Teledyne Benthos Adapts the Toyota Product Development System

An inside look at one company's journey.

Patricia Panchak

Everybody in manufacturing by now knows that Toyota knows something about product development that most other companies don't. Until recently, however, the car company's ability to deliver new high-quality vehicles twice as fast and with a quarter of the number of engineers as other car makers remained a mystery. Now many manufacturers are discovering some of the strategies Toyota employs to attain such unmatched new-product development benchmarks.

Still only a few North American companies have begun to adapt and implement what they know of the vaunted Toyota Product Development System (TPDS), as the company's process has come to be known. Kohler Company, Eaton Corporation, HP, and Ford Motor Company are among the first and furthest along in implementing product development processes (PDP) based on the TPDS principles. Few are willing to talk about their progress because they don't want to risk losing the competitive advantage they'll gain by it. Teledyne Benthos is one company among this elite group who, two years into its PDP transition and getting ready to introduce later this year its first product developed with the new process, is willing to tell its story.

A leading provider of undersea exploration systems, as well as quality control instrumentation used in packaging, Teledyne Benthos launched its most recent initiative to transform the company's PDP in 2005. The company had been working to improve operations and new product development process since President Ron Marsiglio joined the company in June 2001, the end of a fiscal year that Marsiglio characterizes as "a very difficult time, (when) everything was going the wrong way."

In Brief

Teledyne Benthos is on a journey to create a knowledge-based product development (KBPD) process. It is one of the first and furthest along in North America of the conversions to a new product development process based on the Toyota New Product Development system.

About Teledyne Benthos

Teledyne Benthos, North Falmouth, MA, is a leading provider of undersea exploration systems for oil and gas companies and oceanographic researchers, as well as quality control instrumentation used in the food, beverage, and pharmaceutical markets. The company was formed in January of 2006 with the merger of Benthos, Inc. into Teledyne Technologies, Inc.

"When I came here in 2001, the product development process was quite loose," Marsiglio says in understatement. "One remotely operated vehicle came out four or five years ago, and I think we only sold one. It was overweight, under-featured, and too expensive." Soon after his arrival, the company made its first attempt to improve product development and operations along lean principles with funding from the Commonwealth of Massachusetts. To help, the company enlisted the Center for Competitive Change at the University of Dayton, in Dayton, OH, with whom Marsiglio had previously worked.

By 2003 Teledyne Benthos had implemented a new PDP based on the traditional stage-gate approach. With this approach, engineers got specs for a new product from the sales and marketing department, along with a schedule and a budget, and then worked to meet them. At several predetermined stages in the development, the company reviewed its progress and decided, based on a variety of factors, whether the product would continue to the next phase of development. "It was certainly better than what we'd had," Marsiglio says. "We got better results but the product would still be late, and our success rate was close to zero in terms of hitting all the specs without expensive loop backs." The stage-gate process assumed that the remotely operated vehicle specs and the cost-size-payload requirements set out in the initial design could be balanced out, but they couldn't be, he explained.

It's a problem most companies can relate to — and one that the TPDS elegantly addresses.

By April of 2005, Marsiglio and the engineering team were ready to start over from scratch. "At that time, we knew we wanted to do something really different with product development, but we had no idea what that might be," he said. The timing coincided with the release of Michael N. Kennedy's book, *Lean Product Development*, which described a fictional company's struggle to identify a new PDP and its discovery of and attempts to understand the TPDS. The consultants at the Center for Competitive Change had heard Kennedy speak at a conference and decided Teledyne Benthos would be the perfect company to try to adapt it. It seemed intriguing, Marsiglio recalls, but no one seemed to have implemented it.

Marsiglio read Kennedy's book, then told his engineering staff, "You guys are going to read this too," relates Robert Chevalier, Jr., a Teledyne Benthos engineering manager. The engineering staff thought the ideas were intriguing, but "it wasn't like a big light bulb went off. It was kind of soft. It sounded good, but what do you really do?" At first, he and the other engineers were skeptical, but it got them thinking and talking. "It convinced you that there was a better way of doing things — that you had to think a different way," said Ken Scussel, another Teledyne Benthos engineering manager.

