A. CANDIDATE'S STATEMENT

A-1 Professional Activities

I have made major contributions for the NPS mission and DoD needs in my research, teaching and service in the areas of system cost modeling, affordability and tradespace analysis, related Model-Based Systems Engineering (MBSE) methods, process modeling and simulation, systems engineering education, and integrating systems and software engineering disciplines.

Recent research includes developing and demonstrating new methods for integrating MBSE approaches for early architectural definition, effectiveness analysis, and cost estimation. New cost modeling research for agile software processes in the DoD is also underway. It leverages my earlier definitive work at NPS in software cost estimation metrics for defense systems that resulted in significant DoD policy changes. I continue to extend cost models for Total Ownership Cost (TOC) encompassing multiple engineering disciplines, and modeling systems and software engineering processes. Empirical-based research methods underpin all these.

My leadership in research communities is also evidenced by awards, key conference tutorials, workshops I have led, invited presentations, DoD webinars, expert panels, and major service for relevant journals and conferences. I received a Lifetime Achievement Award from USC for "Innovative Development of a Wide Variety of Cost, Schedule and Quality Models and Simulations". Within the DoD, I am a regular highlighted speaker at the annual DoD Systems Engineering Research Center (SERC) Research Review. Earlier, the Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD(SE)) asked me to advise them on an expert panel for schedule assessment methods and models.

As a primary go-to person for DoD system cost estimation at NPS, I have been expanding our teaching curricula and research in integrated systems, software and hardware cost aspects. I have been a linchpin between research communities and disciplines, and performing substantial internal and external service. I'm Academic Associate for our largest curriculum and course coordinator (multiple). I helped create a new master's degree curriculum at NPS, work intimately with other departments and their Ph.D. students, and supported many students theses. Externally I've served on journal editorial boards, peer reviewed numerous journal papers, and served on conference program committees for leading venues in my fields. I'm also very active with the International Council on Systems Engineering (INCOSE) as a 4-year Chapter Board Member including President, and am a handbook chapter author.

Besides pure research I develop practical and widely used cost estimation tools for the DoD community and public. My web-based tools have real impact as tangible products used daily on DoD projects and others across the globe (typically several hundred or more estimates each day) and undergo continuous improvements. The *COCOMO Suite* [205] [206] [208] and more extensive *System Cost Model Suite* [204] lower the barriers to parametric cost models and are used extensively in government, industry, and academia. Numerous users send acknowledgments representing DoD projects (government and contractors), other U.S. agencies, foreign governments, commercial companies, professors, students, and consultants. They are the standardized estimation tools in some organizations, many universities are teaching with them, and their usage has demonstrably continued to expand. Furthermore I developed many of the encapsulated cost/risk models in addition to the tool implementations.

Activities straddling research and service include 1) being a key researcher and very active collaborator with the SERC, 2) spearheading our formal membership in the International Software Engineering Research Network (ISERN) for empirical-based research and continuing as the NPS representative working with the empirical community, and 3) being a primary contributor to the definitive systems engineering references Systems Engineering Body of Knowledge (SEBoK) [9], Graduate Reference Curriculum in Systems Engineering (GRCSE) [10], and the INCOSE Systems Engineering Handbook [8] (authoring chapters in each).

At NPS I was instrumental aligning us with the SERC to conduct sponsored research and was the first funded. I continue to be one of the most active SERC researchers having performed on 11 multi-year SERC Research Topics, and participate in related workshops and technical reviews representing NPS as a principal collaborator.

I have been key to integrating systems and software engineering in research, service and our curriculum. My new textbook [1] covers this integration to strengthen interdisciplinary engineering practices. I also collaborate with the Software Engineering Ph.D. program in Computer Science, revamped our software engineering course, made relevant subject matter contributions to the SEBoK, and am integrating parametric cost models of the disciplines.

I recently published *What Every Engineer Should Know About Modeling and Simulation* [2] and *Systems Engineering Principles for Software Engineers* [1] will be out in early 2018. My peer reviewed publications include 5

In this document, supporting hyperlinks are shown with underlines so reviewers using printouts will know they exist. A version without underlines is here, if preferred. These are available with sample publications on GitHub.

books, 21 journal papers, 8 book chapters, 1 conference proceedings book, 47 conference papers, and several topics in the SEBoK. More journal papers are in-process. Per Google Scholar I currently have 6088 citations, h-index 23, i10-index 38, am ranked 4th at NPS and 17th in the systems engineering specialty.

Research

Post-tenure research leadership is demonstrated by my initiating innovative MBSE joint research with AFIT[168] [169], new cost model development [36], conference workshops I have led [91] [88], invited presentations for the SERC [161] [162] and international software metrics venues [89], and awards [85]. I have new funded lines of research just beginning. Other recent technical progress includes extending cost models for Total Ownership Cost (TOC) encompassing multiple engineering disciplines with Monte Carlo simulation; and modeling systems and software engineering processes.

I continue to be one of the most active and influential SERC PI researchers for the System Qualities Ontology, Tradespace and Affordability Program (SQOTA) funded by ODASD(SE) for the 6th continuous phase . My joint research with AFIT is furthering model-centric system tradespace and affordability analysis. Our shared case studies and models are for Intelligence, Surveillance and Reconnaissance missions with multi-tiered collections of heterogenous UASs. This research has also supported many student theses at NPS and AFIT.

My PI research comprising multiple awards from the Air Force Cost Analysis Agency (AFCAA) includes definitive work culminating in the book *Software Cost Estimation Metrics Manual for Defense Systems* [3]. Related significant impact includes critical DoD policy changes. I developed core metrics definitions to strengthen reporting requirements for DoD programs involving software development. OSD adopted and formally implemented changes to the DoD Software Resources Data Report deliverable based on our empirical analysis standardized to my definitions. This is quite significant because the submitted data is now more rigorous and consistent, resulting in improved DoD cost data, more stable models and insights for informed decision-making.

Earlier on SQOTA (previously the Ilities Tradespace and Affordability Program), I enhanced cost models for operations and maintenance for TOC, and furthered Monte Carlo simulation capabilities. The *System Cost Model Suite* now covers systems engineering, software engineering, hardware development and production. The models are tailorable for DoD domains, and demonstrated as a web-based service for other programs through an API.

I was PI for Naval Surface Warfare Center conducting a Business Case Analysis (BCA) for the Littoral Warfare Engineering Facility. The BCA was instrumental at NAVSEA for strategic decision-making and planning. My economic analysis was presented to the highest levels including Admirals across the Navy, Coast Guard, and High Energy Laser program for joint operations.

Space and Naval Warfare Systems Command (SPAWAR) sponsored my PI research for systems cost estimation support in 2011, and was funded for SPAWAR PMS-485 cost estimation support in 2010-2012. These efforts investigated the sources of cost and risk for systems engineering on their programs.

Earlier on the SERC Valuing Flexibility research project in 2010-2011, I developed new models for product line TOC. These provide unique capability for DoD program analysis and are the basis of parametric models used at NAVAIR summarized next.

Research funded by NAVAIR involved cost and ROI modeling of avionics software product line development on the Future Airborne Capability Environment (FACE) business model development. It validated costing efforts across different airborne platforms, identified effort drivers for a FACE model, and integrated software cost models. Other funded simulation research was for the SERC Agile-Lean Software Engineering (ALSE): Evaluating Kanban in Systems Engineering, where I used hybrid simulation to assess agile systems engineering processes for complex DoD projects. Earlier I initiated joint simulation research with AFIT and The Aerospace Corporation modeling the JCIDS weapon acquisition system to investigate DoD acquisition process policies.

Overall, my research funding has been increasing and sponsors have been very satisfied with my results. This is exemplified by multiple continuations with ODASD(SE) and AFCAA, regular invitations to present my research as a highlight at the annual DoD SERC research reviews, and the interest of other universities in collaborating on MBSE and cost modeling. I have brand new research funding for agile software processes and causal system cost modeling.

Teaching

I am the department course coordinator for two courses. This role includes continual monitoring, review of course journals, course improvements, and I helped support the successful ABET accreditations for the department. I have been serving as SE4003: Software Systems Engineering course coordinator since coming to NPS and took responsibility for SE3011 Engineering Economics and Cost Estimation course coordinator as of AY2017.

My teaching record shows clear improvement in student evaluations since tenure. This includes teaching SE4003 where I recently revamped the course with new assignments and material that has been adopted by other NPS instructors. I also teach SE3011 and created substantial new material for it. A unique asset is my web-based cost estimation tool that improved the course and streamlines student logistics to focus on concepts enabling more complex assignments. I also supplemented the course for new systems, software, and hardware cost models.

I work closely with the Computer Science department in its Software Engineering program. Each year I write and administer the Software Engineering Ph.D. written exam in Software Management and Economics, am on some of their student Ph.D. committees including co-advising, and support other Ph.D. students via my research.

Thus far I have served as advisor, co-advisor or second reader for 55 students graduating in Systems Engineering on individual theses and group capstones. For the new Master in Cost Estimation and Analysis (MCEA) at NPS I developed the module on Software Cost Estimation and taught it to initial cohorts. This important degree program is being delivered jointly with NPS and AFIT students.

Service

Internally I serve as Academic Associate (post-tenure) for the largest student curriculum at NPS, the Systems Engineering (SE) Curriculum 311 (also the large majority in SE). I'm also serving on the Faculty Council Scholarship Committee since tenure. The Council is on track to adopt student evaluation revisions from our Committee.

I have been very engaged serving on the INCOSE San Diego Chapter Executive Board for four years. This service is both professional for local systems engineers, and community-oriented due to our extensive STEM support activities and funding for local school science projects. Leading as the President in 2016, our chapter received the very competitive INCOSE Gold Chapter Award for our activities.

A substantial service activity was contributing to the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE) project creating the SEBoK and GRCSE. I was the lead author for the Systems Engineering Management chapter topics, subject expert for the thread of software engineering and its overlap with systems engineering concepts, and contributed to other sections for cost analysis, affordability, engineering use cases, integrating disciplines and terminology. On GRCSE I was lead author on the Entrance Expectations chapter.

I'm an Associate Editor on the board of the Journal of Cost Analysis and Parametrics (JCAP) and served on the Editorial Board of the International Journal of Information Technology and the Systems Approach (IJITSA). At NPS I have been a journal article reviewer for over 20 papers for top peer reviewed journals.

External service also includes being on the program committees each year for primary international conferences in my areas: the International Conference on Systems and Software Process (including program co-chair), the Conference on Systems Engineering Research, and the International Forum on COCOMO and Systems/Software Cost Modeling. Since instituting our membership in ISERN I have continued as the NPS representative.

A-2 Career Plans

I will continue developing new engineering knowledge in models, methods, and tools focusing on national security. This entails empirical-based research because quantitative data from DoD projects is critical for building better models. Cost models and tools should continuously improve and adapt to new aspects which I will do. Intellectually I will continue broadening my areas across disciplines and DoD purview, such as moving towards a larger DoD enterprise-wide acquisition perspective in modeling and simulation.

Currently I have newly funded research ahead with anticipated future sponsorship of foundational model-based systems engineering research. These will provide ample opportunities for M.S. and Ph.D. theses and capstone projects. I will strive to keep producing high impact results, and involve students with relevant application topics.

Continuous improvements in our teaching curricula and delivery methods are necessary to maintain our academic excellence at NPS. I want to teach additional courses, and develop new courses for important and emergent areas in model-based systems engineering and cost estimation.

As full professor I will support junior faculty, continue on strategic and academic committees, departmental evaluation committees (for higher positions), hiring committees (as chair), and lead future accreditation efforts. I would like to serve on the Faculty Council again, on INCOSE Working Groups and its Board of Directors.

It would be beneficial to visit campus more regularly to mentor resident students, guest teach resident classes, and work with colleagues. It will increase my collaboration with other departments, I can be more effective on the Faculty Council, and help harmonize resident and distance learning teaching modes with the experience.

NPS has provided me a most stimulating environment and challenging opportunities. There is much important work left and relevant contributions to make. My books will need updated editions with the advancing knowledge. I eagerly look forward to expanding my repertoire, and increasing my value to NPS and the DoD for a long time.

B. FACTUAL INFORMATION

I. BIOGRAPHICAL INFORMATION

1. Demographic Information

Raymond J. Madachy, Ph.D.
Associate Professor
Department of Systems Engineering
Bullard Hall, Room 201J
(619) 847-0986
US citizen
Secret clearance

2. Education

University of Southern California
Ph.D. Industrial and Systems Engineering, 1994
Areas: systems engineering, systems architecting, computer science
Dissertation: "A Software Project Dynamics Model for Process Cost, Schedule and Risk Assessment"
Advisor: Behrokh Khoshnevis

University of California, San Diego
M. S. System Science, 1983
Comprehensive exam covered digital signal processing and system dynamics
Research in bio-engineering, orbital mechanics and man-machine interface

University of Dayton
B.S. Mechanical Engineering, 1981
Minor: Aerospace Engineering
Magna Cum Laude

3. A chronology of professional history

2008-present	Naval Postgraduate School Tenured Associate Professor, Department of Systems Engineering, 2015-present Associate Professor, Department of Systems Engineering, 2008-2015
2005-2008	University of Southern California Research Assistant Professor and Interim Director of Systems Architecting and Engineering Program, Department of Industrial and Systems Engineering, 2007-2008 Research Scientist, Departments of Industrial and Systems Engineering and Computer Science, 2005-2007
2001-2005	Chief Science Officer, Cost Xpert Group Inc.
2001-2005 (part-time)	Research Associate, University of Southern California, Department of Computer Science
2000-2001	Chief Scientist, C-bridge Internet Solutions, C-bridge Institute
1992-2000	Litton Systems Manager, Software Engineering Process Group, Litton Guidance & Control Systems, 1997-2000 Senior Engineering Specialist, Litton Data Systems, 1992-1997

1988-1992	Librascope Corporation Staff Engineer, 1991-1992 Lead Software Engineer, 1989-1991 Programming Research Specialist, 1988-1989
1987-1988	Laboratory Manager, University of California, Los Angeles
1985-1986	Independent Contractor, TRW Electronics and Defense, Advanced Programs Division
1982-1985	Member of Technical Staff, Hughes Aircraft Co., Radar Systems
1981-1982	Aerospace Engineer, General Dynamics, Convair

4. Academic concentrations and research interests

Initially I chose mechanical engineering for a major because it was the most extensive engineering curriculum at my undergraduate school covering diverse technical subjects. It was also best suited for my chosen minor in aerospace engineering.

I became interested in a broader systems view (and study of systems themselves), and chose a masters in systems science at UCSD for a multidisciplinary approach to the analysis and solution of complex systems problems (there was no SE major). My exam was in digital signal processing and system dynamics; and I conducted research in bio-engineering, orbital mechanics and man-machine interfaces.

Finally I went for my Ph.D. in systems engineering with further concentrations in systems architecting, and computer science for software engineering aspects. My dissertation was *A Software Project Dynamics Model for Process Cost, Schedule and Risk Assessment.*

I have continued in these areas of cost estimation and process simulation of systems and software engineering, and now broadening into hardware cost modeling.

Current research interests include total ownership cost modeling; affordability and tradespace analysis; modeling and simulation of systems and software engineering processes, and the DoD acquisition process; integrating systems engineering and software engineering disciplines, and empirical-based research with process simulation.

Recently I have expanded into other areas of Model-Based-Systems Engineering (MBSE). I'm developing new methods and approaches for incorporating affordability and tradespace analysis in a more automated fashion in conjunction with other MBSE methods (e.g. integrated systems architecting/design and cost analysis derived from common model artifacts).

5. Professional certifications or registrations

II. INTERNAL NPS ACTIVITIES

1. Internal Teaching Activities

a. Course and laboratory development

Before tenure I developed new course materials for the software cost estimation modules in the new M.S. Cost Estimation and Analysis (MCEA) curriculum.

b. DoN/DoD applications

I developed the MCEA materials described in section II.1.a. and taught them jointly with AFIT to focus on defense project applications.

