Best Practices Fusion: Lean Six Sigma and CMMI®

By Gary A. Gack

Use of Lean Six Sigma in software development and IT in general has increased significantly over the last several years, and many organizations are learning to leverage the relationships between Lean Six Sigma and other approaches to software process improvement, including the Software Engineering Institute's Capability Maturity Model Integrated (CMMI®), the IT Infrastructure Library (ITIL®), the Project Management Institute's Project Management Body of Knowledge (PMBoK®), and others. Integration of Lean Six Sigma with ITIL® and the PMBoK® are addressed in other White Papers in this series and are available from the author. Lockheed Martin, Motorola, Raytheon, and many others have reported significant gains by combining the best features and ideas from several different best practices models and methods, in several cases creating a "local brand" of integrated process improvement methods.

The current state of the art in proven process improvement methods is defined by the synthesis of Lean and Six Sigma, collectively known as "Lean Six Sigma", hereinafter, "LSS".

Lean

The Lean thought process has been thoroughly described in the books *The Machine That Changed the World*[1] and in *Lean Thinking*[2]. The authors, Womack and Jones, summarize the key ideas of Lean into five core concepts:

- Specify the value desired by the customer
- Identify the value stream for each product providing that value and challenge all of the wasted steps (generally nine out of ten) currently necessary to provide it
- Make the product flow continuously through the remaining, value-added steps
- Introduce pull between all steps where continuous flow is possible
- Manage toward perfection so that the number of steps and the amount of time and information needed to serve the customer continually falls

Lean has evolved significantly beyond its origins in manufacturing and is now widely used in services industries and "transactional" applications across all industry groups. In the software field Lean concepts have been influential in the formulation of "Agile methods"[3] and Lean Software Development as illustrated most recently by the work of Mary and Tom Poppendieck[4].

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[1] *The Machine That Changed the World* by James Womack and Daniel Jones, Scribner (October 10, 1990)
[2] *Lean Thinking* by James Womack and Daniel Jones, Free Press; 2nd edition (June 10, 2003)
[3] *The Agile Manifesto*, by Kent Beck, Mike Beedle, Arie van Bennekum, Alistair Cockburn
Ward Cunningham, Martin Fowler, James Grenning, Jim Highsmith, Andrew Hunt, Ron Jeffries, Jon Kern, Brian Marick,

1568 Linkside Drive ◆ Orange Park, FL ◆ 32003 USA
+1 (904) 579-1894 ◆ ggack@Process-Fusion.net

Lean, in a general sense, focuses on issues that effect cycle time.

Six Sigma
Originated at Motorola in the mid 1980s and subsequently elaborated mostly notably by GE (and many others), Six Sigma has evolved to include three primary elements:

- A deployment strategy that defines roles (Champions, Yellow-Green-Black and Master Black Belts), describes a process for selection of improvement projects explicitly linked to the organizations strategic imperatives, and provides a governance process that emphasizes financially measured benefits and institutionalization of gains.
- A process improvement approach often referred to as a "roadmap" known as DMAIC (Define, Measure, Analyze, Improve, Control) – most often used to improve an existing process or product
- A new product/process design approach known generally as "Design for Six Sigma" and described by several different "roadmaps" including DMADV (Define, Measure, Analyze, Design, Verify), IDOV (Identify, Design, Optimize, Validate), and DMEDI (Define, Measure, Explore, Develop, Implement) – despite impassioned arguments by their respective proponents, all are equivalent in practice.

Six Sigma, in a general sense, focuses on reduction in variance and reduction in "defects", defined in the broadest sense to include any deviation from customer requirements or expectations.

At least in the context of software and IT, the state of the practice has effectively combined Lean and Six Sigma into an integrated process improvement method that we will refer to as "Lean Six Sigma" (LSS) in the remainder of this article.

CMMI® 1.2
The earlier Software and Systems Engineering Capability Maturity models, influenced in part by Crosby's "Quality Maturity Grid", were developed by the Software Engineering Institute (SEI) at Carnegie Mellon University beginning in the mid 1980s and have subsequently evolved to the current version, known as CMMI® 1.2.

