Small Project Survival Among the CMMI Level 5 Big Processes

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In the past several years, many engineering firms have stepped up and achieved Capability Maturity Model Integrated (CMMI) Level 5 [1]. *Currently, 13.9 percent of the 2,140 appraised organizations have achieved CMMI Level 5 using the Standard CMMI Appraisal Method for Process Improvement (SCAMPI). To achieve this maturity level, the organization must implement a rigorous process definition to address the CMMI model through maturity Level 5. Once defined, the organizational process must be implemented throughout the organization even by small projects. I will examine how, in my business unit, we have successfully achieved CMMI Level 5 across five geographically dispersed business units and how small projects have survived within our significantly large process definition.*

The Raytheon Network Centric Systems (RNCS) has five major engineering centers across the country. An interesting footnote is these five major engineering sites had five completely different process definitions because before they were part of a common business unit, they were actually competing companies. The Northeast location in Marlborough, Massachusetts where I work, was part of the original Raytheon. The St. Petersburg, Florida, location was originally part of E-Systems. The Fullerton, California, location was part of Hughes Defense. The Fort Wayne, Indiana, location was also part of Hughes, but a different internal organization. The McKinney, Texas, location was part of Texas Instruments. Each had their own organizational process definition and in the past each had conducted separate Capability Maturity Model evaluations and CMMI appraisals ranging from maturity levels 3 to 5 and for a variety of discipline combinations: software or software-systems.

Raytheon has defined and implemented a company-wide Integrated Product Development System (IPDS) that provides a program-level process for all Raytheon programs. IPDS provides an extensive process definition describing what should be done throughout a program; the organizations managing programs had to define processes on how IPDS was going to be implemented in their programs. These organizational processes were the ones the RNCS organizations used in their Standard Capability Evaluation (SCE) or SCAMPIs and, of course, they were all different. Then the enlightened senior management of RNCS made a crucial business decision that all five sites were going to have a common engineering implementation of IPDS with the ultimate goal of having the capability to move work across the five sites. The five sites endeavored over a couple of years to define, deploy, and implement the RNCS Common Process Architecture (CPA). The effort ultimately led to the five major engineering centers successfully conducting our SCAMPI that resulted in a Maturity Level 5 rating reported to the Software Engineering Institute (SEI) as *Raytheon Network Centric Systems (Engineering – software engineering, software, hardware [SE/SW/HW]) projects with engineering development in the scope of the project* [2].

We included hardware amplifications in order to include in the appraisal our hardware engineering discipline. In addition to – and key to – our success was our internal program engineering discipline. The key to our successful SCAMPI was the definition and deployment of the organizational CPA across the five RNCS sites. Let us examine this CPA organizational process definition.

Figure 1: *Introduction to WT*[1]

Work Instruction

Detailed Planning

Number	U0141CRP
Revision	B
Supersedes	A
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Introduction

The purpose of the Detailed Planning WI is to direct a program's detailed engineering planning activities based on the initial planning outputs and the scope of the awarded contract as part of preparing for the program's Gate 5. During the detailed planning activities those work products from the initial planning activities are reviewed, and updated or expanded as necessary. Any planning work products that may have not been produced as a result of the initial planning activities, but are determined to be required after contract negotiations will need to be created as part of the detailed planning activities.

The complete set of detailed planning activities is defined by this WI and the supporting Plan Generation Work Instructions for the various program plans. Refer to *Appendix A* for an overview of the plans hierarchy. A program can use the NCS Engineering process to tailor the engineering plans identified in *Appendix A* based on the needs of the program. The program plans should be put under configuration control per the NCS Work Product Management Work Instruction.

Input(s)

- Contract Documents
- Engineering Cost Estimates
- IPDS Tailoring
- NCS Engineering Tailoring
- Program Organization Structure
- Initial Engineering Program Plans
- Lessons Learned Repository
- Process Assets Library
- Work Breakdown Structure (WBS)
- Engineering Budget

CPA

The design of the CPA followed the typical life cycle that our programs follow. We initially started creating CPA with a requirements definition phase where we used our Raytheon IPDS, the CMMI model, and International Organization for Standardization (ISO) 9000, to provide the requirements for the CPA. As we defined our CPA, the identified requirements were entered in our requirements database and then were flowed down to organizational behavior activities. I am not going into the details of the overall CPA process, which is not the focus of this article. However, to make a very long story short, the main artifacts of the CPA definition were a series of CPA Work

