Software Engineering Institute | Carnegie Mellon

25TH ANNIVERSARY
YEAR IN REVIEW

25

DRIVING THE FUTURE OF COMPLEX SYSTEMS

Software Engineering Institute

Carnegie Mellon

MESSAGE FROM THE DIRECTOR

In 2010, the SEI celebrated a quarter century of leadership, excellence, and growth in software engineering. During our anniversary year, we took time to remember how, through DoD-sponsored research, the SEI had grown from its flagship methodology—the Capability Maturity Model Integration (CMMI)—to research advances in software product lines, strides in software architecture, and the establishment of CERT, the world's best-known network and computer security program.

The Institute enjoyed a busy and productive 2010, despite the significant challenge of economic conditions worldwide. It was also a year of beginnings and, sadly, endings.

In September, we welcomed Douglas Schmidt to the staff as deputy director, research, and chief technology officer. Doug's appointment further adds to our technology and research capabilities and is a concrete example of the efforts the SEI is taking to strengthen its focus on research and development.

In October, we were saddened by the death of Watts Humphrey, an engineering icon and SEI Fellow. Watts joined the Institute in the early years—in 1986—and became known as the "Father of Software Quality" for his work establishing the Software Capability Maturity Model, the basis of CMMI. His career and life were extraordinarily productive. His last book, *Leadership, Teamwork, and Trust: Building a Competitive Software Capability,* with co-author Jim Over, was published a few months after his death. We miss him. This report features a retrospective of Watts' journey (see page 6).

Elsewhere in the report, learn about the work we did in 2010 and accomplishments we marked. Here are just a few:

- The SEI launched the CERT Resilience Management Model (CERT-RMM), helping organizations improve their ability to carry out their missions while facing a changing risk environment and potential disruptions (see page 8).

- The SEI published the latest version of the Capability Maturity Model Integration—CMMI Version 1.3, a model that is leaner and more efficient, with clearer high-maturity concepts (see page 12).

- SEI researchers explored ways to strengthen agile practices by applying architecture principles—helping agile meet its potential to help reduce the footprint of traditional software offerings and move to providing continuous delivery of new or improved capabilities (see page 15).

- SEI technical staff took their research to the field—and sky—as they explored tactical implications for service-oriented architecture (SOA): operating on a smartphone to access information from tactical assets such as unmanned aerial vehicles (UAVs) (see page 25).

With 25 years of accomplishments under our belt, we enter the current year with confidence and enthusiasm to pursue the growing opportunities and challenges in software engineering. We are committed to working collaboratively with the global software engineering community—providing leadership where appropriate—and to driving the future of complex systems. We are working to enhance our research while continuing our excellence in transition and acquisition support. I am confident that with our talented, experienced team and your support, we will continue to have significant impact—for many years to come.

Sincerely,
Paul D. Nielsen
Director and CEO

Strategy

The SEI achieves its goals through technology innovation and transition. The SEI creates usable technologies, applies them to real problems, and amplifies their impact by accelerating broad adoption.

Create

The SEI addresses significant and pervasive software engineering problems by
- motivating research
- innovating new technologies
- identifying and adding value to emerging or underused technologies
- improving and adapting existing solutions

SEI technologies and solutions are suitable for application and transition to the software engineering community and to organizations that commission, build, use, or evolve systems that are dependent on software.

The SEI partners with innovators and researchers to implement these activities.

Apply

The SEI applies and validates new and improved technologies and solutions in real-world government and commercial contexts. Application and validation are required to prove effectiveness, applicability, and transition potential. Solutions and technologies are refined and extended as an intrinsic part of the application activities.

Government and commercial organizations directly benefit from these engagements. In addition, the experience gained by the SEI informs
- the "Create" activities about real-world problems and further adjustments, technologies, and solutions that are needed
- the "Amplify" activities about needed transition artifacts and strategies

The SEI works with early adopters to implement the "Apply" activities.

Amplify

The SEI works through the software engineering community and organizations dependent on software to encourage and support the widespread adoption of new and improved technologies and solutions through
- advocacy
- books and publications
- certifications
- courses
- leadership in professional organizations
- licenses for use and delivery
- web-based communication and dissemination

The SEI accelerates the adoption and impact of software engineering improvements.

The SEI engages directly with the community and through its partners to amplify its work.

AMPLIFY

APPLY
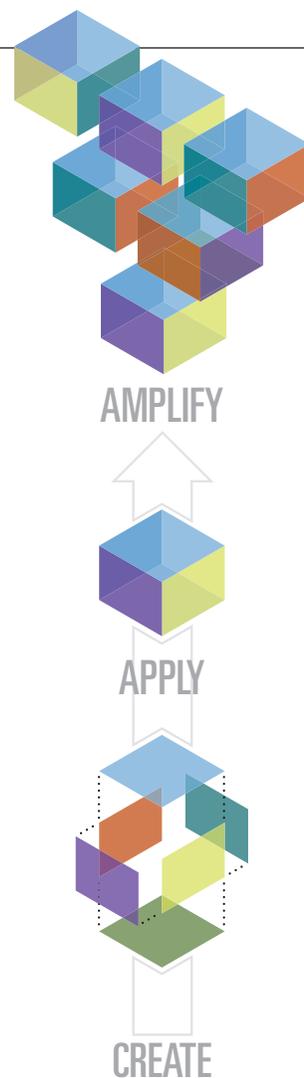
CREATE

Areas of Work

The SEI technical program—created and carried out by world-recognized leaders in software engineering, security, and process management—consists of four technical programs. The SEI also conducts new research into emerging topics in software and systems engineering.

Quality software that is produced on schedule and within budget is a critical component to U.S. defense systems, which is why the U.S. Department of Defense (DoD) established the SEI in 1984. Since then, the SEI has advanced software and systems engineering principles and practices, while serving as a national and international resource for the software and systems engineering communities. As an applied research and development center, the SEI brings immediate benefits to its research partners and long-term benefits to the software industry as a whole.

Operated by Carnegie Mellon University—a global research university recognized worldwide for its world-class arts and technology programs—the SEI operates at the leading edge of technical innovation. The SEI's core purpose is to help organizations improve their capabilities and to develop or acquire the right software, defect free, on time, and on budget, every time.

The SEI offers solutions to customers in the areas of
- Acquisition
- Process Management
- Risk
- Security
- Software Development
- System Design

The SEI's technical focus areas, together with its outreach activities, are aimed at meeting the defined software engineering needs of the DoD. Within these areas of work, the SEI collaborates with defense, government, industry, and academic institutions to continuously improve software-intensive systems. The SEI's body of work in technical and management practices is focused on developing software right the first time, which results not only in higher quality, but also predictable and improved schedule and cost.

Researching Resilience Measurement and Analysis

The SEI is currently researching resilience measurement and analysis using the CERT Resilience Management Model V1.0 (CERT-RMM) as the foundation for the project. Measurement involves transforming management decisions, such as strategic direction and policy, into action and measuring the performance of that action. As organizations strive to improve their ability to effectively manage operational resilience, it is essential that they have an approach for determining what measures best inform the extent to which they are meeting their performance objectives. Operational resilience comprises the disciplines of security, business continuity, and aspects of IT operations.

Meaningful measurement occurs in a context, so this research project is further defined by exploring, deriving, and defining example measures within the context of

selected ecosystems, which are collections of process areas that are required to meet a specific objective. This research is also informed by measurement challenges arising in ongoing customer engagements, results from CERT-RMM appraisals, and insights gained from CERT-RMM Users Group participants.
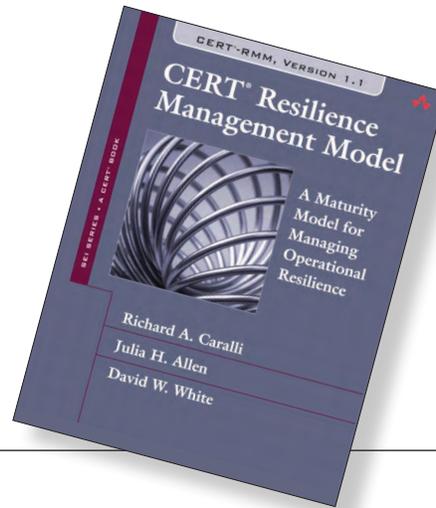
The SEI is researching resilience measurement and analysis as a way of improving the ability of organizations to manage their operational resilience.

SEI Partners with *IEEE Software* Magazine to Present SATURN 2010 Conference

In 2010, the SEI collaborated with *IEEE Software* magazine to host the sixth annual SEI Architecture Technology User Network (SATURN) Conference in Minneapolis. The SATURN Conference provides a forum for software and systems professionals at all levels to meet, share ideas and experiences, network, and learn about new and existing technologies.

"The collaboration with our colleagues at *IEEE Software* added an extraordinary dynamic to this year's SATURN Conference, including the addition of new elements and exceptional talks by IEEE speakers Philipe Kruchten and Linda Rising," said Ipek Ozkaya, SATURN 2010 Conference chair.

Among the new elements was the first-ever SATURN Awards, sponsored by *IEEE Software*. The SATURN Awards honored two outstanding presenters for their contributions to architecture-centric practices. Recipients of the awards were selected by attendee vote.

Following the conference, representatives from *IEEE Software* and the SEI selected six presenters to submit papers on the topics of their presentations for consideration for publication in the January/February 2011 issue.