The CMMI® is in part a guide to software process improvement, in that it identifies necessary processes and best practice attributes of those processes. It is non-prescriptive regarding “how to” implement the processes identified.

The CMMI® defines Process Areas (PAs) and associated Goals and Practices that are the basis for the "Standard CMMI Appraisal Method for Process Improvement" (“SCAMPI”). These Appraisals assign "maturity" level (pertaining to an organization as a whole) or "capability" level (pertaining to an individual PA) to PAs and/or organizations.

The CMMI® "Continuous" representation consists of four process categories, each containing several process areas indicated in Table 1. The "Staged" representation (Table 2) organizes the PAs into

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Robert C. Martin, Steve Mellor, Ken Schwaber, Jeff Sutherland, and Dave Thomas http://agilemanifesto.org/ These individuals and others have authored dozens of books on this topic.
[4] *Implementing Lean Software Development: From Concept to Cash*, by Mary and Tom Poppendieck, Addison-Wesley (2007)

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+1 (904) 579-1894 ◆ ggack@Process-Fusion.net

"Maturity levels" which effectively dictates the order in which they are to be addressed, whereas the Continuous version leaves that decision to the discretion of the user. Essentially, the focus of the Continuous mode is on individual PAs whereas the Staged mode focuses on overall capability of an organization.

SCAMPI Appraisals come in three 'flavors'
- “C” informal, identify opportunities
- “B” more depth, typically 1 week
- “A” formal, results in a level rating officially registered with the SEI

SCAMPI does not evaluate actual performance outcomes, whereas that is the primary focus of LSS. Certainly there is a correlation between maturity or capability level and actual performance, but one does not guarantee the other.

Continuous representation Appraisals focus on individual PAs “Capability level” (rating them 0-5, Incomplete-Optimizing), while “Staged” representation Appraisals focus on PAs grouped into 4 “Maturity levels” as indicated in Table 2. Staged mode Appraisals focus on organizational maturity – all PAs associated with a given Maturity level must achieve the indicated level (no fractional ratings).

Table 1: CMMI® v1.2 – "Continuous" Representation

Process Category	**Process Area**
Process Management	Organization Process Definition (OPD) + IPPD
	Organizational Process Focus (OPF)
	Organizational Training (OT)
	Organizational Process Performance (OPP)
	Organizational Innovation and Deployment (OID)
Project Management	Project Planning (PP)
	Project Monitoring and Control (PMC)
	Supplier Agreement Management (SAM)
	Integrated Project Management + IPPD (IPM)
	Risk Management (RSKM)
	Quantitative Project Management (QPM)
Engineering	Requirements Management (REQM)
	Requirements Development (RD)
	Technical Solution (TS)
	Product Integration (PI)
	Verification (VER)
	Validation (VAL)
Support	Configuration Management (CM)
	Process and Product Quality Assurance (PPQA)
	Measurement and Analysis (MA)
	Decision Analysis and Resolution (DAR)
	Causal Analysis and Resolution (CAR)

1568 Linkside Drive ◆ Orange Park, FL ◆ 32003 USA
+1 (904) 579-1894 ◆ ggack@Process-Fusion.net

Table2: CMMI® v1.2 – "Staged" Representation
(Source: **CMU/SEI-2006-TR-008)**

Process Area	*Category*	*Maturity Level*
Configuration Management	Support	2
Measurement and Analysis	Support	
Project Monitoring and Control	Project Management	
Project Planning	Project Management	
Process and Product Quality Assurance	Support	
Requirements Management	Engineering	
Supplier Agreement Management	Project Management	
Decision Analysis and Resolution	Support	3
Integrated Project Management +IPPD	Project Management	
Organizational Process Definition +IPPD	Process Management	
Organizational Process Focus	Process Management	
Organizational Training	Process Management	
Product Integration	Engineering	
Requirements Development	Engineering	
Risk Management	Project Management	
Technical Solution	Engineering	
Validation	Engineering	
Verification	Engineering	
Organizational Process Performance	Process Management	4
Quantitative Project Management	Project Management	
Causal Analysis and Resolution	Support	5
Organizational Innovation and Deployment	Process Management	

The architecture of the CMMI® includes a statement of purpose for each Process Area (PA), and a set of "Generic Goals" (GGs), sub-divided into "Generic Practices" (GPs) (applicable to multiple PAs) and a number of "Specific Goals" (SGs) sub-divided into "Specific Practices" (SPs) applicable to a particular PA. A partial example is provided in Table 3.

