Process Standards and Capability Models for Engineering Software-Intensive Systems

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Current standards and models have improved the quality, cost, and repeatability of systems engineering products and processes. However, soon-to-be-published documents are the next step in developing, maintaining, and reengineering large, complex, software-intensive systems. These efforts consolidate existing documents and minimize the impact of transitioning your process improvement activities. This article explains the changes and how they affect you.

Fortunately for systems engineering (SE), the recent changes in process standards and capability models are for the better. In addition to documenting and expanding our body of knowledge, the SE community is combining the efforts of several agencies into consolidated documents (Figure 1). These emerging "best practices" will show forward-looking organizations how to stay competitive in our ever-changing field. Of special interest is the expanding role software engineering plays in systems engineering.

SE Process Standards

Current and emerging standards on how to engineer a system, although similar, have varied scopes (Figure 2). Their intended audience, e.g., manager, practitioner, determines the level of detail and breadth of coverage. You may choose the standard that best meets your needs or, with the emerging standards, choose only the processes that apply to you.

Current Standards

MIL-STD-499B, *Systems Engineering Management*; EIA Interim Standard 632, *Processes for Engineering a System*; and Institute of Electrical and Electronics Engineers (IEEE) 1220-1994, *Application and Management of the Systems Engineering Process* all cover one SE process, which consists of the following:

- Requirements analysis.
- Functional analysis.
- Synthesis.
- Systems analysis.
- Control.

You may apply any of the versions of this process to the development or modification of a system. These standards require specific tasks for each activity of the process and

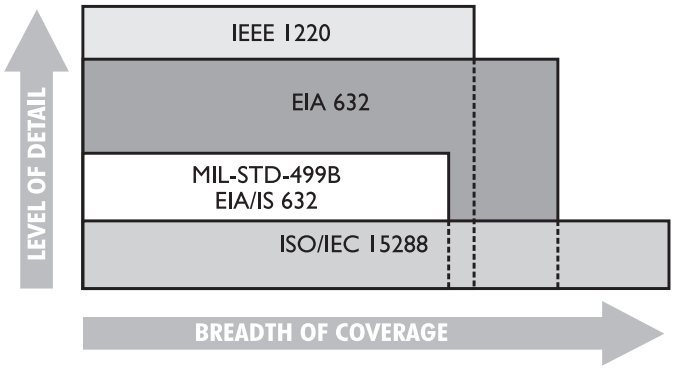
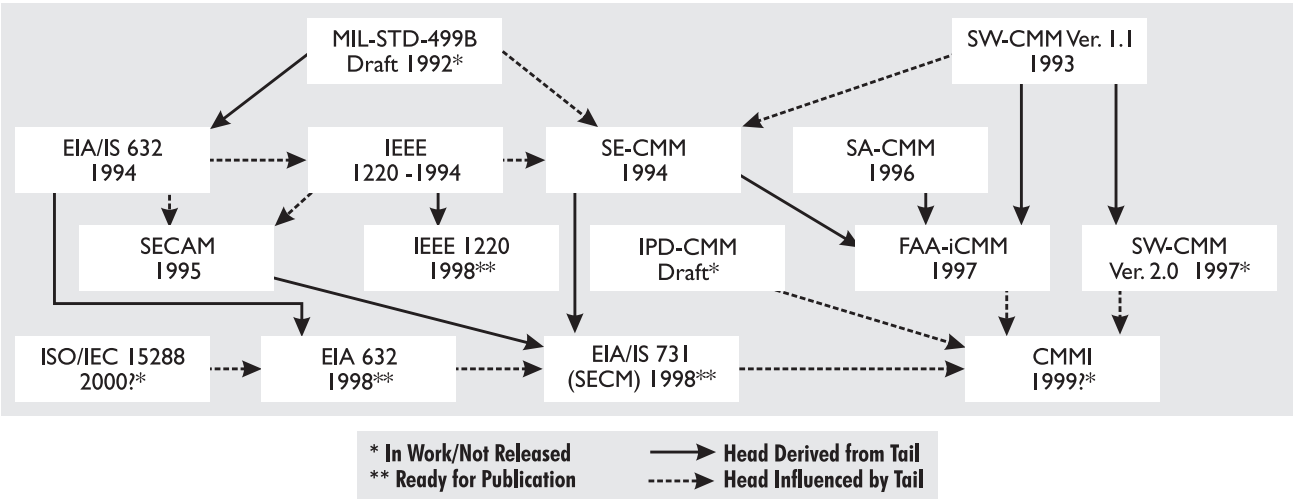


