FACTORS AFFECTING NEW PRODUCT DEVELOPMENTS

Commander John T. Shields, USN

Fourteen commercial and 13 Department of Defense (DoD) new product developments are reviewed and analyzed to understand the factors responsible for reducing development times. The major groupings of factors affecting new product developments were found to be the extent and character of functional interactions, disciplined product development techniques and methods, development process adaptations and to a limited extent capital investments.

INTRODUCTION

As U.S. industry faces increasing world competition following the end of the Cold War, the United States must be extremely quick in product developments to stay ahead of other world competitors. This is a view shared by Arnold Putnam (1985, p. 139) who says,

> Investing in new technology will not alone ensure the competitiveness of U. S. industry. Things have to be run right, and processes must be efficient. Industry must do its job correctly and quickly. Despite the investment and attention it has recently given to manufacturing, American industry is still slower to market than some of its foreign competitors, and the final product often has many defects.

CDR Shields is a Professor of Engineering Management at the Defense Systems Management College. He is a graduate of the U.S. Naval Academy and holds a masters degree in aeronautical engineering from the California Institute of Technology.

Every day we see examples of how foreign products capture U. S. market share. Examples of differences in product developments between U. S. and Japanese companies are given in Table 1. However, the United States has not always lagged the world in speedy new product developments. During and after World War II, several new developments were accomplished in record time: the North American P-51 Mustang in 120 days, the Lockheed "Skunk Works" P-80 jet in 143 days, and the 1955 Chevrolet in two years. But, over the past several decades America has lost two-thirds of its machine tool industry and one-third of its automobile industry market share (Ziemke & Spann, 1991).

In numerous instances competitors have garnered market share by being faster to market. In the Boeing-pioneered wide body aircraft market, Boeing lost 50 percent of its wide body aircraft orders because Airbus Industrie came to market several years earlier with its A-300 model than Boeing's comparable Boeing 767 model (Ziemke & Spann, 1991). United Research Co. of Morristown, N.J., found that 6 out of 10 chief executive officers (CEOs) see shortening of the design and manufacturing cycle as the critical factor to

Table 1.
TIME VARIANCES BETWEEN JAPANESE AND U.S. PRODUCT DEVELOPMENT CYCLES

TYPE OF PRODUCT	JAPAN	U.S.
Aircraft (concept to delivery)[a]	6-7 yrs	12-14 yrs
Dies and Forgings (concept to production)[a]	1/2 U.S. time	
Office Automation Equipment[a]	1/2 U.S. time	
Automobiles (concept to delivery)[b]	24-36 mo	54-60 mo
Flexible Manufacturing Systems[c]	18 mo	30-36 mo

Sources:

[a] Clinton W. Kelly, III., and J. L. Nevins, et al, *Findings of the U.S. Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Arlington, VA: Defense Advanced Research Project Agency (DARPA), 1989), 15.

[b] Kim Clark and Takahiro Fujimoto, "Overlapping Problem Solving in Product Development," Harvard Business School working paper 87-048, April, 1988, in *Findings of the U.S. Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Arlington, VA: DARPA, 1989), 15.

[c] R. Jaikumar, "Post-Industrial Manufacturing," *Harvard Business Review*, (November-December 1986) in *Findings of the U.S. Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Arlington, VA: DARPA, 1989), 15.

maintain market share (Rohan, 1990). Bringing products on-line faster has other benefits which could improve both the bottom line and long term competitiveness. According to Takeuchi and Nonaka (1986), company emphasis should be on new products as a source of new sales and profits. To support this assessment, Takeuchi and Nonaka state that 25 percent of 3M's sales is realized from products less than five years old. In addition, a 1981 survey of 700 U. S. companies forecasted that one-third of profits in the 1980s will come from new products whereas only one-fifth of profits in the 1970s came from new products (Fraker, 1984).

Many different industries seem to realize the importance of time to market. According to Earl Koops, the Ford manufacturing director, "Now that the quality gap has closed, time to market is where the competitive edge is" (Owen, 1992, p. 69). If a company can decrease the time it takes to develop new products, then it can pursue new strategies. Products can have shorter lives which allows the company to make more models or to cash in on the products at their optimum profitability.

