Switching Tracks: Finding the Right Way to Get to Maturity Level 2

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When your customer contract requires that your "software development process must be CMMI Level 2," there's a right way and a wrong way to go about meeting that demand. KNORR Brake tried both ways and has the scars and the rewards to show for it. This is the story of how a very small organization first headed down the wrong track then changed direction—resulting in a successful maturity level 2 appraisal less than nine months later. KNORR Brake Corporation supplies pneumatic and hydraulic braking systems, air conditioning equipment (HVAC), and door operators, as well as repair, overhaul, and maintenance services, for all types of mass transit rail vehicles, including Metro, Light Rail, High-Speed Trains, Commuter Rail, and Monorail. Key characteristics of KNORR Brake products include high reliability, safety, integrated operations and communications, and specialized functionality not available from other vendors.

Of about 250 employees, fewer than 30 are involved in systems and software engineering; the others are employed in the manufacturing facility. Each software project involves one or two highly experienced electrical engineers who develop customized embedded software that is integrated with the hardware at the systems level.

KNORR Brake has maintained ISO-9001-2000 registration since 1994 and must also adhere to IRIS (International Railway Industry Standard) and follow the quality management standards of its parent company, KNORR-Bremse.

The Wrong Route

With such a strong quality management system in place, when a customer required "CMMI Level 2," we thought it would be easy, only requiring the addition of a few new artifacts. No one expected any significant gaps, but if gaps were found, everyone assumed there

would be an opportunity to fix minor issues and still achieve the level. Unfortunately, this misunderstanding resulted in a SCAMPI A appraisal that was an expensive way to discover that the organization was rated "mud-sucking, bottom-dwelling Level 1." It also cost the goodwill and enthusiasm of many of the people involved.

Based on our assumption that little or no preparation would be needed, we scheduled our SCAMPI A appraisal almost immediately. Several managers and engineers went to the SEI-authorized Introduction to CMMI course so they could learn what small additions CMMI required them to make to the current quality management system, as well as to meet the requirements for participating as appraisal team members. However, the course examples and model informative material were not very relevant to the world of embedded software and we were still confused about what the model required. Based on the course information and advice from our lead appraiser, we put in place some new processes and procedures, even though none of them provided any value to the business. People were willing to use these new "CMMI processes," but considered them to be useless overhead.

Assuming that all lead appraisers are equivalent, KNORR Brake hired the same lead appraiser who was working with several other subcontractors of the customer. Unfortunately, although he was very experienced and knowledgeable, the lead appraiser tried to assess our implementation of CMMI practices as if KNORR Brake was a large software application development organization—not a group of very small teams developing embedded software.

Although the customer contract specified that "software development must be CMMI Level 2," we assumed that the entire organization would need to comply with the CMMI standard—as if it were ISO or IRIS. As a result, the entire organization, including systems engineering and manufacturing as well as software engineering, was included in the scope of the appraisal. The large scope increased the duration and cost of the appraisal and made it more difficult to find the right evidence of implementation for each practice. At the same time, the areas the customer really cared about were not appraised.

Even though we weren't trying to improve any processes beyond adding some documents, the staff spent hundreds of unplanned hours just preparing for the appraisal, doing things like collecting artifacts. Based on our understanding of the SCAMPI A requirements for "objective evidence," the team wrongly assumed that each practice required at least two unique pieces of evidence; they copied and stored hundreds of documents in Practice Folders within Process Area Directories. Most of the artifacts collected were useless to the appraisal team who ended up looking for all of the evidence again after being unable to make sense of the information so laboriously provided.

The appraisal itself was an agonizing experience. People were nervous about preparation, and then once they were in an interview, they felt like they were on trial. Questions were asked in CMMI-speak rather than in the terminology used in KNORR Brake processes, so the answer was often, "We don't do that" when a particular CMMI practice was something they really did implement. Because no one in KNORR Brake really understood the CMMI model, the assumption was that there was nothing open to question in the lead appraiser's expectation of how practices should be implemented. No one could translate the KNORR Brake processes for embedded software development into CMMI terminology that the lead appraiser would understand. As a result, the organization was rated maturity level 1, the recommendations for addressing gaps weren't useful or implementable, and the whole organization felt that CMMI was a waste of effort.

Switching to the Right Way

Because the contract still required CMMI Level 2 for Software Development, senior management decided to learn more about CMMI and try again. It wasn't easy because we had to overcome some very negative attitudes toward CMMI and SCAMPI in particular, as well as consultants, process improvement, and appraisals in general.