I have inserted many DoD applications in the courses I have taught for cost modeling and systems software engineering. I'm continuously creating and adapting teaching material for DoD environment contexts, striving to mirror the actual types of projects students will encounter.

c. Teaching techniques developed

The aforementioned cloud-based cost estimation tools are unique for teaching and student usage. The tools are also compatible with corresponding new course material described in Section II.1.g. These are new capabilities in the classroom whereby executable web-based tools replace desktop applications. The cost analyses taught in class can be developed and saved in the cloud. For example, during a distance learning lecture I can send the populated models via a URL in the chat which students can then view and modify.

I have also inserted cloud-based software development in my SE4003 class. Students only need a browser, without the overhead and constraints of desktop programming environments. Similar to SE3011, the class examples and software development assignments can be shared with a URL as executable programs. Files don't have to be imported into a desktop application in order to execute.

d. Thesis supervision

The student theses supervised since tenure are in the Figure 1 timeline. Completed theses are shown as milestones.

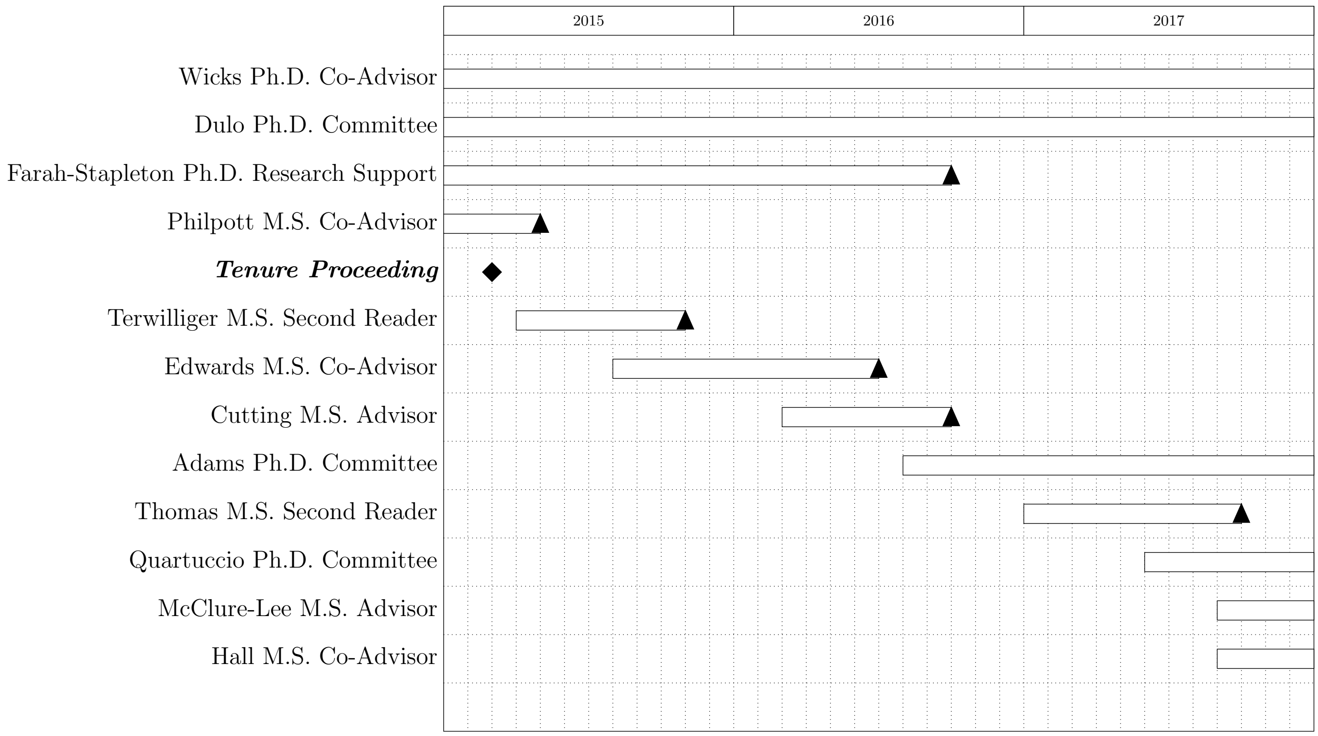


Figure 1: Student Thesis Timeline

(i) advisor

Since tenure I have served as advisor (or advisor to-be) for the following MS and Ph.D. students.

Current students:

In 2017 I began a Directed Study course for early Ph.D. student Socrates Frangis supporting his advancement to candidacy, and expect to become his advisor in the area of embedded firmware and software assurance security research . Expected graduation is June 2020.

Landa McClure-Lee, "How Does an Agile Methodology for Software Development/Sustainment Impact a Software-Intensive Weapon System Lifecycle from Cradle to Grave?", MS in Joint Executive Systems Engineering Management, expected graduation March 2018

Since tenure I advised the following matriculated students:

Cutting, Alexander, "Analysis of Electromechanical Actuators Used to Move Jet Blast Deflectors on Aircraft Carriers", MS Systems Engineering Management, September, 2016

Edwards, Dennis, "Exploring the Integration of COSYSMO With a Model-Based Systems Engineering Methodology in Early Trade Space Analytics and Decisions", MS Systems Engineering, June 2016

Previous students I advised include:

Peter P. Labbe, “Standardization of Software Application Standards and Governance”, MS Systems Engineering Management, December 2014

Nam H. Tran. “Integrating Information Assurance with Systems Engineering to Improve Security and Interoperability of the Warfare System on USS George H. W. Bush (CVN 77)”, MS Systems Engineering, September 2013

(ii) co-advisor

Since tenure I have served as co-advisor for the following MS and Ph.D. students.

Alan Philpott, “Benefits of Design Budget Approach to New Ship Construction”, MS Systems Engineering Management, April 2015

Current students:

LT Robert Hall, ”Utilizing a Systems Architecture Approach to Develop a Combat Systems Product Line to Meet the Future Needs of Information / Digital Warfare”, MS Systems Engineering, expected graduation June 2018

LT Rollie Wicks, “User Centric Cloud”, Ph.D. Software Engineering, expected graduation 2018

Previous students and capstone teams I co-advised include:

Nicole Becker, Timothy Byram, David Frank, Kevin Hogan, Richard Kim, Glenna Miller, Shane Schonhoff, Scott Myers, Heather Whitehouse, “Application of Model-Based Systems Engineering (MBSE) To Compare Legacy And Future Forces In Mine Warfare (MIW) Missions”, Master’s Degree in Systems Engineering Capstone Project, Naval Postgraduate School, January 2015

Clayton Bennett, Christopher Farris, Paul Foxx, Hughlyn Henderson, Stacy Himes, Corey Kennington, Matthew Mussman, Michael Newman, Maysam Sarfaraz, Brandon Harwood, “Operational Energy/Operational Effectiveness Investigation For Scalable Marine Expeditionary Brigade Forces In Contingency Response Scenarios”, Master’s Degree in Systems Engineering Capstone Project, Naval Postgraduate School, December 2014

Khoa Pham, “An Investigation of the Benefit of Applying the Dual-Vee Systems Engineering Model to a Software Product Line”, MS Systems Engineering, December 2014

(iii) second reader

Since tenure I was second reader for the following matriculated students:

Theresa L. Thomas, ”Requirement Verification And Systems Engineering Technical Review (Setr) On A Commercial Derivative Aircraft (Cda) Program”, MS Systems Engineering Management, September 2017

Terwilliger, Katherine, ”Investigating Outfitting Density as a Cost Driver in Submarine Construction Costs”, MS Systems Engineering Management, October, 2015

Previously I was second reader for the following students and teams:

Steven A. Newton, “A Construct for Governing and Evaluating Platform Cyber Infrastructure at the Enterprise Level”, MS Systems Engineering Management, September 2014

Jacob M. Hempen, Examination of On-orbit Solar Array Data to Determine GPS Satellite Reliability and Lifetime, MS Systems Engineering Management, September 2014

Linda Banner-Bacin, Tim Carpenter, David Chacon, James Chandler, James Childs,Tuyen Hoang, Robert Howard, James Isaian, Seung Kang, Michael Kinberg, James Kong, Jeremy Manz, Ruth Matela, Jonathan Mendiola, John O’Neil, Leonard Oriz, Tan Pham, Jamal Rayshouny, Eric Sarabia, Kihoon Sung, Heng Sysavath, Caleb Vajdos, Armando Valdez, Armando Vasquez, Alan Wellesley, Mindy Wentland, “Application of Model Based Systems Engineering Methods to Development of Combat System Architectures”, MS in Systems Engineering Capstone Project, Naval Postgraduate School, March 2009

(iv) Ph.D. dissertation committee member [1]

Since tenure the new Ph.D. committees I'm serving on include:

John Quartuccio, "Identification of Behavior Patterns in Systems of Systems Architecture", Ph.D. Systems Engineering, expected graduation June 2018

Curtis Adams, "Agent and object oriented model based concept design for mobile cyber physical systems", Ph.D. Systems Engineering, expected graduation December 2017

Additionally, my support and collaboration was integral for Monica Farah-Stapleton who completed her CS Ph.D. in 2016 was essential and we are continuing to present and publish [92] [92].

Monica F. Farah-Stapleton, "Executable Behavioral Modeling Of System And Software Architecture Specifications To Inform Resourcing Decisions", Ph.D. Software Engineering, September 2016

I'm continuing on the following Ph.D. committees started before tenure:

Rollie Wicks, "User Centric Cloud", Ph.D. Software Engineering, expected graduation 2018 (as co-advisor per section II.1.d.ii)

Donna Dulo, "A Knowledge-Based Framework for the Development of Safe and Resilient Aircraft Software", Ph.D. Software Engineering, expected graduation March 2018

e. Self-improvement efforts

I attended the course Foundations of Teaching and Learning (FTL) in 2012. My continuous self-directed learning of new software technology provides a more informed perspective for DoD systems; and creating better cost modeling and simulation tools.

f. Reading courses taught

g. Instructional materials

Since tenure several major improvements were made to materials for SE3011 and SE4003. The cost modeling tools were updated with new features including the capability to save/modify estimates in the cloud. My *Systems Engineering Cost Estimation Workbook* was also updated and refined for additional problems and model details.

I revamped SE4003 in 2016 with substantial new assignments and material to meet Command needs for software-intensive systems. Software development and related exercises were introduced so that students obtain a more informed perspective. These major revisions included a reference military application of battle simulation. The new material complements the traditional high-level overview of software engineering methods and issues. With this broader exposure students better understand implementation details with practical hands-on experience, and can become more effective systems engineers all-around. Other SE4003 instructors have subsequently incorporated the changes in their classes.

The COCOMO Suite web-based tool improves accessibility and usability of parametric cost models. It reduces the effort for estimation, ensures correct and repeatable estimates with known models, and allows for increased sophistication of analyses and student problems. Parametric models can be selected in different combinations by the user and it includes Monte Carlo simulation. The System Cost Model Suite is the new and upgraded program that covers a broader swath of engineering disciplines, lifecycle phases and associated parametric models for TOC with an improved user interface.

In 2017 for SE3011, I added the capability for file saving in the cloud to the System Cost Model Suite. It also allows for updating of previous estimates. Previously it functioned as a calculator providing one-off estimates. Now the cost estimates can be developed, saved, and shared online with no other installations or accounts required.

Earlier considerable effort went into updating, reformatting and improving the SE3011 course material for cost estimation of software-intensive systems to better reflect most DoD projects. Initially I procured a number of professional estimation tools for SE3011 educational use by working with vendors and introduced these into the classroom. It was found that the provided vendor tools were overly cumbersome for the students, given their computer platforms and Navy network constraints. Thus I went further on improving the *COCOMO Suite Tool*

[1] This subsection was added to the standard NPS outline.

and more recently the System Cost Model Suite so that students could use them instead for all of their assignments. Submission of assignments with their work was streamlined via URLs of the data files.

In 2011-2013, SE3011 instruction materials were incrementally updated for TOC integrated estimates covering multiple disciplines. I supplemented the SE3011 course for new systems, software and hardware cost models incorporating maintenance. I further elaborated hardware cost modeling in course teaching and tools, with examples for specific DoD domains. Monte Carlo analysis was expanded into additional cost factors.

My *Systems Engineering Cost Estimation Workbook* for SE3011 and other cost estimation courses was continuously improved along these lines. By updating the curriculum material, replacing the prior textbook with my own workbook, and improving the course delivery my SOFs increased dramatically. Students have concurred the more comprehensive TOC view was relevant for their programs. Materials for the software cost estimation portion of the Master of Cost Estimating and Analysis (MCEA) were also completed as an inter-school effort with the Graduate School of Operational and Information Sciences (GSOIS). Improvements in the *COCOMO Suite* toolset also support the classes and new MCEA degree. New instructional materials are also discussed in Sections II.2.a.-c.

h. Mentoring

N/A

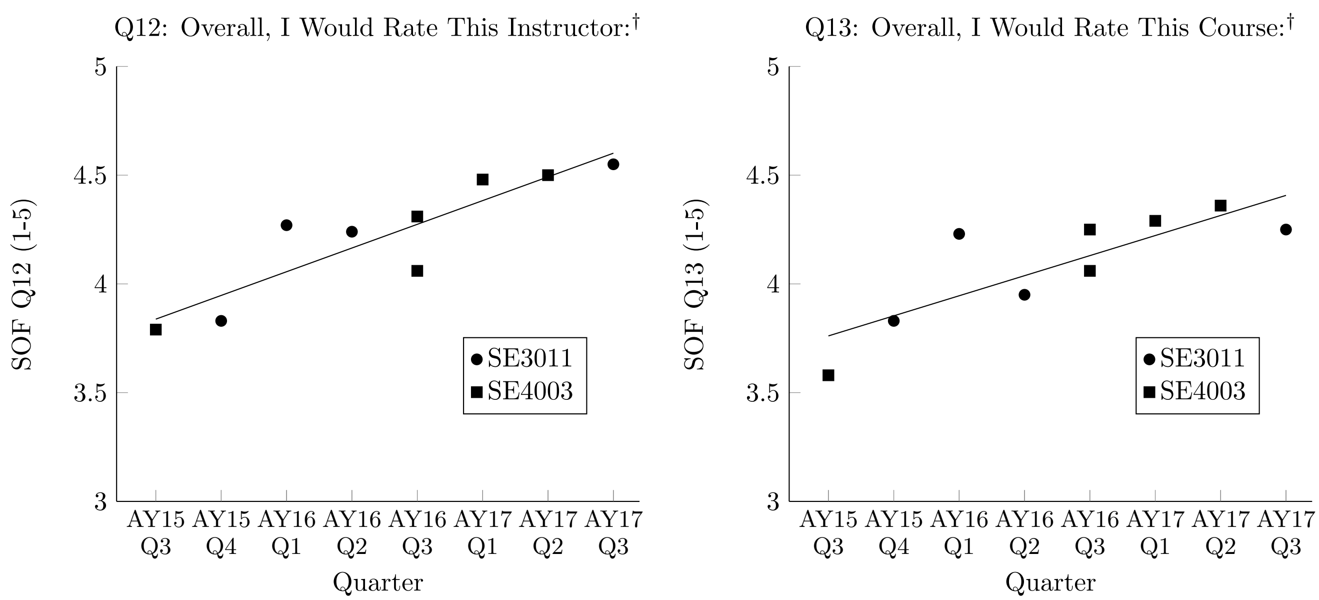
i. Course coordination

I started as Course Coordinator for SE3011 in AY2017. This includes continual monitoring of course deliveries, review and approval of course journals, course improvements, approvals of student course credit requests (ensuring same topics were adequately covered), and supporting future ABET accreditation.

I have been the SE4003 course coordinator since 2009. This activity includes the same activities as above, and I also supported the successful ABET preparation and assessment process.

j. Other instruction information

Figure 2 shows my post-tenure SOFs for the two courses I've taught with best fit trend lines for Q12 and Q13 summary questions. The trends indicate nearly a single point of improvement for both questions on the 1-5 scale. Since tenure I have taught SE4003 and SE3011, and made major changes in both that are reflected in Table 2. See details in Section II.1.j.