Within a short time, the engineering team realized the fundamental flaws inherent in traditional product design that the new process would fix. Three lessons stood out and became the basis for the company's new process, called the Knowledge Based Product Development (KBPD) process. They are:

1. Test first, then design — not design, then test.
2. Customer interest is the engineers' job, not the sales and marketing team's.
3. Capture the knowledge developed during the process.

Test First, Then Design

"Mike Kennedy and Associates convinced us that before you design a product, you have to know you can produce it," says Marsiglio. "Instead of design and test, they convinced us to test and design. That was

Learning-First Product Development (LFPD)

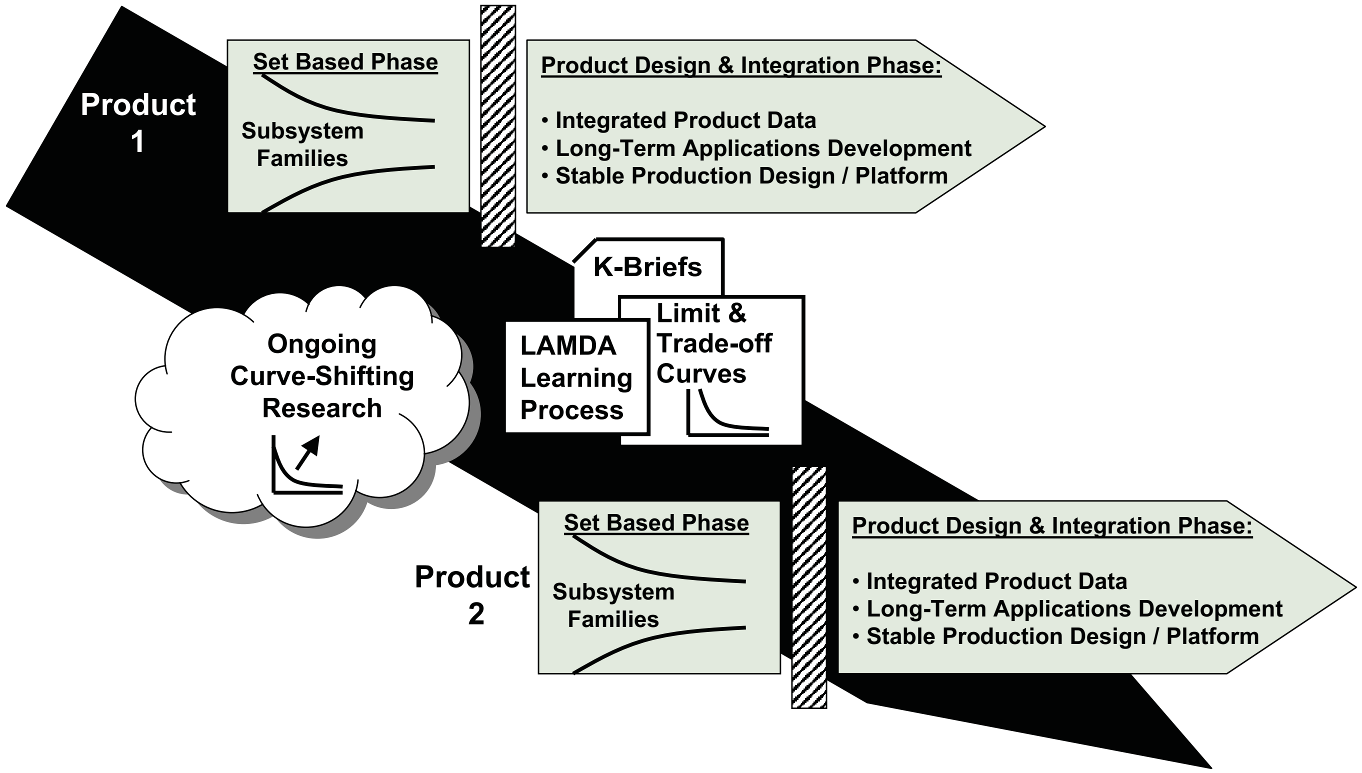

Figure 1. Teledyne Benthos' Knowledge Based Product Development process is derived from Michael N. Kennedy's Learning-First Product Development, based on the Toyota system. (Teledyne Benthos does not release its internal version for competitive reasons.) Courtesy of Michael Kennedy, Targeted Convergence Corp.

