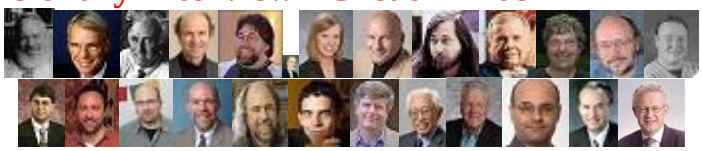
# Frontier Journal

## High-tech Think Tank and Action Workbench



**Kluwer Academic Publisher Editorial**
**Frontier Leadership Interview Column**
**Featured Columnists - Brian Bailey, Dr. Danny Rittmen, Prof. Orit Hazzan**
**Featured Industrial Column – Analog Devices**

## Frontier Visionary Interview - Great Minds Think Alike, Really?



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# Content

Frontier Kluwer Academic Publisher Editorial

# Frontier Visionary Interview

**Frontier Journal (FJ):** How did Garage manage to avoid The 10 Lies of Entrepreneurs when it pitched up to VCs and angels for funding in early days?

**Guy Kawasaki (GK):** Who said that we did. We were relatively early in the dotcom days, so at least the lies were relatively fresh back then.

**FJ:** What prompted Garage to decide to fund both Kaboodle and Simply Hired, which goes quite well as of today?

**GK:** In both cases we liked the idea of "social shopping" and "vertical search," respectively because we could see their broad applicability. I used Kaboodle to keep track of several projects, and many people that I know have used SimplyHired. Both were cases of easy-to-believe examples that the dogs will eat the food.

**FJ:** You worked for Apple twice as a significant contributor to the success of Mac. As an insider, could you let us know why Apple succeeded in 1980s, failed in 1990s, and now thrive again in 2000s?

**GK:** Apple is a product-driven company that focuses on engineering. When it produces things that people like, it does well. When it doesn't, it doesn't.

**FJ:** Garage in, Garage out. From HP to Apple, from yahoo! to google, and now Youtube among other Web 2.0 stars, all started at garages, all at Silicon Valley, all from engineering backgrounds. Are there a startup pattern there, from the Art of Startup's perspective? Why made they so wildly successful?

**GK:** There is a pattern: Unproven entrepreneurs with unproven technology and unproven business models who are building something that they'd like to use.

Ironically, most venture capitalists are looking for proven entrepreneurs with proven technology and proven business models.

**FJ:** With the widespread of open source software movement as well as the rapid drop of hardware costs, starting up startups in software related sector has becoming never so easy anytime in history. What is the impact to venture capital industry?

**GK:** Entrepreneurs can certainly get to market faster and cheaper than ever. This means that they are less dependent on venture capital. If nothing else, it means that venture capitalists will be investing in companies that are in the market, not just drawn on the back of napkins.

**FJ:** When you evaluate a deal, how do you distinguish between practical startups and impractical startups? How do you distinguish between practical people and impractical people?

**GK:** The honest answer is, "With hindsight. " It's very hard to do this at the decision point. My theory is that you declare victory with successes and blame your partners for failures.

**FJ:** When was the most difficult time for Garage so far? How did Garage make strategic shifts those days?

**GK:** We were definitely smacked around by the dotcom implosion. Those were difficult times. We switched from the boutique investment banking model to early-stage investing during that timeframe.

**FJ:** Your most recent book titled The Art of Start, is strictly for entrepreneurs, what is the Art of Exit? Do you have plan to write a new book on that?

**GK:** Nope, no plans to write about that topic. I haven't had enough experience with the subject!

**FJ:** Through out your career so far, you have interviewed quite a few visionary leaders in industry. What are the rule of thumbs in raising questions during those interviews?

**GK:** You've got to do your research before the interview. Just reading their bio, the About page for their company, and doing a quick Google scan is sufficient. But you'd be amazed at how few interviewers do this.

**FJ:** What is your advice for those who are running their funded startups? And what is your advice for those who are running their bootstrapping startups?

**GK:** The most important piece of advice that I can give either type of startup is, "Sales fixes everything." That is, revenue is everything—not partnerships, not scaling, not strategies. You either make your numbers or you don't.

Prof. Orit Hazzan's Column

# Qualitative Research in Software Engineering

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## Introduction

This column discusses the application of qualitative research for research in Software Engineering (SE). Specifically, we outline what research questions are suitable for investigation using qualitative research, what research tools are used for data gathering in qualitative research and how the qualitative data analysis process guides the formulation of answers to the research questions. Accordingly, the column provides basic knowledge for determining whether qualitative research is suitable for the investigation of specific research questions in SE. By doing so, the column contributes to researchers in the field and assists them in deciding whether to adopt the qualitative research approach

.

The importance of the column stems from the fact that only very few works presented in the SE literature contain some qualitative experimental component. For example, according to Glass, Ramesh and Vessey (1994), SE research produces products that are almost exclusively technical. Specifically, SE research examines topics related to systems and software concepts at technical levels of analysis by formulating processes, methods and algorithms. Furthermore, according to Glass *et al.*, most SE research studies (58%) use formulative approaches, e.g., formulation of an algorithm, some studies (28%) use descriptive

research approaches, while even fewer are evaluative in nature (14%).

This column is based on our experience with qualitative research processes in a variety of SE situations. Accordingly, the illustrative examples, presented in this column to demonstrate the suitability of qualitative research for research in SE, are taken from our database.

**Background**

The qualitative research approach is usually used for the investigation of social phenomena, or in other words, situations in which people are involved and different kinds of processes take place. Within this arena, qualitative research is usually conducted in cases in which what we wish to learn about environments, situations and processes cannot be retrieved by quantitative data analysis methods. Indeed, quantitative data analysis can shed light on many aspects of such situations and may enable us to argue with a certain degree of generalization. The nature of quantitative research does not, however, enable the researcher to explore complex situations in depth. By the same token, we are not claiming that the qualitative research approach enables us to present a full picture of complex situations. We are proposing, however, that the qualitative research approach enables us to highlight many angles of people-centered situations. This perspective is illustrated in Table 1.

Table1.:example of a situation in which qualitative research enables to highlight a people-centered perspective.

One situation in which we adopt qualitative research approach is in learning about software organizations prior to the assimilation of a new software development method. In most cases, quantitative data about the software development processes in the said organization is available to those in the organization who initiate the process; they wish, however, to learn also about the practitioners' perspective on the current situation, as well as the practitioners' willingness to make the transition to a new development process. For this purpose, we employ the qualitative research approach and conduct a qualitative-based organizational survey prior to such assimilation processes. In such qualitative-based organizational surveys we mainly address human aspects related to software development processes.

The qualitative-based organizational surveys are based on observations at the

organization sites, interviews with different role holders in the organization, questionnaires that are completed by different role holders in the organization and meetings with different role holders in the organization management. Since we use a variety of data-gathering tools, when data is analyzed, the findings can be validated by illustrating how the same finding is supported by different data items. In most cases, the themes that emerged from the data analysis address human-related factors in SE, such as the customers, software development culture, and teamwork. The added value of such an approach is that the practitioners' voice is heard and, based on these voices, guidelines for the assimilation of the new software development method are outlined.

Qualitative Research -Essence, Connections to Other Research Approaches and Application .

The main characteristic of qualitative research is that instead of aiming at accepting or rejecting an a priori defined hypothesis, research works that use a qualitative approach aim at constructing a theoretical framework that emerges from the analysis of the data gathered during the research and enables to explain the research results in a coherent manner. Such a framework is called a grounded theory (Glaser and Strauss, 1967). Glaser and Strauss explain: “Generating a theory from data means that most hypotheses and concepts not only come from the data, but are systematically worked out in relation to the data during the course of the research.” (p. 6).

This approach inspires a special research setting and process. Specifically, in order to construct a grounded theory, qualitative research is characterized by a spiral structure, in which each phase is based on the previous stages and elaborates on the framework that has been constructed so far. Metaphorically, the qualitative research approach can be described as an on-going dialog between the researcher and the research field, through which the former improves his or her understanding of the latter. This approach, which intertwines the development of a theory together with the research process itself, is therefore especially suitable for the investigation of topics that have not been previously researched. Table 2 presents an example of a research work in which such a process was applied.

Table 2: Example of a grounded theory construction process

This example deals with teaching software development methods in a project-

based software development capstone course (Dubinsky, 2005; Dubinsky and Hazzan, 2005). The goal of the research was to construct a teaching framework for software development methods in higher education. For this purpose, the teaching of software development methods was examined in a project-based course in which Extreme Programming was used.

To achieve the research target, Action Research (Lewin 1946, reproduced in Lewin 1948) was conducted, in which the teaching framework was constructed iteratively and each research cycle was composed of planning – action – collection of data available as a result of the action – data analysis – reflection – refinement of the constructed framework. Specifically, the academic environment enabled the establishment of an iterative process, during which the proposed teaching framework was shaped through an inductive process, while the results obtained were constantly applied, and the suitability of the developed framework was continually examined and compared to newly gathered data and findings through the well-defined constant comparison process.

As the research progressed and the teaching framework started to be shaped and refined, the question of when to stop the research cycles was considered. Specifically, questions such as the following were raised: How does one know how many research cycles are sufficient? Attempts to answer such questions clarified that no final version of the teaching framework can be formulated and that it should have a dynamic nature. In other words, it was clear that such a teaching framework can not be static; changes in technology, in SE methods and in teaching and learning approaches will continue to affect the proposed teaching framework. In practice, the dynamic nature of the teaching framework will provide future teachers using it with the ability to refine and maintain it according to their needs and those of their students.

An examination of the previous paragraph reveals that questions of this kind also emerge with respect to software development processes, for instance: How does one know when the software is ready to be delivered to the customer and shipped to end users? In fact, it is a well-known fact that the life cycle of software does not end when it is shipped to the users, and that the maintenance phase enables users to introduce and ask for changes in the software tool according to their needs.

This similarity between the two processes led, at the first stage, to the formulation

of an analogy between action research and an agile software development method. In a later phase, it turned out, that this analogy is also suitable as a basis for the process of *teaching* software development methods in a computer science project-based capstone course. In fact, analysis of the emerged teaching framework revealed that it fits and extends the above analogy. Thus, the theory that emerged from the research consisted of a 3-dimensional analogy between Action Research, Agile Software Development Methods, and Teaching Software Development Methods.

The construction of a grounded theory is a meta-characteristic of the qualitative research approach from which stem most of its other characteristics. Due to space limitations, we mention in what follows only three additional important characteristics of the qualitative research approach.

First, the data and products of qualitative research are verbal. With respect to the data collection tools, this characteristic of the qualitative research is expressed by the fact that the main data gathering tools are interviews and observations.

Second, the data analysis methods employed in qualitative research aim at directing the researchers to interpret the data from the perspective of the participants in the investigated situation, i.e., to understand the meaning that the participants in the research associate to the researched phenomenon.

Third, with respect to the question of the generalization of qualitative research, we claim that generalization has a different meaning in the case of qualitative research. As mentioned before, the main target of qualitative research is to construct a grounded theory. In order to do so, the course of a typical qualitative research work is iterative, and is based largely on data collection by means of interviews and observations. As a result of such a research setting, a qualitative research work usually focuses on a relatively small number of participants who are part of the research field. In order to enable the potential reader of a qualitative research to evaluate the relevance of the research findings to the case he or she is dealing with (in other words, to assess the level of generalization of the results of a qualitative research), the research participants are selected very carefully and the description of the research field and its results is very detailed (this writing style is called "thick description"). Table 3 presents an example that illustrates this perspective.

Table 3: Example of a study that illustrates generalization in qualitative research

In Dubinsky and Hazzan (2003) we presented a framework for coaching student projects in computer science capstone courses. This research was based on a retrospective process of four coaches who coached and guided students in the development of software projects within the framework of Extreme Programming. The retrospective data were collected using qualitative research tools that included open questionnaires and a series of interviews. The analysis of this gathered data was aimed at eliciting the meaning attributed by the coaches to a new situation, whereby they were required to guide their students in software development processes.

The analysis of the retrospective data yielded six categories that formed the framework for coaching student software projects. The *Project* category emphasizes the management of resources needed for the project, such as a time schedule and various organizational aspects. The *Method* category addresses the software development method's practices and the tools used in the project. The *Development Team* category focuses on the development environment and on communication among team members. The *Customer* category introduces the business aspect into the project and focuses on requirements and product acceptance. The *Feelings* category refers to the people involved in the project, from the viewpoint of their inner being. The last category, *Coaching Team*, emphasizes the support given to the coaching team in order to maintain continuous learning and receipt of feedback. Naturally, there are overlaps between these six categories; from the analysis of the retrospective data, however, it is seen that each of these categories plays a significant role.

