IEEE Life Cycle Standards and the CMMI®-Implementation Considerations

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Agenda

- Presentation Objective
- Problem Statement
- The Organizational Context
- Developing Life Cycle Processes
- Organizational Standard Processes
- Life Cycle Models
- Process Mapping
- Implementation Pathways
- Conclusions
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- Bibliography
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- Contact Information

Presentation Objective

- **Explore some common perceptions about the SEI CMMI® and the IEEE* Life Cycle Standards**
  - CMMI® can be leveraged for IEEE Standards
  - IEEE Standards support CMMI®-based process improvement
- **Define a feasible approach for using the SEI CMMI® and the IEEE Life Cycle Standards together**
  - Key questions:
    - How to exploit the synergy?
    - How to resolve the differences?

Life Cycle Standards to be covered in this presentation will be referred as:
[IEEE 1997] IEEE 12207, Software Life Cycle Processes
[IEEE 1998] IEEE 1062, IEEE Recommended Practice for Software Acquisition
[IEEE 2005] IEEE 15288, System Life Cycle Processes
[IEEE 2006] IEEE 1074, IEEE Standard for Developing a Software Project Life Cycle Process

® CMMI is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University
** IEEE – Institute of Electrical and Electronic Engineers*

tion – Government Perspective

- **Two key elements of successful acquisition of software-intensive systems**
  - Selecting the right suppliers
    - **Capability assessment** of the potential suppliers is a key element of the acquisition process, and the current, widely embraced recommendation is the reliance on the **CMMI®** [SEI 2007]
  - Assuring mission success
    - Aerospace experience shows that mission success is achieved via the use of **robust development standards*** [Eslinger 2006].
      - **Eslinger demonstrates that even the use of so-called "mature" processes, such as the CMMI® is inadequate, and the government must make a robust software standard contractually compliant**
  - It seems that we need both the CMMI® and the IEEE standards

* *Note that Eslinger's development standard recommendation is based on IEEE 12207*

- Supplier (Contractor) Perspective

- **It seems that we need both the CMMI® and the IEEE standards…**
  - CMMI®
    - It is the de-facto process improvement standard
  - IEEE Standards
    - The government is using them to define a framework for development planning and engineering
- **Contractors' main concerns**
  - Finding the most effective/efficient ways to ensure dual compliance
  - Be pro-active and prepared for rapid tailoring of the standards
    - Simultaneously with compliance though, need to find out how to ensure agility and competitiveness from the development processô perspective
  - Last but not least, to make a profit

t-hearted) Problem Statement

- **" We are from the SEI and the IEEE and we are here to help you"**

  --- Paraphrased use from Ronald Reagan

- **"Standards are always out of date. That's why we call them standards."**

  --- George F. Will

Serious) Problem Statement

- **Regarding “Help”, all the mentioned sources have noble goals; however, their objectives are different …**
  - CMMI®
    - The objective of CMMI® for development is to help contractors improve their development and maintenance processes for both products and services
      - *Based on [Chrissis 2007]*
  - IEEE Standards
    - IEEE Standardsôobjective is to eliminate misunderstandings between contractors and procurers
      - *Based on [IEEE 1997]*
  - **ISO* Standards**
    - ISO Standardsôobjective is to promote a free and fair global trading system via worldwide standardization
      - *Based on the ISO website [ISO 2007]*

** ISO – International Standards Organization. Note that the discussed key life cycle standards have their origin in ISO standards*

roblem Statement (cont.)

- **The typical, current IEEE standard development process has some inherent characteristics:**
  - IEEE Standards are developed in isolation
    - Authors in most cases give lip-service only to other IEEE standards
    - The CMMI® has only minor, vague references to IEEE Life Cycle Standards
    - The IEEE Life Cycle Standards have only some vague references to process improvement (nothing specific regarding the CMMI®)
  - IEEE Standards are developed by volunteers
  - IEEE Standardsôtext is finalized and balloted via consensus
- **As a result, most standards share some common characteristics:**
  - The final material is always a result of major negotiations
  - The process takes several years
  - The standards are not consistent with each other
  - Standards ï at most ï codify state-of-the-practice, and never reflect the state-of-the-art
- **The CMMI® has not been developed by the IEEE, but with respect to these problems it is not very different**

Why Are These Problems?

