

Raytheon Stands Firm on Benefits of Process Improvement

CROSSTALK Managing Editor Pam Bowers interviewed Robert L. Keys, senior principal software engineer, and Ginger Tonkin-Sugimoto, principal software engineer, Software Engineering Process Group, about benefits they have seen and experienced during Raytheon Missile Systems' advance from Capability Maturity Model® Level 2 to Level 4. This interview is part two of an investigation into the relationship between acquisition reform and process improvement that was initiated in November 2000 CROSSTALK in the AMRAAM and JASSM programs article. The final part in this series will appear in a later issue.

CrossTalk: What was Raytheon's motivation to initiate a software process improvement program?

Tonkin-Sugimoto: Our motivation for software process improvement is to produce higher quality products at lower cost and within schedule. Achieving these goals will ensure we remain the contractor of choice. The Software Engineering Institute's (SEI) Capability Maturity Model® (CMM) provides a worldwide-accepted model for achieving these goals. A secondary benefit of the assignment of a CMM rating is that it represents a significant competitive advantage. It's an observable rating, far more concrete than simply saying, 'We have great processes. You just have to believe us.'

Keys: Since we began progressing from CMM Level 2 in 1994 to Level 4 in 1998, we have concrete evidence of an increase in financial performance and of a 144 percent productivity improvement. So we believe that progressing to the next level of CMM maturity will continue to reap benefits for us.

CrossTalk: What were the hardest internal obstacles you overcame in moving from CMM Level 3 to Level 5? What was necessary to overcome them?

Tonkin-Sugimoto: The hardest internal obstacles in the move from Level 3 to Level 5 have been misconceptions and a lack of understanding. We have heard "We have Level 3, why go farther?," "Is Level 5 worth it? Is it really value-added?" [and] "We didn't sign up to do that!"

The major factors in overcoming these attitudes are:

- Senior management buy-in.
- SEPG support for process improvement across the organization.

But this is not all that process improvement requires. Many activities support process improvement. Training that facilitates the implementation of new processes and metrics is necessary. These new processes and metrics must be used consistently across the organization. We require monthly program review packages with both reports and metrics. Our software quality engineers monitor both product and process. Metrics are monitored across the organization and senior management measures projects via these metrics. With this, process improvement takes on a new importance. To further support process improvement, our SEPG mentors projects in using their metrics to define the root causes of problems. We get project personnel involved in developing and analyzing their process improvements.

CrossTalk: What are the most difficult obstacles you overcame when dealing with process improvement resistance from your clients? How do you overcome these struggles?

Tonkin-Sugimoto: Few of the customers we work with are obstacles to process improvement. We have occasionally heard that they don't care about process improvement ("It's a contractor problem.") or they don't see the value in process improvement ("We aren't paying you to do that. Process costs too much.") or it doesn't apply to their projects ("We're special."). Primarily, our customers are concerned with cost and schedule. When our customers understand that process improvement has a positive effect on productivity and quality, they no longer resist. Here is how these potential obstacles are overcome:

- Providing real data that demonstrates a positive return on investment resulting from process improvement.
- Training to show our customers that process improvement improves productivity and product quality.
- Offering assistance to projects (developing metrics and analysis as needed).
- Senior management support of process improvement across projects.

CrossTalk: Can you provide an example of how a higher rating has helped you to deliver a better product, or other benefits?

Tonkin-Sugimoto: Our Advanced Medium Range Air-to-Air Missile (AMRAAM) projects are operating to the Level 5 practices and procedures of the Raytheon Missile Systems Software Directive System (RMS SDS). Early in the AMRAAM Foreign Military Sales Tape 8 project, both budget and schedule were deemed at risk. With our continuous improvement culture, project management developed the Design Impact Assessment Process to reuse previous work while training less experienced engineers. Project metrics showed that this process allowed them to quickly create a basis for the detailed design, to build confidence that schedule and budget constraints could be met, and to enable less experienced engineers to be effective within the time constraints. This process is currently being piloted on another project.

