Using Pilots to Assess the Value and Approach of CMMI Implementation

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Abstract
At Goddard Space Flight Center (GSFC), we have chosen to use Capability Maturity Model Integrated (CMMI)[1] to guide our process improvement program. Projects at GSFC consist of complex systems of software and hardware that control satellites, operate ground systems, run instruments, manage databases and data and support scientific research. It is a challenge to launch a process improvement program that encompasses our diverse systems, yet is manageable in terms of cost effectiveness.

In order to establish the best approach for improvement, our process improvement effort was divided into three phases:

1: Pilot projects
2.: Staged implementation
3: Sustainment and continual improvement

During Phase 1 the focus of the activities was on a baselining process, using pre-appraisals in order to get a baseline for making a better cost and effort estimate for the improvement effort. Pilot pre-appraisals were conducted from different perspectives so different approaches for process implementation could be evaluated. Phase 1 also concentrated on establishing an improvement infrastructure and training of the improvement teams.

At the time of this paper, three pilot appraisals have been completed. Our initial appraisal was performed in a flight software area, considering the flight software organization as the organization. The second appraisal was done from a project perspective, focusing on systems engineering and acquisition, and using the organization as GSFC. The final appraisal was in a ground support software area, again using GSFC as the organization.

This paper will present our initial approach, lessons learned from all three pilots and the changes in our approach based on the lessons learned.

1.0 Introduction:

Software engineering is a core capability and key enabling technology necessary for the support of NASA's missions. Ensuring the quality, safety and reliability of software is of paramount importance in achieving mission success. The exponential growth in the

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[1] CMMI is a service mark of Carnegie Mellon University. CMM, Capability Maturity Model and Capability Maturity Modeling are registered in the US Patent and Trademark Office.

scope, complexity, and importance of software is expected to continue, challenging our ability to manage it effectively. In order to meet these challenges, NASA has begun improvement initiatives in both software and systems engineering.

For the NASA Software Initiative, a committee of representatives from each of the NASA Centers developed the NASA Software Initiative Implementation Plan to outline a comprehensive approach for improving software engineering to a quantifiable maturity level commensurate with the mission criticality of the software. The four strategies included in the NASA plan are:

- To develop and implement Agency-wide and Center plans for continuous software process and product improvement in NASA and Contractor developed software; also to establish an infrastructure and measurement system to support improvement.
- To improve safety, reliability, and quality of software products through the integration of sound software engineering principles and standards.
- To provide input for research based on identified software problem areas and infuse research results.
- To improve the software engineering knowledge base in NASA, and implement strategies for attracting and retaining software engineers.

As a part of this plan, the use of either the Software Engineering Institute's Capability Maturity Model (CMM) or the Capability Maturity Model Integrated (CMMI) as a measure of improvement was recommended.

In response to the NASA Software Initiative Implementation Plan, Goddard Space Flight Center (GSFC) developed a software process improvement plan to address the four NASA strategies at Goddard. After careful consideration of the two recommended models, GSFC chose to use the CMMI model to measure its improvements. The remainder of this paper will focus on Goddard's plan and the experiences gained during the early implementation of this plan.

The Capability Maturity Model Integrated (CMMI) is a framework for process improvement containing a collection of best practices that can be expected of organizations producing quality systems and software. Concepts covered by this model include project management areas such as planning, monitoring and control, engineering areas such as technical solution, verification and validation, organizational areas (or process management areas) such as organizational training, and organizational focus, and support areas such configuration management and measurement. The staged representation of CMMI identifies five levels of maturity through which an organization evolves as it improves its processes. For GSFC, the initial plan was to achieve Level 3 maturity on all projects determined to be mission critical or otherwise critical to GSFC's business goals.

In the systems engineering area, another NASA-wide team was formed to improve processes and best practices for systems engineering on projects and programs throughout the Agency. This group is also developing an improvement plan and is investigating the use of various models, such as the CMMI for use in their improvement program. At GSFC, the systems engineering group is working with the software people to

evaluate the use of CMMI in the systems engineering areas. This pilot will help NASA with the choice of a model for systems engineering.

