On the Probabilistic Analysis of Successful Project Completion Under Resource Constraints: Literature Survey & Description of Project Completion as System	Ramirez-Marquez
On the Probabilistic Analysis of Successful Project Completion Under Resource Constraints: Selection of Modeling Approaches	Ramirez-Marquez

Topic	Advisor
On the Probabilistic Analysis of Successful Project Completion Under Resource Constraints: Optimization Techniques	Ramirez-Marquez
System Maturity Indices for Decision Support in the Acquisition Process	Sauser
System Integration Readiness and Maturity – Defining Levels and Metrics	Jain
Interoperability and Open System Integration	Jain
Impact of system architecture and design on systems integration complexity	Jain
Reliability, Maintainability & Supportability of Software Intensive Systems	Robinson
Reliability, Maintainability and Supportability of COTS-based Systems	Robinson
Quality Management of Systems Design	Robinson
Reliability, Maintainability and Supportability of Network-centric Systems	Robinson
The Evolution of Software and Its Impact on Complex System Design	Pennotti
A Complexity Model for Software Intensive Systems	Pennotti
The potential of simulations to reduce system-of-system complexity	Bernstein

Requirements networks and their role in expediting systems engineering

Background: The traditional way of organizing requirements is to use a tree structure. Stakeholder requirements are gradually refined into greater detail and specificity creating a list of derived requirements in a traceable hierarchy. The nature of most complaints about requirements focuses on their incompleteness, incongruity and infirmity. Further, the tree structure of requirements is unable to make explicit certain kinds of interdependencies and associations between requirements that cut across this structure. Examples include dependencies and associations around resource sharing, common or conflicting stakeholders, and input/output dependency. Some questions arise:

1. Would a requirements network be a better form of requirements capture, as compared to a tree structure? The properties of some types of network yield greater insight into the centers of gravity of the systems being represented (critical hubs for example) which might conceivably aid the systems engineering process in regard to identifying the vital few requirements. Please study this hypothesis.
2. How would you model a requirements database as a network that enumerates interdependencies between types of requirements; developing network views of a transformed requirements database; creating filtered views of networks based on weighted functions of interdependencies; eliciting network metrics from the filtered views; interrelating the network views to expert heuristic assessments; and, summarizing conclusions.

Abstract of the Paper

For details please email John.Boardman@stevens.edu

Student requirements

Experience in systems engineering and ideally in requirements engineering/management.

Understanding of complexity theory and in particular network/graph theory

References

Albert-Laszlo Barabasi. Linked, Penguin, 2003 ISBN 0-452-28439-2

And see http://easyweb.easynet.co.uk/~iany/consultancy/papers.htm

Faculty Advisor(s):

Dr. John Boardman, Dr. Jose Ramirez-Marquez, Dr. Brian Sauser

Boundary constructors and their intended/unintended consequences

Background: The definition of a "boundary" is considered central to the definition of a "system". This becomes an interesting proposition for a network centric system, an enterprise system, a system of systems, or an evolving/adaptive system. Issues arising are:

1. Explore the concept of boundaries for Enterprise Systems, Network Centric Systems, and System of Systems.
2. What constitutes a boundary for such systems? Provide examples and appropriate research to substantiate your response.

Abstract: For details please email John.Boardman@stevens.edu

Student requirements

Experience as a systems engineer/project engineer/program manager.

Confident abstract thinker

Good researcher and competent writer

References

J. Boardman. (Jul 1995). "Wholes and Parts - A Soft Systems Approach", IEEE Transactions: Systems Man and Cybernetics, 25 (7).

Faculty Advisor(s)

Dr. JohnBoardman, Dr. Brian Sauser.

Systems of Systems – Distinguishing Characteristics

Background:

Some argue that a system of systems (SoS) is nothing new and that traditional systems engineering will serve well in building and managing an SoS. Clearly an SoS is a system but the manner of its assembly and particularly the style of its operations conceivably point to radical differences to a system (of components) which requires its parts to be fully subordinated to its purpose and their interrelationships to be fully defined and unalterable through its lifecycle. The challenge is to identify by quantitative means the qualitative distinction in both structure and behavior between an SoS and a system (of components). Please study the attached paper on System of System Characteristics, and:

Study the 5 characteristics proposed in the context of a "real" System of Systems that you are involved with. Are these five characteristics translatable into measurable parameters that can be used to distinguish a System of Systems from a System (of components)? Please develop an argument on an example System of Systems to validate or invalidate these characteristics.

Abstract:

For details please email John.Boardman@stevens.edu

Student requirements:

Experienced systems engineer, ideally in the space of systems of systems. Abstract thinker. Ideally some computer science skills.

References:

Gorod, A., R. Gove, B. Sauser, and J. Boardman. (2007). "System of Systems Management: A Network Management Approach." *IEEE International Conference on System of Systems Engineering*. April 14-16, San Antonio, TX

Sauser, B. and J. Boardman. (2007). "Complimentarity: In Search of the Biology of Systems." *IEEE International Conference on System of Systems Engineering*. April 14-16, San Antonio, TX

Frederick, C. and B. Sauser. (2007). "Studies on Systems Engineering Benefits." *5th Conference on Systems Engineering Research*, March 14-16, Hoboken, NJ.

Sauser, B. and J. Boardman. (2006). "From Prescience to Emergence: Taking Hold of System of Systems Management" *27th American Society for Engineering Management National Conference*, October 26-28, Huntsville, AL

Faculty Advisors: Dr. John Boardman, Dr. Brian Sauser.

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Accessing and Leveraging the Genius in Systems Engineering

Background:
This project concerns the luminary thinking of Tom Kelly, an outstanding architect, who many say was the father of the Lunar Module. Secondly, it highlights the potential hazard of corporate memory loss, such as that of Tom Kelly to Northrop Grumman, when people retire and with them go experience, know-how, heuristics and insights that could still serve the organization they leave behind exceedingly well.

This project will examine the text of a 1966 interview with Tom Kelly in which he discusses the Lunar Module, as engineering and architecture, in a socio-political context (http://users.specdata.com/home/pullo/KELLY.HTM). The mission of the project is to identify three key issues arising from the interview. For example these could be: a systems engineering process; the systems architecture for the LEM within the context of the Lunar Mission architecture; and the changes in the aerospace industry landscape. Further literature searches will of course be expected. Having identified these issues, appropriate text will be composed, faithful to the sources. Storyboards for each key issue will be developed for communication to a live audience of peers and seniors in order to validate the findings and to capture reactions. Further, this project will conclude with recommendations for action in terms of corporate memory retention and systems architecting.

Abstract:
For details please email John.Boardman@stevens.edu

Student requirements:
Experienced engineer. Experience of systems projects. Student of history. Some experience of process codification, engineering heuristics, and project review.

