

# **Relationships and dependencies between Technical Solution and Product Integration.**

## **CMMI Engineering Process areas**

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### **Legend:**

**TS: Technical Solution**

**PI: Product Integration**

**ICWG: interface control working group**

**PC: Product component**

### **Objectives of TS and PI:**

**The objective of TS** is to design (developing architecture, high level and low level/detail design), develop (coding or data conversion activity for Data migration), and implement (successful deployment at the customer's site) solutions as per agreed and documented requirements (as per the requirements management and development activities/phase). This includes products, PCs (programs or modules), and product-related lifecycle processes (user manual, design manuals etc). **The objective of PI** is to ensure planned successful assembling of the complete product (or services) from one or more, simple or complex PCs (or service components), ensuring that the product (or services), as integrated, functions properly as intended by design , and deliver/deploy the product (or services) at the end user/customer site.

### **Where TS and PI applies:**

#### **TS SCOPE:**

TS is applied to every product and service that the organization develops/deploys including PCs (units, modules, large programs etc), product related life-cycle process and service/maintenance of products/PCs at all levels of the product architecture. Also, the product-related life-cycle processes are developed along with the product/PC, selecting and adapting existing processes (including standard processes) for use as well as developing new processes as per the tailoring guidelines in the model and the QMS. The interfaces are identified and defined during the design phase (**TS:SG2**). TS is valid for various types of projects like support activities, off shore development, software maintenance, ERP implementation, data migration etc. TS has a clear focus on:

1. Evaluating/selecting “design approaches/concepts” or “prototypes/preliminary designs/Proof of concepts” that potentially satisfy an appropriate set of allocated requirements or PC prototypes or service models.
2. Implementing the designs (of product, PCs or service models) with integrated activities interactively support each other.

#### **PI SCOPE:**

PI deals with achieving complete and functionally successful PI through progressive assembling of PCs, in one or incremental stages, according to defined integration sequence and procedures. PI calls for interface management throughout the project ie. the management of internal/external interfaces of the products and PCs to ensure compatibility among the interfaces as defined by design team and ICWG.

This process may begin with analysis and simulations (e.g., threads, rapid prototypes, virtual prototypes, and physical prototypes) and steadily progress through increasingly more realistic and incremental functionality until the final product is achieved. To ensure smooth and successful product verification and

validation, in each successive build, prototypes (virtual, rapid, or physical) are constructed, evaluated, improved, and reconstructed based upon knowledge gained in the evaluation process.

### **Inputs to TS and PI from RD:**

TS accepts requirements from RD, subsequently convert it into product architecture, PC (coding or data conversion activity for Data migration) or PC design (high or low level). PI accepts requirements from RD where PCs are combined and interfaces are verified (by ICWG) to ensure that they meet the interface requirements supplied by RD. PI may refer to RD for detail information on interfaces and may refer to RM for information on managing changes to interface requirements.

### **Impact on RM due to TS-PI interdependencies :**

RM ensures fundamentally controls changes to requirements are reflected in the deliverables of other engineering PA's (due to recursive and dynamic sequence of events by RM) and subsequently in integrated project plans, activities and work products. The table of TS-PI deliverables (at the end of this document) clearly depicts the goalwise deliverables of TS and PI (ie the requirements generated by enacting TS-PI activities) , the activities which are to be included in the project plan and managed by RM.

### **Differences in TS-PI Base and Advance practices.** *PI does not have advance practices.*

- In TS, SP1.1-1(base practice) “Develop Alternative solutions” is there, on which TS 1.1-2, (advance practice) is built, as “Develop **detailed** Alternative solutions” which is relatively more demanding. Thus TS 1.1-2 is included in the staged model and **it subsumes TS.SP1.1-1(base practice).**
- In TS. SP2.3-1(base practice) we have “Establish Interface Descriptions” and in TS.SP2.3-3 (advance practice is built on base practice), we see” Design Interfaces Using Criteria” .Thus TS 1.1-2 is included in the staged model and **it subsumes TS.SP2.3-1(base practice).**

### **Interdependencies between TS and PI process areas.(Specific Practices)**

#### **PI: SG 1 Prepare for Product Integration**

#### **SP 1.1 Determine the product component Integration Sequence**

The integration sequence should be harmonized with **selection of PC solutions TS:SP1.3-1** and **design of product and PC in TS: SP2.1-1** (use **DAR** process if applicable). It will also reflect in **Plan the process PI: GP2.2**, (and impact activities of PP – project planning ) which is linked with **TS:GP2.2** and **TS.SP2.1-1**. ie Once a detailed design/ PC solutions is developed, the PI solution can be identified. PI sequence is identified with a rationale for selecting/rejecting the sequence. **SAM** procedures may be used if external suppliers/internal departments are involved in supplying COTS or transitioning acquired products/PCs. Documented relationships between requirements and PCs and solutions, Product architecture and PC designs from TS shall determine the PI sequence with rationale for selecting or rejecting the sequence. Revision to the PI sequence and available procedures is done as appropriate. For complex PI activities , **Risk management** procedure may be used to mitigate risks.

