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Applying CMMI-AM to a C4ISR Project from the Buyer's View

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Abstract

In this paper, we study and use the CMMI-AM approach, from the buyer's point of view, to consider a military C4ISR project whose development process is from the prototyping system evolution stage to the production system generation stage. At first, we adopted some of the guidelines of the process area of the CMMI-AM to develop the C4ISR prototype system by using the CASES and the CAPS. Then we are applying most of the guidelines of the process areas of the CMMI-AM to catch the operational need of the C4ISR system by using the SA with DoD AF based on the C4ISR prototype system. We will follow the guidelines in the CMMI-AM to establish the acquisition planning and request for proposal, to evaluate the submitted proposal in order to select supplier candidates, to decide the best supplier, and to monitor and control the whole project. Generally, the C4ISR System is a huge-grain system, and its process is complicated. The CMMI-AM is a complement to the capacities of the CASES, CAPS, and SA for developing a C4ISR system. We described the relationship between the project organization and the CMMI-AM via the experiences of developing the Army Fire Support and Coordination System (FSCS) of Taiwan, R.O.C.

Keywords: Capability Maturity Model Integration (CMMI), Process Area (PA), C4ISR System, Computer-Aided Prototyping System (CAPS), System of System (SoS).

1. Introduction

The C4ISR system (Command, Control, Communication, Computer, Intelligence, Surveillance, and Reconnaissance System) is a kind of C2 Systems (Command and Control systems) that include the human phase, the information technology (IT) phase and the physical battlefield phase. Because of the frequent interaction of battlefield objects among these phases, the C4ISR system is a huge and complicated system whose interfaces include man-machine, man-battlefield and machine-battlefield. It is very hard to seek an experienced and qualified project team to help a customer of the C4ISR system to firm the user's requirements before starting a C4ISR project. Thousands of battlefield objects of the C4ISR system can be classified into five types: military people, weapon systems, navigation systems, platform sensors, and communication links [Harn *et al.*, 2004]. The interactive relationship among these battlefield objects is difficult to describe in detail how the operational, systematic and technological architectures work together vertically and horizontally. Even though we use a powerful tool such as the CAPS, CASES, and the SA (System Architect) with the DoD AF (DoD Architecture Framework) to specify the user's requirements, the recognition gap between system developers (or called suppliers) and customers (or called acquirers/buyers) still exists. If the two sides between suppliers and acquirers lack confidence during the system development process, a failure C4ISR project might occur finally.

The purpose of this study is to find a better method that can solve the C4ISR project management issues. In this paper, we study and use the Capability Maturity Model Integration (CMMI) approach, from the buyer's point of view, to consider a military C4ISR project whose development process is from the prototyping system evolution stage to the production system generation stage. Recently, after learning the experiences of developing a C4ISR system from U.S. Army, the R. O. C. Army is dedicating to find the best solution to acquire and deploy a C4ISR system. The C4ISR system is a large outsourcing project that has to be tailored to fit the user's needs. From the acquirer's side, especially the operational unit, there is no enough capacity to develop such a large scale project. Many kinds of the C4ISR systems have to be integrated from the global view, i.e. the relative C4ISR project could not be conducted from the local view because of avoiding stovepipe adversity. Therefore, a C4ISR project should be achieved by a specific research and development (R&D) unit/company via an outsourcing contract. These supporting R&D candidate units/companies may come from outer or inner country. For assuring these contractors' capabilities to execute our awarded projects, our study group selects the CMMI approach from the buyer's point of view to plan, analyze, execute, control, monitor and evaluate the C4ISR project.

The CMMI was developed by Software Engineering Institute (SEI), Carnegie Mellon University (CMU), sponsored by the U.S. DoD, specifically the Office of the Under Secretary of Defense, Acquisition, Technology, and Logistics (OUSD/AT&L). The CMMI has been successfully applied to the business system development, integration and maintenance, and has efficiently helped the business organization refines its business model through the practice of business process reengineering (BPR), project management and so on. For example, Boeing Australia experienced a 33 percent reduction in the average cost to fix a defect; General Motors experienced an 80 percent reduction in late deliveries; Lockheed Martin Integrated Systems and Solutions experienced a 30 percent gain in software productivity [Gallagher *et al.*, 2004]. Potential benefits of the process improvement might accrue with respect to cost, schedule, quality, and/or customer satisfaction [Goldenson *et al.*, 2003] [Brian *et al.*, 2004]. Parenthetically, the use of CMMI has become commonplace among software development organizations, especially among defense contractors [Blanchette *et al.*, 2005].

Due to the coercive formalization feature of the BPR for developing business information system, using the CMMI is one of the best ways to resolve the issues of business process improvement. The execution of the CMMI has enabled business organization to deliver products or services more efficiently for keeping away from project management crises like over time, over budget, low quality, and low productivity. In general, as a buyer of the C4ISR system, the primary questions would be: “Can the supplier’s maturity guarantee the success of a C4ISR project?” and “What can the acquirer do to contribute the success of a C4ISR project?” In Figure 1, Blanchette provided a maturity grid of the technical and management skill for project acquirers and suppliers to portrait these questions. The mismatched maturity between the acquirer and supplier will affect project quality, cost, and schedule, and even cause disaster outcome [Blanchette *et al.*, 2005].

