



This white paper is the second in a five-part series dedicated to examining problems organizations encounter when operating in multimodel environments and the current process improvement approaches such organizations need to consider.

Strategic Technology Selection and Classification in Multimodel Environments

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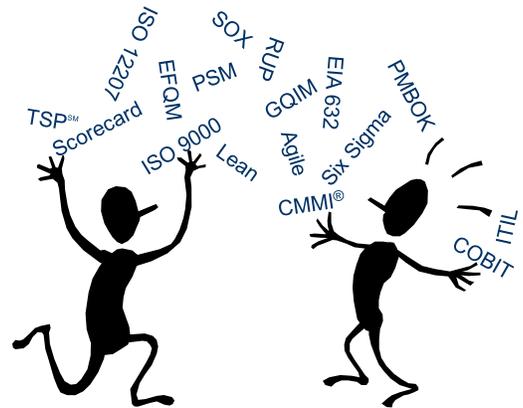
We would also like to acknowledge Alan Lawson, Visiting Scientist at the SEI, who provided key inputs to our discussion of the value proposition from both technical and business viewpoints.

About this series

This white paper is the second in a five-part series dedicated to examining problems organizations encounter when operating in multimodel environments and the current process improvement approaches such organizations need to consider. It examines the approaches needed in technology selection including a strategic taxonomy, the decision authorities associated with that selection at all levels in the organization, and considerations for thoughtful sequencing of implementation in alignment with the organizations' mission, goals and objectives.

The rest of this series addresses, in more detail, each phase of the reasoning framework for technology harmonization in a multimodel environment:

- The 1st white paper addresses the benefits of a harmonized approach when implementing more than one improvement model, standard, or other technology and provides a high-level description and underlying paradigms of a reasoning framework for technology harmonization.
- The 3rd white paper examines technology composition in relation to the concepts introduced in the previous white papers; a proposed element classification taxonomy to make technology integration effective in practice; and the role of technology structures, granularity and mappings in technology composition.
- The 4th white paper examines the current state of the practice for defining process architecture in a multimodel environment, methods and techniques used for architecture development, and underlying questions for a research agenda that examines the relationship of technology strategy and composition to process architecture as well as the interoperability and architectural features of different process technologies.
- The 5th white paper addresses the implementation challenges faced by process improvement professionals in multimodel environments, where it becomes necessary to coordinate roles and responsibilities of the champions for different technologies, to integrate and coordinate training, to optimize audits and appraisals, and develop an integrated approach to project portfolio management.



Those responsible for process improvement in their organizations may use a required (by management or by legal regulations) set of models/standards; and, they also may have latitude to select additional technologies¹ to help achieve organizational process improvement objectives. Regardless of responsibility or authority, the decision to adopt improvement technologies should focus on what need or opportunity each technology addresses, which is not necessarily a simple task. Complexities arise when considering such questions as:

- Do any of the selected improvement technologies address the same or similar need?
- Are there any technical or feature overlaps among them?
- How differently is each technology applied?

To help navigate the complex nature of technology adoption decisions, one might consider using structured approaches to aid with decision-making, for instance:

- Affinity groupings or taxonomies
- Selection and implementation patterns
- Formal decision methods (such as Pugh's or QFD)

Using such tools and techniques for deciding on multimodel combinations is a new area of research and the subject of an increasing number of papers. For instance, the following papers describe high-level comparisons of multiple technologies that could inform adoption decisions:

- In "A Systems Approach to Process Infrastructure," Armstrong describes the components of process infrastructure as best practices and supporting tools, a process improvement infrastructure, and measurement [Armstrong 05].
- Bendell's paper, "Structuring Business Process Improvement Methodologies," presents a problem-solution decision model with particular improvement technologies focusing on particular types of problems. For instance, Lean to address chronic waste, Six Sigma to address variation, and ISO 9001 to address market pressure [Bendell 05].
- In "A Taxonomy to Compare SPI Frameworks," Halvorsen, Printzell, and Conradi used a 25-factor taxonomy to compare commonly used frameworks. This challenging task resulted from their observations that choosing a software process improvement (SPI) framework is often subjective and rarely rooted in objective evidence [Halvorsen 01].
- CIO magazine (2004) published Mayor's process model selection framework. The framework arranged the models based on their relevance within the IT domain and on their comparative levels of abstraction [Mayor 03].

We have contributed to this new research area by developing a multimodel strategic classification taxonomy, which:

- groups models by their strategic contribution and discipline or application focus
- indicates typical decision authority
- serves as a backdrop for pattern analysis

¹ In this series of white papers, we use the terms *improvement technologies*, *technologies*, or *models* somewhat interchangeably as shorthand when we are referring in general to the long list of reference models, standards, best practices, regulatory policies, and other types of practice-based improvement technologies that an organization may use simultaneously.

Coupled with observed case-based patterns and descriptions of model relationships, this taxonomy can be useful when developing a multimodel strategy. It can enable making the link from an organization's mission translation to its improvement plan. And, while this generalized taxonomy is informed by the design features and characteristics of the technologies, its usage informs an organization's process architecture and process designs. Essentially, an organization's instantiation of this taxonomy can serve as a framework for its technology composition and its process architecture.