Figure 2. *Scope of SE process standards.*

Figure 1. *Relationships of SE standards and models.*



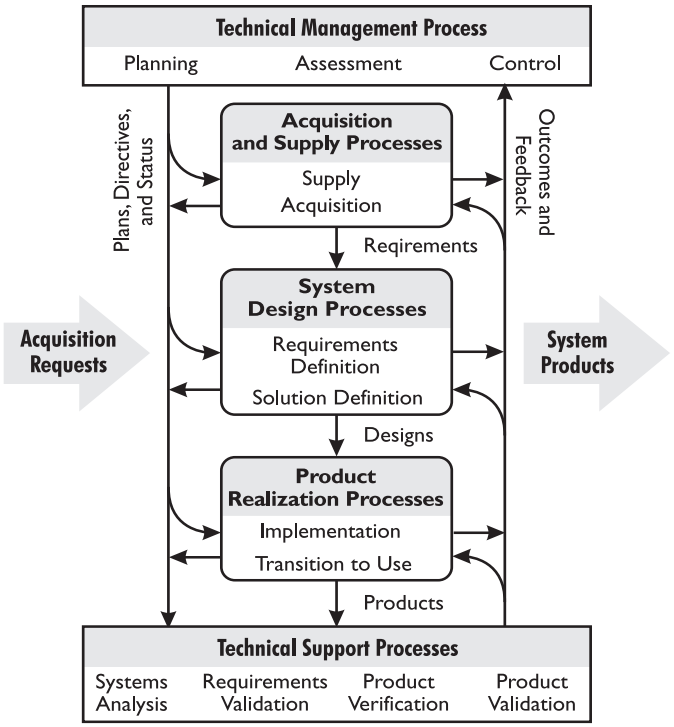


Figure 3. *EIA 632 processes.*

the use of a detailed management plan and event-based and time-based schedules.

Emerging Standards

The upcoming IEEE 1220 will change little from the "trial use" 1220-1994. Electronics Industry Association (EIA) 632, *Processes for Engineering a System*, expands on previous work and will be the basis for implementation of International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 15288, *System Life Cycle Processes*, in the United States. EIA 632 has 13 technical and project processes (Figure 3) that cover

- Acquisition and supply.
- System design.
- Product realization.
- Technical management.
- Technical support.

The working draft of ISO/IEC 15288 currently has 22 generic processes that address enterprise-wide issues and technical and project concerns (Figure 4). With EIA 632, you apply the appropriate processes (each consisting of one to five requirements along with recommended tasks and expected outcomes) for the top-down design of system products as well as the bottom-up realization of such products (Figure 5). With ISO/IEC 15288, you choose the processes you need (each consisting of two to five activities with recommended tasks) to meet specified lifecycle requirements of a software-intensive system. This process goes down to, but does not include, the software.

Process Standards for Software

MIL-STD-498, *Software Development and Documentation* was canceled May 27, 1998. Its replacement is IEEE/EIA 12207, *Information Technology – Software Life Cycle Processes*, the U.S. implementation of ISO/IEC 12207. Reportedly, but unconfirmed, the commercial interim standard J-STD-016-1995, *Software Life Cycle Processes for Software Development* (derived from MIL-STD-498) is not going away and should be finalized (J-STD-016) sometime next year.

SE Capability Models

Current and emerging capability models for systems engineering aim to repeat the benefits of the Software Engineering Institute's (SEI) *Capability Maturity Model for Software* (SW-CMM):

- Better competitive position.
- Returns on investment of between 4.5 and 7.7-to-1 (as have been experienced by Hughes, Tinker Air Logistics Center, and Raytheon).
- Predictable and reduced cost and schedule.
- Reduced risks and fewer trouble reports.
- Improved customer satisfaction and employee morale.
- Less overtime, absenteeism, and turnover.