References:
Tom Kelly. "Moon Lander: How We Developed the Apollo Lunar Module", Smithsonian, 2001. ISBN-13: 978-156098998

J. Boardman and AJ Cole. (Dec 1995). "Modeling product development processes using a soft systems methodology", 1st World Conf. on Integrated Design and Process Technologies, Austin, Texas. .

J. Boardman. (Oct 1993). "Developing a framework for concurrency by capturing systems engineering rationale using a process modeling methodology", Computing in Aerospace 9 Conference. San Diego. 173-181.

Faculty Advisors: Dr. John Boardman, Dr. Brian Sauser

Alignment between Organizational, Logical, and Physical System Boundaries and Interfaces

Key Questions:

How do you assess the alignment between organizational, logical and physical architectures? Should this alignment evolve over the life of an architecture?

- Document the logical and physical architecture of a system that you are working on, or familiar with. How would you assess alignment between these two? Are there metrics that you would use to measure this alignment? (Multiple masters projects are desired just on this topic)
- Document the "orthogonality" (mapping between n requirements and m functions) between system requirements and the logical architecture for a system you are working on or familiar with. How would you assess alignment between the two? Are there metrics that you would use to measure this alignment? (Multiple masters projects are desired just on this topic.)
- Document multiple architectures from a product line that you are familiar with (multiple radar architectures, multiple sonar architectures, multiple avionics architectures, multiple C^3 architectures). Are you able to synthesize the underlying reference architecture? (Multiple masters projects are desired on this topic.)

What is the impact of the alignment on flexibility and agility in responding to changing market conditions and missions?

- With so much need for the rapid deployment of capabilities and functions, conduct a literature search on agile systems and flexible systems. What is the state of practice? What is the state of research? (A couple of masters projects are desired on this topic.)

How do we assess the maturity of architectures or their entropy?

- If you are working on a system that has evolved considerably over time (10 to 20 year timescale), study the manner in which it has evolved. How has the architecture evolved? Why? (Multiple masters projects are desired on this topic.)

Faculty Advisor:
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Requirements for Large Scale Complex Systems

Key Questions:

Should we continue to use “shall” statements? Is there a better way, particularly when developing large scale complex systems and system-of-systems? On programs like Joint Strike Fighter, the number of “shall” statements now exceeds 35,000; According to Kelly Miller (NSA), the traditional wisdom is that specificity in writing requirements reduces program risk, but the opposite seems to be the case for systems that have a need for agility and evolvability; According to Secretary Paulson, the UK stock exchange is more resilient and adaptive than the US stock exchange because the first is principle-based, while the second is rule-based. Within IBM, there is an effort to make requirements “language-independent,” since there is a need for flexibility in global outsourcing. They want to take the requirements of a French customer and outsource the development to India or China. Currently, language barriers get in the way. How can this be facilitated?

- Study the requirements database of 4 systems that you are familiar with and address these questions: a) What is the average scaling factor in the number of requirements from one abstraction level to the next (in other words, x number of system requirements on average result in y number of derived requirements on the sub-system level) (Multiple masters projects are desired on this topic.)
- Study the requirements documents of 6 different systems that you are familiar with, or have access to. Are you able to distinguish common patterns in the table of contents of these documents? Are you able to suggest a template for a requirements document? Would this template change as a function of program size or program type (e.g., Technology or Concept Demonstration versus System Development and Integration)? Are you able to propose metrics to assess the “goodness” of a requirements document? (The student can answer 2 of the 3 questions, if the scope is considered too broad) (Multiple masters projects are desired on this topic.)
- Study the Interface Definition and Control Documents from 4 programs. Can you recommend a template for such a document? Could you suggest metrics to assess the goodness of such a document? (Multiple masters projects are desired here.)

Faculty Advisor:
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SSE School of Systems&Enterprises

Value of Systems Engineering

Background:

There is an increasing desire to assess the "value" or "business utility" of systems engineering as a function of investment. This is particularly hard to do since systems engineering is not a discrete activity, completely decoupled from project and program management, project and program leadership, and so on. What is the state of research in this regard? Can we assess similar efforts in software engineering or TQM or project management to learn how to address these questions in the systems engineering discipline?

Key Questions:

- Please study 6 program budgets for systems that you are familiar with. What percentage of the program development budget that has been allocated to systems engineering; to program management; to system test and integration? Can you identify reasons why these budget allocations are higher or lower on certain programs?

Faculty Advisor:
Dr. Dinesh Verma
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Systems Engineering Education

Key Questions:

How do we assess the goodness of systems engineering education from a "business perspective?"

- Study the course feedback from 4 years of 625 and 650. Study the "comments" provided by the students. Can you identify some common patterns in the feedback? Can you identify some evolving patterns in the feedback over the years? (A couple of masters projects are desired here.)
- Stevens Institute of Technology/SDOE Program can identify the students who provided specific feedback 2 years ago when they took 625 and 650. Given the contact information for these students, develop a survey for these students and assess their "impression" and utility of these courses 2 years later. In what manner are these courses helping the students 2 years later? What could have been done differently? (A couple of masters projects are desired here.)
- INCOSE has just developed a reference curriculum for Systems Engineering Graduate Education. Assess the compliance of the Stevens SE Graduate Program with this reference curriculum using spider charts. Similarly assess the correlation of 3 other universities. (Multiple masters projects are desired here.)

Can we develop case studies and vignettes to convey SE concepts more effectively? Conventional wisdom is that it take 15 years or more of experience to develop effective systems engineers. Can this time period be significantly reduced?

- Develop a Systems Engineering Case Study from the Capability Definition and Mission Need Statement phase through the Test and Integration Phase for a system that you are familiar with. A template will be provided to you for this purpose. (This is an ideal project for a group of 3 to 4 students who want to collaborate on a masters project. Multiple such groups are desired.)
- Develop 4 systems engineering scenarios in consultation with a senior systems engineer, chief engineer, chief architect, or program manager of a program that you are working on. You will be provided a template for the development of these scenarios or vignettes. The objective of this program is to serve as a learning exercise and to synthesize heuristics often used by senior SEs, SAs, and PMs. (Multiple masters projects are desired on this topic.)

Faculty Advisor:
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Case Study on Integrating Software and Systems Engineering Processes, Governance, and Organization

Background: There is heightened interest in integrating software engineering (SwE) and systems engineering (SE) for a variety of reasons, especially (1) the majority of the value of new systems is delivered through software; (2) software is usually much of the "glue" by which complex systems are integrated; and (3) changes in systems requirements are often achieved by modifying software rather than hardware. The integration of SwE and SE faces many challenges; e.g., in companies and government agencies, systems and software engineers often reside in different organization, reporting to different executives. Different individuals may be responsible for SwE and SE processes, tools, training, career paths, etc. There are many approaches that individual companies and government agencies can take to achieve effective integration of the two disciplines. It would be very valuable to the community to understand what approaches are being taken, how successful those approaches are, and what lessons learned can be offered to help those still facing the integration of SwE and SE.

