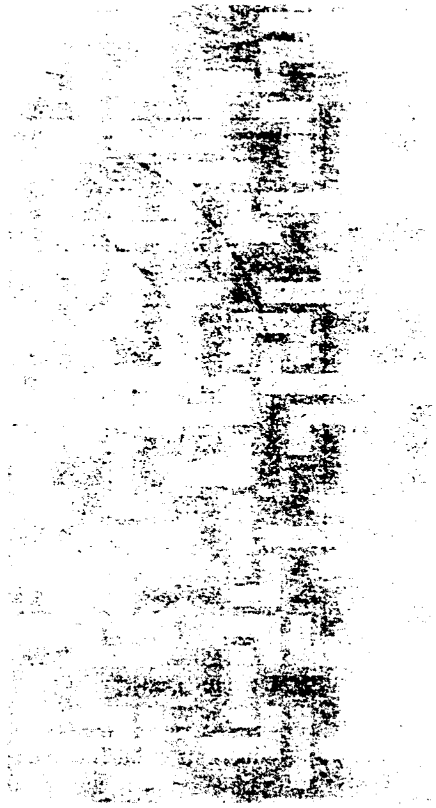
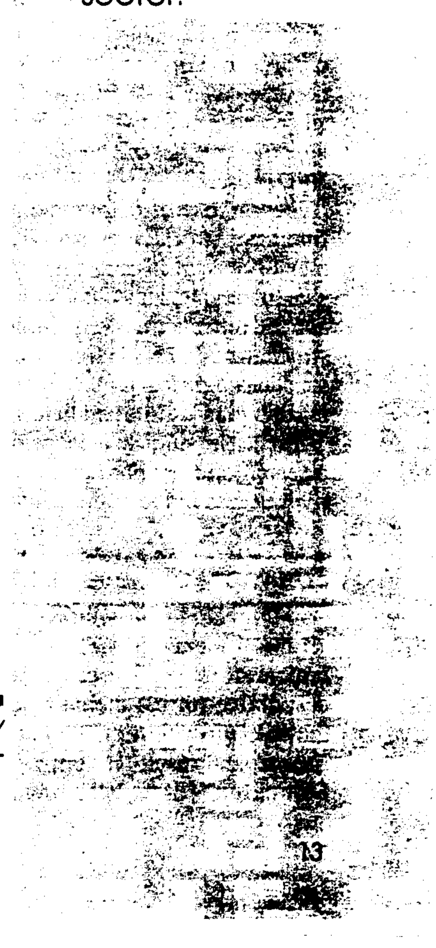
Time Management in New Product Development: Case Study Findings

Stephen R. Rosenthal and Mohan V. Tatikonda



Case studies show how product introduction time affects competitive success in the manufacturing sector.



Abstract—Rapid time-to-market for new products has been recognized as a critical capability for manufacturers aiming to succeed in an arena of time-based competition. This paper summarizes findings from seven case studies on the management of the time in development projects. Challenges to achieving rapid time-to-market are identified, and directions for future research on product development projects are addressed.

Introduction

Until recently, the management of new product development had been a grossly neglected field of study. Falling somewhere between the established fields of R&D management and manufacturing management, product development began to attract academic attention when its widespread competitive significance became apparent. In the late '80s, the manufacturing and engineering communities began to accept the importance of design-for-manufacture and simultaneous engineering [3, 7]. At about the same time, management literature began to emphasize the competitive importance of time-based management in the introduction of new products [1, 2, 6].

To learn more about the reality of managing the time dimension in the new product development (NPD) cycle, the Boston University Manufacturing Roundtable sponsored a cross-industry research project. The scope of this exploratory study was to examine the product development cycle from the first formal efforts at idea justification and conceptual design, through detailed design, development, and testing, and ending with the first customer deliveries from a volume production facility. We studied how companies had approached this process, what they experienced, and how they subsequently tried to improve what they were doing. Ultimately, we wanted to capture managerial insights that would continue to be relevant for a wide range of manufacturers. As shown in Fig. 1, we adopted an integrated perspective that included how the development work was structured, how projects were planned and managed, how cross-functional problem solving was attempted, and how technology choices were made.