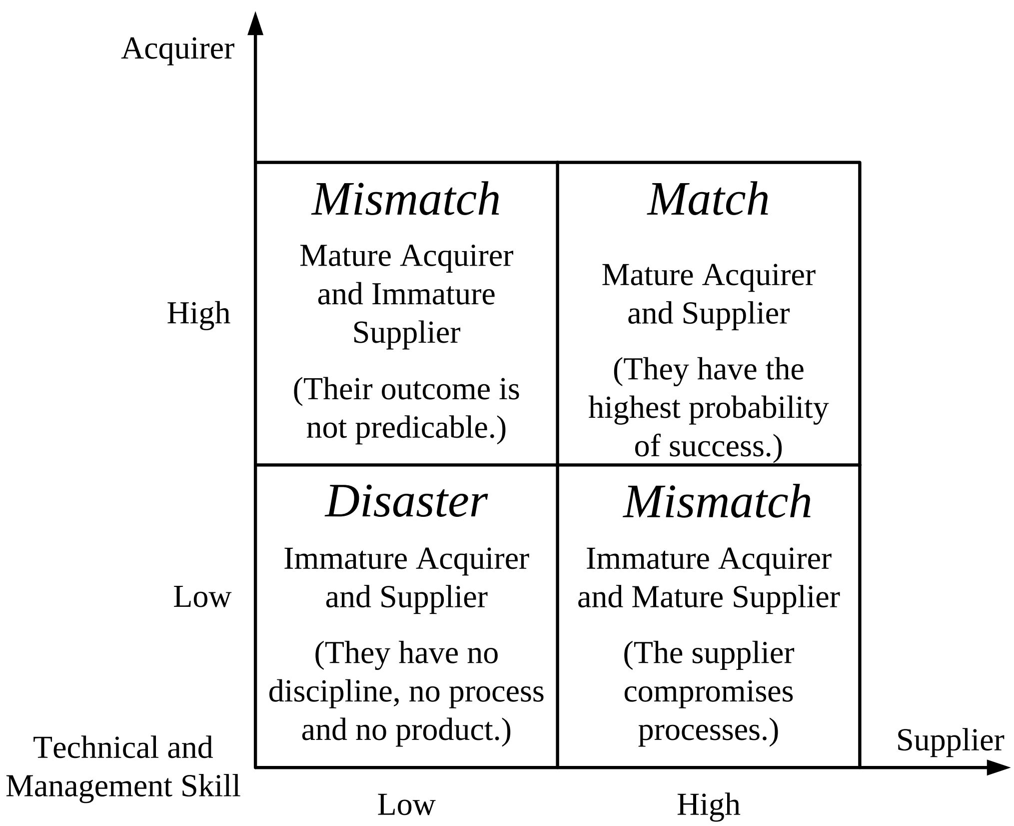

Figure 1: The maturity grid of the technical and management skill for project acquirers and suppliers by Blanchette

In our study, we tried to enhance the technical and management maturity of both sides of C4ISR system acquirers and suppliers. Furthermore, we found that the key point of developing a successful C4ISR system is on the acquirer's side. The rationale is as the following description in [Bernard *et al.*, 2005]: "*Acquisition activities are complex because acquisition projects are directed outwardly toward acquiring products, systems, services, and capabilities from developers to meet a set of the operational expectations and inwardly toward ensuring the acquisition process itself is conducted with rigor.*" Thus, we regarded the relationship between acquirers and suppliers as an energetic one, modeling with the Chinese Tai Chi theory (See Figure 2). The Chinese Tai Chi theory depicts the win-win policy. From the user's view, the acquirer should play more active roles to help and complement the supplier and to make sure that the project is successful as the inescapably intertwined duality of Tai Chi. We suppose the supplier's maturity has been scrupulously qualified by the acquirer, and the acquirer's maturity has to be enhanced because the acquirer lacks the capacity and experience of requirements planning and system analysis generally.

Figure 2: Acquirer/Supplier Duality modeling with Tai Chi

To develop a successful information system, the extreme goal and critical success factors (CSFs) should be specified in advance. The extreme goal can be broken down into several subgoals called CSFs. The information system goal with CSFs will be accomplished by a serial acquisition and development processes. It has been proposed by Goldenson that the acquisitions of the software intensive systems often suffer from continued failure of the acquisition and development efforts to meet cost, schedule, quality, productivity and performance needs. These difficulties have been linked to the inability of both the acquirer and the developer to manage the acquisition and development process, especially where software is involved [Goldenson *et al.*, 2000]. The CMMI Acquisition Module (CMMI-AM) incorporates this connected duality by recognizing that some of these activities are under the direct control of the acquisition project, while others are directed toward monitoring or facilitating success of development or operational partners [Bernard *et al.*, 2005].

In this paper, we focus on acquisition and apply CMMI-AM as an approach to verify a military C4ISR project from the prototyping system evolution stage to the production system generation stage, that is, from the prototype of operational needs to the transition of products/services.

2. C4ISR Systems

The C4ISR system plays a critical role in the Network Centric Warfare (NCW) which is a primary component of U.S. DoD planning for the military transformation. A shared awareness of the battle space is expected to achieve via a powerful C4ISR system with its related networked communications. Sun Tzu reminded us: “Know the enemy and know yourself; in a hundred battles, you will never be in peril.” He illustrated the concept of awareness sharing, mission transparency and command speed about information superiority.