#### **SP 1.2 Establish and maintain the Environment needed to support the integration of the product components.**

This includes identifying requirements for PI environment, decide whether to make or buy the needed PI environment or develop an integration environment. It may call for maintaining the PI environment throughout the project. The PI environment may call for reuse of existing resources, the decision for which is taken in **TS: SP 2.4 Perform Make, Buy, or Reuse Analyses** using the **DAR** process. COTS products may have incomplete documentation. It may call for the requirements to establish a supplier agreement. (**SAM**)

- *The TS deliverables are Criteria for design and PC reuse, make-or-buy analyses and Guidelines for choosing COTS PCs. These are used to generate verified and documented environment for PI.*

This PI practice is also dependant on **TS:SP1.2 Evolve Operational Concepts and Scenarios, like** interaction of the PC with the environment, users, and other PC. The environment of any given PC will be influenced by other PC and the external environment. A detailed alternative designs/solutions may be developed with operational scenarios and candidate PC solutions, leading to documented PC selection decisions and rationale. Relationships between requirements and PCs, solutions, evaluations, and rationale are documented alongwith timeline analyses of PC interactions using OOAD and Use cases.

### **SP 1.3 Establish and maintain procedures and criteria for integration of the PC.**

PI procedures and criteria are defined at the organizational level but needs to be tailored for the project requirements and PCs. This practice collects data from all the 3 practices of **TS: SG1 – Select product component Solutions**. PI procedures can include number of incremental iterations, level of testing for build components, verification of interfaces, details of the expected tests and other stage wise evaluations. PI criteria can indicate the readiness of a PC for integration or its acceptability, how the PCs are to be verified, how the assembled PCs and final integrated product are to be validated and delivered and degree of simulation permitted for a PC to pass a test etc.

### **PI:SG 2 Ensure Interface Compatibility**

Categories of interfaces are identified and list of interfaces /category are developed on the basis of the Product architecture, design (high and low level) and PC designs. This is also defined on the basis of **TS:SG2** ie . Product architecture, design (high and low level) along with PC designs is developed. Then interface design specifications with criteria are developed. On the basis of Product architecture, PC designs, documented interface design specifications with criteria, interface control documents are prepared. ICWG group may be involved for defining and documenting the interfaces.

On the basis of interface control documents produced by practices of TS:SG2, mapping of interfaces between the PCs and PI environment is done, resulting in a table of relationships amongst PCs (themselves) and between PCs and the external environment is generated. Also a list of agreed-to interfaces defined for each pair of PCs is made.

### **SP 2.1 Review Interface Descriptions for coverage and Completeness**

This practice is dependant upon the **TS:SP 2.3-1 Establish Interface descriptions and TS:SP 2.3-3 Design Interfaces Using Criteria**. The interfaces include mechanical, noise , climatic , thermal , fluid ,electrical, electromagnetic, human-machine (e.g., audio, display types, TV screen, or liquid crystal display, indicators, LEDs, LCDs, manual controls, joystick, ball, keys, push buttons, touch screen etc). Up to some extent it is also related to **TS: SP 2.1 Design the Product or Product Component**.

- *TS work products like interface design and documents, product architecture and PC designs, interface design specifications and interface control documents are used in creating deliverables for PI interface categories, list of interfaces /category and mapping interfaces to the PC and PI environment.*

### **SP 2.2 Manage Interfaces: Manage internal and external interface definitions, designs, and changes for products and product components.**

It ensures the compatibility of the interfaces throughout the life of the product. It resolves conflicts, noncompliances, change issues and maintains a common repository for interface data that is accessible to the relevant project participants. The interfaces should include, PC interfaces and environments for verification, validation, operations and support.