Set-Based Thinking

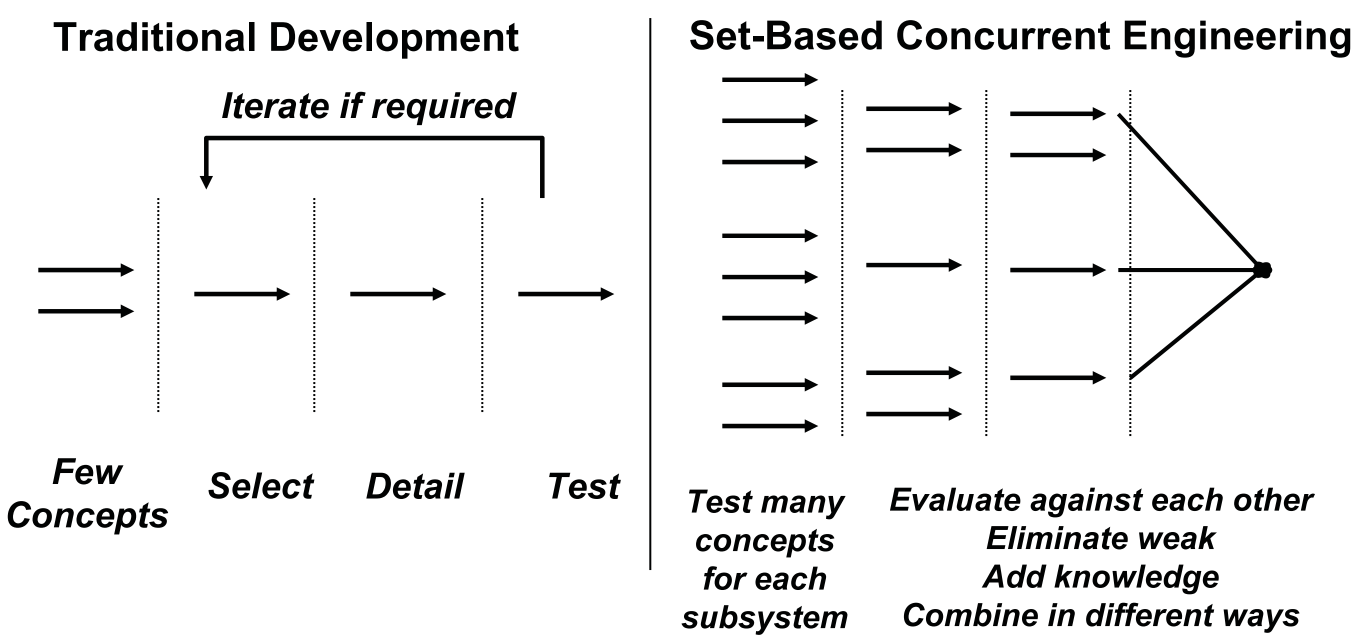

Figure 2. Traditional product design, illustrated on the left, sets design specs at the beginning and then designs to meet them, which then requires a lot of "loop-back" because one design change affects much else. TPDS, on the right, flips this around. Engineering concurrently tests a variety of sub-component designs, eliminating the need for many loop-backs and maintaining flexibility to move the project forward. Courtesy of Michael Kennedy, Targeted Convergence Corp.