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Table 3: Goals / Practices Example – Requirements Management

SG 1	Requirements are managed and inconsistencies with project plans and work products are identified.	
	SP 1.1	Develop an Understanding with the requirements providers on the meaning of the requirements.
	SP 1.2	Obtain commitment to the requirements from the project participants.
	Etc	
GG 1	The process is institutionalized as a managed process.	
	GP 2.1	Establish and maintain an organizational policy for planning and performing the requirements management process.
	GP 1.2	Establish and maintain the plan for performing the requirements management process.
	Etc.	

GGs, GPs, SGs and SPs are defined for each PA. Goals and Practices are organized and numbered by maturity level – in other words, for a particular PA to be appraised at a certain level means the it must achieve the associated GGs and SGs. While the associated GPs and SPs are not strictly speaking required, they are regarded as evidence that the goals are being achieved, and if not implemented as stated there must be evidence of an equivalent practice.

Combining LSS and CMMI® 1.2

There are potentially an almost unlimited number of ways that LSS and CMMI® can be synergistically combined, many more than can be thoroughly explored in this article. I have attempted to examine some of the most common and important of these, but do not propose to claim that this article is a definitive examination of the topic. I will happy to discuss other aspects – feel free to call or send me an email.

Whereas a CMMI® implementation approach might focus on creation of a comprehensive MA (and other) infrastructure, a Lean Six Sigma implementation approach would more likely focus on achieving a specific improvement to a specific problem that has quantifiable (typically in currency) near-term benefit – leading ultimately (as a consequence of a series of time-bounded projects) to an infrastructure likely quite similar to that resulting from a CMMI® initiative. The emphasis is different, with LSS placing more emphasis on smaller, shorter (typically 4 months or less) projects that have measurable benefits – in the end aggregate outcomes may be very similar. LSS will "eat the elephant one bite at a time". Full tummies every night.

LSS projects concerned with any aspect of software development can be related to one or more CMMI® Process Areas (PAs) (and in many instances also to PMBoK® and other standards). It is always advisable to identify the relevant PAs and familiarize the LSS project team with Generic and Specific Goals associated with them.

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When deploying CMMI® is an organizational intent, applicable LSS projects "begin with the end in mind[5]" and make incremental progress while delivering near term financial benefits. Even when deploying CMMI® is not an objective good ideas are nonetheless often suggested by the PAs - not "solutions", rather attributes of solutions proven successful.

CMMI® Generic Goal 2: "The process is institutionalized as a managed process" is applicable to every PA and to every LSS project. The essential outcome of every LSS project, realized as a result of the Control phase of a DMAIC project, will always be expected to achieve this Generic Goal. Associated Generic Practices (GPs) are a useful checklist for final project results; addressing these topics aids LSS project success. This goal and associated Specific Goals must be achieved for any PA to be rated at Capability level 2 in the Continuous representation and for all PAs included in the Staged representation to achieve a level 2 Maturity rating. Existence of the associated GPs is evidence of attainment of the Generic Goal. As indicated in Table 4, these Generic Practices map directly to various elements of a typical DMAIC roadmap.