If models are quick in development then deficiencies can be quickly corrected in future models. Panasonic uses such a strategy in consumer electronics where a vast number of models in each product line is put on the market in order to see which product sells before gearing production up to full volume (Reiner, 1989). In 1981 Honda, facing a challenge from Yamaha in the motorcycle market, successfully blunted that challenge by replacing or introducing 113 new models in 18 months compared to a 60-model line before the challenge. Yamaha could not keep up, and publicly pledged respect for Honda after this remarkable new product development display (Stewart, 1989).

We have a number of examples where rapid new product developments either reflect a more competitive market environment or determine a more competitive strategy. The machine tool industry, traditionally a more static product line, recently experienced a situation where 50 percent of their current products sold did not exist five years ago. A quick development cycle and intimate working relationship with processor supplier Intel gave Compaq Computer the market lead in the introduction of the DeskPro 386 Model with only a 6-9 month development time, compared to industry average of 12-18 months. In new cars, Honda took 2 years to develop a new model whereas GM took 5-6 years. Therefore, in 10 years Honda went through the new product development process five times compared to GM's two (Reiner, 1989).

Being able to introduce new products is a defensive and offensive strategy. Durivage Pattern and Manufacturing, Inc., of Williston, Ohio, eliminated their competition by producing molds for Pontiac within four months while their competitor took twice the time (Rohan, 1990). Therefore, the supposition that speedy new product developments are crucial to maintaining or recapturing market share in the world marketplace is supported. How then can U. S. companies be world competitors through quick new product developments?

INVESTIGATION

In this article, I will investigate which factors most improve a company's ability to introduce new products speedily. Information was sought about government and commercial product developments to ascertain what was defined by the companies or various authors as key factors responsible for reducing new product development times. Where available, the reduced development time experienced was recorded. I picked 14 commercial and 13 defense industry companies for study. I evaluated each company to determine the factors which the author cited as key contributors to speeding developments, and then analyzed them to determine their relative strength in speeding new product developments in both commercial and defense product areas.

FINDINGS

In collecting data I found a number of different factors were cited as influential in reducing the cycle time. These factors are grouped into the following five major categories: functional interaction, interaction characteristics, product development techniques and methods, development process adaptations, and capital investments. Table 2 gives a more complete breakdown of these factors. I will equate functional interaction with the term "team." Interaction characteristics or team characteristics defined how the new product development teams themselves functioned. In the product development techniques and methods category, primary focus was on externally developed techniques or methods used by new product developers as a means of improving or expediting new product developments or production. In a number of new product developments, the companies modified their pocesses. I have assembled these development process changes under a development process adaptations category. Finally, a category of capital investments and major capital expenditures were linked to speeding product development or manufacture.

I investigated 27 products to determine the reason the product development was successful in decreasing the cycle time, and to establish an idea of the product development time reduction realized. Table 3 reflects the results of the investigation for commercial products, and Table 4 reflects the results for defense products. The reasons for success, as tabulated in Tables 3 and 4, are keyed to the factors by number and letter in Table 2. Only those factors mentioned as the reasons for reduced development time were tabulated. Analysis of the determinant for success can be instructive. Table 5 summarizes the individual factors which reduced the development cycle time, and Table 6 analyzes the major categories to determine rank order.

Table 2.
FACTORS WHICH REDUCE PRODUCT DEVELOPMENT TIMES

1. **Functional Interaction**
    a. **Design Engineering and Manufacturing**
    b. **Design Engineering, Manufacturing and Suppliers**
    c. **Design Engineering, Manufacturing, Marketing and Suppliers**
    d. **Design Engineering, Manufacturing, Marketing and Sales**
    e. **Design Engineering, Manufacturing, Marketing, Sales and Suppliers**
    f. **Design Engineering and Suppliers**
    g. **Multiple teams for each product**
    h. **Producibility, Reliability and Maintainability on team**

2. **Interaction Characteristics**
    a. **Collocation**
    b. **Small size**
    c. **Broadly experienced**
    d. **Team members trained or educated**
    e. **Team decision making allowed**
    f. **Guru as head of team**