"We are thrilled to have had *IEEE Software* as a partner for the SATURN 2010 Conference and have already begun planning our collaboration for the SATURN 2011 Conference," said Ozkaya.
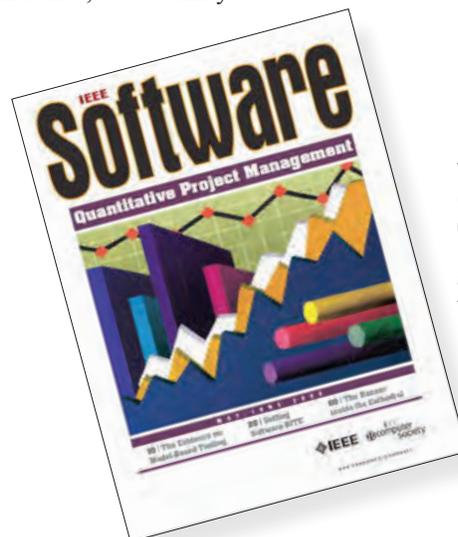
The SEI's SATURN Conference began a collaboration with *IEEE Software* in 2010 that added new elements to the annual conference.

Successful Technical Mentoring Modules Offered Online

With the SEI's help in 2009, US-CERT launched Technical Mentoring (TM) to rapidly educate its technical staff on the latest cybersecurity tools, techniques, intruder attacks, and best practices. The program set ambitious goals and anticipated the need to scale the training so that it could be made available to a large audience. With this goal in mind, the team delivered each session in a classroom environment and also recorded it so it could be posted in the CERT Virtual Training Environment (VTE) for on-demand access. The planning paid off. The demand was so high for these classes that there was often a waiting list. According to Damon Morda, the SEI's TM project lead, "Moving the modules to the VTE made the information available to students at their convenience from any computer with internet access. Even students who attend the live sessions can benefit: they can use the VTE courses as a refresher to reinforce what they learned."

The VTE sessions feature video, audio, transcripts, demos, and interactive labs from the live sessions—making the online experience rich and comparable to being in a classroom. These labs, accessed through a web browser, emulate real networks and add a real-life component to the training; students can use them as a sandbox—a safe place to practice the tools and techniques taught in the lecture.

These modules offer other benefits too. In a recently conducted survey, TM students cited convenience as the main reason they like the CERT VTE. Beverly Faulk, TM project lead at US-CERT, sums it up this way: "In addition to helping us save money in travel costs and time away from the office, the VTE modules leverage the expertise and efforts of SEI staff by making the material available 24/7 to our employees. They can view a module anytime and then review parts of it over and over to really learn the content." Because US-CERT sees great value in this effort, TM is being integrated into its staff training plans.

The TM program is designed to help those in cybersecurity defense detect, analyze, and respond to increasingly sophisticated cyber threats while meeting regulatory requirements. Topics in 2010 included incident handling, vulnerability analysis, insider threats, and malware analysis. In 2011, 12 new TM modules are planned on topics such as analyzing common network protocols, reverse engineering, performing analysis on document-based malware, and using advanced SiLK tools for network analysis. All of these modules will be added to the VTE TM library to form a rich set of online learning materials that can allow US-CERT to train its staff more quickly and more cost-effectively than ever before.

Smart Grid Maturity Model V1.1 Released

Energy and environmental demands are changing. To meet the new energy reality, the nation's power grid must be made more secure, reliable, efficient, affordable, and interoperable. The SEI's smart grid initiative, part of a public-private partnership with government and industry, addresses cybersecurity, architecture, interoperability, and other challenges of modernizing the country's aging power grid.

In 2009, the SEI became the independent steward of the Smart Grid Maturity Model (SGMM). Utilities can use this management tool to understand their current smart grid deployment and capabilities, as well as plan for future smart grid implementation. Almost 100 utilities worldwide have participated in the model as of December 2010.

In September 2010, the SEI released *Smart Grid Maturity Model: Model Definition* Version 1.1. This is the core of the SGMM suite of products, which is available for download at http://www.sei.cmu.edu/smartgrid.
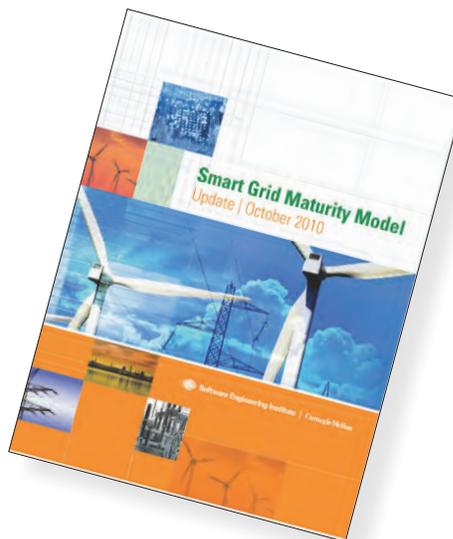
The SEI Smart Grid initiative addresses cybersecurity, architecture, interoperability, and other challenges of modernizing the power grid. The Smart Grid Maturity Model is the centerpiece of the initiative.

Master of Software Assurance Curriculum

In 2010, CERT developed the Master of Software Assurance (MSwA) Reference Curriculum, the first curriculum focused on assuring the functionality, dependability, and security of software and systems. Sponsored by the Department of Homeland Security, this curriculum addresses the growing need for skilled software assurance professionals.

The MSwA curriculum provides guidelines for a well-rounded education on key assurance topics, including assurance across life cycles, risk management, assurance assessment, assurance management, system security assurance, system functionality assurance, and system operational assurance. The curriculum can be used to create a standalone MSwA degree program or an MSwA track within existing software engineering or computer science master's degree programs.

Led by senior researcher Nancy Mead, CERT staff collaborated with educators from Embry-Riddle Aeronautical University, Monmouth University, and Stevens Institute of Technology on this curriculum.

Educational institutions have begun incorporating the curriculum into their offerings. Stevens Institute of Technology now offers a master's degree concentration in software assurance. Other universities are also working to implement the curriculum.

The IEEE Computer Society recognizes this curriculum recommendation as appropriate for a master's program in software assurance.

1927
Watts Humphrey is born on July 4th in Battle Creek, Michigan.

1944
After being diagnosed with dyslexia and failing first grade, Humphrey graduates valedictorian of his high school. In 1944 he enlists in the U.S. Navy where he is initially trained to be a radio gunner. Later he is trained to take Morse code and once again, he earns top marks.

1953
Humphrey begins work at Sylvania in Boston where he was put in charge of a small engineering group designing circuits.

1959
Humphrey begins work at IBM where he initially starts working in hardware, as a computer designer and architect. He transitions into software and becomes the director of programming and vice-president of technical development where he supervises 4,000 software professionals across 15 laboratories and seven countries. This transition from hardware to software management and the challenges Humphrey faced become yet another catalyst for his research into the field of knowledge work.

Father of Software Quality, Watts Humphrey, Dies at 83

Watts Humphrey, founder of the Software Process Program at the Software Engineering Institute and recipient of the National Medal of Technology, died October 28, 2010, at his home in Sarasota, Florida. He was 83.

"Watts Humphrey was one of the icons of software engineering—one of a handful of engineers like Barry Boehm, Fred Brooks, and Vic Basili who have helped define this young field," said SEI director and CEO Paul Nielsen. "Watts brought engineering to software engineering. His work has had immeasurable impact on the global software community, tirelessly urging the community to emphasize quality, measurement, and performance."

Known as the "Father of Software Quality," Humphrey dedicated the majority of his career to addressing problems in software development including schedule delays, cost increases, performance problems, and defects. Humphrey joined the SEI in 1986, after making what he described as an "outrageous commitment to change the world of software engineering."

"As the pioneering innovator behind several important software development processes, Humphrey more than met his promise to change the world of software engineering. His contributions go well beyond methodology and the many awards and accolades he received. For decades, his work inspired software engineers and his colleagues and friends worldwide. His warmth, energy, great spirit, and dedication will be missed by all of us at Carnegie Mellon," said Jared L. Cohon, president of Carnegie Mellon University.

After serving in the United States Navy, Humphrey earned a bachelor's degree in physics at the University of Chicago. He then completed a master's degree in physics from the Illinois Institute of Technology (IIT) and an MBA degree from the University of Chicago.

1986
Humphrey joins the Carnegie Mellon Software Engineering Institute after making what he describes as an "outrageous commitment" to change the world of software engineering by developing sound management principles.

1989
Humphrey authors the book *Managing the Software Process,* the first installment in Addison-Wesley's SEI Series in Software Engineering.

1993
The SEI releases the Personal Software Process (PSP) methodology, developed by Humphrey, which teaches individual software engineers the skills they need to track their own work, adhere to plans, and develop defect-free software.

1994
Humphrey authors the book *A Discipline for Software Engineering.*

1996
The SEI releases the Team Software Process (TSP) methodology, developed by Humphrey, which enables PSP-trained engineering groups to apply integrated team concepts to the development of software-intensive systems, yielding improved productivity, lower costs, and improved time to market.

Humphrey authors the books *Managing Technical People: Innovation, Teamwork, and the Software Process* and *Introduction to the Personal Software Process (PSP).*

1999
Humphrey authors the book *Introduction to the Team Software Process.*

2001
Humphrey authors the book *Winning with Software: An Executive Strategy.*

2005
At a ceremony in the White House, President George W. Bush awards Humphrey the National Medal of Technology for his work in the field of software engineering. Humphrey authors the books *PSP: A Self-Improvement Process for Software Engineers* and *TSP: Leading a Development Team.*

2009
The Association for Computing Machinery (ACM) names Humphrey an ACM Fellow, its most prestigious member category, for his contributions to improving the software engineering process.

2010
Humphrey authors his 12th book, *Reflections on Management: How to Manage Your Software Projects, Your Teams, Your Boss, and Yourself.*

He arrived at the SEI after working for nearly three decades at IBM where, as director of programming and vice-president of technical development, he supervised 4,000 software professionals spread across 15 laboratories in seven countries.

At the SEI, Humphrey established the Software Process Program, led development of the Software Capability Maturity Model, and introduced the Software Process Assessment and Software Capability Evaluation methods. These later became the basis for the development of the Capability Maturity Model Integration (CMMI), a framework of software engineering best practices that has been adopted by thousands of organizations across the globe.

Anita Carleton, director of the SEI's Software Engineering Process Management (SEPM) Program, said Humphrey's passion for his work influenced her decision to come to the SEI.

