



# Smart Buying with the Federal Aviation Administration's Integrated Capability Maturity Model

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*The Federal Aviation Administration (FAA) has developed an integrated Capability Maturity Model<sup>SM</sup> for the acquisition of software-intensive systems. This model, known as the FAA-iCMM<sup>®</sup> [1], integrates the Systems Engineering Capability Maturity Model (SE-CMM, Version 1.1), the Software Acquisition CMM (SA-CMM, Version 1.01), and the CMM for Software (SW-CMM, Version 1.1). The FAA is achieving more effective and efficient processes and process improvement by using the integrated model rather than the three source CMMs separately. This article describes the FAA's process improvement environment, why the FAA-iCMM was constructed, the model's architecture, domain, capability levels, maturity levels, and the FAA-iCMM Appraisal Method.*

The FAA developed the FAA-iCMM to guide improvement of the engineering, management, and acquisition processes it uses to acquire software-intensive systems. Three CMMs were being used separately in different FAA directorates that work on different aspects of acquisition: the SW-CMM [2], the SE-CMM [3], and the SA-CMM [4]. These CMMs have different architectures, goals, terminology, and appraisal methods, and none alone covers all FAA system acquisition activities. Although some improvements were being made using one model, the goal of FAA-wide, full lifecycle process improvement remained elusive. In addition, the FAA had moved to using integrated product teams as the implementation arm for its new Acquisition Management System [5], and these teams needed processes that interrelated their disciplines.

The FAA-iCMM initiative began in fall 1996 with an analysis and preliminary merger of these three CMMs at the process area level. One sample process area was also elaborated at the base practice level [6, 7]. These efforts demonstrated that it was possible to integrate CMMs of different architectures and that the resultant model contained a significant reduction in the number of process areas and practices while still covering the individual CMM disciplines.

*Capability Maturity Model is a service mark of Carnegie Mellon University. CMM is registered in the U.S. Patent and Trademark Office.*

In March 1997, the FAA formed a team of FAA and external CMM and domain experts and began work on the integrated model. The project purpose was to derive a reference model that would

- Describe key elements of an effective system acquisition process.
- Describe an evolutionary improvement path.
- Have an associated appraisal method.
- Faithfully and robustly capture all features of its three source CMMs (SA-CMM, SE-CMM, and SW-CMM).

Meanwhile, the Software Engineering Institute (SEI) began to develop a Common CMM Framework (CCF) [8] to provide guidance to multiple CMM users and to assist CMM developers and integrators. The FAA-iCMM project followed those draft guidelines as they continued to evolve in parallel with FAA efforts.

A complete draft of the FAA-iCMM was completed by June 1997 and submitted to the SEI for review. FAA management adopted an FAA-iCMM-related performance goal that same month. In late September, a joint SEI-FAA review and working session was held to ensure consensus that the FAA's work captured its source CMMs and followed CMM principles, construction guidelines, and requirements as identified in the latest draft CCF documents. Version 1.0 of the FAA-iCMM was released in November 1997 with endorsement by the SEI

as a new product type—an integrated Capability Maturity Model (iCMM).

## General CMM Integration Decisions

### What to Integrate (Scope)

The FAA chose to integrate the three CMMs that were already in FAA use and which together covered the engineering, acquisition, and management processes used by the FAA to acquire software-intensive systems. The Integrated Product Development CMM was briefly considered, but the draft model did not seem stable enough to be included at that time. The various drafts of SW-CMM, Version 2.0 were also coming out, but the FAA decided to use validated versions of the source CMMs to the extent possible for the initial version of the model.