MISSION TRANSLATION INFORMS IMPROVEMENT STRATEGY

Whether you use taxonomies or other formal decision methods, the difficulty of technology selection can vary greatly. If you have clear improvement objectives and a clear relationship to the mission, making technology decisions might be easier (although that doesn't necessarily mean easy). Decision-making difficulties arise when improvement objectives are not clear and not aligned with the organizational goals. It is for this reason that the guidance questions introduced in the 1st white paper of this series² begin with a mission focus:

- What is our mission? What are our goals?
- Are we achieving our goals? What stands in our way?
- What process features, capabilities, or performance do we need to support our goals? Which improvement technologies provide or enable these features?

Ronald Recardo et al state

Translating organizational goals and metrics to individuals and teams continues to be one of the most difficult management activities and is often a stumbling block to implementation [Recardo et al. 07].

What we call mission translation is a methodical approach to addressing this difficult and real challenge by offering a means of decomposing mission and high-level enterprise objectives into operational goals and objectives. A key part of harmonization, this decomposition serves as a starting point for initial improvement technology selections. Plus, decomposition also serves as a guide for a coordinated improvement project portfolio and a backdrop for an aligned measurement system³.

² The Value of Harmonizing Multiple Improvement Technologies: A Process Improvement Professional's View

³ Improvement project portfolio and measurement are discussed in more detail in the 5th white paper of this series, Implementation Challenges in a Multimodel Environment.

There are several methodical approaches that can be used for mission translation, such as

- Function Analysis Systems Technique (FAST) goal decomposition
- Six Sigma's Y-to-x decomposition (briefly described in {book ref} and fully described in numerous Six Sigma references)
- Critical success factors [developed Daniel 61; refined Rockart 86]
- Systems thinking's current and future reality trees and other system dynamics methods
- Traditional strategic planning methods
- Balanced scorecard strategy maps

Of these, FAST goal structures are particularly suited to the process improvement professionals' task to connect enterprise objectives and strategies to engineering improvement efforts and to identify accompanying measurements. Adapted from the Functional Analysis Systems Technique, a FAST goal structure is essentially a goal and function decomposition. A topmost goal is decomposed repeatedly by asking the question "How?" Each goal and subgoal is ideally expressed as a verb-noun pair. The structure is validated by answering "Why?" from bottom to top. Each goal and subgoal is supported by the explicit identification of a strategy, which includes improvement technology selections.

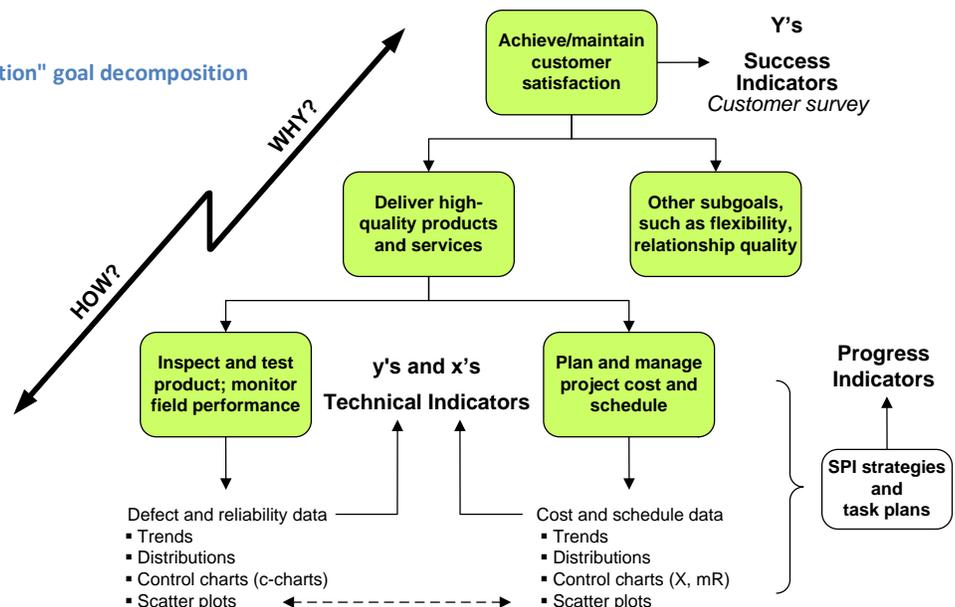
Creating, Aligning, and Decomposing Goals

In this sidebar, we include two examples that both stem from the ubiquitous goal of customer satisfaction. The first focuses on the basics of creating and aligned goal structure via the FAST goal decomposition approach. The second shows a different goal structure that supports customer satisfaction and then briefly elaborates on the identification of a supporting strategy and measurement system.

Customer Satisfaction Example 1: A Goal Decomposition

Figure 1 shows a simple goal decomposition, using the universal goal of customer satisfaction, ultimately linked to tactical goals and functions—for instance, product inspection and project cost and schedule management.

