3.4.4 Process Engineering

The process engineering model specifies the process to be followed by a program's product manufacturing projects to derive a product model. A product manufacturing process is a formulation for the managed specification, generation, evaluation, deployment, and evolution of instances of an associated product family. An adjunct to this specification is provision of a corresponding product manufacturing capability.

The essence of product manufacturing is the development of a product specification. A product specification is a (partial or complete) resolution of the domain decision model. An instance product model is derived by applying a product specification to the product family model:

[product family (product specification) == product model] -> product

A manufacturing capability is a realization of assistance/environment provided to product developers for the performance of the specified manufacturing process to build customized instances of the product family.

{effect of targeted investment/DsE process capability level for domain (in 3.2?)}

Product Manufacturing Process

{address hdw/sw codesign tradeoff; how this is factored into process engineering (defining the manuf process for both hdw & sw components)}

The manufacturing process element specifies the capabilities needed by projects to perform product manufacturing for the domain, referencing the decision model and product family engineering model elements. In general, these capabilities encompass the notional elements of product manufacturing (as described in section 3.3): project management, product specification, product derivation, product evaluation, and product delivery.

In practice, the process may anticipate and support conventionally developing parts of a product that are not supported by existing domain capabilities (i.e., the product family model is only a partial realization of its envisioned scope). Generally, this would entail a

product design accommodating optional components that have defined interfaces but are not yet implemented for all deferred decisions in the product family model.

A product manufacturing process has an analogous objective to basic software-based product development—timely delivery of a product that meets the needs of a customer —but with improved quality and lower cost to build. DsE product manufacturing should in some form support six essential capabilities:

- project management – the means to orchestrate the incremental and iterative performance of the process for realization of a product customized to a customer's specific needs

- product specification – the resolution of deferred decisions to specify a problem-solution that represents the essential needs of a customer

- problem-solution evaluation (validation) – the evaluation of the degree to which the product specification is consistent and complete relative to a best understanding of actual customer needs given domain capabilities

- product model realization – the derivation from the product family model, based on a product specification, of a product model for a deployable product

- product model evaluation (verification) – the evaluation of the degree to which the product model is a consistent and complete realization of the product specification

- product delivery – the deployment and support for operational use of a product by a customer

A Product Specification

A product specification is the resolution of the decision model that has been specified as characterizing a product family. The decision model is a structured representation of a set of deferred decisions that are meaningful to customers. Each resolution of a decision eliminates instances of the product family as candidates, resulting in a subfamily.

Decisions are iteratively resolved, resulting in progressively smaller product subfamilies, until a single buildable product has been identified.

The process engineering model defines a medium within which developers can specify a customized product. A product specification is the means by which resolution of deferred decisions are captured. When completed, this is sufficient to characterize a particular instance of the supported product family as the product that is the best buildable fit to a given customer's needs.

<-------------- (some or all of the following may belong in 3.4.2)

The decision model may be organized into a single or multiple decision sets. Each decision set can be presented to the developer in the product specification in differing formulations. Each decision, depending upon its particular resolution, may warrant the resolution of other dependent decisions. As decisions are resolved, the set of products that correspond to those decisions is reduced. A product family corresponds to a set of buildable candidate products from which a developer can select one that best fits a given customer's specific needs.

(a simple linear/tabular conditional-hierarchical series of questions eg selecting & tailoring of available capabilities, a constructive model eg specify hdw config that determines product capab & selective physical layout of facility)

The decision model defines the range of values that can be given to each decision. The process requirements element specifies how individual decisions and decision sets are presented to a developer. An individual decision can take any of several forms:

- Every decision initially, having an uncertain resolution, has an undefined value. Alternatively, it can be designated as having a default value. A developer can be given the means to assign or remove a decision's value

- A decision may be constrained to a limited or fixed value when the product family model as currently specified does not support its full range of values. The developer may be informed of such implementation-based limitations so as to evaluate its significance to the customer.

- A decision may have a value that is determined in relation to the changing values of other decisions, including whether any such decision has a known or unknown value.

- A decision or decision set that has been specified as multi-valued (ordered or unordered) can be given multiple values of the associated type.

Optionally, any decision or decision set, whether specified as being single- or multi-valued, may be given multiple "candidate" resolutions until a best value has been resolved (i.e., the product is an instance of one of multiple alternative subfamilies, depending on a final resolution;). Generally, this supports differing values being given by developers or determined based on other decision values, establishing a conflict as to the correct resolution. Associated criteria are needed to resolve this conflict. Each value can be assigned a level of confidence by the developer or be computed based on the confidence associated with decisions referenced in computing the value.

decisions may be ordered or developer selected to resolve; one set of decisions or partitioned (eg, per work product or user role)?

- how decisions within a variability-based model are presented to a developer as a product specification

- applying a product specification to the product family to derive the corresponding product model

- evaluating the product, using the product analytics and product verification models relative to the product environment model, all as defined by the product model

- building, deploying, and supporting the product in customer evaluation and operational environments

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Product Manufacturing Capability

A product manufacturing capability is a software-based product that supports performing a specified product manufacturing process. This product is definitive guidance on the performance of the specified product engineering process for the product family with which it is associated. Depending on the level of program investment in domain engineering, this guidance may be augmented with partial or fully automated support for that process.

A domain-specific environment enables, through the provision of appropriate mechanisms and raw materials, the streamlined building of instances of an encompassed product family. The process requirements element specifies the needed mechanisms and the product family element provides the raw materials from which customized products are derived.

a variant of software development project with the specified manufacturing capability as its product. result is a mix of automated capability and developer guidance. (simplest process provide written materials that support manually deriving and applying prod spec to product family to derive instance product.)

A DsE product manufacturing capability is not intended to be an efficient or effective means for building products outside the scope of the product family. The more narrow an environment's scope the more efficient it will be within that scope and the more it will inhibit building anything outside that scope. Modifying a generated product may serve as an expedient for building an otherwise excluded product but can be difficult not just initially but over time as its associated needs change. A better alternative is to initially build only a close approximation of the needed product and then extend the domain to encompass the missing capabilities of the previously excluded product. In fact, a domain is intended to evolve over time, not only to extend the product family to permit building previously excluded products but also to accommodate changes in the market composition and its aggregate needs.

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specify product model (decisions) {may be compartmentalized}

evaluate(->validate) model with analytic & empirical (w env simul) capab

generate (whole or operationally useful) product {incl deliverable materials (user docum)} => derive rqmts, design, component, & delivery models; => derive env, analytics, & verif models

verify product to product model

{see 2.9 => deliv & oper supp to customer} {plus validate to decision-based customer needs & certif criteria}

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