Key Differences in NPD Process Observed at Toyota

Category	Traditional	Toyota
Design decisions	Made as early as possible	Delayed as long as possible
Design iterations	Design is iterated until specs are met (or time runs out)	Specs converge with design decisions
Prototyping & Testing	Verification so team knows what to fix	Build knowledge from which design decisions are made
Project management	Administrative - small group creates detailed task based plans, and tracks progress	Technical - Chief Engineer defines product concept, milestone dates. Engineers create their own plans
Manufacturing Involvement	Follower and advisor who receives design	Customer / driver who sets most tolerances and some specification

Figure 3. Summary by Michael N. Kennedy, Targeted Convergence Corp., of primary conclusions by the late Alan Ward and others from a lengthy University of Michigan study sponsored by the National Center for the Manufacturing Sciences, Ann Arbor, MI.

one of the big changes." The concept turns traditional product development on its head: The old way, the product specs are established at the beginning of the process, then designed and tested as the product progresses through development. With KBPD, as with TPDS, the product specs are not finalized until as late as possible in the process.

The big problem with the traditional approach is the dreaded loop-back. Inevitably, during the design process, the engineers discover they do not have the knowledge to achieve one or — more often — more of the specs, and must "go back to the drawing board" to accommodate a design change. Once the original specs are changed, a cascading set of loop-backs for each of the other product components — already well-along in the design phase — also must occur to accommodate the first change. The result is frustration, delays, and cost overruns.

By finalizing the product specs after tests are complete, the company eliminates loop-backs and gains the flexibility needed to keep the project moving forward.

Customer Interest

With engineers responsible for determining customer interest, the decision-making focus changes as well. Says Scussel: "In the old process, the decision point was how much money can we make — or think we can make." It was marketing driven, with only vague ideas of what the customer wanted and what the engineering team could design within a specified amount of time and a set budget. Engineers tend to be isolated from the customer, instead getting directives about new product attributes from the sales and marketing department. With KBPD, the engineer owns the responsibility for understanding the customer interest and plays at least a coequal role with sales and marketing in determining and meeting customer interest. (At Toyota, the chief engineer has sole responsibility for intimately understanding — and meeting — the customer interest. When Toyota embarked on designing a full-sized pick-up truck, the Tundra, it was the chief engineer who set out on a cross-country road trip to discover first-hand what pick-up drivers want.) As a result, the engineers get specs they can work with. "Before, engineers might get information that was too generic, such as 'the product needs to be easier to use,' or too specific," Scussel says. When made responsible for knowing customer interest, the engineer can work to fully understand the customer need by asking the "five whys" and match that with the engineering knowledge the engineers can deliver.

The new process helps engineers avoid over-engineering out of fear or the desire to perfect a technology beyond what the customer is willing to pay. "Now, because we know the customer interest and we've run the tests and have the limit curves, we can be sure where we're meeting the customer interest," Chevalier says.

"And we're only spending money where it makes a difference," Marsiglio adds. "Engineers are often accused of polishing the cannon ball to get it rounder and smoother, but a cannon ball only needs to be round enough to work." With this new process, he says, the engineers have become more aware of that. "We're shooting for 'that's good enough,'" he adds. "It'll be exciting for customers to get a product that meets their needs better than anything else and earn money for the company. Not being an endowed academic institution, we're not *only* after the endless search for knowledge."

Lest engineers or other executives misunderstand, the goal is to put the investment in design that matters to the customer, not to short-change innovation or quality to save a few pennies. "There's no point putting racing tires on a car if you're going to drive 60 miles per hour," Marsiglio asserts. "You have to know what's important." The engineers then find the challenge is to hit the sweet spot of delivering the right technology at the right price at the right time, rather than in pushing technology for technology's sake.

Capture the Knowledge

A cornerstone of the KBPD process is the Knowledge Brief (See, "What's a Knowledge Brief [KB]), a single sheet of 11-by-17-inch paper on which is recorded all information about a particular aspect of a specific product under development. (At Toyota it's called an A3.) With traditional product design, knowledge resides with the engineer and is not captured for future company use. Prior to implementing KBPD, for example, the only place Teledyne Benthos engineers kept notes about the technology they developed was in engineering notebooks that only the author could understand. "When they left they had boxes of them," says Rick Smith, engineering support services manager. "We put them in a box and sent them into an archive. It was a daily drain on the knowledge from the company." Scussel adds: "Engineers would come to me before, and they would ask a question. I'd get on a white board and do a whole diagram, the next guy would come in and I'd erase it and do another. Now I put [such diagrams] in a KB." The benefit: the company now owns that knowledge, and Scussel doesn't have to repeatedly explain the same concepts to different engineers; he can direct them to the KB.