### How to Represent the Model (CMM Architecture)

The FAA chose to use a hybrid architecture that includes both the continuous and staged features of its source CMMs (see Table 1). Through this “continuous with staging” architecture, the FAA-iCMM provides guidance to improve process capability and organizational maturity. As in a continuous representation, the FAA-iCMM describes the domain aspect, e.g., process areas and base practices, separately from the capability aspect (capability levels and generic practices). This feature of the continuous representation provides guidance

FAA-iCMM (Ver. 1.0) (Continuous with Staging)	SA-CMM (Ver. 1.01) and SW-CMM (Ver. 1.1) (Staged)	SE-CMM (Ver. 1.1) (Continuous)
Domain Aspect: Implementation (What You Do)		
Process Areas (PAs)	Key Process Areas	Process Areas
Purpose	Purpose	Purpose
Process Area Goals	Goals	
Base Practices (BPs)	Key Practices of the “Activities Performed” Common Feature	Base Practices
Process Capability: Institutionalization (How Well You Perform a Process Area)		
Capability Levels		Capability Levels
Capability Level Goals		
Generic Practices (GPs)	Key Practices of the “Commitment to Perform” “Ability to Perform” “Measurement and Analysis” “Verifying Implementation” Common Features	Generic Practices
Staging: Organizational Maturity (What to Focus on Next)		
Maturity Levels	Maturity Levels	

Appraisal note: *The FAA-iCMM Appraisal Method uses process area goals and capability level goals as the major rating components during an appraisal. Maturity levels are optionally derived from capability level ratings, according to the FAA-iCMM definition of maturity level.*

Table 1. *FAA-iCMM architecture summary: architectural constructs across the source models.*

to improve any of its process areas to any capability level desired (from 1 to 5).

In addition, goals were added to process areas and capability levels. The FAA-iCMM also provides staging that groups the process areas and generic practices into maturity levels. This feature provides guidance regarding improving organizational maturity and regarding “what to focus on next” if needed. It also allows a summary rating of an organization’s process maturity (from 1 to 5) if needed. For more information on architecture conversion issues, refer to [9, 10].

**Traceability**

To satisfy its robustness, fidelity, and traceability requirements, the FAA-iCMM contains extensive tracing tables. These tables are at the process area level and the practice level and are included as part of each process area and base practice description. Additionally, complete mapping tables are provided in an appendix that helps readers locate where any practice in any of the source models is mapped in the FAA-iCMM (see [1]).

**Overview of the Model**

The FAA-iCMM is structured to answer three process improvement questions: What activities should be performed (the domain aspect), how can performance be improved (the capability aspect), and what processes should be focused on next (maturity levels)? The FAA-iCMM Appraisal Method (FAM) supports application of the model. Each aspect is briefly described below.

**The Domain Aspect**

The domain is the acquisition of software-intensive systems. There are 23 process areas derived from integrating the 52 process areas or key process areas of the three source CMMs. These process areas are grouped into four categories:

- Lifecycle or engineering.
- Management or project.
- Supporting.
- Organizational process areas.

Table 2 shows the 23 process areas of the FAA-iCMM and the major sources used to derive each process area.

Each process area description includes a purpose, goals, and from two to 10 fully elaborated base practices. Some excerpts from the Requirements Process Area (PA 02) are provided in Table 3.

**The Capability Aspect**

There are five capability levels in the FAA-iCMM, and generic practices at each level provide guidance to improve any process. Generic practices are additive as process capability increases through the five levels. The capability levels, their goals, and their generic practices are summarized in Table 4.

**Maturity Levels**

Maturity levels in the FAA-iCMM are groupings of process areas and generic practices. They “stage” the process areas to provide guidance to improve organizational maturity. Maturity levels are conceptually the same as capability levels, i.e., the same five levels are employed, but they provide guidance on what processes together contribute to each step of organizational maturity. Maturity levels are described in Table 5.

**Appraisal Method**

FAA developed the FAM, which includes several variations. The full internal appraisal is similar to the CMM-Based Appraisal for Internal Process Improvement [11] method, except it has been adapted to a continuous model with both process area goals and capability level goals. Other appraisal types include facilitated discussion, training-based, document-intensive, questionnaire-based, interview-intensive, and external appraisal (for use by external agencies that may want to appraise the FAA’s process capability).