The detailed description of the research presented in Dubinsky and Hazzan enables readers to judge the degree of generalization of the research results with respect to specific situations they are dealing with. Relationships between qualitative and quantitative research approaches

This sub-section explores the combination of quantitative and qualitative research approaches. One option for such a combination is to start with a qualitative research work, trying to identify the important observations as they are revealed by the participants in the research field. Then, based on the findings of the first stage, several hypotheses are tested in a quantitative manner and then, based on the findings of the second phase, a second qualitative research phase is performed,

that aims at explaining those quantitative findings. Table 4 presents another way in which qualitative and quantitative approaches may be combined in a single research field . Then, based on the findings of the first stage, several hypotheses are tested in a quantitative manner and then, based on the findings of the second phase, a second qualitative research phase is performed, that aims at explaining those quantitative findings. Table 4 presents another way in which qualitative and quantitative approaches may be combined in a single research study.

Table4:Example of a study that illustrates the combination of qualitative and quantitative research approaches

The research described by Dubinsky, Hazzan, Talby and Keren (2006) examined the transition to an agile development process in a large-scale software project in the Israeli Air Force, as it was perceived from the system analysis and design perspectives. Specifically, during the first half-year of transition, the project specifications of an agile team are compared with those of a team that continued to work according to the previous "heavyweight" method. Size and complexity measures were used as the basis of the comparison. In addition to inspecting the specifications, the change in the role of the system analysts, as conceived by the system analysts, was examined.

Using a quantitative research approach, specifications produced from both kinds of teams – the traditional one and the agile one – were examined and compared. From a qualitative research approach, we wished to understand the process from the system analysts and designers' point of view. Accordingly, we interviewed system analysts and asked them questions such as “Do you feel that your role has been changed? If no, please describe your role before and after the transition. If yes, please describe how your role has been changed.”, “Please compare the traditional way with the agile one.”, and so forth.

The combination of the quantitative and the qualitative research approaches enabled to present a wider, as well as deeper, picture of how the transition process looks from the system analysis and design perspective.

**Application of qualitative research**

So far, we discussed the usefulness of the qualitative research approach and what it can achieve. We also addressed some relationships between qualitative research and quantitative research. In what follows, we address data-gathering tools and

data analysis tools.

We start with data gathering tools. The most common data gathering tools used in qualitative research are interviews and observations (which sometimes are recorded on videotape to enable repeated viewing). For example, one of the main research tools used in the research described in Table 2, which deals with teaching framework for software development methods, was observations of software development teams. The observations provided an opportunity to document the actions, behavior, reactions and additional environmental characteristics in the researched environment. In addition, open interviews with students and coaches were conducted, in which the participants in the research field were asked to describe their perspective of the teaching environment. The interviews with the students focused also on specific practices of the software development method.

In addition to observations and interviews, other qualitative research tools exist for data gathering, such as researcher diary, reflections, questionnaires, artifacts and documents. For example, in the above research work on teaching software development methods, forum messages were also used as means for data gathering. In general, each data gathering tool can complement, deepen and broaden findings obtained using other data gathering tools.

Table 5: Example of a study that illustrates the use of questionnaires to elicit reflection processes

The research described by Talby, Hazzan, Dubinsky and Keren (2006) analyzed reflections of an agile team working on the development of a large-scale project in an industrial setting. The team used an Iteration Summary Meeting practice, that included reflection as one of its four elements. The technique used for the entire meeting, and for the reflection element in particular, is described in the column, and empirical evidence is given to show that the reflection was assessed as highly effective, achieving its intended goals, and increasing team satisfaction.

The main research method used in this research was personal reflection of the team members on the reflection process, collected by means of written questionnaires completed several months after the reflections in question took place.

Different data analysis methods also exist. The main data analysis method used in the construction of a grounded theory is inductive analysis. Inductive analysis is supported by the constant comparison technique, which guides the researcher to keep examining his or her findings, relative to information constantly obtained from different sources (interviews, observations, etc.) and from different informants, at the different research stages. The research described in Table 2, for example, employs this approach extensively.

**Embracing qualitative research in SE**

We now explain why, in our opinion, qualitative research has not yet been largely embraced by the SE research community. Before we delve into the explanation, we would like to re-mention that qualitative research approach *is* used in the SE. For example, Sharp, Hovenden and Woodman (2005) report on using metaphor in a SE qualitative research, aiming to uncover non-technical factors affecting the adoption and evolution of software quality management systems. We propose, however, that the potential contribution of the qualitative research approach to SE research has not yet been fully exploited.

We propose that the reason that the SE community does not use qualitative research more extensively is related to the communities within which SE research is conducted. Naturally, in most cases, SE research is conducted in Computer Science or SE departments, which, as mentioned earlier, do not commonly apply a qualitative research approach.

**Conclusion**

We summarize the column by presenting two main benefits that may be gained by using the qualitative research approach in SE: expanding the research scope and deepening specific research findings.

First, qualitative exploration may enable us to *expand* our scope of research. The open nature of the qualitative research may lead us to new, and sometimes even unpredicted, research directions that were not considered at the onset of the research.

Second, the qualitative approach may enable us to *deepen* our findings. As previously mentioned, in many cases, SE research addresses topics that deal with human-related processes. Such processes, by nature, are rich, consisting of many details and perspectives. Accordingly, it is reasonable to assume that if we

approach these processes with a qualitative approach, which concentrates on the details that constitute them, we may deepen our understanding of such processes.

In summary, and as mentioned before, we note that there is no one approach (quantitative or qualitative) that is preferable over the other. Yet some phenomena are more suitable for investigation using a qualitative research approach.

**References**

Dubinsky, Y. and Hazzan, O. (2003). Extreme Programming as a framework for student-project coaching in computer science capstone courses,

Proceedings of the IEEE International Conference on Software – Science, Technology & Engineering, Herzelia, Israel, pp. 53-59.

Dubinsky, Y. and Hazzan, O. (2005). A framework for teaching software development methods, Computer Science Education 15(4), pp. 275-296.

Dubinksy, Y. (2005). Teaching Software Development Methods, Ph.D. Research Thesis, Technion – Israel Institute of Technology.

Dubinsky, Y., Hazzan, O., Talby, D. and Keren, A. (2006). System analysis and design in a large-scale software project: The case of transition to agile development, Proceedings of the 8th International Conference on Enterprise Information Systems, Paphos, Cyprus.

Glass, R. L., Ramesh, V. and Vessey, I. (1994). An analysis of research in Computing disciplines, Communications of the ACM 47(6), pp. 89-94.

Glaser, B. and Strauss, A. L. (1967). The Discovery of Grounded Theory: Strategies for Qualitative Research, Chicago, Aldine.

Lewin, K. (1948). Resolving Social Conflicts; Selected Columns on Group Dynamics. Gertrude W. Lewin (ed.). New York: Harper & Row.

Sharp, H., Hovenden, F. and Woodman, M. (2005). Using metaphor to analyse qualitative data: Vulcans and humans in software development, Empirical SE 10(3), pp. 343 -365.

Talby, D., Hazzan, O., Dubinsky, Y. and Keren, A. (2006). Reflections on reflection in agile software development, Proceedings of the Agile 2005 Conference, Minneapolis, Minnesota, USA, pp. 100-110.

# CMMI Acquisition Module (CMMI-AM), Version 1.1

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## Executive Summary

Building on relevant best practices extracted from the Capability Maturity Model Integration (CMMI) framework, this report defines effective and efficient practices for acquisition projects. These best practices focus on the activities performed by acquisition professionals in the acquisition program office. They also address internal program office activities that support the monitoring and control of development contractors and suppliers. They provide a foundation for acquisition process discipline and rigor that enables product and service development to be repeatedly executed with high levels of ultimate acquisition success.

This report documents acquisition practices that should be performed by government acquisition projects acquiring systems or services. These practices, however, can also be used by non-government organizations to improve their acquisition practices. This report does not contain prescribed implementation approaches for achieving acquisition best practices. Instead, the proven content of the CMMI framework is used as a base, and amplifications that are specific to the acquisition process have been added.

The information in this report can also be used by acquisition organizations that manage several related acquisition projects (e.g., product centers, acquisition commands, Program Executive Officers, Service/Component acquisition executives) to establish an acquisition process improvement program, ensuring the success of projects in their purview.

## 1 Introduction

The CMMI Acquisition Module (CMMI-AM) is a stand-alone guide that describes best practices for use in the acquisition of products. It focuses primarily 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. The information contained in this report can also be used by organizations that manage multiple programs (e.g., product centers, acquisition commands, Program Executive Officers, Service/Component acquisition executives, etc.) to implement organizational process improvement activities. These activities help establish the environment and infrastructure required to increase project success of the projects within their portfolios (see the section "Improving Acquisition Practices" in the Appendix).

### 1.1 Purpose and Goals

Acquisition activities are complex because acquisition projects are directed outwardly toward acquiring products, systems, services, and capabilities from developers to meet a set of operational expectations and inwardly toward ensuring the acquisition process itself is conducted with rigor. The CMMI-AM incorporates this 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.

Lack of acquisition guidance is a major concern for projects involved in the acquisition and sustainment of systems, including software-intensive systems. Over the past decade, much of the headquarters and field-level acquisition guidance has been rescinded, simplified, or reduced in scope. As a result, only minimal acquisition-related guidance remains in many acquisition areas.

This reduction in guidance coincides with rising levels of system complexity and the software contribution to overall system functionality. System development efforts face the challenge of meeting aggressive performance, cost, and schedule baselines. At the same time, acquisition leaders work to create a flexible environment for acquisition projects, while drastically decreasing acquisition cycle times and improving credibility. Increased complexity, demands for agile,

adaptable products, and shortened delivery timeframes place stress on existing acquisition practices.

The congressional and Department of Defense (DoD)-level guidance that remains in place emphasizes software acquisition process improvement, including the measurement of process performance. The goal of this guidance is to influence the outcome of the acquisition process, delivering the right capabilities to operational users, on schedule, and at predictable costs. One way to meet this goal is through the disciplined application of effective acquisition processes. Applying this approach, however, requires renewed dedication to defining, implementing, measuring, and maintaining the acquisition processes fundamental to a technically sound project.

The purpose of this document is to define effective and efficient acquisition practices that focus on the activities performed by acquisition professionals inside the acquisition program office. The best practices also address internal program office activities that support the monitoring and control of external development contractors and suppliers. Best practices provide a basis for acquisition process discipline, while balancing the need for agility. Note, however, that this report identifies acquisition practices that should be implemented, but does not prescribe specific implementation approaches.

### 1.2 Acquisition Processes and Practices

Acquisition projects perform a number of basic processes to achieve success. These processes are described in general terms to support the numerous variations in application that occur in different acquisition environments. Because variations in execution are at the discretion of the acquisition project, this module focuses on "what" should be done, not "how" it is done.

Many acquisition practices and amplifications in the CMMI-AM module are drawn and summarized from existing sources, including the Software Acquisition Capability Maturity Model (SA-CMM), the Capability Maturity Model Integration (CMMI) framework, the Federal Aviation Administration (FAA) Integrated Capability Maturity Model (FAA-iCMM), and additional coverage areas defined by experienced acquisition professionals.

### 1.3 Terminology and References to CMMI Content

In general, this module uses the terminology contained within the CMMI framework and contains amplified text from that framework. Rather than create a set of recommended processes and practices from scratch, this module utilizes proven content derived from the CMMI framework and adds amplifications specific to the acquisition process to address the unique facets of acquisition.

Throughout the CMMI-AM, there are references to the CMMI Product Suite and the CMMI framework to allow interested readers to explore additional material about best practices. For more information about the CMMI framework, see the CMMI model, which contains all currently published disciplines, namely CMMI for Systems Engineering, Software Engineering, Integrated Product and Process Development, and Supplier Sourcing (CMMI-SE/SW/IPPD/SS), Version 1.1 Continuous Representation, released in March 2002. The continuous representation structures the process areas in groupings related to Process Management, Project Management, Engineering, and Support. The CMMI-AM mainly emphasizes select Project Management, Engineering, and Support process areas. The Process Management process areas in the CMMI framework provide details on how to define and improve processes within the context of the organization in which the acquisition project resides. For more information about using the CMMI-AM in conjunction with the CMMI Framework for organizational process improvement, see the section "Improving Acquisition Practices" in the Appendix.

References to CMMI terminology should be understood in both the acquisition and the process improvement contexts. For example, in the CMMI Product Suite

- The term project denotes a managed set of interrelated resources that delivers one or more products to a customer or end-user. In the CMMI-AM , a "project" (or program, depending on local interpretation), refers to the Entire acquisition project or, perhaps, major subsets of the acquisition project. The scope of the term is tailored to the specific acquisition.
- The term organization is typically used to denote an administrative Structure in which people collectively manage one or more projects. Projects share a senior manager and operate under the same policies. Examples of acquisition organizations include larger or "super" program offices, product centers, acquisition commands, Program Executive Officers, and Service/Component acquisition executives.

- The term work product is any artifact produced by a process.
- The term product denotes a tangible output or service that is a result of a process and that is intended for delivery to a customer or end user. A product is a work product that is delivered to the customer.
- The term system is not used in the CMMI framework, except with respect to system engineering; CMMI uses the term product instead. In the CMMI-AM module, the term "system" is used in the introductory portion of the module only.
- You should decide how these terms apply in your environment.