Abstract: This paper explores the ongoing integration of SwE and SE at XXX, where I work. SwE and SE are both vital disciplines to XXX. Over the past nn years, an initiative to integrate the two disciplines has been underway, focusing on organization, training, processes, tools, and career paths. For example, when the initiative began, there were separate and uncoordinated training efforts for software and systems engineers. Now there is an integrated curriculum, which is training systems engineers for software-intensive systems. There is now a combined competency model that recognizes the overlap between the two disciplines. Techniques that began in the SwE field, such as agile development, are spilling over into how systems are developed. Integrating the two disciplines has led to fewer defects during systems integration, improved job satisfaction, and an ability to recruit higher caliber graduates from leading engineering schools. Nevertheless, problems remain. Some systems engineers with no software backgrounds have had trouble becoming qualified in the new software competencies.

Student Requirements: The student should have worked as either a software engineer or a systems engineer and understand the basics of organizational change. The student will need access to appropriate people and data in his or her organization to perform this case study.

References: The CMMI provides an integrated view of SwE and SE from a process perspective. Readings can be found at www.sei.cmu.edu. *CMMI Distilled (2nd edition)* by Ahern, Turner, and Clouse provides a good overview. The IEEE Software Engineering Body of Knowledge (www.swebok.org) states competencies expected of software engineers. "The Process of Enhancing a Systems Engineering Training and Development Program" by P.N. Trudeau in *Proceedings of 2005 IEEE Aerospace Conference* describes how MITRE approached improving systems engineering, including career path, training, and competency development. See also "Some Future Trends and Implications for Systems and Software Engineering Processes" by B. Boehm in *Systems Engineering*, Volume 9, Issue 1, 2006.

Faculty Advisor: Dr. Art Pyster, art.pyster@stevens.edu

Infrastructure Resilience and the Impact of Natural and Human-Made Disasters on Transportation Systems

Background: Natural and human-made disasters such as Hurricane Katrina or the 9/11 terrorist attacks have highlighted the importance of resilience in critical infrastructure systems. In addition to direct humanitarian and financial losses as a result of such events, there are also indirect losses that occur as a result of the increasing interconnectedness of critical infrastructure, as well as the psychological effects of an inadequate response of the system vis-à-vis such disasters. It is intuitive that minimizing the recovery time for such systems is key to minimizing the potential losses associated with catastrophic events.

Abstract: Resilience is an inherent ability of a system to sustain or rapidly recover its core value delivery in the face of change. System resilience is therefore a function of a system's *vulnerabilities* and its *adaptive capacity*.

This research will seek to characterize vulnerabilities and adaptive capacities of transportation systems in the face of natural or human-made disasters. Using case studies, the different types of vulnerabilities and adaptive capacities in a particular transportation system that was faced with a catastrophic event will be analyzed and strategies for reducing vulnerabilities and increasing adaptive capacities will be proposed.

Student Requirements

- Undergraduate degree in a field of engineering preferred
- Thorough understanding of probabilities and statistics required
- Having passed SYS.611 or equivalent with an excellent grade
- Familiarity with decision analysis and risk analysis methodologies preferred
- Experience with infrastructure systems in particular transportation systems, or disaster response desirable
- Excellent written communications skills

References:

- Critical Thinking: Moving from Infrastructure Protection to Infrastructure Resilience http://cipp.gmu.edu/archive/CIPP_Resilience_Series_Monograph.pdf
- Linkages between vulnerability, resilience, and adaptive capacity by Gilberto C. Gallopin http://sustsci.aaas.org/files/GG%20on%20VRA%20linkages.pdf

Faculty Advisor:
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Infrastructure Resilience and the Impact of Natural and Human-Made Disasters on Energy Systems

Background: Natural and human-made disasters such as Hurricane Katrina or the 9/11 terrorist attacks have highlighted the importance of resilience in critical infrastructure systems. In addition to direct humanitarian and financial losses as a result of such events, there are also indirect losses that occur as a result of the increasing interconnectedness of critical infrastructure, as well as the psychological effects of an inadequate response of the system vis-à-vis such disasters. It is intuitive that minimizing the recovery time for such systems is key to minimizing the potential losses associated with catastrophic events.

Abstract: Resilience is an inherent ability of a system to sustain or rapidly recover its core value delivery in the face of change. System resilience is therefore a function of a system's *vulnerabilities* and its *adaptive capacity*.

This research characterizes vulnerabilities and adaptive capacities of energy systems in the face of natural or human-made disasters. Using case studies, the different types of vulnerabilities and adaptive capacities in a particular energy system that was faced with a catastrophic event will be analyzed and strategies for reducing vulnerabilities and increasing adaptive capacities will be proposed.

Student Requirements

- Undergraduate degree in a field of engineering preferred
- Thorough understanding of probabilities and statistics required
- Having passed SYS.611 or equivalent with an excellent grade
- Familiarity with decision analysis and risk analysis methodologies preferred
- Experience with infrastructure systems in particular energy systems, or disaster response desirable
- Excellent written communications skills

References:

- Critical Thinking: Moving from Infrastructure Protection to Infrastructure Resilience http://cipp.gmu.edu/archive/CIPP_Resilience_Series_Monograph.pdf
- Linkages between vulnerability, resilience, and adaptive capacity by Gilberto C. Gallopin http://sustsci.aaas.org/files/GG%20on%20VRA%20linkages.pdf

Faculty Advisor:
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The Impact of Modularity on Flexible Systems Design

Background: In the last decade, the concept of modularity has caught the attention of engineers, management researchers and corporate strategists in a number of industries. When a product or process is "modularized," the elements of its design are split up and assigned to modules according to a formal architecture or plan.

From an engineering perspective, a modularization generally has three purposes:

- To make complexity manageable;
- To enable parallel work; and
- To accommodate future uncertainty.

Abstract: Modularity accommodates uncertainty because the particular elements of a modular design may be changed after the fact and in unforeseen ways as long as the design rules are obeyed. Thus, within a modular architecture, new module designs may be substituted for older ones easily and at low cost. This makes modularity a primary strategy to design flexible systems.

In this research looks at the different ways modularity can impact the flexibility of engineered systems. Each student can select a case study within areas of space systems, manufacturing systems, infrastructure systems, or networked systems to explore the concept of modularity in detail.

Student Requirements

- Undergraduate degree in a field of engineering preferred
- Having passed SYS 611 and SYS 625 or equivalent with an excellent grade
- Familiarity with decision analysis and risk analysis methodologies preferred
- A familiarity with real options is desirable
- Excellent written communications skills

References:

- Modularity in the Design of Complex Engineering Systems by Baldwin and Clark (2004) http://www.people.hbs.edu/cbaldwin/DR2/BaldwinClarkCES.pdf
- Measuring the Value of Flexibility in Systems: A Six Element Framework http://www3.interscience.wiley.com/cgi-bin/abstract/114029122/ABSTRACT?CRETRY=1&SRETRY=0

Faculty Advisor:
Dr. Roshanak Nilchiani
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Product Portfolio Analysis

Background: Product portfolio analysis can often be a political or a legacy based process in lieu of an objective, quantifiable resourcing exercise. A lot of research has been conducted in the area using simple techniques such as weighted scoring. However, more advanced techniques such as Data Envelopment Analysis (DEA) can be used to compare many dimensions of the products.