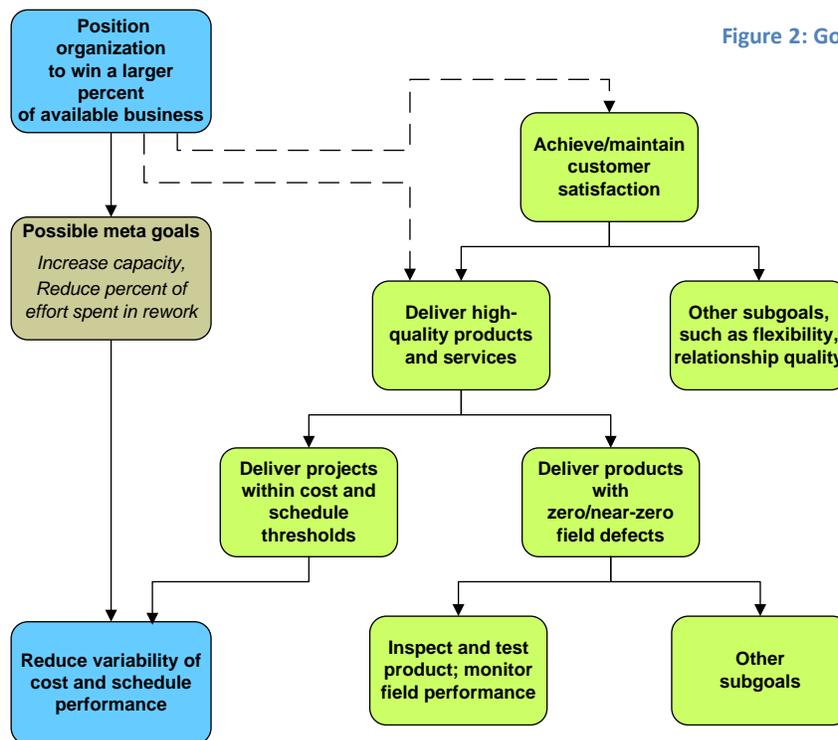
Figure 1: "Customer Satisfaction" goal decomposition



Creating, Aligning, and Decomposing Goals (con't)

In the case study from which this figure was drawn, baselines for inspection, cost, and schedule data were established, thus completing the initial examination of goals and measures per the above-listed guidance questions. The result was the emergence of cost and schedule variability improvement objectives. It was against such objectives that the relevant elements of different improvement technologies (such as CMMI, the PMBOK and TSP) were evaluated.

To further delineate the importance of goal decomposition as a backdrop for improvement technology selection, project portfolio management and measurement, consider the quandary that the organization found itself in. It perceived a real need for cost and schedule performance improvement, yet its customer survey data indicated high levels of customer satisfaction. Pursuing a cost/schedule improvement project aligned to customer satisfaction risked becoming process improvement for the sake of process improvement. Herein lies the value of mission translation through goal structures. *Figure 2* depicts a redrawn goal structure that shows alignment of cost and schedule performance both to customer satisfaction and to the organization's competitive position in the marketplace. While this realignment caused minimal change on the reference improvement technologies that were selected, it dramatically increased their real and perceived relevance (thereby increasing adoption success). And, it had significant impact on measurement and analysis to evaluate success, progress and technical results.



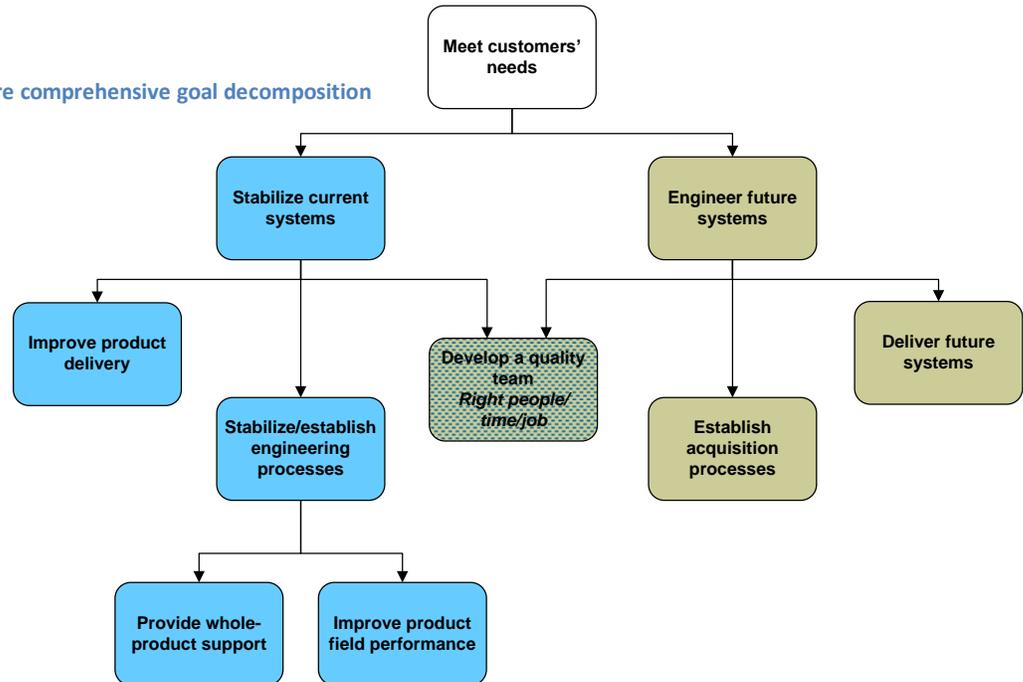
Customer Satisfaction Example 2: Initial Technology Selection and Strategy

Goal decomposition and performance benchmarking leads to identifying high priority improvement projects and relevant improvement technologies, which nicely follows the guidance questions.