3. **Product Development Techniques/Methods**
    a. **Statistical Process Control (SPC)**
    b. **Quality Functional Deployment (QFD)**
    c. **Design of Experiments (DOE) or Taguchi Methods**
    d. **Total Quality Control (TQC) or Total Quality Management (TQM)**
    e. **Just-In-Time (JIT)**
    f. **Factory layout changes**
    g. **Design for Assembly (DFA)**

4. **Development Process Adaptations**
    a. **Design rules**
    b. **Expert systems**
    c. **Attitude changes (including workforce training or education)**
    d. **Manufacturing process development overlapped with design**
    e. **Computer design tools**

5. **Capital Investments**
    a. **Automation equipment**
    b. **Computer Aided Design/Computer Aided Manufacturing (CAD/CAM)**

In the commercial products analyzed, there was no single predominant factor (as defined by having significantly more instances of being mentioned as compared to the rest of the factors). However, functional interaction factors were mentioned the most as the reason for reduced new product development time. In defense products, however, several predominant factors emerge. Engineering and manufacturing functional interaction as a factor (with a count of 9) lead followed by the computer design tools factor in process adaptations (with a count of 8). For defense products, the development process adaptations category contributed most to reducing the development process.

Table 3.
RESULTS OF INVESTIGATION INTO COMMERCIAL NEW PRODUCT DEVELOPMENT TIMES

COMPANY	PRODUCT	DATE	CYCLE TIME REDUCTION	WHY
John Deere[a]	Combine & Log Skidder	1985	50%	1b,1g,2a,2e,3f,4c,4d
Vista Chemical[b]	Chemicals	1990		1d,4d
Chevrolet[c]	1955 Model	1955	80%	2b.2c
B. F. Goodrich[d]	Carbon Brake		67%	4e
Allen-Bradley Co.[d]			50%	1a
PTA Corp.[d]	Molds		50%	4e,5b
RCA[d]	TV Chassis		50%	1a,3f
Rogers Corp.[d]	Elastomeric		70%	1a,3f
Compaq Computer[e]	PC	1980	50%	1f
Fuji-Xerox[f]	Copier	1978	24%	1b,2a,3d,4d
Murcury Computers[g]	Processor Boards		28%	1c
Boeing[g]	Boeing 777	1990	50%	1e,4e
Hewlett-Packard[g]	Oscilloscope	1980	33%	1d,1h,3d,3g,4e
Cisco Systems[g]	Multiport Comm Board	1989		1e

Sources:

[a] Richard E. Anderson, "Strategic Integration: How John Deere Did It," *Journal of Business Strategy* 13 (July/August 1992): 26.

[b] Bob Isenhour and Kathryn Payne, "Getting Serious About Product Development," *Management Review* 80 (April 1981): 20.

[c] Ziemke, "Don't Be Half-Hearted," 47-48.

[d] Rohan, "In Search of Speed," 79.

[e] Reiner, "Winning the Race," 52.

[f] Takeuchi and Nonaka, "The New New Product Development Game," 141.

[g] Alfred Rosenblatt, ed., "Concurrent Engineering," *IEEE Spectrum* (July 1991): 22.

Table 4.
RESULTS OF INVESTIGATION INTO DOD NEW PRODUCT DEVELOPMENT TIMES

COMPANY	PRODUCT	DATE	CYCLE TIME REDUCTION	WHY
Texas Instruments[a]	Micro-Electronics	1990	24%	1h,3a,3b,3c,4b,4c,4e 5a
ITT Corp.[a]	Electronic	1982-84	33%	1a,1h,2a,3a,3b,3c,4a 4c
IBM[a]	Masterslices	1980s	40%	1a,4a,4d,4e
Hewlett-Packard Co.[a]	Multiple		35%	1e,2d,3a,3b,3c,3d,3e 4c
Northrup Corp.[a]	Bulkhead		54%	1a,1h,3a,3d,4d,4e
Boeing Missle[a]	Missiles	1985		1b,1g,2b,2d,2e,3d,4c 4e
Grumman Corp.[a]	C-17			1a,2a,4e
McDonnell Douglas[a]	AV-8, T-45	1987		1a,1h,3a,3b,3c,4b,4c 4e
Raytheon Inc.[b]	Patriot	1985		1a,1h,4a,4e,5b
ITEK Optical[b]	Mirrors			1a,4c
Lockheed Skunk Works[c]	P-80	1943	20%	1a,2a,2b,2c,2e,2f
North American Aviation Corp.[d]	P-51 Mustang	1940		1a,2b,2c
Collins[e]	GPS		42%	4e