Instructions (WI). There are 88 WIs to be exact. Each of these has associated with it enablers to assist in process implementation, such as the following: software tools, templates for required documents, process checklists, and other enablers to be used by all programs at the five engineering sites. Naturally, the CPA organizational process definition is substantial in detail and volume, but one of the major cost advantages is that while it consists of a large amount of documentation, it pales in size to having five different sites each with their own process definition, set of tools, templates, and enablers. It was common and had to be used by all programs. The CPA has to be robust enough to support programs with engineering staffs of more than 100 engineers such as the next generation destroyer for the Navy or the replacement of all the Air Traffic Control systems in the United States. Well, CPA is robust enough not only to support these substantial programs being implemented across the five engineering sites, but also supports CMMI Maturity Level 5 processes.

What about the programs that do not have a marching army of engineers with budgets in the millions and billions that are executed over multiple years? How do these small programs deal with the substantial organizational process that was formally appraised at CMMI Level 5 and now required by all RNCS programs? It can be wrapped up in one word: tailoring. Tailoring is a key organizational process that is used by large, medium, and small programs. All programs can eliminate WIs and can accept, reject, or modify the WI requirements as well as modify the contents of the plans as needed by each program's contracts; it is the extent and depth of the tailoring that allows the small programs to survive. However, before getting into tailoring, it is important to understand the general structure of the CPA WIs.

CPA WI Structure and Tailoring

Every WI has the same format structure (see Figures 1 through 4, each one will be detailed in this section).

Figure 1 is the first part of the CPA WI that provides an introduction to the WI process, WI name and configuration management information of the WI. It also provides the input necessary for the process. This particular WI is the main WI used by the typical large program to perform the detailed planning of the program during the program start-up phase that occurs right after contract award. The Detailed Planning WI defines all the steps that the program management team accomplishes in the approximately 45 days after the contract is signed. In actuality, some of the Detailed Planning WI steps require updates to documents and other artifacts previously drafted during the Initial Planning WI steps that were accomplished during the proposal stage of the project. From the Initial Planning WI there are several outputs that are also inputs to the Detailed Planning WI, for example: Initial Engineering Program Plans and Work Breakdown Structure (WBS). Typically, several of the Initial Engineering Program Plans (i.e., Software Development Plan [SDP], System Engineering Plan [SEP]) are drafted during the proposal stage and in the beginning of the program after contract award during program start-up, they are reviewed and finalized. Likewise, the WBS is generated during the proposal time and may have to be adjusted depending on the results of contract negotiations. A portion of the Detailed Planning WI is shown in Figure 2.

Process Summary	ID	Steps at a Glance	Responsible Role
_	1	Define Planning Strategy for Detailed Planning	Program Engineer Program Planning Team
_	2	Update the SEP, HDP, SDP, and QPP	Program Engineer Program Planning Team
_	3	Update Program's Life Cycle Model	Program Planning Team

Note: SEP – System Engineering Plan, HDP – Hardware Development Plan, SDP – Software Development Plan, and QPP – Quality Program Plan.

Figure 2: *Detailed Planning Steps at a Glance*[2]

In Figure 2, you see the first three *requirements* or steps at a glance in the 33 steps in the detailed planning process. Interestingly, these Steps at a Glance were flowed-down as requirements from IPDS, CMMI, and ISO9001 into the detailed planning behavior process (Figure 3).

Figure 3 shows the expected outputs from when the CPA Detailed Planning WI implemented the detailed planning process, which included multiple engineering plans and the WBS. These are artifacts produced or updated as the detailed process is implemented. Most of the plans generated from this work instruction are updates to those drafted in the initial planning and proposal phase. Each of the plans is enabled through the use of templates with

Figure 3: *Outputs From the Detailed Planning Process*[3]

Output(s)

- Earned Value Management System (EVMS) baseline
- Engineering Cost Estimates
- Engineering Decision Analysis and Resolution Plan
- Engineering Measurement, Analysis and Improvement Plan
- Engineering Training Plan
- Work Project Management Plan (WPMP)
- Gate Review Plan
- Hardware Development Plan
- Integrated Master Plan
- Integrated Master Schedule
- Integration, Verification and Validation Plan
- IPDS Tailoring
- NCS CPA Tailoring
- Planning Strategy
- Program Organization Structure
- Program's Security Plan
- Quality Program Plan
- Risk and Opportunity Management Plan
- Software Development Plan
- Systems Engineering Plan
- WBS

Update Program's Life Cycle Model	**Requirement** Update and document the development life-cycle model that will be used. **Guidance** 1. Review and update as necessary the program's life cycle phases on which to scope the detailed planning effort. Refer to the Life Cycle Models in the Raytheon Process Assets Library (RayPAL), for descriptions of candidate models. See *References* section for further information on accessing these models in RayPAL. 2. Document the life cycle phases in the applicable program plans such as the SEP, SDP, or Hardware Development Plan (HDP). 3. Update the systems engineering capabilities expected at the end of each applicable life cycle phase in the SEP. 4. Update the software engineering capabilities expected at the end of each applicable life cycle phase in the SDP. 5. Update the hardware engineering capabilities expected at the end of each applicable life cycle phase in the HDP.