**2 Executive Questions**

The questions included in this section will help acquisition project managers and program executives determine if their projects perform acquisition activities in accordance with best practices. The questions help verify that best practices are being employed and provide a means of gathering background information necessary to determine if the products or services being acquired will meet operational needs.

The questions in the tables below were designed to facilitate review and improvement of the acquisition process in organizations. They focus on whether or not strategy, planning, and estimating activities occur for an acquisition project. These early activities determine, in large part, the success of an acquisition from the outset. The questions also focus on risk identification, management practices, capabilities definition and requirements generation, and the existence of repeatable processes that enable organizations to institutionalize best practices. Note that for each question in the left-hand column, the relevant CMMI-AM process areas are listed in the right-hand column. The process areas are described in detail in Section 3 of this document.

| **1. Acquisition Strategy** | |
|---|---|
| Questions | CMMI-AM Process Areas |
| a. How have you determined the most appropriate acquisition strategy for this acquisition? | Project Planning, Decision Analysis and Resolution, Risk Management |

| | |
|---|---|
| b. How does your selected acquisition strategy mitigate the risks you have identified? | Project Planning, Risk Management |
| c. Which stakeholders were involved in establishing the acquisition strategy? | Project Planning, Integrated Project Management |
| | |
| **2. Acquisition Planning** | |
| Questions | CMMI-AM Process Areas |
| a. How do your acquisition plans reflect and implement the acquisition strategy? | Project Planning, Integrated Project Management, Decision Analysis and Resolution |
| b. How did you determine and document the scope of the program including acquisition project activities, supplier activities, and other related activities (operational testing, user activities, etc.)? | Project Planning |
| c. How did you determine the size/magnitude of the development effort? | Project Planning |
| d. How did you determine resource needs for each element of the project? | Project Planning |
| e. How did you determine a critical path? | Project Planning, Integrated Project Management |
| f. How have the plans been coordinated with relevant stakeholders at both the management and working levels? | Project Planning, Integrated Project Management |
| g. How will you ensure that you have adequate staff with the necessary experience and training to execute your plans? | Project Planning |

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| h. How will you ensure that the supplier has the resources and tools needed to complete the project? | Project Planning, Solicitation and Contract Monitoring |
| i. How will you ensure that the supplier has the domain experience and process capability needed to complete the program? | Project Planning, Solicitation and Contract Monitoring |
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| **3. Cost, Schedule, and Performance Baselines** | |
| Questions | CMMI-AM Process Areas |
| a. How have you ensured that the cost, schedule, and performance baselines are integrated, realistic and executable? | Project Planning, Integrated Project Management, Solicitation and Contract Monitoring |
| b. What provisions have you made for independent reviews of your cost, schedule, and performance baselines? | Project Planning, Integrated Project Management, Solicitation and Contract Monitoring, Requirements Development, Requirements Management |
| c. How have you ensured that all the life cycle costs are included in the baselines (e.g., testing, training, sustainment and support)? | Project Planning, Integrated Project Management, Transition to Operations and Support |
| d. How do you plan to track cost, schedule, and performance of the project throughout its life cycle? | Project Monitoring and Control, Measurement and Analysis |
| e. How have you accommodated risks and engineering changes in your baselines? | Project Planning, Risk Management, Requirements Management |
| f. How do you manage changes to the baselines? | Project Monitoring and Control, Requirements Management |

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| g. How do you evaluate the impact of changes in cost and schedule on contractual development efforts? | Project Monitoring and Control, Solicitation and Contract Monitoring, Requirements Management |
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| **4. User Requirements** | |
| Questions | CMMI-AM Process Areas |
| a. How do you intend to manage users' involvement in the requirements process? | Project Planning, Integrated Project Management, Requirements Management, Requirements Development |
| b. How do you ensure a clear understanding of the user needs by relevant stakeholders? | Requirements Management, Requirements Development, Solicitation and Contract Monitoring, Integrated Project Management |
| c. What role does your organization play in establishing the requirements? | Requirements Management, Requirements Development |
| d. What is the strategy for keeping up with the evolving operational environment (e.g., threat, concept of operations, technology readiness)? | Integrated Project Management, Requirements Management |
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| **5. Product Engineering** | |
| Questions | CMMI-AM Process Areas |
| a. Is there a process in place to define, verify, and validate requirements and architectures for the product? | Requirements Development |

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| b. How will the status of development be monitored? | Project Monitoring and Control, Measurement and Analysis, Solicitation and Contract Monitoring |
| c. Describe your strategy for incorporating non-developmental products (e.g., commercial off-the-shelf [COTS], government off-the-shelf [GOTS], reuse, product lines) into the project. | Project Planning, Decision Analysis and Resolution, Requirements Development |
| d. What percentage of the software is planned to be non-developmental? | Project Planning, Measurement and Analysis |
| e. How have you determined that you can achieve the planned percentage of non-developmental software use on this project? | Project Planning, Risk Management, Verification, Validation, Decision Analysis and Resolution |
| f. How will you determine that the planned non-developmental products will provide the required functionality and performance? | Measurement and Analysis, Requirements Development, Verification, Validation, Decision Analysis and Resolution |
| g. How will you determine that the interfaces for non-developmental products are defined and agreed to by relevant stakeholders? | Requirements Development |
| h. How have you accounted for the effort required to test and integrate non-developmental products? | Requirements Development, Verification, Validation |
| i. How will the contractor demonstrate the performance and stability of the development environment and tools? | Solicitation and Contract Monitoring |
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| **6. Acquisition Processes** | |
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| Questions | CMMI-AM Process Areas |
| a. Describe the content and source of your acquisition processes. | Project Planning, Integrated Project Management |
| b. What mechanism do you use to monitor, control, and improve your acquisition processes? | Project Monitoring and Control, Measurement and Analysis |
| c. How do you know your project is adhering to your acquisition processes? | Project Monitoring and Control |
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| **7. Risk Identification and Management** | |
| Questions | CMMI-AM Process Areas |
| a. How do you identify program risks? | Project Planning, Risk Management |
| b. What risks have you identified related to your acquisition strategy and plans? | Project Planning, Risk Management |
| c. What are the risks associated with cost and schedule? | Project Planning, Integrated Project Management, Risk Management |
| d. How have you ensured that you understand the cost risk of obtaining the required capability? | Project Planning, Risk Management, Requirements Development |
| e. What risks have you identified related to supplier execution? | Project Planning, Risk Management, Solicitation and Contract Monitoring |
| f. What risks have you identified that are | Project Planning, Integrated |

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| outside your control? | Project Management, Risk Management |
| g. How do you assess (likelihood and consequence) program risks? | Risk Management |
| h. How do you monitor mitigation efforts for identified risks? | Risk Management |
| i. Describe the risk management tool(s) you employ. | Project Planning, Risk Management |
| j. Who is involved in program risk assessment (e.g., users, supplier, independent subject matter experts)? | Integrated Project Management, Risk Management |
| k. Explain how you have built in sufficient reserves for risk mitigation and absorbing the impact of realized risks. | Project Planning, Risk Management |
| l. How do you assess the mechanisms the supplier uses to encourage execution of their organization's processes from the outset of the project? | Project Monitoring and Control, Solicitation and Contract Monitoring, Risk Management |

**3 Acquisition Process Areas**

The acquisition process areas in this section are abstracted from a number of sources, principally the CMMI framework, the SA-CMM, and the FAA iCMM. Amplifications related specifically to acquisition are included to provide a context for the best practices used in acquisition settings.

The acquisition process areas represent a minimal set of processes that cover the best practices needed to successfully address the entire acquisition life cycle. Each acquisition project operates within a unique environment that influences the definition of its life cycle. The acquisition life cycle, especially as it applies to upgrades and modifications, may restart after a cycle has been initiated and partially completed. For example, acquisition of a major upgrade may be initiated for a product that has already been developed, fielded, and placed into operation.

In this case, the deployment of the CMMI-AM could result in the upgrade acquisition being considered a new acquisition life cycle, with complex implementation requirements of its own that may impact another acquisition life cycle already underway. Or, in other cases, the acquisition life cycle may continue throughout the product's life cycle through disposal.

In the process areas listed below, goals are shown in bold-faced text. Below each goal are numbered statements that reflect the recommended practices.

### 3.1 Project Management Process Areas

Project management process areas cover project management activities related to planning, monitoring, and controlling projects.

**Project Planning (PP)**

The purpose of Project Planning is to establish and maintain plans that define project activities.

For acquisition, project planning starts by setting the acquisition strategy and is followed by planning the acquisition process in ever-increasing levels of detail. The resulting plans should be reviewed for consistency with the overall acquisition plans. The acquirer and developer project planning processes are continuous and the plans evolve to meet the project's needs.

The acquisition strategy relates the objectives for the acquisition, the constraints, availability of assets and technologies, consideration of acquisition methods, potential contract types and terms, accommodation of end user considerations, consideration of risk, and support for the program over the life cycle.

If an existing product is to be replaced as part of the acquisition, the acquirer may be required to consider transition from operation and the disposal of the existing product as part of the planning for executing the new product. Any such transition activities should be included in the project plan, and provisions for accommodating such specialized requirements should be included. It may be beneficial to refer to the Transition to Operations and Support process area when planning.

Project Planning can best be described by the following goals and practices.

**1. Estimates of project planning parameters are established and maintained.**

**1.1 Establish a top-level work breakdown structure (WBS) to estimate the scope of the project.**

The WBS should include tasks for the entire project to include activities performed by the acquisition project as well as suppliers and other stakeholders (e.g., test community, operational users) to ensure the planning effort includes the scope for the entire acquisition.

**1.2 Establish and maintain estimates of the attributes of the work products and tasks.**

Estimates of the attributes of the work products and tasks are used to bound the budget and schedule.

**1.3 Define the project life-cycle phases upon which to scope the planning effort.**

Typical life cycle choices include single-step acquisition, evolutionary incremental, or evolutionary spiral. Include in the planning the entire known life cycle from user needs through initial and subsequent upgrades. The acquisition organization should consider the full collection of contracts within a project context so that an integrated approach results, rather than dealing with activities individually. This supports the project planning activities on the occasions when some elements of the acquisition or life cycle may be out of the control of a particular acquisition organization.

**1.4 Estimate the project effort and cost for the work products and tasks based on estimation rationale.**

In addition to creating an estimation of the project work products, the acquisition organization is encouraged to have its estimate independently reviewed by individuals external to the project to ensure that the project estimation can be validated. Be sure to include the effort and cost supporting execution of the acquisition processes as well as developing the product. Estimates of the effort and cost of work products and tasks are used to establish the overall project budget and schedule.

**2. A project plan is established and maintained as the basis for managing the project.**

**2.1 Establish and maintain the project's budget and schedule.**
The acquisition project budget and schedule, including the life-cycle-related activities of the acquisition organization itself, the supplier efforts, and those of the supporting organizations and other stakeholders, including any contractors to support the acquisition organization, should be created and maintained for the duration of the project.

**2.2 Identify and analyze project risks.**
Identify risks from multiple perspectives (e.g., acquisition, technical, management, operational, contractual, industry, support, user, etc.) to ensure all project risks are considered in planning activities.

**2.3 Plan for the management of project data.**
Consider how data, to include informal data as well as formal project data and plans, will be shared across all relevant stakeholders. Include plans for managing data within integrated teams and the infrastructure required to manage data between the supplier, operational users, and other relevant stakeholders. Decide which program data and plans require version control, or more stringent configuration control, and establish mechanisms to ensure project data is controlled. Consider the implications of controlling access to classified information and sensitive but unclassified information (e.g., proprietary, export controlled, source selection sensitive) and other access controlled data.

**2.4 Plan for necessary resources to perform the project.**
Plan for resources for the acquisition project as well as tools and infrastructure required during the life of the program. Include consideration of integration and test facilities.

**2.5 Plan for knowledge and skills needed to perform the project.**
Plan for knowledge and skills required by the project team to perform their tasks. Knowledge and skill requirements can derive from project risk. For example, if the project team is acquiring a software-intensive product, ensure expertise in systems and software engineering exists within the project team, or provide training for the project team in these areas. Include orientation and training for

project team and stakeholders in acquisition practices and the domain knowledge required to execute the project.

**2.6 Plan the involvement of identified stakeholders.**

Stakeholders can include operational users and project participants from test or other support communities as well as potential suppliers. When acquiring products that need to interoperate with other products, plan for involvement of stakeholders from other projects or communities to ensure the delivered product can perform as required in its intended environment.

**2.7 Establish and maintain the overall project plan content.**

The overall project plan can take on many forms and may even be found in multiple plans, such as Acquisition Strategy, Single Acquisition Management Plan, Program Management Plan, Life-Cycle Management Plan, and the Systems Engineering Plan.

Regardless of form, the plan or plans should address the acquisition strategy as well as the cradle-to-grave considerations for the project and product to be acquired.