However, this time, we treated the effort as a project, not as an activity to be done in the margins. As long as we had to do it, we decided that we might as well do something useful. We looked at the contract requirement for CMMI Level 2 as an opportunity for

understanding KNORR Brake written and unwritten processes and then improving them as needed to add business value.

Senior management demonstrated their commitment by allocating an experienced project manager to manage and facilitate the process improvement effort full-time and granting him the authority and resources necessary to make it happen. This person not only had quality assurance experience, project management experience, and some CMMI training, he was highly respected and trusted by everyone based on his technical experience and skill in delivering a product.

All of the software engineering staff had time allocated to the process improvement program and were involved and engaged in clarifying, understanding, defining, and improving the program lifecycle, operational procedures, work instructions, and the flow and dependencies among them. As an added benefit, the engineers ended up learning a lot from each other, as well as defining processes that worked.

The first step was to look carefully at the contract requirement for CMMI Level 2 to determine exactly where to focus. At the same time, the CMMI Project Manager began to look for a certified lead appraiser to serve as a consultant; someone who would understand the needs and context of a very small organization that does embedded software and who could coach us in interpreting the CMMI model for implementation in that context. The initial phase of the process improvement project included working with the selected consultant to review the contract language to ensure that we really understood what was required, and then to confirm that understanding with the customer. This narrowed the scope of the effort to the software engineering group processes, rather than trying to change the whole enterprise. This approach made the process improvement project more manageable and increased the likelihood of success.

On any journey, whether it's an actual journey by rail or a metaphorical journey of process improvement, it's important to start by understanding where you are and where you want to go. We worked with the new consultant on an in-depth current state analysis to understand the overall KNORR Brake software engineering process architecture, map "what software engineers do and how they do it" to

the CMMI model practices to identify possible gaps, and then decide what to do to address those gaps.

CMMI was used as a guide, but all implementation decisions were based on the KNORR Brake process context and culture. A highly interactive version of the SCAMPI B methodology that didn't require the organization to prepare evidence ahead of time was used for the current state analysis to reduce adverse impact on current product development activities without impacting the quality and usefulness of the appraisal results, to increase the learning opportunities during the appraisal, and to be able to tell the customer about process improvement progress in terms of CMMI and their contract requirements.

Over the next several months, the CMMI Project Manager met twice a week for two-hour sessions (lunch provided!) with members of the software engineering group to understand, clarify, and enhance the processes and procedures related to developing embedded software. The CMMI Project Manager reported progress regularly at management status meetings and also met weekly by phone for coaching with the consultant to go over progress, issues, and achievements.

The consultant returned twice for a few days each time to provide customized training and lead hands-on workshop sessions with the team to cover some specific areas of need related to process architecture definition, estimation, risk management, and measurement and analysis. Although everyone was fully engaged with defining processes and procedures, the CMMI Project Manager was responsible for actually documenting them and for ensuring that the KNORR Brake document manager formatted them appropriately and submitted them to the corporate repository correctly.

Our initial focus was to define and document the work flow into the KNORR V-Model (a view of the project lifecycle). When the effort started, program management had monitored only customer document deliverables and three other software engineering tasks: design, code, and test. No one other than software engineers could understand why the software engineering effort and duration estimates were so high, when there appeared to be so little work to do. After we finished, all of

the key activities, dependencies, and deliverables were captured in the V-Model; as a result, program management and senior management now had a much better understanding of the software engineering work. CMMI practices in the Requirements Management, Project Planning, Project Monitoring and Control, and Measurement and Analysis processes areas provided guidance for our implementation of the KNORR V-Model.

The KNORR V-Model provided the foundation for an improved and more useful work breakdown structure (WBS), which in turn was used as a starting point for identifying and estimating the factors that impact how much effort each task or deliverable would require. Although the CMMI model informative material and formal training provided many examples of these factors, such as number of functions, source lines of code, and numbers of pages, it turned out that the examples given were not the primary factors affecting effort and schedule estimates in KNORR embedded development.

Engineers knew what factors impacted their effort, but had never captured or shared this tacit knowledge. For example, the amount of work required for customer-deliverable documents is affected by the number of circuit boards and the number of revisions a particular customer is likely to require, rather than the number of pages in a document. With some initial coaching from the consultant, the team was able to determine what factors did make a difference, and then use Wide Band Delphi techniques to estimate typical effort ranges for tasks, depending on the values of those factors and historical effort data for similar activities.

The typical effort ranges were used in the updated project plans and as input to new bids and projects. As a result, KNORR Brake was able to more accurately estimate the cost of new software engineering work, and provide customers with a more accurate prediction of delivery dates. CMMI practices in the Project Planning, Project Monitoring and Control, and Measurement and Analysis process areas helped us implement the new WBS.