Table 4: DMAIC Mapping to CMMI® Level 2 Generic Practices

CMMI® 1.2 Level 2 Generic Practices	**Mapping to DMAIC**
GP 2.1 Establish an Organizational Policy	Typically these are elements of the Improve pilot and are incorporated in the Control Plan
GP 2.2 Plan the Process (also see PP)	
GP 2.3 Provide Resources	
GP 2.4 Assign Responsibility	
GP 2.5 Train People (also see OT)	Typically an element of the operational turnover that occurs during the Control phase
GP 2.6 Manage Configurations (also see CM)	Control plans are expected to include provisions for maintaining necessary documentation and other process artifacts, including version control; may invoke an existing process
GP 2.7 Identify and Involve Relevant Stakeholders (also see PP)	This occurs initially during the Define phase and is updated as necessary during the project
GP 2.8 Monitor and Control the Process (also see PMC, MA)	The central focus of the Control plan; tested during the Improve pilot; may invoke existing MA capabilities and/or establish new MA requirements
GP 2.9 Objectively Evaluate Adherence (also see PPQA)	An element of the Control plan and post-implementation follow up; will leverage established processes when they exist
GP 2.10 Review Status with Higher Level Management	Occurs with each Tollgate review at the end of each DMAIC phase

CMMI® Generic Goal 3 ("The process is institutionalized as a defined process.") will generally be attained when the results of a successful LSS pilot project are scaled across an organization. The results of individual LSS projects are, in CMM®I terms, "Organizational Process Assets". Generalizing

[5] Covey, Stephen, *The 7 Habits of Highly Effective People,* Fireside, 1989

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pilot results for broader applicability across the organization and adding tailoring guidelines can satisfy Generic Goal 3. The difference between “Defined” and “Institutionalized” is essentially the difference between local and global scope of the process definition. Consistent with the time-limited scope of LSS projects they are often, but not always, confined to a subset of the organization and will hence require replication more broadly to satisfy GG 3.

Generic Practices supporting Goal 3 include:

GP 3.1 Establish a Defined Process (also see OPD, IPM)
GP 3.2 Collect Improvement Information (also see OPD, IPM)

Every successful LSS project is expected to achieve the intent of GP 3.1 and 3.2, but perhaps only within the scope of the pilot, typically a subset of the organization – replication and scaling usually is required for organization wide use.

CMMI® Generic Goal 4 (“The process is institutionalized as a quantitatively managed process.”) will generally be attained when the results of a successful LSS pilot project are scaled across an organization. “Quantitatively Managed ” requires control of the process using statistical and other quantitative techniques – always an expected outcome of every LSS project.

Generic Practices supporting Goal 4 include:

GP 4.1 Establish Quantitative Objectives for the Process (also see QPM)
GP 4.2 Stabilize Sub-process Performance (also see QPM)

Every successful LSS project is expected to achieve the intent of GP 4.1 and 4.2, but only within the scope of the pilot, typically a subset of the organization – replication and scaling usually is required for organization wide use.

CMMI® Generic Goal 5 (“The process is institutionalized as an optimizing process.”) will generally be attained by the aggregate results of an on-going LSS program, with special emphasis on the role of the Deployment process, Sponsors, and Champions.

Generic Practices supporting Goal 5 include:

GP 5.1 Ensure Continuous Process Improvement (also see OID)
GP 5.2 Correct Root Causes of Problems (also see CAR)

While described by CMMI® as a level 5 process, LSS regards CAR as "business as usual" – an approach always used during the Analyze phase of every LSS project. Hence, LSS lays to foundation for more advance maturity levels as soon as it begins to be used. Experience indicates organizations that use LSS before CMMI® often achieve surprisingly high initial capability/maturity ratings.

"Appraisals in three different organizations that were well into Six Sigma deployment … were significantly different than the *average* initial appraisal. A significant number of processes were already documented and used, as opposed to the usual blank stares when procedures / templates are requested. All three had results more typical of a second or third round of appraisals than the normal results.

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Especially noticeable was the difference in the quantitatively based Process Areas (PA), e.g. **Measurement and Analysis (MA)** at Staged Level 2 and the Level 4 and 5 Process Areas covering Quantitative Process Management (QPM) and Organizational Process Performance (OPP). In most initial Class C Appraisals, we do not even bother to look at Levels 4 – 5, sometimes not even Level 3. In all three cases, plans called for reviewing only Levels 2 and 3. As the appraisals progressed, the results were so startling that the Levels 4 – 5 were also reviewed." [6]

Table 5 lists PAs included in CMMI® 1.2 along with a statement of the purpose of each, in some instances paraphrased from the original source. Any or all of these could reasonably be the focus of an LSS project. Equally, any LSS project might touch aspects of several different PAs.