Abstract: This research should produce a conference paper or a white paper describing a process that can be used internally in an organization to prioritize and optimize a product portfolio. Methods such as weighted scoring, DEA, and/or modeling and simulation should be investigated as possible decision tools. Ideally, the student should have access to a product portfolio with quantifiable metrics (cost, earned value, etc) in order to investigate these techniques. The student should then use several of these techniques to compare the results and hopefully develop a recommended process for their domain. The optimization of the portfolio is just one small step in the systems process that the student should articulate as part of this research.

Student Requirements: A class in decision and risk analysis and/or modeling and simulation along with access to data used to make decision about project and portfolios

References: Please see Dr. Farr for papers on this subject.

Faculty Advisor: Dr. John Farr
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Complex System Modeling and Activity Monitoring

Background: Due to technology advancements in hardware and software, many engineering systems record and process huge amounts of data in production, business transactions, and service operations. These data streams contain very useful knowledge and information that can be extracted through data modeling, characterization, monitoring, and forecasting.

Abstract: This project aims at developing generic techniques for business activity monitoring applications including fraud detection, churn prevention, sensor and sensor networks for manufacturing quality control, and network intrusion detection. Some questions arise:

- Identifying complex system with unknown structures through data modeling and graphing to identify important factors and events that can help explain system behaviors
- Modeling system dynamics and interactions using modern theory and technology of control and machine-learning in order to develop an adaptive self-learning modeling system
- Forecasting system behaviors and detecting abnormal system activities using statistics, artificial intelligence, and data mining methods
- Developing agent-based modeling and simulation tools to take advantage of distributed computing resources, coordinate teams of interacting robots, and increase system robustness
- Innovating research methodologies to describe and characterize network-centric systems in Command and Control

Reference:

- Hastie, T., Friedman, J. H., and Tibshirani, R. (2001). Elements of Statistical Learning: Data Mining, Inference, and Prediction. New York: Springer-Verlag.
- W. Jiang, S.-T. Au, ad K-L. Tsui (2007) “A Statistical Process Control Approach for Customer Activity Monitoring”, IIE Transactions on Quality and Reliability, 39, 235-249.
- Qian, Z. G., W. Jiang, and K-L. Tsui (2006) “Churn Detection via Profile Modeling”, International Journal of Production Research special issue on Applications of Data Mining in Design, Manufacturing, and Logistics Engineering, 44, 2913-2933.

Advisor: **Prof. Wei Jiang**
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Data Integration and Information Quality Management

Background: Many business and industrial applications critically rely on the quality of information stored in diverse databases and data warehouses. It is speculated that the cost associated with making decisions based on poor-quality data can be as much as 8% to 12% of the revenue of a typical organization, and more informally speculated as 40% to 60% of a service organization's expense [Redman 1998]. It is estimated about $US600 billion per annum to the US economy [TDWI 2003]. More importantly, the lack of high quality data is a major barrier to the adoption of new technology and continuous growth of national economy.

Abstract: The goal of this research project is to develop a systematic methodology of data quality analysis and improvement to achieve robust decision making under imperfect information environments. The core component is to develop a unified framework for data quality assessment and evaluation, which can be utilized to model inter-relationships between data quality metrics and facilitate statistical quality control tools for root cause identification and data quality improvement.

- Identifying modeling tools for data quality modeling. In particular statistical sampling and data mining methods will be investigated and advanced learning methods such as reinforced learning that integrated sampling and data mining tools will be explored
- Developing statistical process control tools for data quality improvement. Particular interests are laid in understanding the relationships between data quality and software/system quality so that limited resources can be allocated to optimize information quality
- Innovating robust decision making methods under imperfect information environments. Robust statistics and data mining are expected to delivery hand-on tools for fusing different sources of information for robust decision making

References:

- Ballou, D. P., Wang, R., Pazer, H. L., and Tayi, G. K. (1998), "Modeling Information Manufacturing Systems to Determine Information Product Quality", Management Science, 44(4), 462-484.
- English, L. P. (1999), Improving Data Warehouse and Business Information Quality: Methods for Reducing Costs and Increasing Profits. John Wiley & Sons, New York.
- Lee, Y., Strong, D., Kahn, B. and Wang, R. (2002), "AIMQ: A Methodology for Information Quality Assessment", Information & Management, 40, 133-146.
- Redman, T. C. (1998), "The Impact of Poor Data Quality on the Typical Enterprise", Communications of ACM, 41(2), 79-82.

Advisor: Prof. Wei Jiang
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Literature Survey & Description of Distributed Detection Networks

Background*:* The use of sensors as a means of detection has become prevalent in every area of technology. However, the problem of allocating these sensors to provide the highest system/network detection capability under different design constraints has largely been overlooked. Thus, this project is focused on developing techniques for the modeling, the computation and the optimization of distributed detection in sensor networks. The project has broad areas of application ranging from manufacturing to homeland security. Finally, the project has been divided in three major sub-projects from which interested students can choose.

Abstract: The focus of this project is on identifying the different types of sensor networks used for detection and how different existing mathematical models can be implemented. The emphasis is on providing specific applications where sensor networks are being used for purposes of detection or identification and propose a general definition of what capability means in this context. The completion of the task should also include a description of how current mathematical models may be used in these specific applications, and what are the limitations.

Student Requirements: basic mathematical skills to understand current modeling techniques. Also, the ability to write clear and organized project summaries is highly desired.

Advisor: Dr. Jose Emmanuel Ramirez-Marquez
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Modeling of Distributed Detection in Probabilistic Sensor Networks

Background*:* The use of sensors as a means of detection has become prevalent in every area of technology. However, the problem of allocating these sensors to provide the highest system/network detection capability under different design constraints has largely been overlooked. Thus, this project is focused on developing techniques for the modeling, the computation and the optimization of distributed detection in sensor networks. The project has broad areas of application ranging from manufacturing to homeland security. Finally, the project has been divided in three major sub-projects from which interested students can choose.

Abstract: The focus of this project is that the student develops a mathematical model that accurately represents the detection capability of a sensor network in a specific area of application. The model developed will be complemented by computational techniques to obtain exact or approximate values associated to the probability of network detection capability. Moreover, it is expected, Monte-Carlo and Discrete event simulation programs will complement these models.

Student Requirements: strong mathematical skills to understand current modeling techniques and to develop a new approach. Also, the ability to write clear and organized project summaries is highly desired.