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Our research on this topic adopted the perspective that time management in new product development would be affected by the organizational structures in place and the particular problem-solving processes employed. Accordingly, we set out to describe how each of our case studies conducted its new product development effort as background for understanding the complexities of time management in different settings.

We began this comparative research with several general premises:

- The actual time required to introduce a new product is only one measure of NPD success and must be considered in the context of potential trade-offs with cost and quality outcomes.
- Time targets should reflect a reasonable understanding of the demands inherent in executing the NPD project.

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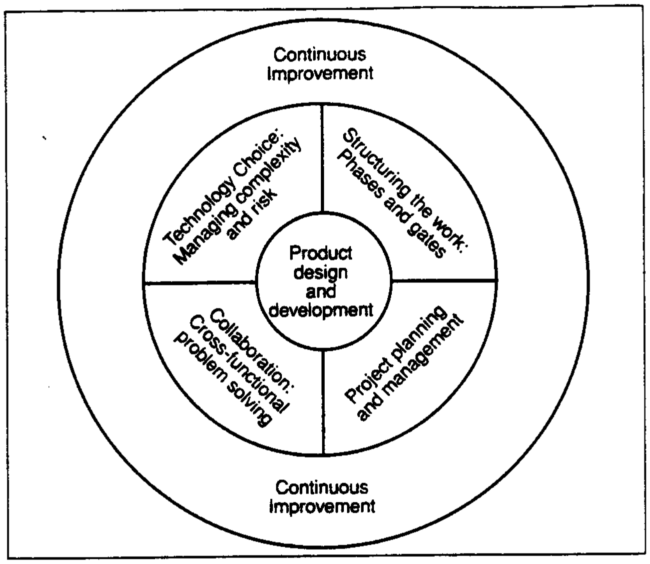

Fig. 1. An integrated view of product design and development.

- Reductions in NPD cycle time will be achieved through a combination of reducing nonproductive time and increasing the overlap with which tasks are performed.

We conducted in-depth case studies in seven companies-AGFA Compugraphic, Amdahl Corporation, GE Aircraft Engines, Interlake Conveyors, Motorola Paging Division, NeXT Inc., and Northern Telecom. For each company, we selected a single, completed new product development effort and prepared, under faculty direction, a written case history, based for the most part on interview and documentary research performed by members of the business unit under study. These descriptive, historical case studies vary in length from 30 to 100 pages (including text and figures). The case studies, enriched by a series of five two-day workshops attended by the entire project team of academics and industry people, formed the basis for comparative analysis and findings on common themes of managing new product development. These findings and associated lessons are documented in book length [4] and summary format [5]. Chapters 1 and 2 of Ref. 4 provide an introduction to essential tasks in product design and development and give an overview of the NPD process.

The purpose of this article is to summarize the case study findings with an emphasis on aspects of time-based management. For each case, the information presented is more extensive than typical anecdotes reported in the trade press. Taken as a set, the seven cases illustrate the variety of contexts within which the NPD cycle time becomes a factor. An appreciation for such empirical realities is important for avoiding artificial abstractions on the challenges of time-based management. These case studies also provide a foundation for further research on how product introduction time affects competitive success in the manufacturing sector.

Summary of Case Studies

Table 1 identifies the seven case studies and some of their critical attributes. The cases are summarized in a standardized descriptive format including a brief history of each project, the role of cycle time among the project's critical success factors, and results in terms of the product and the process. Full accounts of the Motorola, NeXT, Northern Telecom, and GE Aircraft Engine cases are published in Ref. 4. The Interlake, Amdahl, and AGFA Compugraphic cases are available as working papers of the Boston University Manufacturing Roundtable [8-10].