† 5 - Outstanding (top 10%)	3 - Average (middle 40%)	1 - Poor (lowest 10%)
4 - Excellent (top 30%)	2 - Fair (lowest 30%)	0 - Not Applicable

Figure 2: Post-Tenure Student Opinion Form Trends

k. Other information on evaluation of instruction

Numerous follow-up emails from past students indicate they are using cost estimation methods and tools from my classes on DoD projects.

2. Internal Research Activities

a. Summary of internal research projects

I did not participate in the NPS Research Initiation Program (RIP) because I had my own external funding.

b. Thesis Contributions

Before and after tenure, my support and collaboration with Monica Farah-Stapleton who matriculated with her Software Engineering Ph.D. was essential in demonstrating that software size measures could be measured from Monterey Phoenix architectural behavior model entities [92] [87]. This was the another major aspect of integrating MBSE approaches to support automatic cost estimation for tradespace analysis.

Dennis Edwards' M.S. thesis was coordinated and supported with my MBSE research integrating parametric cost modeling with SysML. His thesis showed the first demonstration of the method for automatically capturing system size from SysML models [86] [83].

In Nam Tran's M.S. thesis, he used a direct application of my cost model and COSYSMO tool for his central quantitative assessment of Information Assurance processes and impacts to program costs.

c. Contributions to interdisciplinary NPS research projects

My contributions to the interdisciplinary research projects (and Ph.D. dissertations) between the Systems Engineering and Computer Science departments has been with system behavioral modeling using Monterey Phoenix. I function as a domain expert in systems and software sizing and cost modeling. E.g., my thesis contributions in this research are described in Section 2.b [92] [87]. I have also supported system sizing and cost modeling aspects [86] [83], and we are continuing this research on SQOTA.

d. Visiting researchers attracted

N/A

e. Other contributions

3. Internal Administrative and Service Activities

A timeline of post-tenure major internal administrative and service activities is in Figure 3. Supporting details in the sub-sections below are roughly sized by the relative efforts involved.

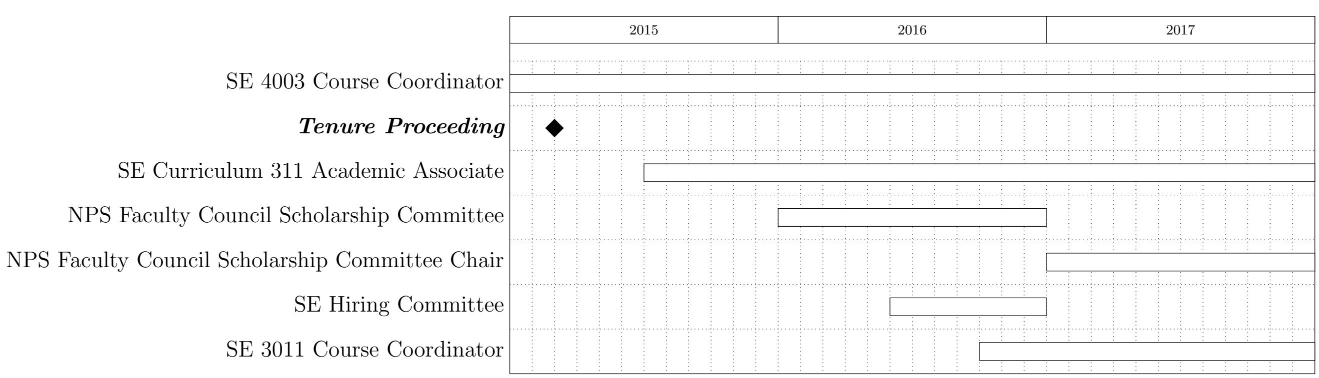


Figure 3: Internal Administrative and Service Activities Timeline

a. Committee Service

Faculty Council Scholarship Committee Member and Chair, 2016 - Present
The Faculty Council Scholarship Committee is responsible for all matters of scholarship as they apply to the faculty and student body. This includes teaching load, curriculum development, requirements for the awarding of degrees, etc. Since I began serving on the Committee, it completed a major report on SOF process recommendations. The Faculty Council is in the process of adopting the recommendations school-wide. In 2017 I am serving as the Scholarship Committee Chair.

Committee Member, Systems Engineering Dept. Hiring Committee, March 2016 - December 2016
The committee screened, interviewed and recommended new SE hires.

Member of the Software Engineering (SWE) Ph.D. committee, 2009 - Present
I present at student seminars, mentor students, assess their progress, and help maintain the integrity of the program.

b. Service as Academic Associate

I started as Academic Associate for the SE (DL) Curriculum 311 in July 2015. I review student records, support the selection process, maintain program integrity, assess and approve ABET equivalencies, address student concerns, approve capstones and theses, and support graduation award selections. I regularly present at cohort introductory sessions to overview the program and explain the role of Academic Associate. I have helped improve communications and processes with the NPS Admissions office by clarifying degree requirements and acceptance of previous credits in Engineering and Science. Previously it was ill-defined with Admissions about what constituted valid classes in the areas.

Curriculum 311 has the largest enrollment of all NPS degree curricula, and is by far the largest curriculum in the Systems Engineering Dept. During my tenure, 258 Curriculum 311 students have graduated from September 2015 to June 2017 (not including September 2017 students). Currently there are 242 students enrolled in 15 cohorts.

III. EXTERNAL ACTIVITIES

1. External Teaching Activities

a. Courses

My MCEA software cost estimation lectures are conducted jointly with AFIT students. I have presented several invited guest lectures for Software Engineering and Management, and Software Cost Estimation at USC.

b. Course materials

The COCOMO Suite tool is in wide external use at many universities, though the exact number is indeterminate. See a partial representative list in section 3.c. totaling 28 known universities. It's used for both a required tool for homework in academic curricula; and a teaching aid to demonstrate cost modeling and project management concepts.

My book *Software Process Dynamics* has been a required textbook and used in graduate courses at many universities, primarily for Software Engineering and Software Project Management courses. It has also been used in modeling and simulation courses and recently for software data mining. Known universities are in many of the U.S. states, Canada, South America, Europe and Asia. It has served as an integral reference for dozens of known M.S. theses and Ph.D. dissertations. Many students have used my book models as their basis, including the Ph.D. research. They have produced some excellent new and extended models, and some will be featured in the next edition of *Software Process Dynamics*.

Our new book *What Every Engineer Should Know About Modeling and Simulation* [2] is suitable for undergraduates and a supplement for graduate classes. At this time we are developing additional materials with the book for new external courses.

The SEBoK has already become a widely used reference in systems engineering curricula and research.

c. Other significant products

d. Short course initiation, coordination and participation

e. Distance Learning course initiation, coordination and participation

In 2009 I supported initial SPAWAR distance learning classes. I also helped plan their classroom construction in San Diego which has been used since.

2. External Research Activities

a. Summary of externally funded research projects

I am currently PI on the first three research projects listed next, and was PI on the other completed projects below.

DoD AGILE SOFTWARE DEVELOPMENT EARLY PHASE COST MODELING, Naval Research Program (NRP), $55,000 FY18

This research addresses needed improvements in cost estimation metrics, models and methods for agile software development projects to reflect emerging trends in the Navy and across DoD. Software effort estimates are necessary and critical at an early phase for decision makers to establish initial budgets, and in a government context to select the most competitive bidder for a contract. The challenges are that estimated software requirements is the only size information available at this stage, compounded with the newly increasing adoption of agile processes in the DoD. This study will improve cost estimation by investigating available sizing measures, and providing practical effort estimation models for agile projects during the contract bidding phase or earlier. The analysis will explore the effects of independent variables for product size, peak staff, domain and other measures on effort. The empirical data for model calibration is from industrial projects recently completed for the DoD, among a larger dataset of recent projects using other lifecycle processes.

Publications:

W. Rosa, R. Madachy, C. Wallshein, B. Clark, and B. Boehm, Early phase cost models for agile software processes in the US DoD, In *Proceedings of the 2017 ACM / IEEE International Symposium on Empirical Software Engineering and Measurement*, Toronto, Canada, November 2017. Accepted.

ILITIES TRADESPACE AND AFFORDABILITY PROGRAM, Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD(SE)), $40,000 FY13 (Phase 1); $30,000 FY13-FY14 (Phase 2); $30,000 FY14-FY15 ((Phase 3 Task 2); $30,000 FY14-FY15 ((Phase 3 Task 3)
SYSTEM QUALITIES ONTOLOGY, TRADESPACE AND AFFORDABILITY PROGRAM, $30,000 FY15-FY16 ((Phase 4 Task 2); $30,000 FY15-FY16 ((Phase 4 Task 3) $38,400 FY16-FY17 (Phase 5) $38,400 FY17-FY18 (Phase 6) (8 awards, total $276,400)

This ongoing PI research is for the System Qualities Ontology, Tradespace and Affordability Program (SQOTA) Program (earlier called the Ilities Tradespace and Affordability Program (ITAP)) for multiple Research Topics with the DoD Systems Engineering Research Center (SERC).

Affordability is of paramount importance in the system tradespace. DoD organizations generally separate systems engineering technical analyses from financial-community cost analyses, often leading to technical specifications with unnecessarily expensive or simply unaffordable costs. The goal of Total Ownership Cost (TOC) modeling is to enable affordability tradeoffs with integrated software-hardware-human factors. Decisions made early in the system development cycle determine a majority of the total lifecycle costs as well as establish a baseline for long term system performance and thus it is vital to program success to choose favorable design alternatives.

This research is combining cost modeling with architecture based behavior and performance analysis for improved tool integration. It is developing translation rules and constructs between MBSE methods, performance analysis and cost model inputs. Demonstrations of tool interoperability and tailorability for DoD domains are provided for piloting feedback.

As the PI at NPS, in Phase 1 I helped define DoD ility tradespace priorities and critical T&A analysis success factors for Naval domains. I also created initial demonstration capabilities for ITAP analysis toolsets and explored piloting by user organizations. One framework was to assess a product line approach for providing multiple benefits with respect to ilities.

The Constructive Product Line Investment Model (COPLIMO) from my prior research was extended at the systems level, to assess flexibility and ROI tradeoffs associated with developing and reusing product line assets across families of similar applications. The parametric approaches determine the TOC for various levels of investment in product line architecting. A service-based tool demonstration for software cost/quality modeling was also developed for tradespace tool integration.

My phase 2 activities improved and piloted the analysis toolsets of Phase 1. The transitioning focus was for applications in the Ships and Aircraft domains, and making provisions for Space Systems in Phase 3. I supported outreach efforts to demonstrate ITAP capabilities to potential early-adopter organizations. The tools were tailored for software product line cost modeling, and total ownership cost for integrated engineering activities. The early adopters represented NAVAIR and NAVSEA. NAVSEA proceeded with avionics software product line modeling collaboration.

A previous shortfall of the TOC toolset was lacking the capability to estimate operations and maintenance. I added parametric maintenance models into the system cost model suite for systems engineering, software engineering, hardware development and production. Cost uncertainty modeling was also extended via improvements in Monte Carlo analysis. Additional size inputs were made available for probabilistic distributions, as well as a wider array of distribution types. Other improvements were identified for going forward in Phase 3.

Phase 3 continued elaboration of the system cost model suite for improved domain-specific cost models (e.g. ships, satellites) vs. general parametric cost models. It included the research and development of an initial version of a full-coverage, cyber-physical-human, flight-ground-launch, full-lifecycle Constructive Satellite-System Cost Model (COSATMO).

We started assessing SysML for extracting cost attributes and Monterey Phoenix (MP) [5] [6] for automatically providing cost information from the architectural models. MP can be used to extract software sizing information. It generates function point measures which are inputs into COCOMO. We also assessed how MP architectural elements can be mapped into systems engineering cost model inputs.

A new effort in Phase 4 built on prior work associated with early concept evaluation and cost estimation at AFIT and NPS. It explored the use of executable architectures associated with Model Based Systems Engineering tools to guide design decisions in the early stages of system development by assessing architectural variations. It also aimed to use the architectural definition to support modeling inputs for improved and simultaneous cost estimation.

The approach was to develop operational and system architectures to capture sets of military scenarios. These architectures were transitioned to the MBSE environments to design and demonstrate the UAV ISR tradespace. The architectures also supported parametric software and system cost estimating approaches. Cost model interfaces were developed for components of the architectures in order to evaluate cost effectiveness in an uncertain future environment.

In order to demonstrate the initial value in the application of executable architectures for trade space decisions and cost estimation, three variants of a fictional unmanned aerial system were developed and simulated. Measures of effectiveness (MOEs) were selected for evaluation, and parameters of interest were varied during simulation to create four test case scenarios against which to evaluate each variant. Analysis of the resulting simulation demonstrated the ability to obtain a statistically significant difference in MOE performance. This effort also prototyped methods for parsing CONOPS scenarios and Use Cases associated with the architecture to provide inputs for the COCOMO and COSYSMO cost estimation models.

NPS continued extending the scope and tradespace interoperability of cost models and tools in Phase 4. Some of these improvements were based on piloting feedback in earlier phases for parametric model enhancements and tool automation improvements. As core researchers on the COCOMO III and COSYSMO 3.0 cost models, we engaged domain experts for Delphi estimates, evolved baseline detailed definitions of the cost driver parameters and rating scales for use in data collection, and gathered initial data.we research teams and co-lead workshops.

For tool interoperability we integrated cost models in new ways with MBSE architectural modeling approaches and as web services. We furthered the service-based cost model tools for additional factors, and successfully demonstrated an MP integration with costing. NPS also provided domain expertise to USC and Georgia Tech for the SysML cost model integration effort. We provided reference documentation to Georgia Tech for systems engineering cost modeling with automated risk assessment capabilities for SysML integration.

In Phase 5, NPS and AFIT continued developing and demonstrating methods for integrating MBSE approaches for early architectural definition, effectiveness analysis, and cost estimation. Our shared case studies and models are for ISR missions of increasing complexity with multi-tiered collections of heterogeneous UAS. AFIT has been defining architectures using SysML compliant modeling packages, with the intent being direct simulation and evaluation of the underlying concepts, and the population of early cost estimation tools to provide useful relative cost estimates associated with possible variations of the architecture. NPS demonstrated the viability of using the SysML model for direct inputs to cost models.

An example case study in 2016 demonstrated proof of principle for the method. The application was a basic multi-vehicle architecture using Small UAS to locate, confirm, track and engage widely dispersed targets. Architectural variations included numbers of vehicles, quality (performance measures) of the sensors, and C2 variations that considered operator-in-the-loop versus full autonomous operation. While the architectures for this initial example were relatively simple, the effectiveness analysis revealed significant differences in overall performance, and cost variations could be analyzed together.

Next we developed a more complex architecture based on Small UAS providing remote targeting support for larger, standoff vehicles. Architectural views included requirements diagrams, functional decomposition (hierarchical), activity diagrams, block definition diagrams, and interface definition both across system elements and at the subsystem level within a system element. This level of definition included operational threads, requirements, and interfaces at the appropriate decomposition level as direct input to parametric cost models. The thorough and detailed SysML model comprising size inputs enables a COSYSMO cost estimate and extrapolated full lifecycle cost, amenable to later architectural variations.

Phase 6 is continuing the collaboration with AFIT for system architecture modeling and cost estimation of ISR mission variations involving heterogeneous teams of autonomous and cooperative Unmanned Aerial Systems. NPS will provide cost modeling expertise, modeling tools, and analysis support. A focus is on translations between MBSE models and tools, specifically mapping architectural elements into cost model inputs to support tradespace analysis via automated costing.

A Remote Targeting System UAS is our current study with full SysML models enabling automated cost analysis based on the architecture. We will continue refining the guidance and consistency rules to support the SysML and COSYSMO integration for MBSE practitioners. This revolves around proper modeling of COSYSMO-equivalent levels of decomposition in the SysML constructs.

Publications:

R. Madachy, D. Jacques, K. Giammarco, and D. Edwards. Model-based systems engineering tradespace analysis with sysml and cosysmo. In *Proceedings of the 32nd International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2017. Accepted.

R. Madachy, K. Giammarco, D. Jacques, and D. Edwards. System cost modeling and sysml integration. In *Proceedings of the 31st International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2016.