**3. Commitments to the project plan are established and maintained.**

**3.1 Review all plans that affect the project to understand project commitments.**

The project may have a hierarchy of plans (e.g., Risk Management Plan, Systems Engineering Plan, Requirements Management Plan). In addition, stakeholder plans (e.g., Operational, Test, Support, Supplier plans) should be reviewed to ensure consistency among all project participants.

**3.2 Reconcile the project plan to reflect available and estimated resources.**

When available resources (to include personnel, facilities, stakeholders, schedule, and funding) are inadequate to accomplish the project, consider de-scoping the effort to match available resources. When this is not feasible, identify and mitigate these risks.

**3.3 Obtain commitment from relevant stakeholders responsible for performing and supporting plan execution.**

Major project plans should be coordinated with and approved by relevant stakeholders.

For more extensive treatment of the goals and practices of Project Planning, see the source documents referenced in the bibliography.

**Project Monitoring and Control (PMC)**

The purpose of Project Monitoring and Control is to provide an understanding of the project's progress so that appropriate corrective actions can be taken when the project's performance deviates significantly from the plan.

For acquisition, monitoring and control functions are directed within the acquisition project early in the process as the acquisition planning is performed and the strategy is defined. As the acquisition process unfolds, monitoring and controlling are essential to ensuring that appropriate resources are being applied and that acquisition activities are progressing according to plan. Project Monitoring and Control involves establishing the planned internal activities and schedule for completion and then monitoring the status of these activities and work product completions through measurement and analysis (metrics). It is important that the acquisition project has internal processes, plans, and work products that are monitored for satisfactory completion and progress.

Included in those internal items monitored should be work product completion (specifications, plans, Request for Proposal components, etc.), staffing levels and qualifications applied, product performance objectives and thresholds, infrastructure readiness (tools, networks, etc.) and other activities and products included in project planning. Project risk identification and mitigation should also be monitored for status.

Corrective action should be applied when execution does not match project planning (e.g., internal staffing, project plan completion dates, draft and final solicitation, and contract award milestone dates).

If a corrective action is required to resolve variances from project plans, these actions should be defined and tracked to closure.

After a supplier is selected and an award is made, the role of monitoring and control becomes twofold, concerned with continuing to monitor and control internal acquisition activities while also monitoring and controlling the progress of the supplier execution under the supplier project plan.

Project Monitoring and Control can best be described by the following goals and practices.

**1. Actual performance and progress of the project are monitored against the project plan.**

**1.1 Monitor the actual values of the project planning parameters against the project plan.**
Monitoring of schedule, budget, and acquisition activity progress should begin as soon as a project plan is established.

**1.2 Monitor commitments against those identified in the project plan.**
Commitments for resources that will result in expenditures (e.g., issued purchase orders, completed deliverables that have been accepted) should be tracked when incurred, even prior to formal payment, to ensure that future financial and legal obligations are accounted for as soon as they are incurred.

**1.3 Monitor risks against those identified in the project plan.**
The acquisition project should manage risks independent of the contractor risk management procedures Many risks are the responsibility of the acquisition project and may include sensitive information that should not be shared with the contractor (e.g., source selection sensitive, re-competition, internal staffing or other risks).

**1.4 Monitor the management of project data against the project plan.**

**1.5 Monitor stakeholder involvement against the project plan.**

**1.6 Periodically review the project's progress, performance, and issues.**

**4.7 Review the accomplishments and results of the project at selected project milestones.**

**2. Corrective actions are managed to closure when the project's performance or results deviate significantly from the plan.**

**2.1 Collect and analyze the issues and determine the corrective actions necessary to address the issues.**
The acquisition project should manage issues and corrective actions independent of the contractor issues and corrective actions management procedure. Many issues and corrective actions are the responsibility of the acquisition project and may include sensitive information that should not be shared with the contractor (e.g., source selection sensitive, re-competition, internal staffing or other issues).

**2.2 Take corrective action on identified issues.**

**2.3 Manage corrective actions to closure.**
For more extensive treatment of the goals and practices of Project Monitoring and Control, see the source documents referenced in the bibliography.

Solicitation and Contract Monitoring (SCM)
The purpose of Solicitation and Contract Monitoring is to prepare a solicitation package that identifies the needs of a particular acquisition, to select a supplier that is best capable of satisfying those needs, and to establish the process for monitoring the supplier for the duration of the contract.

For acquisition, the solicitation must comply with the applicable federal, departmental, and service acquisition regulations and policies. The solicitation should address activities appropriate to the product domain or acquisition environment (e.g., supplier process evaluations, operational safety, suitability, and effectiveness, certifications, architecture evaluations, and interoperability). The representatives responsible for these activities within the project or stakeholder organizations should be consulted for proper inclusion of those activities into the solicitation and contract monitoring process. The solicitation practices apply equally to initial contractual actions and subsequent change orders, task orders, etc.

The Solicitation and Contract Monitoring process area creates a proactive environment that enables the acquirer to initialize and adapt the relationship with

the supplier over the duration of that relationship for the successful execution of the project. In addition, it encourages creation of a contract that allows the acquirer to execute its monitoring and control of supplier activities using other process areas, such as Project Monitoring and Control. This encouragement may include levying a contractual requirement on the supplier to create a project plan that will successfully execute the contract, to define and execute the processes needed to achieve success, and to commit to execute their plan as it evolves during contract execution.

The Solicitation and Contract Monitoring process area involves planning for and performing the practices necessary to develop and issue a solicitation package, preparing for the evaluation of responses, conducting an evaluation, conducting supporting negotiations, making recommendations for award of the contract, and overseeing the execution phase to ensure the needs of the acquisition are met.

The acquirer and supplier establish and maintain a mutual understanding through effective, timely, and appropriate communication. The acquirer should clearly identify and prioritize its needs and expectations, as well as its suppliers' capabilities. The acquirer works closely with suppliers to achieve a mutual understanding of product requirements, responsibilities, and processes that are applied to achieve project objectives.

Solicitation and Contract Monitoring can best be described by the following goals and practices.

**1. The project is prepared to conduct the solicitation.**

**1.1 Designate a selection official responsible for making the selection decision.**

**1.2 Establish and maintain a solicitation package that includes the needs of the acquisition and corresponding proposal evaluation criteria.**
For task orders or contractual changes against an existing contract, ensure the acquisition project has documented evaluation criteria against which to evaluate the proposed changes from the contractor.

Define the proposal content that the offerors must submit with their response.
Examples include:

The requirement to provide evidence of existing organizational processes upon which the project processes will be based, and the commitment to execute those processes from project inception;

The requirement to reflect in the proposed contractual documents such as the Statement of Work (SOW), Integrated Master Plan (IMP), Integrated Master Schedule (IMS) and Software Development Plan (SDP) the processes, tasks and activities characteristic of the proposed development approach;

The requirement to describe how the proposed approach (e.g., SOW, IMP, IMS, SDP or other contractual documents) demonstrates a commitment to execute the project using the processes and methods proposed from project inception. Require offerors to provide evidence of a mechanism to encourage and monitor execution of organizational processes at project start up. Require offerors to describe measurements that provide the project team visibility into the supplier process adherence;

The requirement to describe how the proposed approach demonstrates high confidence that the size and complexity of the development and integration effort is understood, the effort and schedule necessary to develop the required products are estimated with high confidence, and that the proposed development effort is compatible with and can be completed within the proposed funding and schedule; Plans appropriate to the scope and content of the program (e.g., Integrated Management Plan, Systems Engineering Plan, Software Development Plan, Risk Management Plan);

Identification of the measurements (to include development progress measures) to be used in the project and made available to the project office;

A description of the offeror planned use of COTS or re-use of previously developed hardware or software components, including non-deliverable components. This should include identification of any limitation on data rights and rationale for the offeror confidence that the levels of COTS and re-use can be achieved;

An approach to provide visibility for development task progress and costs at a level appropriate for the type of contract and commensurate with the degree of risk related to the acquisition;

Identification of the work to be performed by lower-level suppliers;

Proposed tasks and activities to support product verification, validation, and transition to operations and support;

Technical, non-technical, and product verification requirements to be satisfied by the supplier;

Deliverables that provide the acquisition project sufficient data to allow verification and validation of acquired products;

Requirements to ensure that the supplier supports each of the acquisition project verification and validation activities; and Requirements for the supplier to establish a corrective action system that includes a change control process for rework and reevaluation.

The acquisition organization should request evidence of adherence to the supplier organization mechanism for project start up in accordance with their defined processes.

**1.4 Establish and maintain independently reviewed cost and schedule estimates for the products to be acquired.**

To ensure objectivity and realism, cost and schedule estimates should be reviewed by individuals independent of the acquisition project team and supplier's team. Representatives from the functional or "Home Office" organizations at the acquisition organization, such as finance and engineering, can support these efforts.

Validate the solicitation package with end users and potential offerors to ensure the approach and cost and schedule estimates are realistic and can reasonably lead to a usable product.

In a competitive environment, ensure all potential offerors have equal access and opportunity to provide feedback on the solicitation package. Provide the opportunity for the selected suppliers and end users to clarify points of ambiguity in the set of required capabilities as well as any disconnects or concerns with the proposed solution. In a sole source or change order environment, make sure relevant stakeholders understand the intent of the effort or changes before placing the additional work on contract.

**2. Suppliers are selected based on the solicitation package.**

**2.1 Evaluate proposals according to the documented evaluation criteria.**
The criteria are used to evaluate the offerors technical approach as well as their management practices, sufficiency of plans, process capability in key program risk areas, relevant domain experience, cost, schedule, and past performance.

**2.2 Use proposal evaluation results as a basis to support selection decisions.**

**3. Contracts are issued based on the needs of the acquisition and the suppliers' proposed approaches.**

**3.1 Establish and maintain a mutual understanding of the contract with selected suppliers and end users based on the acquisition needs and the suppliers' proposed approaches.**
As points of clarification and ambiguities continue to arise after contract award, ensure the mutual understanding is revised and maintained through the life of the project. Ensure that the supplier makes a contractual commitment to execute its proposed processes.

**3.2 Establish and maintain communication processes and procedures with suppliers that emphasize the needs, expectations, and measures of effectiveness to be used throughout the acquisition.**
The acquisition project is responsible for establishing and maintaining the ground rules for supplier communication, documenting decisions, and conflict resolution through the life of the project. The acquisition project facilitates this with relevant project stakeholders. Specific roles and responsibilities of relevant project stakeholders for interaction with or direction of the suppliers need to be defined, coordinated, and adhered to.

After the contract is awarded, the acquisition project should verify that the supplier is effectively executing its organization processes.

**4. Work is coordinated with suppliers to ensure the contract is executed properly.**

**4.1 Monitor and evaluate selected processes used by the supplier based on the supplier's documented processes.**
The supplier plans and processes are used as the basis for monitoring its activities. The acquisition project is responsible for ensuring the supplier s implemented processes address the needs of the project. The acquisition project should verify that the supplier processes are executed from project inception.

**4.2 Evaluate selected supplier work products based on documented evaluation criteria.**
The acquisition project must decide based on risk and available resources which products will be evaluated. This may include interim work products as well as delivered products.

**4.3 Revise the supplier agreement or relationship, as appropriate, to reflect changes in conditions.**
When the supplier processes or products fail to meet established criteria, the acquisition project may decide to apply contractual remedies. While monitoring process adherence and product development, the acquisition project may find contractual requirements that are no longer optimal based on the supplier progress or environment changes. Examples include overly burdensome documentation, reporting requirement, or evolving process requirements when warranted by demonstrated performance on the contract. In these cases, the acquisition project should be flexible to facilitate achieving efficient processes that still meet the needs of the overall project. Examples where flexibility may be warranted based on demonstrated performance on the contract include overly burdensome documentation, reporting requirements, and evolving process requirements.

For more extensive treatment of the goals and practices of Solicitation and Contract Monitoring, see the source documents referenced in the bibliography.
Integrated Project Management (IPM)

The purpose of Integrated Project Management is to establish and manage the project and the involvement of the relevant stakeholders according to an integrated and defined process that is tailored from the organization's set of standard processes.

For acquisition, Integrated Project Management involves establishing project management processes consistent with and tailored from the organization standard processes. This includes higher level acquisition guidance, regulations, instructions, and local practices established to be used across various projects in the local organization. Establishing an integrated project management process that incorporates and involves relevant stakeholders (e.g., executive level acquisition offices, users, test organizations, developers, and associated government support organizations) is critical to the success of the project. This defined project management process is typically defined in an overall project management plan or equivalent document.

The integrated project management process needs to involve and integrate all relevant acquisition, development, support, and operational activities. Depending on the size of the project, the size of the coordination efforts can be significant. Formal interfaces among project stakeholders take the form of memorandums of understanding (MOUs), memorandums of agreements (MOAs), contractual commitments, associate contractor agreements, and similar documents, depending on the nature of the interfaces and involved stakeholders.

Integrated Project Management is best described by the following goals and practices.