2.0 Goddard Space Flight Center's Improvement Plan Using CMMI

The primary focus of the GSFC Process Implementation Plan is to improve the processes and practices in use at GSFC, using the CMMI as a measure of progress. The specific goals are to increase the percentage of on-time, within-cost software development projects, to increase productivity, and to reduce the post-delivery error rate after delivery. GSFC's plan calls for a three phases of implementation as follows:

- Phase 1: A pilot project phase to baseline the processes and practices in use and to assess the implementation approach of the process improvement effort
- Phase 2: Staged implementation of process improvement effort on all mission critical and mission support projects with the eventual target of raising the maturity levels, as measured against CMMI.
- Phase 3: Maintain maturity achieved and support a continuous process improvement program

2.1 Infrastructure for Improvement

In order to manage the process improvement effort three organizations were established: the Management Oversight Group, the Engineering Process Group, and the Asset Management Group. These groups will support the implementation of the process area activities and other improvements identified during the entire process improvement effort. These groups were formed during the initial phase of the implementation. The Groups and their interaction are described below:

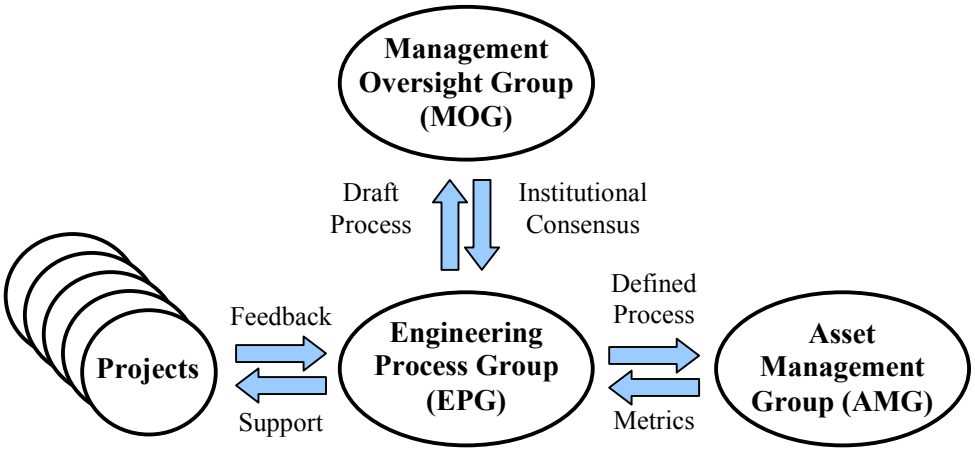
2.1.1 The Management Oversight Group

The Management Oversight Group (MOG) is responsible for ensuring that the process improvement activities address GSFC needs, that GSFC institutional processes are defined, and that the stakeholder organizations are committed to using the established policies and procedures. During the initial phases, the MOG continually evaluates the progress and determines the potential source of needed resources. As CMMI implementation is rolled out to GSFC projects, the MOG will determine the schedule for projects and programs participating in the process improvement effort.

2.1.2 The Engineering Process Group

The Engineering Process Group (EPG) is the focal point for software process improvement across GSFC, and its responsibilities have recently been expanded to include systems engineering. The EPG maintains the overall view of current efforts and facilitates those efforts on a continuing basis. The EPG develops and maintains expertise in process definition, organizational change, and technology related to improving and ensuring software/systems quality. The EPG also facilitates deployment of improved software/systems development activities by working closely with the projects to enhance their understanding and application of any new process and technology improvements. This is critical to the success of the process improvement implementation. EPG members foster collaboration among everyone at GSFC involved with software/systems development process improvement or application of the practice. The EPG is staffed by

software/systems process engineering experts and by software/systems engineers with practitioner experience representing all directorates across GSFC.