Keys: The corporation developed a set of standard operating instructions (SOIs). We used these as a starting point then instantiated them into the RMS software development process. In some cases we used the SOIs as they were. In other cases, they required some modification. For example, we augmented them for our metrics program with very specific templates for each metric so that we have a common look and feel to all of our program review packages.

CrossTalk: Do higher CMM level teams consistently perform better? How do you measure this?

Tonkin-Sugimoto: We have found that higher CMM level teams consistently perform better. Our organizational productivity has shown improvement in our journey from Level 2 to Level 4. Our

organizational Cost Performance Index (CPI) and Schedule Performance Index (SPI) have shown improvement between 1998 and the present. Organizational defect containment has shown improvement since 1995. These metrics measure both product and process performance.

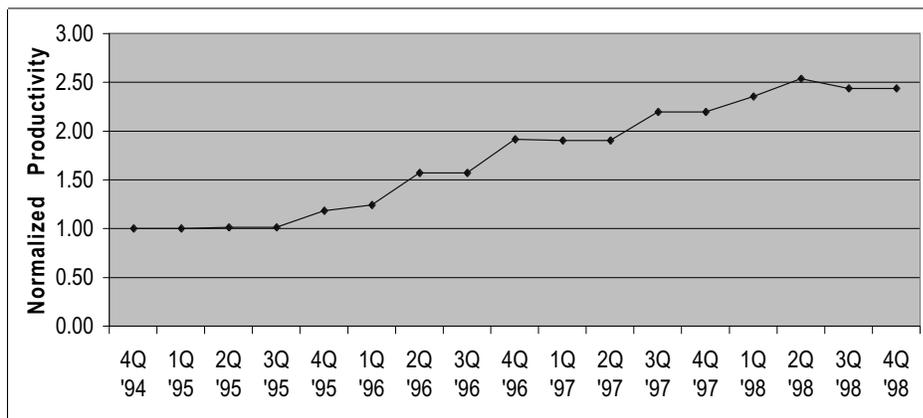
Keys: The measurements we generate, which include productivity, show improvement as an organization. While our CPI and SPI numbers as an organization have been getting better, they also are less volatile than they once were. There are contributing factors such as defect containment that have a significant impact on productivity and financial performance. We're detecting our defects during peer reviews within the current phase (in phase) as opposed to finding them in later software development phases where they are much more expensive to find and fix. We've been showing more than a 10 percent improvement per year.

CrossTalk: Can you provide hard data on defect containment or productivity improvement between Levels 2 and 5?

Tonkin-Sugimoto: The data in Figures 1 and 2 show that our organization's productivity has improved 144 percent from 1995 when we were a Level 2 to 1998 when we were a Level 4. During the period that productivity was increasing by 144 percent, we expended 6 percent of the annual budget on process improvement. This yields a 6-to-1 return on investment. Our overall defect containment during the same period increased from 32 percent in phase to 72 percent in phase.

CrossTalk: Is productivity translated into faster coding?

Keys: Yes, we are producing more lines of code per staff-hour. Our 144 percent productivity improvement in the rate of creating lines of code is because we're doing it right the first time. There are lots of parameters to increased productivity. The learning curve decreases dramatically as engineers move from project to project and the same for managers. All these things add up to improve productivity, which we measure starting with the design activity and ending prior to formal qualification testing. Requirements analysis is excluded from our productivity number.



Date	4Q '94	1Q '95	2Q '95	3Q '95	4Q '95	1Q '96	2Q '96	3Q '96	4Q '96	1Q '97	2Q '97	3Q '97	4Q '97	1Q '98	2Q '98	3Q '98	4Q '98
Productivity	1.00	1.00	1.01	1.01	1.18	1.24	1.57	1.57	1.91	1.90	1.90	2.20	2.20	2.35	2.54	2.44	2.44

Figure 1. Organizational Productivity

CrossTalk: How do you measure project success? Is it different for teams at different CMM levels?