"He was a wonderful leader and a wonderful man. He set forth an energizing goal and an inspiring mission that we all wanted to be a part of," said Carleton.

After being named the first SEI Fellow—an honor given to individuals who have made an outstanding commitment to the work of the SEI—Humphrey focused on the development of the Team Software Process (TSP), an approach that teaches software engineers the skills they need to make and track plans and produce high-quality software. TSP has been adopted by leading software organizations across the globe including Adobe, Intuit, and Oracle.

For his work in software engineering, Humphrey was awarded the 2003 National Medal of Technology which he received from President George W. Bush in a special ceremony at the White House in 2005. Humphrey was the author of 12 books on software engineering and hundreds of technical reports, journal articles, and columns.

CERT Resilience Management Model Helps Companies Predict Performance Under Stress

What can the popular Slinky spring toy teach us about resilience? The Slinky simply and elegantly illustrates the fundamental concept of resilience: the ability to return to a normal operating condition after being pushed to an operational limit. Stretched beyond its operational limit, a Slinky can no longer function as intended. Like a Slinky, organizations today are stretched by challenges that include security breaches, natural disasters, and equipment failures. As challenges and risks evolve and multiply, it is more critical than ever for companies to know their operational limits and be able to recover from incidents that stretch them to capacity and beyond.

The SEI's CERT Resilience Management Model (CERT-RMM) is helping organizations improve their ability to carry out their missions while facing a changing risk environment and potential disruptions. "The driver for building RMM was to give organizations a better way to express and predict their competency—to give them more control over their destiny in rough times," says Richard Caralli, technical manager of the Resilient Enterprise Management team in the SEI CERT Program.

CERT-RMM establishes an organization's resilience management system: a collection of essential capabilities that the organization performs to ensure that its important assets (technology, information, facilities, and people) stay productive in supporting business processes and services. The model provides guidance for measuring the current competency of essential capabilities, setting improvement targets, and establishing plans and actions to close any identified gaps.

Caralli notes that the word "model" might bring to mind the SEI's well known Capability Maturity Model Integration (CMMI). Although CERT-RMM indeed uses the CMMI architecture for ease of adoption, he points out that "as a capability model, CERT-RMM allows for improvements by process, so there isn't an aggregation of processes or a prescriptive path through the processes." This means that users can adopt CERT-RMM process area by process area or even specific practice by specific practice (within selected process areas) according to their own needs.

More than 1,000 people have downloaded the CERT Resilience Management Model materials—a set of publicly available tools that includes the current model, previous drafts, and the *Code of Practice Crosswalk,* which describes the connection between the model and practices commonly used by organizations in their information security, business continuity, and IT operations departments. Training is also under way: Since its first offering of the Introduction to the CERT Resilience Management Model course in 2009, the SEI has trained 127 people in the fundamentals of CERT-RMM. The SEI is also working with several organizations around the world to incorporate CERT-RMM activities into their normal business routines.

These arrangements range from appraisals to CERT-RMM training tailored to an organization's specific needs. Early research in measuring operational resilience is producing promising results to aid decision makers in making better-informed investment decisions.

More and more companies and organizations are realizing the importance of resilience management, and the CERT-RMM community continues to grow. As the CERT Resilience Management Model book puts it, CERT-RMM is helping these organizations become better Slinkys.

Richard Caralli

"The driver for building RMM was to give organizations a better way to express and predict their competency—to give them more control over their destiny in rough times."

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In 1987, the SEI published the first technical reports describing the Capability Maturity Model (CMM) for Software and a methodology for assessing the process maturity of defense contractors.

Photos courtesy of Beckman Coulter

Alan Willett

"TSP requires that the team is responsible for schedule and quality. The team exceeded its expectations as well as management's."

25 At the urging of the Defense Advanced Research Projects Agency (DARPA) in 1988, the SEI created the first computer emergency response team after an internet worm crippled 10 percent of computers on the internet.

TSP Gives Team Immediate Results, Long-Term Benefits

Tim Lancaster, a staff software engineer with Beckman Coulter, recently worked as part of a team of engineers on a high-pressure, high-profile project that involved the simultaneous management of a large number of challenges, including multiple geographies and multiple disciplines. Beckman Coulter, based in Brea, California, manufactures and markets biomedical testing instrument systems, tests, and supplies. Given the nature of the team's work, it is regulated by the U.S. Food & Drug Administration.

"We, as a team, had a vision for the type of process enhancement we wanted to build. We needed something that was going to give us immediate improvements. There are a large number of process options out there, but we needed something that would work out of the box and allow us to customize it over time," explained Lancaster, who works in Beckman Coulter's research and development group. In March 2009, Lancaster's team piloted the SEI's Team Software Process (TSP), an approach that teaches software developers the skills they need to make and track plans and produce higher-quality products. Groups of developers use TSP to apply integrated team concepts to the engineering of software-intensive systems. TSP builds upon the Personal Software Process, which teaches individual software developers how to track and manage high-quality software development work.

"We could see immediate improvement in our ability to work as a team and the initial quality of the software produced," Lancaster explained. After implementing TSP, the team had better visibility at the detailed, task level into what it was trying to accomplish, how that workload was balanced across team members, and the team's progress against the plan.

Those immediate results led to long-term benefits. Lancaster said his team began hitting all of its milestones more consistently, and the software that it produced remained of high quality.

The team of approximately 15 engineers did face some challenges implementing TSP, chief among them the cultural shift necessary at the personal, team, and organizational levels.

Alan Willett of the SEI's TSP team said that for TSP to be successful in an organization, it's important to have the support of the entire organization, which helped Lancaster's team address the challenges.

"TSP requires that the team is responsible for schedule and quality," said Willet. "The team exceeded its expectations as well as management's."

Lancaster said another challenge the team faced was learning a new way to plan and execute programs, and track its time. As with any long-term change, after the team's early wins, it became a challenge to maintain the same level of early intensity.

Most surprising to Lancaster was the way that TSP helped change team dynamics in a positive manner.

"I would expect to continue to use it on future projects that I am involved in," Lancaster said.

25 Addison-Wesley began publication of the SEI Series in Software Engineering in 1989. Today the series consists of more than 50 books on a wide range of software engineering topics.

With Help from Community Collaborators, CMMI V1.3 Brings Clarity to High Maturity

The latest version of the Capability Maturity Model Integration—CMMI Version 1.3—released in October 2010, is no small milestone. The SEI revised the model over an 18-month period with the help of many experts from the CMMI community, resulting in a model that is leaner and more efficient, with clearer high-maturity concepts.

"The CMMI Model Team worked closely with CMMI users in government and industry to incorporate changes that brought greater harmonization to the Development, Acquisition, and Services models and linked them more closely," said Paul Nielsen, SEI director and CEO. The SEI engaged industry, government, and academic organizations as collaborators on the new version, which includes improvements to the entire product suite: CMMI for Development, CMMI for Acquisition, and CMMI for Services.

"One of the biggest challenges for CMMI V1.3 was the clarification of high maturity," said M. Lynn Penn, director, Process Management, Lockheed Martin Information Systems & Global Solutions, and CMMI V1.3 Industry and High Maturity Team lead. "CMMI V1.3 gave us the opportunity to establish explicit high maturity requirements based on the experience and input from industry contributors."

Lisa Ming, a senior principal electrical engineer with BAE Systems in Nashua, New Hampshire, and a member of the SCAMPI Upgrade Team, added, "It was important to clarify the high maturity process areas as this was the area most often misunderstood and poorly implemented."

Over the lifetime of the CMMI V1.3 project, more than 100 community collaborators from more than 40 organizations all over the world contributed to the development of the new model, meeting regularly at the SEI's Pittsburgh, Pennsylvania, and Arlington, Virginia, offices and collaborating as a distributed team to capture the nuances of important concepts.

Many of the collaborators represented organizations that are also SEI Partners—organizations licensed by the SEI as providers of official SEI services. "Our Partners teach CMMI and conduct appraisals in their work, so they are aware of the needs and challenges facing CMMI users," said Lisa Masciantonio, manager of the SEI Partner Network. "By involving Partners, we gained insight into how users apply the model in real-world situations."

CMMI has long been praised by organizations that have used CMMI to improve their productivity, time to delivery, and adherence to budget. Current economic conditions underscore the value of process improvement efforts. In recent reports to the SEI, organizations have noted some specific benefits of using CMMI, including a 5 percent boost in on-time deliverables, a 19.2 percent improvement in estimation and execution of schedule, and defect discovery and repair savings mitigating a potential 5 to 6.5 months in schedule delay. CMMI Version 1.3 comes at a time when organizations worldwide are examining the way they work and striving to make the most of their effort.

"With the V1.3 improvements, we have a framework for enterprise-wide performance enhancements for both technical and business practices," said Mike Phillips, CMMI program manager at the SEI.

25 In 1991, the SEI published Version 1.0 of the CMM for Software (SW-CMM). More than 30,000 people were eventually trained in the principles and techniques of CMM, and more than 2,400 organizations were assessed on the five-level CMM scale. The SW-CMM was upgraded to CMM Integration (CMMI) in 2000.

Photo courtesy of Lockheed Martin

Lisa Masciantonio

"By involving Partners, we gained insight into how users apply the model in real-world situations."

Mike Phillips

"With the V1.3 improvements, we have a framework for enterprise-wide performance enhancements for both technical and business practices."

25

The SEI introduced in 1993 the SEI Personal Software Process (PSP) methodology, by which individual software engineers use disciplined, repeatable practices to produce software.

Ipek Ozkaya

"The concrete benefit of having real options involves the tradeoff between 'Do nothing, possibly spend a lot later and do just a little, later spend less.'"

Nanette Brown

"End users demand enhancement agility, the ability to keep adjusting a product to emerging needs through the addition of new features."