Advisor: Dr. Jose Emmanuel Ramirez-Marquez,
jmarquez@stevens.edu

Optimization of Distributed Sensor Networks Under Design Constraints

Background*:* The use of sensors as a means of detection has become prevalent in every area of technology. However, the problem of allocating these sensors to provide the highest system/network detection capability under different design constraints has largely been overlooked. Thus, this project is focused on developing techniques for the modeling, the computation and the optimization of distributed detection in sensor networks. The project has broad areas of application ranging from manufacturing to homeland security. Finally, the project has been divided in three major sub-projects from which interested students can choose.

Abstract: The focus of this project is that the student implements evolutionary algorithms to solve problems related to resource (sensors, budget, etc…) allocation in distributed sensor networks/systems where tight design constraints must be enforced. Phase 1 sub-project emphasizes on understanding the resource allocation problem in order to build a mathematical model that accurately represents the network. The seconds Phase 2 will provide evolutionary optimization techniques to obtain solutions to these models.

Student Requirements: interested in this project are: a strong background in Probability, Statistics, Modeling and Simulation, and Operations Research. Also, the ability to write clear and organized project summaries is highly desired.

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On the Probabilistic Analysis of Successful Project Completion Under Resource Constraints: Literature Survey & Description of Project Completion as System

Background: We are undertaking a project to provide modeling and optimization approaches to the problem of planning, scheduling and managing the activities that entail the successful completion of projects. Most literature in project management has been focused on qualitative techniques to develop successful projects. However, new approaches are needed to: 1) help quantify how the allocation of resources increases the probability of successful completion of a particular project stage and 2) help identify the most critical stages of the project so that resources can be effectively allocated. Also of interest is how to extend the models to account for constraints on the available resources. Finally, the project has been divided in three major sub-projects from which interested students can choose.

Abstract: The focus of this project is on identifying the different types of networks that can be used the different potential stages leading to project completion. The emphasis is providing general classes of "projects" that can be translated into a network/system diagram. The completion of the task should also include a description of how current network models may be used in these classes of "projects" and what are their limitations.

Student Requirements: basic mathematical skills to understand current modeling techniques. Also, the ability to write clear and organized project summaries is highly desired.

Advisor: Dr. Jose Emmanuel Ramirez-Marquez
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School of Systems&Enterprises

On the Probabilistic Analysis of Successful Project Completion Under Resource Constraints: Selection of Modeling Approaches

Background: We are undertaking a project to provide modeling and optimization approaches to the problem of planning, scheduling and managing the activities that entail the successful completion of projects. Most literature in project management has been focused on qualitative techniques to develop successful projects. However, new approaches are needed to: 1) help quantify how the allocation of resources increases the probability of successful completion of a particular project stage and 2) help identify the most critical stages of the project so that resources can be effectively allocated. Also of interest is how to extend the models to account for constraints on the available resources. Finally, the project has been divided in three major sub-projects from which interested students can choose.

Abstract: The focus of this project is on generating a mathematical model that can be used to quantify the impact that the allocation of resources has on the completion of a project stage. Phase 1 will be focused on developing a sound model that provides a clear mathematical representation of how a specific stage of a project is affected by changes time, budget and personnel. In Phase 2 of this sub-project, the focus will move on to the development of a model that represents the whole project as a network of the different stages and where the interest lies into quantifying the probability of its successful completion. Definitions on what constitute a successful project completion (in this network context) will have to be proposed.

Student Requirements: probability and statistic knowledge to understand current modeling techniques and to develop a new approach. Also, the ability to write clear and organized project summaries is highly desired.

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School of Systems & Enterprises

On the Probabilistic Analysis of Successful Project Completion Under Resource Constraints: Optimization Techniques

Background: We are undertaking a project to provide modeling and optimization approaches to the problem of planning, scheduling and managing the activities that entail the successful completion of projects. Most literature in project management has been focused on qualitative techniques to develop successful projects. However, new approaches are needed to: 1) help quantify how the allocation of resources increases the probability of successful completion of a particular project stage and 2) help identify the most critical stages of the project so that resources can be effectively allocated. Also of interest is how to extend the models to account for constraints on the available resources. Finally, the project has been divided in three major sub-projects from which interested students can choose.

Abstract: The focus of this project is on provide optimization techniques for maximizing the probability of "project" completion. Initially, the student will concentrate on developing a sound mathematical optimization model, which can be solved via traditional optimization. Then, surrogate formulations and heuristic techniques will be proposed to improve the initial solutions obtained. Application of these optimization models into real business scenarios will help validate the techniques.

Student Requirements: a strong background in Operations Research. Also, the ability to write clear and organized project summaries is highly desired.

Advisor: Dr. Jose Emmanuel Ramirez-Marquez
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System Maturity Indices for Decision Support in the Acquisition Process

Background: The Technology Readiness Level (TRL) scale is a measure of maturity of an individual technology, with a view towards operational use in a system context. A comprehensive set of concerns becomes relevant when this metric is abstracted from an individual technology to a system context, which may involve interplay among multiple technologies that are integrated through the defense acquisition process. This research proposes the development of a system-focused approach for managing system development and making effective and efficient decisions during the defense acquisition process. For this to be accomplished, a new System Readiness Level (SRL) index will incorporate both the current TRL scale and the concept of an integration readiness level (IRL).

Abstract: This paper builds the foundations for the SRL and provide techniques for determining current and future readiness of a system to determine its position in the defense acquisition process. In addition, this research will investigate the optimization of the SRL index based on constrained resources to provide a decision support approach to enhance managerial capabilities in defense acquisition.

Student Requirements:

- Knowledge of Technology Readiness Levels.
- Basic capability in operations research

References:

GAO, "Better Management of Technology Development Can Improve Weapon System Outcomes." vol. GAO/NSIAD-99-162, U. S. G. A. Office, Ed.: Government Accounting Office, July 30, 1999.

DoD, "Technology Readiness Assessment (TRA) Deskbook," D. (S&T), Ed.: Department of Defense, 2005.

D. Cundiff, "Manufacturing Readiness Levels (MRL)," Unpublished white paper, 2003.

B. Sauser, D. Verma, J. Ramirez-Marquez, and R. Gove, "From TRL to SRL: The Concept of Systems Readiness Levels," in Conference on Systems Engineering Research, Los Angeles, CA, 2006.

Faculty Advisor: Dr. Brian Sauser
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System Integration Readiness and Maturity – Defining levels and Metrics

Background: Systems Integration Maturity (SIM) indicates the level of stability and sophistication of systems integration activities and processes. A high maturity level is an indicator of a well-integrated system and is demonstrated in terms of a harmonized, stable, and scalable system. Systems Integration Maturity is also an indication of lower integration risks, the higher the maturity, the lower the risk in integration activities. Lower risk in integration activities means expected and required functionality of the integrated systems are ensured.