Tonkin-Sugimoto: We measure both product and process status monthly via 14 metrics and 14 reports on each software project. These include the Enterprise Metrics: Software Size, CPI, SPI, Equivalent Productivity, and Fault Density that are collected throughout Raytheon. Our CMM Level 5 frontrunner projects monitor and report all of these metrics. Lower CMM level projects are not able to report all of these metrics or reports and must tailor some metrics. This inhibits their ability to manage their projects but it provides improvement opportunities that are addressed in their software process improvement plans (SIPs).

Process measurement begins with the definition of project goals. Thresholds are established and actual project performance is monitored via the metrics. This provides fact-based management with early insight into unexpected results and allows for early root-cause analysis and

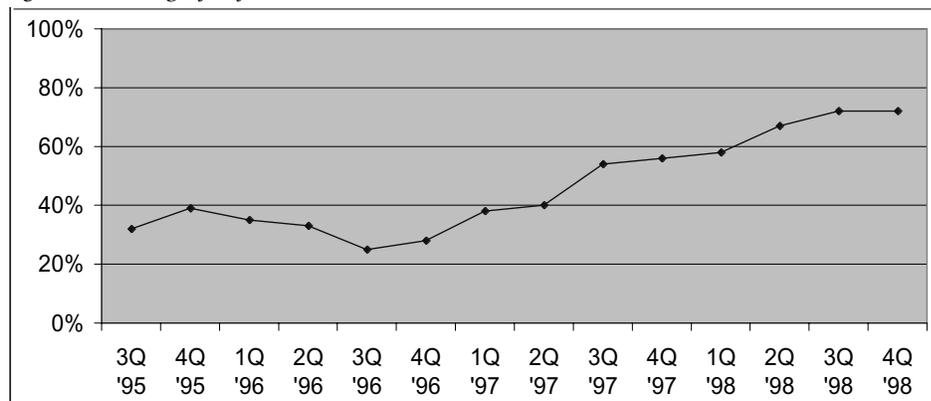
mitigation planning.

Keys: Each program fills out a blank monthly metrics template. The templates are all Excel, Word, and PowerPoint files that automatically link all the underlying data into the presentation package. Less mature projects tailor the templates while a Level 5 project will adopt the full process. Less mature projects might tailor out the cost of quality metric because it is very advanced and very mature. All reviewers—the software lead, the department managers, the SEPG and the Team of Five (TOF)—are looking for negative trends or unexpected results, which exceed control limits in either a positive or negative direction. We like to investigate either situation.

CrossTalk: How did the merger between Raytheon and Hughes impact your software process improvement effort?

Tonkin-Sugimoto: The Tucson facility has undergone three recent transitions: 1. The merger of General Dynamics and Hughes Missile Divisions.

Figure 2. Percentage of Defects Found in Phase



Date	3Q '95	4Q '95	1Q '96	2Q '96	3Q '96	4Q '96	1Q '97	2Q '97	3Q '97	4Q '97	1Q '98	2Q '98	3Q '98	4Q '98
Defects in Phase	32%	39%	35%	33%	25%	28%	38%	40%	54%	56%	58%	67%	72%	72%

2. The transition of the Hughes Canoga Park, Calif. work to Tucson.
3. The merger of Raytheon, Texas Instruments, and Hughes Missile Divisions. The Tucson software process effort was greatly impacted when projects from Massachusetts (legacy Raytheon) and Texas (legacy Texas Instruments) were moved to the Tucson facility in a consolidation effort. It was at this point that the corporation developed the Raytheon SOIs from the three sets of best practices.



“We have found that higher CMM level teams consistently perform better.”
—Ginger Tonkin-Sugimoto

The SOIs were instantiated for use at RMS in the form of the RMS SDS, which all frontrunner projects have adapted. Others are in transition as documented in their project SPIPs. This has been a major effort and took up much of our software process effort. We had originally planned to prepare for a Level 5 CMM-Based Appraisal Internal Process Improvement in 2000 but that has moved to 2001 (see Figure 3). We completed a Process Baseline Assessment in 2000 to measure our preparation for the 2001 assessment. It showed that we have maintained our quantitative process management/software quality management capabilities in spite of the merger of the three organizations.