2.1.3 The Asset Management Group

The Asset Management Group (AMG) supports the EPG and focuses on the establishment and maintenance of the infrastructure elements necessary to support a continuous process improvement effort. It is chartered with maintaining a profile of GSFC software processes and products, and with the collection of information that will maximize the return on GSFC investment in software intellectual property. These activities will continue throughout the process improvement activities. To this end the AMG is responsible for software knowledge management, the on-line deployment of GSFC documented software policies and procedures, and the provision of software engineering tools that support GSFC software engineering practices. Although currently focused on the software process improvement effort, there are plans to expand the AMG to include systems engineering next year

3.0 Phase 1 Activities

Currently GSFC is working to complete its Phase 1 activities and to begin more detailed planning for Phase 2. As mentioned previously, several pilot areas were chosen to be representative of software developed at GSFC. Then these pilot areas were evaluated against the staged CMMI model using SEI-certified appraisers during pre-appraisals. The objectives of using pilot projects in Phase 1 of the implementation were to:

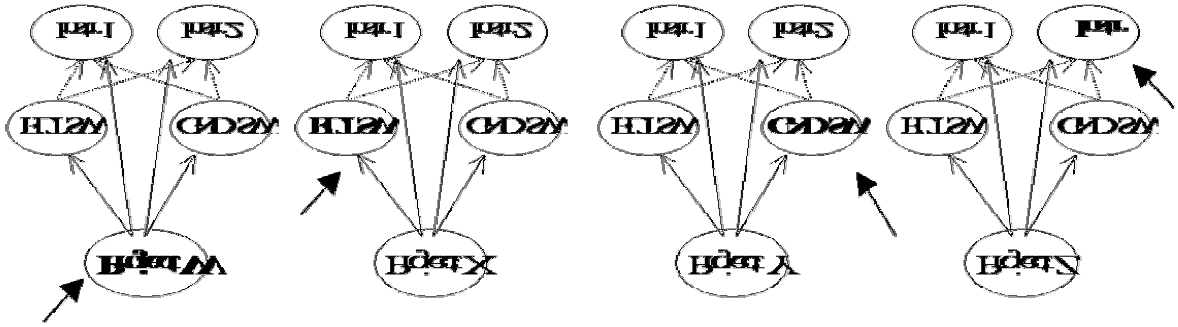
- Understand the resources (i.e., resources defined primarily as personnel time) needed to implement process areas in the CMMI maturity levels two and three,
- Understand the comprehensiveness and interaction between the process areas,
- Be aware of critical issues and potential problems with process improvement in relation to the GSFC culture,
- Be aware of major issues and the impact of metrics collection required for CMMI,

- Establish the baseline of current costs and quality of software developed.

Originally, four pilot areas were planned. To date, three pilot areas have been appraised, and the fourth has been deferred due to the lack of available projects meeting the criteria for the fourth pilot.

3.1 Selection of Pilot Areas

At GSFC, a software project can be described in its simplest form as composed of flight software, ground software, and instruments. The flight and ground software along with the instruments will be viewed as suppliers to the project to simplify the application of the CMMI model. Therefore, there are four types of components that need to be assessed against CMMI: the project itself (including systems engineering and acquisition), the flight software, the ground software, and each instrument. It was recommended that there be four pilot areas, one from each component area. For Phase 1, one component project from each pilot area was chosen for improvement activities following the appraisal. This is shown below by the arrows.



Pilot Project Implementation Selection

The following criteria were used to select projects in each pilot area:

- Project is already established so that there are existing procedures to evaluate.
- Project management is stable, willing to support participation in the process improvement effort, and has the necessary funding available.
- Project is comprised of enough project members to ensure that all process areas can be evaluated and improved.
- Project has visibility within GSFC to ensure appropriate emphasis on the process improvement effort.

3.2 The First Appraisal

Our initial appraisal was performed on the Flight Software area, using one completed project with all documentation in place and one project nearing the preliminary design review point. For this appraisal, the organization was considered the flight software organization, and few interviews included people outside of this organization.

Project participants were given a three-day CMMI class, but had very little other preparation for the pre-appraisal. No attempt was made to map their documentation to

CMMI process areas or to identify alternative practices that might be in place before the appraisal. Most of the flight software participants were on very tight schedules and every attempt was made to minimize their preparation and interview time during the appraisal process.