M. Farah-Stapleton, R. Madachy, M. Auguston, and K. Giammarco. Executable architecture modeling. In *Proceedings of the 31st International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2016.

R. Madachy. Software maintainability metrics workshop. In *Proceedings of the 2016 International Software Engineering Research Network Meeting*, La Ciudad, Spain, September 2016.

B. Clark and Madachy R. COCOMO III workshop. In *Proceedings of the 30th International Forum on COCOMO and Systems/Software Cost Modeling*, Washington, DC, November 2015.

M. Farah-Stapleton, R. Madachy, M. Auguston, and K. Giammarco. Resource analysis based on system architecture behavior. In *Proceedings of the 30th International Forum on COCOMO and Systems/Software Cost Modeling*, Washington, DC, November 2015.

System Qualities Ontology, Tradespace and Affordability (SQOTA) Project - Phase 5. Technical Report SERC-2017-TR-105, Systems Engineering Research Center, April 2017.

System Qualities Ontology, Tradespace and Affordability (SQOTA) Project – Phase 4. Technical Report SERC-2016-TR-101, Systems Engineering Research Center, February 2016.

Tradespace and Affordability – Phase 2 A013 - Final Technical Report. Technical Report SERC-2013-TR-039-2, Systems Engineering Research Center, December 2013.

Tradespace and Affordability – Phase 1 A013 - Final Technical Report. Technical Report SERC-2013-TR-039-1, Systems Engineering Research Center, July 2013.

INTEGRATED CAUSAL MODEL FOR SOFTWARE COST PREDICTION & CONTROL (SCOPE), Software Engineering Institute, $300,000 at $100,000 per year for NPS portion, FY18-FY20

The DoD needs to better model the sources for risks of technology, cost, and schedule for both new development and sustainment/modernization of major weapons systems. This is even more imperative in the current political environment in which significant stepwise, paradigm-shifting improvements are sought in DoD program performance. The DoD acquisition community needs a firm understanding of the primary causal factors of risk as they negotiate and evaluate defense contractor bids and monitor contract performance and incentives to help ensure program success.

Leveraging initial causal models of software cost, a broadly-integrated causal model of the effects of technology, cost, and schedule risk (and their interactions) on program success will be developed. The project will gain access to data from NPS research activities and capitalize on the Software Engineering Institute (SEI) advantage of applying causal learning to research data.

Expanding on previous work populating a universal causal model of the sources of DoD program costs, we can obtain significant schedule and technology risk data from DoD sources. We will then discover, propose, and incrementally verify and validate an integrated model of cost, schedule, and technology risk. Such a comprehensive model (in the form of a Directed, Acyclic Graph) will produce heuristics that would be used by the acquisition community to inform systems engineering, price negotiations, and preventive/mitigative oversight actions for active programs. The universal causal model from this project can be strong and sufficiently robust to weigh in on DoD policy development and legal aspects surrounding DoD contractor program performance.

This joint project is approved for funding with the SEI, University of Southern California and University of Arizona. The internal approval for this awarded research project is still in-process.

SOFTWARE COST ESTIMATION METRICS, U. S. Air Force Cost Analysis Agency, $75,000 FY09-FY10; $65,000 FY10-FY11; $25,000 FY11; $15,000 FY11-FY12 (4 awards, total $180,000)

I was PI for this ongoing research that met its objective to establish a robust and cost effective software metrics collection process and knowledge base that supports the legitimate data needs of the DoD, while imposing minimal burdens on the Acquisition Workforce, and its industry partners. Further objectives met were to enhance the utility of the collected data to oversight and management entities, and to academic and commercial research into improved cost estimation of future DoD software-intensive systems, as well as to the DoD cost community.

We used data submitted to DoD in the Software Resources Data Report (SRDR) forms to provide guidance in estimating software costs for future DoD projects. In analyzing the data, we found variances in productivity data that made such SRDR-based estimates highly variable. We performed additional analyses that provided better bases of estimate, but also identified ambiguities in the SRDR data definitions that enabled us to help the DoD DCARC organization develop better SRDR data definitions.

I developed the consistent metrics definitions used in the research and subsequently implemented in DoD contractual reporting criteria, serving as a cornerstone for current and future data analysis. This has directly impacted the DoD data collection process. These improvements have strengthened the SRDR reporting. They has been reflected in improved, more consistent and complete data in the Defense Automated Cost Information System (DACIMS).

After the change incorporation by DCARC, this continuing research furthered prior empirical data analysis with specific advancements in DoD domain analysis. A wiki representation of the material was created; and workshops were conducted to coordinate the SRDR database analysis. SRDR data was further analyzed for influences on activity distribution variations by domain, size, and requirements volatility. We integrated the costing benchmarks with MIL-STD-881B WBS categories.

The results have been used for documenting metrics guidance for practitioners in a manual. The Software Cost Estimation Metrics Manual for Defense Systems has now been thorough external peer reviews during and after this research.

Publications:

B. Clark and R. Madachy (Eds.), *Software Cost Estimation Metrics Manual for Defense Systems*, Software Metrics Inc., Haymarket, VA, 2015.

W. Rosa, R. Madachy, B. Boehm and B. Clark, "Simple Empirical Software Effort Estimation Model", Proceedings of 2014 Empirical Software Engineering and Measurement International Symposium, IEEE, September, 2014

W. Rosa, R. Madachy, B. Boehm, B. Clark, C. Jones, J. McGarry and J. Dean, "Improved Method for Predicting Software Effort and Schedule", Proceedings of the 2014 International Cost Estimating and Analysis Association (ICCEA) Conference, 2014

(Best Paper Award)

R. Madachy, B. Boehm, B. Clark, T. Tan, W. Rosa, “US DoD Application Domain Empirical Software Cost Analysis”, Proceedings of 2011 Empirical Software Engineering and Measurement International Symposium, IEEE, September, 2011

W. Rosa, B. Boehm, B. Clark, R. Madachy, J. Dean, “Domain-Driven Software Cost and Schedule Estimation Models: Using Software Resource Data Reports”, Proceedings of the 2013 International Cost Estimating and Analysis Association (ICCEA) Conference, 2013

B. Boehm, J. Lane, T. Tan, M. Moazeni, R. Madachy, W. Rosa, “Software Intensive Systems Cost and Schedule Estimation”, Final Technical Report SERC-2013-TR-032-2, Systems Engineering Research Center, June 2013

W. Rosa, B. Boehm, B. Clark, T. Tan, and R. Madachy, “Domain-Driven Software Cost Estimation: Space, Air, Ship, and Ground Systems”, Proceedings of the 2012 SCEA/ISPA Joint Annual Conference and Training Workshop, 2012

B. Clark, R. Madachy, B. Boehm, and W. Rosa, “Software Cost Estimation Metrics Manual Online“, Proceedings of the 28th International Forum on Software Cost Modeling, Los Angeles, CA, 2013

B. Clark, R. Madachy, “DoD Software Resource Data Reports (SRDRs) and Cost Data Analysis Workshop”, Proceedings of the 27th International Forum on COCOMO and Systems/Software Cost Modeling, Pittsburgh, PA, 2012

W. Rosa, B. Boehm, B. Clark, T. Tan, and R. Madachy, “Domain-Driven Software Cost Estimation”, Proceedings of the 27th International Forum on COCOMO and Systems/Software Cost Modeling, Pittsburgh, PA, 2012

R. Madachy, B. Boehm, B. Clark, T. Tan, W. Rosa, “Software Cost Estimation Metrics Manual”, Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2011

B. Clark and R. Madachy, “Air Force Estimation Guidebook Workshop”, Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2011

B. Boehm, B. Clark, R. Madachy, W. Rosa, T. Tan, “Estimation Challenges for 21st Century Software Systems”, Proceedings of the 2011 ISPA/SCEA Conference, June 2011

B. Clark and R. Madachy, ”Building Cost Estimating Relationships for Acquisition Decision Support”, 14th Annual Practical Software and Systems Measurement (PSM) User’s Group Conference, 2010

B. Boehm, R. Madachy, B. Clark and W. Rosa, “Future Ground System Software Estimation and Metrics”, Ground System Architectures Workshop (GSAW), 2010

B. Clark and R. Madachy, “SRDR Data Analysis Research Workshop”, Proceedings of the 25th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2010

R. Madachy, B. Boehm, B. Clark, D. Reifer and W. Rosa, “A Sizing Framework for DoD Software Cost Analysis”, Proceedings of the 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, MA, 2009

W. Rosa, B. Clark, R. Madachy, D. Reifer and B. Boehm, “Software Cost Metrics Manual, Proceedings of the 42nd Department of Defense Cost Analysis Symposium, Williamsburg, VA, 2009

PMS-485 SYSTEMS AND SOFTWARE SUPPORT, SPAWAR, $12,000, FY12 PI: Raymond Madachy

I was PI for this research supporting systems and software cost estimation in Maritime Surveillance Systems (PMS 485). The goal was to improve the Integrated Common Processor (ICP) cost estimation process and related process areas. Specific objectives include improving the predictability of systems and software cost estimates, providing tool advice and best practices for cost estimation and reduction of software development cost, shoring up governance procedures for measurement visibility in support of cost estimation, identifying related programmatic risks and initializing plans for risk reduction by the PEO.

I employed a variety of models and metrics to 1) assess the generic cost estimation process and 2) support detailed cost estimates of individual ICP builds. A new data collection form was created. We collected build data and performed estimation model calibration for the COSYSMO and COCOMO parametric cost models. Issues in the data collection, such as sizing inconsistencies, were flagged and followed up with the prime contractor. Finally a set of recommendations was given for continued improvements.

Publications:

R. Madachy, "PMS 485 Integrated Common Processor Systems and Software Cost Estimation Support", 2010

SYSTEMS OF SYSTEMS COST ESTIMATION SUPPORT TO SPAWAR, SPAWAR 5.1.1, $29,750, FY11

Traditional cost estimating procedures do not account for system of system enterprise efforts needed for Naval Power 21. SPAWAR 5.1.1 needs to learn more about newer techniques which can be used to estimate enterprise labor costs.

As PI, my work was acquiring data and supporting pilot projects for SoS. New models to estimate SoS enterprise labor costs were provided. An SoS data collection form was produced for this. Also an SoS model for systems-of-systems engineering cost estimation was prototyped for multiple module estimation. Example pilot SoS cost analyses were generated using the new proposed cost model.

LITTORAL WARFARE ENGINEERING FACILITY BUSINESS CASE ANALYSIS, Naval Surface Warfare Center, Port Hueneme Division, $32,500 FY13-FY14

My research as PI supported the Littoral Warfare Engineering Facility (LWEF) Business Case Analysis (BCA). NSWC PHD is evaluating a joint land-based test capability for the Littoral Combat Ship (LCS), Coast Guard National Security Cutter (NSC), and Directed Energy (DE) High Energy Laser (HEL) programs that would constitute a test capability focused on Littoral Warfare Engineering.

I developed the BCA analysis framework and performed cost, sensitivity and risk analyses for different LWEF alternatives. Group meetings and extensive data collection was necessary to quantify costs/savings of ten separate operations and support the following use cases as-is vs. to-be across the options. 1. Enhance Distance Support 2. Validate Technical Documentation 3. Support Interoperability Exercises 4. Contribute to the System of System Integration of Future Builds 5. Augment Fleet Training 6. Perform Test & Evaluation 7. Conduct Engineering Investigations 8. Provide Design Feedback 9. Retain Operational Battle Spares 10. Software Support

The LWEF BCA has been instrumental at NAVSEA for decision-making and planning. It has been presented to all levels including Admirals across the Navy, Coast Guard, and HEL program for joint operations.

Publications:

Business Case Analysis: Littoral Warfare Engineering Facility (LWEF), Version 1.0, NSWC PHD, L Department, Code L01, 2013

FUTURE AIRBORNE CAPABILITY ENVIRONMENT (FACE) BUSINESS MODEL DEVELOPMENT, NAVAIR, $104,000 FY14-FY15

My PI research is performing cost and ROI modeling of avionics software product line development for NAVAIR for the Future Airborne Capability Environment (FACE) Business Model Development. This will validate costing efforts across different airborne platforms, validate and refine effort drivers for a FACE model, modify current NAVAIR costing models to align with our NPS software cost models, and provide inputs to the FACE government team. A survey for the FACE Consortium partners is being developed for model data collection.

I was Co-PI on the following research projects.

AGILE-LEAN SOFTWARE ENGINEERING (ALSE): EVALUATING KANBAN IN SYSTEMS ENGINEERING (SERC RT35), National Security Agency, $120,000 FY12, Co-PI at $40,000 FY12

This research was to evaluate Kanban scheduling techniques in systems engineering. The research focused on systems engineering where rapid response software development projects incrementally evolve capabilities of existing systems and/or systems of systems.

As Co-PI I performed modeling and simulation of systems engineering processes with Kanban methods injected. This was to enable determination if systems engineering functions are accomplished more effectively and efficiently, whether the overall value of the systems of systems over time is increased, and whether other expected results are fulfilled.

Phase I considered applications of alternative scheduling methods and suggested possible outcomes of on-demand scheduling coupled with a service-oriented approach to systems engineering. It defined a conceptual model and developed initial simulations to capture the model and better understand the impact.

Phase II focused on applying the method to multi-level service-based SE in complex Systems of Systems (SoS). Using the models and simulations from Phase I, a prototype network of kanban-based scheduling systems (KSS) for a target environment SoS was defined. The KSS network was partially simulated to demonstrate its general behavior. The prototype will be used further in comparing performance with traditional systems engineering methods.

Publications:

R. Turner, R. Madachy, D. Ingold, and J. Lane, "Modeling Kanban Processes in Systems Engineering," Proceedings of the 2012 International Conference on Software and System Process, Zurich, Switzerland, IEEE, 2012

R. Turner, R. Madachy, D. Ingold, and J. Lane, "Improving Systems Engineering Effectiveness in Rapid Response Development Environments," Proceedings of the 2012 International Conference on Software and System Process, Zurich, Switzerland, IEEE, 2012

R. Turner, J. Lane, D. Ingold, R. Madachy, "A Lean Approach to Improving SE Visibility in Large Operational Systems Evolution", Proceeding of the 23rd Annual INCOSE International Symposium, 2013

R. Turner, D. Ingold, J. Lane , R. Madachy, D. Anderson, "An Event-driven, Value-based, Pull Systems Engineering Scheduling Approach", Proceedings of the IEEE Systems Conference, Vancouver, March 2012

R. Turner, D. Ingold, J. Lane, R. Madachy and D. Anderson, "Effectiveness of Kanban Approaches in Systems Engineering Within Rapid Response Environments", Proceedings of the 10th Annual Conference on Systems Engineering Research, March 2012

R. Turner, R. Madachy, "Improving Systems Engineering Effectiveness Using Kanban-based Scheduling and a Service-oriented Approach", Proceedings of IEEE SysCon, March 2012

R. Turner, R. Madachy, J. Lane, D. Ingold and L. Levine, "Agile-Lean Software Engineering (ALSE) Evaluating Kanban in Systems Engineering", A013 - Final Technical Report SERC-2013-TR-022-2, 2013

VALUING FLEXIBILITY (SERC RT18), Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD), $100,000 (2010-2011) (Co-PI at $11K FY11)

A significant challenge in systems engineering and acquisition is to justify investments in system flexibility. We evaluated Naval program data including SHIPMAIN and developed models for valuing flexibility.

As Co-PI, I developed models and tools for 1) systems-level DoD product line Total Ownership Cost (TOC) and 2) detailed software product line TOC. These models for valuing flexibility can be calibrated to project data.