In addition, integrated SE and software models should save time and money and reduce redundancy in assessments for both software and SE process improvement. Fortunately, the models map well to each other (Figure 6). Even at lower levels of detail, the models specify similar functions. Improvement efforts based on older models will not be wasted, and the transition to a newer model should not be traumatic. For example, if winning a contract de-

Figure 4. *ISO/IEC 15288 processes (working draft).*

Agreement Processes
- Acquisition
- Supply
- Negotiation

Enterprise Processes
- Investment Management
- Multi-Project Management
- Enabling Infrastructure
- Human Resources
- Process Management
- Quality Management
- Risk Management

Project Management Processes
- Planning
- Assessment
- Control

Technical Processes
- Acquirer Requirements Definition
- Other Stakeholder Requirements Definition
- System Requirements Definition
- System Architecture Design
- System Architecture Design Implementation
- System Product Validation
- System Product Verification
- System Product Transition
- Systems Analysis

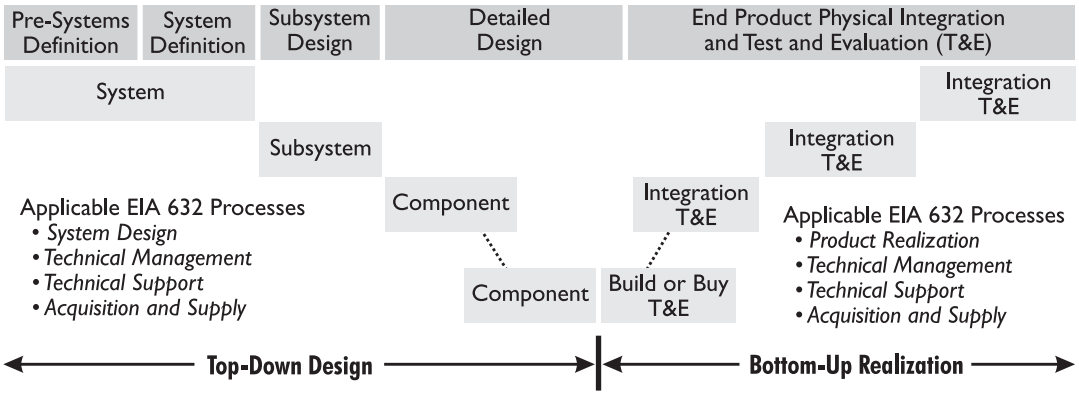


Figure 5. *Engineering lifecycle.*

pends on an evaluation using a newer model, most of what you have already done should "find a home" under a new name.

Current Models

The *Systems Engineering Capability Maturity Model* (SE-CMM), was published by the Enterprise Process Improvement Collaboration in 1994. About the same time, the International Council on Systems Engineering (INCOSE) developed the *Systems Engineering Capability Assessment Model* (SECAM). Although SECAM has less visibility than SE-CMM, both are being used in the SE community. Anecdotal evidence from those who have used the SE-CMM suggests a return on investment similar to software CMM use. Lockheed Martin has reported "a positive difference" from "more mature systems engineering processes."

Last year, the Federal Aviation Administration (FAA) published its *Integrated Capability Maturity Model* (FAA-iCMM[SM]), which combines the software, the systems engineering, and the software acquisition CMMs into one integrated model. FAA uses this in-house and freely distributes it. Plans are under way for three divisions at Warner-Robins Air Logistics Center (software, SE, and acquisition) to use FAA-iCMM and Integrated Process and Product Development (IPPD) as guides for "enterprise-wide process improvement."

Emerging Models

EIA Interim Standard 731, *Systems Engineering Capability Model* (SECM), provides complete coverage of EIA 632 and is consistent with IEEE 1220. SECM (a merging of SE-CMM and SECAM) has 19 focus areas that address technical, management, and environment issues (Figure 7). The future of this interim standard depends on the National Defense Industrial Association's *Capability Maturity Model Integration* (CMMI) effort. If CMMI successfully incorporates SECM concepts, EIA Interim Standard 731 would be duplicative and would probably be rescinded. Otherwise, the SECM will progress to a full (vs. interim) standard.

CMMI will provide a common framework for multiple capability models. In its first version, CMMI will integrate SECM, the software CMM, and Integrated Product Development CMM (IPD-CMM) concepts and build on the FAA-iCMM effort. The result will be a core of common processes and additional domain-specific processes for software and for SE (Figure 8). Reportedly, there is much commonality between the three models and few domain-specific processes. CMMI's first version will give

Figure 6. *Mapping of SE capability models.*

SE-CMM	SECAM	SECM	FAA-iCMM
Engineering	Systems Engineering	Technical	Lifecycle or Engineering Supporting (Not Lifecycle Dependant)
Project	Management	Management	Management or Project
Organization	Organization	Environment	Organizational