25 The 1993 *Practitioner's Handbook for Real-Time Analysis: Guide to Rate Monotonic Analysis (RMA) for Real-Time Systems* describes the use of RMA techniques, which became widely adopted and were credited with helping NASA restart the Mars Pathfinder in 1998 after a system shutdown.

Architectural Agility: Working to Strengthen Agile Practices

Today's software users want new features quickly— as soon as the need for them arises. In response, SEI researchers are exploring ways to reduce the footprint of traditional software offerings and move to providing continuous delivery of new or improved capabilities. Nanette Brown, Robert Nord, and Ipek Ozkaya are working to strengthen agile practices by applying architecture principles. In the context of agile release planning, informed anticipation with just enough architecting can help bring the right balance of agility, innovation, and speed on the one hand, and system governance, flexibility, and planning for future needs on the other.

"End users demand enhancement agility, the ability to keep adjusting a product to emerging needs through the addition of new features," said Brown. In contrast to traditional methodologies, agile software development methods focus on delivering observable benefits, early and often, to the end user through working software. "What's often overlooked is the crucial role of architecture in keeping products viable as they undergo enhancements."

In the agile approach, functional user stories illustrate that particular capabilities are required. "These collected stories are prioritized by end-user need," said Nord. "But almost every story has an impact on upcoming stories. So optimizing value to the user requires teams to look ahead and anticipate future needs."

Stories also have dependencies upon the architectural elements of the system. For example, effective architecture can ensure that adding a particular capability won't hinder the performance of a future capability. The ability to identify and analyze these dependencies and address them during development is what the SEI team calls architectural agility. This approach allows for benefits derived from architectural activity to be allocated either to the current release or to future releases.

With engagement of the just-in-time model, delivery of features is not delayed pending the completion of exhaustive requirements and design activities and reviews. Concurrently, architectural agility maintains steady focus on continuing architectural evolution to support emerging features.

Architectural agility requires just enough anticipation. Such architectural anticipation must be informed, a state achievable through certain tools—dependency analysis, real options analysis, and technical debt management.

After a development team selects capabilities to develop within each iteration, it then identifies the architectural elements it must implement to support them. The team also considers non-functional requirements, such as modifiability and security, and requirements of stakeholders beyond the user category. Through such dependency analysis, the development team can prioritize and schedule work within a release.

Real option analysis examines how taking a certain action today provides an option for action in the future. A higher level of uncertainty provides a greater reason to defer decisions. Thus, the agile community has incorporated the concept of real options in separating immediate concerns from those that can wait.

In addition to identifying dependencies within a given release, architectural agility also requires understanding the deliberate shortcuts taken to achieve high-priority functionality. These shortcuts must be revisited at each iteration, as they often incur technical debt—a need for extra effort later.

"The cost and benefit tradeoff is often misrepresented as a choice between doing nothing and spending a lot of time on something you may not need," explained Ozkaya. "The concrete benefit of having real options involves the tradeoff between 'Do nothing, possibly spend a lot later' and 'Do just a little, later spend less.'"

After a development team selects capabilities to develop within each iteration, it then identifies the architectural elements it must implement to support them.

The 1994 technical report, *An Introduction to Software Architecture*, by David Garlan and Mary Shaw, described the design problems inherent in large systems and provided an introduction to the emerging field of software architecture. This soon became a major focus area for the SEI.

Experiments Show Value of Service-Oriented Computing and Smartphone Technology for Situational Awareness

A ground patrol in a war zone has just learned that a roadside bomb detonated near a Stryker armored vehicle that was on a resupply mission to an outpost—wounding four warfighters, two critically. The patrol sets out to reach the Stryker and its crew, knowing that it must efficiently cross unfamiliar terrain and pass near several villages. They want to keep away from main roads to avoid ambush and roadside bombs. They know that information about the area may be available from electronic data sources, and updates on enemy activity can be accessed from several sensor devices.

Ed Morris, one of the SEI researchers who investigated the technology issues embedded in this scenario, pointed out that the "military needs some strategy that simplifies the connections for interoperability between sensors and mobile, handheld devices in tactical environments."

"We know that service-oriented computing, in the service-oriented architecture paradigm [SOAP], provides a standardized interface for the exchange of information," Morris continued. "But can SOA work on a smartphone in an environment where network bandwidth and availability are limited?"

The SEI team implemented a series of prototypes to test the viability of using service-orientation (via SOAP-based web services) and mobile handheld technologies (Android) to access information from tactical assets, including unmanned aerial vehicles (UAVs), and to use this information to enhance the situational awareness of warfighters.

The team developed prototypes in the SEI RTSS Concept Lab in Pittsburgh and tested them in field experiments at the USSOCOM-NPS Field Experimentation Cooperative Capabilities Based Experimentation (CBE) lab at Camp Roberts, California, during May and August 2010.

Through those experiments, the SEI researchers— Morris, William Anderson, Dan Plakosh, Joseph Seibel, and Soumya Simanta—found that a subset of SOA (using SOAP) is viable in tactical environments and that smartphones provide a sophisticated software development platform.

They analyzed the performance of secure (256-bit AES encryption) video feeds using SOAP-based messaging displayed on the smartphone, finding it to be comparable visually to video feeds displayed on standard desktop machines. Simanta pointed out two caveats: The use of SOAP leads to large message sizes that may be problematic in networks with highly constrained bandwidth; and to make SOA practical, the SEI team made atypical SOA choices, including the use of UDP as a transport layer protocol rather than the more common TCP/HTTP combination.

In addition, modern smartphones exceeded the team's expectations—they can be roughly as powerful as a circa 2000 desktop machine and provide a sophisticated software development platform.

Finally, the experiments identified other engineering questions to consider in follow-on work, including improving performance through support of on-demand messaging and implementing a reliability layer.

SEI research into service-oriented computing on handheld devices in resource-poor environments can aid others in addition to warfighters. "Cities and ports may have many sensors for radiation detection," Morris explained. "First responders to a radiation leak scene could carry smartphones to access data from those sensors. Or in the aftermath of an earthquake, hurricane, flood, or some other natural disaster, the many agencies responding must be able to share information accessed from many different types of sensors."

RTSS Concept Lab

RTSS is the SEI's Research, Technology, and System Solutions Program. RTSS established and runs the Concept Lab to encourage the development of engineering prototypes that further understanding of new system capabilities and help explain these capabilities to SEI stakeholders.

Ed Morris

"We know that service-oriented computing, in the service-oriented architecture paradigm, provides a standardized interface for the exchange of information. But can SOA work on a smartphone in an environment where network bandwidth and availability are limited?"

25 The Capability Maturity Model Integration (CMMI) project was initiated in 1997 by the DoD to establish a framework to accommodate current and future models and bring the CMM approach into line with international industry standards.

Looking Forward: An SEI Innovation Center

Global industry and academia drive R&D and innovation in areas of great need to the Department of Defense (DoD) and the Intelligence Community (IC) for operating in cyberspace, but the current state of DoD and IC information technology architectures, applications, services, and development approaches inhibits the timely and seamless incorporation of research and innovation. As the government continues to migrate from proprietary, mission-specific, hardware-centric systems to open, flexible, software-centric architectures, a broad set of needs has emerged to accelerate the adoption of innovation.

In pursuit of accelerating innovation, key questions arise: Is acceleration possible, and if so, how? What could help the DoD and the IC expeditiously transition and integrate rapidly developing research and innovation into both unclassified and highly classified environments? What is needed to facilitate this connection between the needs and opportunities presented by the DoD and the IC, and the new technological innovations presented by industry and academia?

"An SEI Innovation Center could perform accessible and unclassified R&D and support rapid prototyping and transition activities as needed," said Terry Roberts, SEI executive director, Acquisition Support Program/ Interagency and Cyber. "Such a center focused on fast-tracking new technologies and products would address key needs of the DoD and IC."

Those needs include
- capabilities for maintaining high levels of cyber performance, security, standards, and assurance for interoperable IT architectures, applications, and services
- scalable processing of high volumes of incoming data (including network data, imagery, video, and other intelligence information)
- assured, scalable, and extensible data storage and processing architectures
- data integration and interoperability, including global search and discovery mechanisms and fused situational-awareness information
- phased analytic processing across multiple massive-scale data sets and feeds
- usable information systems that allow analysts and operators to focus on mission rather than the mechanics of accessing and viewing information

The SEI and Carnegie Mellon University have finalized initial sponsorship with a leading defense agency for the creation of a innovation center Concept of Operations (CONOPS). The CONOPS will be flexible and scalable, expanding as appropriate to include several DoD and IC agencies, and will collaborate with other innovative academicians and industry participants. Co-located with Carnegie Mellon, a nationally recognized technology pioneer with world-class programs in computer science, engineering, and cybersecurity, the SEI is well positioned to establish a center that is
- aligned with the SEI, a mature DoD federally funded research and development center and a trusted third-party institute
- organized to provide a creative outreach mechanism to industry
- created as an unclassified facility to advance and transition innovation between academia and industry to provide direct impact on DoD/IC problems
- approached incrementally with a few critical initiatives that allow the center to evolve and become more effective and efficient in meeting DoD and IC customer requirements

A crucial design element of the center's structure is the capacity to effectively transition cyber-centric solutions to the DoD and IC. Collaboration and interaction with dynamic customer demands and innovation from across the spectrum of research organizations is vital to the success of the center. The center will have the capability to engage an expansive consortium of industry partners and the capacity to leverage and reach the defense industrial base and key IT companies. To accomplish this objective, the center plans to synergistically integrate a number of elements (see diagram, page 19).

Doug Schmidt, SEI deputy director, research, and chief technology officer, explained: "This model leverages the federal investment in cyber-, architecture-, and computing-related basic research while integrating the federal service labs to afford rapid transition to the DoD-IC infrastructure. The inclusion of a federally funded research and development center provides an opportunity to blend response to classified needs and link the center to broader cyber and architecture response capabilities." The CONOPS is expected to be completed and prototyped in 2011, with the center being fully operational in early fiscal year 2012.