It was a difficult process because it was such a massive undertaking. A large team reviewed every procedure or SOI that we developed with various program representatives. They each had the opportunity to provide input. If you don't have all the various parts working together to develop your best practices, someone is not going to go with you.

Keys: Communication was our greatest problem during the transitions. I would be talking to someone from Texas about what we called “earned value” in Tucson, which is a measure of cost and schedule performance; but it would mean something completely different to him. It took about 12 grueling months to complete the procedures to define the process, but it was key. If you talk to any of our folks now, you can't tell which legacy organiza-

tion they came from. We're all talking the same language now.

CrossTalk: Does a higher level of maturity help with modifications? Is current code at Level 5 easier to modify in the future?

Keys: Yes, the code we're developing now will be much more maintainable than perhaps some of the code from a long time ago. That is because the CMM emphasizes the peer review process. We also emphasize having clear, well-defined work instructions and standards, which may not have always been the case in the past. The process causes us to more carefully evaluate our approach to doing the job, documenting it more clearly, and establishing clearer exit criteria.

CrossTalk: When you come up against a brick wall in funding process improvement, how do you overcome that?

Tonkin-Sugimoto: A brick wall in funding process improvement is brought about by a lack of understanding. Process improvement is not expendable. It improves productivity and quality of products. If funding is an issue, the first step is to demonstrate its importance to the organization's future. From there we get buy-in from either senior management or from program management. They are the source of the funding. How well you demonstrate process improvement can determine future funding. We use real data and actual success stories from projects to demonstrate the value of process improvement.

CrossTalk: Do CMM rankings provide a level playing field to compare contractors?

Tonkin-Sugimoto: CMM rankings only provide a level playing field when they are performed to the same standard and are performed regularly. The Raytheon Software Assessment Team has held to strict standards when assessing the various Raytheon facilities. We are aware that some outside assessors do not necessarily hold the same standards. When you look at an organization's assessments you need to know who did the assessment.

When comparing contractors, confidence is greatest when the project is part of the assessment. Confidence is reduced if the project is not part of the assessment.

Keys: Another important factor on this level playing field is to take into account the date of the assessment because there is no expiration date on the SEI ratings. So an assessment performed five years ago, especially considering industry mergers and transitions, could be invalid even within two or three years.

CrossTalk: What effect does a performance level rating have on past performance evaluations?

Tonkin-Sugimoto: It depends upon the organization that you are evaluating. Past performance evaluations for lower process level companies do not readily forecast how that company will perform on a new contract. When a company has been rated at least CMM Level 3, its processes are institutionalized. The tools, procedures, and training are in place to enable personnel to perform at least as well as they did in the past.

CrossTalk: What steps do you take to ensure you maintain your capability level?

Tonkin-Sugimoto: The RMS SDS is CMM Level 5 compliant, and we assure our capability by having all projects tailor their processes from the RMS SDS.

We maintain our capability through monthly TOF meetings that include the project software lead, software configuration management representative, software quality engineer, product line SEPG representative, and department manager. The TOF evaluates software project metrics, accomplishments, risks, and problems, and can initiate mitigation efforts. Our capability is assured at three different levels:

1. Organizationally, a software process engineer is assigned for each product line and process training is required for all engineers. At the project level, SQE audits of project software processes are performed throughout the life of each software project. At the directorate level, engineering process reviews are held each month to evaluate and report process status across all disciplines.
2. Organizationally, we develop a SPIP every year that details our improvement goals for the year. We measure our efforts against this plan monthly.
3. SEI suggests that CMM assessment ratings be reviewed every 18 to 30 months. As part of Raytheon, we are assessed on this schedule. The Tucson

facility was assessed in 1996 as a CMM Level 3 and in 1998 as a CMM Level 4. Recently, we underwent a Process Baseline Assessment to determine our weaknesses in reaching CMM Level 5. Our next CMM assessment is in 2001.

CrossTalk: What do you see in the future for process improvement? What would you like to see? Do you plan a transition to CMMI? Why?

Tonkin-Sugimoto: Software process improvement at this facility is institutionalized. This was brought about by Raytheon's software process improvements specifically but also across the board by Raytheon Six Sigma. This program encourages every employee to improve their activities, to make them more efficient, faster, less costly, and improve quality. We're beginning to feel empowered to make improvements.