It's critical to note that the KB reports are not just another database of best practices information. According to Mike Kennedy, "Many companies have really good knowledge capture — best practices databases and the like — and they think they're doing a really good job. But when they really think about it, they realize they don't use the knowledge. It has to be a system, integrated into the product development process, not a report written up at the end of a successful launch. We all think we're going to write that report. But few people ever do."

The KBs are logged and stored in a database with some search capability. They include information about why a

What's a Knowledge Brief (KB)?

Teledyne Benthos uses 13 types of Knowledge Briefs (KBs) to capture product development knowledge in a short, concise, and consistent format that anyone in the company can understand. The KBs start out as blank forms, with a set of questions and statements that guide the person writing them, much like an open-ended exam.

What follows are brief descriptions of the KBs and the type of information collected in each.

Customer Interest KB is used to describe the customer interest in detail, how it was defined, and which customers it serves. Information includes:

Description of Customer Interest:
LAMDA: How was this interest defined (VOC)? (See Figure 4, "What's LAMDA?")

Who is (are) the customers:
Analysis of customer need and competitive position:
Model of customer problem creating the interest:
Statement of the customer interest as a design decision:
Actions for determining if customer interest has been satisfied:
What is the range of this customer interest?:
Which class of interest does this fall into (Performance and Functionality, Quality, Reliability, Safety, Cost)?:
What are the units of measure/figure of merit for this customer interest?:

General Proposal KB is used to propose a new course of action or project; offers background, justification, alternatives, and an action plan:

Background:
Objectives:
Strategies:
Recommendation:
Implementation:

Proposal for Improvement KB is used to propose a new course of action or project; offers background, justification, alternatives, and an action plan:

Current State or Situation:
Analysis:
Vision of Future Statement:
Gap Analysis:
Implementation Plan:

Proposal for New Product KB is used to propose a new course of action or project; offers background, justification, alternatives, and an action plan:

Competitive Analysis:
Product Concept:
Simplified Specification:
Success Criteria:
Risks:
Financial Analysis (EVA):
Resource Plan:
Timeline:
Peer Review:
Knowledge Base (Limit Curves, Trade Offs):

Proposal for Solution Alternative KB is used to propose a new course of action or project; offers background, justification, alternatives, and an action plan:

Statement of the Problem:
Proposed Solution:
Why the Proposal Resolves the Problems:
Advantages and Disadvantages:
Resource Plan:
Timeline:

Proposal for Technology Development KB is used to propose a new course of action or project; offers background, justification, alternatives, and an action plan.

Background:
Needs Analysis:
Success Criteria:
Alternatives:
Financial Analysis:
Resources Plan:
Timeline:

Knowledge Brief for Information

Knowledge Brief for Relations

Knowledge Brief for Status

Knowledge Brief for Test Results

Knowledge Brief for Decision

Knowledge Brief for Problem

Knowledge Brief for Release of New Product

Compiled by Rick Smith, Engineering Support Services Supervisor, Teledyne Benthos

decision was made along with the engineering data so others can more fully understand design decisions and use them in the future. They are written in very short, concise, and standard formats, so anyone on the product development team, not just the engineers, can understand and use the information.

The process of capturing the knowledge also helps the engineers identify knowledge gaps, so they can rectify them, and enables the engineers in the company's three groups to collaborate more frequently and easily. To facilitate such sharing, the engineers at Teledyne Benthos created 12 core competency groups based on the basic knowledge the entire company must have to be successful. Each group includes a leader and six to eight engineers from across the three groups with the most experience on the specific topic (some engineers are on more than one core group). The core groups document the state of the knowledge the company has, identifies knowledge the company needs, and recommends how to learn and close the gap. They are also responsible for the peer review of the KBs within their area of expertise.

"Before (the product groups) were more autonomous," says Chevalier. So even though products from each group needed the same component, such as a transducer or a power supply, the designers didn't know that the technology to produce the component they needed already existed in the company in another group. "Before (we designed to) the best of the *group's* ability, now it's the best of *company's* ability," Chevalier says.