25 In 1997, the SEI Architecture Tradeoff Analysis Method (ATAM) framework was developed and used on the Army's Mortar Fire Control Systems to identify critical architectural risks. The ATAM is now used worldwide to evaluate software architectures.
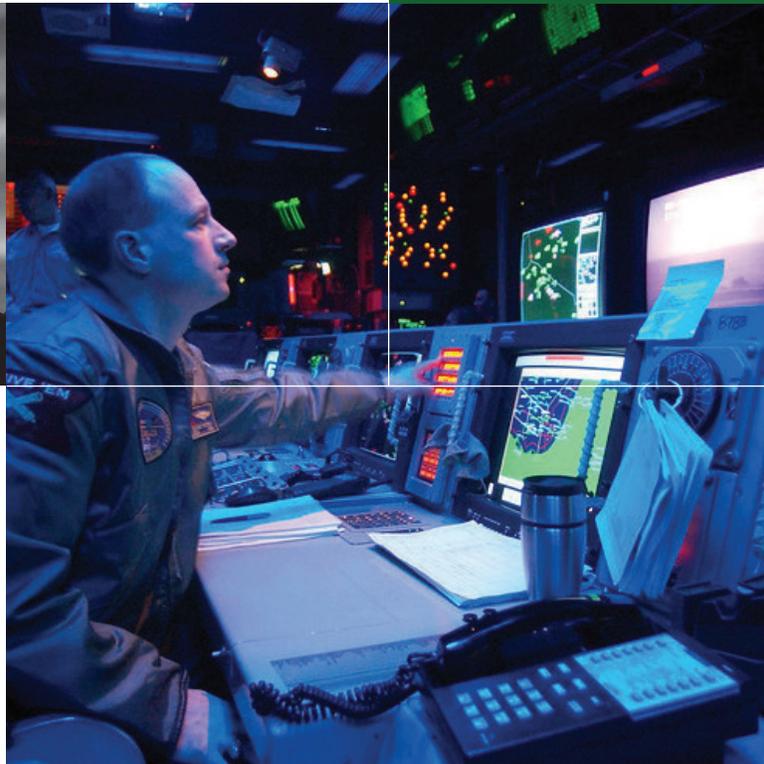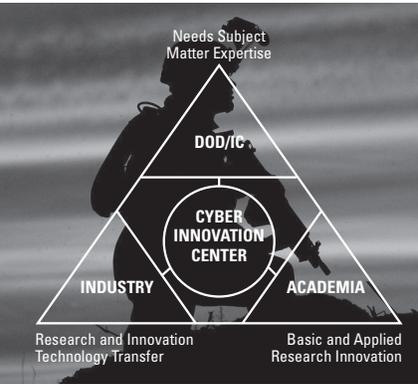
Terry Roberts

"An SEI Innovation Center could perform accessible and unclassified R&D and support rapid prototyping and transition activities as needed."

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The first book on software architecture for practitioners, *Software Architecture in Practice*, was written by SEI technical staff members in 1998 and won the prestigious JOLT award from *Software Development* magazine. This book was followed by three other SEI books on software architecture, which together have sold more than 40,000 copies.
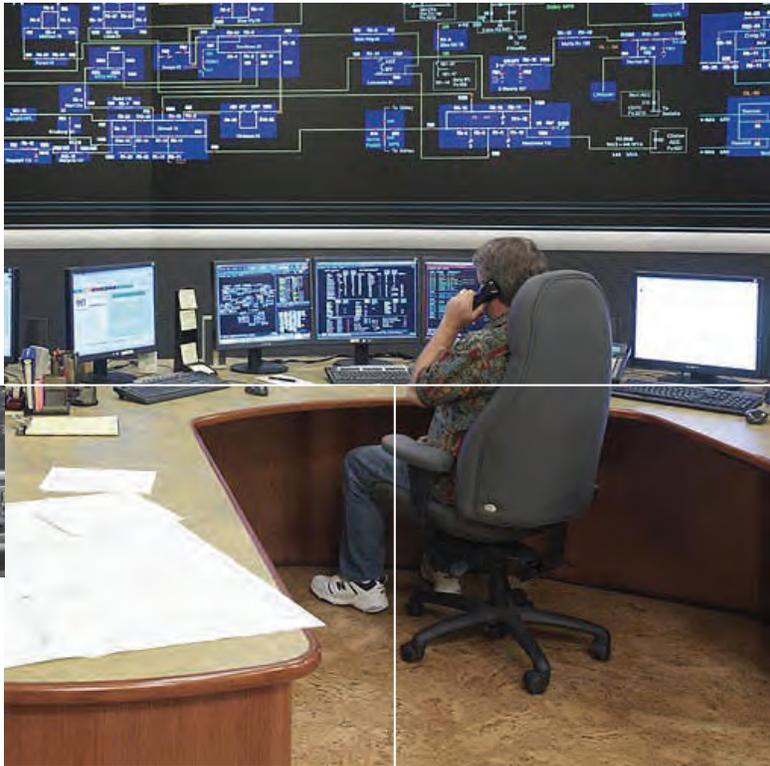
Photo copyright and courtesy of Barco
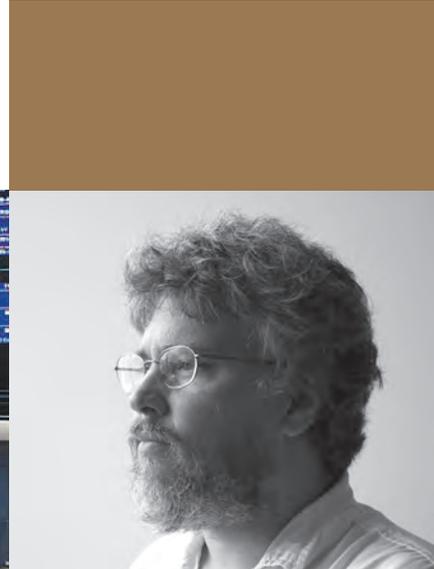
Robert Seacord

"Even though certification of conformance to a secure coding standard provides no guarantee of overall system security, the CERT secure coding standards establish an ambitious goal for software development, and SCALe conformance testing demonstrates a commitment to secure coding and software quality."

25 In 2001, the SEI established the Acquisition Support Program to help the DoD and other government organizations improve their practices in acquiring software-intensive systems.

SCALing the Software Security Cliffs

Software vulnerability reports and reports of software exploitations continue to grow at an alarming rate, and a significant number of these reports result in technical security alerts. To address this growing threat to governments, corporations, educational institutions, and individuals, systems must be developed that are free of software vulnerabilities. For example, improving the security of control systems that enable the automated control of our energy production and distribution is critical for protecting the energy infrastructure and the integral function that it serves.

Coding errors cause the majority of software vulnerabilities. A study published by IEEE reported that 64 percent of the nearly 2,500 vulnerabilities in the National Vulnerability Database in 2004 were caused by programming errors.

The CERT Secure Coding Initiative (SCI) takes a comprehensive approach to identifying and eliminating software vulnerabilities and other flaws. The SCI is leading a community effort to develop secure coding standards and automated analysis tools to help programmers code securely. Secure coding standards provide a detailed enumeration of coding errors that have caused vulnerabilities, along with their mitigations for the most commonly used software development languages. CERT also works with vendors and researchers to develop analyzers that can detect violations of the secure coding standards.

Improving software security by implementing code that conforms to the CERT secure coding standards can be a significant investment for a software developer, particularly when refactoring or otherwise modernizing existing software systems, according to Robert Seacord, SCI manager. He said, "However, a software developer does not always benefit from this investment because it is not easy to market code quality."

To address these problems, Seacord and team have created the Source Code Analysis Laboratory (SCALe) that offers conformance testing of software systems to CERT secure coding standards. The SCALe evaluates client source code using multiple analyzers, including static analysis tools, dynamic analysis tools, and fuzz testing. CERT team members report any deviations from secure coding standards to the client, who may then repair and resubmit the software for re-evaluation. Once the process is completed, a report detailing the conformance or nonconformance to each secure coding rule is provided to the client.

An overview of the conformance testing process is shown in the following diagram.

1. **Client contacts CERT.** The process is initiated when a client contacts CERT with a request to certify a software system.

2. **CERT communicates requirements.** CERT team members communicate requirements to the customer, including (1) selection of secure coding standard(s) to be used, (2) a buildable version of the software to be evaluated, and (3) a build engineer.

3. **Client provides buildable software.** Client selects standard(s), provides a buildable version of the software to be evaluated, and identifies the build engineer, who is available to respond to build questions about the system.

4. **CERT selects tool set.** CERT team members choose and document the tool set to be used and procedures for using that tool set in evaluation of the system.

5. **CERT analyzes source code and generates conformance test report.** CERT members evaluate the system against specified standard(s) and provide the conformance test results to the client. If the system is found to be conforming, they issue a certificate and terminate the conformance testing process.

6. **Client repairs software.** Client has the opportunity to repair nonconforming code. Client sends system back to CERT for final evaluation.

7. **CERT issues conformance tests results and certificate.** CERT members re-evaluate the system using the tools and procedures used in the initial assessment. CERT provides the conformance test results to the client and, if the system is found to be conforming, a certificate.

"SCALe does not test for unknown code-related vulnerabilities, high-level design and architectural flaws, the code's operational environment, or the code's portability," said Seacord. "Conformance testing is performed for a particular set of software, running in a particular translation environment under particular control options and executing in a particular execution environment."

It is possible that software that conforms to a secure coding standard is insecure. For example, a software system whose code conforms to the *CERT C Programming Language Secure Coding Standard* could implement an insecure design or architecture. However, conforming software systems are likely to be more secure than nonconforming or untested software systems. Seacord said, "Even though certification of conformance to a secure coding standard provides no guarantee of overall system security, the CERT secure coding standards establish an ambitious goal for software development, and SCALe conformance testing demonstrates a commitment to secure coding and software quality."