2.1 C4ISR System Features

The important lesson learned from the Bosnia operation [Wentz 2002], NATO-led Implementation Force (IFOR), was “Effective C4ISR is a critical ingredient for the success of any military operation.” We agree Wentz’s report that the C4ISR system is a kind of the joint operation style that always presents a complex set of challenges for the military C4ISR system planners, implementers, and operators. However the most difficult technology is how to provide integrated C4ISR services and capabilities to satisfy the needs of multinational forces. Therefore, the C4ISR system could be an inter-organizational information system (IOS) that is used/linked among military organizations over one country.

On the other side, although integrated C4ISR services with awareness sharing is the desired objectives, the realities tend to drive the solution to stove-piped implementations. Some of the external links may be ignored while we develop a C4ISR system. In spite of technological advances, the interoperability problem of the C4ISR system still exists. The adaptive C4ISR system for a specific operation force may be tailored because we consider the different operational platforms and simplify the user’s requirements. The better solution to the interoperability problem is to design an interface that can connect different battlefield objects smoothly in the operation environments and to design a meta-system that can integrate the system of system (SoS).

From the experiences of the coalition operations using the C4ISR system in Bosnia, we found that the complexity of developing a huge-scale C4ISR system challenges not only the implementers and operators but also the traditional process for acquiring and the integrated capability of the project manager. Luqi has pointed out the features of the C3I systems considered from the acquirer's view as follows [Luqi, 1992]:

- · *Their use in strategic, operational, and tactical defense applications makes correctness and reliability critical.*
- · *They are influenced by many people, by organizations, and by policies, so their requirements are complex and difficult to determine.*
- · *Their design depends on techniques to guarantee that hard real-time constraints will be met both in large distributed systems connected by long-haul networks and in local distributed systems with many hardware structures.*
- · *Their complex, dynamic interfaces make it almost impossible to deal with changes in requirements.*
- · *As with any large system, their development is costly, and the current low productivity of software development aggravates the problem.*

The C4ISR system still keeps the features of the C3I systems and extends more developmental difficulties, such as the problem domains of integration, interoperability, surveillance, reconnaissance and so forth. We use the CMMI-AM to resolve many of these difficulties.

2.2 Developmental Experiences of a C4ISR System

In the development process of a military C4ISR system, the operational needs/requirements have to be defined first. In order to evaluate the C4ISR system requirements, a project team with over 200 military officers was assembled by the National Defense University of Taiwan, R. O. C, in 2003. In this project, we integrated numerous battlefield objects of C4ISR system including military people, weapon systems, navigation systems, platform sensors, and communication links by using a heterogeneous integration tool: Computer-Aided Prototyping System (CAPS) and created 230 large-grain prototypes of C4ISR subsystems, to help Taiwan Army develop and integrate C4ISR systems [Harn *et al.*, 2004].

We spent almost one year to conduct them by this project team, which was divided into nine project groups. Each project group had one leader and 24 members in charge of 25 large-grain programs. We assigned group A to integrate the C4ISR systems of Army, Navy and Air Force and group B to I to create new Army C4ISR systems. We had one project chairman and 4 project technical instructors to direct the project members. They collected the operational requirements of the C4ISR system from the acquirer's view and discussed the operational architecture with their senior officers and colleagues. Finally, we integrated the Army C4ISR system with the Navy and Air Force C4ISR systems and designed interfaces to incorporate different heterogeneous platforms including hardware, software, data base and network protocol for enhancing the interoperability of these battlefield objects.

2.3 An Army C4ISR Prototype System

In 2003, an Army C4ISR prototype system was constructed by the SoS architecture that consists of an assemblage of systems. Each system is capable of a separate, independent existence, and each individual component system is self-sustaining and purposeful like the description in [Wilson, *et al.*, 2005]. In our project, one of the Army C4ISR prototype systems, Fire Support and Coordination System (FSCS), was created, and the other assemblages of systems were classified as follows: Joint Operational Command and Control System (JOCCS), Decision Support System of Operation Area Commander (DSSOAC), Battle Command System (BCS), Intelligence Surveillance and Reconnaissance System (ISRS), Air Defense System (ADS), Disaster Control System (DCS), Operational Service System (OSS) and Personnel Information Integration System (PIIS).

The functional integration of FSCS is composed of six subsystems which are incorporated by a main fire support computer shown as Figure 3. The FSCS is functionally decomposed as the following SoSs:

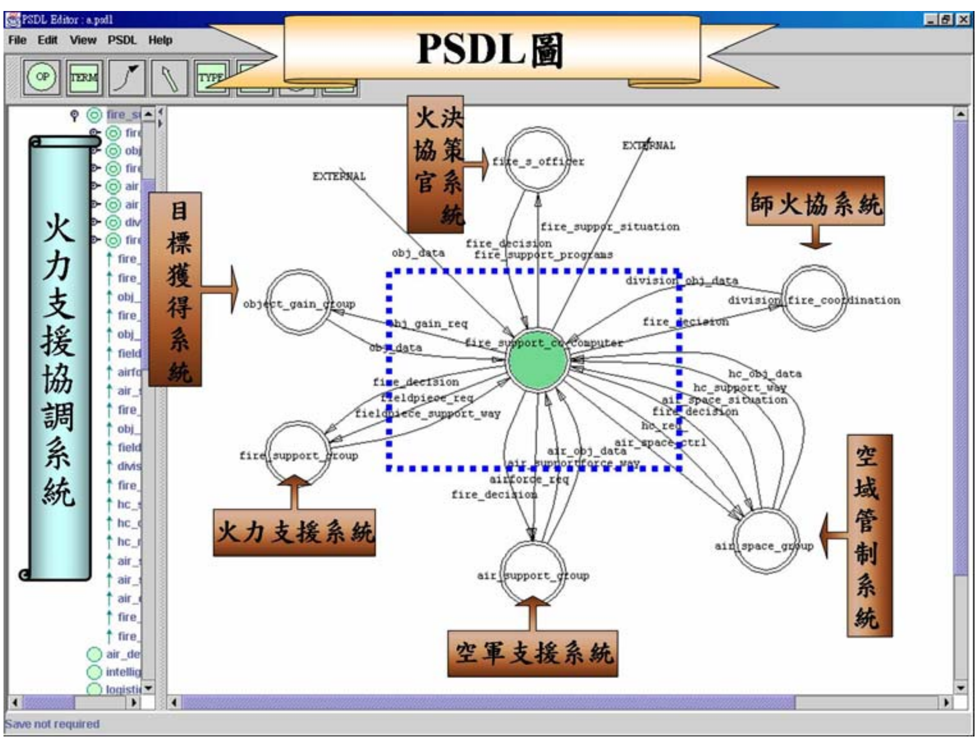

Figure 3: The functional integration of six subsystems in FSCS

- · Object-obtaining subsystems,
- · Fire-supporting subsystems,
- · Fire-coordinating subsystems,
- · Air-supporting subsystems,
- · Air-controlling subsystems, and
- · Fire-coordinating command and control subsystems.

Each subsystem of FSCS is a set of lower-level software objects, modeling the battlefield objects of the physical domain. The software object refinement depends on the feasibility analysis of the operational requirements, including the situation of economic, technical, and legal considerations. In accordance with the experience of constructing the Army C4ISR prototype systems, we are applying the CMMI-AM, from buyer's view, to verify our future Army C4ISR systems. This future Army C4ISR system will be constructed through the prototyping process formed as a spiral model in the next section.

2.4 C4ISR System Acquisition

We specify two acquisition stages: prototyping system evolution stage and production system generation stage, for developing a C4ISR system. The prototyping system evolution stage is a spiral model shown as Figure 4, published in [Harn *et al.*, 1999a] [Harn, 1999b], which has six steps: requirements analysis step, specification design step, module implementation step, prototype program integration step, prototype program demo step and issue analysis step, and seven components: initial ideas, requirements, specifications, modules, prototype program, criticisms and issues. Because the C4ISR prototype system is still a prototype, most of the battlefield objects can be simulated as software components. The production system generation stage is also a spiral model, which is modified from the linear model of the products/services development process in the CMMI-AM Version 1.1 Update, presented in NDIA Systems Engineering Division Meeting, April 12, 2005, shown as Figure 5, and has seven steps: acquisition planning step, request for proposal (RFP) preparation step, solicitation step, source selection step, program leadership step, system acceptance and transition step, and eight components: operational needs, acquisition plans, RFP, suppliers, developers, insight or oversight results, developed systems and delivered systems.

The Gallagher's acquisition model generalizes the model for any products/services, and we apply these steps to obtain the real C4ISR product system. There are three channels of obtaining a C4ISR product system: end-user computing, outsourcing and package introducing. However, if we use above any channels, the developer could follow the following five steps: plan step, design step, develop step, integrate and test step, and deliver step, to finish the final product/service of the C4ISR system.

In the prototyping system evolution stage, we can use the Computer-Aided Prototyping System (CAPS) iteratively and rapidly to prototype a raw C4ISR system. The raw system will gradually be mature from the initial life cycle to the final life cycle in the six-step spiral model. The purpose of the prototyping system evolution stage is to elicit and specify the operational need of the C4ISR system. This kind of C4ISR prototype system is an intensive software system. Some of the battlefield objects can be realized if the battlefield resources are available.