The goal decomposition shown in *Figure 3* begins with a customer satisfaction oriented goal. This particular goal decomposition is broader, however, in that it spans the performance stabilization of an existing system, the creation of new or replacement systems, and the creation of the appropriate team to support both. As such, it is very comprehensive and shows the interplay of what ordinarily may be treated as separate operational objectives. To achieve each goal, a strategy and underlying tactical plan, with accompanying measures, must be identified.

Creating, Aligning, and Decomposing Goals (con't)

Figure 3: Broader, more comprehensive goal decomposition



Below, *Figure 4* shows the strategy for the goal Establish Acquisition Processes. In this particular case, the explicit holistic view provided by the goal decomposition allowed the organization to develop a blended model adoption and implementation plan for the establishment of acquisition processes—a plan that leveraged what was already underway for stabilizing engineering processes. Specifically, the organization chose a blend of CMMI (portions of which were being implemented in engineering), ISO 12207 and the SA CMM predecessor to what is now codified in the CMMI-ACQ.

In the comprehensive plan, such strategies would be identified for each goal.



Figure 4: Strategy to accomplish goal

STRATEGIC TECHNOLOGY CLASSIFICATION AND REFINING YOUR SELECTION DECISIONS SPEAKS VOLUMES

In the Customer Satisfaction examples, goal decompositions and measurement baselines were used to make initial selections of improvement technologies within the strategies for achieving each goal, which directly related to the third set of guidance questions:

“What process features, capabilities, or performance do we need to support our goals? Which improvement technologies provide or enable these features?”

In some cases, and definitely at the lower tiers of a goal structure, the needs are very specific or deeply technical, for example:

- We need change management or risk management or project management
- We need more innovation, perhaps a new product/service or a greater market share for an existing product/service
- We need cycle time reduction or more speed to market.

Certainly, these questions/needs will lead you to adopt a technology with particular features. Yet, in practice, there may be numerous technologies that have the desired features. When implemented, such overlaps ultimately need to be resolved. Furthermore, the technology combination resulting from feature-driven decision making may be incomplete. Higher-level goals, implied goals (such as “adhere to the law”), and other factors, may drive decisions to adopt technologies. From a strategic view, it is important to ensure that mandated (internally or externally) technologies are in the mix, even if they may seem to overlap in terms of features and addressing particular needs. And, there also may be internal history or cultural situations that lead to the inclusion of improvement technologies that are appropriate yet may have some degree of technical overlap.

To address this complicated technology combination selection process, we have developed a way to both screen and select technologies at a more strategic level using a strategic classification taxonomy. Figure 5 shows the current version of the strategic classification taxonomy. It depicts three major types of technologies: governance, infrastructure, and tactical. Plus, the taxonomy divides these categories into discipline-specific and non-discipline-specific segments. We have populated Figure 5 with a sampling of technologies, which is by no means exhaustive. This particular taxonomy is also annotated with directional arrows indicating decision authority of engineering (discipline-specific) improvement groups. These groups have increasing decision authority toward the discipline specific and toward the tactical technologies.

By definition, our strategic taxonomy is broad, yet it is designed to allow adding several more columns for different disciplines, thus broadening its reach.