Figure 7. *EIA interim standard 731 focus areas.*

Technical
1.1 Define Stakeholder and System Level Requirements
1.2 Define Technical Problem
1.3 Define Solution
1.4 Assess and Select
1.5 Integrate System
1.6 Verify System
1.7 Validate System

Management
2.1 Plan and Organize
2.2 Monitor and Control
2.3 Integrate Disciplines
2.4 Coordinate with Suppliers
2.5 Manage Risk
2.6 Manage Data
2.7 Manage Configurations
2.8 Ensure Quality

Environment
3.1 Define and Improve the Systems Engineering Process
3.2 Manage Competency
3.3 Manage Technology
3.4 Manage SE Support Environment

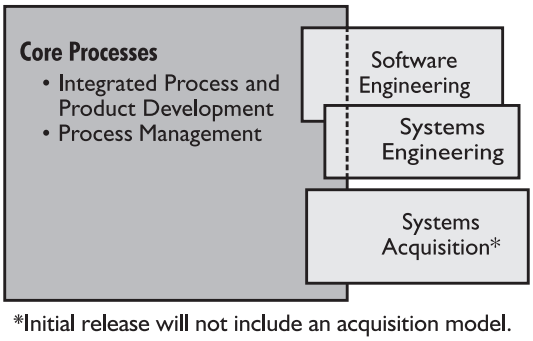


Figure 8. *CMM Integration.*

three models from which to choose. You may

- Conduct a software assessment using core processes and software processes.
- Conduct an SE assessment using core processes and SE processes.
- Conduct an integrated assessment using core processes and combined software and SE processes.

The next version of the CMMI is likely to incorporate the software acquisition CMM (SA-CMM). Subsequent versions may address additional models (Secure Systems Engineering CMM, People CMM, Team CMM, etc.)

Capability Models for Software

The CMM for Software (versions 1.0 and 1.1) has seen wide use and acceptance since 1993. SEI has halted the nearly complete update (version 2.0, draft C) in anticipation of CMMI (described above).

Development of Some Models Placed On Hold

Some organizations are so interested in an integrated capability model they are developing their own in-house versions, as the FAA did. However, since CMMI seems imminent, Litton PRC and Rockwell/Collins (and probably others) have halted such efforts. Likewise, SEI will not release version 2.0 of the SW-CMM. It also is uncertain whether the FAA will update its iCMM as planned. Finally, as reported above, EIA Interim Standard 731 (SECM) is not currently being considered for publication as a full standard.

Impetus for Change

You have seen how the SE climate is changing; current standards and models are giving way to better ones. You know the benefits of improving your business; staying competitive is imperative. Structured process improvements are the key to successful adoption of these new technologies.

- "If you don't know where you are, a map won't help." – *Watts Humphrey*
- "If you don't know where you are going, any road will do." – *Chinese proverb*
- "Even if you're on the right track, you'll get run over if you just sit there." – *Arthur Godfrey*

Acknowledgments

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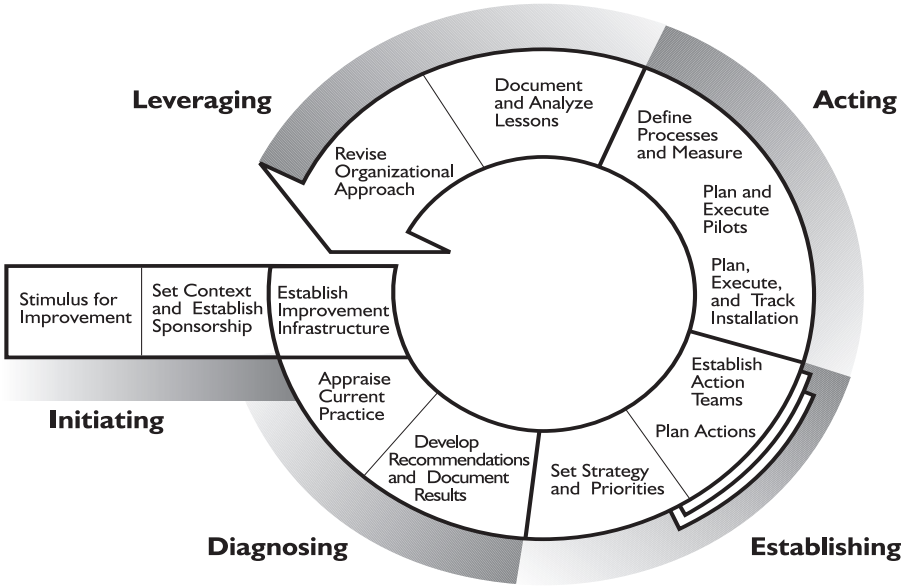
About the Author