Interlake Conveyors

Interlake Conveyors recognized problems with an existing conveyor product, the Selecta-Flo shelf system, in 1986. This product resembled a tall, open multi-shelf structure in which small wheels enclosed in narrow rails allowed cartons to roll down the shelf as needed. It had been on the market since 1981. While there were several internal memos circulated on the issue, and a few very minor design changes made, no real action was taken until a salesperson sent in a letter explaining great customer dissatisfaction with some aspects of the product in February 1987. A corporate design engineer started working on the product, and presented a design for review. While this prototype was deemed inadequate, a few of its changes were introduced immediately into production. Ideas regarding the product were discussed, and a better sense of what was required came about. Design activity continued for several months until a vice president said that the project had to be completed and asked that the newest design be presented as soon as possible. The newest prototype was practically the same design reviewed earlier. It was tentatively approved in October 1987 and blueprints were sent to the factory for development of a large-scale prototype. This large-scale version proved that the design was not very manufacturable, and so required major revision. At this point, a plant-level engineer took on responsibility for the new design, and with the help of a multifunctional, plant-level new product committee, developed a revised design. This activity took place in the first half of 1988, with the product receiving approval in June 1988.

The plant manager had expected production to start in February 1988 with ramp-up completed by May, and had already collected orders for the new product. These orders needed to be fulfilled, but due to the time slip, there was no new manufacturing equipment in place, critical material had not been procured, and assemblers had not been trained. In the rush to meet these orders, existing tooling was overstressed, temporary tooling was acquired, and assemblers learned on the job. This led to occasional poor quality parts, excessive machine downtimes, and delays. The production process became much more efficient and effective once appropriate tooling was on-line.

Having several competitors in this market, Interlake had to provide the best quality, features, price, and service to guarantee product differentiation. They had traditionally responded to market-driven design needs, and had no plant level R&D. In particular, there were no established new product development procedures or control mechanisms. For this product, time targets were never very explicit, with the real issue being the product features in terms of usability, transportability, on-site construction, costs, and manufacturability. No efforts were made to reduce time-to-market by lowering quality (functionality) or cost objectives.

Interlake did meet product quality and cost goals, but was late (four months later than the plant manager expected). The plant-level design was a first-time effort that benefited from cross-functional communication. As a result, a formal new

Table 1. Summary of Cases

Company	NPD Project	Were Time Targets Explicit	Importance of Time Objective vs. Cost, Functionality	Time Target Was Subsequently Traded Off with Cost or Functionality	Original Time Target Was Met	Project Was Technological Success	Product Was Market Success
Interlake Conveyors	Industrial Shelving	No	Low	No	No	Yes	Yes
Motorola Paging	Pocket Pagers	Yes	Low	Yes	No	Yes	Yes
NeXT Computer	Computer Workstation	Yes	Medium	Yes	No	Yes	No
AGFA Compugraphic	Text/Graphic Imagesetter	Yes	Medium	Yes	No	Yes	Yes
Northern Telecom	Small Business Telephone System	Yes	Medium	Yes	Yes	Yes	Yes
Amdahl	Mainframe Computer	Yes	High	No	Yes	Yes	Yes
GE Aircraft Engine	Commercial Jet Engine	Yes	High	No	Yes	Yes	No

product development process was put in place for the plant, and a plant-level R&D group was developed and empowered.

The new product achieved a more than 50 percent increase in sales over the old version. A minor design improvement was made in April 1989.

Motorola Paging Division

The Motorola Paging Division decided in 1987 to fund development of a family of new voice pagers that would ensure that Motorola provided a complete product line in all voice paging markets. The pocket pager, called Keynote, would replace large numbers of existing, aging pagers. The new pager was to be the industry leader in all aspects including low price, small size, long battery life, aesthetic features, superb audio, and ease-of-use. A cross-functional team was put together at the headquarters plant in Florida to initiate preliminary design activities. They set specific design objectives, required the use of a component from an existing high-volume product, and mandated a new design approach to replace a traditionally unreliable component common in all previous products. This product was low priority relative to ongoing production and other product development projects in progress.