The Engineering Directorate for the enterprise is actively moving to CMMI by building on our software successes. Raytheon has had two pilot CMMI projects: one in Bedford, Mass., and one in St. Petersburg, Fla. Our CMMI activity will represent another competitive advantage for Raytheon in the same way that the software CMM maturity has. As all engineering disciplines reach a culture of continuous process improvement, we will be able to produce better and better products.

Keys: The value of software CMM process maturity is diluted by the fact that other disciplines don't have the same type of controlled processes and maturity that we do. This is particularly true in the

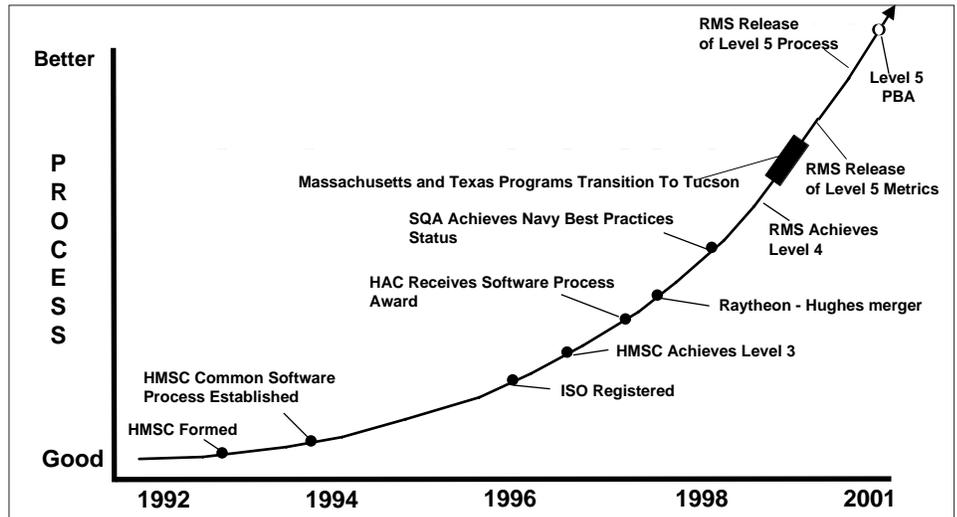


Figure 3. Raytheon's Process Improvement Timeline

area of systems engineering and requirements development. If we can bring those organizations up to our level of maturity, then we're going to get tremendous bang

for the buck. It will increase the benefits of software maturity as well as help out other disciplines, program management, and all other areas.u

Robert L. Keys is a senior principal software engineer at Raytheon Missile Systems (RMS) in Tucson, Ariz. He has 23 years of experience developing and managing real-time embedded software for various defense-oriented applications, including command and control systems and missile systems. For the past four years he has worked in the Software Engineering Process Group (SEPG) as RMS has progressed from Software Engineering Institute's CMM Level 3 to Level 4. He is currently the metrics-based management specialist within the organization and has been the leader of the software metrics program since 1998. He is also currently involved in developing the Level 5 processes and providing support for Level 5 project activities in prepara-

tion for certification in May 2001. Keys earned a bachelor's degree in computer science from San Diego State University.

Ginger Tonkin-Sugimoto is a principal software engineer at Raytheon Missile Systems in Tucson, Ariz. She has 28 years of experience developing and managing real-time embedded defense software. For the past four years she has worked in the Software Engineering Process Group (SEPG) and currently represents process for the air-to-air software product line. She is an active member of assessment teams working throughout Raytheon to mentor other organizations and to improve software development processes. She earned a bachelor's degree in mathematics from the University of California, Santa Barbara.

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To gain wider input to Air Force requirements for software improvement projects, CRSIP is interviewing engineers and program managers of software intensive programs for inputs. The results of the needs analysis will be summarized at STC, and used to structure the Air Force's investment strategy for software improvement. If you would like your input to be a part of this effort, see <http://crsip.hill.af.mil> for a questionnaire and more information.