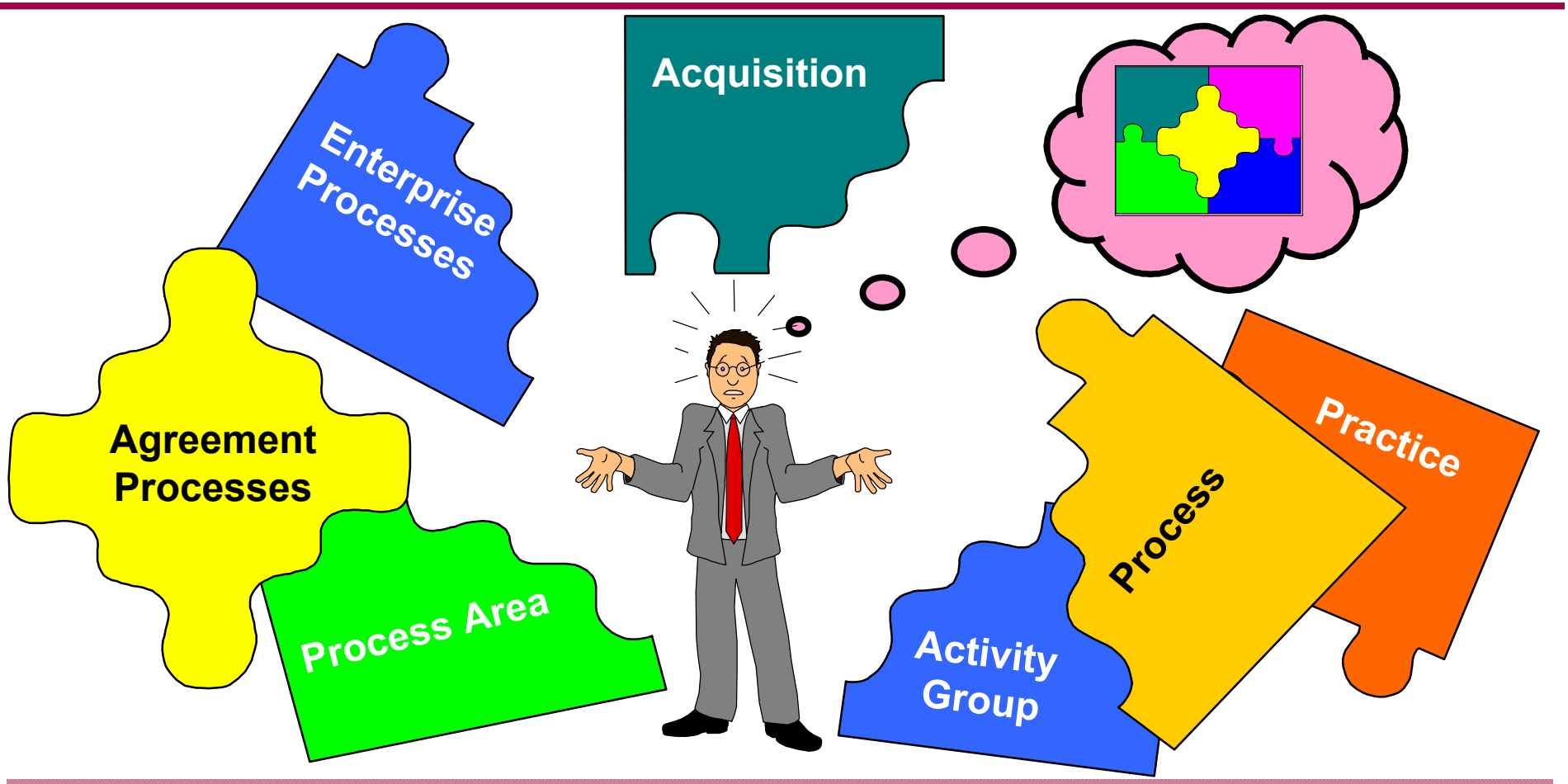
- **The use of IEEE standards only makes sense for compliance**
  - Sure, they can be used as guidance materials by novices, but better, more up-to-date, and widely accessible materials are available for instructional purposes
- **The CMMI® is also about compliance**
  - It is claimed that the model is for guidance, and only describes "what"-type required characteristics for process improvement, without prescribing the "how". However,
    - Unconditional satisfaction of all goals is required on every maturity level
    - In reality, during appraisals when the level of institutionalization is determined, the level of compliance with all the pre-defined organizational processes is probed

It is really difficult to simultaneously satisfy so many conflicting compliance requirements

EE Standards That Are Out Of Scope For This Presentation

- **IEEE 1062**
  - The use of 1062 is not recommended for government acquisitions
    - Various government entities have their own, strictly binding acquisition policies and instructions (e.g., the DOD 5000 series, NSSAP 03-01, etc.)
  - Acquirers are better off with directly using their respective policies
- **IEEE life cycle standards have serious technical, compliance, and tailoring problems of their own**
- **IEEE life cycle standards are poorly harmonized with each other**
  - There are some harmonization efforts in progress, but no tangible results yet

Array of Terminology Ambiguities



Unfortunately, IEEE Std. 610.12-1990, IEEE Standard Glossary of Software Engineering Terminology, is so out-of-date that it is not even referenced anymore in the standards.

ne Organizational Context

Organizational terms and their hierarchy

IEEE 15288	IEEE 12207	IEEE 1074	CMMI®
Enterprise	Organization	Organization	Organization
Project	Project	Project	Project

- **Concerns:**
  - The organizational terms and their hierarchical relationship seem to be the same for the IEEE Standards and the CMMI® (IEEE 15288ôs ñEnterpriseòis the sole exception); however, the underlying definitions are different
    - E.g., the CMMI® definition of an ñorganizationòis the most constrained
  - All standards allow for recursive invocation of these terms
    - é but they donôt provide guidance on the details

rganizations and Projects

- **“Project” across the IEEE Standards is not well defined**
  - In 1074 the term is used to limit the standardôs scope
    - It only implies an endeavor in conjunction with software development and maintenance
- **“Organization” in the IEEE Standards is also only vaguely defined**
  - In general, it refers to the environment (people and facilities) where the ñprojectsòare executed
- **“Project” in the CMMI® refers to a managed set of interrelated resources delivering one or more products to a Customer***
- **“Organization” in the CMMI® refers to an administrative structure where projects share a Senior Manager** and operate under the same policies**

** “Customer”: The party accepting the product or authorizing payment*
*** “Senior Managers” focus on the long-term vitality of the organization rather than the short-tem pressures of the projects.*

ion: Rely on the CMMI® Interpretations

- **The first step is always to develop the WBS**
  - There must be at least one product
- **Next, map the WBS to contractor relationships**
  - Where there is a Contract, there is a **Customer** and a **Supplier**é
  - This will also help to determine what should be considered as **Projects**
  - For determining **Organizations**, use the existence or lack of Senior Managers (by CMMI® definition) to draw up the organizational boundaries for process development, maintenance, and improvement
- **The WBS can also be used to determine which standard to use and where**
  - 15288 for Systems Engineering projects
  - 12207 and 1074 for Software Engineering projects
- **Discipline coverage**
  - The CMMI® covers Hardware, Software, and Systems Engineering
  - IEEE process standards cover only Systems Engineering and Software
  - Note that there are no applicable, true hardware process standards (Hardware development processes are not Life Cycle Model-driven like Systems or Software Engineering processes)