Randall R. Wright is a consultant at the Software Technology Support Center (STSC) specializing in systems engineering products and services, representing the STSC on the CMMI project, and coordinating the next version of *Guidelines for Successful Acquisition and Management of Software-Intensive Systems*. He has over 20

Figure 9. *IDEAL model.*



years military and civilian service with aircraft, missiles, and various anti-armor munitions and nuclear delivery systems. He has performed at various levels in maintenance, acquisition, logistics, operations, and policy. He has a bachelor's degree in electrical engineering from Arizona State University, completed Air University's Software Professional Development Program and Air Command and Staff College, holds three acquisition professional certifications, and is a captain in the Air Force Reserves.

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Successfully Adopting New Technologies

Adopting a new technology (whether it is a process, methodology, or tool) means *change!* This is more than a technical issue; you must overcome social, behavioral, managerial, and organizational barriers. To quote Capers Jones, "As a general rule, technology [adoptions] are not very rapid processes, and the bigger the organization, the longer it takes."

When adopting new technologies, the STSC recommends implementing them with the aid of the SEI's IDEAL Model (Figure 9).

- Initiating "sets the stage" for process improvement by stimulating change and laying the necessary groundwork.
- Diagnosing is the gap analysis to see where you are, decide where you want to be, and determine what you will do next.
- Establishing puts the people and plans in place.
- Acting is the execution of your plans with appropriate measures and project tracking.
- Leveraging lets you learn from what you did and do better the next time.

Document Sources

Copies of the documents discussed in this article can be obtained from the following sources.

Capability Maturity Models

SEI Customer Relations
4500 Fifth Avenue
Pittsburgh, PA 15213
Voice: 412-268-5800
E-mail: customer-relations@sei.cmu.edu
Internet: http://www.sei.cmu/pub/documents/...
.../96.reports/pdf/tr020.96.pdf (SA-CMM)
.../96.reports/pdf/hb004.96.pdf (SE-CMM)
.../94.reports/pdf/tr24.94.pdf (SW-CMM)

FAA-iCMM

Federal Aviation Administration
AIT-5, 800 Independence Avenue SW
Washington, DC 20591
Voice: 202-267-7443
E-mail: linda.ibrahim@faa.dot.gov
Internet: http://www.faa.gov/ait/ait5/FAA-iCMM.htm

IEEE 1220, IEEE/EIA 12207

IEEE Service Center
P.O. Box 1331
Piscataway, NJ 08855-1331
Voice: 800-678-4333
E-mail: customer.service@ieee.org
Internet: http://standards.ieee.org

DoD agencies may obtain copies at

Standardization Order Desk
700 Robbins Avenue, Building 4/D
Philadelphia, PA 19111-5094

SECAM

INCOSE, 2033 Sixth Avenue #804,
Seattle, WA 98121
Voice: 800-366-1164, 206-441-1164
E-mail: incose@halcyon.com
Internet: http://www.incose.org/priclist.html

EIA 632, EIA 731 ISO/IEC 12207, ISO/IEC15288, J-STD-016, MIL-STD-498, MIL-STD-499B ***(commercial source)***

Global Engineering Documents
15 Inverness Way East
Englewood, CO 80112-5776
Voice: 800-854-7179
E-mail: global@his.com
Internet: http://global.his.com

Recommended Reading

1. Hollenbach, Craig R. and Steve Mosier, "Developing and Applying a Joint SW-CMM and SECM Appraisal Methodology," *Eighth Annual International Symposium of INCOSE*, Vancouver, British Columbia, Canada, July 26-30, 1998.
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7. Schaeffer, Mark D., "Capability Maturity Model Process Improvement," *CROSSTALK*, May 1998, p. 3.
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11. Sheard, Sarah A., Susan Rose, Linda Inrahim, and Wafa Makhlouf, "Two Approaches to CMM Integration," *Eighth Annual International Symposium of INCOSE*, Vancouver, British Columbia, July 26-30, 1998.
12. Widmann, E. R., "Key Features of the "Merged" EIA/IS 731-1 Systems Engineering Capability Model," *Eighth Annual International Symposium of INCOSE*, Vancouver, British Columbia, July 26-30, 1998.