These appraisal types draw on and adapt from several appraisal methods such as the SE-CMM Appraisal Method [12], Software Capability Evaluation [13], and Interim Profile [14]. Again, FAA’s concept is to integrate and draw together

Table 2. The integrated process areas of the FAA-iCMM.

FAA-iCMM Version 1.0 Process Area	Systems Engineering SE-CMM Version 1.1 Process Area	Software Acquisition SA-CMM Version 1.01 Key Process Area	Software Engineering Software-CMM Version 1.1 Key Process Area
Lifecycle or Engineering Processes			
PA01 Needs	Understand Customer Needs and Expectations		
PA02 Requirements	Derive and Allocate Requirements	Requirements Development and Management	Requirements Management (*Software Product Engineering)
PA03 Architecture	Evolve System Architecture		(*Software Product Engineering)
PA04 Alternatives	Analyze Candidate Solutions		
PA05 Outsourcing	Coordinate with Suppliers	Solicitation	Software Subcontract Management
PA06 Software Development and Maintenance			Software Product Engineering
PA07 Integration	Integrate System		
PA08 System Test and Evaluation	Verify and Validate System	Evaluation	
PA09 Transition		Transition to Support	
PA10 Product Evolution	Manage Product Line Evolution		
Management or Project Processes			
PA11 Project Management	Plan Technical Effort Monitor and Control Technical Effort	Software Acquisition Planning Project Management Project Performance Management	Software Project Planning Software Project Tracking and Oversight Integrated Software Management
PA12 Contract Management	(*Coordinate with Suppliers)	Contract Tracking and Oversight Contract Performance Management	Software Subcontract Management
PA13 Risk Management	Manage Risk	Acquisition Risk Management	(*Integrated Software Management)
PA14 Coordination	Integrate Disciplines		Intergroup Coordination
Supporting Processes (Not Lifecycle Phase Dependent)			
PA15 Quality Assurance and Management	Ensure Quality		Software Quality Assurance
PA16 Configuration Management	Manage Configuration		Software Configuration Management
PA17 Peer Review	Level 3 Common Features		Peer Reviews
PA18 Measurement	Level 4 Common Features	Quantitative Process Management Quantitative Acquisition Management	Quantitative Process Management Software Quality Management
PA19 Prevention	Level 5 Common Features		Defect Prevention
Organizational Processes			
PA20 Organizational Process Definition	Define Organization's Systems Engineering Process	Process Definition and Maintenance	Organizational Process Focus Organizational Process Definition
PA21 Organizational Process Improvement	Improve Organization's Systems Engineering Process	Continuous Process Improvement	Process Change Management
PA22 Training	Provide Ongoing Skills and Knowledge	Training Program	Training Program
PA23 Innovation	Manage Systems Engineering Support Environment	Acquisition Innovation Management	Technology Change Management

\*Some of the practices in this process area contributed to the practices integrated into the FAA-iCMM process area.

**Purpose:** The Requirements process area develops requirements to meet the customer's operational need, to analyze the system and other requirements, to derive a more detailed and precise set of requirements, and to manage those requirements throughout the acquisition lifecycle.

#### Goals

1. Requirements are derived from customer needs and other appropriate sources (BP 02.01, BP 02.02, BP 02.03, BP 02.04).
2. Requirements are allocated to support the synthesis of solutions (BP 02.05).
3. Requirements are unambiguous, traceable, and verifiable (BP 02.06, BP 02.09).
4. Requirements are controlled to establish a baseline for engineering and management use (BP 02.07, BP 02.09).
5. Plans, products, and activities are kept consistent with requirements (BP 02.08, BP 02.09).