Clear definition of Organizations is critical because both the IEEE Standards and the CMMI® are referring to so-called Organizational Process Assets

ocess Development in IEEE 1074 and in the CMMI®

- **The process to develop a SW Project Life Cycle Process in IEEE 1074 and the process to develop a Defined Software Process in the CMMI® look similar*, but there are subtle, critical differences:**
  - IEEE 1074 only specifies Activity Description, Input Information, and Output Information for every Activity
  - However, a **defined process** in the CMMI® must clearly state the following:
    - Purpose
    - Inputs
    - Entry criteria
    - Activities
    - Roles
    - Measures
    - Verification steps
    - Outputs
    - Exit criteria

** Note backup slides showing the details of both processes*

*** See [Chrissis 2007], page 152-154 for the distinctions between a **managed** and a **defined** process in the CMMI®*

izational Standard Processes*

- **In terms of reliance on Organizational Standard Processes the CMMI® is stricter than the IEEE Standards**
  - IEEE 1074 does not mandate the use of any existing SPLCP (Software Projectôs Life Cycle Process) during the creation of the current SPLCP (It doesnôt assume their existence)
    - In fact, the recommended Organizational Process Assets are more supporting than defining elements of the ñto be createdò SPLCP (e.g., policies, metrics, tools, methodologies, etc.)
  - A CMMI® Defined Process must be tailored from the OSSP (Organizational Set of Standard Processes)

** Note backup slides showing how IEEE 1074 and the CMMI® are dealing with Organizational Standard Processes*

ional Standard Processes (Cont.)

- **It makes a difference on what CMMI® maturity level the organization is when the decision is made to comply with the IEEE Standards**
  - For a Level-2 organization it is not a problem
    - SPLCP created with the use of the IEEE Standards immediately satisfies the conditions for a Managed Process
    - Eventually these kind of processes could become part of OSSP
  - For a Level-3 or higher maturity organization there is a conflict
    - Newly created, IEEE Standards-based processes can not be immediately applied because first they would have to be made part of OSSP
      - **Also, appropriate tailoring guidelines would have to be developed and documented**
    - The new processes can also affect (override) existing sub-process selection for quantitative management
    - The undesired side-effect is administrative delays and overhead

Life Cycle Models

- **Good News:**
  - There is no difference in how the IEEE Standards and the CMMI® treat Life Cycle Models
- **Bad News:**
  - The same ☺
- **Both expect the availability of a collection of life cycle models**
  - CMMI®
    - OPD (Organizational Process Definition) SP (Specific Practice) 1.2: Establish Life Cycle Model Descriptions
  - 1074
    - Clause 4.2.1 shows the existence of a collection of SPLCMs, but it also declares that this collection is out of scope for the standard
- **Nevertheless, neither the CMMI® nor 1074**
    - Specifies where these models supposed to come from
    - Specifies how they should be documented
    - Provides guidance on tailoring
- **IEEE Standards do provide some guidance on selecting a life cycle model for a project, e.g., 12207 for software**
  - However, guidance is for a limited number of Life Cycle Models only

Process Mapping

- **Mappings have been carried out on the CMMI® Process Area level***
  - CMMI® Ÿ 15288 (Coverage = 68%)
  - CMMI® Ÿ 12207 (Coverage = 72%)
  - CMMI® Ÿ 1074 (Coverage = 59%)
- **IEEE Standard support/leverage by CMMI® Process Area Category**
  - Basic Process Management
    - **Weak**
  - Advanced Process Management
    - **Missing due to lack of quantitative management focus**
  - Basic Project Management
    - **Well covered**
  - Advanced Project Management
    - **IEEE Standards do not provide robust enough support**
  - Engineering
    - **Well covered**
  - Basic Support
    - **Adequate coverage, except for Measurement & Analysis**
  - Advanced Support
    - **Partial coverage due to lack of quantitative management focus**

** See detailed mapping at the end of the presentation in the Backup Slides section.*
*Definition of Coverage [%] = (22 - ∑"Not covered" / 22) * 100, where 22 is the total number of CMMI® Process Areas*

nularity of Process Mapping

- **Should the IEEE Standards be evaluated (mapped) on a lower, CMMI® practice/sub-practice, level?**
  - **No**, practices and sub-practices are not **required** model components
    - Practices are only **expected**
    - Sub-practices are only **informative**
  - Process tailoring must be based on specific business goals and mission objectives
    - Equivalency/Adequacy of actual process steps must be assessed on a case-by-case basis
    - Early attempts for low-level evaluations in absence of specific business goals and objectives could be educational, but do not provide an effective/efficient solution

nplementation Pathways

- **(1) Introducing IEEE Standards in a high maturity environment**
  - The introduction of IEEE Standards-based processes is well facilitated by the robust process development, maintenance, and improvement infrastructure
  - As it was discussed, there is some ambiguity related to the CMMI® interpretation of a Defined Process, but mission success and the use of robust development standards should be the primary concern
- **(2) Introducing CMMI® where IEEE Standards are the norm**
  - IEEE Standards-based processes provide a good starting point
  - Pay attention though to the much stricter process documentation requirements of the CMMI®
- **(3) Ideal situation would be simultaneous introduction**
  - Use business and mission objectives as primary tailoring drivers
  - Pay attention to the CMMI® Context

Conclusions

- **IEEE Standards support CMMI®-based process improvement**
  - IEEE Standards can be helpful in creating both managed and defined CMMI® Process Assets
  - **However, be prepared that their practical application is time-consuming and requires effective tailoring**
  - Another caveat: IEEE Standards are weak and need special attention in the following four areas when introduced to support the implementation of CMMI®-based process improvement:
    - Definition of the process management infrastructure
    - Measurement & Analysis Process Area
    - Characterization of defined processes, due to
      - **The need for more detailed documentation that provides greater insight into process activity relationships**
      - **More rigorous execution requirements**
      - **Process improvement focus**
    - Quantitative Management
- **CMMI® can be leveraged for IEEE Standards**
  - Tailoring of IEEE Standards is more efficient if it is done with the understanding of CMMI® requirements and terminology