A team of six appraisers was used; three were EPG members and three were SEI-certified appraisers from outside GSFC. The appraisal team divided the process areas and each took the lead on interview questions in their area. The appraisal took four days with the majority of the interviews on two days and the remaining two days devoted to document review. Although less formal, a SCAMPI-type of approach was used, where findings are the result of team consensus, supported by multiple data points from multiple sessions. A findings briefing was given on the last day describing the weaknesses identified in each process area by specific practice. A draft findings presentation was not given which resulted in problems during the final findings briefing. Practices in both Levels 2 and 3 were evaluated, but no maturity level rating was given.

Following the appraisal, the EPG team members who had participated in the appraisal met with the flight software manager to discuss the weaknesses and her priorities for addressing them. Then the EPG determined what existing assets and resources could be applied in those areas and made an improvement proposal to the manager. Based on the improvement proposal and the flight software manager's priorities, five process action teams were formed to address weak areas.

3.3 The Second Appraisal

The second appraisal was done from the project perspective, focusing on systems engineering and looking at the software components as acquisitions. Three major spacecraft projects were chosen to participate. One was still in the formulation stage, nearing a systems requirements review. The second was a major project in mid-development, with about two years remaining until launch and the third was a project within a program developing a series of "turn-key" spacecraft. For this appraisal, the organization was considered to be GSFC, since GSFC is a matrix organization with personnel from different functional groups assigned to each of the projects.

Project participants were given an overview of CMMI, but not the three-day class. Although there was still a desire to minimize the amount of the project personnel time, participants were given lists of example types of documentation and sample types of questions.

Again, a team of six appraisers was used, with three SEI-certified Lead appraisers and three EPG members. This time, the EPG members of the appraisal team included one systems engineer, one quality assurance person and one software person. The SEI-certified Lead appraiser asked the majority of the interview questions. The same methodology was followed as in the first appraisal, except that more emphasis was placed on interviews and less on documentation. The appraisal took five days, with most of three days devoted to interviews. The fourth day was used for document review and a draft findings presentation. The final briefing was presented in terms of weaknesses and

strengths for the goals of the process areas in Levels 2 and 3. No maturity ratings were determined.

3.4 The Third Appraisal

The third appraisal was similar to the first in the choice of projects, since the projects chosen were subsystems of larger projects that were being managed relatively independently of their larger project. Two projects were chosen, both being developed in a ground support system software organization. One project was completed, and the development team was just beginning a very similar project. The second project was in a testing phase. For this appraisal, the organization was again considered to be GSFC. The larger project was considered for the areas of support it provided.

A new appraisal methodology was used for this appraisal. During the course of the year that we had been trying to do pilot appraisals, the appraisal methodology for this type of "quick-look" appraisal had been evolving at the Software Engineering Institute and among the authorized appraisers. A new tool called a Process Implementation Indicator Document (PIID) was introduced for this appraisal. This document listed all the expected practices in the model and provided space to record any evidence of the practice in boxes marked "direct work product", "indirect work product" or "affirmation."

In order to use the tool, the appraisal team, consisting of two SEI-authorized appraisers and four GSFC EPG members, was given a three-day "team training" to learn how to use the PIIDS. This occurred about a month before the actual appraisal. The internal appraisal team members met with the leads of the participating projects and gathered what they felt would be appropriate documentation to begin populating the PIID. Then the GSFC EPG team members and the SEI-authorized appraisers spent another week working to fill in the PIID information, using the documentation gathered from the team leads. No interviews were done during this week of preparation for the appraisal.

Again, with this appraisal, there was a strong desire to minimize the time of the project people spent on the appraisal. Project participants were again given an overview of CMMI, but were not involved in the initial efforts to populate the PIIDS. During the actual appraisal week, the project people were interviewed to verify what had been entered in the PIIDS and to learn about anything that had not been collected initially. Again a draft findings briefing was held and then a final briefing of the strengths and weaknesses on the fifth day. The process areas at levels 2 and 3 were examined, but due to the time constraints, most of the process areas with an organizational focus were not evaluated.

