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Editorial

Analogy for a Concurrent Product Design, Development and Delivery (PD^3) Process

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1. Introduction

The product environment in modern manufacturing is very complex. It consists of many elements of products, processes, and services, including information technology (IT) services (IT hardware, software, networks and communications). The design of an automobile, for example, involves 2000 to 3000 parts, and literally calls for thousands of engineers making millions of design decisions over its life-cycle. None of these parts are designed and developed in isolation from each other [4]. Figure 1 compares the process of a product design, development and delivery (PD^3) [2] with a process of fluid-flow through a maze of pipes. Each pipe of an assembly represents a part or an information build-up activity in a conventional PD^3 process [4]. Serial engineering process involves a number of connected parts or repeated activities of an assembly, such as plan, redo, down-load, up-load, iteration, retrieve, store, etc., which must be performed in the proper sequences. The fluid flowing through the pipes denotes information flow of a PD^3 process. The fluid pressure is equivalent to needs for information build-up in a PD^3 process. The activities or parts to be designed are represented by straight pipes. The cross-section of each pipe represents the corresponding design parameters. A typical conventional decision-making step is shown in Figure 1 by a pipe elbow or an end-coupling. Similar to how an end-coupling changes the direction of the fluid-flow, decision-making in the conventional serial process changes the steps or parts required for subsequent information build-up. The length of each pipe in the assembly denotes the time it takes to complete or build-up the necessary information for the next serial step of a PD^3 process. Each design decision is a trade-off affecting many other design decisions or selection of parameters. Such a traditional breakdown of design tasks, even though it resembles a hierarchical pattern, is repetitive and inefficient [6]. Decision-making in the conventional PD^3 process, therefore, can be very difficult and total lead time could be very large considering the magnitude and complexity of the products and processes that need to be addressed. These complexities are often compounded by the presence of the following domain factors [5]:

- *Large Interconnected Components:* There is a high stake on decisions that must be made simultaneously. In modern manufacturing, where both parts and information move rapidly through a plant, a small change (say a material change) at design-end of a PD^3 process can have a significant impact on the production-end. This is likely whether or not parts are stamped, machined, or injection molded. Most changes—static or dynamic—must be managed in real time.

$$\frac{\Delta\text{production}}{\Delta\text{design}} \Rightarrow \text{Large (A factor of 100 or more)} \qquad (1)$$

- *Limited Resources:* Most modern manufacturers have down-sized their resources (7Ts, as shown in Figure 1 [1]) to a bare minimum. Resources are shared to contain costs. Repetitive high demand of shared resources increases the burden of managing them efficiently:

$$\{T\} \le \{T_{max}\} \qquad (2)$$

where the set $\{T\}$ = [talents, tasks, teamwork, techniques, technology, time, tools] and $\{T_{max}\}$ is the allowable stretch of $\{T\}$.

- *Geographical Distributions:* Manufacturing is a global phenomena; it is distributed over a vast geographical area. For example, a part may be designed in Detroit, manufactured in Kentucky, and assembled in Korea or Mexico. Thus, the costs of travel, transportation, relocation, communication, currency exchange, and labor agreements are some of the additional parameters that are commonly factored into the cost equation.

$$\begin{aligned}\text{Cost} = f\,[&\text{Travel, Transportation,} \\ &\text{Relocation, Communication,} \ldots\text{, etc.}]\end{aligned} \qquad (3)$$