CERT Supports and Develops Certification Program for Government Cybersecurity Initiative

In 2010, CERT continued its ongoing efforts to support the Department of Homeland Security (DHS) with implementation of the Trusted Internet Connection (TIC) Initiative. The TIC Initiative is an effort, begun in 2007, to optimize individual network services into a common solution for the federal government, improving the government's security posture and incident response capabilities by reducing and consolidating the overall number of external connections to the internet.

As part of the TIC Initiative, a team from the CERT Program, in support of the Federal Network Security (FNS) branch within DHS, developed a set of products that are used to assess the compliance of Trusted Internet Connection Access Providers (TICAPs) against a set of technical capabilities mandated by the Office of Management and Budget. The assessment process is known as the Cybersecurity Compliance Validation (CCV) program.

In addition to developing the tools to assess the TICAPs, the CERT CCV team also developed a certification program, which trains and certifies government and technical experts to serve on CCV assessment teams. Assessment teams consist of a government lead and technical team members who visit government facilities and interview staff, collect data, and review capabilities of devices, operations and services for TICs, network operations centers, and security operation centers.

"The CCV certification program was created to provide the federal agencies and Networx providers—contract vehicles that provide a full range of communications services to federal government agencies—with assurances that the CCV teams were deployed with qualified subject matter experts and that the teams followed well established methods, processes, and techniques when conducting the CCV assessments," said Georgia Killcrece, CCV project team lead for CERT.

"We also wanted to assure that these assessors abided by U.S. government- and SEI-established rules of conduct for protecting information and handling data appropriately as well as maintaining confidentiality of the TICAPs that were assessed," said Killcrece.

Each position on the CCV assessment teams has a set of certification requirements, some with more requirements than others. For example, those who are scheduled to become a CCV assessment team lead must complete the full certification process, which includes training, an examination, and observation.

"The CCV certification that has been developed, and for which CERT is the steward, is an acknowledgment that the individual has the required set of skills, attained a defined level of understanding related to the CCV assessment methods (the ability to assess against the TIC Reference Architecture body of knowledge), and also is able to maintain commensurate expertise over a specific period of time," said Killcrece.

Killcrece and her team also developed a transition package for the CCV project that was delivered to the DHS. The transition package provides DHS with the methods, training, documentation, database, and certification materials for conducting CCV assessments. The package allows the SEI to continue to certify and register CCV assessment teams, while allowing DHS to continue to expand its Compliance and Assurance Program requirements and continue to conduct assessments that will ultimately contribute to keeping the U.S. government's federal digital infrastructure secure.

25 In 2003, the SEI responded to the rapid expansion of international software development with its first international office: SEI Europe in Frankfurt, Germany.

Georgia Killcrece

"The CCV certification program was created to provide the federal agencies and Networx providers— contract vehicles that provide a full range of communications services to federal government agencies— with assurances that the CCV teams were deployed with qualified subject matter experts and that the teams followed well established methods, processes, and techniques when conducting the CCV assessments."

Photo courtesy of Lockheed Martin

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Major General Paul D. Nielsen was named SEI director in 2004. Nielsen previously commanded the Air Force Research Laboratory at Wright-Patterson Air Force Base. In July 2009, he was reappointed to a second five-year term.

Jeff Thieret

"This approach fosters software risk reduction processes throughout the acquisition lifecycle."

Tom Merendino

"Typically, programs focus on functional requirements and underemphasize the nonfunctional aspects of the system. Worse yet, nonfunctional aspects aren't identified at all. This becomes a significant problem later since stakeholder expectations almost always lie with the system qualities."

25

In 2005, Watts S. Humphrey received the National Medal of Technology for his contributions to the software engineering community. The National Medal of Technology is the highest honor awarded by the President of the United States to America's leading innovators.

Technical Architecture Challenges in Unmanned Aerial Vehicles

Getting any two parties, let alone leaders of independent acquisition programs, to agree on complex system architecture decisions is a daunting task. To meet this challenge, the SEI is helping the unmanned aircraft systems (UAS) acquisition community solve its dynamic software technology challenges.

The mission of the Air Force's Global Hawk is to provide autonomous, long-endurance, near-all-weather, day-night, near-real-time, wide-area reconnaissance and surveillance imagery and signals intelligence collection and dissemination. Global Hawk is composed of segments for air vehicle, ground, payload, and support.

The SEI team focuses on bringing software technology and acquisition best practices to Global Hawk's Ground Segment Re-Architecture (GSRA) program. The aim of GSRA is to acquire a modern, redesigned ground segment that is compliant with emerging DoD common ground architecture guidelines and standards.

Initially enlisted to provide technical expertise and guidance to the GSRA PMO, the SEI team of Charles (Bud) Hammons, Tom Merendino, and Jeff Thieret has seen its role rapidly expand in technical scope and impact. Its work has become a catalyst for pursuing architectural synergy among the Air Force's GSRA program, the ground segment portion of the Navy's Broad Area Maritime Surveillance (BAMS) UAS program, and the common ground segment architecture being developed in parallel by the DoD's UAS Control Segment Working Group (UCS-WG).

A June 2010 agreement recognized the pursuit of synergy between GSRA and BAMS: "Air Force and Navy officials partnered to maximize commonality, eliminate redundant effort, and increase interoperability between BAMS unmanned aircraft systems and the Global Hawk system."

The SEI team provides technical guidance that recognizes the importance of early identification of architectural quality attributes (i.e., nonfunctional aspects) to realizing subsequent satisfaction of stakeholders' expectations for acquired systems. Merendino said, "Typically, programs focus on functional requirements and underemphasize the nonfunctional aspects of the system. Worse yet,

nonfunctional attributes aren't identified at all. This becomes a significant problem later since stakeholder expectations almost always lie with the system qualities." The SEI team has helped GSRA and the UCS-WG identify and define these nonfunctional aspects. As a result, the GSRA and UCS-WG communities are adopting and incorporating these quality attributes into the engineering design artifacts. These nonfunctional aspects will guide key architectural design decisions that promote the most important stakeholder quality and synergy expectations as part of the development process. According to Jeff Thieret, the SEI team lead, "this approach fosters software risk reduction processes throughout the acquisition lifecycle."

There are future challenges also, involving codification of a means to measure architectural synergy. Looking ahead, Hammons said, "A big-bang approach is not likely to work. It's challenging to identify a graduated means for programs of record to conform to a common architecture. Programs must be able to chart a path into the common ground-system architecture via on- and off-ramps that reflect where programs are and where they want to go. Measures of success for determining how well an architecture exhibits synergy are also challenging."

The SEI introduced a new research agenda on Ultra-Large-Scale Systems in 2006.

Integrated Solution Provides 'What' and 'How' for New System Development

Half a continent away from its Pittsburgh research headquarters, the SEI demonstrated that two of its proven technologies can work together—and work well. In a project for Bursatec, the technology arm of Grupo Bolsa Mexicana de Valores (BMV, the Mexican Stock Exchange), the SEI blended its Team Software Process (TSP) and architecture-centric engineering (ACE) methods to support the development of a new trading engine.

BMV determined that Bursatec should replace three existing trading engines (stocks, derivatives, and futures) with one system developed in house. Bursatec needs its new system to have blazing speed, to handle spikes in trading volume, and to work flawlessly.

"Because of the requirement for high quality, we suggested using TSP to launch an architecture team and manage the process of developing an architecture as well as the actual system's code," said Greg Such, SEI business manager.

"TSP helped the Bursatec teams and individuals manage their development work," said Jim McHale, TSP coach for the project. "ACE methods defined the work to be done."

"The ACE concept of identifying quality attributes fits very nicely into TSP," Such added. Quality attribute scenarios are derived from the business goals. The quality attributes are used to plan the architecture tasks. The architecture is analyzed to demonstrate how the scenarios are realized and, hence, how business goals are satisfied.

In 2010, the SEI team embedded in TSP some elements of a suite of ACE methods—Business Thread Workshop (BTW), Quality Attribute Workshop (QAW), Attribute-Driven Design (ADD) method, Active Reviews for Intermediate Design (ARID) method, and the Architecture Tradeoff Analysis Method® (ATAM®).

Working with Bursatec to develop an architecture also involved coaching its developers. According to the SEI's Felix Bachmann, ACE team lead for the project, architecture coaching "followed a program of 'tell, watch, teach, then disengage.'"

Every two weeks, an SEI architecture coaching team spent two days with the Bursatec group—the first day looking backward and assessing current state and the next day looking forward to plan the next two weeks of architecture activities. Architecture tasks enabled the development team to create a skeleton system that allowed incremental addition of features. This resulted in releases that were shown to the stakeholders for early feedback.

Under this coaching approach, the Bursatec architects produced an instantiation of the architecture every six weeks.

Bachmann added that the combination of the TSP and ACE methods "provides the means and language to communicate with management about what they need the system to do, what the state of the design is, and what the design team can do to provide it."

Throughout 2010, system development using TSP and ACE progressed on schedule and within budget, with early tests confirming performance that far exceeded specifications. Bursatec is seeing that "architecture provides a sound base for design, and TSP assures implementation quality," said McHale.

"In the highly competitive and dynamic environment of exchanges, technology is clearly one of the key differentiators between competitors as well as a survival factor. Having the right technology at the right cost is crucial for exchanges to survive," said Enrique Ibarra, senior vice president of technology at BMV and general manager of Bursatec. "We have the firm commitment of creating the fastest possible trading engine for the Mexican markets, with the right quality attributes needed by the business, and built with the highest possible software quality. The work with the SEI and their guidance have contributed greatly to our objectives."

Jim McHale

"TSP helped the Bursatec teams and individuals manage their development work. ACE methods defined the work to be done."

Enrique Ibarra

"We have the firm commitment of creating the fastest possible trading engine for the Mexican markets, with the right quality attributes needed by the business, and built with the highest possible software quality. The work with the SEI and their guidance have contributed greatly to our objectives."