Figure 4: *Step 3 of Detailed Planning Work Instruction*[4]

embedded instructions on what information should be included in the plans (see Figure 4).

Figure 4 shows one of *33 Steps at a Glance* in the Detailed Planning WI. It shows how each step is expanded into the CPA process requirement under the *Requirement* heading along with its associated Guidance on how to implement the Step at a Glance CPA requirement. Naturally, there is a WI for tailoring the WIs, which in itself can also be tailored (see Figure 5). Along with the Tailoring the CPA Process WI, the organization has provided a Guidance enabler on tailoring that includes guidance for tailoring small programs as well.

Figure 5 shows one of the main steps in the tailoring process – this is actually step 8 of 12 steps (see Step 8 in Figure 6).

As you can see, most of the WI describes how the tailoring process is conducted (Steps 1-7 and 9-11 in Figure 6), how the tailoring decisions are stored in iPlan (Step 8), and how the tailoring is approved by the stakeholders and finally approved by the ultimate stakeholder (Step 12), the Engineering Process Group (EPG). So, a program cannot go wild and tailor out important portions of the CPA. Tailoring is a key concept in the CMMI model, and it is a critical task for programs using our CPA, and critical to survival for small programs using CPA. The model recognizes that many factors impact the process implementation on a particular program, for example:

- Program size.
- Program complexity.
- Contractual requirements.
- Customer deliverable requirements and format requirements.
- Specific measurements required by the organization and the customer.

As far as our CPA tailoring, each of the WI requirements can be accepted (i.e., accepted as written), rejected (i.e., deleted from the work instruction) or modified (i.e., rewritten, such as SDP will be written to customer format versus CPA format). The Guidance for each of the CPA Requirements can be adjusted for the specifics of the program and contractual requirements, the output documents can be rejected or modified to meet the contractual requirements, and they can be adjusted for the program size. All tailoring is captured in the iPlan tool as modified WIs for the specific program. The iPlan tool provides a Program Tailoring Workspace – a virtual library for the program's approved process definition. The iPlan tool captures all the tailoring done to each of the CPA WIs, the EPG approved justification for all the tailoring, and the actual modified WIs for reference by program engineers during implementation. I must emphasize again: that all tailoring is approved by the EPG before the program's tailored process is implemented. For larger programs with extended schedules, the tailoring of the CPA process can be done incrementally by program phase so you do not have to do tailoring of the system test process if that process is not needed for several years. This process flexibility is expected in the CMMI and is an integral part of the RNCS CPA tailoring process. It is especially important for the small programs that have to survive among the big program processes, which leads us to small project tailoring.

Figure 5: *Main Step in Tailoring Work Instruction*[5]

8. Make Tailoring Decisions	**Requirement** Tailor the CPA Work Instruction Requirements (WIRs) for each WI. **Guidance** 1. For each work instruction provided by the iPlan tool, the tailoring team evaluates the work instruction requirements to determine the program tailoring decisions. WI Requirement decisions are the following: a. Accepted b. Rejected c. Modified The *Tailoring Decisions and Work Instruction tab* in the Tailoring Workspace of the iPlan tool provides visibility into the WIRs for each WI and allows the program to select or deselect specific WIRs and provides a utilization summary for each WI. The *Library Utilization* section of the *Work Instruction tab* is used to record the programs tailoring decisions with regard to a specific set of WIRs. Work Instruction Utilization Acceptance is automatically determined by iPlan based on the following: a. Accept – all WIRs accepted. b. Modified – one or more (but not all) WIRs rejected c. Reject – all WIRs rejected. 2. This process is repeated for all work instructions provided for this tailoring workspace. Note that the tailoring workspace may be different for each discipline and for the program level (multi-discipline). 3. The tailoring team consults with the EPG representative or iPlan SME to evaluate the effect on higher requirements when WIRs have not been accepted. Although tailoring is not to be considered something negative and programs should do what is smart for their business, the organization has an interest in understanding how and why programs are deviating from the organizational standards. Keeping with this notion, when a program tailors or rejects WIRs, the Notes field for that set of WIRs must be filled in to address 'why' the program is deviating from the organizational standard.