**1. The project is conducted using a defined process that is tailored from the organization's set of standard processes.**

It is possible that an organization has not established a standard set of processes. If so, the project should define its own processes appropriate to its need.

**1.1 Establish and maintain the project's defined process.**
Often, the defined process for a project is developed by tailoring and integrating higher level organizational guidance. For example, the DoD Acquisition

Framework (http://akss.dau.mil/dag/) describes a series of requirements and tailoring guidelines for acquisition projects. This guidance, in conjunction with lower level guidance at the Service, Component, or other level, would be used by a project to establish the process to be used to acquire the project unique product or service. Where no organizational process exists, the project should develop defined processes itself.

**1.2Use the organizational process assets and measurement repository for estimating and planning the project's activities.**
When available, use the results of previous planning and execution activities as predictors of the relative scope and size of the effort being estimated for the acquisition.

**1.3 Integrate the project plan and the other plans that affect the project to describe the project's defined process.**
Tiered plans are often effective for large programs.

**1.4 Manage the project using the project plan, the other plans that affect the project, and the project's defined process.**

**1.5 Contribute work products, measures, and documented experiences to the organizational process asset**s.
If a repository of previous information exists at the start of the project, consider retaining the project estimates and actual results for use in estimating future projects.

**2. Coordination and collaboration of the project with relevant stakeholders are conducted.**

**2.1 Manage the involvement of the relevant stakeholders in the project.**
The acquisition organization should encourage stakeholder involvement and manage their activities, ensuring that stakeholder coordination and cooperation are maximized to the extent possible.

**2.2 Participate with relevant stakeholders to identify, negotiate, and track critical dependencies.**

Stakeholder activities that include dependencies that are critical to the project should be negotiated with the stakeholders to obtain commitment to perform. The critical dependencies should be identified in the project plan so those activities can be monitored and controlled relative to the dependent activities.

**2.3 Resolve issues with relevant stakeholders.**
For more extensive treatment of the goals and practices of Integrated Project Management, see the source documents referenced in the bibliography.

**Risk Management (RSKM)**
The purpose of Risk Management is to identify potential problems before they occur, so that risk-handling activities may be planned and invoked as needed across the life of the product or project to mitigate adverse impacts on achieving objectives.

For acquisition, risk identification and estimation of probability of occurrence and impact, particularly for those risks involved in meeting performance requirements, schedules, and cost targets, largely determines the acquisition strategy. The acquirer has a dual role: first, in assessing and managing overall project risks for the duration of the project, and second, in assessing and managing risks associated with the performance of the supplier. As the acquisition progresses to the selection of a supplier, the risk specific to the supplier technical and management approach then becomes important to the success of the acquisition.
The particular risks associated with conducting the project using integrated teams should be considered, such as risks associated with loss of inter-team or intra-team coordination.

Risk Management can best be described by the following goals and practices.

**1. Preparation for risk management is conducted.**

**1.1 Determine risk sources and categories.**
Acquisition organizations should identify and categorize risks and risk sources for the project initially and refine those risks and categories over time (e.g., schedule, cost, contractor execution, technology readiness, issues outside control of acquisition organization).

**1.2 Define the parameters used to analyze and categorize risks and the parameters used to control the risk management effort.**

Acquisition organizations should record the parameters used to analyze and categorize risks so that they are available throughout the project period for reference when circumstances change over time. In this way, risks can easily be re-categorized and analyzed relative to the original information when changes occur.

**1.3 Establish and maintain the strategy to be used for risk management.**

**2. Risks are identified and analyzed to determine their relative importance.**

**2.1 Identify and document the risks.**

**2.2 Evaluate and categorize each identified risk using the defined risk categories and parameters, and determine its relative priority.**

**3. Risks are handled and mitigated, where appropriate, to reduce adverse impacts on achieving objectives.**

**3.1 Develop a risk mitigation plan for the most important risks to the project, as defined by the risk management strategy.**

**3.2 Monitor the status of each risk periodically and implement the risk mitigation plan as appropriate.**

Risks should be continually monitored and, when warranted, the mitigation plan should be adjusted to adapt for change. When the situation requires action, mitigation actions should be executed promptly based upon the mitigation plan.

For more extensive treatment of the goals and practices of Risk Management, see the source documents referenced in the bibliography.

**3.2 Engineering Process Areas**

The engineering process areas establish a consistent set of requirements that are derived from stakeholder needs and operational capability statements so that work products developed internally by the acquirer and work products and delivered products from the suppliers are proven to successfully satisfy end user needs and provide operational capabilities.

**Requirements Development (RD)**

The purpose of Requirements Development is to produce and analyze customer, product, and product-component requirements.

For acquisition, Requirements Development has two contexts. The first context is the amalgamation and coordination of the operational requirements (i.e., customer requirements) into a set of requirements that will define the scope and direction of the acquisition. The second context is the allocation and extension of the customer requirements and additional acquirer requirements (e.g., product characteristics, design requirements, architecture requirements) that become the basis of the product and component requirements derived and developed by the supplier organization.

There is a continuous iteration of requirements down through the multiple tiers of requirements documents associated with the components of a product. For example, requirements flow from the stakeholders to the top level down to multiple lower levels and eventually to either hardware or software component levels. The responsibility for developing requirements down through the levels is generally split between the acquirer and the supplier. The acquirer is generally responsible for the higher levels, starting with operational requirements, and the supplier is generally responsible for lower levels. The division of responsibilities between the acquirer and supplier is determined by each project.

The acquirer is responsible for defining and baselining the requirements levels under its control and also monitoring the supplier definition of the lower level requirements.

When acquiring services instead of products, the same requirements process is used to define high-level operational needs and to allocate those needs to lower level components of the service to ensure the resulting service meets the original intent.

Requirements Development can best be described by the following goals and practices.

**1. Stakeholder needs, expectations, constraints, and interfaces are collected and translated into customer requirements.**

**1.1 Elicit stakeholder needs, expectations, constraints, and interfaces for all phases of the product life cycle.**

**1.2 This includes review, coordination, and formalization with the user of top level operational needs and requirements.**

Transform stakeholder needs, expectations, constraints, and interfaces into customer requirements.

This includes the transformation of the top level user requirements into engineering oriented requirements that are typically included in a solicitation. Requirements also include non-functional requirements and other attributes such as evolvability, maintainability, and re-usability, which can drive the definition of the product requirements and architecture.

This includes definition of high-level interface requirements in the system of systems and interoperability domains.

**2. Customer requirements are refined and elaborated to develop product and product-component requirements.**

**2.1 Establish and maintain product and product-component requirements, which are based on the customer requirements.**

The level of involvement of the acquirer in allocating system-level requirements to lower level subsystems and components will vary depending on the acquisition environment.

**2.2 Allocate the requirements for each product component.**

As each level of requirements is defined there is an iterative process of allocation, high-level design, and requirements definition (for the next-lower level). Beyond the level of the architecture at which this responsibility has been assigned to the supplier, it is the acquirer role to oversee the adequacy of the supplier process and the resultant flow-down and definition of the lower level requirements

**2.3 Identify interface requirements.**
Requirements include not only the classical functional and performance requirements, but also interface requirements, whether they are contained in separate interface specifications or within the requirements specifications.

**3. The requirements are analyzed and validated, and a definition of required functionality is developed.**

**3.1 Establish and maintain operational concepts and associated scenarios.**
Concepts of Operations Documents or similar documents that define the intended usage concepts and environments are useful in developing requirements and designs that will ultimately satisfy the user operational needs.

**3.2 Establish and maintain a definition of required functionality.**
Formal definition and maintenance of the user top level operational requirements is effective in scoping and managing overall performance expectations throughout the development.

**3.3 Analyze requirements to ensure that they are necessary and sufficient.**

**3.4 Analyze requirements to balance stakeholder needs and constraints.**
Balance stakeholder needs against constraints such as development cost and schedule or operational and support considerations.

**3.5 Validate requirements to ensure the resulting product will perform as intended in the user's environment using multiple techniques as appropriate.**
For more extensive treatment of the goals and practices of Requirements Development, see the source documents referenced in the bibliography.

**Requirements Management (REQM)**
The purpose of Requirements Management is to manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project's plans and work products.

For acquisition, requirements management is applied to the requirements that are received from the requirements development process. During the acquisition, requirements management includes the direct management of acquirer-controlled

requirements and oversight of supplier requirements management. Requirements are managed and maintained with discipline so that changes are not executed without recognizing the impact to the project.

Requirements Management does not end with the selection of a supplier and an award. The acquisition project continues to manage high-level requirements, including changes, while the selected supplier manages the lower level requirements.

Requirements Management can best be described by the following goals and practices.

**1. Requirements are managed and inconsistencies with project plans and work products are identified.**

**1.1 Develop an understanding with the requirements providers on the meaning of the requirements.**

The acquirer should define authorized requirements providers and an approved path by which requirements are provided to the supplier. This definition prevents suppliers from receiving requirements changes from unauthorized sources that are outside the flow of the acquirer established requirements management process.

**1.2 Obtain commitment to the requirements from the project participants.**

Commitment to the requirements by the project participants includes having coordinated and approved documents that define requirements.

**1.3 Manage changes to the requirements as they evolve during the project.**

Each change to a controlled requirement should be assessed for impact to the project performance, cost, and schedule baselines and to project risk. The existing cost, schedule, and performance baselines should be changed, as required, to accommodate the requirements change

.

**1.4 Maintain bidirectional traceability among the requirements and the project plans and work products.**

Bidirectional traceability ensures that all higher level requirements are accounted for by the totality of the lower level requirements. It also ensures that lower level requirements are tied to a parent requirement to prevent orphan requirements at

the lower levels. Bidirectional traceability also supports requirements change impact analysis when either high or lower level requirements change.

**1.5 Identify inconsistencies between the project plans and work products and the requirements.**

For more extensive treatment of the goals and practices of Requirements Management, see the source documents referenced in the bibliography.

**Verification (VER)**

The purpose of Verification is to ensure that selected work products meet their specified requirements.

For acquisition, verification involves ensuring that the evolving work products of the acquisition project meet specified requirements for those products. The acquisition project should ensure that a proper verification environment exists and that it selects work products to evaluate based on documented criteria. Peer reviews are intended to be used for work products developed by the acquisition project.

The acquisition project is also responsible for ensuring that the supplier uses appropriate methods to verify its work products. In this context, the test community is a major stakeholder, including participation in up-front planning through final-product acceptance. The supplier and/or the test community may perform many of these practices, with the acquisition project facilitating the correction of deficiencies or enhancements by the supplier or follow-on maintenance organization. It is important that the acquirer define at the outset the degree to which verification is required both early in the definition of the project and later when the products are received.

Verifications of the evolving products by both the supplier and project team are routinely conducted throughout the entire contract performance period, and results are analyzed to determine acceptability of the products. Acquisition project verification activities should be designed to reduce interference with supplier and test community performed activities and to reduce duplication of the verification efforts.

Verification can best be described by the following goals and practices.

**1. Preparation for verification is conducted.**

**1.1 Select the work products to be verified and the verification methods that will be used for each.**
Work products can be developed by either the acquisition project or the supplier. Peer reviews are one of the methods used to verify work products produced by the acquisition project. Other methods should be selected when verifying work products from the supplier. Examples of these other methods include demonstration, inspection, and actual testing.

**1.2Establish and maintain the environment needed to support verification.**
The acquisition project should provide an adequate environment to carry out its verification activities.

**1.3 Establish and maintain verification procedures and criteria for the selected work products**.

**2. Peer reviews are performed on selected work products.**

A peer review is a method for conducting verification of work products that has had great success in detecting defects, especially in documents for requirements and design. The intent is for the acquisition project to use peer reviews on selected products (e.g., solicitation documents, system engineering plans, test plans) they produce internally to find and remove defects and to ensure compliance to acquisition standards. Many work products produced by the acquisition project set the stage for the program success and are critical to the supplier performance The supplier typically uses peer reviews internally on selected interim work products during development, but the acquirer should not rely solely on these results.

**2.1 Prepare for peer reviews of selected work products.**

**2.2 Conduct peer reviews on selected work products and identify issues resulting from the peer review.**

**2.3 Analyze data about preparation, conduct, and results of the peer reviews.**

**3 Selected work products are verified against their specified requirements.**

**3.1 Perform verification on the selected work products.**

**3.2 Analyze the results of all verification activities and identify corrective action.**

For more extensive treatment of the goals and practices of Verification, see the source documents referenced in the bibliography.

**Validation (VAL)**

The purpose of Validation is to demonstrate that a product or product component fulfills its intended use when placed in its intended environment.

Validation activities can be applied to all aspects of the product in any of its intended environments, such as operation, training, manufacturing, maintenance, and support services. The methods employed to accomplish validation can be applied to work products as well as to the product and product components. The work products (e.g., requirements, designs, prototypes) should be selected for validation based on which are the best predictors of how well the delivered end product and product components will satisfy user needs.