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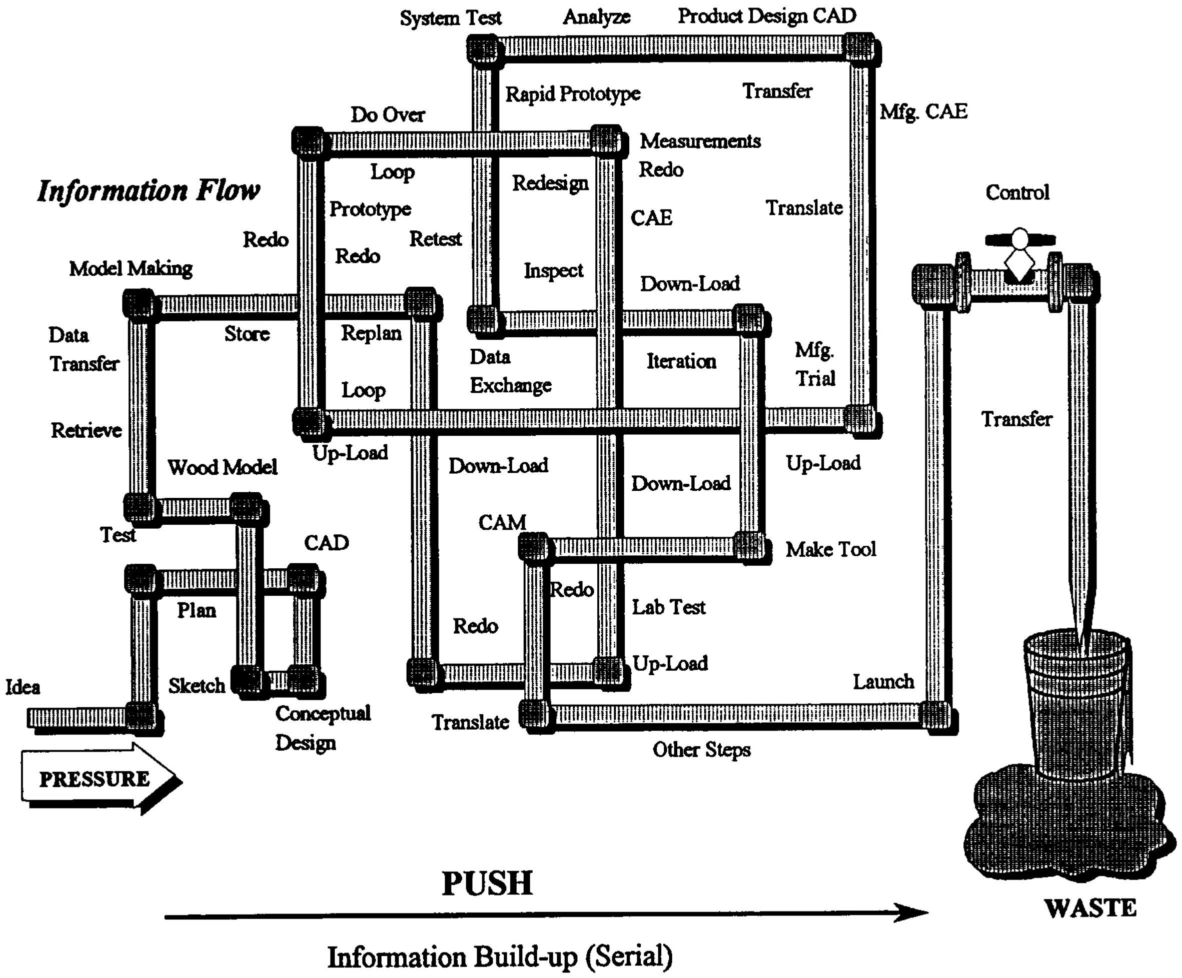

Figure 1. An analogy for a serial PD^3 process.