Acronyms

CMMI	Capability Maturity Model Integration
CMU	Carnegie Mellon University
COTS	Commercial Off-The-Shelf
CSSE	Center for Software and Systems Engineering (at USC)
DOD	Department of Defense
HW	Hardware
IEEE	Institute of Electrical and Electronics Engineers
IPT	Integrated Product Team
ISO	International Standards Organization
MOIE	Mission-Oriented Investigation and Experimentation
NSSAP	National Security Space Acquisition Policy
OPA	Organizational Process Assets
OPD	Organizational Process Definition (CMMI® Process Area)
OSSP	Organizational Set of Standard Processes
PDSP	Project's Defined Software Process
PPBE	Planning, Programming, Budgeting, and Execution
SEI	Software Engineering Institute
SP	Specific Practice (of a CMMI® Process Area)
SPLC	SW Project's Life Cycle
SPLCM	SW Project's Life Cycle Model
SPLCP	SW Project's Life Cycle Process
STD	Standard
SW	Software
USAF	United States Air Force
USC	University of Southern California
WBS	Work Breakdown Structure

Bibliography

Chrissis 2007 Chrissis, M. B., et al, CMMI® Second Edition – Guidelines for Process Integration and Product Development, Addison-Wesley, 2007

Eslinger 2006 Eslinger, S., Mission Assurance-Driven Processes for Software-Intensive Ground Systems, Aerospace Technical Report, ATR-2006(8056)-1, September 2006

Ferguson 1998 Ferguson, J., and Sheard, S., Leveraging Your CMM Efforts for IEEE/EIA 12207, IEEE Software, September/October 1998

IEEE 1997 IEEE/EIA 12207.0-1997, Industry Implementation of International Standard ISO/IEC 12207:1995, (ISO/IEC 12207) Standard for Information Technology – Software Life Cycle Processes, IEEE March 1998

IEEE 1998 IEEE Std 1062, 1998 Edition, IEEE Recommended Practice for Software Acquisition, IEEE December 22, 1998

IEEE 2005 IEEE Std 15288™-2004, Adoption of ISO/IES 15288:2002 Systems Engineering-System Life Cycle Processes, IEEE June 8, 2005

IEEE 2006 IEEE Std 1074™-2006, IEEE Standard for Developing a Software Project Life Cycle Process, IEEE July 28, 2006

ISO 2007 http://www.iso.org/iso/en/aboutiso/introduction/index.html#eight

Land 2005 Land, S. K., The Application of IEEE Software and System Engineering Standards in Support of Software Process Improvement, CMMI Conference 2005

SEI 2007 Understanding and Leveraging a Supplier's CMMI® Efforts: A Guidebook for Acquirers, SEI Technical Report, CMU/SEI-2007-TR-004, March 2007