Sources:

[a] Robert I. Winner et al., *The Role of Concurrent Engineering in Weapons Systems Acquisition*, (Alexandria, VA: Institute for Defense Analyses, December 1988), 64, 71, 73, 80, 83, 87, 91, 95.

[b] Alfred Rosenblatt, ed., "Concurrent Engineering," 34-36.

[c] Ben R. Rich, Lecture, "The Skunk Works' Management Style," for Wright Brothers Lectureship in Aeronautics.

[d] Ziemke and Spann, "Warning: Don't Be Half-Hearted," 47.

[e] Rohan, "In Search of Speed," 79.

Table 5.
SUMMARY OF WHY CYCLE TIME WAS REDUCED

FACTORS	COMMERCIAL	DOD
1. Functional Interaction		
1a Engineering & Manufacturing	3	9
1b Engineering, Manufacturing & Suppliers	2	1
1c Engineering, Manufacturing, Marketing & Suppliers	1	0
1d Engineering, Manufacturing, Marketing & Sales	2	0
1e Engineering, Manufacturing, Marketing, Sales & Suppliers	2	1
1f Engineering & Suppliers	1	0
1g Multiple teams for each product	1	1
1h Producibility, Reliability & Maintainability on team	1	5
2. Interaction Characteristics		
2a Collocation	2	3
2b Small Size	1	3
2c Broadly Experienced	1	2
2d Team members trained or educated	0	2
2e Team decision making allowed	1	2
2f Guru as head of team	0	1
3. Product Development Techniques/Methods		
3a Statistical Process Control (SPC)	0	5
3b Quality Functional Deployment (QFD)	0	4
3c Design of Experiments (DOE) or Taguchi Methods	0	4
3d Total Quality Control (TQC) or Total Quality Management (TQM)	2	3
3e Just-in-Time (JIT)	0	1
3f Factory layout change	3	0
3g Design for Assembly (DFA)	1	0
4. Development Process Adaptations		
4a Design Rules	0	3
4b Expert Systems	0	2
4c Attitude changes (including workforce training & education)	1	6
4d Manufacturing process development overlap with design	3	2
4e Computer design tools	4	8
5. Capital Investments		
5a Automation equipment	0	1
5b Computer Aided Design Computer Aided Manufacturing (CAD/CAM)	1	1

In contrast, the commercial new product developments show more integration of the other functional interaction factors such as marketing, sales and suppliers as the reasons for success. In new defense product developments, the study results indicate less emphasis on multifunctional teaming as opposed to multiple discipline teaming where the "ilities" (producibility, reliability and maintainability) are the predominant team members. The highest count value for a single factor in commercial products was the use of com-

Table 6.
RESULTS OF WHY CYCLE TIME WAS REDUCED BY MAJOR CATEGORIES

	COMMERCIAL TOTAL			DOD TOTAL		
MAJOR CATEGORY	COUNT	PERCENT	RANK	COUNT	PERCENT	RANK
1. Functional Interaction	13	39%	1	17	24%	2
2. Interaction Characteristics	5	15%	4	13	19%	3
3. Production Development Techniques/Methods	6	18%	3	17	24%	2
4. Development Process Adaptations	8	24%	2	21	30%	1
5. Capital Investments	1	3%	5	2	3%	4

puter design tools. In defense products, the computer design tools factor did not have the highest single count, however, with strong support from the attitude changes factor, the development process adaptations category in total ranked first. Strong influence is indicated with a second order ranking from both the functional interaction and the product development techniques and methods categories. Therefore, defense product developments value the use of these quality tools and techniques more heavily than the commercial product category and mention them as often as factors in the functional interactions category as being responsible for speeding developments. The data indicates little difference between commercial or defense product categories regarding interaction characteristics and capital investments. Each mentions these factors relatively equally. Neither product area relied on capital investments for reductions to new product time. Overall, the degree of improvement in new product development time between commercial and defense developments is significant. Commercial products average a 50 percent reduction in development time as compared to 35 percent reduction for defense products.