After the KNORR V-Model was established, the software project attributes identified, and the WBS completed, the Program Management Schedule was updated to reflect the actual activities, so it

was much easier to predict how long a project would take and monitor progress during the project. An additional benefit was that the rest of the organization gained a much better appreciation of the value the software engineering team was providing to the business. Understanding the real project attributes and WBS made a huge improvement in managing our software engineering resources across projects and provided valuable input when bidding new projects.

Some KNORR Brake customers required a Software Requirements Traceability Matrix (SRTM) as a deliverable, but the SRTM was often created after all the work was completed and used to document what existed, rather than a means to manage the work. However, one software engineer had discovered that it was a useful tool, and shared that experience with the other team members during the weekly meetings. The KNORR V-Model was then used to update the structure for the SRTM so that it helps ensure requirements coverage and assessment of the impact of changes throughout a project.

KNORR Brake already had a process for capturing requirements changes that were charged to the customer. However, if a change seemed small or the program manager decided to give it to the customer without charge, it wasn't recorded, and the impact on project schedules, effort, and cost was not assessed. We enhanced and institutionalized the Project Change Request (PCR) process with a new PCR Procedure that requires systems and software engineers to evaluate all changes to determine impact on the schedule, cost, and/or scope and identify any risks related to the change.

We quickly saw the value in the new procedure because several requests that would have been assumed to be small turned into revenue-producing changes, whereas others did not generate a customer charge, but still required replanning of the project resources because they affected the effort and schedule. In conjunction with the KNORR V-Model and the new WBS, CMMI practices in the Requirements Management, Project Planning, Project Monitoring and Control, and Configuration Management process areas helped guide the changes made in the SRTM and the new PCR change request template and procedure.

All of the process and procedure changes interacted synergistically, each supporting and enhancing the others. All either clarified or enhanced the way work was already being done; none added useless overhead. Because the changes were a natural extension of the current processes, it was easy to institutionalize them within the KNORR Quality Management System.

After the process changes were established and as they were becoming institutionalized, the organization began planning for the SCAMPI A appraisal. Working with the consultant, the CMMI Project Manager defined a set of questions to use when interviewing potential lead appraisers to determine whether the candidate would be capable of understanding how CMMI practices can be implemented in a very small organization that creates embedded software. The lead appraiser needed to be able to adapt to the KNORR Brake organizational and process culture, rather than expecting KNORR Brake to do things in a particular way. Because KNORR Brake wanted to have the appraisal before the end of the calendar year, a time that many other organizations are also trying to schedule appraisals, the selection process began in the late summer to increase the likelihood that the lead appraiser chosen would be available when needed.

Each new process advancement and tool improvement was merged into our existing Quality Management System by writing new work instructions and/or operational procedures and storing them in an online repository we call REX (Rail Excellence). This allows both existing and new employees to easily find the appropriate procedures and templates within the context of the process maps that clearly define the development and design lifecycles.

Preparing evidence for the SCAMPI A appraisal turned out to be simple. Because the CMMI Project Manager knew which KNORR Brake processes implemented which CMMI practices, it was just a matter of pointing to the actual work products once they were created. Most of the artifacts selected for evidence had sections that were appropriate for multiple CMMI process areas and practices. The consultant reviewed the evidence with the program manager to make sure the work products selected were appropriate and complete, and that there were clear explanations of the context so that the appraisal

team would understand why those particular artifacts were selected. It didn't matter which projects were eventually chosen by the lead appraiser to represent the organization, because the work product links pointed to directory structures that included all projects.

The appraisal was interactive and cooperative rather than confrontational. Work outputs were projected on a screen and the lead appraiser asked participants to explain their work for the entire appraisal team to review. If questions or concerns were raised, they were answered immediately rather than waiting for a separate validation session. Because the appraisal focused on KNORR Brake processes and evaluated CMMI model implementation within that context, rather than focusing on CMMI itself, no one felt threatened and the information was complete and accurate.

The appraisal was finished in less than four days and KNORR Brake software engineering achieved their goal of being rated maturity level 2. Although achieving that rating was certainly important for contractual reasons, perhaps more significantly, staff and management learned that CMMI practices could add value without adding overhead. Members of other functional groups and product lines were asking, "Why do only the software engineers get to do CMMI? We want to do it too!"

Moving Forward (The Journey Continues . . .)