Systems Integration Readiness (SIR) is a measure of the integration capability and suitability of a system, subsystem or component that will be integrated within a particular final system. The readiness of a subsystem or system for integration indicates its preparedness to be integrated. If the system is not ready there is a risk of integrating it. [Readiness is also a measure of how each subsystem or component complies with the specified requirements and how the interfaces comply with the interface descriptions. Higher readiness denotes lower risk

If the systems are not designed to be integration-friendly, it leads to further problems in integrating the systems. It is important that new systems are designed to be integration-friendly in order to decrease the issues and increase the maturity of the Systems Integration. Integration friendliness of systems indicate whether they have been designed and architected for ease of integration. Integration friendliness can be achieved by having an open architecture which is based on good standards that are current, relevant, and scalable; an architecture that is compatible with changing environment, well-documented, and simple to implement. The focus of research is on:

- Integration readiness and maturity life cycle.
- Attributes of system integration that result in its maturity.
- Metrics of system integration readiness and maturity.
- Tools and techniques for measuring and improving system integration maturity

Abstract of the Paper/Report to be produced: Contact Dr. Rashmi Jain for details

Student Requirements: Experience of integrating systems, ability and a strong willingness to conduct research.

References:

1. Systems Security Engineering Capability Maturity Model® SSE-CMM® Model Description Document Version 3.0 June 15, 2003.
2. Data Warehousing Process Maturity. IEEE Transactions on Engineering Management, Vol. 53, No.3, August 2006.
3. Beecham, S.; Hall, T.; Rainer, A. Defining a Requirements Process Improvement Model, Software Quality Journal, 13, 247-279, 2005.
4. Oshana, R.S.; Linger, R.C. Capability Maturity Model Software Development Using Cleanroom Software Engineering Principles: Results of an Industry Project. Proceedings of the 32nd Hawaii International Conference on System Sciences - 1999

5. Overcoming Barriers to Systems Engineering Process Improvement. Sarah A. Sheard; Howard Lykins; and James R. Armstrong. Journal of Systems Engineering 3: 59.67, 2000.
6. Browning, T. R. On Customer Value and Improvement in Product Development Processes; Systems Engineering; Vol. 6, No.1, 2003.
7. CMMI: Guidelines for Process Integration and Product Improvement, SEI Series in Software Engineering
8. An Overview of the Systems Engineering Capability Model EIA731 by Don E. Barber (IEEE 1998)

Faculty Advisor(s): Dr. Rashmi Jain
Rashmi.jain@stevens.edu

Interoperability and Open System Integration

Background: The evolution of systems demands scalability and adaptability to interoperate with other existing and new systems. This evolution of systems puts interoperability as a critical characteristic of a system. The growing usage of the term interoperability in the systems engineering literature over the past few years shows the widespread understanding of its importance and criticality. The term has been used in various contexts in systems engineering and other domains. There is a need to clearly state and define interoperability in systems engineering. In order to define the term the need and its importance has to be studied in various contexts.

Interoperability is a difficult challenge whether the goal is to increase interoperability between systems that originally did not interact, or to architect new systems designed to interoperate. Maintaining interoperability with legacy systems sometimes conflicts with achieving greater levels of interoperability between newer systems and this can lead to decisions to accept reduced interoperability between old and new systems. Interoperability is also an issue for COTS based systems integration and standards and architecture play an important role for the interoperability of COTS based systems integration. Component level interoperability issue for COTS and legacy integration and is related to architecture. Component interoperability has become an important concern as companies migrate legacy systems, integrate COTS products, and assemble modules from disparate sources into a single application.

One common pattern in addressing the need for interoperability in a system is through the compliance requirements and architecture. This led us to research on relationships between interoperability, standards, system architecture and integration. The two research questions that were considered were, “Does adherence to standards lead to better interoperability?”, and “Does interoperability lead to better system architecture and integration?” When these questions were studied in detail it emerged that interoperability can be achieved by two approaches, one by compliance and another by flexible designs.

Compliance can be defined as conformance to standards which indicates that such systems or components meet the requirements specified by a “standard”.

Flexible designs promote “flexibility” and “adaptability”. Flexibility characterizes system’s ability to be changed easily, where adaptability characterizes a system’s ability to adapt itself towards changing environments.

The focus of research is on:

- Causal factors of interoperability
- Design for achieving interoperability
- Role of standards in defining interoperability
- Selecting and implementing standards to achieve interoperability

Abstract of the Paper/Report to be produced: Contact Dr. Rashmi Jain for details

Student Requirements: Experience of integrating systems, ability and a strong willingness to conduct research.

References:

1. Institute of Electrical and Electronics Engineers. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York, NY: 1990.
2. Brownsword, L et. al. Current Perspectives on Interoperability (CMU/SEI-2004-TR-009). Pittsburgh, PA: Software Engineering Institute, 2004.
3. SEI, Topics in Interoperability: System-of-Systems Evolution. David Carney, David Fisher, Patrick Place, March 2005
4. IEEE 100 The Authoritative Dictionary of IEEE Standards Terms Seventh Edition, 2000.
5. Ouksel, A.; Sheth, A. Semantic Interoperability in Global Information Systems, ACM Sigmod Record, 1999.
6. Edwin Morris, et al, “Systems of Systems Interoperability (SOSI): Final Report,” Carnegie Mellon Software Engineering Institute, April 2004.
7. C4ISR Interoperability Working Group, Department of Defense. Levels of Information Systems Interoperability (LISI). Washington, DC: 1998.
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9. Tolk, Andreas & Muguira, James A. “The Levels of Conceptual Interoperability Model.” 2003 Fall Simulation Interoperability Workshop Orlando, Florida, September 2003.
10. Achieving Interoperability for Integration of Heterogeneous COTS Geographic Information Systems, 2002.
11. The impact of component architectures on interoperability. Journal of Systems and Software, Volume 61, Issue 1, 1 March 2002, Pages 31-45. L. Davis, R. F. Gamble and J. Payton.

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Impact of system architecture and design on systems integration complexity

Background: It is necessary to determine if integration of the defined physical elements and interfaces in system architecture contributes to system integration process complexity. Today's systems are usually expected to function independently and in cooperation with the existing systems (system of systems). The cooperating systems undergo frequent changes. Interoperability becomes a key factor and a major contributor to system integration process complexity. Interoperability is based on the existence of conceptual view. Conceptual view can be embodied in requirements and architecture/ design. Architecture determines the level of interoperability. The system integration process complexity includes interoperability.

The major focus of this research is on the cause and effect relationship between system requirements, system architecture, and system integration process complexity. The research will involve establishing the context by defining and discussing system integration process, and its complexity classification. In order to understand, analyze and prioritize the causal factors a cause and effect relationship model will be developed and relevant attributes of good requirements and architecture need to be identified. These attributes of requirements and architecture redefine the activities involved in these two critical phases and enable a relatively simplified integration process. Further a set of activities/factors of system requirements and system architecture will be identified.