The primary dependency is on **TS: SP 2.3-1 Establish Interface Descriptions which** establishes and maintains (manages) the solution for PC interfaces , PCs ,lower level PC and higher level PC,PC and product -related life-cycle processes, PC and external items. The second dependency is on **SP 3.1 Implement the Design** ie the fabrication or coding activity that includes the allocation, refinement, and verification of each PC. It also involves the coordination between the various PC development efforts. Any changes happening to interface descriptions needs to be configured and version controlled so that all can know the current state of interfaces. (CM)

*Typical Work Products of TS like interface design; interface design documents and implemented design help generate the following work products in PI that enables interface management*

:

1. *Table of relationships amongst PCs and between PCs and the external environment.*
2. *List of agreed-to interfaces defined for each pair of PCs.*
3. *Reports from the ICWG meetings.*
4. *Action items for updating interfaces*
5. *Updated interface description and defined APIs*

## **PI: SG 3 Assemble Product Components and Deliver the Product**

### **SP 3.1 Confirm Readiness of Product Components for Integration**

**Confirm, prior to assembly, that each product component required to assemble the product has been properly identified, functions according to its description, and that the product-component interfaces comply with the interface descriptions.**

This practice of PI is enacted after the activities performed in **TS: SP 3.1-1 Implement the design** and that includes:

- . Software coding, data, services and process documentation
- . Electrical and mechanical parts are fabricated and facilities construction

*For Software Engineering it also means*

- . *Structured programming using coding standards with coding and reuse criterion*
- . *Object-oriented programming*
- . *Automatic code generation*
- . *Use of applicable design patterns*

#### **Unit testing:(Verification)**

Various types of unit testing like functionality test, loop test, smoke test, exception test etc are performed using various methods like statement/branch/full path, boundary value analysis, equivalent partitioning etc. Whatever are the defects found in the program are removed and the program is retested using regression testing. If there are no defects found and the test stop criterion is satisfied, then the program is ready for assembling or integration.

Clear test reports from **TS:SP 3.1-1 Implement design** practice signals readiness for the **PI:SP 3.1 Confirm Readiness of Product Components for Integration**, creating assembled products or PCs.

### **SP 3.2 Assemble Product Components**

***Assemble product components according to the product integration sequence and available procedures.***

This is assembly and build function and it logically follows **PI:SP 3.1-1** (coding and unit tests) but has interdependencies with **TS:SG2 goal and its practices ie. Design product, PCs, technical data package,**

**establish and design interfaces and make – buy – reuse analysis.** While assembling it is necessary to follow the **PI sequence (PI:SP1.1-1),procedures (PI:SP 1.3-3) and verify(Verification)** the product design, PC design, interfaces and COTs components.

Deliverables generated are assembled product or PCs with record of configuration status, serial numbers of the PCs, types, and measurements.

- **PI:GP2.6** PI configuration items(CM) should be consistent with that of the work products delivered by the TS practices(defined in the table below) to ensure the **PI:SP 3.2-1 (Assemble PCs )** happens as intended.

### **SP 3.3 Evaluate Assembled Product Components**

This evaluation involves examining and testing assembled PCs for performance, suitability, or readiness using the available procedures and environment as per PI sequence, available procedures and the needs of the product architecture. Integration testing and review can done progressively, or one step at a time or if need be the Integration testing can be done only after all the assembled PCs are ready for testing. Deliverables of this activity are exception, Interface evaluation reports and PI summary reports.

This practice evaluates the product on the basis of the **TS: SP 2.1 Design the Product or Product Component** and **TS:SP 2.3-3 Design Interfaces Using Criteria** in **TS:SG2**.

### **SP 3.4 Package the assembled product or product component and deliver it to the appropriate customer.**

The packaging requirements for some products may be addressed in their specifications and **verification** and **validation** criteria. The activities include effective methods to package and deliver the assembled product, preparing the operational site for installation, install the product, get it operational and deliver the product and related documentation. Also review the requirements, design, product, **verification and validation** results, and documentation to ensure that issues affecting the packaging and delivery of the product are identified and resolved. If items are stored and transported by the customer, there may be environmental and stress conditions specified for the package circumstances. Examples of software packaging and delivery methods include magnetic tape, diskettes, compact disks and other electronic distribution items. As **TS:SP 2.2 Establish and maintain a technical data package** includes all applicable technical data such as drawings, design descriptions, design databases and **“packaging details”** it impacts this practice. This practice delivers packaged product or PCs and delivery documentation.

### **Generic Practices:**

In the generic practices the following are the relationships and interdependencies between TS and PI.

- **GP 2.2** While planning the PI sequence, adequate relevance should be drawn from TS: SP 2.1-1 and TS:GP 2.2.
- **GP 2.3,GP 2.4 and GP 2.5** : Adequate technical and trained human resources should be provided for PI that can understand the Products, PCs, interfaces, design, implementation issues and product support documentation generated during enactment of TS practices ie. TS:SP 2.1-1, 2.3-3,3.1-1 and 3.2-1.PC interface coordination may be accomplished with ICWG consisting of people who represent external and internal interfaces and to elicit needs for interface requirements development. Prototyping tools, Simulation tools and Interface management tools are the common resource needs for TS and PI activities apart from other individual needs. Both the PA call for training in Application domain of product and PC and the respective procedures and criteria.