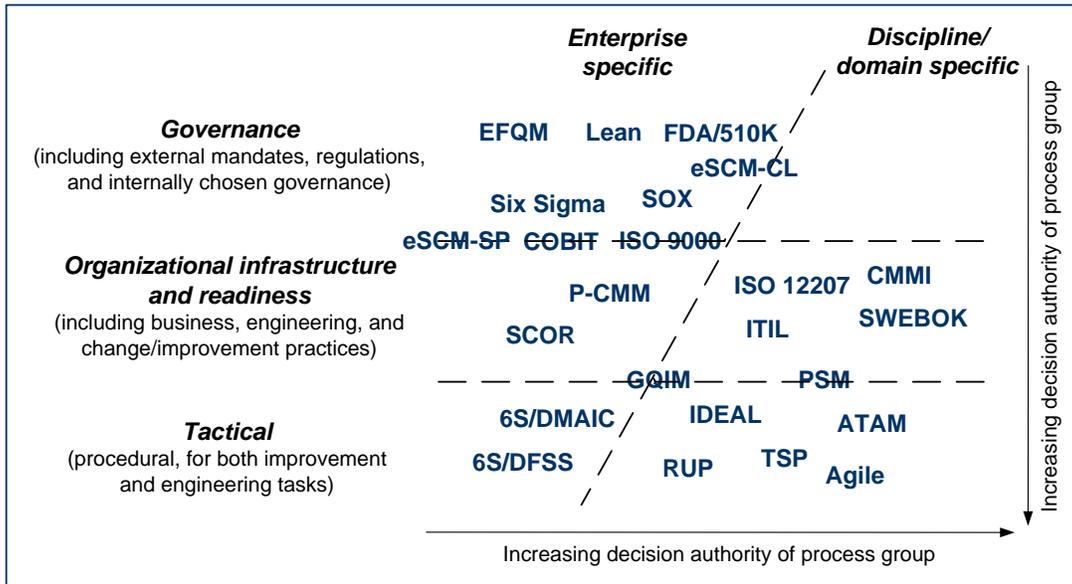


Figure 5: Strategic classification taxonomy

In practice, this taxonomy can be populated with feature-driven technology selections, as well as technologies chosen for any other reasons. For example, see the highlight below, Strategic Classification and Lockheed Martin IS&GS.

Following the population of the taxonomy, a logical analysis and/or benchmarking can be done. In a logical analysis, the grid can be examined for under- or over-populated areas. For instance, a complete absence of governance technologies should raise questions, as there are few organizations that have no governance requirements. Likewise, an absence of engineering or architecture technologies might raise questions if the organization is heavily involved in new product development and innovation. In both cases, such an absence in the taxonomy does not necessarily lead to or require that a technology be selected; it should just raise the appropriate questions.

Conversely, if the discipline-specific infrastructure portion of the taxonomy is over-populated, it might raise questions about the respective contribution of each technology. Every technology might well be needed, so this taxonomy can help to explain and communicate why.

In benchmarking, the taxonomy provides a basis for examining the selection patterns of similar organizations. For instance, IT organizational patterns and principles tend toward combinations containing ITIL, and telecommunications industry combinations typically include TL9000. In addition to which technologies are selected, taxonomy-based logical and benchmarking/pattern analysis can reveal the preferred implementation sequence in similar organizations. This may seem moot if your improvement effort is well underway and you are sorting through a myriad of technologies already in place or facing the addition of just one or two new models to an already established mix. However, for such situations, sequencing patterns can illustrate strategic enabling relationships and help prioritize the order of remaining implementation tasks. If you are just starting out, patterns and decision guides based on taxonomic classifications can assist with initial decisions about whether to

implement technologies sequentially or simultaneously, thus providing the basis for a strategy that leverages the best available thinking from the community.

The following are guidance questions to support the use of this matrix as a decision aid [Siviy 07]:

- What decision-making authority do you have?
- For governance models (whose selection is typically outside the engineering process group) or for non-domain-specific models (which also may be outside your authority):
 - What selections have been made—by both customer dictates and senior managers or other decision authorities?
 - Do you need to leverage models to solve a particular problem? Do you have a business case? A champion to help sell the decision makers?
- For types of models within your authority:
 - Have you translated your mission into actionable goals and baselined performance? What particular problems need to be solved? What new capabilities are needed?
 - What efforts are already under way?
 - Minimally, have you identified a reference model or practice for measurement, for lifecycle practices, and for improvement methods? At the infrastructure and at the procedural levels?
 - Which models enable others?

Using a taxonomy such as ours can help you to develop an overall, comprehensive multimodel strategy more quickly and with more ease and assurance by providing a basis for examining the selection patterns of similar organizations and making choices that are logic- and principle-based. Taxonomy-based pattern analysis can also reveal the preferred implementation sequence in similar organizations, which can help you prioritize your own strategy.

Strategic Classification and Lockheed Martin IS&GS

Together, *Figure 6* and *Figure 7* show the strategic classification and timeline associated with Lockheed Martin IS&GS's journey, as described in the book *CMMI and Six Sigma: Partners in Process Improvement*. The selection of the standards shown in *Figure 6* was often dictated by customers; therefore, there was no hesitation in adoption. It became adoption by direction. Some standards, such as Systems Engineering Capability Maturity Model (SE-CMM), Rational Unified Process (RUP), and People CMM, filled gaps in IS&GS's overall organizational process infrastructure. Their adoption expanded the process discipline into new areas and therefore put process in an all-inclusive light. During the process benchmarks, it became evident that the organization was starting to adopt some Agile concepts without the formality of organizational direction. A value stream mapping was held to define the meaning of Agile within the IS&S organization. An Agile Requirements Manual (ARM) was generated, which basically was tailoring guidance on how to implement Agile using the IS&GS PPS. Once adopted, a CMMI benchmark was conducted to see if use of the ARM was CMMI compliant.