Management decided to design and develop this product using a combination of professionals in Florida, the location of the division's central office and final assembly plant, and in Singapore, the location of the front-end manufacturing facility. This first effort at global new product design was also intended to develop a design capability in Singapore, and take advantage of international sourcing of parts and equipment.

The cross-functional team began by reviewing previous product development efforts for factors leading to success and failure. They determined that high up-front resources from.many functional groups were required for the Keynote project. The group had also been involved in product development time and task reduction training provided by a consultant. To achieve NPD success, they employed a project management technique called the Contract Book (first employed with a previous development project) that detailed all task responsibilities, functional goals, deadlines, and resource expectations. In addition, to meet new corporate six sigma quality, they decided that a design-for-assembly approach was required.

Use of an existing part guaranteed low cost but introduced design difficulties in accommodating and interfacing with that part. In addition, similar design problems arose with a module that was to be different in each version of the Keynote pager. Early in the design process, pager size was increased to guarantee quality audio, and a printed circuit board with more expensive parts was chosen to guarantee higher quality. These changes did not cause major time delays. Major time delays were caused by communication difficulties with Singapore operations due to cultural differences, the 12-hour time difference, and general mistrust. Engineering turnover in Singapore contributed to delays. Both facilities experienced resource problems leading to delays because ongoing production was first priority. Electro-magnetic interference caused by a particular chip led to a major design delay until it was solved.

With the support of local suppliers, a number of quick prototype test cycles were conducted, leading to a high quality product and few engineering change orders in the first year of production. Semi-hard production tooling was used to allow tweaking of the process during prototype runs. The collaborative product and process design led to an easily roboticized assembly procedure for the product. The product was introduced in 1989, which was later than planned. Product sales boomed, and production was shifted from traditional manufacturing to full robotic assembly.

Product quality, feature, and cost goals were set early. While time deadlines were also set, they were not considered paramount. The product goals were set with the intent to provide a higher function, lower cost, higher quality product than any competitor's.

While functionality, quality, and cost goals were met, the product reached the market late. This project exhibited several firsts for this division: design-for-assembly was used rigorously, several functional areas were integrated, and global new product development was undertaken. A strong base was set for future NPD.

Sales were very strong. The product outsold existing products, and several product features were hailed by customers as particularly innovative and desirable. The division considers it a great success.

NeXT Corporation

NeXT was founded in September 1985, with a goal of providing an "insanely great" personal computing system for academic and business markets. NeXT wished to have a product of the highest quality with state-of-the-art features and technologies and aesthetic and ergonomic characteristics with importance equal to technical functionality. In their first year, NeXT recruited individuals carefully selected for specific experience and skills. Also during this time, the company conducted extensive technological reviews and selected and entered into close relations with a few suppliers. In the Fall of 1986, the NeXT computer system product development was formally launched, the functional goals of the product clearly stated, and a two-year development deadline set. Time-to-market was important to NeXT, but considered much less relevant than product features. While the product specifications changed greatly before product introduction, the primary technological issues having to do with package design, VLSI chips, microprocessor chips, and data storage technology had been set in place at the time of formal launch.

Manufacturing staff was hired in early 1987. NeXT planned and carried through simultaneous development of product and process. There was colocation of the team until the manufacturing facility, located miles from headquarters, opened.

The product was intentionally designed so that software applications could be easily developed, reducing downstream efforts fur NeXT and other companies. NeXT planned surface-mount printed circuit board (PCB) assembly from the start. While this was a technological and time risk, they felt it would allow them to establish manufacturing quality as a competitive advantage and also set a base for quick future technological change. The optical disk chosen for data storage was another source of considerable technology and time risk, and NeXT worked closely with the supplier on this design. Another supplier, Fujitsu, was required to create a greatly enhanced chip that increased its development and manufacturing burden while significantly simplifying NeXT's manufacturing operations. This caused a time delay that NeXT anticipated and accepted. NeXT actively cultivated specific suppliers not only for tasks at hand but in anticipation of future opportunities.