For acquisition, validation involves ensuring that the evolving acquisition work products (e.g., RFPs, SOWs, plans) meet the acquisition project needs. Validation activities are normally performed early and continuously throughout the acquisition life cycle. The acquirer als uses validation processes to ensure that the product or service received from the supplier will fulfill its intended use. In this context, the test community is a major stakeholder, participating in up-front planning through final-product acceptance. The supplier and/or the test community may perform many of the validation practices, with the acquisition project facilitating the correction of deficiencies or enhancements by the supplier or follow-on maintenance organization.

Validation involves the development of requirements for the validation approach, including acceptance criteria, which are incorporated into both the solicitation package and the contract. Validations of the evolving products by both the supplier and project are routinely conducted throughout the entire contract

performance period and results are analyzed to determine acceptability of the products. Project validation activities should be designed to reduce interference with supplier and test community-performed activities and to reduce duplication of the validation efforts. Validation processes support establishing and validating requirements. See the Requirements Development process area for more information.

Validation canbest be described by the following goals and practices.

**1. Preparation for validation is conducted.**

**1.1 Select products and product components to be validated and the validation methods that will be used for each.**

It is important that the acquirer define at the outset the degree to which validation is required both early in the project (e.g., requirements validation activities) and later when the end products are received.

**1.2 Establish and maintain the environment needed to support validation.**

Plans should identify adequate resources to execute validation activities.

**1.3 Establish and maintain procedures and criteria for validation.**

**2. The product or product components are validated to ensure that they are suitable for use in their intended operating environment.**

**2.1 Perform validation on the selected products and product components.**

**2.2 Analyze the results of the validation activities and identify issues.**

For more extensive treatment of the goals and practices of Validation, see the source documents referenced in the bibliography.

**2.3 Support Process Areas**

The support process areas include the processes and tools required to allow projects to effectively apply measurement and decision techniques to manage the project. In addition, they include activities to ensure the products or capabilities

acquired can be transitioned into operational use and maintained during the operational life of the product or capability.

**Decision Analysis and Resolution (DAR)**

The purpose of Decision Analysis and Resolution is to analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria.

For acquisition, a repeatable criteria-based decision-making process is especially important, both while making the critical decisions that define and guide the acquisition process itself and later when critical decisions are made with the selected supplier. The establishment of a formal process for decision-making provides the acquisition project with documentation of the decision rationale. Such documentation allows the criteria for critical decisions to be revisited when changes that impact project requirements or other critical project parameters change.

Decision Analysis and Resolution can best be described by the following goals and practices.

**1 Decisions are based on an evaluation of alternatives using established criteria.**

**1.1 Establish and maintain guidelines to determine which issues are subject to a formal evaluation process.**

Not every decision is significant enough to require a formal evaluation process. The choice between the trivial and the truly important may be unclear without explicit guidance. The significance of a particular decision is dependent on the project and circumstances and is determined by the established guidelines.

**1.2 Establish and maintain the criteria for evaluating alternatives and the relative ranking of these criteria.**

Regular use of decision-making criteria, even for less significant decisions, can be extremely helpful in creating a practice for disciplined decision making. Practiced evaluators have demonstrated that defined criteria and weighting can be a significant contributor to the speed and consensus level of a decision.

**1.3 Identify alternative solutions to address issues.**
A wider range of alternatives can surface by soliciting as many stakeholders as practical for input. Input from stakeholders with diverse skills and backgrounds can help teams identify and address assumptions, constraints, and biases. Brainstorming sessions, with support from the stakeholder, may stimulate innovative alternatives through rapid interaction and feedback.

**1.4 Select the evaluation methods.**

**1.5 Evaluate alternative solutions using the established criteria and methods.**

**1.6 Select solutions from the alternatives based on the evaluation criteria.**

Document the results of the evaluation for future reference.

For more extensive treatment of the goals and practices of Decision Analysis and Resolution, see the source documents referenced in the bibliography.

**Measurement and Analysis (MA)**
The purpose of Measurement and Analysis is to develop and sustain a measurement capability that is used to support management information needs.
For acquisition, the acquisition project has information needs for determining the status of its activities throughout the life cycle of the acquisition, the supplier activities per contractual requirements, and the status of the evolving products acquired. In acquisition projects where multiple products are acquired to deliver a capability to the end user, or where there are teaming relationships with other acquisition projects to acquire joint capabilities, additional information needs may be identified to ensure programmatic, technical, and operational interoperability product objectives are identified, measured, and achieved.

Measurement and Analysis can best be described by the following goals and practices.

1. **Measurement objectives and activities are aligned with identified information needs and objectives.**

Not all measurements are valuable. Those that address the needs and objectives of the acquisition project are the most valuable. It is best to identify those measures that are focused on the objectives, rather than measures that are easily obtained but have questionable value.

**1.1 Establish and maintain measurement objectives that are derived from identified information needs and objectives.**

Identify what information is needed to keep the acquisition on track to a successful conclusion. Establish what measurement objectives and measurement criteria are needed to provide this information.

**1.2 Specify measures to address the measurement objectives.**

**1.3 Specify how measurement data will be obtained and stored.**

**1.4 Specify how measurement data will be analyzed and reported.**

**2. Measurement results that address identified information needs and objectives are provided.**

**2.1 Obtain specified measurement data.**

**2.2 Analyze and interpret measurement data.**

**2.3 Manage and store measurement data, measurement specifications, and analysis results.**

**2.4 Report results of measurement and analysis activities to all relevant stakeholders.**

For more extensive treatment of the goals and practices of Measurement and Analysis, see the source documents referenced in the bibliography.

**Transition to Operations and Support (TOS)**

The purpose of Transition to Operations and Support is to provide for the transition of the product to the end user and the eventual support organization and to accommodate life-cycle evolution of the product.

For acquisition, Transition to Operations and Support involves the processes used to plan for and manage the transition of new or evolved products into operational use and their transition to the eventual maintenance or support organization. Identify any special conditions that may apply during the eventual decommissioning or disposal of the products. The acquisition project is responsible for ensuring the acquired products not only meet specified requirements (see the Verification process area) and can be used in the intended environment (see the Validation process area) but also that they can be transitioned into operational use to achieve the users desired mission capabilities and can be maintained and sustained over their intended life cycles.

The acquisition project is responsible for ensuring reasonable planning for transition into operations is conducted, clear transition criteria exist and are agreed to by relevant stakeholders, and planning is completed for product maintenance and support of products after they become operational. These plans include reasonable accommodation for known and potential evolution of the products and their eventual removal from operational use.

Transition to Operations and Support can best be described by the following.

**1 Preparation for transition to operations and support is conducted.**

**1.1 Establish and maintain a strategy for transition to operations and support.**

Planning for transition includes establishing the strategy for support (e.g., source of repair) through organic support infrastructures, contractor logistics support, or other sources. It can also include defining the levels of support to be established (e.g., organization, intermediate, depot). The strategy is important because it drives most of the other transition planning activities, as well as product design considerations.

1.2 **Establish and maintain plans for transitioning acquired products into operational use and support**.

Transition plans for products should be consistent with the overall transition strategy and agreed to by relevant stakeholders.

**1.3 Establish and maintain training requirements for operational and support personnel**.

**1.4 Establish and maintain initial and life-cycle resource requirements for performing operations and support.**
This includes identifying and providing for initial spares, operational and support training capabilities, facilities, etc. Eventual disposal of the product should also be considered. Disposal of any existing products to be replaced should also be considered.

**1.5 Identify and assign organizational responsibility for support.**
The roles and responsibilities of the acquirer, supporter, and user should be defined for the life-cycle support of the product. Explicitly identifying organizational responsibility for support (i.e., evel 1 maintenance) and for enhancements (i.e., evel 2 maintenance) ensures that relevant stakeholders are involved early in the acquisition project planning processes.

**1.6 Establish and maintain criteria for assigning responsibility for enhancements.**
Responsibility for capability enhancements during the support phase should be defined. Criteria used to support the assignment of responsibilities should include the magnitude and complexity of the envisioned change, required domain knowledge and experience, and required acquisition expertise

**1.7 Establish and maintain transition criteria for the acquired products.**

**2 Transition decisions and actions are executed in accordance with transition criteria.**

**2.1 Evaluate the readiness of the acquired products to undergo transition to operations and support.**
Readiness is evaluated throughout the acquisition life cycle based upon transition criteria. Definition of the transition criteria supports an objective evaluation of the products readiness for transition.

**2.2 Evaluate the readiness of the operational and support personnel to assume responsibility for the acquired products.**
Readiness is evaluated throughout the acquisition life cycle based upon transition criteria. Using the previously defined transition criteria, objectively evaluate the products readiness for transition.

**2.3 Analyze the results of all transition activities and identify appropriate action.**
As a result of analysis, transition activities and actions may be required of the acquisition project, the supplier, the user, or the support organization. The analysis may also identify areas for improvement in future transition activities.

For more extensive treatment of the goals and practices of Transition to Operations and Support, see the source documents referenced in the bibliography.

**4 Generic Practices**
Generic practices are practices that should be included in every process area, in addition to the specific practices that appear in each process area description. Generic practices improve the power of a process by ensuring that the specific practices are executed and that there is appropriate planning of the process to ensure that it is feasible and well supported and that stakeholders are properly involved.

In this section, practices are denoted by bold-faced text and followed by a brief explanation. The last two generic practices documented in this section ensure that the performance of each process and the lessons learned are saved and that this knowledge is used to establish new projects or to improve the performance of an existing project.

1. **Establish and maintain an organizational policy for planning and performing the process.**

The purpose of this generic practice is to define the organizational expectations for the process and make these expectations visible to those in the organization who are affected. In general, senior management is responsible for establishing and communicating guiding principles, direction, and expectations for the organization.

Not all direction from senior management will bear the label "policy." The existence of appropriate organizational direction is the expectation of this generic practice, regardless of what it is called or how it is imparted.

**2. Establish and maintain the plan for performing the process.**

The purpose of this generic practice is to determine what is needed to perform the process and achieve the established objectives, to prepare a plan for performing the process, to prepare a process description, and to get agreement on the plan from relevant stakeholders.

Planning of a process applies to all process areas including Project Planning. The process for planning the project requires planning (e.g., resource, duration) just like any other activity.

The objectives for the process may be derived from other plans (e.g., the project plans). Included are objectives for the specific situation, including quality, cost, and schedule objectives. For example, an objective might be to reduce the cost of performing a process for an implementation over its previous implementation.

Establishing a plan includes documenting the plan and providing a process description. Maintaining the plan includes changing it as necessary in response to either corrective actions or to changes in requirements and objectives for the process.

The plan for performing the process typically includes the following elements:

- process description
- standards for the work products and services of the process
- requirements for the work products and services of the process dependencies among the activities, work products, and services of the process specific objectives for the performance of the process (e.g.,quality, time scale, cycle time, and resource usage)
- resources (including funding, people, and tools) needed to perform the process
- assignment of responsibility and authority

- training needed for performing and supporting the process
- work products to be placed under configuration management and the level of configuration management for each item
- measurement requirements to provide insight into the performance of the process, its work products, and its services
- involvement of identified stakeholders
- activities for monitoring and controlling the process
- objective evaluation activities for the process and the work products
- management review activities for the process and the work products

**3. Provide adequate resources for performing the process, developing the work products, and providing the services of the process.**

This generic practice ensures that the resources necessary to perform the process as defined by the plan are available when they are needed. Resources include adequate funding, appropriate physical facilities, skilled people, and appropriate tools.

**4. Assign responsibility and authority for performing the process, developing the work products, and providing the services of the process.**

This generic practice ensures that there is accountability for performing the process and achieving the specified results throughout the life of the process. The people chosen should have the appropriate authority to perform the assigned responsibilities.

Responsibility can be assigned using detailed job descriptions or in living documents, such as the plan for performing the process. Dynamic assignment of responsibility is another legitimate way to perform this generic practice, as long as the assignment and acceptance of responsibility are ensured throughout the life of the process.

**5. Train the people performing or supporting the process as needed.**

This generic practice ensures that the people have the necessary skills and expertise to perform or support the process.

Training supports the successful performance of the process by establishing a common understanding of the process and by imparting the skills and knowledge needed to perform the process.

**6. Place designated work products of the process under appropriate levels of configuration management.**

This generic practice establishes and maintains the integrity of the designated work products of the process (or their descriptions) throughout their useful life.

The designated work products are specifically identified in the plan for performing the process, along with a specification of the level of configuration management.

**7. Identify and involve the relevant stakeholders as planned.**

This generic practice establishes and maintains the expected involvement of stakeholders during the execution of the process.

The objective of planning the stakeholder involvement is to ensure that interactions necessary to the process are accomplished, while not allowing excessive numbers of affected groups and individuals to impede process execution.

**8. Monitor and control the process against the plan for performing the process and take appropriate corrective action.**

The purpose of this generic practice is to perform the direct day-to-day monitoring and controlling of the process. Appropriate visibility into the process is maintained so that appropriate corrective action can be taken when necessary. Monitoring and controlling the process involves measuring appropriate attributes of the process or work products produced by the process.