- **GP2.6** PI configuration items should be consistent with that of the work products delivered by the TS practices (defined in the table below) to ensure the PI:SP 3.2-1 (Assemble PCs ) happens as intended.
- **GP 2.7** Both the process areas have a common set of relevant stakeholders from customers, end users, developers, producers, testers, suppliers, marketers, maintainers, disposal personnel, and others who may be affected by, or may affect, the product as well as the process. ICWG should be also involved in proceedings to ensure the interface compatibility.
- **GP 2.8** The team managing TS and PI operations needs to be trained and aware of all the activities done by the TS team (and vice versa) to resolve issues, non-compliances and ensure the right PI of the PCs. TS tracks cost, schedule effort, requirement metrics, size and complexity of product, PCs, interfaces and documentation and defect density of work products. Whereas PI tracks PC integration profile, integration defects with aging.
- **GP 2.9 and GP2.10:** During audits, the PI activities and the deliverables should be reviewed and mapped with those of the TS. Non compliances and uncontrolled deviations should be recorded effectively wrt interdependencies between the processes and the mapping tables, mapping interfaces to the PCs and PI environment along with the table of relationships amongst PCs and between PCs and the external environment. Senior management may periodically (or if required on event driven basis) review all the issues, non compliances and the effectiveness of Ts and PI process end to end.
- **PI GP 3.2 :** Improvement information may be collected for both TS and PI during and after the enactment of their practices and review of deliverables, and the relevant procedures be updated for future implementations.

**Difference table for the work products generated (goal wise) for TS and PI:**

TS	PI
<p>TS has <b>3 goals (9 SPs with 2 base practices)</b> for TS with the below Deliverables/ work products.</p> <p><b>a) Select PC Solutions</b></p> <ul style="list-style-type: none"> <li>▪ Alternative solution screening criteria leading to solutions.</li> <li>▪ Evaluations of new technologies</li> <li>▪ Selection criteria for final selection</li> <li>▪ PC operational concepts, scenarios, and environments for all product-related life-cycle processes(e.g. operations, support, training, manufacturing, deployment and delivery)</li> <li>▪ Timeline analyses of PC interactions using OOAD and Use cases</li> <li>▪ PC selection decisions and rationale</li> <li>▪ Documented relationships between requirements and PCs, Document solutions, evaluations, and rationale.</li> </ul> <p><b>b) Develop the Design</b></p> <ul style="list-style-type: none"> <li>▪ Product architecture, PC designs</li> <li>▪ Technical data package</li> <li>▪ Interface design specifications with criteria</li> <li>▪ Interface control documents</li> <li>▪ Rationale for selected interface design</li> <li>▪ Criteria for design and PC reuse</li> <li>▪ Make-or-buy analyses and Guidelines for choosing COTS PCs.</li> </ul> <p><b>c) Implement the Product Design</b></p> <ul style="list-style-type: none"> <li>▪ Implemented design</li> <li>▪ End-user training materials, User's/Operator's manual, Maintenance manual, online help etc.</li> </ul>	<p><i>PI has 3 goals (9 SPs - no base practices)</i> with the respective Deliverables/work products listed. ie</p> <p><b>a) Prepare for Product Integration</b></p> <ul style="list-style-type: none"> <li>• PI sequence with a rationale for selecting or rejecting the sequence.</li> <li>• Verified and documented environment for PI</li> <li>• PI procedures and criteria</li> </ul> <p><b>b) Ensure Interface Compatibility</b></p> <ul style="list-style-type: none"> <li>• Categories of interfaces and list of interfaces/category</li> <li>• Mapping interfaces to the PCs and PI environment.</li> <li>• Table of relationships amongst PCs and between PCs and the external environment.</li> <li>• List of agreed-to interfaces defined for each pair of PCs.</li> <li>• Reports from the ICWG meetings.</li> <li>• Action items for updating interfaces</li> <li>• Updated interface description and defined APIs</li> </ul> <p><b>c) Assemble PCs and Deliver the Product</b></p> <ul style="list-style-type: none"> <li>• Acceptance documents for the received PCs</li> <li>• Delivery receipts/documentation, Checked packing lists</li> <li>• Exception reports and Waivers</li> <li>• Assembled product or PCs</li> <li>• Interface evaluation reports and PI summary reports</li> <li>• Packaged product or PCs</li> </ul>