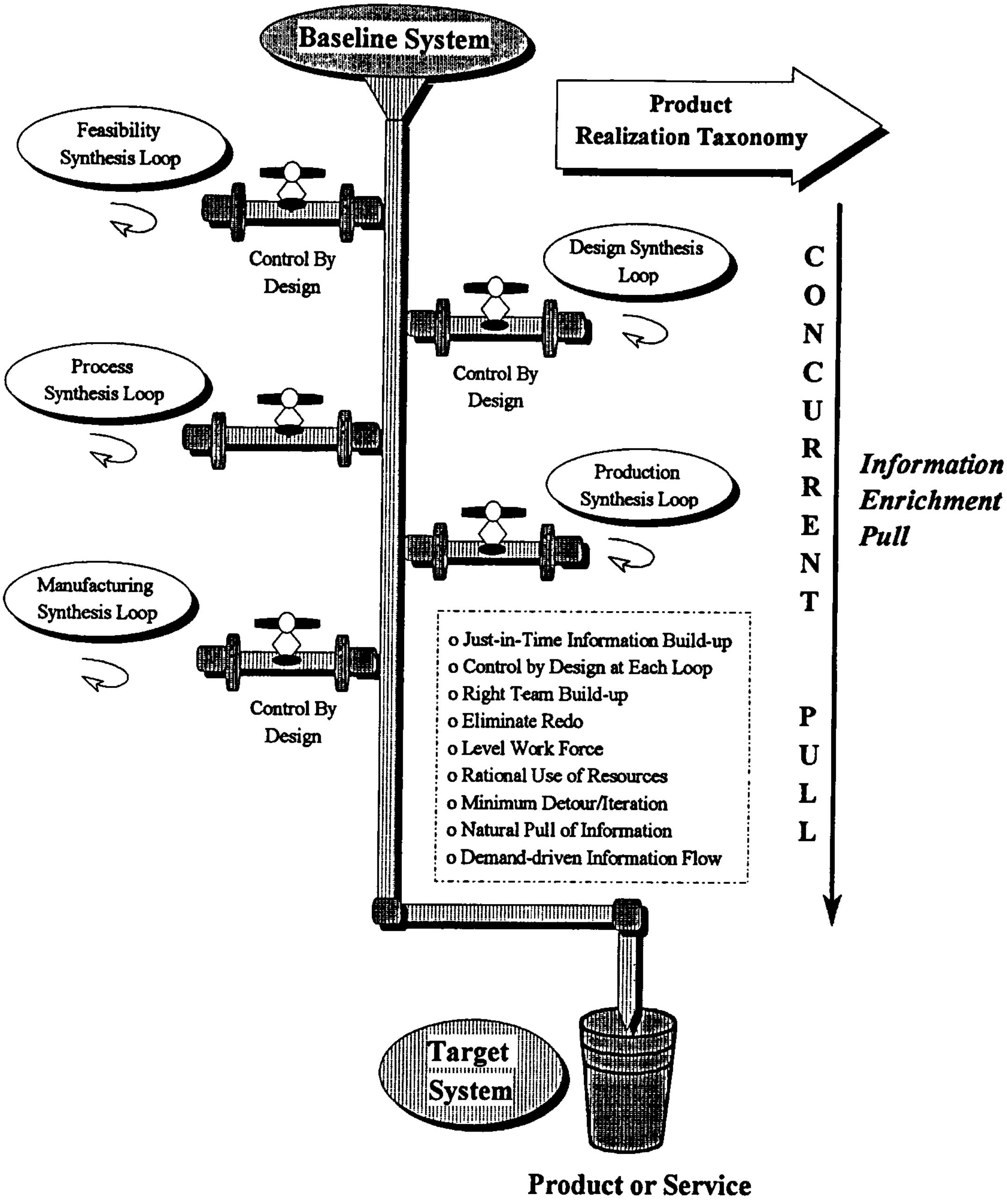

Figure 2. An analogy for a concurrent PD^3 process.

- *Many Goals & Objectives:* In most large companies, there are sets of independent goals and objectives, F_{ui}, developed by each independent department or unit. Not all of these goals and objectives are in agreement with the enterprise goals, mission statements or its vision, F_{ej}, assuming the latter exits. There is often no constancy-of-purpose between these independently specified goals. The situation gets worse if there are more than one strategic business units (SBU), each having its own set of independent visions or mission statements. If we define

$$\text{Goals that may be in Conflict} = \cup\,(F_{ui}, F_{ej}) \qquad (4)$$

where big $\cup$ stands for Union-of. The small u stands for a unit, and e stands for an enterprise.

The goals that are good candidates for constancy-of-purpose are those for which intersections of F_{ui} and F_{ei} are nonzero.

$$\text{Constancy-of-purpose Goals} = \cap\,(F_{ui}, F_{ei}) \qquad (5)$$

The terms u and i in F_{ui} take a value as governed by: $1 \leq u \leq$ number-of-SBUs, and $1 \leq i \leq$ number-of-unit-goals.

The subscript j in F_{ej} take a value as governed by: $1 \leq j \leq$ number-of-enterprise-goals

A method is a specific way of capturing and displaying information concepts (Webster's New College Dictionary, [7]). Various methods for CE were captured on the basis of taxonomy in Chapters 1–4 of Volume 2 [4]. In Chapter 5 of *Concurrent Engineering Fundamentals, Volume I* [3], key success factors for realizing team cooperation—7Cs (Collaboration, Commitment, Communications, Compromise, Consensus, Continuous Improvement, and Coordination) were described. Chapter 7 of Volume I contained a general classification for information modeling, while Chapter 8 of Volume I, described what constituted a functional "whole system." Chapter 9 of Volume I [3] discussed taxonomy for product realization.

$$\begin{aligned}\text{Product realization} = \cup\,(&\text{Planning, Design, Process,}\\ &\text{Production, Manufacturing or Assembly,}\\ &\text{Delivery and Service)}\end{aligned} \qquad (6)$$

2. A Concurrent Analogy for an IPD Process

Figure 1 showed "a fluid flow through a pipe analogy" for a serial PD³ process. The same analogy has been redesigned now in Figure 2 for a concurrent PD³ process. Instead of placing the control at the end of the pipe assembly as in serial engineering, the control is now placed at each loop-level of the concurrent product realization process. This is called control by design at each loop level. The configuration of the pipe connections and their relative positions along the vertical direction is governed by the taxonomy of product realization as discussed in Chapter 9 of Volume I [3]. The numerous bends and elbow-connections in Figure 1 have been replaced by loops tapped in at designated points (and governed by the taxonomy) along a vertical tube. The fluid pressure in the pipe is created naturally due to the gravity force. In a concurrent PD³ process, this is equivalent to "just-in-time" information build-up for each loop. Five loops run concurrently as shown in Figure 2. The amount of information build-up at each loop level is governed by a natural pull of the information rather than a force "push" found in the serial engineering case. There are many advantages associated with the concurrent IPD methodology. The methodology recognizes that product and process data in the early stage of product development is fuzzy, incomplete and often uncertain [8]. Concurrent IPD provides a taxonomy-based CE process to sort through this fuzzy set of information to establish rationally what will work and what will not. The methodology balances the needed reduction in responsiveness (with respect to time-to-market) against the risk of design changes by using incomplete or uncertain information upfront in the taxonomy-based process. The IPD methodology thus provides an integral mechanism to manage the risks appropriately. Concurrent IPD eliminates excessive redo, minimizes detours and iterations, and requires a leveled work-force. The methodology is based on rationally utilizing the resources, and demand-driven is the main accessing mechanism for pulling information through a process taxonomy maze.

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