**9. Objectively evaluate adherence of the process against its process description, standards, and procedures, and address noncompliance.**

This generic practice provides credible assurance that the process is implemented as planned and adheres to its process description, standards, and procedures.

**10. Review the activities, status, and results of the process with higher level management and resolve issues.**

The purpose of this generic practice is to provide higher level management with the appropriate visibility into the process.

Higher level management includes those levels of management in the organization above the immediate level of management responsible for the process. In particular, higher level management includes senior management. These reviews are for managers who provide the policy and overall guidance for the process, not for those who perform the direct day-to-day monitoring and controlling of the process.

The two following generic practices form the basis for propagating good practice to future acquisition projects. They facilitate process definition and identify process benefits that encourage adoption of best practices on new projects.

A defined process is tailored from the organization's set of standard processes according to the organization's tailoring guidelines and contributes work products, measures, and other process-improvement information to the organizational process assets.

These two generic practices activate a process improvement cycle. The organization maintains a process asset library and standard process that can be drawn upon by a project to create its processes. In turn, the project provides information about the performance of its process to the organization's process asset library, which is used to improve and extend the standard processes.

The organization's set of standard processes, which are the basis of the defined process, are established and improved over time. Standard processes describe the fundamental process elements that are expected in the defined processes. Standard processes also describe the relationships (e.g., the ordering and interfaces) between these process elements. The organization-level infrastructure

to support current and future use of the organization's set of standard processes is established and improved over time.

**11.Establish and maintain the description of a defined process.**

The purpose of this generic practice is to establish and maintain a description of the process that is tailored from the organization's set of standard processes to address the needs of a specific instantiation. The organization should have standard processes that cover the process area, as well as guidelines for tailoring these standard processes to meet the needs of a project or organizational function. With a defined process, variability in how the processes are performed across the organization is reduced and process assets, data, and learning can be effectively shared.

12. Collect work products, measures, measurement results, and improvement information derived from planning and performing the process to support the future use and improvement of the organization's processes and process assets.
The purpose of this generic practice is to collect information and artifacts derived from planning and performing the process. This generic practice is performed so that the information and artifacts can be included in the organizational process assets and made available to those who are (or who will be) planning and performing the same or similar processes. The information and artifacts are stored in the organization's measurement repository and the organization's process asset library.

Appendix A: Improving Acquisition Practices

**Project-Level Process Improvement**
Acquisition projects are concerned with ensuring the practices they perform effectively reduce risks associated with common management, engineering, and support issues that arise during the performance of the project. The specific practices, along with the generic practices for each process area, represent the set of project-level practices and can be used to identify gaps in implementation or process-related risks to the project. Careful use of selected measures can help gain insight into the effectiveness of project-level process implementation.

In addition, higher level acquisition organizations with multiple projects or with oversight responsibility can use these practices to identify areas that may require process improvement focus. A project that has well-defined processes has a greater ability to deal with risk and complexity.

**Organizational Process Improvement**

Process improvement at the organizational level is concerned with creating an effective environment and infrastructure to allow acquisition projects within the organization's span of control greater probability to succeed. When a project has clear guidance, starter templates, historical data, and a strong process culture at the organizational level, it is more likely to sustain effective practices and ultimately achieve its goals.

Acquisition organizations can improve by working with successful projects to capture success stories, measure the effectiveness of processes across their projects, and begin to build a standard set of acquisition practices, proven by their success in real projects, for use in subsequent projects. Senior leaders can establish an infrastructure and strong process culture that reward projects that build realistic plans and execute according to those plans.

Acquisition organizations can improve both the capability of their organization processes as well as the capability of selected project-level processes across their organization using the CMMI-AM in conjunction with selected process areas from the CMMI framework. Process areas from the CMMI framework to explore when improving organizational capability include Organizational Process Focus, Organizational Process Definition, and Organizational Training.

**Bibliography**

[Bernard 04] Bernard, Tom; Bate, Roger; Gallagher, Brian; & Wilson, Hal. CMMI Acquisition Module (CMMI-AM), Version 1.0 (CMU/SEI-2004-TR-001). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2004.

[Cooper 02] Cooper, Jack & Fisher, Matt. Software Acquisition Capability Maturity Model, Version 1.03 (CMU/SEI-2002-TR-010,

ADA399794). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2002.

[FAA 01] Federal Aviation Administration. The Federal Aviation Administration Integrated Capability Maturity Model® (FAA-iCMM®), Version 2.0. Washington, DC: Federal Aviation Administration, September 2001.

[SEI 02] CMMI Product Team. Capability Maturity Model Integration for Systems Engineering/Software Engineering/Integrated Product and Process Development/Supplier Sourcing, Version 1.1 Continuous Representation (CMU/SEI-2002-TR-011, ADA339818). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2002.

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Morgan Kaufmann Book Chapter Column

# Data Quality Assurance

The previous chapters define accurate data. They talk about the importance of data and in particular the importance of accurate data. They describe how complex the topic really is. You cannot get to accurate data easily. They show that data can go wrong in a lot of different places. They show that you can identify much but not all inaccurate data and that you can fix only a small part of what you find.

Showing improvements in the accuracy of data can be done in the short term with a respectable payoff. However, getting your databases to very low levels of inaccuracies and keeping them there is a long-term process.

Data accuracy problems can occur anywhere in the sea of data residing in corporate information systems. If not controlled, in all probability that data will become inaccurate enough to cause high costs to the corporation. Data accuracy problems can occur at many points in the life cycle and journeys of the data. To control accuracy, you must control it at many different points. Data can become inaccurate due to processes performed by many people in the corporation. Controlling accuracy is not a task for a small, isolated group but a wide-reaching activity for many people.

Data accuracy cannot be “fixed” one time and then left alone. It will revert back to poor quality quickly if not controlled continuously. Data quality assurance needs to be ongoing. It will intensify over time as the practitioners become more educated and experienced in performing the tasks necessary to get to and maintain high levels of data accuracy.

This chapter outlines the basic elements of a data quality assurance pro-gram. It focuses on data accuracy, a single dimension of data and information quality. This is not to mean that the other dimensions should not also be

addressed. However, data accuracy is the most important dimension, and controlling that must come first.

### 4.1 Goals of a Data Quality Assurance Program

A data quality assurance program is an explicit combination of organization, methodologies, and activities that exist for the purpose of reaching and maintaining high levels of data quality. The term assurance puts it in the same category as other functions corporations are used to funding and maintaining. Quality assurance, quality control, inspection, and audit are terms applied to other activities that exist for the purpose of maintaining some aspect of the corporation's activities or products at a high level of excellence. Data quality assurance should take place alongside these others, with the same expectations.
Just as we demand high quality in our manufactured products, in our financial reports, in our information systems infrastructure, and in other aspects of our business, we should demand it from our data.

The goal of a data quality assurance program is to reach high levels of data accuracy within the critical data stores of the corporation and then keep them there. It must encompass all existing, important databases and, more importantly, be a part of every project that creates new data stores or that migrates, replicates, or integrates existing data stores. It must address not only the accuracy of data when initially collected but accuracy decay, accurate access and transformation of that data, and accurate interpretation of the data for users. Its mission is threefold: improve, prevent, monitor.

Improvement assumes that the current state of data quality is not where you want it to be. Much of the work is to investigate current databases and information processes to find and fix existing problems. This effort alone can take several years for a corporation that has not been investing in data quality assurance.

Prevention means that the group should help development and user departments in building data checkers, better data capture processes, better screen designs, and better policies to prevent data quality problems from being introduced into information systems. The data quality assurance team should engage with projects that build new systems, merge systems, extract data from new applications, and

build integration transaction systems over older systems to ensure that good data is not turned into bad data and that the best practices available are used in designing human interfaces.

Monitoring means that changes brought about through data quality assur-ance activities need to be monitored to determine if they are effective. Moni-toring also includes periodic auditing of databases to ensure that new problems are not appearing.

### 4.2 Structure of a Data Quality Assurance Program

Creating a data quality assurance program and determining how resources are to be applied needs to be done with careful thought. The first decision is how to organize the group. The activities of the group need to be spelled out. Properly skilled staff members must be assigned. They then need to be equipped with adequate tools and training.

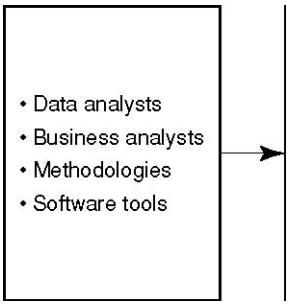
### Data Quality Assurance Department

There should be a data quality assurance department. This should be orga-nized so that the members are fully dedicated to the task of improving and maintaining higher levels of data quality. It should not have members who are part-time. Staff members assigned to this function need to become experts in the concepts and tools used to identify and correct quality problems. This will make them a unique discipline within the corporation. Figure 4.1 is a rela-tional chart of the components of a data quality assurance group.

The group needs to have members who are expert data analysts. Analyz-ing data is an important function of the group. Schooling in database architec-ture and analytical techniques is a must to get the maximum value from these activities. It should also have staff members who are experienced business analysts. So much of what we call quality deals with user requirements and business interpretation of data that this side of the data cannot be ignored.

The data quality assurance group needs to work with many other people in the corporation. It needs to interact with all of the data management pro-fessionals, such as database administrators, data architects, repository own-ers, application developers, and system designers. They also need to spend a great deal of time with key members of the user community, such as business

Data quality Advisory groupassurance




Projects
Issues
Remedies
Business analysts
Subject matter experts
User departments
Database administrators
Data analysts
Application developers

Components of a data quality assurance group.

analysts, managers of departments, and web designers. This means that they need to have excellent working relationships with their customers.

is a strong parallel between the emergence of data quality assurance to the improvements made in software development in the 1970s and 1980s. Software development teams back then consisted mostly of programmers. They wrote the code, tested the product, and wrote the user manuals. This was the common practice found in the best of software development groups.

In my first job at IBM I designed, developed the code, tested, wrote user documents, and provided customer support of a software product (Apparel Business Control System). It was a one-person project. Although the prod-uct had high quality and good customer acceptance, I believe it would have gone better and been a better product if I had access to professional writers and software quality assurance people.

In response to the continual prob-lems of poorly tested products and very poor user manuals, companies started dedicating some of the programmers to ensuring the quality of code (testing) and began to hire professional technical writers.

There was an immediate improvement in both the code and user manuals. As time went on, these two areas became established disciplines. Software development companies spe-cialized in building tools for these dis-ciplines; colleges offered classes and tracks for these disciplines.

The programmers that tested were no different from those that wrote the code in the beginning. They made huge improvements only because they were dedicated to testing, worked with the programmers throughout the entire project, and brought another view to the use of the code. In time, they became even better as they developed very effective methodologies and tools for testing. Testing became a unique technology in its own right.

The cost of these programs is clearly zero. Every serious development group today separates code quality assurance from code development. Projects finish earlier, with higher- quality results. The projects spend less money (much less money) and use up less time (much less time) than they would if programmers were still doing the testing.

Data quality is emerging as a major topic 20 years later. The same evolution is happening. Making data quality the responsibility of the data management staff who design, build, and maintain our systems means that they do not become experts in the meth-odologies and tools available, do not have the independence to prioritize their work, and do not focus on the sin-gle task of ensuring high-quality data. Data quality assurance must be the full-time task of dedicated profession-als to be effective.

### 4.2 Structure of a Data Quality Assurance Program

One way to achieve a high level of cooperation is to have an advisory group that meets periodically to help establish priorities, schedules, and inter-actions with the various groups. This group should have membership from all of the relevant organizations. It should build and maintain an inventory of quality assurance projects that are worth doing, keep this list prioritized, and assign work from it. The advisory group can be very helpful in assessing the impact of quality problems as well as the impact of corrective measures that are subsequently implemented.

### Data Quality Assurance Methods

Figure 4.2 shows three components a data quality assurance program can build

around. The first component is the quality dimensions that need to be addressed. The second is the methodology for executing activities, and the last is the three ways the group can get involved in activities.

The figure highlights the top line of each component to show where a concentration on data accuracy lies. Data accuracy is clearly the most important dimension of quality. The best way to address accuracy is through an inside-out methodology, discussed later in the book. This methodology depends heavily on analysis of data through a process called data profiling. The last part of this book is devoted to explaining data profiling. Improving accuracy can be done through any of the activities shown. However, the one that will return the most benefit is generally the one shown: project services.

Any data quality assurance function needs to address all of the dimensions of quality. The first two, data accuracy and completeness, focus on data stored in corporate databases. The other dimensions focus on the user community and how they interpret and use data.