#### Base Practice List

- BP 02.01 Develop detailed operational concept:** Develop a detailed operational concept of the interaction of the system, the user, and the environment that satisfies the operational need.
- BP 02.02 Identify key requirements:** Identify key requirements that have a strong influence on cost, schedule, functionality, risk, or performance.
- BP 02.03 Derive and partition requirements:** Derive and partition requirements that may be logically inferred and implied as essential to system effectiveness from the system and other, e.g., environmental, requirements.
- BP 02.04 Identify interface requirements:** Identify the requirements associated with external interfaces to the system and interfaces between functional partitions or objects.
- BP 02.05 Allocate requirements:** Allocate requirements to functional partitions, objects, people, or support elements to support synthesis of solutions.
- BP 02.06 Analyze requirements:** Analyze requirements to ensure that they can be implemented, verified, and validated by methods available to the development effort.
- BP 02.07 Capture and baseline requirements:** Capture, baseline, and place under change control the system and other requirements, derived requirements, derivation rationale, allocations, traceability, and requirements status.
- BP 02.08 Analyze and incorporate requirements changes:** Analyze all requirements change requests for impact on the product being acquired, and upon approval, incorporate the approved changes into the product, work plans, and activities.
- BP 02.09 Maintain consistency and traceability:** Maintain consistency and traceability among requirements and between requirements and plans, work products, and activities.

Table 3. Purpose, goals, and base practice list of the Requirements process area of the FAA-iCMM.

various appraisal methods, just as it integrated its source CMMs. All FAM variations are tailorable and cover needs for initial, interim, or full appraisal.

### Real-World Use of the Model

The FAA's CMM integration goals are to increase the efficiency and effectiveness of FAA processes and process improvement efforts. Increased efficiency is being realized by reducing the number of process areas from 52 in the separate models to 23 in the integrated model, by replacing separate training and appraisals against three CMMs with efforts against one model, and by replacing largely redundant efforts to improve similar

processes with a single effort to improve an integrated process. Increased effectiveness is being realized through development of processes that cover all FAA acquisition lifecycle phases and that integrate the management, engineering, and acquisition activities of an integrated product team.

FAA management adopted the FAA-iCMM by setting an aggressive improvement goal for FAA's major software-intensive programs to achieve maturity Level 2 by December 1999 and Level 3 by December 2001. In the first year of FAA-iCMM usage, over 1,250 managers and practitioners were trained, and about 20 programs (including the tar-

geted "major" programs, plus programs voluntarily signing up) are using the model to guide their process improvement. FAA-iCMM process improvement workshops and appraisals are finding that the model raises and promotes resolution of process integration issues across the disciplines and across the acquisition lifecycle. Working to improve the Requirements and the Transition process areas for example (both staged at maturity Level 2) has required extensive cross-directorate, cross-discipline, and cross-lifecycle participation.

A major appraisal has recently been conducted to determine interim status, to facilitate process improvement plan adjustment, and to promote even broader discussions and learning about process improvement. Meanwhile, the FAA process improvement goal is being strengthened to include new programs as they are initiated.

Other government organizations, including Warner Robins Air Logistics Center and the Internal Revenue Service, have received FAA-iCMM training and are looking toward adopting an integrated approach to process improvement. Several companies, including Lockheed Martin, have also expressed interest.

Other models may be included in future versions of the FAA-iCMM, (such as models generated from the government-industry-SEI Capability Maturity Model Integration [15] project) and other disciplines (including Human Factors and Information Security) are now being studied for inclusion. The model is available in the public domain for organizations seeking to improve their acquisition processes.

### Summary and Conclusions

CMMs provide valuable guidance to organizations committed to process improvement. When an organization needs to use multiple CMMs to cover its business needs, however, CMM-based process improvement can become costly and confusing because of the differences in CMM architecture, terminology, appraisal methods, etc. The FAA endeavored to solve this problem by integrating three CMMs into the FAA-iCMM,