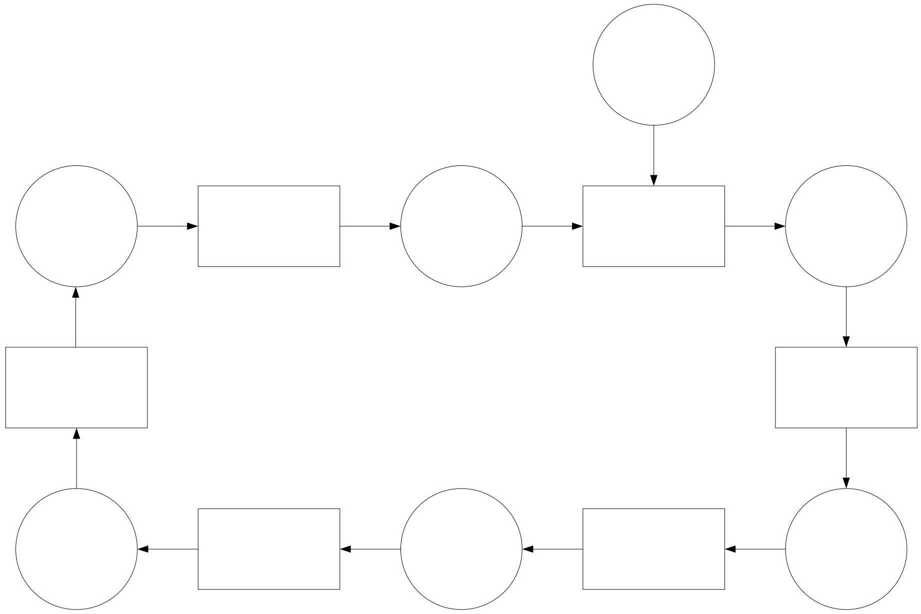

Figure 4: The six-step spiral model in the prototyping system evolution stage

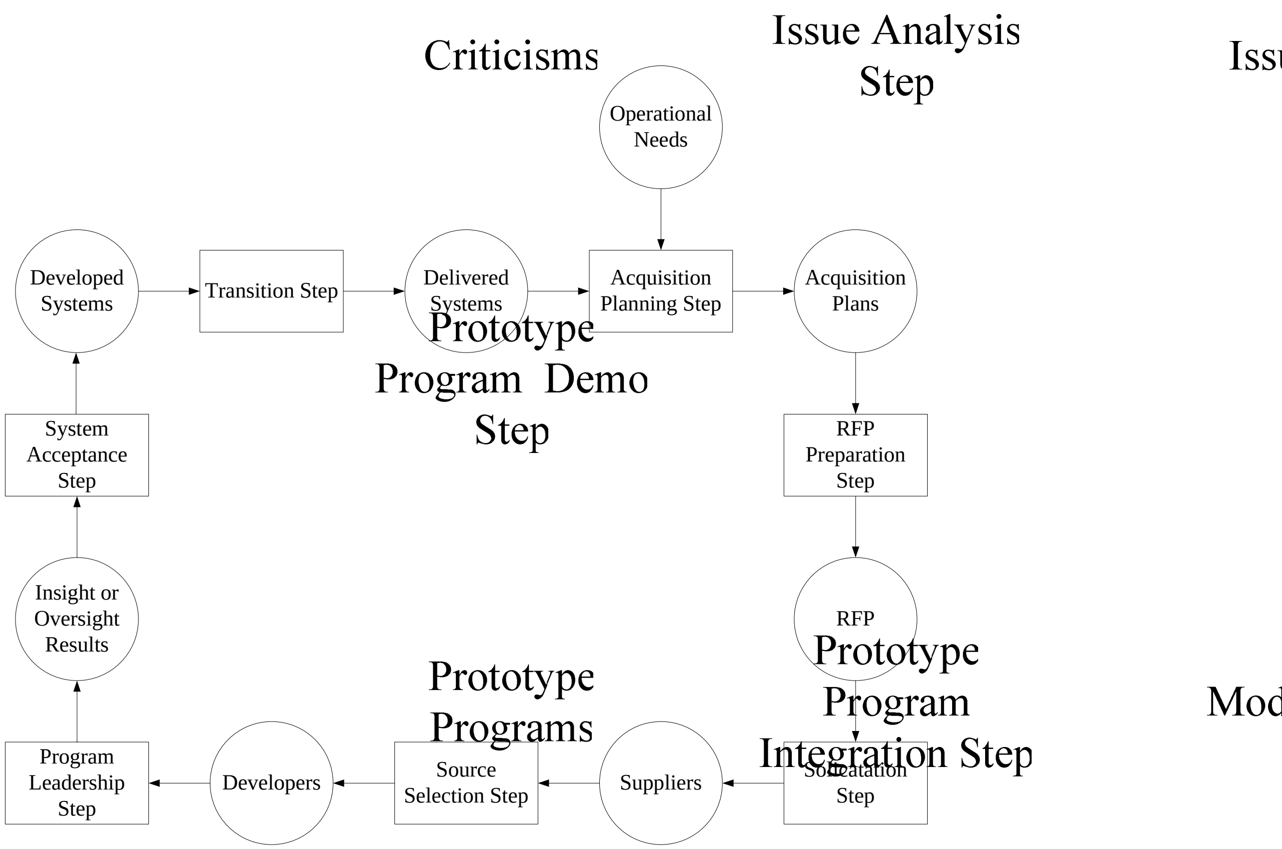

Figure 5: The seven-step spiral model in the production system generation stage

In the production system generation stage, we can use the SA with the DoD AF to construct the C4ISR system architecture based on the results by the CAPS and refer CMMI-AM guidelines to direct the whole project. The C4ISR product system will be conducted by going through the seven-step spiral model. The purpose of the production system generation stage is to plan and analyze the acquisition, to solicit and select suppliers, to monitor and manage the project, and to accept and transit the product/service of the C4ISR system. Each step must optimize the developmental resources available and formalize the developmental process possible. The abundance of developmental resources comes from the information technology, budget, time, people's professional literacy and so on. The detailed developmental process can be tailored to fit the need of acquirers and suppliers.

3. C4ISR Systems with CMMI-AM

The CMMI-AM v1.1 evolves from CMMI-SE/SW/IPPD/SS v1.1 and CMMI v1.0 (See Figure 6 in Appendix). There are twelve process areas in the 2005 CMMI-AM v1.1: *Project Planning (PP), Project Monitoring and Control (PMC), Solicitation and Contract Monitoring (SCM), Integrated Project Management (IPM), Risk Management (RSKM), Requirements Management (REQM), Requirements Development (RD), Verification (VER), Validation (VAL), Decision Analysis and Resolution (DAR), Measurement and Analysis (MA)* and *Transition to Operations and Support (TOS)*. These process areas are classified into three categories: project management, engineering, and support (See Table in Appendix). The project management category includes *PM*, *PMC*, *SCM* and *IPM* process areas; the engineering category includes *REQM*, *RD*, *VER* and *VAL* process areas; and the support category includes *DAR*, *MA* and *TOS* process areas [Gallagher *et al.*, 2004] [Bernard, *et al.*, 2005].