The methods for addressing data quality vary as shown in Figure 4.3. Both of these methodologies have a goal of identifying data quality issues. An

| Data quality dimension component | Methodology component | Activities component |
|---|---|---|

**Accuracy**

- Inside-out
- Project services
- Completeness
- Outside-in
- Stand-alone
- Relevance
- Teach and preach
- Understood
- Trusted

Components of a data quality assurance program.


| Outside-in | | |
|---|---|---|
| External evidence | Issues | Data and data entry processes |
| Inside-out | | |
| | ➤ | External impacts and data entry processes |

Methodology comparisons.

issue is a problem that has surfaced, that is clearly defined, and that either is costing the corporation something valuable (such as money, time, or custom-ers) or has the potential of costing the corporation something valuable. Issues are actionable items: they result in activities that change the data quality of one or more databases. Once identified, issues are managed through an issues management process to determine value, remedies, resolution, and monitor-ing of results. The process of issue management is discussed more fully in the next chapter.

**INSIDE-OUT METHOD**

The inside-out method starts with analyzing the data. A rigorous examination using data profiling technology is performed over an existing database. Data inaccuracies are produced from the process that are then analyzed together to generate a set of data issues for subsequent resolution.

The analysis should be done by a highly qualified data analyst who under-stands the structure of the data. The methodology starts with a complete and correct set of rules that define data accuracy for the data. This is metadata. It consists of descriptions of the data elements, values permitted in them, how they relate to one another in data structures, and specific data rules that describe value correlation conditions that should always be true within the data. All of these categories are discussed at length in later chapters.

Of course, such a rigorous rule set for any operational database does not exist. The metadata that is available is generally incomplete and most likely inaccurate. The data profiling process described in later chapters is a process that completes

and corrects the metadata, along with using it to find evidence of inaccurate data. This intertwined process has a very valuable by-product: accurate and complete metadata.

The process of determining the correct metadata inevitably involves conferring with business analysts and end users. The data analyst will detect a behavior in the data and require consultation to determine why it is so. This often leads to modifications to the metadata. These consultations are

**4.2 Structure of a Data Quality Assurance Program**

always productive because the question is always backed up by information from the data.

The data analyst should identify who in the user community will be the most valuable in consulting on issue identification and form a small, dynamic working group with them. In the end, they should always agree on what the final metadata is, and agree on the inaccurate data facts derived from the comparison with the actual data.

The inaccurate data evidence produced is a collection of facts. It may be explicit cases of wrong or missing values, or it may identify rules that fail without being able to say what values are wrong. For example, one fact may be that 30% of purchase order records do not have a supplier ID. Another may be that the employee birth date field has values that are invalid: too long ago or too recent. Another might be that the percent of the color BLUE in a data-base is too large. In this case, the analyst does not know which instances are correct and which are wrong; only that some of them must be wrong.

The facts are aggregated into issues. Some facts are issues by themselves. For example, the supplier ID problem may be the basis for a single issue. Oth-ers are aggregated into a larger issue. An example is that customer demo-graphic fields in a marketing database contain numerous errors in all fields, possibly indicating a general problem with form design.

**OUTSIDE-IN METHOD**

This method looks for issues in the business, not the data. It identifies facts that suggest that data quality problems are having an impact on the business. It looks for rework, returned merchandise, customer complaints, lost customers, delays in

getting information products completed, high amounts of work required to get information products produced, and so on. Interviews are done with users to determine their level of trust in the accuracy of data com-ing from the information systems and their level of satisfaction with getting everything they need. It may also include looking for decisions made by the corporation that turned out to be wrong decisions.

These facts are then examined to determine the degree of culpability attributable to defects in the data. The data is then examined to determine if it has inaccuracies that contribute to problems, and to determine the scope of the contribution. This examination is generally pointed at the specific problem. It is generally not a thorough data profiling exercise, although it could be expanded to that if the evidence indicates a widespread quality problem with the data.

This approach is generally the work of the data quality assurance team member with skills as a business analyst. It involves heavy participation on the part of outside people. It also requires conference sessions with user commu-nity experts. The result is a collection of data issues that are then tracked on the same path as those from the inside-out methodology.

## COMPARISON OF METHODS

Neither approach is superior to the other: they both bring value to the pro-cess. However, they do not get to the same end point. Data quality assurance groups should use both methodologies as applicable.

Inside-out is generally easier to accomplish and uses less people time. A single analyst can analyze a great deal of data in a short time. The data quality assurance group can accomplish a great deal with this approach with the staff within their own department. The outside-in approach requires spending a lot of time interviewing people in other departments.

The inside-out approach is nondisruptive. You just get a copy of the data you want to analyze and do it offline. The outside-in approach requires sched-uling time for others, thus interrupting their regular activities.

The inside-out approach will catch many problems the outside-in approach does not catch. For an outside-in approach to catch a problem, it must manifest itself in some external behavior, and that behavior must be rec-ognizable as being not good.

An example of a hidden problem is a case in which missing supplier ID numbers on purchase orders causes a company not to get maximum discounts they were entitled to from suppliers. The purchase order volumes were sum-marized by supplier ID and, because the field was missing on 30% of the records, the amounts were low. The company was losing millions of dollars every year because of this and was completely unaware that it was happening. The inside-out approach catches this; the outside-in approach does not.

Another type of problem are those inaccuracies that have the potential for a problem but for which the problem has not yet occurred. An example of this is where an HR database failed to capture government classification group information on employees accurately. Many minority employees were not classified as minorities, nor were handicapped employees all being identified as handicapped. No problem may have surfaced yet. However, the potential for being denied contracts in the future because of these inaccuracies is wait-ing to happen. Inside-out analysis will catch this; outside-in will not.

The opposite is also true. The inside-out approach will not catch prob-lems where the data is inaccurate but valid. The data can pass all metadata tests and still be wrong. This can happen either because the rule set is incom-plete or because the data hides underneath all of the rules. An example is get-ting the part number wrong on orders. The wrong merchandise is shipped. An analysis of the data will not reveal inaccurate data because all of the part num-

### 4.2 Structure of a Data Quality Assurance Program

bers are valid numbers. The outside-in approach catches these problems bet-ter. (The inside-out approach may catch this if the analysis finds the percentage of orders returned to be higher than an acceptable threshold. This is possible if a data rule or value test has been formulated. These topics are covered in Chapters 11 and 12).

There is another class of problems not detectable by either approach. The data is valid but wrong and also produces insufficient external evidence to raise a flag. Although these generally are of little concern to a corporation, they have the potential to be costly in the future if not detected. A data quality assurance program built exclusively using only one approach is generally going to miss some important issues.

**Data Quality Assurance Activities**

The data quality assurance team must decide how it will engage the corpora-tion to bring about improvements and return value for their efforts. The group should set an explicit set of guidelines for what activities they engage in and the criteria for deciding one over another. This is best done with the advi-sory group.

There are three primary roles the group can adopt. This is shown as the last column in Figure 4.2. One of them, project services, involves working directly with other departments on projects. Another, stand-alone assess-ments, involves performing assessments entirely within the data quality assur-ance group. Both of these involve performing extensive analysis of data and creating and resolving issues. The other activity, teach and preach, involves educating and encouraging employees in other groups to perform data audit-ing functions and to employ best practices in designing and implementing new systems.

**PROJECT SERVICES**

The vast majority of projects being pursued by the IT organization involve repurposing an existing database. It is rare these days to see a truly new appli-cation being developed that does not draw from data that has already been collected in an existing application. Examples of projects that involve working with existing data stores are data migration to new applications (generally packaged applications)

consolidation of databases as a result of mergers and acquisitions
consolidation of databases to eliminate departmental versions of applications

replication of data into data warehouses, data marts, or operational data stores
building a CRM system
application integration that connects two or more applications
application integration that connects an older database to the Internet

There is a real danger in all of these applications of introducing errors through mistakes made due to a misunderstanding of the data. There is also a real danger in the data from the original systems not being of sufficient quality to meet the demands of the new use of the data. Both of these are classical con-cerns that if

not addressed will certainly cause great difficulty in completing the projects, as well as unhappiness with the outcome.

The data quality assurance team can provide an invaluable service to these projects by profiling the data. By doing this they provide two valuable out-puts: an accurate and complete metadata description of the data and an inven-tory of data quality problems uncovered in the process.

The metadata repository produced should be used to match target system requirements against the content and structure of the source systems. It is also the perfect input to developing processes for extraction, transformation, cleansing, and loading processes.

The data quality assurance team can use the inaccuracy facts to determine either whether the data is strong enough to satisfy the intended use or whether there is a need to establish new projects from the issues to drive improvements in the source systems. Of course, this applies to cases in which the source data-bases continue to live past the project, as is the case for replication and inte-gration projects.

The data quality assurance team can also provide advice and oversight in the design of target database structures, as well as processes for collecting or updating data. They also have a good opportunity to get data checking and monitoring functions embedded in the new systems to help prevent future quality problems.

Why should the data quality assurance team perform these tasks, as opposed to the project teams? The answer is that the data quality assurance team are experts in data quality technologies. They are experienced in data pro-filing, investigation of issues, and fabrication of data quality problem remedies.

One of the most valuable outputs of data profiling at the beginning of a project is to learn that the project cannot achieve its goals because of the con-dition of the source data. When this happens, the project team can then make decisions about changing target design, changing target expectations, making improvements to data sources, or scrapping the project outright. This is the

### 4.2 Structure of a Data Quality Assurance Program

perfect place to make these decisions: before most of the project money has been spent and before most of the development work has been done.

Projects that do not perform a thorough review of the source data gener-ally do not discover the match between the data and the project requirements until after much time and money has been spent. It is generally very expensive to repair the damage that has already been done and impossible to recoup the money spent and the valuable time lost.

## STAND-ALONE ASSESSMENTS

A stand-alone assessment is a project organized for the purpose of determin-ing the health of an existing database. The database is chosen because of suspi-cions or evidence about problems coming from the use of the data, or simply because it is an important data source for the corporation.

The data quality assurance team will generally execute the entire project. Using the inside-out method, they will profile the data, collect quality facts, produce issues, and then follow the issues through to remedies.

The advantage of assessment projects is that they do not require as much interaction with other project teams and can be scheduled without concern for other plans in IT. Of course, it makes no sense to schedule an assessment of a database that is about to get a facelift as a result of another project.

An assessment can be quite disruptive to other departments, even if no change activity is under way for the data source. Time from them will be needed to develop perfect understanding of the metadata and to interpret facts that come out of profiling. If remedies are needed, negotiations with IT and users will be needed to get them designed and implemented. It may also be quite disturbing to people to find out that they have been using flawed data for a long time without knowing it. The data quality assurance team needs to involve the other departments in the planning phase and keep them involved throughout the process.

It is important not to appear as an outside hit team trying to do damage to the reputation of the operational organizations. Involving them makes them part of the solution.

## TEACH AND PREACH

This function involves training information system staff members on the technology available for data quality assessment, the techniques and best practices available for building and maintaining systems, and how to develop quality requirements and use them to qualify data.

Few information systems professionals come out of college with training explicitly targeted to data quality. The principles are not difficult to understand, nor are the disciplines difficult to use in daily practice. Educating them will improve all of the work they do.

The data quality assurance group should function as the experts in data quality. They should not keep this knowledge exclusively to themselves. The more they educate others in the corporation, the more likely the information systems will reach and stay at a high level of quality.

Preaching means that the data quality assurance department should encourage and insist that quality checkpoints be put into all projects. They should encourage upper management to be cognizant of the need for data quality activities. They should collect and advertise the value to the corpora-tion realized from these activities.

The data quality assurance group should not depend exclusively on teaching and preaching. If that is all they do, the company will never develop the focused expertise needed to analyze the mountains of data and drive improvements.

### 4.3 Closing Remarks

If you want high data quality you must have highly accurate data. To get that you need to be proactive. You need a dedicated, focused group.

You need to focus on data accuracy. This means you need an organization that is dedicated to improving data accuracy. You also need trained staff mem-bers who consider the skills required to achieve and maintain data accuracy as career-building skills.

You need to use technology heavily. Achieving high levels of data accu-racy requires looking at data and acting on what you see. You need to do a lot of data profiling. You need to have experienced staff members who can sniff out data issues.

You need to treat information about your data as of equal or greater importance than the data itself. You must install and maintain a legitimate metadata repository and use it effectively.

You need to educate other corporate employees in the importance of data and in what they can do to improve the accuracy. This includes the following elements.

Business users of data need to be sensitized to quality issues.
Business analysts must become experts on data quality concepts and play an active role in data quality projects.
Developers need to be taught best practices for database and application design to ensure improved data accuracy.

**Closing Remarks**

Data administrators need to be taught the importance of accuracy and how they can help improve it.
All employees who generate data need to be educated on the importance of data accuracy and be given regular feedback on the quality of data they generate.
The executive team needs to understand the value of improved data accuracy and the impact it has on improved information quality.

You need to make quality assurance a part of all data projects. Data quality assurance activities need to be planned along with all of the other activities of the information systems department. Assisting a new project in achieving its data quality goals is of equal or higher value than conducting assessment projects in isolation. The more integrated data quality assurance is with the entire information system function, the more value is realized. And finally, everyone needs to work well together to accomplish the quality goals of the corporation.