OBSERVATIONS

Wheelwright and Clark (1992) use the terms upstream and downstream to describe the relative position of functional elements of an organization to the product development location at a particular time. Therefore, to them, upstream functional elements provide inputs to downstream functional elements. Traditionally, U.S. design engineers tended to develop the entire product then "throw the design over the wall" to manufacturing for production. By doing that designers forfeit understanding manufacturing constraints and limitations, and manufacturing cannot easily influence improvements to the design to improve efficiency or yield.

This predicament can work in both directions. Service departments can "throw the service problem back over the wall" to design or manufacturing based on field feedback. As a new product develops, the upstream functional elements must be willing to share preliminary information with downstream organizational elements. Conversely, the downstream organizational elements must be willing to act on this early information or ideas. A certain risk exists in this arrangement. A mutual trust and commitment between these upstream and downstream organizational elements must develop. In the organization, teamwork and sharing must be valued as highly as technical competence and they must be open enough to tolerate mistakes as a learning process.

The overwhelming method used to share information across functional areas was through some form of teaming arrangement combining a number of key functional elements or disciplines. This functional interaction was variously described as concurrent engineering (CE), simultaneous engineering, integrated product development (IPD), or cross functional integration. This team forming need not be limited to the developing organization. A number of instances were seen where suppliers and even customers were active members of new product development teams.

However, just forming a project team was not enough. Other ingredients needed to be fostered. A key ingredient was communication between the upstream and downstream organizational elements that allows the integration of capabilities, the understanding of constraints and the understanding of risks. Communication was speediest and most effective when the various functions were collocated. The AT&T devised a 50-yard rule which stated communication among team members decreases by 80 percent when the members are more than 50 yards apart (Owen, 1992). Communications must be developed early in the project and lead to integrated problem solving.

To foster information sharing essential to speedy new product development, there must also be a management attitude which allows cross functional communication, tolerates trial and error learning, develops skills through training and education, and allows a degree of team autonomy in product development decisions. In Japan, the combination of these management attitudes coupled with the forming of design and manufacturing teams around a senior "guru" working as a united, interdepartmental group, is called "wa" (Ziemke & Spann, 1991).

Trust must be exhibited. Design functions must be willing to share preliminary information with manufacturing (and other) functions, and these downstream functions must be willing to act on this early information. Teamwork and sharing must be nurtured and valued as highly as technical performance of the product. Trust is enhanced if the interacting functional elements are staffed with technically competent personnel. This product development approach using teamwork is not often taught in engineering schools; therefore, it must be supported by management and ingrained in the company culture. Risks exist in functional development teaming. If the team is ineffective, the management not fully supportive, or the project so mammoth that functional integration becomes unwieldy, then the benefits of functional teaming will not be realized. Putting together all the elements mentioned above is not easy. A key ingredient to success is management's ability to maintain visibility on the new product development and management support for the functional interactions.

Another area significantly affecting new product development was using computer design tools. Rockwell International's Collins Government Avionics Division designed the Global Positioning Satellite receiver to fit a tight, two-inch space in the Tomahawk missile using 3-dimensional computer aided design software in 14 months vice 2 years (Rohan, 1990). In other applications, design software facilitated communication between design and manufacturing personnel by forcing them to work together on the software design workstations. In another instance, a jet engine builder used a desktop manufacturing workstation to create prototype turbine blades in a few days as compared to their previous experience of 9 months (Rohan, 1990). In each of these cases, the new product development was shortened by time savings caused by using the software tool.

Tools to aid design or manufacturing make normal tasks faster. Particularly helpful was computer technology applied to paperless design and design aids. Incorporating algorithms to automatically do circuit layout, thermally analyze circuits, or incorporate expert experience greatly speeds the design process itself.