4.0 Lessons Learned to Date

To date, initial evaluations of the activities and the processes used during Phase 1 are being summarized and have resulted in lessons learned for future activities. Some lessons learned are GSFC-specific, but many others may be useful to other organizations beginning process improvement. The lessons presented here relate to training, choice of organization for improvement, management support, and pre-appraisal lessons.

4.1 Definition of the "organization" can be difficult
For the first appraisal, GSFC defined the "organization" to be appraised as the line organization that contained developers/engineers producing like types of component software or services. Examples of these types of organizations would be "flight software organization", "ground software organization", "systems engineering organization".

Since GSFC uses a matrix organization, groups from each of these types of organizations are assigned to support each spacecraft project. The line management organization is responsible for the training and detailed process activities of these groups, but all project management activities (requirements, schedules, budgets, interface coordination, etc.) are performed by the spacecraft project organization. For the second and third appraisals, the "organization" was defined as GSFC, a much larger entity, which contains both the spacecraft project organizations as well as the smaller component organizations.

The advantage of defining the organization using the component types of organizations is that the scope you are dealing with is much smaller. The primary disadvantage in a matrixed organization such as GSFC is that many of the process areas are addressed at GSFC by other component organizations, making it very difficult to determine whether the appropriate practices are being performed without looking in detail at the other supporting organizations.

4.2 Management support is key to finding co-operative pilots
Typical projects at GSFC have deadline-driven schedules and a budget that is usually less than desirable. Thus project managers are not anxious to engage in any types of activities such as appraisals or classes that will not directly assist them with their primary goal—that of delivering an operational spacecraft system. Initially, the EPG members spoke with many of the project managers about participating in the Phase 1 pilot areas. Very few were willing to participate in the appraisals.

In order to obtain participants for the second set of appraisals, the EPG enlisted assistance from the MOG. One of the members of the MOG accompanied the EPG member to present the request for participation to the projects. Using this approach, every project contacted agreed to participate. Similarly, in the third appraisal, the line manager of the component organization was very supportive, and the projects chosen in that organization were very cooperative.

4.3 Pre-appraisals by an outside group provide a good starting point
Many organizations beginning process improvement start by working on the areas they feel are weak, without having the benefit of external guidance. GSFC chose to have SEI-certified appraisers outside NASA help them with their initial benchmarking against the CMMI model. In retrospect, there are many advantages to this approach.

First, in one short week, we were able to amass a tremendous amount of information on exactly how activities were being performed in different areas and what documentation was being used. By using multiple projects in our "pilot areas", we also got a good view

of the consistency of activities across projects. This baseline information was very useful in providing a benchmark of comparison with industry standards for senior management to evaluate and determine what types of improvements they would like to sponsor.

The use of appraisers outside NASA enabled the EPG to get a good view of exactly how the existing GSFC processes and documentation would be viewed in a more formal appraisal. In some cases, the documentation reviewed was considered sufficient by the outside appraisers, when the EPG would have considered that additional documentation was necessary. The use of outside appraisers also gave a more official flavor to the pre-appraisals, which encouraged the participating projects to assure that the appropriate people would be available for interviews.

Finally, the major benefit of using the pre-appraisals with certified Lead appraisers was training it provided to the EPG members participating in the appraisals. EPG members now have a very clear idea of exactly how a SCAMPI appraisal would be conducted, and a very good idea of how the CMMI model would be applied to activities at GSFC. In addition, the process of going through an appraisal is very helpful in becoming more familiar with the CMMI model and its interpretation. The model is very large and complicated, and it takes time to learn it well. The appraisal process provides a practical way to increase model knowledge in a short time period.

The major disadvantage of spending a significant percentage of our available process improvement effort on the pre-appraisals was that very few resources were available for actual improvements in the areas of weaknesses discovered. This resulted in very slow improvements on the actions identified for the pilot project from the first appraisal and very slow feedback on action planning for the pilot project from the second project. A recommendation for others using this pre-appraisal approach is to assure that sufficient staffing is available to assist with improvements immediately following the pre-appraisals.