Backup Slides

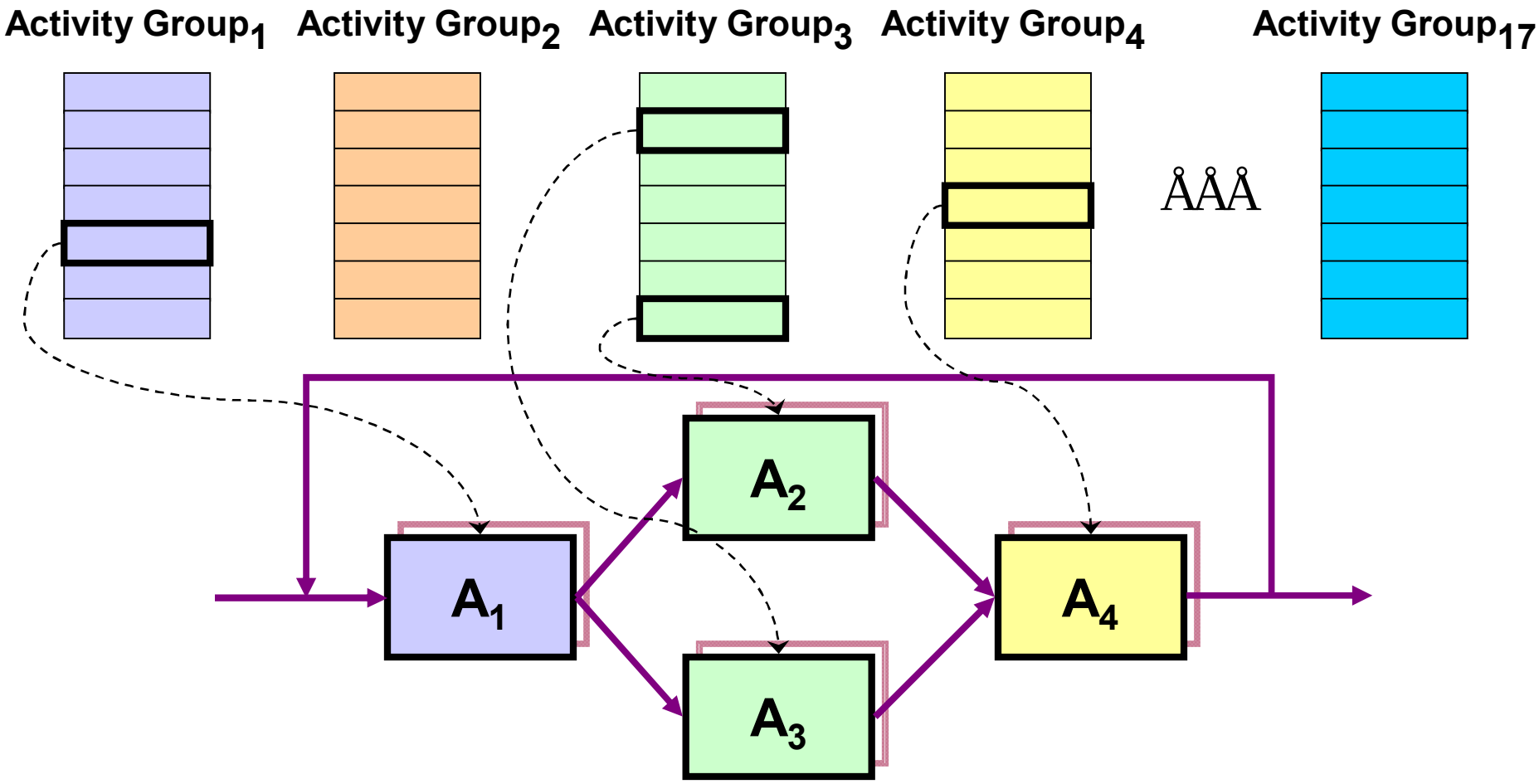
System Life Cycle Processes

- **Enterprise Processes**
  - Enterprise Environment Management
  - Investment Management
  - System Life Cycle Process Management
  - Resource Management
  - Quality Management
- **Agreement Processes**
  - Acquisition and Supply
- **Project Processes**
  - Project Planning
  - Project Assessment
  - Project Control
  - Decision Making
  - Risk Management
  - Configuration Management
  - Information Management
- **Technical Processes**
  - Stakeholder Requirements Definition
  - Requirements Analysis
  - Architectural Design
  - Implementation
  - Integration
  - Verification
  - Transition
  - Validation
  - Operation
  - Maintenance
  - Disposal

Software

- 12207 Software Life Cycle Processes
  - Primary Life Cycle Processes
    - Acquisition
    - Supply
    - Development
    - Operation
    - Maintenance
  - Supporting Life Cycle Processes
    - Documentation
    - Configuration Management
    - Quality Assurance
    - Verification
    - Validation
    - Joint Review
    - Audit
    - Problem Resolution
  - Organizational Life Cycle Processes
    - Management
    - Infrastructure
    - Improvement
    - Training
- 1074 Software Activity Groups
  - Project Management
    - Project Initiation
    - Project Planning
    - Project Monitoring and Control
  - Pre-Development
    - Concept Exploration
    - System Allocation
    - Software Importation
  - Development
    - Software Requirements
    - Design
    - Implementation
  - Post-Development
    - Installation
    - Operation and Support
    - Maintenance
    - Retirement
  - Support
    - Evaluation
    - Configuration Management
    - Documentation
    - Training

N Project Life Cycle Process in 1074



Information Flow

How to Determine What "Organizations" and "Projects" Are

Mapping the WBS into the Organizational Structure

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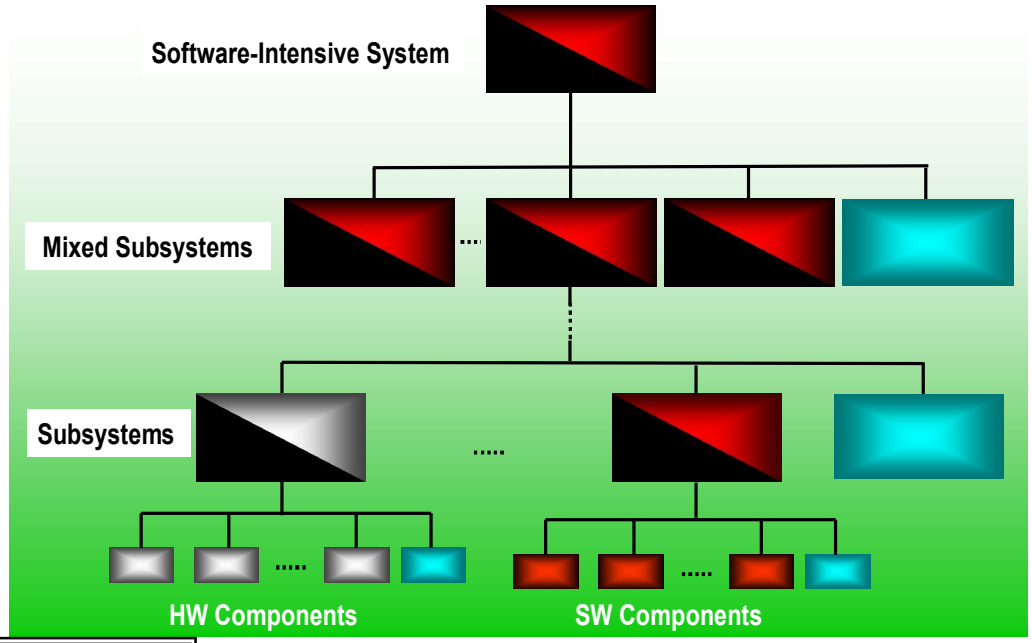
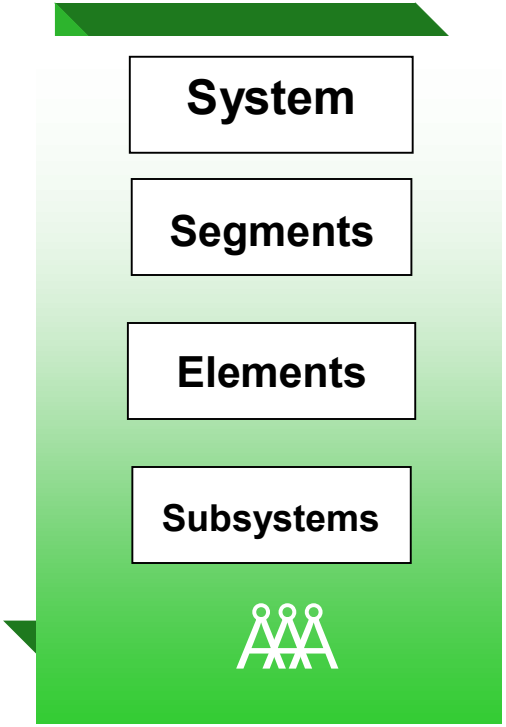
System WBS (Work Breakdown Structure)