Consistent with the Lean "pull" principle, an LSS project would be unlikely to be chartered explicitly to implement a particular process area as such, whereas a CCMI® project undertaken by, for example, a Software engineering Process Group (SEPG) might well have such a charter. An LSS project will be chartered to achieve a specific (often financially) measurable objective within a limited time such as 4 months. In many organizations, especially those where CMMI® is not effectively mandated (as it generally is for many large government contractors), it will be much easier to justify and sustain an improvement program that has explicit near terms financial goals and is able to demonstrate convincing results short term. CMMI® implementation often face a severe challenge under such conditions, as the benefits are typically realized over a longer time frame and are difficult to associate with specific improvement activities. With rare exceptions, it's much easier to sell the CFO on LSS than on CMMI® - most CFOs do not regard improved maturity level as a measurable benefit.

Table 5: CMMI® 1.2 Process Areas and Purposes

Process Area	Purpose
Configuration Management	Establish and maintain the integrity of work products using configuration identification, control, status accounting, and audits
Measurement and Analysis	Develop & sustain measurement capability to support information needs of other PAs
Project Monitoring and Control	Provide an understanding of the project's progress so that corrective actions can be taken when performance deviates significantly from the plan
Project Planning	Establish and maintain plans that define project activities
Process and Product Quality Assurance	Provide staff and management with objective insight into processes and associated work products
Requirements Management	Manage the requirements of the project's products and product components and identify inconsistencies between those requirements and the project's plans and work products
Supplier Agreement Management	Manage the acquisition of products from suppliers
Decision Analysis and Resolution	Analyze possible decisions using a formal evaluation process; evaluate alternatives against established criteria.
Integrated Project Management + IPPD	Establish and manage the project and the involvement of the relevant stakeholders according to an integrated and defined process that is tailored from the organization's set of standard processes
Organizational Process Definition + IPPD	Establish & maintain a usable set of process assets and work environment standards
Organizational Process Focus	Plan, implement, and deploy process improvement
Organizational Training	Develop the skills and knowledge of people so they can perform their roles effectively and efficiently
Product Integration	Assemble the product from the product components; ensure the product functions properly; deliver product
Requirements Development	Produce and analyze customer, product, and product component requirements
Risk Management	Identify potential problems before they occur so that risk-handling activities can be planned and invoked as needed to mitigate adverse impacts on achieving objectives
Technical Solution	Design, develop, and implement solutions to requirements
Validation	Demonstrate that a product or product component fulfills its intended use in its intended environment
Verification	Ensure that selected work products meet their specified requirements
Organizational Process Performance	Establish & maintain quantitative understanding of process performance; provide data, baselines, models
Quantitative Project Management	Quantitatively manage project's defined process to achieve quality & performance objectives
Causal Analysis and Resolution	Identify causes of defects and other problems and take action to prevent them
Organizational Innovation and Deployment	Select & deploy incremental and innovative improvements; support performance objectives

[6] "Connecting Software Industry Standards and Best Practices: Lean Six Sigma and CMMI®", *CrossTalk* Feb 2007 by Gary A. Gack and Karl D. Williams http://www.stsc.hill.af.mil/crosstalk/2007/02/0702gackwilliams.html

1568 Linkside Drive ◆ Orange Park, FL ◆ 32003 USA
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Conclusion

LSS and CMMI® are mutually reinforcing. LSS tends to provide a stronger and more convincing linkage to business benefits – it helps with justification, demonstrates concrete benefits early, and increases the chances improvements will be sustained. CMMI® provides concrete specifics well understood within the software community and helps to provide the domain specific guidance that ensures LSS projects stay well grounded in relevant specifics.

It's not about either/or – it's about win/win!

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