Strategic Classification and Lockheed Martin IS&GS (con't)

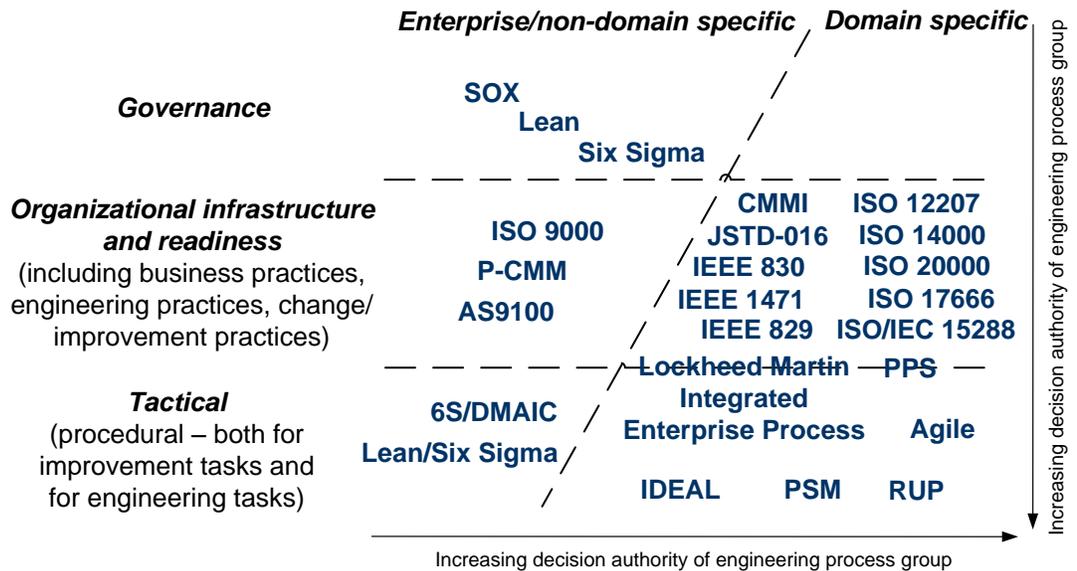


Figure 6: Lockheed Martin IS&GS Strategic Classification

Note that the PPS, the organization's internally developed process technology, is included in the figure. Also included is LMCO's Integrated Enterprise Process (IEP), which was a PPS-like approach at the overall enterprise level. These two are included not only as tactical standards but also as the formative documents for the actual process infrastructure.

Figure 7 shows the timeline and sequencing for technology implementation. Those infrastructure standards shown in Figure 6 but not in Figure 7 were auxiliary or supplemental standards that were mapped and tracked but not foundational to the organization's overall process assets.

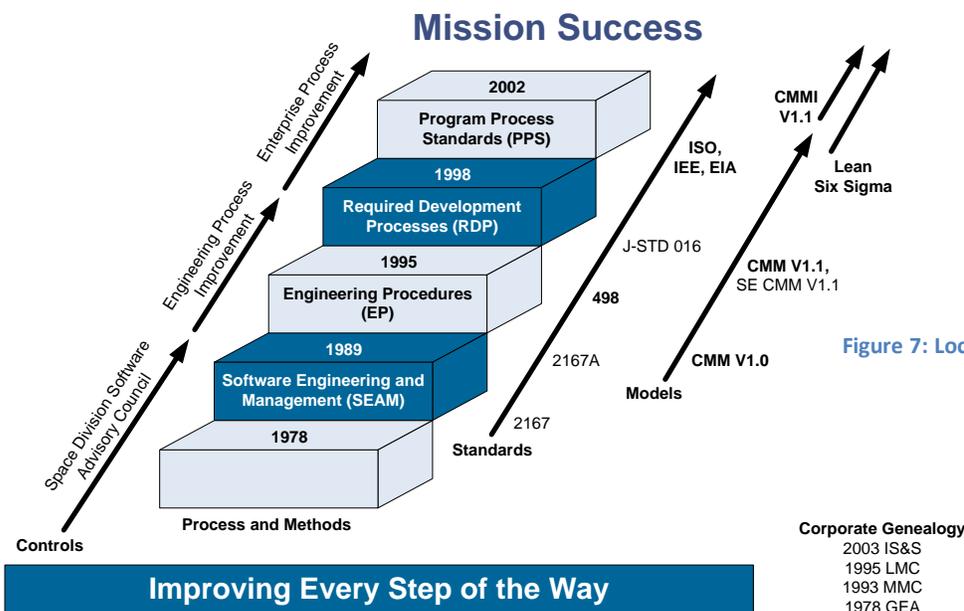


Figure 7: Lockheed Martin IS&GS Timeline

TRANSLATING STRATEGY INTO ACTION

There are a few considerations we have identified for translating strategic improvement technology selections into practice:

- What is the desirable implementation sequence?
- What are the enabling and other strategic relationships between technologies?
- How are the selected technologies interwoven and implemented?

In addition to which technologies are selected, taxonomy-based benchmarking can serve as data about the preferred implementation sequence through evaluation of patterns from similar organizations. Also, foundational research and logical analysis can shed light on enabling or other strategic relationships that may influence sequencing decisions, and may also help refine selection decisions. For instance, People CMM has been observed in many high performing organizations as an enabler of discipline-specific infrastructure technologies such as CMMI and ISO 12207. And, Six Sigma has been found feasible as an enabler and accelerator of technologies such as CMMI and ITIL [Siviy 04].

With strategic technology decisions made, the detailed multimodel solution must be designed and implemented. Multimodel solution design involves layers, much like products have design layers. Figure 8 shows our current view of these layers, along with crosscutting implementation issues.