Publications:

B. Boehm, J. Lane and R. Madachy, "Total Ownership Cost Models for Valuing System Flexibility", 2011 Conference on Systems Engineering Research, Los Angeles, CA, April 2011

B. Boehm, J. Lane, R. Madachy, Valuing System Flexibility via Total Ownership Cost Analysis, 13th Annual NDIA Systems Engineering Conference, 2010

SERC RT18 - Valuing Flexibility Phase II, A013 – Final Technical Report SERC-2012-TR-10-2, 2012

SPAWAR PMS 485 SUPPORT, SPAWAR, $27,000 FY 11

This research as Co-PI supported systems/software cost estimation and risk management for the PMS 485 towed array product line. I began collecting measurements, conducted initial cost analyses and identified tasks for further improvements in cost estimation. Became PI for FY12 follow-on.

b. Products distributed outside NPS

Publications since tenure are those dated April 2015-2018 in the subsections below. These include two books: [1] in May 2018 and [2]; one book chapter forthcoming [7]; five conference papers: [36] [37] [38] [39] [40]; two invited conference presentations: [85] [89], nine other workshop or conference presentations [83] [84] [86] [87] [88] [90] [91] [92] [93]; three other technical presentations [168] [160] [169]; and four newsletter articles [212] [213] [214] [215].

(i) Books

[1] R. Madachy. *Systems Engineering Principles for Software Engineers.* CRC Press, Boca Raton, FL, 2018.

[2] R. Madachy and D. Houston. *What Every Engineer Should Know About Modeling and Simulation.* CRC Press, Boca Raton, FL, 2017.

[3] B. Clark and R. Madachy, editors. *Software Cost Estimation Metrics Manual for Defense Systems.* Software Metrics Inc., Haymarket, VA, 2015.

[4] R. Madachy. *Software Process Dynamics.* Wiley-IEEE Press, Hoboken, NJ, 2008.

[5] B. Boehm, C. Abts, W. Brown, S. Chulani, B. Clark, E. Horowitz, R. Madachy, D. Reifer, and B. Steece. *Software Cost Estimation with COCOMO II.* Prentice-Hall, 2000.

Conference Proceedings Books (Editor)

[6] Q. Wang, V. Garousi, R. Madachy, and D. Pfahl (Eds.). *Trustworthy Software Development Processes, International Conference on Software Process 2009.* Springer, Berlin-Heidelberg, Vancouver, Canada, 2009.

(ii) Chapters in Books

[7] R. Valerdi (Ed.). *'Risk Assessment' in Systems Engineering Cost Estimation with COSYSMO.* Wiley & Sons, Hoboken, NJ, 2018.

[8] International Council on Systems Engineering (INCOSE). *"Project Planning" in Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities, Version 4.0.* John Wiley & Sons, Hoboken, NJ, 2015.

[9] A. Pyster, D. Olwell, N. Hutchison, S. Enck, J. Anthony, D. Henry, and A. Squires (Eds). *Systems Engineering Management. Guide to the Systems Engineering Body of Knowledge (SEBoK) version 1.0.1.* Hoboken, NJ: The Trustees of the Stevens Institute of Technology 2012, 2012. URL http://www.sebokwiki.org.

[10] A. Pyster, D. H. Olwell, T. L. J. Ferris, N. Hutchison, S. Enck, J. Anthony, D. Henry, and A. Squires(Eds.). *Expected Background for Students Entering a Master's Program. Graduate Reference Curriculum for Systems Engineering (GRCSE).* Hoboken, NJ, USA:The Trustees of the Stevens Institute of Technology. Available at, 2012. URL http://www.bkcase.org/grcse/.

[11] D. Petkov, D. Edgar-Nevill, R. Madachy, and R. O'Connor. Towards a wider application of the systems approach in information systems and software engineering. In D. Paradice, editor, *Emerging Systems Approaches in Information Technologies: Concepts, Theories and Applications.* IGI Publishing, 2010.

[12] D. Petkov, D. Edgar-Nevill, R. Madachy, and R. O'Connor. Information systems, software engineering and systems thinking: Challenges and opportunities. In M. Gordon Hunter, editor, *Strategic Information Systems: Concepts, Methodologies, Tools and Applications.* IGI Publishing, 2009.

[13] R. Madachy and B. Boehm. *"Software Dependability Applications" in Software Process Modeling.* Kluwer Academic Publishers, 2004.

[14] R. Madachy. *"Simulation in Software Engineering" in Encyclopedia of Software Engineering.* Wiley and Sons, Inc., New York, NY, second edition, 2001.

(iii) Refereed Journal Papers

[15] H. Zhang, D. Raffo, T. Birkholzer, D. Houston, R. Madachy, J. Munch, and S. Sutton. Software process simulation — at a crossroads? *Journal of Software: Evolution and Process*, 2014.

[16] E. Kocaguneli, T. Menzies, J. Keung, D. Cok, and R. Madachy. Active learning and effort estimation: Finding the essential content of software effort estimation data. *IEEE Transactions on Software Engineering*, 99, December 2012.

[17] R. Madachy, B. Boehm, and D. Houston. Modeling software defect dynamics. *DoD Software Tech News*, 13 (1), April 2010.

[18] T. Menzies, S. Williams, O. Elrawas, D. Baker, B. Boehm, J. Hihn, K. Lum, and R. Madachy. Accurate estimates without local data. *Software Process Improvement and Practice*, 14, 2009.

[19] R. Madachy. Cost modeling of distributed team processes for systems of systems and global development. *Software Process Improvement and Practice*, 2008.

[20] D. Petkov, D. Edgar-Nevill, R. Madachy, and R. O'Connor. Information systems and software engineering and systems thinking: Challenges and opportunities. 2008.

[21] T. Menzies, O. Elwaras, J. Hihn, Feather M., B. Boehm, and R. Madachy. The business case for automated software engineering. *IEEE Automated Software Engineering*, 2007.

[22] R. Valerdi and R. Madachy. Impact and contributions of mbase on software engineering graduate courses. *Journal of Systems and Software*, 80(8), August 2007.

[23] R. Madachy, B. Boehm, and J. Lane. Assessing hybrid incremental processes for sisos development. *Software Process Improvement and Practice*, 2007.

[24] B. Boehm, L. Huang, A. Jain, and R. Madachy. Reasoning about the roi of software dependability: the idave model,. *IEEE Software*, 21(3), 2004.

[25] R. Madachy and D. Tarbet. Case studies in software process modeling with system dynamics. *Software Process Improvement and Practice*, (Spring), 2000.

[26] R. Madachy and D. Tarbet. Initial experiences in software process modeling. *Software Quality Professional*, (Spring), 2000.

[27] B. Boehm, E. Horowitz, R. Madachy, and C. Abts. Future trends, implications in cost estimation models. *Crosstalk*, 2000.

[28] K. Bennett, E. Burd, C. Kemerer, M. Lehman, M. Lee, R. Madachy, C. Mair, D. Sjoberg, and S. Slaughter. Empirical studies of evolving systems. *Empirical Software Engineering*, 4(4):370–380, December 1999.

[29] M. Kellner, R. Madachy, and D. Raffo. Software process simulation modeling: Why? what? how? *Journal of Systems and Software*, (Spring), 1999.

[30] B. Boehm, A. Egyed, D. Port, A. Shah, J. Kwan, and A R. Madachy. Stakeholder win-win approach to software engineering education. *Annals of Software Engineering*, 6, 1998.

[31] B. Boehm, A. Egyed, J. Kwan, A. Shah, and R. Madachy. Using the winwin spiral model: A case study. *IEEE Computer*, 1998.

[32] R. Madachy and B. Khoshnevis. Dynamic simulation modeling of an inspection-based software lifecycle process. *Simulation*, 69(1), July 1997.

[33] R. Madachy. Heuristic risk assessment using cost factors. *IEEE Software*, 1997.

[34] R. Madachy. Knowledge-based risk assessment and cost estimation. *Automated Software Engineering*, 1995.

[35] B. Boehm, B. Clark, E. Horowitz, C. Westland, R. Madachy, and R. Selby. Cost models for future software life cycle processes: Cocomo 2.0. *Annals of Software Engineering*, pages 57–94, 1995.

(iv) Non-Refereed Journal Papers

(v) Refereed Conference Papers

Rigorously peer reviewed
These are stringently and exhaustively peer-reviewed in detail with multiple iterations and follow-up. Typical paper acceptance rates are about 20%.

[36] W. Rosa, R. Madachy, C. Wallshein, B. Clark, and B. Boehm. Early phase cost models for agile software processes in the us dod. In *Proceedings of the 2017 ACM / IEEE International Symposium on Empirical Software Engineering and Measurement*, Toronto, Canada, November 2017. Accepted.

[37] R. Madachy. System dynamics behaviors for modeling lawmaking processes. In *Proceedings of the 4th Annual Science of Laws Conference*. The Science of Laws Institute, November 2017. Accepted.

[38] M. Green and R. Madachy. Hitchins' 5-layer model as an evaluation framework for regulations. In *Proceedings of the 4th Annual Science of Laws Conference*. The Science of Laws Institute, November 2017. Accepted.

[39] R. Madachy. System dynamics structures for modeling lawmaking processes. In *Proceedings of the 3rd Annual Science of Laws Conference*. The Science of Laws Institute, 2016.

[40] W. Rosa, B. Boehm, R. Madachy, B. Clark, C. Jones, J. McGarry, C. Wallshein, and N. Lanham. Early phase software effort and schedule estimation models. In *Proceedings of the 2015 International Cost Estimating and Analysis Association Conference*, June 2015. Best Paper Award.

[41] W. Rosa, R. Madachy, B. Boehm, and B. Clark. Simple empirical software effort estimation model. In *Proceedings of the 8th ACM/IEEE International Symposium on Empirical Software Engineering and Measurement*, September, 2014. ACM/IEEE.

[42] R. Turner, R. Madachy, D. Ingold, and J. Lane. Modeling kanban processes in systems engineering. In *Proceedings of the 2012 International Conference on Software and System Process*, Zurich, Switzerland, 2012. IEEE.

[43] R. Turner, R. Madachy, D. Ingold, and J. Lane. Improving systems engineering effectiveness in rapid response development environments. In *Proceedings of the 2012 International Conference on Software and System Process*, Zurich, Switzerland, 2012. IEEE Computer Society.

[44] J. Wirthlin, D. Houston, and R. Madachy. Defense acquisition system simulation studies. In *Proceedings of the 2011 International Conference on Software and System Process*, Waikiki, HI, 2011. IEEE Computer Society.

[45] R. Madachy, B. Boehm, B. Clark, T. Tan, and W. Rosa. Us dod application domain empirical software cost analysis. In *Proceedings of 2011 Empirical Software Engineering and Measurement International Symposium*, Banff, Canada, September 2011. IEEE Computer Society.

[46] R. Madachy, R. Valerdi, and G. Wang. Interdisciplinary impacts: A tribute to prof. barry w boehm. In *Proceedings of the Barry W. Boehm Symposium*, Beijing, China, 2011. International Journal of Software and Informatics.

[47] T. Birkholzer, R. Madachy, D. Pfahl, D. Port, H. Beitinger, M. Schuster, and A. Olkov. A library of reusable components for software process simulation. In *Proceedings of the 2010 International Conference on Software Process*, Paderborn, Germany, 2010.

[48] R. Madachy and B. Boehm. Assessing quality processes with odc coqualmo. In *Proceedings of the 2008 International Conference on Software Process*, Liepzig, Germany, 2008.

[49] R. Madachy. Distributed global development parametric cost modeling. In *Proceedings of the 2007 International Conference on Software Process*, Minneapolis, MN, 2007.

[50] R. Valerdi and R. Madachy. Impact and contributions of mbase on software engineering graduate courses. In *Proceedings of 19th Conference on Software Engineering Education and Training*, IEEE Computer Society, 2006. Turtle Bay, HI.

[51] R. Madachy. Reusable model structures and behaviors for software processes. In *Proceedings of the Software Process Workshop/Workshop on Software Process Simulation 2006*, Shanghai, China, May 2006. Springer-Verlag.

[52] R. Madachy, B. Boehm, and J. Lane. Spiral lifecycle increment modeling for new hybrid processes. In *Proceedings of the Software Process Workshop/Workshop on Software Process Simulation 2006*, Shanghai, China, May 2006. Springer-Verlag.

[53] R. Madachy. Simulation for business value and software process/product tradeoff decisions. In *Proceedings of The 8th International Workshop on Economics-Driven Software Engineering Research at the 28th International Conference on Software Engineering*, Shanghai, China, 2006. IEEE Computer Society.

[54] R. Madachy. Integrating business value and software process modeling. In *Proceedings of the 2005 Software Process Workshop*, Beijing, China, May 2005. Springer-Verlag.

[55] R. Madachy. Software process and business value modeling. In *Proceedings of the 6th International Workshop on Software Process Simulation and Modeling*, St. Louis, MI, 2005. IEEE.

[56] R. Madachy. People applications in software process modeling and simulation. In *Proceedings of the 6th International Workshop on Software Process Simulation and Modeling*, St. Louis, MI, 2005. IEEE.

[57] R. Madachy. A software product business case model. In *Proceedings of the 5th International Workshop on Software Process Simulation and Modeling*, 2004.

[58] B. Boehm, L. Huang, A. Jain, and R. Madachy. Quality as stakeholder value. In *Proceedings of the Second Work shop on Software Quality*. IEEE Computer Society, 2004.

[59] B. Boehm, J. Bhuta, D. Garlan, E. Gradman, L. Huang, A. Lam, R. Madachy, N. Medvidovic, K. Meyer, S. Meyers, G. Perez, K. Reinholtz, R. Roshandel, and N. Rouquette. Using empirical testbeds to accelerate technology maturity and transition: The scrover experience. In *Proceedings of the 2004 International Symposium on Empirical Software Engineering*. IEEE Computer Society, 2004.

[60] B. Boehm, A. W. Brown, R. Madachy, and A Y. Yang. Software product line life cycle cost estimation model. In *Proceedings of the 2004 International Symposium on Empirical Software Engineering*. IEEE Computer Society, 2004.

[61] Y. Chen, B. Boehm, R. Madachy, and R. Valerdi. An empirical study of eservices product uml sizing metrics. In *Proceedings of the 2004 International Symposium on Empirical Software Engineering*. IEEE Computer Society, 2004.

[62] R. Madachy and D. Tarbet. Case studies in software process modeling with system dynamics. In *Proceedings of the ProSim 1999 Workshop*, Silver Falls, OR, June 1999.

[63] B. Boehm, A. Egyed, J. Kwan, and R. Madachy. Developing multimedia applications with the winwin spiral model. In *Proceedings of the Sixth European Software Engineering Conference and Fifth ACM SIGSOFT Symposium on the Foundations of Software Engineering*, Zurich, Switzerland, September 1997. Verlag.

[64] R. Madachy. System dynamics modeling of an inspection-based process. In IEEE Computer Society Press, editor, *Proceedings of the Eighteenth International Conference on Software Engineering*, Berlin, Germany, March 1996.

[65] R. Madachy. Modeling software processes with system dynamics: Current developments. In *Proceedings of the 1996 International System Dynamics Conference*, Cambridge, MA, July 1996.

[66] R. Madachy. Measuring inspections at litton. In *Proceedings of the Sixth International Conference on Applications of Software Measurement*, Orlando, FL, October 1995. Software Quality Engineering. Best Paper Award.

[67] R. Madachy. Knowledge-based risk assessment and cost estimation. In *Proceedings of the Ninth Knowledge-Based Software Engineering Conference*, IEEE Computer Society Press, September 1994. Monterey, CA.

Moderately peer reviewed
These are formally peer reviewed with moderate level of detail and have typical acceptance rates around 40% - 50%.

[68] M. Towhidnejad, T. Ferris, A. Squires, and R. Madachy. Enabling systems engineering program outcomes via systems engineering body of knowledge. In *2013 Conference on Systems Engineering Research, Procedia Computer Science, 16*, pages 983–989, 2013.

[69] R. Turner, J. Lane, D. Ingold, and R. Madachy. A lean approach to improving se visibility in large operational systems evolution. volume 23, 2013.

[70] T. Hilburn, A. Squires, and R. Madachy. A model for educating systems engineers. In *Proceedings of the IEEE Systems Conference*, Vancouver, Canada, March 2012. IEEE.

[71] R. Turner, D. Ingold, J. Lane, R. Madachy, and D. Anderson. An event-driven, value-based, pull systems engineering scheduling approach. In *Proceedings of the IEEE Systems Conference*. Vancouver, March 2012.