The Product Space Map also is crucial to the gathering, recording, and sharing of knowledge at Teledyne Benthos. The map documents higher-level, decision-making tradeoff curve design data about a particular product type. "All the technical tradeoffs are set out in a Product Space Map," says Ron Allen, a Teledyne Benthos engineering manager. "We can look at it and see if the product can be developed based on what we know, or whether we need to develop new knowledge (technology)."

Changing the Process

With the additional responsibilities of defining customer interest and writing knowledge briefs, along with making time for five two-day seminars, plus additional coaching days for each individual group over a two-year period from April 2005 to April 2007, it was difficult to know where to begin. "There was a lot of confusion on how to get started in the changeover," Marsiglio says. The project seemed daunting, as the apparent need to document the knowledge behind how all the company's products work loomed as a monumental task. "We were the guinea pigs," Marsiglio says. "(Consultants) described and trained us to understand a whole new approach, but the A-B-C-D steps to get there were not as clear to us. I think we both learned something."

The first big breakthrough happened when the team realized that it could write up problems and communicate solutions in a Problem KB instead of via long-strings of difficult-to-retrieve e-mail. "We included it as part of what we already were doing," says Chevalier. "Any problem that appeared to be significant for the customer, marketing, manufacturing, or engineering, we'd open a Problem KB, which listed the details and circumstances of the problem." Then the team would conduct a LAMDA process (See figure 4) to arrive at a solution, and, after marketing, sales, manufacturing, and engineering agreed, the Problem KB was signed off and logged into a database. The engineers easily understood the benefit of this, says Chevalier: "They are solving a problem as they are creating the KB, and the solution to the problem wasn't locked up in some engineer's brain, so if something like that happened again you can go to the KB and start where it left off." Similarly, and shortly afterward, the group also started to "jot down" customer interests in Customer Interest KBs, and the transition to KBPD started to take hold.

Still, the information gathering and recording was only the prelude to actual product development. To begin the new process, some new major product development was suspended, which, according to Marsiglio, was the hardest part of the transition. This pause resulted because the team now understood that they needed more knowledge, explains Marsiglio. They understood that in the KBPD process they needed to know they could design the product before they started to design it — that they needed to test first, then design. Adds Chevalier: "So instead of *starting the design* of a new product, we started *gathering the knowledge* for the next product."

The second hardest part was changing the culture from a "doing" culture to a "learning" culture, Marsiglio says. In traditional product development, he explains, the focus is on designing the next product, the "doing;" in the KBPD process, the focus is on gathering knowledge, the "learning." The difficulty, the engineering team agrees, is that the pressure to move quickly from knowledge-gathering to designing is intense.

"We also went into a 'stabilization mode' to finish up old projects, to clean up old issues, for a few weeks or months," Chevalier explains. "We had to finish the final loop-backs on products that were begun on the old system before we really delved into the new process."

As for who in the company needed to be involved in such a dramatic change, Marsiglio reports that the company "really didn't require much effort outside the engineering staff so far." Marketing was included in some training early on, to acquaint them with engineering's new involvement with determining customer interest.

But though the cultural transition has started to take hold, Marsiglio cautions that the company is still in the initial stages of implementing the KBPD process. The company will introduce three new products, their first developed the new way, within the year, but it hasn't been through the complete development cycle yet.

Still the Teledyne Benthos team seems to understand that the ultimate goal of the KBPD process (and of TPDS) is "to find the rhythm," says Kennedy. "What is really the greatness of Toyota, is that it has figured out how to continuously develop product knowledge so that it enables a rhythmic flow of products that customers want. That you must think about, and the company has to develop the knowledge so that it not only flows with the product, it lasts forever. And to do that, reporting has to be simple and easy." Further, he says, Teledyne Benthos is well on its way to toward achieving that goal.