The product was introduced in October 1988, one month after PCB assembly started and before all manufacturing capabilities were in place. First units were shipped in December 1988, but operating system software was not available until September 1989.

The original sales price was to be $3,000 and specific performance characteristics were set at what were perceived to be state-of-the-art levels. The desired functionality was determined by review of technologies and in consultation with academics. The product was to have superb quality, aesthetics, and ergonomics. Time-to-market was a concern, but secondary to product features and quality. It is not clear that the stated two-year development time was rigorously computed. As the project continued, evaluations of what were state-of-the-art technologies and customer desires changed, partly due to dynamic markets, leading to increased functionality designed into the product. In general, time was never considered a constraint.

Product quality was very high, and functionality was much higher than originally intended. Product price was two to three times above original targets, reflecting the pursuit of increased performance. Close communication between functional groups and with vendors set a firm base for future development projects. The project was not completed on time due in part to the one-year delay in software availability.

The product was sold at prices two to three times higher than originally set. The product was removed from the market in May 1990, due to poor sales resulting from the high price and certain functional decisions that dissatisfied customers (slow processing speed, black and white monitor, general lack of applications software). A second generation of NeXT computers was introduced in September 1990, with favorable reviews.

AGFA Compugraphic Corporation

In 1985, AGFA Compugraphic identified a market opportunity for a high quality, moderately priced image setter. This product, the CG9400, would apply text and graphic images to photo-media for use by commercial print shops, advertising agencies, graphic designers, newspapers. and desktop publishers. While they held a majority share domestically and internationally, they needed to achieve a low unit production cost to remain viable in this market. Customers were looking for value, high product compatibility with industry standards, and low product downtimes. In addition, customers desired products embodying the latest photographic technologies.

The company began by reviewing competitors' product capabilities as well as existing and new product technologies. To maintain a technological lead over competitors, set a learning base to support future products, and reduce total product cost, they decided to adopt a new technology. This was a new laser diode technology that also required compatible optics and motors. Vendors were invited to aid in the product concept development. The development continued on two separate but related tracks-one devoted to hardware and the other devoted to software. A number of alternative approaches to design of particular modules were evaluated. In some cases, modules were borrowed from older recent products to reduce development effort and risk. Special software was developed to aid in analysis of optics and photomedia systems. Design approaches were defended before individuals from several functional groups. Several iterations of prototype modules and full systems were made in the design stage, some with active participation of manufacturing engineers.

The adoption of these new technologies led to a number of development surprises, thereby increasing total design and manufacturing engineering efforts and time. Consider able experience was gained in the characterization of photo-media and optics. Certain design vagaries of these technologies emerged and had to be understood before design revisions and resulting process changes could be put in place. There was considerable interaction with vendors in an attempt to meet specifications. Modules borrowed from other recent products had previously unnoticed peculiarities requiring resolution for effective use in the CG9400.

AGFA Compugraphic recognized that simultaneous development activity was needed to achieve shorter development time frames, and had planned overlapping development efforts for design and manufacturing engineering. Manufacturing engineers helped assemble several design engineering prototypes, and served to critique designs from a producability perspective. Production Control personnel aided design engineers in parts procurement and development of parts lists. This activity also greatly aided in having early stocks of production materials. Design engineers worked to guarantee manufacturability and congruence with manufacturing needs. Design engineers assisted manufacturing engineers in tooling development and assembly of ramp-up prototypes. Manufacturing engineers, from their early knowledge of the product, were able to start development of the process tooling early. Vendor production of custom parts also started early.

External consultants were brought in to aid in design of certain tools. Technicians were trained in calibration and operation of assembly equipment, who in turn trained shop floor personnel. Tooling ramp-up activities took place in an advanced manufacturing shop floor at company headquarters. Once fully debugged, the manufacturing process was transferred in whole, equipment and personnel, to a full volume manufacturing site. These continuously overlapping stages reduced NPD time.