We define:

> System Integration process complexity as an outcome of the interaction between degree of feasibility and level of effort required to understand, describe, implement, manage and document the system integration process for a given system development and operational environment.

The focus of research is on:

- Causal factors of system integration complexity
- Attributes of system architecture that impact system integration complexity
- Categorize the different levels of integration complexity.
- Tools and techniques to measure and address system integration complexity

Abstract of the Paper/Report to be produced: Contact Dr. Rashmi Jain for details

Student Requirements: Experience of integrating systems, ability and a strong willingness to conduct research.

References:

1. Bachmann, F., Bass, L., Chastek, G., Donohoe, P., Peruzzi, F., "The Architecture Based Design Method", Software Engineering Institute, Carnegie Mellon University (SEI-CMU), 2000.
2. Bachmann, F., Bass, L., Klein, M., "Deriving Architectural Tactics: A Step Toward Methodical Architectural Design", SEI-CMU, 2003.
3. Bachmann, F., Bass, L., Klein, M., "Illuminating the Fundamental Contributors to Software Architecture Quality", SEI-CMU, 2002.
4. Bass, L., Clements, P., Kazman, R., "Software Architecture in Practice", Addison-Wesley, 2003.
5. Buede, D., "The Engineering Design of Systems", Wiley Series in Systems Engineering, 2000.

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9. Elias, G., Jain, R., "Exploring Attributes for Systems Architecture Evaluation", CSER, 2007.
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12. Jain, R., Chandrasekaran, A., Erol, O., "System Integration Process Model (SIPM)", Working Paper, Stevens Institute of Technology, 2007.
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15. McCabe, R., Pollen, M., "Evaluating Architectures With System Attributes", Software Productivity Consortium, 2004.
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Reliability, Maintainability & Supportability of Software Intensive Systems

Background:

Most complex systems these days are characterized, at least in part, by the software that they incorporate. When considering the Reliability, Maintainability and Supportability (RM&S) of such systems, therefore, the RM&S of the software itself should be included.

The intent of this Master's Project is for the student to apply the systems engineering concepts, principles and practices they have learned to:

1. A "real" software system RM&S problem of interest to them, their sponsor and their assigned academic advisor;

2. An investigative study of some aspect of software system RM&S design; or

3. The development of a software system RM&S design case study.

Key Questions that could be considered for this Master's Project:

What are Systems Software Reliability, Maintainability and Supportability? Do these concepts really apply to software?

How can Systems Software Reliability, Maintainability and Supportability be verified? How much is 'good enough'?

What are current best practices in managing/improving Systems Software Reliability, Maintainability and Supportability? How can the *practices* be improved?

What are the cost/schedule considerations for Systems Software Reliability, Maintainability and Supportability?

What are the customer/user expectations for Systems Software Reliability, Maintainability and Supportability? How can we understand those expectations?

Student Requirements

This Master's Project is intended for students with experience in systems engineering and requirements engineering/management.
Some experience in the management and design of complex Software Intensive Systems would be beneficial.

References

The Software Engineering Institute www.sei.cmu.edu.

The IEEE Software Engineering Body of Knowledge (www.swebok.org) states competencies expected of software engineers.

SDOE 645 – Design for System Reliability, Maintainability and Supportability class notes

For more information please email wvrobinson@optonline.net

Faculty Advisor:

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Reliability, Maintainability and Supportability of COTS-based Systems

Background:

Most complex systems these days are characterized, at least in part, by the Commercial-Off-The-Shelf (COTS) subsystems that they incorporate. When considering the Reliability, Maintainability and Supportability (RM&S) of such systems, therefore, the RM&S of the COTS should be included.

The intent of this Master's Project is for the student to apply the systems engineering concepts, principles and practices they have learned to:

1. A "real" COTS-based system RM&S problem of interest to them, their sponsor and their assigned academic advisor;

2. An investigative study of some aspect of COTS-based system RM&S design; or

3. The development of a COTS-based system RM&S design case study.

Key Questions that could be considered for this Master's Project:

How can COTS-based Systems Software Reliability, Maintainability and Supportability be verified? How much is 'good enough'?
How do programs that use COTS know how 'good' it is?

What are current best practices in COTS-based Systems Reliability, Maintainability and Supportability? How can the *practices* be improved?

What are the cost/schedule considerations for COTS-based Systems Reliability, Maintainability and Supportability?

What are the customer/user expectations for COTS-based Systems Reliability, Maintainability and Supportability? How can we understand those expectations?

Student Requirements

This Master's Project is intended for students with experience in systems engineering and requirements engineering/management.

Some experience in the management and design of complex Systems would be beneficial.

References

The Software Engineering Institute www.sei.cmu.edu.

SDOE 645 – Design for System Reliability, Maintainability and Supportability class notes

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Faculty Advisor:

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Quality Management of Systems Design

Background:

When considering the Operational Excellence of Systems, the *Quality* of the system must be considered.

The intent of this Master's Project is for the student to apply the systems engineering concepts, principles and practices they have learned to:

1. The systems Quality Management approach/results of a "real" system RM&S problem of interest to them, their sponsor and their assigned academic advisor;

2. An investigative study of some aspect of systems Quality Management approaches/results; or

3. The development of a systems Quality Management design case study.

Key Questions that could be considered for this Master's Project:

How can System Quality Management be verified? How much is 'good enough'?

What are current best practices in System Quality Management? How can they be improved?

What are the cost/schedule considerations for System Quality Management?

What are the customer/user expectations for System Quality Management? How can we understand those expectations?

What are the differences/similarities between System Quality Management and System Reliability, Maintainability and Supportability (RM&S)?

Student Requirements

This Master's Project is intended for students with experience in systems engineering and requirements engineering/management.

Some experience in the management and design of complex Systems would be beneficial.

References

SDOE 645 – Design for System Reliability, Maintainability and Supportability class notes

For more information please email wvrobinson@optonline.net

SSE School of Systems&Enterprises

Faculty Advisor:

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Reliability, Maintainability and Supportability of Network-centric Systems

Background:

Today, most complex systems are best characterized as t Network-centric Systems.

Examples include the Internet, Telecommunications Systems, Distributions Systems, and Warfare Systems.

When considering the Reliability, Maintainability and Supportability (RM&S) of such systems the *Network* aspects need to be considered.

The intent of this Master's Project is for the student to apply the systems engineering concepts, principles and practices they have learned to:

4. A "real" Network-centric system RM&S problem of interest to them, their sponsor and their assigned academic advisor;

5. An investigative study of some aspect of Network-centric system RM&S design; or

6. The development of a Network-centric system RM&S design case study.

Key Questions that could be considered for this Master's Project:

How can Network-centric Systems Software Reliability, Maintainability and Supportability be verified? How much is 'good enough'?