Felix Bachmann

"[The combination of the TSP and ACE methods] provides the means and language to communicate with management about what they need the system to do, what the state of the design is, and what the design team can do to provide it."

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CMMI for Acquisition (CMMI-ACQ) was launched in 2006 in collaboration with General Motors, Hewlett Packard, Defense Threat Reduction Agency, the CMMI Steering Group, and others. This CMMI model helps those who select and purchase products and services to improve relationships with their suppliers.

Gene Miluk

"With AIM, organizations often can see results in 10 to 15 months. In the past, it could take years to see similar results."

Tim Chick

"AIM integrates and leverages the best elements of TSP, CMMI, and Six Sigma, resulting in a repeatable approach to creating and maintaining world-class performance at the individual, team, project, and organizational levels."

25

In 2007, the SEI CERT Program introduced the Resiliency Engineering Framework model. In 2009, release of an expanded, revised version of the framework began under a new name, the CERT Resiliency Management Model.

Accelerated Improvement Method Provides Integrated Process Improvement Approach

When SEI clients began pointing out the complementary nature of SEI products—specifically, the Capability Maturity Model Integration (CMMI), the Personal Software Process (PSP), and the Team Software Process (TSP)—the SEI saw an opportunity to merge the advantages of these separate but related process-improvement approaches. The possibility of combining CMMI's organizational top-down approach with the TSP's individual- and project-oriented, bottom-up approach promised an incredibly efficient and effective synergy. The result: the Accelerated Improvement Method (AIM), an integrated method that allows organizations and the teams within them to drastically reduce costs and rapidly improve quality and schedule predictability.

According to Gene Miluk of the SEI TSP team, field results confirm that AIM combines the best components of each of these offerings.

"CMMI contributes a set of specifications for high-quality process at the organizational level; PSP and TSP provide high-performance operational processes on the individual and team levels. In addition, AIM incorporates Six Sigma techniques and a comprehensive embedded measurement system," Miluk said.

Two independent teams used a structured development methodology to develop AIM. The TSP team first mapped and evaluated TSP practices and artifacts to CMMI. While examining the artifacts that TSP produces and exploring how they would satisfy CMMI practices, it became apparent that there were gaps. Miluk and Jim McHale, also a member of the TSP team, then developed improvement proposals based on the gap analysis to maximize compliance with CMMI.

Tim Chick of the SEI led the improvement of the TSP infrastructure to fill as many gaps as possible. The AIM processes were piloted with CGI, a global company that specializes in IT, business process, and professional services. The team installed the original iteration of TSP and then conducted a gap analysis with the Standard CMMI Appraisal Method for Process Improvement (SCAMPI B). Next, they held a launch with both the traditional TSP development team as well as the engineering process group. After

some organizational tailoring and a final cycle of development using the tailored processes, a SCAMPI A appraisal was performed. CGI achieved Maturity Level 3 in less than 15 months by using AIM. Additionally, defects from previous versions were reduced by more than 50 percent, while productivity improved by more than 35 percent.

"AIM integrates and leverages the best elements of TSP, CMMI, and Six Sigma, resulting in a repeatable approach to creating and maintaining world-class performance at the individual, team, project, and organizational levels," said Chick.

With AIM, results are quick, impressive, and measurable, starting from the first project. "AIM provides a very compelling value proposition: known up-front investments coupled with a comprehensive embedded measurement program means that sponsors of process improvement efforts can get reliable ROI data based on their own environment and experience," Miluk said. "With AIM, organizations often can see results in 10 to 15 months. In the past, it could take years to see similar results."

AIM makes CMMI and TSP viable for customers in medium and small companies. Each component in AIM has proved to help organizations reduce costs and improve quality and schedule predictability. For new projects, AIM provides a way to quickly form high-performing, productive, and cost-effective teams. For projects already under way, AIM augments a team's efforts, helping it to get maximum performance and quality.

SEI insider threat research efforts were published in 2007.

Linear Decision Diagrams: A New Data Structure for Verification of Software

Verification of software presents unique challenges. Material things have limits: We can only make things so large, such as airplanes and ships, or so small, such as chips and circuits. But software is unbounded.

"Because software has no significant physical limits, the only thing that limits it is the human brain," said SEI researcher Sagar Chaki. And most problems related to software verification are undecidable, which means that it is impossible to construct an algorithm that can solve them correctly in all cases. This does not mean that nothing can be done; rather it means that we must limit our expectations. For example, completely automated techniques for verifying software can be created, but the software they work on must be severely restricted. Other techniques can work on software that is not restricted, but they require expert human guidance. Techniques that are fully automatic and do not require restricted software exist, but they might produce false negatives.

"Because all the most interesting problems in verification are either undecidable or exponential, they are rarely completely solved," said Ofer Strichman, a visiting scientist at the SEI. "The main goal of this field is to find automatic methods that will work on many real cases." Over the past three years, Chaki, Strichman, and fellow SEI researcher Arie Gurfinkel have devoted much of their research efforts to improving methods that can automatically verify correctness aspects of ever more complex software systems. Their work is in the area of formal verification, which treats programs as mathematical entities and relies on logic and algorithms to show not only that a defect does not occur in a particular test case, but to guarantee that a defect is mathematically impossible.

They began their current research by developing a joint application of two techniques already used for verification: static analysis with numeric abstract interpretation and software model checking with predicate abstraction. This led to the development of linear decision diagrams (LDDs), a data structure that extends binary decision diagrams (BDDs) by allowing the use of linear inequalities instead of Boolean variables. LDDs enable a more efficient way to reason about numeric constraints and are well suited for the

existential quantification of numeric variables, which is typically a bottleneck in the verification process. Hence, any improvement in this particular step makes it easier to verify programs. Their experiments revealed that through the use of LDDs, some programs that could not be verified with any known technique can now be verified in a short amount of time.

In 2011, the SEI continued this research by using LDDs for verifying the correctness of software when it is migrated to multi-core platforms, a task that has been difficult for other testing techniques due to the large number of interactions among components. "We believe this work is a stepping stone to future approaches for verification of concurrent software that runs on multi-core platforms," said Gurfinkel.

To allow others to build on this work, an implementation of the LDDs and a set of benchmarks resulting from their application have been made available at http://lindd.sourceforge.net.
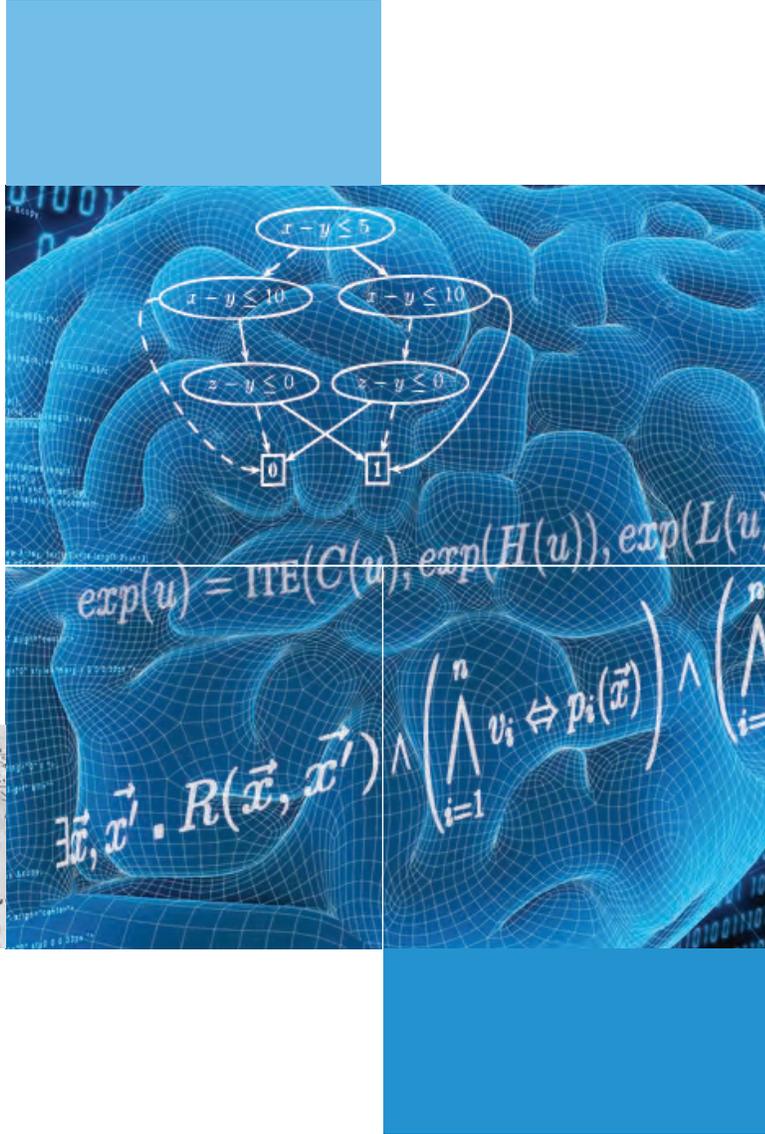
Sagar Chaki

"Because software has no significant physical limits, the only thing that limits it is the human brain."

25 The SEI launched CMMI for Services (CMMI-SVC) in 2009 to help service providers reduce costs, improve quality, and improve the predictability of schedules. Services make up more than 80 percent of the world's economy.

Dennis Goldenson

"These workshops have been successful in what we consider vital for the future of PPMs, which is to stimulate collaborative research and publication."

Bob Stoddard

"When you don't use a model, you don't know the interrelationships and tradeoffs of the decisions you're making."

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In 2010, the SEI received a five-year contract extension, with a face value of $584 million, from the U.S. government through June 2015.