The four-year development effort had a nine-month delay. Three months of the delay could be attributed to surprises arising in the hardware design stage, which had to be resolved. By far the leading contributor to this delay was software development. Software specifications were not firm early in the development, and changed during the NPD. In addition, project management techniques were not used in the software development group, and there was considerable turnover in this section.

Optimistic time targets were initially set for the CG9400 in order to meet a market window. System-level quality and functionality goals were also set quite early. As development delays arose, downstream activities were compressed to save time. Also, the multiple overlapping activities served to save time, even though they did not make up for the delays. Quality was the primary objective, and the product was not shipped until all divisions agreed that the CG9400 had high quality.

While the development was late, most of the NPD efforts were conducted well and on time. The NPD produced a product of very high quality and at close-to-targeted original costs. First efforts at overlapping development were generally successful, and would help the organization tremendously in development of downstream products.

The introduction of the CG9400 was highly successful in terms of market response, which dramatically exceeded sales forecasts. The firm brought the latest technology to its customers at a modest price. The product achieved service call rates much lower than targeted.

Northern Telecom

Northern Telecom conducted rigorous market research starting in March 1984, to determine what customers wanted in a small business phone system (two to 100 users). They found that ease of use, high reliability, quality of transmission, and upgradability were desired product attributes. Northern Telecom wanted to replace the existing Vantage phone system, which had been on the market since 1979. Sales had fallen greatly due to its out-of-date technologies, mediocre quality, and relatively high cost. The organization also wished to have a new and popular product fur the small business end of its product line. Northern Telecom already had highly successful systems for large businesses and felt the need to provide a full product line.

The project, called Norstar, was to meet customer desires within a four-year development time, two years shorter than the Vantage NPD had taken. The project was the first in Northern Telecom to have a formal Executive Gate Review process. Past projects did have formal design reviews, but this new review process required executive management approval for additional allocation of resources to continue the project into downstream stages. They would not release for further development efforts until all pending deliverables at that stage were achieved. Three gate reviews were scheduled and held: one after the concept definition stage, one after the detailed product specifications and design were in place, and one after manufacturing prototypes were on hand. The last gate served as final approval for the project, and allowed first customer shipments to start.

Prior to the first gate review, it was decided that the product should have "mature first cost" and so there was great emphasis on manufacturability from the start. Northern Telecom decided to spend extra time in the initial design stages to make sure that the resulting product would not require many changes. The first gate, supposed to be held in December 1985, was delayed to June 1986 when part of the product design was incomplete and certain manufacturing and marketing plans were not in place. Lack of software development resources also contributed to this delay. Critical design choices were made about this time. In one case, increased functionality in terms of ease of use was accepted, even in face of increased costs. In another case, lower cost product packaging was chosen even though there was some slight risk of reduced functionality. In these cases, development time was not affected. One design choice did have the potential to delay the project. This had to do with use of surface mount technology (SMT) electronic components. Manufacturing had no previous SMT capability, and to avoid risk, did not want any to be used for the Norstar. On the other hand, engineering wanted 100 percent SMT usage to guarantee technological superiority. In the end, a compromise was made where an intermediate level of SMT usage was accepted because it balanced quality, functionality, and risk concerns.

A major contributor to the delay in passing the first gate was a change of engineering management. The first engineering manager who led development efforts through the conceptual development stage had considerable technical skills, and was generally thought to be an appropriate engineering manager for that stage. He was replaced for the remainder of the project by a new engineering manager who had superior project management and communication skills. This switch, which had been anticipated, caused a three-month delay. However, this lost time was recouped later, in part due to the leadership skills of the second manager.

In the design phase, close relations were fostered with internal and external suppliers. In many cases, key suppliers became part of the NPD team. Engineering was located in

Ottawa, and manufacturing was located in Calgary, 2000 miles away. This distance did contribute to communication and decision-making delays. Nonetheless, there were high levels of simultaneous engineering activity, with 80 percent overlap of the two functions for certain product elements.

The Calgary group was particularly concerned about the survival of their division in the corporation. This pressure led to great efforts to achieve manufacturability early. In addition, personnel worked very hard to achieve success, even though demands of maintaining ongoing production often competed with the manufacturing development demands of Norstar.