Conceptual WBS



Space System Terms



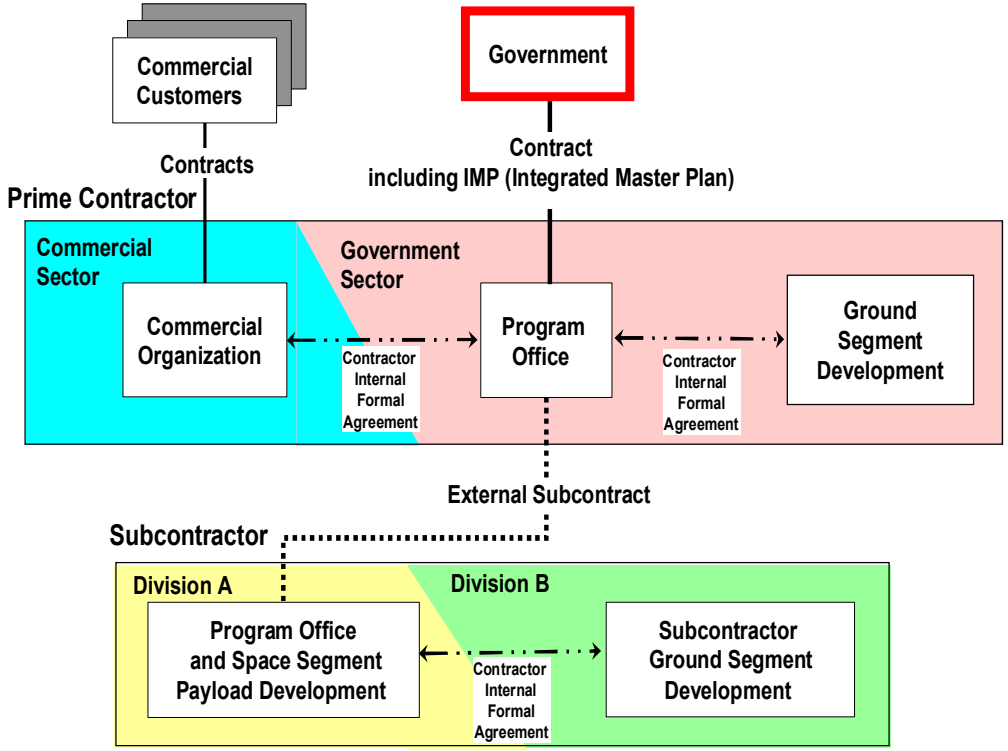
LEGEND

- Software
- Hardware
- Activities

"Activities" in WBS jargon refer to the creation, integration, and management of the product elements on every level

Contractor Structure

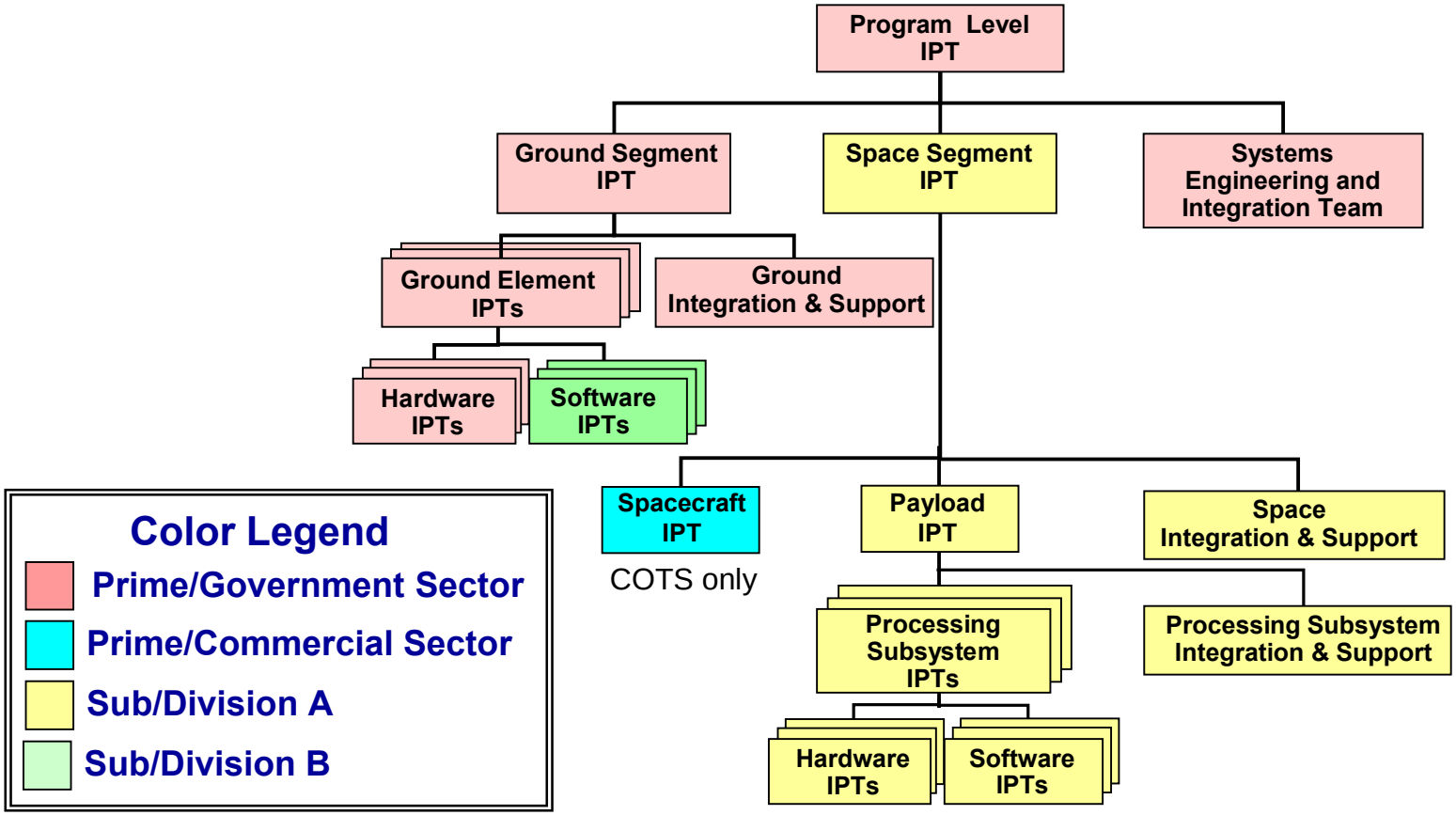
Example (Simplified) Space System Contractor Relationships



The product's WBS and the contractor relationships together will determine the actual organizational structure (See next slide)

lapping the WBS Into an IPT-Based Organizational Structure

(Simplified) Space System IPT (Integrated Product Team) Structure



The challenge: What are the "organizations" and what are the "projects"?