Predictive Modeling for Achieving Success

Analyzing the data after a project is completed to determine what went wrong and how to do better in the future is useful. But even more useful is the ability to use the data while the project is still ongoing to predict the impacts of decisions and make changes that are most likely to lead to success. Some data analysis methods are good at explaining what happened, while others are useful for predicting what will happen. Process performance models (PPMs) have been used for both, but many of the organizations that create the models never made it past explaining to predicting when it came to project or program performance. Noting this missed opportunity, the SEI began to explore ways to help organizations better use PPMs.

"Before 2007, most people used a PPM as part of a post-mortem to understand what went wrong. They used the information they got to update a model that might relate to a similar future project. We wanted to help people create models that would allow managers to anticipate the future when it comes to the development of software-intensive systems instead of being reactive and fixing problems," said Bob Stoddard, a Six Sigma Master Black Belt on the SEI staff.

Beginning in 2008, the SEI organized a series of workshops to bring together leaders in process performance modeling. These workshops provided a unique opportunity for candid discussions among participants and a chance for them to share the models they were using. Participants described what they found useful for quantitative management, process performance, and product quality in their organizations.

The broader goal of these workshops was to promote a viable community of interest around PPMs and other analysis techniques and publish best practices and case studies to further expand their transition into use. "These workshops have been successful in what we consider vital for the future of PPMs, which is to stimulate collaborative research and publication," said Dennis Goldenson, the primary organizer of the workshops.

Two reports describing this work are available for download on the SEI website. *CMMI High Maturity Measurement and Analysis Workshop Report: March 2008* describes the motivation for the project and the first workshop. The 2010 report *Approaches to Process Performance Modeling: A Summary from the SEI Series of Workshops on CMMI High Maturity Measurement and*

Analysis describes the models developed by participants from more than 20 organizations, including Lockheed Martin, Accenture, Northrop Grumman, Esterline AVISTA, and Hill Air Logistics Center. It also gives a description of PPMs in concrete, practical terms by providing a list of what are considered the seven "healthy ingredients" of a model. Some healthy ingredients include the ability to model uncertainty, the inclusion of at least one controllable factor to ensure the model results are actionable, and the ability of the model to show consequences of decisions made earlier in the life cycle or process.

Stoddard and Goldenson are optimistic about the future use of PPMs in making decisions about how to develop complex software. "For example, in the development of high risk software, PPMs can help you make important decisions about which staffing skills are going to be the most critical and which programming languages to use," said Stoddard. "When you don't use a model, you don't know the interrelationships and tradeoffs of the decisions you're making."

TRANSITION

SEI Partner Network

The SEI Partner Network is an elite group of SEI-trained organizations on the leading edge of software engineering processes and technologies. SEI Partners are licensed to deliver SEI services in the following areas:
- Architecture Tradeoff Analysis Method
- CERT Information Security
- CMMI and SCAMPI Appraisals
- People Capability Maturity Model
- Service-Oriented Architecture
- Smart Grid
- Software Architecture
- Software Engineering Measurement and Analysis
- Team Software Process

By delivering services worldwide, SEI Partners provide a critical distribution channel for accomplishing the SEI mission.

In fiscal year 2010, the SEI Partner Network consisted of 439 Partner organizations.

For more information about the SEI Partner Network, visit www.sei.cmu.edu/partners

SEI Affiliate Program

Through the SEI Affiliate Program, sponsoring organizations contribute technical staff members to the SEI's ongoing effort to define superior software and systems engineering best practices. Affiliates lend their technical knowledge and experience to SEI teams investigating specific technology domains.

Affiliates are immersed in the inquiry and exploration of new tools and methods that promise to increase productivity, make schedules predictable, reduce defects, and decrease costs.

For more information about the SEI Affiliate Program, visit www.sei.cmu.edu/collaborating/affiliates

SEI Membership

SEI Membership is a business and knowledge network that connects the SEI with software and systems engineering leaders in government, industry, and academia throughout the world. SEI Membership is designed for software and systems engineering professionals who are interested in priority access to SEI technologies and events. Individuals use the SEI Membership program as a means of networking with other professionals to discuss adoption and implementation of software-engineering best practices and challenges of software and systems engineering.

SEI Members include small-business owners, software and systems developers, CEOs, directors, and managers from business, industry, and prominent government organizations in 36 countries around the globe.

The SEI is the only one of 37 federally funded research and development centers that offers membership to the public.

For more information about SEI Membership, visit www.sei.cmu.edu/membership

SEI Professional Development Center

The SEI Professional Development Center incorporates education, training, and credentials, all of which enable individuals to benefit from SEI research in multiple disciplines.

The center provides continuing education for engineering and software professionals in government, industry, and academia.

The SEI addresses professional development needs by
- designing and developing training that is accessible and effective with classroom, blended, and distance learning
- encouraging and recognizing individual accomplishments in various disciplines through certificate programs
- enhancing individual career opportunities through SEI Certification

For more information about SEI training, visit www.sei.cmu.edu/products/courses

For more information about SEI Certification, visit www.sei.cmu.edu/certification

LEADERSHIP, MANAGEMENT, & STAFF

SEI Conferences & Events

As part of its strategy to apply the latest research, the SEI offers conferences, workshops, and user-group meetings. These events represent technical work and research performed by the SEI and its collaborators in the areas of process improvement, software architecture and product lines, security, acquisition, and interoperability. Individuals from around the world attend SEI conferences and events to
- connect with industry leaders
- share best practices
- network with peers
- find potential solutions
- gather the latest research and trends in software systems engineering

Some of the events that the SEI sponsored and co-sponsored in 2010 are
- Army Senior Leadership Education Program
- FloCon
- SATURN
- SEPG Conference Series
- TSP Symposium

For more information about SEI conferences and events, visit www.sei.cmu.edu/events

SEI Board of Visitors

The SEI Board of Visitors advises the Carnegie Mellon University president and provost and the SEI director on SEI plans and operations. The board monitors SEI activities, provides reports to the president and provost, and makes recommendations for improvement.

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Tom Love
Chief Executive Officer, ShouldersCorp; Founder of Object Technology Group within IBM Consulting

Donald Stitzenberg
President, CBA Associates; Trustee, Carnegie Mellon University; Former Executive Director of Clinical Biostatistics at Merck; Member, New Jersey Bar Association

SEI Staff

The SEI attracts top talent to implement its expanding objectives, increasing its staff by a third over the past four years. Staff members are permanent, full-time employees; visiting scientists are temporary SEI employees from government, industry, and academia; affiliates are professionals sponsored by their home organizations to work on SEI technical projects.

425	173	94	15
MTS/MOS*	ADMINISTRATIVE	VISTING SCIENTISTS	AFFILIATES
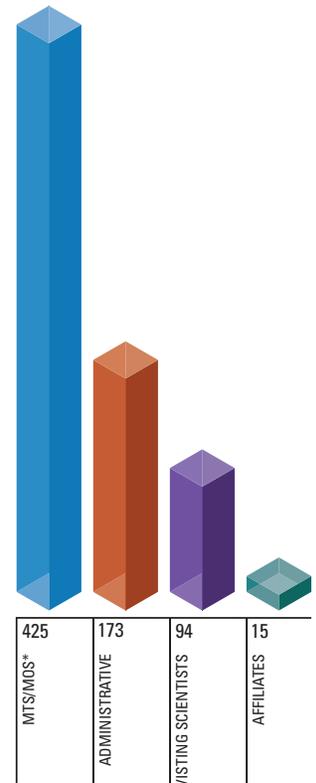
*Members of the technical staff and members of the operational staff

SEI Director's Office

The SEI Director's Office leads the Institute's research program and ensures the smooth, efficient operation of the SEI. Director and Chief Executive Officer Paul Nielsen, Chief Operating Officer Clyde Chittister, and Deputy Director, Research, and Chief Technology Officer Douglas Schmidt build strong, collaborative relationships with leaders in government, industry, and academia, communicating the SEI's vision for software engineering.

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Director
Chief Executive Officer

Clyde G. Chittister
Chief Operating Officer

Douglas Schmidt
Deputy Director, Research
Chief Technology Officer

SEI Management

The SEI Management Team comprises the directors of the research programs, technology transition, and business and technology functions of the SEI.

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Director, Program Development
and Transition

Anita Carleton
Director, Software Engineering
Process Management

Peter Menniti
Director, Financial and
Business Services

Richard Pethia
Director, Networked
Systems Survivability

Terry Roberts
Executive Director, Acquisition
Support Program/Interagency and Cyber

David Thompson
Director, Information Technology
and Security

Linda Northrop
Director, Research, Technology,
and System Solutions

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Work with the SEI

Congress established the SEI in 1984 because software is vital to the national interest. By working with the SEI, organizations benefit from more than two decades of government investment and participation from organizations worldwide in advancing the practice of software engineering.

The SEI creates, tests, refines, and disseminates a broad range of technologies and management techniques. These techniques enable organizations to improve the results of software projects, the quality and behavior of software systems, and the security and survivability of networked systems.

As an applied research and development center, the SEI brings immediate benefits to its research partners and long-term benefits to organizations that depend on software. The tools and methods developed by the SEI and its research partners are applied daily in organizations throughout the world.

How the SEI Works with Government and Industry

SEI staff members help the U.S. Department of Defense (DoD) and other government agencies solve software engineering and acquisition problems. SEI direct support is funded through task orders for government work. Engagements with the SEI are of particular benefit to government program managers, program executive officers, and senior acquisition executives, particularly those with long-range programs that will benefit from strategic improvements that the SEI fosters.

The SEI has a well-established process for contracting with government agencies and will work with an organization to meet its needs.

The SEI works with commercial organizations that want to develop a strategic advantage by rapidly applying improved software engineering technology.
The SEI works with organizations that want to combine their expertise with the SEI's expertise to mature new technology for the benefit of the entire software industry.
The SEI also supports a select group called SEI Partners, which are organizations and individuals trained and licensed by the SEI to deliver SEI products and services.

To determine how to put the SEI to work for your organization, contact SEI Customer Relations at info@sei.cmu.edu.