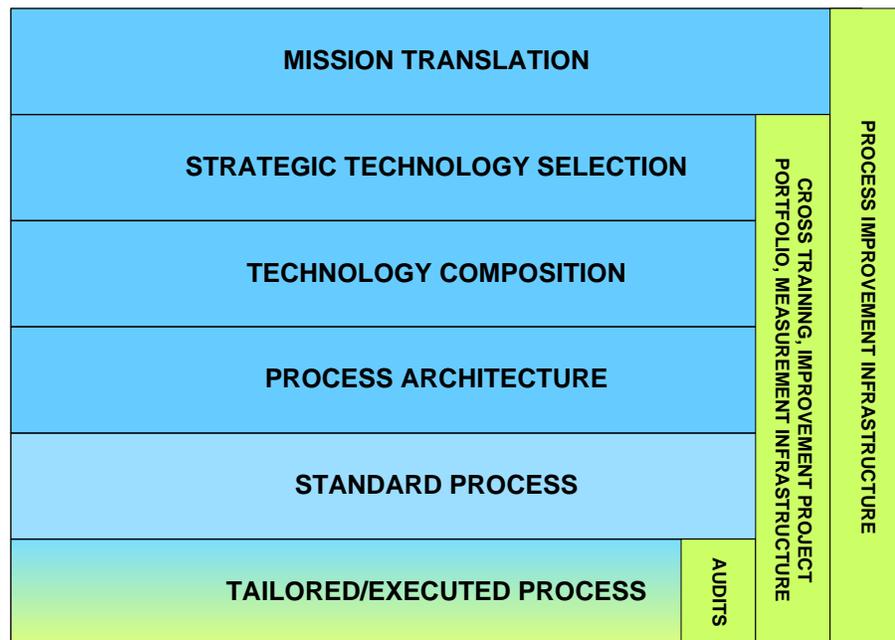


Figure 8: Strategy and design layers for harmonization

Note that it isn't necessary to address the design layers "top down." While mission translation is recommended as an initial task, the other layers may be addressed in whichever order suits your situation. Regardless of starting point, it is typically an iterative endeavor to address all of the layers.⁴

⁴ The technology composition layer, the process architecture layer, and implementation considerations are discussed in the remaining white papers.

IMPLEMENTATION STRATEGIES FOR THE CMMI AND SIX SIGMA AS AN EXAMPLAR FOR OTHER TECHNOLOGY COMBINATIONS

While the strategic taxonomy and thought questions offered in this white paper provide a basis for reasoning about a multimodel strategy, recommended strategies for specific model combinations have not yet been widely developed (see the “Future Research” section). However, our research on the CMMI & Six Sigma combination has yielded insight into joint implementation strategies and sequencing. Extensible to other specific model combinations, these are summarized here.

The following are strategies for the successful joint implementation of CMMI & Six Sigma. These strategies were developed based on implementation patterns in case studies from many organizations as well as on studies of the enabling relationships between the two technologies. The strategies are not mutually exclusive, and several may be “in play” simultaneously within an organization. They are mostly specific to these two models (although the underlying logic can be applied to other combinations), but the last strategy speaks specifically to the idea of harmonization presented in this white paper series. While the reason is not known, this notion of an explicitly harmonized approach and of an internal process standard that incorporates the features of and maps to the selected improvement technologies emerged in numerous CMMI & Six Sigma case studies that we collected. The specific approaches varied and have informed our codification of harmonization ideas.

Strategies [Siviy 07]

1. Implement engineering processes, using CMMI as the reference model, as Six Sigma projects.
2. Apply Six Sigma to those engineering processes implemented using CMMI:
 - Use DMAIC to improve process performance and serve as the tactical engine to achieve high capability and/or high maturity
 - Embed DFSS processes and methods as a means of achieving highly capable engineering processes
3. Apply Six Sigma to the overall improvement effort—the processes executed by the improvement professionals—to design it, to improve performance, or to lean it out.
4. Use CMMI’s institutionalization capabilities (via the generic practices) to institutionalize Six Sigma project results
5. And, lastly, Develop an internal process standard that maps to/integrates the CMMI, Six Sigma, and all other improvement initiatives; this defines the internal process for every project across its entire lifecycle.

The following are our observations about sequencing patterns, also rooted in the case studies from our CMMI & Six Sigma research [Siviy 07]:

- Implement the CMMI to achieve high maturity, and then implement Six Sigma. Use the CMMI as the governance technology to implement engineering processes, through to high maturity. Note that this will require using the analytical and statistical methods of Six Sigma; however it does not necessarily require a formal and “official” Six Sigma deployment. After achieving high maturity, adopt Six Sigma more fully and formally for ongoing process improvement.
- Institutionalize Six Sigma and then the CMMI. Deploy Six Sigma in the organization, and then use it as the governance technology to guide the adoption of the CMMI (as well as other technologies) to solve specific problems in the process infrastructure.
- Jointly implement Six Sigma and the CMMI. Alternate using the CMMI and Six Sigma as governance technology and tactical engine. For example, use Six Sigma to identify the need for particular CMMI process areas, and also to determine the needed efficiency (i.e., “lean”) and operational/performance requirements. Then, use CMMI to quickly identify critical process factors, which might not be easily or quickly identified in absence of a model or existing infrastructure. Also use CMMI to quickly identify opportunities to apply specific Six Sigma frameworks and analytical methods.
- Implement the CMMI to level 3, then establish Six Sigma; continue with a joint implementation. Establish process infrastructure using CMMI, then use Six Sigma to achieve high maturity. Note that this is a variant—some believe a more pragmatic one—of the first sequencing path listed above.