3.1 Formalizing the C4ISR System Development Process

The detailed guideline of the twelve process areas in the CMMI-AM v1.1 [Bernard *et al.*, 2005] can be checked when we undertake a C4ISR system project. The maturity of the military business organization executing a C4ISR system project can be measured by these rigorous guidelines. Some of the guidelines of the process area are critical to the project management from the prototyping system evolution stage to the production system generation stage. Some of the guidelines of the process area may be ignored because of the impertinent resources allocation in an immaterial military business organization.

The formal model of a C4ISR system development process can be decomposed of two stages: the prototyping system evolution stage and the production system generation stage. Each step in the prototyping system evolution stage can be conducted in the software engineering laboratory or operational research and development unit/center. And each step in the production system generation stage must be conducted by the acquisition and development unit/center whose capacity maturity has reached a certain level.

In the prototyping system evolution stage, we used the Computer-Aided Software Evolution System (CASES) to develop, manage and control the C4ISR prototype system. The CASES can solve the issues about software evolution process, software evolution traceability, software evolution description, software evolution management, and software evolution control [Harn, 1999b]. The CASES has successfully connected the CAPS in 1999. The software component of the prototype system can be specified, traced, described, managed and controlled well under the interactive execution of the CASES and CAPS.

In the production system generation stage, we used the System Architect (SA) with the DoD AF to construct the operational architecture, systematic architecture and technical architecture of the C4ISR product system. The transformation from the prototype system to the product system has to do the optimization process because the operational platform of the product system is different from that of the prototype system. The optimizing results to a C4ISR product system are based on the iterative simulation of a C4ISR prototype system. We use these optimizing results to precede the following steps from the acquirer's view: operational needs, acquisition planning, solicitation, source selection, program leadership insight/oversight, system acceptance and transition, and to monitor the following steps from the supplier's view: plan, design, develop, integrate & test and deliver.

While the CMMI-AM involves into the prototyping system evolution stage and the production system generation stage, we have to create a bunch of documentations to check, item by item, the current situation and compare with the relative standard guidelines in the CMMI-AM process area. These documentations, which perform the original request of the CMMI-AM by an automated tool on the web, should be handled by the project team.

3.2 CMMI-AM and the Project Organization

The project organization of a C4ISR system is divided into two kinds of project teams: the kernel project team and the virtue project team. The kernel project team is an inner project team playing the role of acquirers, and the virtue project team is an outer project team playing the role of suppliers. We consider the C4ISR supplier as a virtue and collaborative project team monitored and audited by the kernel project team, which uses the CMMI-AM guidelines to request the suppliers who must follow the process specified in the contract.

In the prototyping system evolution stage, the kernel project team takes the responsibility to plan, analyze and control a C4ISR prototype system project, to solicit, select, and monitor suppliers of developing a C4ISR prototype system by a contract, and to manage, integrate and monitor the whole project based on the detailed guidelines of the process areas in the project management category: *PP*, *PMC*, *SCM* and *IPM*. In this stage, the virtue team is solicited, selected and specified, by the kernel team, to develop, manage, verify, and validate the requirements based on the detailed guidelines of the process areas in the engineering category: *REQM*, *RD*, *VER* and *VAL*. Beside using the process areas of the project management, the kernel teams take the responsibility to analyze the decision, to resolve the relative issues, to measure and analyze the performance, and to support the transition to the C4ISR product system based on the detailed guidelines of the process areas in the support category: *DAR*, *MA* and *TOS*.

Some of the items in the project management category and the support category have been conducted by the CASES, and some of the items in the engineering category have been conducted by the CAPS before the CMMI-AM announced. Even though the purpose of designing the CASES and CAPS was not for the CMMI-AM before, more or less, it is a necessary complement to guide the project successfully.

In the production system generation stage, there is a similar task as the prototyping system evolution stage to the kernel and virtue project team. The kernel project team takes the responsibility to plan, analyze and control a C4ISR product system project, to solicit, select, and monitor suppliers of developing a C4ISR product system by a contract, and to manage, integrate and monitor the whole project based on the detailed guidelines of the process areas in the project management category: *PP*, *PMC*, *SCM* and *IPM*. In this stage, the virtue team is solicited, selected and specified, by the kernel team, to develop, manage, verify, and validate the requirements based on the detailed guidelines of the process areas in the engineering category: *REQM*, *RD*, *VER* and *VAL*. Beside using the process areas of the project management, the kernel teams take the responsibility to analyze the decision, to resolve the relative issues, to measure and analyze the performance, and to support the transition to combine the current C4ISR system based on the detailed guidelines of the process areas in the support category: *DAR*, *MA* and *TOS*.

Although the purpose of designing the tools: SA and DoD AF did not follow the CMMI-AM approach before, when we develop the C4ISR product system by them, the CMMI-AM is helpful to guide us to finish the project successfully.

3.3 Forming Kernel and Virtue Project Teams

In the project organization of a C4ISR system, from the buyer's view, the kernel project team is a group of inner acquirers, and the virtue project team is a group of outer suppliers. The formation of the kernel project team is a hierarchical architecture, including one project leader, many project managers and specialists. The hierarchy of the project organization depends on the functional decomposition of a C4ISR system, which is a SoS structure. The SoS can be classified into three kinds of grains: the huge-grain system, large-grain system and the small-grain system [Luqi, 97]. The huge-grain system includes many large-grain systems, and each large-grain system includes many small-grain systems. When a huge-grain of the C4ISR system is assigned to a project team, the project leader takes the responsibility to the whole system, the project manager takes the responsibility to the large-grain C4ISR system and the project specialist takes the responsibility to the small-grain C4ISR system. Each project specialist is as a window to the virtue team. The project organization of the virtue team depends on its business situation which cannot be controlled by the acquirer. Generally, the virtue team has to specify the relative project specialists as the points of contact to the acquirer's side.