Comparing the Role of Organizational Processes in IEEE 1074 and in the CMMI®

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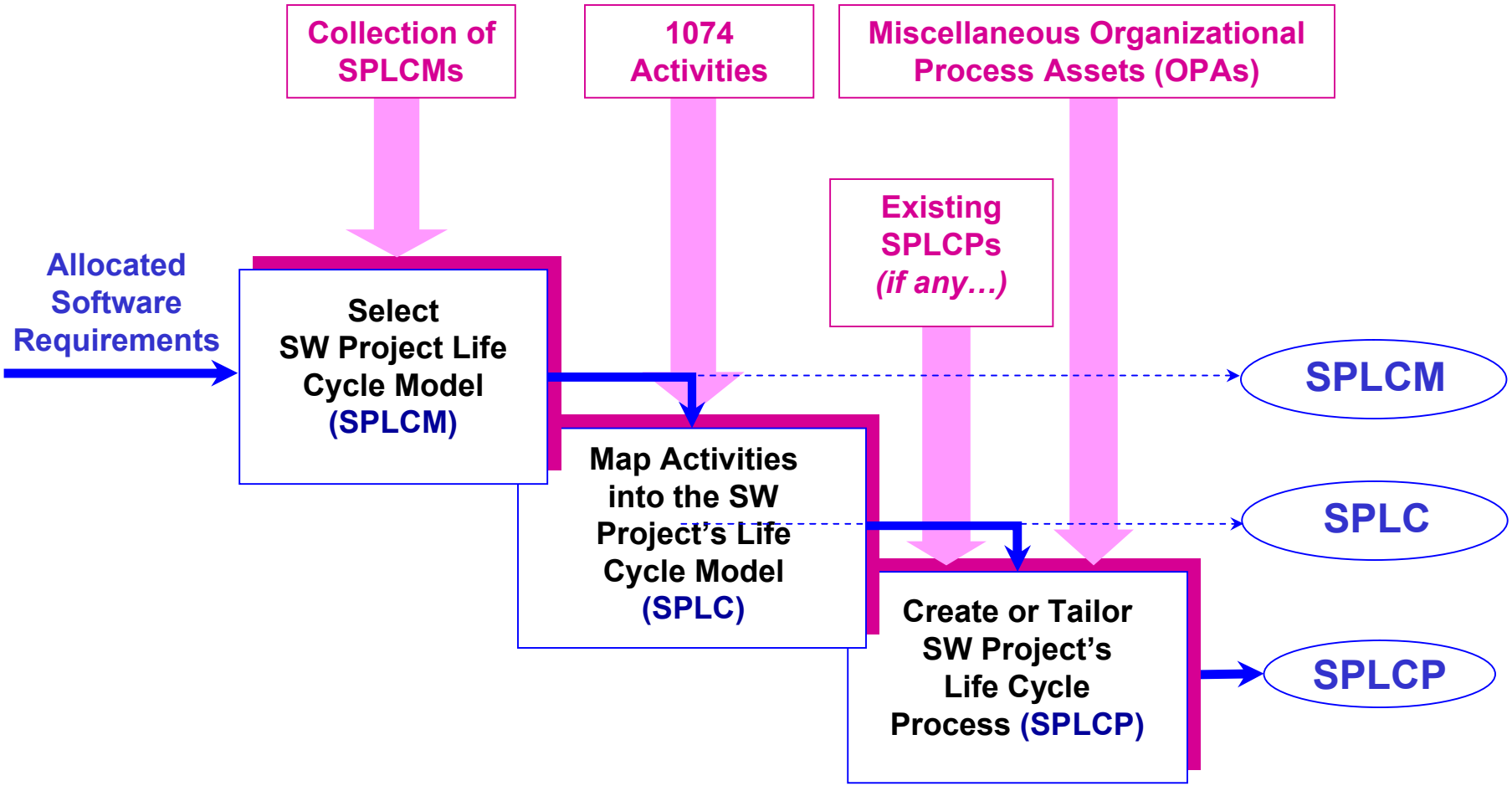
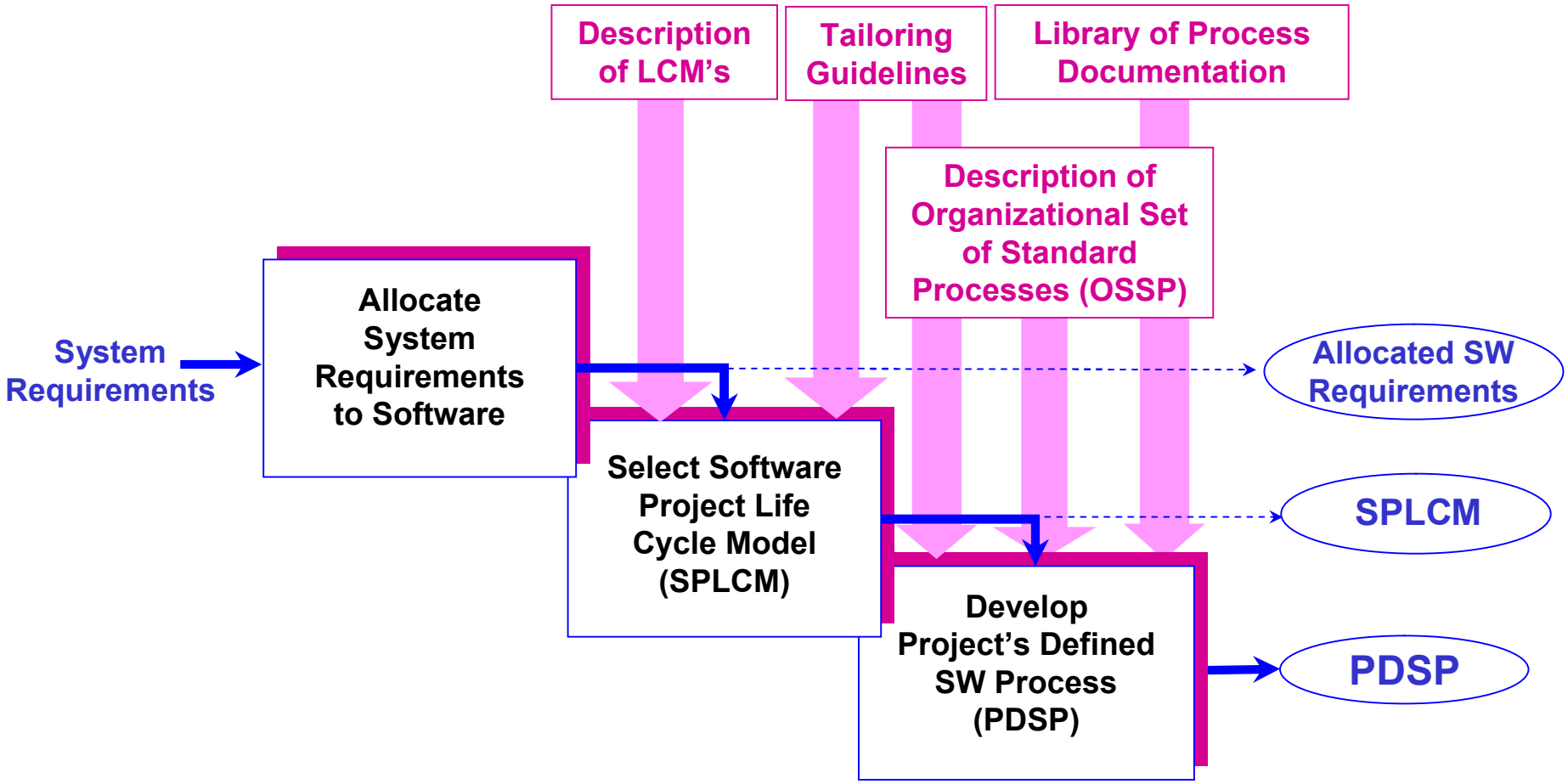
SW Project Life Cycle Process in 1074