The choice about which path to pursue depends on the organization’s circumstances. In some cases, a sequential path is dictated by current reality. For instance, a CMMI adoption may be well under way when the enterprise levies the adoption of Six Sigma on the organization. Or an enterprise may have institutionalized Six Sigma and be well into the process of extending it into engineering when the non-software oriented Black Belts realize that there is no established software process infrastructure or measurement system (as there is in manufacturing). Presuming they have awareness of domain-specific models and standards, they then face the equivalent of a “build or buy” decision: invent software process infrastructure from scratch or tailor what the community has codified. Thoughtful, joint implementation throughout the entire improvement effort is likely to be the most efficient path, but only if the engineering process group and the organization are ready to accept the approach.

In all cases, it comes back to the matters of choice, conscious strategic decision making, and thoughtful designs. Happenstance and timing issues notwithstanding, an organization can be successful with any of the paths.

This paper has provided a view of the strategies needed to select and classify improvement technologies. It has addressed the critical role of mission translation in a multimodel improvement strategy. And, it has presented a strategic taxonomy that cuts across the enterprise and discipline, from governance to tactics. Additionally, it introduced considerations for translating a strategy into action—considerations such as the sequencing of the selected technologies. Such considerations are currently only well understood in the context of specific technology combinations.

While some organizations find this brief description of considerations to be a sufficient set of pointers to get started in the development of their own strategy, additional research is warranted to further codify the underlying principles and guidance to enable the broad community to develop their list of technologies that address customer requirements, solve their product and process problems, and optimize operations without reinventing any wheels (the “wheels” offered by codified improvement technologies, that is).

Following are several areas of relevant research to pursue. It is recommended that several different technology combinations be examined to provide a broad and substantial—and also robust and extensible—basis for results.

- **Pattern analysis**
The evaluation and codification of frequently used combinations (and implementation sequencing) of improvement technologies would serve as a useful decision aid, especially if accessible according to organizational characteristics (domain, size, etc.)
- **Decision models**
Providing a more rigorous and analytical approach, detailed decision models would enable the methodical comparison of business and process needs with technology features. Such decision models might be sophisticated variants of quality function deployment, or they might involve simpler, comparative evaluations using techniques such as Pugh’s concept.
- **Taxonomies**
Enhancing taxonomies and affinity groups for comparing and categorizing technologies—possibly as a basis for pattern analysis and decision models—is also an area needing further research.
- **Strategy elements**
Developing an understanding of and enhancing the definition of each layer in “design stack” shown in **Error! Reference source not found.**, is a key research need. This provides the backbone for harmonization, and as such, is key to a successful multimodel strategy.

References

The following are the references used in this white paper. Additional reading materials are listed in the “References” and the “Additional Resources” appendices of CMMI & Six Sigma: Partners in Process Improvement. This listing includes both model-specific references (for CMMI & Six Sigma, as well as other combinations) and multimodel references.

URLs are valid as of the publication date of this document.

[Armstrong 05]

Armstrong, James. “A Systems Approach to Process Infrastructure.” INCOSE Symposium, 2005.

[Bendell 05]

Bendell, Tony. “Structuring Business Process Improvement Methodologies.” *Total Quality Management* 16, no. 8–9 (October–November 2005).

[Daniel 61]

Daniel, D. Ronald. “Management Information Crisis.” *Harvard Business Review*, September–October 1961.

[Halvorsen 01]

Halvorsen, Christian Printzell and Reider Conradi. “A Taxonomy to Compare SPI Frameworks.” *Lecture Notes in Computer Science 2077* (Proceedings of the 8th European Workshop on Software Process Technology), 2001.

[Mayor 03]

Mayor, Tracy. “Six Sigma for Better IT Operations and Customer Satisfaction.” *CIO Magazine*, December 1, 2003. www.cio.com/archive/120103/sigma.html (accessed September 2007).

[Recardo et al. 07]

Recardo, Ronald, Kathleen Molloy, and James Pellegrino. “How the Learning Organization Manages Change.” *National Productivity Review* 15, no. 1 (January 17, 2007): 7–13.

[Rockart 86]

Rockart, Jack F. “A Primer on Critical Success Factors.” In *The Rise of Managerial Computing: The Best of the Center for Information Systems Research*, ed. with Christine V. Bullen. Homewood, IL: Dow Jones-Irwin, 1986.

[Siviy 04]

Siviy, Jeannine and Eileen Forrester, *Accelerating CMMI Adoption Using Six Sigma*, CMMI Users Group, 2004.

[Siviy 07]

Jeannine M. Siviy, M. Lynn Penn, & Robert W. Stoddard. *CMMI & Six Sigma: Partners in Process Improvement*, Addison-Wesley, December 2007.