[72] R. Turner, D. Ingold, J. Lane, R. Madachy, and D. Anderson. Effectiveness of kanban approaches in systems engineering within rapid response environments. In *Proceedings of the 10th Annual Conference on Systems Engineering Research*, March 2012.

[73] B. Boehm, J. Lane, and R. Madachy. Total ownership cost models for valuing system flexibility. In *2011 Conference on Systems Engineering Research*, Los Angeles, CA, April 2011.

[74] R. Madachy and R. Valerdi. Automating systems engineering risk assessment. In *Proceedings of the 8th Annual Conference on Systems Engineering Research*, 2010.

[75] H. Johnson and R. Madachy. Simulating international space station issue resolution. In *Proceedings of AIAA Space 2008 Conference*, Long Beach, CA, 2008.

[76] R. Madachy, B. Haas, H. Bradbury-Huang, J. Newell, R. Vos, and M. Rahimi. Achieving sustainable development in southern california: Collaborative learning through system dynamics modeling. In *Proceedings of the 18th International Symposium of INCOSE*, Netherlands, 2008.

[77] B. Boehm, D. Ingold, and R. Madachy. The macro risk model - an early warning tool for software-intensive systems projects. In *Proceedings of the 18th International Symposium of INCOSE*, Netherlands, 2008.

[78] R. Madachy, B. Boehm, J. Richardson, M. Feather, and T. Menzies. Value-based design of software v&v processes for nasa flight projects. In *Proceedings of AIAA Space 2007 Conference*, Long Beach, CA, 2007.

Lightly peer reviewed

[79] W. Rosa, R. Madachy, B. Boehm, B. Clark, C. Jones, J. McGarry, and J. Dean. Improved method for predicting software effort and schedule. In *Proceedings of the 2014 International Cost Estimating and Analysis Association (ICCEA) Conference*, 2014. Best Paper Award.

[80] R. Madachy. Knowledge-based assistance for software cost estimation and project risk assessment. In *Litton Software Technology Management Conference*, Santa Barbara, CA, 1994. Best Paper Award.

[81] R. Madachy. Case and hypertext integration issues. In *The Third Annual Teamworkers International User Group Conference*, San Diego, CA, March 1990.

[82] R. Madachy, P. Dousette, and S. Sperling. Librascope case position. In *Advance Working Papers of Third International Workshop on CASE. Imperial College, London, UK, July*, 1989.

(vi) Invited Conference Papers

(vii) Presentations

Conference Presentations

[83] R. Madachy, D. Jacques, K. Giammarco, and D. Edwards. Model-based systems engineering tradespace analysis with sysml and cosysmo. In *Proceedings of the 32nd International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2017. Accepted.

[84] W. Rosa, R. Madachy, B. Clark, and B. Boehm. Agile software development cost modeling for the us dod. In *Proceedings of the 32nd International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2017. Accepted.

[85] R. Madachy. Cost, schedule, and quality models and simulations. In *Proceedings of the 31st International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2016. Invited Presentation.

[86] R. Madachy, K. Giammarco, D. Jacques, and D. Edwards. System cost modeling and sysml integration. In *Proceedings of the 31st International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2016.

[87] M. Farah-Stapleton, R. Madachy, M. Auguston, and K. Giammarco. Executable architecture modeling. In *Proceedings of the 31st International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2016.

[88] R. Madachy. Software maintainability metrics workshop. In *Proceedings of the 2016 International Software Engineering Research Network Meeting*, La Ciudad, Spain, September 2016.

[89] R. Madachy. Software process dynamics. In *Proceedings of the 2016 Brazilian Function Point Users Group*, Sao Paulo, Brazil, August 2016. Invited Presentation.

[90] W. Rosa, B. Boehm, R Madachy, and B. Clark. Early phase software cost and schedule estimation models. In *Proceedings of the 30th International Forum on COCOMO and Systems/Software Cost Modeling*, Washington, DC, November 2015.

[91] B. Clark and Madachy R. COCOMO III Workshop. In *Proceedings of the 30th International Forum on COCOMO and Systems/Software Cost Modeling*, Washington, DC, November 2015.

[92] M. Farah-Stapleton, R. Madachy, M. Auguston, and K. Giammarco. Resource analysis based on system architecture behavior. In *Proceedings of the 30th International Forum on COCOMO and Systems/Software Cost Modeling*, Washington, DC, November 2015.

[93] Madachy R. and B. Clark. Software cost estimation metrics manual for defense systems. In *Proceedings of the USC CSSE Annual Research Review*, Los Angeles, CA, April 2015.

[94] W. Rosa, B. Boehm, R. Madachy, and B Clark. Simple empirical software effort estimation model. In *Proceedings of the 29th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2014.

[95] B. Clark and Madachy R. Software cost estimation metrics manual for defense systems. In *Proceedings of the 29th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, October 2014.

[96] B. Boehm and R. Madachy. Workshop: Empirical specification and evaluation of the ilities. In *Proceedings of the 2013 International Software Engineering Research Network Meeting*, Baltimore, MD, 2013.

[97] B. Clark and R. Madachy. Dod software resource data reports (srdrs) and cost data analysis workshop. In *Proceedings of the 27th International Forum on COCOMO and Systems/Software Cost Modeling*, Pittsburgh, PA, 2012.

[98] R. Turner and R. Madachy. Improving systems engineering effectiveness using kanban-based scheduling and a service-oriented approach. In *Proceedings of IEEE SysCon*, Vancouver, Canada, March 2012. IEEE.

[99] R. Madachy and R. Valerdi. Estimation curriculum development workshop. In *Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2011.

[100] B. Clark and R. Madachy. Air force estimation guidebook workshop. In *Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2011.

[101] B. Clark and R. Madachy. SRDR data analysis research workshop. In *Proceedings of the 25th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2010.

[102] B. Clark and R. Madachy. Software metrics unification & software productivity domains workshop. In *Proceedings of the 24th International Forum on COCOMO and Systems/Software Cost Modeling*, Cambridge, MA, 2009.

[103] W. Rosa, B. Boehm, B. Clark, R. Madachy, and J. Dean. Domain-driven software cost and schedule estimation models: Using software resource data reports. In *Proceedings of the 2013 International Cost Estimating and Analysis Association (ICCEA) Conference*, New Orleans, LA, 2013.

[104] CSSE alumni panel. In *USC CSSE Annual Research Review*, Los Angeles, CA, March 2013.

[105] W. Rosa, B. Boehm, B. Clark, T. Tan, and R. Madachy. Domain-driven software cost estimation: Space, air, ship, and ground systems. In *Proceedings of the 2012 SCEA/ISPA Joint Annual Conference and Training Workshop*, Orlando, FL, 2012.

[106] B. Boehm, J. Lane, S. Koolmanojong, and R. Madachy. Estimating for lifecycle and product line affordability. In *Proceedings of the SCEA/ISPA Joint Annual Conference and Training Workshop*, Orlando, FL, 2012.

[107] R. Madachy. Panel: Software process simulation - at a crossroads?". In *Proceedings of the 2012 International Conference on Software and System Process*, Zurich, Switzerland, 2012. IEEE. Invited Panelist.

[108] B. Clark, R. Madachy, B. Boehm, and W. Rosa. Software cost estimation metrics manual online. In *Proceedings of the 28th International Forum on Software Cost Modeling*, Los Angeles, CA, 2013.

[109] W. Rosa, B. Boehm, B. Clark, T. Tan, and R. Madachy. Domain-driven software cost estimation. In *Proceedings of the 27th International Forum on COCOMO and Systems/Software Cost Modeling*, Pittsburgh, PA, 2012.

[110] R. Madachy, B. Boehm, B. Clark, T. Tan, and W. Rosa. Software cost estimation metrics manual. In *Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2011.

[111] B. Boehm, B. Clark, R. Madachy, W. Rosa, and T. Tan. Estimation challenges for 21st century software systems. In *Proceedings of the 2011 ISPA/SCEA Conference*, Albuquerque, NM, June 2011.

[112] B. Boehm, J. Lane, and R. Madachy. Valuing system flexibility via total ownership cost analysis. In *13th Annual NDIA Systems Engineering Conference*, San Diego, CA, 2010.

[113] R. Madachy, B. Boehm, E. Conrow, K. Nidiffer, and G. Roedler. Panel: Systems engineering management and the relationship of systems engineering to project management and software engineering. In *13th Annual NDIA Systems Engineering Conference*, San Diego, CA, 2010. Panelist.

[114] R. Madachy. Coconomography. In *Proceedings of the 25th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2010. Invited Presentation.

[115] R. Madachy and A. W. Brown. COCOMO suite toolset. In *Proceedings of the 25th International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2010.

[116] B. Clark and R. Madachy. Building cost estimating relationships for acquisition decision support. In *14th Annual Practical Software and Systems Measurement (PSM) User's Group Conference*, 2010.

[117] B. Boehm, R. Madachy, B. Clark, and W. Rosa. Future ground system software estimation and metrics. In *Proceedings of the 2010 Ground System Architectures Workshop (GSAW)*, Los Angeles, CA, 2010.

[118] R. Madachy, B. Boehm, B. Clark, D. Reifer, and W. Rosa. A sizing framework for dod software cost analysis. In *Proceedings of the 24th International Forum on COCOMO and Systems/Software Cost Modeling*, Cambridge, MA, 2009.

[119] R. Madachy. Integrated cocomo suite tool for education. In *Proceedings of the 24th International Forum on COCOMO and Systems/Software Cost Modeling*, Cambridge, MA, 2009.

[120] R. Madachy and R. Valerdi. Risk analysis and mitigation with expert cosysmo. In *Proceedings of the 24th International Forum on COCOMO and Systems/Software Cost Modeling*, Cambridge, MA, 2009.

[121] W. Rosa, B. Clark, R. Madachy, D. Reifer, and B. Boehm. Software cost metrics manual. In *Proceedings of the 42nd Department of Defense Cost Analysis Symposium*, Williamsburg, VA, 2009.

[122] R. Madachy. COCOMO suite model unification tool. In *Proceedings of the 23rd International Forum on COCOMO and Systems/Software Cost Modeling*, CA, 2008. Los Angeles.

[123] R. Madachy. Business valuation with software cost modeling - a case study. In *Proceedings of the 22nd International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2007.

[124] R. Madachy and B. Boehm. Software cost model comparison for nasa projects. In *Proceedings of the 2007 NASA Cost Symposium*, Denver, CO, 2007.

[125] R. Madachy and R. Valerdi. Expert COSYSMO. In *Proceedings of the 22nd International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2007.

[126] R. Madachy and B. Boehm. ODC COQUALMO. In *Proceedings of the 22nd International Forum on COCOMO and Systems/Software Cost Modeling*, Los Angeles, CA, 2007.

[127] J. Richardson, B. Boehm, R. Madachy, L. Huang, D. Port, and R. Kazman. Reducing autonomy risks through rational selection of verification strategies. In *Proceedings of 2006 Ground Systems Architecture Workshop*, Los Angeles, CA, 2006.

[128] B. Boehm, L. Huang, and R. Madachy. Integrated software cost and quality modeling for program risk management. In *Proceedings of 2006 Ground Systems Architecture Workshop*, Los Angeles, CA, 2006.

[129] R. Madachy. Applying gqm to software cost, schedule, and quality estimation. In *Proceedings of the Software Technology Conference 2004*, Salt Lake City, UT, 2004.

[130] R. Madachy. A value-based software product model. In *Proceedings of the Eighteenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, 2003.

[131] Y. Chen and R. Madachy. Results of eservices product sizing metric correlations. In *Proceedings of the Eighteenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 2003.

[132] B. Boehm, Y. Yang, and R. Madachy. Coplimo: A product-line investment analysis model. In *Proceedings of the Eighteenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 2003.

[133] R. Madachy. Using cost models in software risk management. In *Proceedings of the Fourth Joint Annual International Society of Parametric Analysts/Society of Cost Estimating and Analysis International Conference*, Orlando, FL, June 2003.

[134] R. Madachy. Software process concurrence modeling. In *Proceedings of the Fourth Joint Annual International Society of Parametric Analysts/Society of Cost Estimating and Analysis International Conference*, Orlando, FL, June 2003.

[135] R. Madachy. Software process concurrence modeling. In *Proceedings of the Software Management/Applications of Software Measurement 2003 Conference*, San Jose, CA, June 2003.

[136] R. Madachy. Tutorial: Use of cost models in risk management. In *Proceedings of the Seventeenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 2002.

[137] D. Reifer and R. Madachy. COCOMO II/SEER rosetta stone. In *Proceedings of the Seventeenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, 2002.

[138] R. Madachy. Software process concurrence. In *Proceedings of the 2002 International System Dynamics Conference*, Palermo, Italy, July 2002. System Dynamics Society.

[139] R. Madachy. Software schedule analysis with process concurrence. In *Proceedings of the Sixteenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 2001.

[140] R. Madachy and Cocomo Ii:. Airborne radar system example. In *Proceedings of the Fifteenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 2000.

[141] D. Reifer and R. Madachy. An introduction to COCOMO II.2000 (tutorial). In *Proceedings of the Software Technology Conference Salt Lake City*, Salt Lake City, UT, 2000.

[142] R. Madachy. Pal-enabled software metrics and process automation. In *Proceedings of the Litton Software Technology Management Conference*, Santa Barbara, CA, February 2000.

[143] R. Madachy. Cost/schedule/process modeling via system dynamics. In *Proceedings of the Fourteenth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 1999.

[144] R. Madachy and D. Tarbet. Initial experiences in software process modeling. In *Proceedings of the 14th International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 1999.

[145] R. Madachy. An advanced process asset library. In *Proceedings of the Tenth Software Engineering Process Group Conference*, Atlanta, GA, March 1999.

[146] R. Madachy. An advanced process asset library. In *Proceedings of the 1999 Litton Software Technology Management Conference*, Dana Point, CA, February 1999.

[147] R. Madachy and Tutorial: System. Dynamics modeling applied to software development processes. In *Proceedings of ProSim 98 Workshop*, Silver Falls, OR, June 1998.

[148] R. Madachy, R. Nakahara, and M. Cochran. An intranet-based software cost estimation tool. In *Proceedings of the Litton Software Technology Management Conference*, CA, February 1997. Santa Barbara.

[149] R. Madachy. Tutorial: Process modeling with system dynamics. In *Conference on Software Process Improvement*, Irvine, CA, January 1997.

[150] R. Madachy. Tutorial: Process modeling with system dynamics. In *Proceedings of the Eighth Software Engineering Process Group Conference*, Atlantic City, NJ, May 1996.

[151] R. Madachy. System dynamics modeling of an inspection-based process. In *Proceedings of the Litton Software Technology Management Conference*, Santa Barbara, CA, April 1996.

[152] R. Madachy. System dynamics and cocomo: Complementary modeling paradigms. In *Proceedings of the Tenth International Forum on COCOMO and Software Cost Modeling*, Pittsburgh, PA, October 1995. Software Engineering Institute.

[153] R. Madachy. Process improvement analysis of a corporate inspection program. In *Proceedings of the Seventh Software Engineering Process Group Conference*, Boston, MA, May 1995.

[154] R. Madachy. Process improvement analysis of a corporate inspection program. In *Proceedings of the 1995 Litton Software Technology Management Conference*, Newport Beach, CA, April 1995.

[155] B. Boehm, B. Clark, E. Horowitz, C. Westland, R. Madachy, and R. Selby. Cost models for future software life cycle processes: COCOMO 2.0. In *Proceedings of the Eighth Annual Software Technology Conference*, Salt Lake City, UT, April 1995.

[156] R. Madachy. Dynamic modeling of an inspection-based process. In *Proceedings of the 1995 California Software Symposium*, Irvine, CA, April 1995.

[157] R. Madachy. Development of a cost estimation process. In *Proceedings of the Ninth International Forum on COCOMO and Software Cost Modeling*, Los Angeles, CA, October 1994.

[158] R. Madachy and L. Little. Analysis of a successful inspection program. In *Proceedings of the Eighteenth Annual Software Engineering Workshop*, Goddard Space Flight Center, Greenbelt, MD, December 1993. NASA/SEL.