Another characteristic speeding new product development is the ability to do many functions in parallel, rather than serial order. Takeuchi and Nonaka (1986) provide the best simile when they compare the traditional serial approach to a relay race where one member hands the baton to another until the end of the race as opposed to the new concurrent approach similar to a rugby game where each team member passes the ball back and forth as needed to score. Such team allegiance allows information to flow effectively among the various functions so the product development ultimately can be compressed.

An area where work needs to be done is compensation and promotion of members of functional teams. Unfortunately this does not fit with most current compensation and promotion systems. Most companies compensate the individual, rather than seeking to maximize team performance. Actually, compensating the individual tends to create animosity between team members unless rewards are similar. A functional pecking order also hinders equal compensation. Without resolving these policies, the positive aspects of teaming could be diluted because of real or perceived friction.

In addition to faster new product development, there were many other positive benefits that occurred as a result of promoting a concurrent design approach. General Dynamics (Jobe, 1992) ran a concurrent engineering project on a new Atlas payload adapter development. Results were:

20 percent reduction in design hours
45 percent reduction in span time
75 percent reduction in engineering changes
70 percent reduction in hands-on production hours
90 percent better first time quality

Similar results were obtained in other cases from reduced design iterations, reduced design complexity, shorter production times, and flatter learning curves in manufacturing. The following is based on findings of the Department of Defense Technology Assessment Team on Japanese Manufacturing Technology (Kelly, Nevins, et al, 1989):

The application of concurrent design within America has had surprising results. When used on 24 different products ranging from aircraft engine parts to outdoor lighting, it was found that part count was reduced by 30 percent on the average, and labor reduction for assembly operations resulted in a 44 percent savings. In another example, the design being released to production had 20 percent fewer parts and 40 percent less labor than would have otherwise been achieved had concurrent design not been used.

As noted above, there were significant improvements in product quality. For a faster new product development, the quality of the design and the manufactured items must be high to reduce time losing rework (either engineering change orders or product rework) and reduce costs. If everything is done right then it takes less time to do it. Cost savings were mentioned mostly terms of life cycle cost. Initial concurrent engineering costs are higher but the downstream costs are significantly lower when the impact of reduced engineering change orders and reduced manufacturing rework is considered. Not particularly transparent was the injection of innovation into new product developments. As long as the development team exercised design autonomy and was challenged by complexity or schedule, it often developed innovative solutions which saved time. The integrative aspects of the functional interactions aided in the innovation process. As long as management was not interposed in this integrative process, innovation was fostered.

CONCLUSION

Based on the results of the 27 new products investigated, it is apparent that a functional interaction involving manufacturing has significant positive impact on accelerating product development times. Only one instance for speeding new product developments did not involve functrional interaction with manufacturing. In the functional interaction group the interaction between the upstream and downstream elements and the integration of competing design demands in the design process fostered rapid product developments.

Development process improvements are also significant in reducing product development times. Although this study suggests the degree of manufacturing involvement in product design has significant impact on reducing development time, it is not so simple. To be most successful in speeding developments, a company must simultaneously endorse four broad categories: a organizational wide functional team involvement, a supportive environment for team interaction, improvements to the development process, and the employment of useful product development methods.

Success can be achieved with improving the development process or employing proven development methods, but special benefit is derived from using schemes fostering functional interactions. My research indicates that communication fostered through the teaming arrangements across functional boundaries is the clay that molds all the elements together for a successful new product development. In the experiences of an integrated product development team at McDonnell Douglas Corporation, the following lessons learned support this conclusion: team collocation, team empowered to make decisions, focus on the product vice functional department, communication through team meetings, work to an integrated schedule, and concept validation and prototyping (Dutcher, 1991). There are other benefits as well. Not only will this four-pronged attack reduce development time, but it is reasonable to expect the development ultimately will cost less and be conceived more innovatively than if done in serial fashion.

Besides the employment of the above approach, a company should challenge the team with an aggressive goal, but not limit its means to accomplish that goal. The company should use subtle control as defined by Takeuchi and Nonaka (1986) to control the product development by: selecting the right people, creating an open work environment, encouraging engineers to learn from field and customer experience, establishing an evaluation and reward system based on group performance, managing the differences in activities during different phases of the product development, tolerating and anticipating mistakes, and encouraging suppliers to become involved. With this challenge and incremental reviews and performance trade-offs, the new product development has the best chance of being innovatively developed quickly with high quality.