Small Project Tailoring

One of the first steps, of course, is to understand what it means to be a small project. In the beginning of CPA, it was more a concept of what a small program consisted of, i.e., less than a year duration, small budget, small team, etc. Small programs are now formally defined as those with budgets between $500,000 and $4 million, less than a year in duration, and/or a team of eight or less engineers from all disciplines. We now have a definition of a small program which is helpful when we enter the tailoring process. The tailoring process is formalized during the start of the program. Now one of the major structural aspects of Raytheon's IPDS and reinforced in RNCS CPA is the program gating process. Formal gates are reviewed at specific engineering phases: program start-up (gate 5), system requirements

review (gate 6), preliminary design (gate 7), detailed design (gate 8), formal testing (gate 9), etc. As a matter of fact, we have 11 formal gates, four before contract award and seven gates after contract award. The important one for small project tailoring is our gate 5, known as program start-up. Every program right after contract award has 45 days to complete the program start-up process and review the overall program approach with the various senior management levels associated with the execution of the program. Key to this start-up process is the tailoring of the CPA WI to describe how each WI is going to be implemented on the program. As previously stated, in the proposal phase, several of the engineering plans may have been written in draft form or written as part of the proposal. After contract award, during the program start-up phase, the various engineering plans are either going to be updated from the drafts written in the proposal phase or written in the start-up phase. The engineering plans consist of the following:

- SEP.
- SDP.
- HDP.
- Stakeholder Involvement Plan (SIP).
- Measurement Analysis and Improvement Plan (MAIP).
- Integration, Verification and Validation Plan (IVVP).
- Quality Program Plan (QPP).
- WPMP and Work Product List (WPL).
- Several others.

As you can imagine, this can be an intensive period for the managers involved with the program. The small program tailoring of the CPA WIs is a heavy duty effort. Just think of trying to pare down 88 WIs in order to describe how you are going to implement the program using these tailored CPA WIs. The first group of small programs that pioneered their way through this tailoring process and tailoring justifications were reused as the various plans were adjusted and reused. Well, it did not take long to determine that an organizational process improvement was necessary to assist these small programs through the program start-up and tailoring processes: enter the Small Program Variant (SPV) Planning WI.

SPV Planning

The RNCS CPA Engineering Councils collaborated and generated a new WI to be used by small programs to do their program planning called the SPV Planning WI. It essentially provided pre-tailoring of the CPA WIs as a starting point. One of the major steps in the SPV planning was the creation of the Small Program Engineering Plan (SPEP) template. The SPEP template combined the major portions of the SEP, SDP, HDP, and IVVP into the single SPEP. Furthermore, additional planning activities associated with large programs were reduced for the small programs. For example, the amount of measurement data is reduced, such as staffing, since it is easy to keep track of three or four people. Typically, small programs deal with only one or maybe two of the engineering disciplines, so specific discipline WIs can be eliminated, for example: A software-only job can eliminate all the WIs associated with Hardware Preliminary Design, Hardware Detailed Design, Hardware Testing, etc. The details of stakeholder involvement can be reduced on small teams. Details such as formal weekly team meetings can be eliminated especially when the team is two to three people all working in the same cubicle. Formal reviews are reduced to three to four page review packages versus 35 to 40 page detailed, senior manager review packages.

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Small programs still have to deal with 78 WIs and the tailoring of those, but with the creation of the SPEP a significant work load was removed from the programs. There are, however, in the SPV Planning WI some of the other engineering plans, even for the small program, that have to be created and implemented such as the following: the Risk and Opportunity Management Plan, the MAIP, the WPMP, WPL, and the SIP. On my small programs, I have even been able to convince the EPG that some of these required standalones could be downscoped and incorporated into my program's single SPEP, thus reducing the coordination and sign-off cycle of multiple, individual plans; it was done using just my one SPEP.

Other allowable tailoring is the combination of engineering phases. Typically, small programs are associated with extending the functionality of product lines where the preliminary design of the functionality is already known. So, small programs can tailor the conduct of two of the engineering gates reviews into one: the preliminary design and detailed design phases and the associated gates 7 and 8 (Preliminary Design Review [PDR] and Critical Design Review [CDR]). Even more typical, the system requirements are usually small changes to the product line and the System Functional Requirements Review (gate 6) can also be rolled into the combined PDR/CDR. This is all dependent upon the tailoring and permission given by the EPG during the EPG's tailoring approval meeting.