[159] R. Madachy. Knowledge-based assistance for software cost estimation and project risk assessment. In *Proceedings of the Eighth International Forum on COCOMO and Software Cost Modeling*, Pittsburgh, PA, October 1993. Software Engineering Institute.

Other Technical Presentations

[160] Madachy R.and D. Jacques. System Cost Modeling and SysML Integration in Model-Based Systems Engineering. *INCOSE San Diego Chapter Meeting*, December 2016.

[161] D. Jacques and R. Madachy. Model-Driven UAS ISR Tradespace Analysis. *8th Annual SERC Sponsor Research Review*, November 2016.

[162] D. Jacques and R. Madachy. Model-Centric UAV ISR Analysis. *7th Annual SERC Sponsor Research Review*, December 2015.

[163] R. Madachy. iTAP methods, processes and tools. *6th Annual SERC Sponsor Research Review*, December 2014.

[164] R. Madachy. NPS Total Ownership Cost Models. *2014 SERC Annual Technical Review*, March 2014.

[165] R. Madachy. Systems engineering management and the relationship of systems engineering to project management and software engineering. DoD ODASD Webinar Conference, July 2011. DoD Invited Presentation.

[166] R. Madachy. Simulation of processes for developing complex systems. Crystal City, VA, 2011. DoD Schedule Assessment Workshop. DoD Invited Presentation.

[167] Madachy R. Quick Engineering Cost Estimates and Trades using Coconomography. *INCOSE San Diego Chapter Meeting*, February 2011.

[168] R. Madachy. Simulation of processes for complex software-intensive systems. DoD ODASD Webinar Conference, December 2008. DoD Invited Presentation.

(viii) Refereed Technical Reports

(ix) Non-Refereed Technical Reports

[168] System Qualities Ontology, Tradespace and Affordability (SQOTA) Project - Phase 5. Technical Report SERC-2017-TR-105, Systems Engineering Research Center, April 2017.

[169] System Qualities Ontology, Tradespace and Affordability (SQOTA) Project – Phase 4. Technical Report SERC-2016-TR-101, Systems Engineering Research Center, February 2016.

[170] Tradespace and Affordability - Phase 3. Technical Report SERC-2014-TR-039-3, Systems Engineering Research Center, December 2014.

[171] Tradespace and Affordability – Phase 2 A013 - Final Technical Report. Technical Report SERC-2013-TR-039-2, Systems Engineering Research Center, December 2013.

[172] Tradespace and Affordability – Phase 1 A013 - Final Technical Report. Technical Report SERC-2013-TR-039-1, Systems Engineering Research Center, July 2013.

[173] B. Boehm, J. Lane, T. Tan, M. Moazeni, R. Madachy, and W. Rosa. Software Intensive Systems Cost and Schedule Estimation, Final. Technical Report SERC-2013-TR-032-2, Systems Engineering Research Center, June 2013.

[174] Code L01 NSWC PHD, L Department. Littoral Warfare Engineering Facility (LWEF) Business Case Analysis. Technical report, 2013.

[175] RT18 - Valuing Flexibility Phase II. Technical Report SERC-2012-TR-10-2, Systems Engineering Research Center, 2012.

[176] R. Turner, R. Madachy, J. Lane, D. Ingold, and L. Levine. Agile-Lean Software Engineering (ALSE) Evaluating Kanban in Systems Engineering, A013 - Final. Technical Report SERC-2013-TR-022-2, Systems Engineering Research Center, 2013.

[177] RT 6 – Software Intensive Systems Data Quality and Estimation Research in Support of Future Defense Cost Analysis, A013 - Annual and Final Scientific Technical Report . Technical Report SERC-2012-TR-032, Systems Engineering Research Center, 2012.

[178] R. Madachy and B. Boehm. Comparative Analysis of COCOMO II, SEER-SEM and True-S Software Cost Models. Technical report, University of Southern California, USC-CSSE, 2008.

[179] R. Madachy. Risk Model Report and Demonstrations. Technical report, submitted to NASA AMES, 2007.

[180] R. Madachy and B. Boehm. Detailed Plans for CY 2008: Software Risk Advisory Tools Enhancements. Technical report, submitted to NASA AMES, 2007.

[181] D. Ingold and R. Madachy. NASA Macro Risk Model Detailed Case Study. Technical report, submitted to NASA AMES, 2007.

[182] R. Madachy and B. Boehm. Detailed ODC COQUALMO and Accuracy Analysis. Technical report, submitted to NASA AMES, 2007.

[183] R. Madachy and B. Boehm. Calibration of ODC COQUALMO to Predict V&V Effectiveness. Technical report, submitted to NASA AMES, 2007.

[184] R. Madachy. Continuous Risk Model Design, Implementation and Calibration. Technical report, submitted to NASA AMES, 2007.

[185] R. Madachy. 6G Software Cost and Defect Data Collection Form. Technical report, submitted to NASA AMES, 2006.

[186] R. Madachy. Cost Model Comparison Report, Update Version. Technical report, submitted to NASA AMES, 2006.

[187] R. Madachy, B. Boehm, and D. Wu. Comparison and Assessment of Cost Models for NASA Flight Projects. Technical Report USC-CSE-2006-616, University of Southern California, 2006.

[188] R. Madachy. JPL Delphi Survey for V&V Defect Detection Efficiencies. Technical report, submitted to NASA JPL, 2006.

[189] D. Ingold and R. Madachy. Risk Model Calibration Report. Technical report, submitted to NASA AMES, 2006.

[190] R. Madachy. Model Comparison Report. Technical report, submitted to NASA AMES, July 2006.

[191] R. Madachy and B. Boehm. MOCA Final Report. Technical report, submitted to the NASA/USRA MOCA project, March 2006.

[192] R. Madachy. Using ODC COQUALMO to Quantify Risk Exposure for AUTONOMO: Approach and Example. Technical report, submitted to the NASA/USRA MOCA project, 2005.

[193] R. Madachy and. MOCA Autonomo Calibration White Paper. Technical report, submitted to the NASA/USRA MOCA project, September 2005.

[194] R. Madachy. Incremental COCOMO II and Initial System-of-Systems Common Operating Environment (SOSCOE) Sensitivity Analysis. Technical report, submitted to the Army/DARPA Future Combat Systems (FCS), 2005.

[195] R. Madachy. Defect Field Descriptions Supporting the High Dependability Computing Program. Technical report, submitted to NASA-JPL, August 2005.

[196] B. Boehm, L. Huang, A. Jain, and R. Madachy. The Nature of Information System Dependability: A Stakeholder/Value Approach. Technical Report USC-CSE-2004-520, University of Southern California, 2004.

[197] R. Madachy. Incremental COCOMO II and Initial SOSCOE Sensitivity Analysis. Technical report, submitted to Boeing for the Army/DARPA Future Combat Systems (FCS), 2004.

[198] R. Madachy. FCS Software Cost and Schedule Data Collection. Technical report, prepared for contractors on the Army Future Combat Systems (FCS), 2002.

[199] R. Madachy and B. Boehm. MDS software adoption cost analysis. Technical report, submitted to NASA-JPL, 2002.

[200] R. Madachy, D. Reifer, and B. Boehm. FCS software cost estimation initiative plan. Technical report, submitted to Boeing for the Army/DARPA Future Combat Systems (FCS), 2002.

[201] R. Madachy. FCS COCOMO tutorial. Technical report, Army/DARPA Future Combat Systems (FCS) project, Seal Beach, CA, August 2002.

[202] R. Madachy. COCOMO to SEER Rosetta Stone. Technical report, submitted to Army/DARPA Future Combat Systems (FCS), 2002.

(x) Published Computer Programs

[203] R. Madachy. Electric Car Charging Model. In *What Every Engineer Should Know About Modeling and Simulation*, August 2017. URL https://github.com/madachy/What-Every-Engineer-Should-Know-About-Modeling-and-Simulation.

[204] R. Madachy. System Cost Model Suite v.2.0, 2017. URL http://csse.usc.edu/tools/cost_model_suite.

[205] R. Madachy. COCOMO Suite, 2015. URL http://csse.usc.edu/tools/COCOMOSuite.

[206] R. Madachy. COCOMO II, 2016. URL http://csse.usc.edu/tools/COCOMO.

[207] R. Madachy. COCOMO 81, 2016. URL http://softwarecost.org/tools/COCOMO81/.

[208] R. Madachy. COSYSMO, 2015. URL http://csse.usc.edu/tools/COSYSMO.

[209] R. Madachy. Expert COSYSMO, 2011. URL http://csse.usc.edu/tools/expertcosysmo.php.

[210] R. Madachy. ODC COQUALMO, 2011. URL http://csse.usc.edu/tools/COQUALMO.php.

[211] R. Madachy. Expert COCOMO, 2008. URL http://sunset.usc.edu/research/COCOMOII/expert_cocomo/expert_cocomo2000.html.

(xi) Book Reviews

(xii) Other

Newsletter Articles

[212] R. Madachy. From the President. INCOSE San Diego Chapter Newsletter, March 2016. URL https://sdincose.org/wp-content/uploads/2016/10/March20201620SD20INCOSE20Newsletter.pdf. (From the President Column).

[213] R. Madachy. Our INCOSE Heritage: Foundations of Systems Architecting. INCOSE San Diego Chapter Newsletter, June 2016. URL https://sdincose.org/wp-content/uploads/2017/08/June-2016-INCOSE-Newsletter.pdf. (From the President Column).

[214] R. Madachy. Our INCOSE Heritage: Integrating Software and Systems Engineering. INCOSE San Diego Chapter Newsletter, September 2016. URL https://sdincose.org/wp-content/uploads/2016/10/Sept20201620INCOSE20Newsletter.pdf. (From the President Column).

[215] R. Madachy. Our INCOSE Heritage: Systems Engineering Dichotomies. INCOSE San Diego Chapter Newsletter, December 2016. URL https://sdincose.org/wp-content/uploads/2017/01/Dec20201620INCOSE20Newsletter.pdf. (From the President Column).

c. Reviews or other indicators of quality or significance of items listed in (a)

This section contains reviews and other indicators of quality or significance of items listed in both (a) and (b), though the latter is not listed in the standard template.

For publishing, my citation indices from Google Scholar as of 10/1/2017 are in Table 1. With the citations I rank 4th at NPS and 17th in the systems engineering specialty.

Table 1: Google Scholar Citation Data

Citation indices	All	Since 2012
Citations	6088	2046
h-index	23	14
i10-index	38	24

In recognition of my research, I received the 2016 Lifetime Achievement Award in Systems and Software Cost Estimation from the USC Center for Systems and Software Engineering for "Innovative Development of a Wide

Variety of Cost, Schedule and Quality Models and Simulations". With this I gave an invited conference presentation on the models and simulations [85].

Significance of my research is evidenced that the DoD revised policies for software-intensive program. The OSD Cost Analysis and Improvement Group (CAIG) implemented our recommended changes to the mandated Software Resources Data Report Form. This allows better visibility into software size and cost factors, and enabling more precise measurements for effort models and productivity based on our empirical research.

Other recognitions in the DoD includes the following:

Invited by ODASD(SE) to serve on expert panel and give invited presentation on cost and schedule modeling.

Invited by the DoD-sponsored Software Tech News to write an article on software quality modeling [17].

Included on DoD's Data & Analysis Center for Software (DACS) list of software quality and reliability experts.

Invited by OSD-ATL to present webinars on "Simulation of Processes for Developing Complex Software-Intensive Systems" and "Systems Engineering Management and the Relationship of Systems Engineering to Project Management and Software Engineering" at the SSA Software Collaborator Teleconferences in 2008 and 2011.

The significance of my cost modeling tools (some borne of the research in Section III.2.a.) is evidenced by the widespread user base. The partial representative list of tool users in Table 2 is almost all harvested from a quick email search (except where noted as found on the web). Not all email was found. These are only the users who explicitly sent acknowledgments and/or questions. Indications are these represent an extremely small fraction of users per the data files. The majority reporting are using the COCOMO II tool.

Many organizations in Table 2 have standardized on my tool or are using it on multiple programs. The list does not include organizational usage due to any NPS students (during or after my class). There are many instances of students using them after NPS, but their inclusion would be a counting bias for external impact. Also not shown are numerous small consultancies and individuals.

The COCOMO II tool is also referenced in the book: C. Ebert, *Global Software and IT: A Guide to Distributed Development, Projects, and Outsourcing*, IEEE/Wiley, 2011. Also not shown are technical reports, blogs and links referring to the tools.

Below are reviews on the back cover of *What Every Engineer Should Know About Modeling and Simulation*.

> "...an excellent undergraduate introduction to M&S concepts that are truly relevant and useful in any and all engineering subdisciplines. The presentation is largely independent of both software and application domains, and yet still manages to communicate and explain a way to approach the use of simulation tools for decision support and systems analysis."
>
> - Dr. James E. Moore, II, Professor of Industrial and Systems Engineering, Civil Engineering, and Public Policy and Management, Vice Dean for Academic Programs in the USC Viterbi School of Engineering, University of Southern California
>
> "The focus on broadness, simplicity and targeting the non-practitioner audience is the main reason for this book in my opinion. While this book is not targeted to experienced practitioners, the authors' description of the modeling and simulation method in Chapter 2, along with descriptions of lessons they have learned, is a worthy read for novices and experts alike. Take advantage of the concise wisdom and insight offered herein."
>
> - Dr. Grant Cates, Senior Project Leader, The Aerospace Corporation

The capsule reviews on the back cover of *Software Process Dynamics* are the boldfaced sections within the complete reviews below. These are listed with more reviews on the publisher's Software Process Dynamics page.

> "Ray Madachy's new book is **not only the best software engineering book of 2007, but quite possibly the most important book of this entire first decade of the 21st century.** Many of us were excited by the possibilities of system dynamics modeling and simulation of software projects and processes in 1991 based on the important book Software Project Dynamics by Tarek Abdel-Hamid. But it was ahead of its time, and it didn't incorporate many of the real-world issues and problems confronted

Table 2: System Cost Modeling Tool Users - Partial List of Reporting Organizations

DoD and FFRDCs
· SPAWAR 1.6, Washington Navy Yard
· SPAWAR - Atlantic
· US ARMY AMRDEC Software Engineering Directorate
· Naval Surface Warfare Center, Panama City Division
· Defense Contract Management Agency (DCMA)
· Software Engineering Institute
· USAF, Space and Missile Systems Center
· Naval Surface Warfare Center Port Hueneme Division
· Naval Undersea Warfare Center NWPT
· Navair PMA 281
· Naval Sea Systems Command SEA 04
· Navy Airborne Instrumentation Division, Point Mugu
· *Defense Acquisition University (West, Capital & NE)*
· *Air Force Institute of Technology*
· Sandia National Laboratories
· Cyber Security and Information Systems Information Analysis Center (CSIAC)
· US ARMY RDECOM CERDEC, Space & Terrestrial Communications Directorate (and other locations)

Other US and State Government
· U.S. Department of Agriculture
· Federal Communications Commission (FCC) (from web)
· Federal Deposit Insurance Corporation (FDIC)
· Kentucky Department of Human Resources

DoD contractors
· Lockheed Martin
· General Atomics Aeronautical Systems
· IBM
· Northrop Grumman Electronic Systems, ISR&TS Div.
· SAIC, Airspace Mission Planning Division
· iAccess Technologies, Inc.
· Aerojet
· ThalesRaytheonSystems, Missile Defense Business Unit
· Booz Allen Hamilton
· BAE Systems

Universities
· University of Southern California
· Stevens Institute of Technology
· Massachusetts Institute of Technology
· University of Wisconsin (from web)
· Humboldt State University
· Lund University (from web)
· Iowa State University (from web)
· University of Wisconsin
· Clemson University
· Carnegie Mellon University
· University of Arizona
· University of Houston
· Boise State University (from web)
· Kansas State University
· University of Alberta in Canada.
· University of Michigan
· University of Missouri

Universities (Cont.)
· University of Tartu (from web)
· Tampere University of Technology (from web)
· TU Munich
· York University
· University of Chicago.
· University of Western Ontario Canada
· University Putra Malaysia
· *Defense Acquisition University*
· *Air Force Institute of Technology*
· University of Ecuador
· Slovak University of Technology (from web)
· France, unstated school
· India, unstated school
· Mexico, unstated school
· University of Manchester
· University of Houston, Clear Lake
· Georgia State University

Other U.S companies
· Hewlett Packard Enterprise Services
· PNC Bank
· SPi Global
· Mib Software
· Walgreens Health Services
· Total Administrative Services Corporation (TASC)
· Technology Unlimited Group

Foreign
· Fujitsu
· Brazil, Federal Bank
· Aero Engine Controls
· Tieto Poland, Industrial R&D
· ThyssenKrupp AG
· MEI Technologies, Inc.
· ATECH Negócios em Tecnologias SA
· ITK Engineering AG

by today's project managers. Madachy updates Adbel-Hamid's initial work with discussions of object-oriented methods, agile processes, open-source development, and distributed global development; and he also incorporates the best thinking of software cost models such as COCOMO II.