The DoD recognizes that changes are necessary. The 1989 Technology Assessment Team on Japanese Manufacturing Technology report found that Japanese companies use concurrent engineering to better satisfy end-user needs, substantially reduce costs and development time, and ensure availability of appropriate manufacturing means. As reported by Nicholas Torrelli (1992), the Assessment Team recommended to the DoD that the sequential design practices be replaced with streamlined concurrent practices reducing nonvalue added labor, allowing more design options, and simultaneously trading off issues of performance, producibility, supportability, quality and cost from the earliest phases of design. Effectively implemented, these recommendations can improve the new product development process and make the DoD a better customer.

The degree of improvement in new product developments is higher in commercial than defense products. The commercial world has integrated communication throughout its functional organization and its users as the primary means to improve development time. In defense products, there are institutional barriers hindering extensive functional integration. That is why I see more emphasis on discipline interaction and less interaction with customers and government overseers. Consequently, in the defense product area, I see a more predominant emphasis on development process and methods. This may also account for why the development time improvements lag the commercial product area. If DoD were allowed the freeway that successful commercial new product developers are enjoying the results might be just as dramatic.

REFERENCES

Anderson, R. E. (1992, July-August). Strategic Integration: How John Deere Did It. *Journal of Business Strategy*, 21-26.

Dutcher, D. (1991, September 23-25). Experiences of an Integrated Product Development Team at MCAIR. *AIAA Aircraft Design Systems and Operations Meeting, Baltimore, MD,* by American Institute of Aeronautics and Astronautics. Washington, D.C.

Isenhour, B., & Payne K. (1981, April). Getting Serious About Product Development. *Management Review*, 19-22.

Jobe, L. M. (1992, January 24). A Case Study in CE Success. *DoD Concurrent Engineering Forum in Pentagon*, (LMJ920127.01 - LMJ920127.23). Washington, D.C.: Office of the Secretary of Defense.

Kelly, C. W. III., & Nevins, J. L., et al.(1989). *Findings of the U. S. Department of Defense Technology Assessment Team on Japanese Manufacturing Technology*. Arlington, VA: DARPA.

McDonough, E. F. III, & Spital F. C. (1984, September-October). Quick-Response New Product Development. *Harvard Business Review 62n5,*. 52, 56-57.

Owen, J. V. (1992, November). Concurrent Engineering. *Manufacturing Engineering*, 69-73.

Putnam, A. O. (1985, May-June). A Redesign for Engineering. *Harvard Business Review 63n3*, 139-144.

Reiner, G. (1989, August). Winning the Race for New Product Development. *Management Review 78*, 52-53.

Rohan, T. M. (1990, September). In Search of Speed. *Industry Week 239*. 78-83.

Rich, B. R. Lecture. *"The Skunk Works' Management Style."* for Wright Brothers Lectureship in Aeronautics.

Rosenblatt, A. (Ed.). (1991, July). Concurrent Engineering. *IEEE Spectrum*, 22-37.

Stewart, R. D. (1989, November-December). Speed Kills the Competition. *Chief Executive 54*, 46-49.

Takeuchi, H., & Nonaka, I. (1986, January-February). The New New Product Development Game. *Harvard Business Review 64n1*, 137-146.

Torrelli, N. M. (1992, January 24). The DoD Initiative in Concurrent Engineering. *DoD Concurrent Engineering Forum in Pentagon*, 2-0958/m/1 - 20958/m/11. Washington, D.C.: Office of the Secretary of Defense.

Wheelwright, S. C., & Clark K. B. (1992). *Revolutionizing Product Development.* New York, NY,: The Free Press.

Winner, R. I., Pennell, J. P., Bertrand, H.E., & Slusarczuk, M.M.G.(1988, December). *The Role of Concurrent Engineering in Weapons Systems Acquisition.* Alexandria, VA: Institute for Defense Analyses.

Ziemke, M. C. and Spann, M. S. (1991, February). Warning: Don't be Half-Hearted In Your Efforts to Employ Concurrent Engineering. *Industrial Engineering 23*, 45-49.