In the prototyping system evolution stage, there is no obvious difference between the acquirer and supplier if the acquirer uses the CASES and the CAPS to handle the prototyping project and catch the user requirements by himself. Because they are on the same side, the kernel team and the virtue team are in the *same* project group. In the case, the kernel team and the virtue team are in the *different* project groups, the virtue team must use the CASES and the CAPS to produce the C4ISR prototype system for the kernel team, and the kernel team plays a monitor's role. Therefore, some of guidelines in the process areas of the CMMI-AM should be embedded into the manipulative process of the CASES and the CAPS scrupulously.

In the production system generation stage, there is an obvious difference between the acquirer and supplier because the acquirer is not a producer of the C4ISR product system and they have opposite sides to each other. The supplier may conduct the system analysis and design by any tools such as the SA with the DoD AF; however, the game rule should be specified by the two sides in advance. In this stage, there are one input and one output, the operational needs and the delivered systems of the C4ISR system respectively, in a life cycle. The operational need of the C4ISR system is produced by the SA with the DoD AF based on the C4ISR prototype system. The delivered system of the C4ISR system is produced by the suppliers/developers based on the C4ISR prototype system and the operational need by the SA with the DoD AF. From the buyer's view the SA with the DoD AF can elicit the user's requirements in the architecture level. Some of the guidelines of the CMMI-AM should be additionally determined to the whole project in the different process areas. After the output of the SA with DoD AF transfers to the virtue team, the kernel team plays a query and monitor's role as in the prototyping system evolution stage.

4. Lessons Learned

After we developed the prototype of the Fire Support and Coordination System (FSCS) in 2003 (See Figure 3), we tried to seek the best way to establish the real FSCS. We organized a C4ISR research center in Taipei to deal with the research and development of the C4ISR system. Seeking the suitable way to develop a C4ISR system is one of the missions of the C4ISR research center. After we studied the CMMI-AM, Version 1.1 (May 2005), the archetype of the standard operation process for developing a C4ISR system was formed. So, we built the Army C4ISR prototype systems by using the CASES and CAPS in advance and studied the guidelines of the CMMI-AM for the prototyping process needs later. In other words, at first we checked the guidelines of the CMMI-AM with the functions of the CASES and the CAPS. And then we discussed and listed the important guidelines of the CMMI-AM that do not involve in the functions of the CASES and the CAPS. We plan to develop the FCSC first based on the CMMI-AM and then expect to obtain the feedback to confirm these important and selected guidelines of the CMMI-AM. In the near future, we are going to modify the old version of the CASES and the CAPS to satisfy these selected guidelines of the CMMI-AM.

In Figure 3, the square with blue dotted line in the FSCS is the Headquarter Main System where the Fire Coordination Center (FCC) integrates the six subsystems by using the CAPS. The FSCS is a small-grain C4ISR project whose prototype system was created by a group of operational officers and monitored by the CASES. In 2003 we did not introduce the CMMI-AM to design the FSCS, but we run well in the prototyping process because the CASES and the CAPS were built rigorously based on the complete formal model of software engineering like the CMMI-AM spirits.

This year, we are going to develop the FSCS product system via the CMMI-AM method based on the FSCS prototype system by using the SA, which is a tool for requirements engineering to implement the operational architecture, the systematic architecture and the technical architecture as the request of the DoD AF. The outputs of the SA can be easily communicated among the acquirer and the relative suppliers.

The following issues should be faced and solved if we introduce the CMMI-AM to the FSCS project:

1. Developing a project management platform of the CMMI-AM on the web to support and guide the kernel team to achieve the documentation setting and checking,

2. Analyzing the guidelines of the process areas of the CMMI-AM to satisfy the requirements and development process in the prototyping system evolution stage and the production system generation stage,

3. Selecting the suitable guidelines of the CMMI-AM in accordance with the needs in the prototyping system evolution stage and the production system generation stage,

4. Designing a digital learning environment to train our project team members for studying the original and selected guidelines of the CMMI-AM,

5. Enhancing the business organization maturity to recover the unsuitable guidelines of the CMMI-AM that are ignored, and

6. Modifying the development method of the C4ISR system, including the tool use of the CASES, the CAPS and the SA, to fit the guidelines of the CMMI-AM.

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Appendix: CMMI Models and CMMI Acquisition Modules

Developing a business organization information system can be regarded as the BPR activities. The CMMI provides the guidance to both acquirers and suppliers for improving their business organization processes. It is a process improvement approach by which organization appraises its organizational maturity and process area capacity. The CMMI can be used, especially, to integrate traditionally separate organizational functions via a set of formalized procedures that include setting goals and priorities of business organization process improvement, evaluating current business organization processes, furthermore, getting new requirements and specifications, implementing and validating new product and service systems. CMMI-based process improvement has enabled business organizations to more consistently deliver products and services on time, at high quality, and for the predicted cost. So, if using CMMI can help the developers of these systems, why not apply CMMI practices to help the acquirers as well [Gallagher *et al.*, 2004]?