Implementation of Small Programs

With the SPV Planning WI, how does the implementation of small programs differ from the standard programs? To start, the number of WIs to tailor is reduced to 78 WI for SPV down from the 88 used in standard programs. The combined SPEP document combines several of the

Figure 6: *Steps at a Glance of the Tailoring Process*[6]

ID	Steps at a Glance	Responsible Role
1	Establish Tailoring Team	Program Engineer
2	Use CPA Tailoring Guidelines	Tailoring Team
3	Establish Tailoring Workspace	Tailoring SME
4	Execute Tailoring Kickoff	Program Engineer
5	Select Program Characteristics	Tailoring Team
6	Identify Stakeholders	Tailoring Team
7	Document Tailoring Stakeholders	Tailoring Team
8	Make Tailoring Decisions	Tailoring Team
9	Document Planning Strategy	Tailoring Team
10	Capture Tailoring Workspace	Program Engineer
11	Schedule Stakeholder Review	Program Engineer
12	Obtain Stakeholder Approval	Program Engineer, Tailoring Stakeholders

required plans and averages around 45-60 pages. The volume of the individual plans needed for standard programs collectively can be in the hundreds of pages. Measurements are key concepts in high maturity organizations. Regardless of the size of the program (standard, small, or micro) they need to collect the typical EVMS metrics needed to analyze the following: Schedule Performance Index (SPI) and Cost Performance Index (CPI). The difference, however, is the number of cost accounts that are tracked by small programs are around 30 to 40, where in standard programs the number of cost accounts can be in the hundreds of account numbers. Naturally, on small programs the number of data points collected is quite limited. Neverless, there are other measurements recommended in the small program tailoring guidelines in addition to CPI/SPI to manage these small programs. From the *Tailoring Guidelines:*

> The metrics that a [small] program collects is based on the characteristics of the program and customer requirements. The following is a recommended list of metrics that a small program should collect unless there is a valid reason to tailor out, such as:
> - CPI/SPI.
> - Defect Containment [which are collected through peer review/ inspection data and system trouble reporting data].
> - Requirements volatility.
> - Any (i.e. hardware, software, systems) applicable engineering productivity measures.[7]

The small program task managers indicate what measurements they use to manage their programs in their MAIP. The MAIP which identifies the program's measurements requires approval by the EPG. Other adjustments are allowed for small programs during the tailoring process, such as the following:

- Even though they started with 78 potential WIs, and since the disciplines such as hardware can be tailored out if there is no hardware development, the number of applicable WIs can get down to about 20 and those can be substantially tailored even further.
- Monthly review packages (35-40 slides) are reduced to four square charts (three to four slides).
- Process Support Team (PST) meetings where metrics analysis and process compliance checks are reduced both in the team size and the time to conduct the PST meetings.
- The 10 required plans can be combined with the SPEP, the implementation of the various discipline plans are not as detailed, and the associated enablers and templates are also reduced in size.

All the tailoring, even though much reduced, still requires a significant effort by the small program's management team. Therefore, the next step is for the EPGs and the senior level discipline councils to provide even more pre-approved tailoring for each of the WIs and the WIs associated enablers. Going one step further, the follow-on pre-tailoring activity will be to address micro-programs. These micro-programs are even smaller than the small programs I just discussed. The micro-programs typically have work effort content between 1,000 and 8,000 staff hours. Currently, there are a number of WIs being piloted by the RNCS organization that target these micro-programs. Yes, I know what you are thinking – what about the projects under 1,000 hours ... small projects among big trees; ever think about where toothpicks come from?

Summary

If we used the CMMI through Maturity Level 5 itself as a process description, it would be well over 600 pages. So when you establish your standard processes and actually write the organizational process description you can see that all the process-oriented documentation and implementation of these processes can become an insurmountable issue for small programs (e.g., small budget, small team, short schedule). The CMMI recognizes that tailoring is key to the successful implementation of the organizational processes for the variety of programs that organizations have in their business. It is up to the organization to provide the guidance, methodology, and the expectations of the small programs that are being executed in the same process environment as the big trees. An organization has to have an organizational-approved tailoring method for the small programs in order to survive and be successful, while still supporting the essence of the organizational processes. Tailoring is a life-saver for our small programs that also support our overall CMMI Maturity Level 5.◆

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Notes

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