Level 1 – <b>Initial: Performed Informally</b>	<p><b>Description:</b> Base practices of the process area are generally performed.</p> <p><b>Generic Practice:</b></p> <p>1.1 Perform the process.</p>
Level 2 – <b>Repeatable: Planned and Tracked</b>	<p><b>Description:</b> Basic management processes are established. The necessary process discipline is in place to repeat earlier successes with similar work processes. Performance of the base practices in the process area is planned and tracked.</p> <p><b>Goal:</b> The activities for the process are institutionalized to support a repeatable process.</p> <p><b>Generic Practices:</b></p> <p>2.1 Establish policy.                      2.8 Manage configurations.  2.2 Allocate adequate resources.      2.9 Assess process compliance.  2.3 Assign responsibility.                2.10 Verify work products.  2.4 Ensure training.                        2.11 Measure process.  2.5 Document the process.                2.12 Review status.  2.6 Plan the process.                        2.13 Take corrective action.  2.7 Use a repeatable process.            2.14 Coordinate within the project.</p>
Level 3 – <b>Defined: Well Defined</b>	<p><b>Description:</b> Base practices are performed according to a well-defined process using approved, tailored versions of standard documented processes.</p> <p><b>Goal:</b> The activities of the process are institutionalized to support a defined process.</p> <p><b>Generic Practices:</b></p> <p>3.1 Standardize the process.            3.3 Perform reviews with peers.  3.2 Use defined process.                 3.4 Coordinate with affected groups.</p>
Level 4 – <b>Managed: Quantitatively Controlled</b>	<p><b>Description:</b> Processes and products are quantitatively measured, understood, and controlled; detailed measures of performance are collected and analyzed.</p> <p><b>Goal:</b> The activities of the processes are institutionalized to support quantitative management of defined processes.</p> <p><b>Generic Practices:</b></p> <p>4.1 Establish quality objectives for product and process.  4.2 Select processes for measurement.  4.3 Select measures for the process.  4.4 Determine quantitative process capability.  4.5 Use quantitative process capability.</p>
Level 5 – <b>Optimizing: Continuously Improving</b>	<p><b>Description:</b> Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies. A focus on widespread, continuous improvement permeates the organization. The organization establishes quantitative performance goals for process effectiveness and efficiency based on its business goals.</p> <p><b>Goal:</b> Continually improving processes are deployed throughout the organization.</p> <p><b>Generic Practices:</b></p> <p>5.1 Perform continual process improvement on the organizational standard and tailored processes.  5.2 Implement improved processes.</p>

Table 4. *Capability level summary.*

thereby reducing overlap and redundancies yet capturing the features of all three models. Following the latest CMM integration guidance available, the FAA-iCMM is the first proof of concept that CMM integration can work. This integrated CMM can be used to improve the processes used by system engineers,

software engineers, and acquisition practitioners as they work together in integrated product teams to acquire systems. For acquisition organizations, the FAA-iCMM provides guidance for smart buying.

## Acknowledgments

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## About the Author



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**Level 2 Process Areas**

**Lifecycle/Engineering Processes:** PA 01 Needs, PA 02 Requirements, PA 05 Outsourcing, PA 08 System Test and Evaluation, PA 09 Transition.

**Management/Project Processes:** PA 11 Project Management, PA 12 Contract Management.

**Supporting Processes:** PA 15 Quality Assurance and Management, PA 16 Configuration Management.

The above process areas should be at Level 2 (or higher) capability according to an FAA-iCMM appraisal.

**Level 3 Process Areas**

**Lifecycle/Engineering Processes:** PA 03 Architecture, PA 04 Alternatives, PA 06 Software Development and Maintenance, PA 07 Integration.

**Management/Project Processes:** PA 13 Risk Management, PA 14 Coordination.

**Supporting Processes:** PA 17 Peer Review.

**Organizational Processes:** PA 20 Organization Process Definition, PA 22 Training.

All Level 2 process areas plus all Level 3 PAs should be at Level 3 (or higher) capability.

**Level 4 Process Areas**

**Lifecycle/Engineering Processes:** PA 10 Product Evolution.

**Supporting Processes:** PA 18 Measurement.

All Level 2, 3, and 4 process areas of the FAA-iCMM should be at capability Level 4 (or higher).

**Level 5 Process Areas**

**Supporting Processes:** PA 19 Prevention.

**Organizational Processes:** PA 21 Organization Process Improvement, PA 23 Innovation.

All process areas of the FAA-iCMM should be at capability Level 5.

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Table 5. Maturity level summary.

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