What are current best practices in Network-centric Systems Reliability, Maintainability and Supportability? How can they be improved?

What are the cost/schedule considerations for Network-centric Systems Reliability, Maintainability and Supportability?

What are the customer/user expectations for Network-centric Systems Reliability, Maintainability and Supportability? How can we understand those expectations?

Student Requirements

This Master's Project is intended for students with experience in systems engineering and requirements engineering/management.

Some experience in the management and design of complex Systems would be beneficial.

References

SDOE 645 – Design for System Reliability, Maintainability and Supportability class notes

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Faculty Advisor:

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The Evolution of Software and Its Impact on Complex System Design

Background: Historically, systems engineering emerged in the 1940s as a means for managing the growing complexity of engineered systems. In those days, systems were most often comprised of electromechanical elements and system complexity was viewed as a function of the number of elements and the number and complexity of the interfaces between them. Examples of such early systems include World War II artillery rangefinders and the Bell System's relay-based telephone network. While the interactions between system elements often produced complex behavior, the elements themselves were fairly simple and their behavior governed by well-defined physical laws

With the advent of digital computing, this picture began to change. Software allowed a rudimentary form of intelligence to be embedded in system elements. No longer could the behavior of these elements be predicted by the simple application of physical laws. Now, system elements could exhibit conditional behavior, responding in different ways depending on the internal state of the system and the external inputs it encountered. A new level of complexity was thus introduced into engineered systems, driven not only by the number of elements and interfaces, but also by the behavior of the elements themselves.

This form of complexity has only grown over time. The inexorable advance in capability as a consequence of Moore's law has made it possible to embed not only software in physical components, but entire computers, complete with operating systems and enough memory to support extensive calculations. This has dramatic implications for the design of complex systems.

Abstract: This project will trace the evolution of embedded software and identify its impact on system complexity and design. The major challenges faced by system designers in each phase of this evolution will be identified and representative examples provided. The parallel development of new system design techniques to keep pace with this increasing system complexity will also be described and illustrated.

Student Requirements: Experience in the design and development of systems involving embedded software.

Advisor: Prof. Michael Pennotti
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A Complexity Model for Software Intensive Systems

Background: Nearly every discussion of systems engineering today includes a reference to the increasing complexity of modern engineered systems. Version 1.0 of the DoD Architecture Framework notes the importance of architectures in serving "as a means for understanding and managing complexity." Kossiakoff and Sweet, in their book entitled Systems Engineering: Principles and Practices (Wiley, 2003) say, "The function of systems engineering is to guide the engineering of complex systems." Blanchard and Fabrycky in their widely used text Systems Engineering and Analysis (Wiley, 1998) say, "The world is increasing in complexity." And, in four systems engineering case studies published by the Air Force Institute of Technology in 2005, the word "complex" was used 90 times! What is this complexity that is so often spoken about? Is it something new? Is the world truly becoming more complex? In what way? More to the point, are the systems we engineer more complex than those built by previous generations? Would they agree?

One of the earliest systems engineering texts was Goode and Machol's System Engineering: An Introduction to the Design of Large Scale Systems (McGraw Hill, 1958). Its first chapter is entitled "Complexity." A year before its publication, in February 1957, Engstrom published a paper in the journal Electrical Engineering entitled "Systems Engineering: A Growing Concept." He said, "The task of adapting our increasingly complex devices and techniques… has presented modern engineering with its greatest challenge." Still earlier in July 1956, a paper entitled "Systems Engineering – Key to Modern Development," published by Schlager in the IRE Transactions on Engineering Management, justified its subject with the statement, "Increased complexity of systems…has led to an emphasis on the field of systems engineering." And in a lecture delivered on March 23, 1950 to the Royal Society of London, Mervin J. Kelly, then President of the Bell Telephone Laboratories, said, "As the technology of communication has broadened and become more complex, the choice of the technical paths to be pursued… has become increasingly difficult. It is this situation that has led to the evolution of the systems engineering function" (Proceedings of the Royal Society of London, October 1950). If our systems are more complex than those of the 1950s, what were these authors speaking about. Perhaps their systems were just as complex in their time as ours are now. Perhaps is only a matter of perspective. Maybe the things that made their systems complex have now been reduced to practice and new things have arisen to take their place.

Or maybe not. Maybe system complexity has not just been steadily increasing at the pace of the underlying technology. Maybe somewhere along the line, there has been a discontinuity. Maybe today's systems are more complex in some fundamental way. If so, maybe the techniques we need to manage our systems are quite different from those that served previous generations. If that is the case, we need to understand the nature of the discontinuity and its implications for system design.

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Abstract: This project will develop a measure of system complexity that can be used to characterize the growth in the complexity of engineered systems over the past half-century and to identify the nature of that growth. The emphasis will be on identifying any discontinuities in the nature of systems that might call for radically different systems engineering practices or processes for managing complexity

Student Requirements: Experience in the design and development of complex systems of all types and the mathematical agility to analyze and model complex phenomenon.

Advisor: Prof. Michael Pennotti
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The potential of simulations to reduce system-of-system complexity

Background: New features or capabilities for large scale complex software intensive system deployed by government agencies and industries are often examined using simulators. The simulators give insight into the performance of the system considering the introduction of the new feature in the context of the deployed system and its environment. These simulations shed little light on software engineering aspects of the proposed changes. This research will examine the correlation between the complexity of proposed features and resulting trustworthiness, possible schedule and potential costs for the enhanced system. This research ties the system performance to software implementation through innovative uses of the software reliability equation and sizing theory. With performance, reliability, schedule and cost estimate in hand, system engineers can make essential engineering tradeoffs as they set a course of action.

The student will study existing simulation infrastructures, such as the FAA, to understand how changes may reduce the complexity of systems and the software components they model. The goal of this research is to extend and enhance the existing simulation environments to provide the analysis infrastructure for Model –Driven Software Realization that improves the likelihood that software will be trustworthy and delivered on schedule and within budget by reducing complexity. The simulation platforms might be able to be instrumented to assess complexity and analyze the impact of designs. An important part of the research is to define, categorize and to the extent possible quantify multi-dimensional complexity parameters. A significant effort is required to assemble and integrate the many different and valid views of software complexity into a holistic theory.

Abstract: Complexity is a strong factor in the effort required and the time it takes to build software centric systems and their inherent reliability. Specific research is undertaken to evaluate the performance of alternative software solutions using existing simulation models. Knowing the performance we assess the complexity of models of the proposed solutions. Using several complexity measures we then estimate staff, schedule and reliable of the implementation. The result is decision data provided to the stakeholders. The model will be used to track and drive the software development effort following the pioneering work on the Safeguard Antimissile Missile System philosophy. [Bern96].

Student Requirements: Experience of integrating systems, understand software complexity and metrics and the use of simulations. Excellent writing skill is a must. This could be a team effort. Industrial interaction skill is key.

Advisor: Prof. Larry Bernstein

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