TapTone's First Product Development

Even as Teledyne Benthos was refining the KBPD process, the company's TapTone group began using the process to develop a new container packaging inspection system. Within a specific market, the group was aware of a market segment that neither of two existing models satisfied: one they describe as capable, expensive, and large; the other less capable, less expensive, and smaller. So they set out to develop a system that could inspect a wide range of containers and that would be easy to install, easily adjustable for quick changeover, and require preventative maintenance only every six months.

Customer Interest

With the general knowledge of what the product attributes would be, the team began by refining their knowledge of the customer interest. They first created a high-level map of product attributes they didn't want to forget to include in the new product — essentially a list of capabilities the customer wouldn't ask for, but would expect in any new machine. The engineering team visited customers and worked with sales and marketing to formally describe the customer interest. Special attention was paid to the Voice of the Customer (VOC) to identify the product's top few physical parameters and its functionality, which in turn would drive the machines' cost, size, and performance. They came up with a set of preliminary specs that got them into the ball park. They also tried to determine the product requirements of new customers in markets that the company served or would like to serve.

The result of this first step, written down in a Customer Interest KB, was a Research and Development KB, which spelled out the research needed to assess the company's engineering ability to deliver on the customer interest, as well as the funding necessary to complete the research.

What's LAMDA?

The LAMDA Process is a cyclical investigation process with the steps: Look, Ask, Model, Discuss, Act. (It's the product development process equivalent to the Plan, Do, Check, Act process followed in most lean production processes). The design team *looked* at the information they already knew, *asked* questions about that which they didn't know, built *models* to test assumptions, *discussed* the findings, then decided and *acted* on the next step. Once the design team completed the LAMDA Process, a fresh look at the new information tells them whether they needed another LAMDA cycle or if they are ready for the next step. During this step, Information KBs are created.

Figure 4.

The LAMDA Process

The team then set out to discover what they knew and didn't know about developing the product to serve the specified customer interest. This step was made more interesting, says Chevalier, the group's engineering manager, because the engineers who had designed the existing products were no longer at the company. In the old product development process, having only a vague idea of customer interest, not knowing the limits of engineering knowledge, and not having the engineers who had knowledge of the product wouldn't have slowed the team down, Marsiglio says. The company would have specified a design at this stage of the process. "We would have started, hope against hope, that miraculously we would meet customer needs because the (engineering) group was going to work really hard."

To fine tune the product's attributes, the team used the LAMDA process to more specifically identify the customer interest, down to units of measure that the engineer could "grab hold of," start testing and ultimately say, "Yes, we can meet it or not, and if not, how do we move the curve so we can meet it," Chevalier says. For the new container packaging system, the team conducted several LAMDA cycles (Figure 4).

By reviewing the old model, visiting customers, and coming up with preliminary specs, the team had gone through *Look* and *Ask*. In the next step, *Model,* the team built a test jig, a "fixture" that doesn't look anything like the final machine, but that is capable of testing the theories of the design parameters the team wanted to meet. With the test jig, the team ran experiments to collect data on the limit curves — the physics-based limits to achieving the design, such as detection capability versus speed, that they were trying to meet. It's generally understood in packaging equipment that the faster the line, the less capable the detection. The TapTone team tested against those two and other attributes. The limit curves were published in Relationship KBs.

During this phase, the team discovered that a small, inexpensive change to the machine resulted in a fourfold increase in the capability of the machine. With their traditional product design, Chevalier says, they never would have discovered the capability.

Discuss: In spite of the discovery, the team still was unsatisfied. It hadn't yet determined how to design the machine with the speed and accuracy that they wanted, so they continued the design/test iterations. "We needed to understand the physics, and by making subtle changes to the machine, to make it perform better," Chevalier says. "We know how a change in the machine in one parameter or set of parameters will affect the other parameters."

Act: "Based on the limit curves derived in this process, we came up with where we had to be," says Chevalier. As important, Marsiglio notes, the process gained additional knowledge that can be used in future product development. He adds, "One parameter of this machine is critical to performance, but the customer expects products to include another parameter. So we needed to know exactly how to adjust the parameters. With that knowledge, future design changes will protect the critical-interest parameters, and everything else will be designed as inexpensively as possible," he says.