Project managers, IT executives, and CIO's often wring their hands and ask why software development can't be more of an engineering discipline, rather than a completely unpredictable form of witchcraft. Now there's an answer, courtesy of Ray Madachy: serious, metrics-based modeling and simulation of software development. Along with a few other gems like Fred Brooks' "The Mythical Man-Month," I predict that "Software Process Dynamics" is going to be one of those key books that every software engineer, and every IT manager, has on his or her desk."

-Ed Yourdon, internationally recognized consultant and author of 27 books, including *Death March*

"This book is a critically important, timely and exciting contribution to software project management. In the last two decades, the application of System Dynamics to model and study the software development process has added significantly to our understanding of the complexities of software project dynamics. Transferring the lessons learned into practice has heretofore been hampered by the insufficiency of accessible teaching materials. Now, Ray Madachy has given us **a major and much needed new textbook** in his Software Process Dynamics.

Madachy's book is a comprehensive compilation of the wisdom and knowledge gathered over more than twenty years of research in the field, and **contains a wealth of material covering all important aspects of software project dynamics**. Because many of the concepts are accompanied by example models, Madachy has provided the practitioner with the building blocks and the tools to move ahead. This book is a gift to software project managers everywhere."

-Dr. Tarek Abdel-Hamid, Professor in the Graduate School of Business and
Public Policy at the Naval Postgraduate School

"One of the best techniques for reasoning about the effects of complex interacting changes is the System Dynamics modeling framework that Ray Madachy presents in this book. As I've found in numerous applications of the method, it enables project personnel to model such effects and run the models to better understand the implications of candidate project strategies and decisions. His modeling experience as a technical leader in diverse organizations have given him a broad and deep perspective on the critical success factors for modeling various classes of software decision situations, while his teaching and research has enabled him to develop an integrating framework that makes system dynamics modeling much easier and cost-effective to learn and apply.

Overall, the book **brings together a tremendous amount of useful process modeling material and experience in using it in practical software decision situations**. It organizes this material into a unifying framework that makes it easier to apply and explain, and illustrates it with a wide variety of useful examples. I believe that the book will **serve as a standard reference for the software process dynamics field** and a great help to practitioners and researchers for a good long time."

-Dr. Barry Boehm, Professor in the Computer Science and Industrial and Systems
Engineering Departments, University of Southern California

My biography is in the Marquis Who's Who listed as an engineering educator at NPS.

3. External Professional and Service Activities

A timeline of post-tenure major external professional and service activities is in Figure 4. Supporting details in the sub-sections below are roughly sized by the relative efforts involved.

Activities performed since my tenure proceeding are dated after March 2015 in the sections below.

a. Navy/DoD Activity

I served on an Advisory Panel to ODASD(SE) and presented "Simulation of Processes for Developing Complex Systems" at the DoD Schedule Assessment Workshop" in Crystal City, VA in 2011. This was in response to ODASD(SE) asking for my advice on methods and models for schedule estimation.

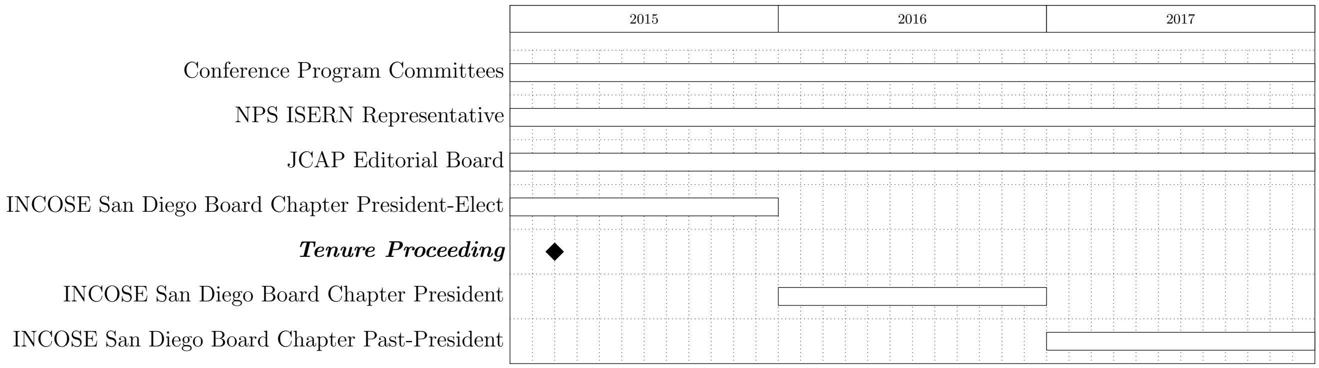


Figure 4: External Professional and Service Activities Timeline

I was invited by OSD-ATL and presented "Simulation of Processes for Developing Complex Software-Intensive Systems" at the SSA Software Collaborator Teleconference in 2008.

I was invited by OSD-ATL and presented "Systems Engineering Management and the Relationship of Systems Engineering to Project Management and Software Engineering" at the SSA Software Collaborator Teleconference in 2011.

Workshops I co-led for AFCAA include:

B. Clark and R. Madachy, "COCOMO III workshop", Proceedings of the 30th International Forum on COCOMO and Systems/Software Cost Modeling, Washington, DC, November 2015

B. Clark and R. Madachy, "DoD Software Resource Data Reports (SRDRs) and Cost Data Analysis Workshop", Proceedings of the 27th International Forum on COCOMO and Systems/Software Cost Modeling, Pittsburgh, PA, 2012

B. Clark and R. Madachy, "Air Force Estimation Guidebook Workshop", Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2011

B. Clark and R. Madachy, "SRDR Data Analysis Research Workshop", Proceedings of the 25th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2010

B. Clark and R. Madachy, "Software Metrics Unification & Software Productivity Domains", Proceedings of the 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, MA, 2009

I was an expert panelist on "Panel: Systems Engineering Management and the Relationship of Systems Engineering to Project Management and Software Engineering" for the National Defense Industrial Association (NDIA) Systems Engineering Conference in 2011.

b. External Professional Activities

Professional Organization Board

The INCOSE San Diego Chapter supports extensive professional activities via monthly meetings, tutorials and mini-conferences with continuing education credits. The Chapter also provides local STEM education awards for the community by raising funds, assessing proposals for middle school science projects, and awarding the funds.

Past-President, INCOSE San Diego Chapter, 2017
Responsible for strategic direction and planning, and serve as Chairman of the Nominations and Elections Committee.

President, INCOSE San Diego Chapter, 2016
Responsible for leading the INCOSE San Diego Chapter. The primary duties are:

- Preside at Board and Chapter meetings

- Act as an ex-officio member of all Chapter committees and working groups
- Recommend Nominations and Elections Committee members
- Nominate Audit Committee members
- Represent the Chapter at the annual International Workshop (IW) and International Symposium (IS)
- Participate in INCOSE Region II meetings (internet and telecon)
- Support or lead and plan joint-chapter events; assist other INCOSE chapters
- Act as INCOSE Member Board interface
- Prepare annual submission for Chapter Award

Under my leadership as President we accomplished the following:

- Held eight Chapter meetings (providing Professional Development Units (PDUs) for Systems Engineering Professional (SEP) certification)
- Conducted a Tutorial (providing PDUs for SEP certification)
- Held a Mini-Conference and co-hosted a Regional Mini-Conference (providing PDUs for SEP certification)
- Raised $10,251 in STEM funds and awarded 13 grants to local middle schools for science projects based on their competitive STEM proposals
- Hosted charity events including a STEM event and Geek Night on the Midway ship in San Diego
- Published quarterly newsletters [212] [213] [214] [215].

The above items are beyond the normal expectations for a chapter of our size. For these contributions and accomplishments we were awarded the competitive INCOSE Gold Chapter Award based on a scale of absolute points for activities. Other chapters receiving this award are far larger. It is a recognition for "reaching the highest goals and standards established by our organization".

President-Elect, INCOSE San Diego Chapter, 2015
I was responsible for the organization of a Chapter program of meetings and events, and enlisting a committee to assist in the program responsibility. I prepared to succeed to the position of the President for the year following.

Treasurer, INCOSE San Diego Chapter, 2014
Managed the finances of the Chapter. Received all funds paid to the Chapter and made payment of all bills incurred by the Chapter as approved by the Board. Made monthly reports to the Board as well as an annual report to INCOSE on the finances of the Chapter.

Professional Organizations

Institute of Electronic and Electrical Engineers (IEEE) (Senior Member)

International Council on Systems Engineering (INCOSE)

Association for Computing Machinery (ACM)

Journal Editorial Boards

Editorial Board, Journal of Cost Analysis and Parametrics (JCAP), 2012 – 2017

Editorial Board, International Journal of Information Technology and the Systems Approach, 2007-2009

Journal Reviewer

Active reviewer for top refereed journals including: *IEEE Transactions on Software Engineering, IEEE Systems Journal, IEEE Software, IEEE Computer, Journal of Software: Evolution and Process, Information and Software Technology, Journal of Systems and Software, System Dynamics Review, ACM Transactions on Software Engineering and Methodology, Empirical Software Engineering, Information and Software Technology, International Journal of Computer Integrated Manufacturing, others*, 1996-2017

Recent reviews are recorded at my Publons profile. Some manuscripts reviewed while at NPS since 2008 are shown below, though the list is incomplete.

System Dynamics Review, 2017 (SDR-17-0015)

Journal of Software: Evolution and Process, 2017 (JSME-16-0191)

IEEE Transactions on Software Engineering, 2009, 2010, 2011, 2014 (TSE-2014-34-0054, TSE-2012-04-0093, TSE-2011-03-0066, TSE-2009-12-0406)

IEEE Systems Journal, 2013 (ISJ-RE-13-02596)

IEEE Software, 2009

Empirical Software Engineering, 2010, 2014 (EMSE-D-14-00093, EMSE430 2010)

Journal of Software Maintenance and Evolution: Research and Practice, 2009

Journal of Cost Analysis and Parametrics, 2013 (UCAP-2013-0001)

ACM Transactions on Software Engineering and Methodology, 2011 (TOSEM-2011-0093).

Information and Software Technology, 2010, 2014 (INFSOF-D-10-00109, INFSOF-D-13-0044)

International Journal of Computer Integrated Manufacturing, 2009 (TCIM-2010-IJCIM-0105)

International Journal of Information Technologies and Systems Approach, 2009

Conference Chairmanship

Program Co-Chair, International Conference on Software Process (ICSP), 2009

Publicity Chair, International Conference on Software Process (ICSP), 2008

Registration Chair, International Symposium on Empirical Software Engineering (ISESE), 2004

Program Chair, International Forum on COCOMO and Systems/Software Cost Modeling, 1998-2001

Conference Program Committee Membership

Program Committee Member, International Conference on Systems and Software Process (ICSSP), 2011-2015, 2017

Program Committee Member, Conference on Systems Engineering Research (CSER), 2012-2015

Program Committee Member, Actionable Analytics Workshop at IEEE Automated Software Engineering (ASE), 2015

Program Committee Member, International Forum on COCOMO and Systems/Software Cost Modeling, 1994-Present

Program Committee Member, International Conference on Software Process (ICSP), 2007-2010

Program Committee Member, Software Process Simulation Modeling Workshop, 1998-2000, 2003, 2005-2006

Program Committee Member, International Symposium on Empirical Software Engineering (ISESE), 2004

Program Committee Member, International Conference on COTS-Based Software Systems (ICCBSS), 2004

Program Committee Member, Feedback and Evolution in Software and Business Processes (FEAST) Workshop, 2000

Program Committee Member, California Software Symposium, 1997-1999

Conference - Other

Reviewer for several papers submitted to the Barry W. Boehm Symposium, 2011

Reviewed conference papers for Engineering Education and Educational Technologies (EEET 2010), 2010

Conference Tutorials Organized

D. Houston and R. Madachy, "Tutorial: Understanding the Dynamics of Software Projects: An Introduction to Software Process Modeling and Simulation", Proceedings of the 2014 International Conference on Software and System Process, IEEE, Nanjing, China, 2014

R. Madachy and R. Valerdi, “Tutorial: Systems Engineering and Total Ownership Cost Estimation”, Proceedings of the 22nd Annual INCOSE International Symposium, Rome, Italy, July 2012

Workshops and Panels Organized

B. Clark and R. Madachy, “COCOMO III workshop”, Proceedings of the 30th International Forum on COCOMO and Systems/Software Cost Modeling, Washington, DC, November 2015

B. Boehm and R. Madachy, “Workshop: Empirical Specification and Evaluation of the Ilities”, Proceedings of the 2013 International Software Engineering Research Network Meeting, Baltimore, MD, 2013

B. Clark, R. Madachy, “DoD Software Resource Data Reports (SRDRs) and Cost Data Analysis Workshop”, Proceedings of the 27th International Forum on COCOMO and Systems/Software Cost Modeling, Pittsburgh, PA, 2012

R. Turner, R. Madachy, “Improving Systems Engineering Effectiveness Using Kanban-based Scheduling and a Service-oriented Approach”, Proceedings of IEEE SysCon, March 2012

R. Madachy and R. Valerdi, “Estimation Curriculum Development Workshop”, Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2011

B. Clark and R. Madachy, “Air Force Estimation Guidebook Workshop”, Proceedings of the 26th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2011

B. Clark and R. Madachy, “SRDR Data Analysis Research Workshop”, Proceedings of the 25th International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA, 2010

B. Clark and R. Madachy, “Software Metrics Unification & Software Productivity Domains”, Proceedings of the 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, MA, 2009

Organized NDIA panel “Panel: Systems Engineering Management and the Relationship of Systems Engineering to Project Management and Software Engineering”, 13th Annual NDIA Systems Engineering Conference, 2010

Organized and led expert panel on “Comparisons of Estimation Tools for Next-Generation Processes” at the 23rd International Forum on COCOMO and Systems/Software Cost Modeling, 2008

Organized and led workshop to refine and extend automated risk mitigation advice for Expert COSYSMO framework at the 24th International Forum on COCOMO and Systems/Software Cost Modeling, 2009

Expert panelist on a literature review for the software process modeling field for the 2009 International Conference on Software Process.

Other Professional Service

Representing NPS for the International Software Engineering Research Network (ISERN), 2008-2017

Co-chairman of Los Angeles Software Process Improvement Network steering committee 1996-1998

Expert Witness

I serve as expert witness for selected cases including court deposition involving software Intellectual Property Theft and Breach of Contract. These are applications of software measurement, forensic analysis and project cost/schedule estimation. Recent cases include:

EPES Software, Inc. v. Seed Technologies
Tulsa County District Court, Case No. CJ-2011-4574, 2015-2016

Ticket Innovations, Inc. v. Ticketmaster
Los Angeles County Superior Court, Case No. BC 327228, 2008

Business to Business Markets, Inc. (B2B) v. Kshema Technologies Ltd.
Los Angeles County Superior Court, Case No. BC280932, 2009-2010

Can-Auto Inspections Inc. and Can-Auto Services Inc. v. Vascor, Ltd.
S.C.B.C Action No. S-073725, Vancouver Registry, 2010

c. Other external service activities

My service with the INCOSE San Diego Chapter is heavily involved in local STEM activities, as described in more detail in section III.3.b.