Defined Software Process in CMMI®



ll® Process Areas to 15288 Processes

CMMI® Process Areas	Related 15288 Life Cycle Processes
Basic Process Management	
Organizational Process Definition	System Life Cycle Process Management
Organizational Process Focus	Not covered
Organizational Training	Not covered
Advanced Process Management	
Organizational Process Performance	Not covered
Organizational Innovation & Deployment	Not covered
Basic Project Management	
Project Planning	Project Planning
Project Monitoring & Control	Project Control
Supplier Agreement Management	Acquisition and Supply
Advanced Project Management	
Integrated Project Management	Enterprise Environment Management
Risk Management	Risk Management
Quantitative Project Management	Not covered
Engineering	
Requirements Development	Stakeholder Requirements Definition, Requirements Analysis
Requirements Management	
Product Integration	Integration
Technical Solution	Architectural Design, Implementation
Verification	Verification
Validation	Validation
Basic Support	
Configuration Management	Configuration Management
Measurement and Analysis	Not covered
Process and Product Quality Assurance	Quality Management
Advanced Support	
Decision Analysis and Resolution	Decision Making
Causal Analysis and Resolution	Not covered

II® Process Areas to 12207 Processes

CMMI® Process Areas	Related 12207 Life Cycle Processes
Basic Process Management	
Organizational Process Definition	Improvement, Infrastructure
Organizational Process Focus	Improvement
Organizational Training	Training
Advanced Process Management	
Organizational Process Performance	Not covered
Organizational Innovation & Deployment	Not covered
Basic Project Management	
Project Planning	Management
Project Monitoring & Control	Management
Supplier Agreement Management	Acquisition
Advanced Project Management	
Integrated Project Management	Management
Risk Management	Management
Quantitative Project Management	Not covered
Engineering	
Requirements Development	Development
Requirements Management	Development
Product Integration	Development
Technical Solution	Development
Verification	Verification
Validation	Validation
Basic Support	
Configuration Management	Configuration Management
Measurement and Analysis	Not covered
Process and Product Quality Assurance	Quality Assurance
Advanced Support	
Decision Analysis and Resolution	Not covered
Causal Analysis and Resolution	Not covered

Process Areas to 1074 Activity Groups

CMMI® Process Areas	Related 1074 Activity Groups
Basic Process Management	
Organizational Process Definition	Not covered
Organizational Process Focus	Not covered
Organizational Training	Not covered
Advanced Process Management	
Organizational Innovation & Deployment	Not covered
Organizational Process Performance	Not covered
Basic Project Management	
Project Planning	Project Planning
Project Monitoring & Control	Project Monitoring & Control
Supplier Agreement Management	Not covered
Advanced Project Management	
Integrated Project Management	Not covered
Risk Management	Project Monitoring & Control
Quantitative Project Management	Not covered
Engineering	
Requirements Development	Software Requirements
Requirements Management	Software Requirements
Product Integration	Implementation
Technical Solution	Design
Verification	Evaluation
Validation	Evaluation
Basic Support	
Configuration Management	Configuration Management
Measurement and Analysis	Project Planning Project Monitoring & Control
Process and Product Quality Assurance	Evaluation
Advanced Support	
Decision Analysis and Resolution	Software Importation
Causal Analysis and Resolution	Not covered

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