Further, Marsiglio says, the process allowed the team to fine tune their findings to gain maximum capability at the right price point: "If the machine were a little better than just good enough, we would have missed the price requirement."

Also, he notes: "We learned more about that machine in a couple of months than we'd learned in the last four to five years." That's knowledge that can be used in future products.

The end of this step of the process is marked by a Product Proposal KB.

Proof of Concept Build

Once the team had the engineering completed on the components, the next step was to create a proof-of-concept machine to test the components together. "The individual pieces say we can do it," Chevalier says. "So now we need to cobble together a prototype that embodies all the parameters from the knowledge curves to prove they work together in one device. We're actually going to measure whether we can meet the requirements." If the team finds that more work needs to be done to improve the machine, it's cheaper to make the changes at this stage.

Once again the team participates in the LAMDA process to determine when it's time to proceed to the next step.

"It's not a gate," Marsiglio insists. "This is building knowledge. They'll have proven they know how to build this machine. Then we'll let them loose to do it. Then, there's no going back."

Project Integration/Evaluation

The next stage brings together the design sets, cost analysis, product space maps, and resources and schedules to begin the process of determining whether the team is ready to begin narrowing design choices to those that will appear in the final product. "It's like taking a test to go to the next grade level," says Chevalier. "We ask ourselves: 'Do we have all the answers we need to get to the next step?'" Quickly, the engineering team builds a prototype with off-the-shelf parts that will work like, but doesn't look like, the final product.

Everyone in marketing, sales, manufacturing, and engineering reviews the information and has a say whether and how the product will go forward to the next step. A set of decisions are made, such as choosing the components to use in the product and setting the date for the product to be released to sales. The goal for the engineers is to choose as many standard, off-the-shelf parts with which to build the product. The team, again, is not looking for optimum, but good enough, on the most critical product attributes. "This machine will meet all the customer interests, but not more," reiterates Marsiglio, in order to deliver what the customer needs at the lowest price. "We're going to discuss and argue about styling here," Chevalier says. Engineering needs it to work; marketing needs it to look good.

It's important to note, Chevalier says that at this stage all of the final product specs are not set; it's just the beginning of the process of narrowing the design set choices to build a beta product.

At the end of this step, the staff reviews a checklist of all the elements that must be included in the final product. Once the team is certain that all the elements are included, the product moves to the next step of the process.

Beta Build

At the beta-build step, the engineers are ready to make the final decisions about the final specs of each component in the product — but not necessarily the final specs of the entire product. "At this stage," says Chevalier, "manufacturing is ramping up and engineering is ramping down." Designs for long-lead parts are decided and released to production or procurement first, narrowing the design choices for parts with shorter leadtimes. Such parts that might be released first include those that require new machine tooling to produce, or require extended procurement schedules.

With each release, design choices become narrower. If the team finds at this late stage that some new technology isn't working as expected, or that the customer need is slightly different, the team reviews its options. It goes to the product space map and reviews all the trade-off curves, and makes a different trade off so the project can move forward when needed to meet the release date. There's no need to loop-back to create new technology, because all the technology that is needed for the new product already has been created in the earlier steps of the KBPD process.

"Everyone knows what can and cannot be done at this point," says Marsiglio. "Sales people can look at the knowledge briefs on the product and determine if a product with certain features can be offered to the customer. In this way, Chevalier adds, "The now 'trivial' task of product variation can be done more quickly. The fun part comes back to engineering. If the trade-off curves are not good enough, you have to go back and move them — and that's called innovation."

Once again, the final stage of this step is a review of a checklist that lists all the elements that must be included in the final product.

Pilot Build

At the pilot build stage, engineering for the product is shut off and production takes control of the product. They'll build a run of final, saleable units, to check for any minor mistakes and, if needed, call for any engineering change orders, such as requests for a different size fastener for a hard-to-reach area. "Production is like the teacher checking the final exam, checking and testing out the documentation," Chevalier says. "But because we have so many LAMDA loops built into the design process, there should be no surprises." Following a final check of another checklist, the product is released to sales. This checklist covers generic business needs such as brochures, manuals, sales literature, and data sheets.

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