Based on the successful SCAMPI A appraisal with the KNORR Brake Software Development Group and the noticeable value added by the new processes and procedures, the company decided to continue the process improvement effort. The CMMI Project Manager was promoted to a newly formed position as Manager, Business Process Improvement with a mandate from senior staff to make improvements throughout KNORR business and engineering processes. Currently, KNORR has four process improvement teams in action.

One team is extending the Brakes software engineering process improvement work into the domain of HVAC software engineering. The team has already completed tailoring the KNORR V-Model lifecycle and WBS for developing embedded code in the HVAC domain. Project schedules have been updated accordingly with

milestones based on a more realistic view of the work required. The HVAC team improved on the Brakes software engineering process with the implementation of a new template for identifying the key project attributes that allows for multiple variations. With this new tool, the HVAC Software Engineer can more accurately characterize the project type, which is a key factor in estimation of effort and schedule.

We are also extending the process improvement work into systems engineering in both the Brakes and HVAC domains. This team is reviewing the systems engineering lifecycle and mapping CMMI practices to the systems engineering process. We are looking at the maturity level 2 process areas, as well as key maturity level 3 process areas where the organization is already strong or where there are issues that need to be addressed in the near term.

Due to the successful process improvement effort completed by the Brakes software engineering group and because the team approach is working extremely well with the newly formed cross-domain software and systems engineering teams, senior management supported formation of a HVAC New Product Design Team that will use CMMI ML2 and ML3 practices in designing new HVAC equipment.

After the systems and software engineering design lifecycles were well understood, we realized that the proposal process needed to be integrated into the overall product lifecycle. A proposal team has completed mapping the entire proposal process and clarifying how it feeds into the systems and software design lifecycle when proposals are awarded. The effort and documentation within the proposal process has proved extremely valuable by providing the framework for future bids as well as helping us predict the resource and time allocation needed for bid preparation itself. In addition, when the contract is awarded, the product and customer details from the bid process are directly transferable into estimates of project size, tasks, and deliverables, thereby saving planning time and effort.

At the end of the year, we will conduct a SCAMPI A that includes systems engineering and software engineering processes for both Brakes and HVAC. We will still use some assistance from an outside consultant to validate our assumptions and decisions, but now that we

are able to understand how to apply the CMMI model within the KNORR context, we need much less direct guidance. Based on our experience with process improvement in Brakes software engineering, we predict a high likelihood of success, which will put KNORR at a competitive advantage in our market domain.

Lessons Learned

As a result of travelling first down the wrong track and then down the right one, we have learned some key lessons, which we will apply as we continue on our journey of process improvement:

1. Question assumptions and trust your instincts. Don't assume that you have to do something because CMMI or some expert "requires" it. If it doesn't seem to make any business sense, it probably isn't a good implementation for your current organizational context.
2. When trying to meet contract requirements, use the contract language to help specify organization and model scope for a formal appraisal. Understanding the contract requirements focuses the improvement effort and helps achieve immediate value.
3. Especially if you have had a previous negative experience with process improvement, demonstrate value early and often. When staff and managers see that a change makes their own work easier or more effective, they are more likely to be willing to embrace further changes.
4. Process improvement using CMMI is not something that can be done in the margins. It requires dedicated effort by a respected and trusted project manager as well as involvement and engagement from everyone at every level in the organization.
5. The CMMI model provides value only if it is used as a guide for process improvement, not as a checkbox exercise. Process improvement is not a matter of documenting what "should" be done and forcing everyone to comply, whether or not it provides any business value. Changing the paradigm from "getting by for certification" to "clarifying and improving our processes and using the CMMI model to help" validates what is already being done, makes any changes "stick," and ensures that those changes add business value.
6. All CMMI goals and practices are useful and do not add unnecessary overhead—as long as you interpret them and implement them within

your own business and technical context. Within your organizational context, each process improvement will often implement several CMMI practices, and synergy among the improvements increases the benefit of each.

7. A consultant who understands the organizational context can provide guidance in areas where the organization doesn't have expertise and can help the program stay on track. However, process changes need to come from inside the organization for the changes to be institutionalized. Be sure to choose a consultant who will coach rather than prescribe.

8. Choosing a lead appraiser who understands the business context ensures that the appraisal will be valid. If the lead appraiser doesn't really understand the business context and there is no one to help translate between CMMI-ese and the organization's processes and terminology, there's a high likelihood that the appraisal results will be invalid due to miscommunication and you will not achieve your goal.

9. When process improvement activities bring clear business value to one part of the organization, other parts of the organization will ask to get on board too. Success breeds success.

After we switched to the right track for our process improvement journey using CMMI, we have had an enjoyable trip, were able to arrive on schedule, and are looking forward to travelling to the next destination!