1. CMMI Models

The CMMI models, which are part of the CMMI Product Suite, are the official documents that contain CMMI best practices. The CMMI Product Suite contains a framework that provides the ability to generate multiple models and associated training and appraisal materials. Currently there are four bodies of knowledge available: Systems Engineering (SE), Software Engineering (SW), Integrated Product and Process Development (IPPD) and Supplier Sourcing (SS), where SE and SW are mandatory and IPPD and SS are optional. In mandatory we can select SE, or SW, or both, so we have 3 selections. In optional, we can select none, IPPD, SS or both, so we have 4 selections. Therefore, in total, there are 12 combinations. When we select a CMMI model, there are 12 CMMI models available, as generated from the CMMI Framework. A selected model can serve as a guide for improvement of organizational processes. Consequently, we need to decide which CMMI model best fits the organization’s process-improvement needs and select a representation, either continuous or staged the organization will use.

The current products of CMMI models as well as notes released by SEI as references sample are as follows:

- · CMMI-SE/SW/IPPD/SS, Version 1.1 (March 1, 2002)

  This model includes systems engineering, software engineering, integrated product and process development, and supplier sourcing.
- · CMMI-SE/SW/IPPD, Version 1.1 (January 11, 2002)

  This model includes systems engineering, software engineering, and integrated product and process development.
- · CMMI-SE/SW, Version 1.1 (January 11, 2002)

  This model includes systems engineering and software engineering.
- · CMMI-SW, Version 1.1 (August 19, 2002)

This model includes software engineering.

2. CMMI Acquisition Modules

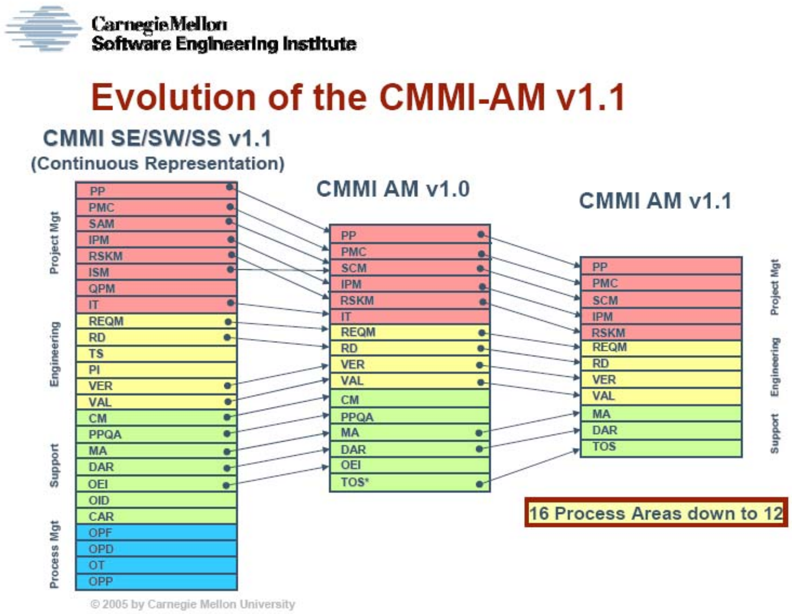
The CMMI Acquisition Module (CMMI-AM) is a stand-alone guide that describes the best practices for use in the acquisition of products. It focuses on effective acquisition activities and practices that are implemented by first-level acquisition projects, such as those conducted by a System Program Office/Program Manager [Bernard *et al.*, 2005]. In order to help Department of Defense (DoD) program offices improve their abilities, the Office of the Secretary of Defense (OSD) announced the creation of the CMMI-AM. The CMMI-AM is a set of documents that are excerpts from a CMMI model with possible trial additions and is available for piloting and use for beginning process improvement. Actually, the CMMI-AM is a condensed form of the CMMI Framework that defines effective and efficient acquisition practices, directed both internally toward the acquisition project and externally toward project monitoring and control of the selected contractors and suppliers.

The current production of CMMI-AM releases are:

- · CMMI Acquisition Module, Version 1.0 (February 2004)
- · CMMI Acquisition Module, Version 1.1 (May 2005)

The CMMI-AM v1.1 evolves from CMMI-SE/SW/IPPD/SS v1.1 and CMMI v1.0. The evolution of CMMI-AM is shown as Figure 6. The acquisition process areas represent a minimal set of processes that cover the best practices needed to successfully address the entire acquisition life cycle.

There are twelve process areas in the CMMI-AM v1.1: *Project Planning (PM)*, *Project Monitoring and Control (PMC)*, *Solicitation and Contract Monitoring (SCM)*, *Integrated Project Management (IPM)*, *Risk Management (RSKM)*, *Requirements Management (REQM)*, *Requirements Development (RD)*, *Verification (VER)*, *Validation (VAL)*, *Decision Analysis and Resolution (DAR)*, *Measurement and Analysis (MA)* and *Transition to Operations and Support (TOS)*. These process areas are classified into three types: project management, engineering and support (See Table).



Source: [Blanchette *et al.*, 2005]

Figure 6: Evolution of the CMMI-AM, Version 1.1

Table: CMMI-AM process areas

CMMI Acquisition Module Process Areas	
Category	**Process Areas**
Project Management	Project Planning (PP) Project Monitoring and Control (PMC) Solicitation and Contract Monitoring (SCM) Integrated Project Management (IPM) Risk Management (RSKM)
Engineering	Requirements Management (REQM) Requirements Development (RD) Verification (VER) Validation (VAL)
Support	Decision Analysis and Resolution (DAR) Measurement and Analysis (MA) Transition to Operations and Support (TOS)