4.4 Determining an Accurate Cost and Effort Estimate for Process Improvement is Difficult

The series of pre-appraisals provided enough information to determine the gaps between our current capability and our desired capability and gave us the necessary knowledge to develop a good work breakdown structure of tasks necessary for the improvement. We were also able to get fairly a good count of items like amount of process documentation to be developed. Our initial plan was to estimate the number of tasks to be done in the work breakdown structure and the cost of these tasks for a better total cost estimate for improvement. While we were able to do this, our experience with the improvement efforts we initiated demonstrated a wide variability in cost for seemingly similar tasks. A larger sample of improvement activities might have given us more confidence in the accuracy of our cost estimates.

4.5 Pre-Appraisal Lessons Learned

In comparing the process used for performing the three pre-appraisals, we were able to draw the following conclusions:

- Allow enough preparation time: It takes time to schedule interviews, handle logistics and plan for an appraisal. We spent at least several weeks in preparation for each of the first two pre-appraisals and about a month for the third appraisal.
- Preparation of participants yields better results. During the second appraisal, when we helped participants identify documentation and provided sample types of questions, we were able to get more accurate results. In the first appraisal, some participants neglected to mention some critical activities that were being performed since they were not very familiar with the CMMI model.
- The CMMI model worked well to evaluate systems engineering activities. The focus of the second appraisal was systems engineering with a large amount of time devoted to baselining system engineering activities. Both the GSFC personnel and an outside systems engineering expert felt that the CMMI model provided a reasonable measurement tool for benchmarking these activities.
- Do a draft findings briefing. A draft findings briefing helps identify any misunderstandings or gaps in information that might exist after the interview periods.
- The use of the PIID to capture information during the pre-appraisal provided the most information for improvement activities following the appraisal. Using the PIID, it was much easier to go back through and see exactly what types of practices were in place for each project and what the artifacts of the practices were. However, the use of the PIIDs caused the pre-appraisals to take longer to perform.
- Follow-up is important. When projects have agreed to participate in appraisals and process improvement activities, they need to receive the feedback from the appraisal in a timely fashion, as well as information on follow-on activities.

4.6 Provide the right training for the right people

One group of project participants was given a three-day CMMI class and the other two groups were given a CMMI overview. We recommend the overview training for project participants. The knowledge the project participants really needed was a good knowledge of the processes used on their projects and the higher levels of process documentation from which their project documentation was derived. The three-day CMMI class was a significant time commitment for most of the project people and they felt overwhelmed with the volume of information. Many attendees thought all process area practices needed to be satisfied by their local organization and overlooked the contributions of the supporting organizations.

All EPG members received the three-day CMMI training. The detailed knowledge of CMMI has provided many benefits to the EPG team, allowing them to assist in mapping existing practices to those of CMMI and to identify alternative practices that are being used. For the third appraisal, the EPG appraisal team members had completed the Intermediate CMMI class, which allowed them take a first cut at filling out the appraisal PIID forms, thus taking much of the time burden off the projects for the pre-appraisal.

5.0 Applying Our Lessons For Phase 2

As a result of the lessons we have learned during our pilot phase, we are making several changes in our approach for Phase 2. All the pre-appraisals were performed using the Staged Representation of the CMMI model, and we have decided to adopt the Continuous Model for Phase 2. This allows us to choose the areas for improvement that are the most important to the organization since our resources are too limited to improve everything at once. We also plan to focus on a smaller, more critical portion of the whole organization so that we will be able to apply enough resources to make progress quickly. This will also provide the necessary "early success" needed to ensure continued management support.

Conclusion

As GSFC completes its first year of process improvement and the end of Phase 1 activities, we are finding that the CMMI model is a useful way to measure an initial capability state of an organization and to identify improvement opportunities. The initial activities of the year have assisted us in establishing a good workable infrastructure for improvement, training our process improvement team members, baselining our current capabilities, and gaining a better understanding of the cost and effort necessary to continue our process improvement efforts. All of this information, as well as our lessons learned during the past year will facilitate our planning for a successful transition into Phase 2: The phased inclusion of many more projects.