The two remaining gates were passed on schedule. The six-month delay had been recouped. This happened in part due to no need for product redesign, implying that the extra efforts expended in market analysis and initial design had been worthwhile. Sixty-one beta sites tested the Norstar in late 1987. Northern Telecom found that customer satisfaction was high, and that the product was easy to use. Manufacturing capacity was fully on-line by February 1988, and the product was introduced on schedule in March of that year.

The time and functionality targets were clearly set early. A general intent for a reasonable cost product was also stated. A number of cost/functionality trade-offs as were appropriate at the time. Very deliberate early design efforts led to time delays that were made up later in the project. Decisions were made in certain design choice cases to reduce risk to assure on-time product delivery.

The product was introduced on time with desired functionality, high quality, and reasonable cost. This was the first time executive reviews were held to monitor project progress. Great levels of simultaneous engineering occurred. Very few subsequent engineering changes were needed. This NPD set a strong base for further improvement of product development efforts.

The Norstar system has been a tremendous commercial success. Over one million units have been sold, which is four times the original sales projections.

Amdahl Corporation

In 1980, Amdahl Corp. started engineering concept development for the 5890 mainframe computer. By 1982, a cross-functional team had been put in place to drive the NPD. This product was to replace the 580 mainframe that was in final development stages at the time. While Amdahl's product development projects typically take five to seven years, the mainframes have product life cycles of just three to five years. Amdahl competed primarily with IBM by offering plug compatibility (complete compatibility) as well as enhancements and price/performance advantages beyond IBM's capabilities. Firm and demanding time, cost, and performance goals were set for the 5890 development—all three criteria were equally important. Since Amdahl relied on its mainframes as its primary source of revenue, this project was considered highest priority and so was generally allocated any resources it needed. Design talent was taken as needed from throughout the corporation, and financial resources were not constrained.

While the 5890 borrowed the same class of components used in the 580, the system architecture was completely redesigned. In addition, this NPD employed the existing Amdahl organizational approach to NPD, which used a product management team to drive the many NPD activities. The development used a formal seven-stage phase program management system with numerous executive reviews. The stages had some overlaps. The first stage, formulation, lasted from 1980 to 1982, and ended with an executive review that approved a product requirements specification document listing all system-level specifications. While it was difficult to assess product costs at that time, preliminary cost targets were set.

Concept design phase activities occurred from 1982 to 1984. Various technological approaches to achieving product specifications were evaluated. The design phase, from 1983 to 1986, included detailed product design and manufacturing process development. This phase had many formal phase reviews. Since Amdahl's strategy was to react to any IBM product offering by making available its own equivalent capability, they could not consider an engineering design to be frozen because IBM could publicly announce a new intended mainframe capability at any time. For the 5890, several machine-level changes were introduced into design in response to new IBM features. The actual enhancements were not made available in initial product releases, but in product releases of the 5890 made at least one year later.

The engineering model build phase took place in 1984 and 1985. Product prototypes were made in the advanced manufacturing engineering initial production operations shop. At this time, it was determined that certain chips required revision. Due to agreements negotiated with chip vendors in early stages of the project, these vendors guaranteed fast turnaround time for chip remakes. Amdahl had placed cost penalties for late turnaround in the vendor contracts. Initial assembly took place in 1984, with the Integration phase taking place in 1985. Here, all printed circuit boards, mechanical frames, and operating systems were integrated and tested in a systems environment. This was a rigorous prove-out. At this time, manufacturing was busy with ongoing production of the 580, taxing manufacturing resources for the 5890 ramp-up. The Acceptance phase began in 1986 with the first customer shipment to a beta site. After this shipment, a cost improvement team with members from all functional groups was created to further cut, product costs and reduce assembly times.

Time, cost, and quality goals were explicit and set early. Each had equal importance, and none were traded off for the others at any time. High levels of resources were made available to achieve each goal. Time goals were set with consideration of replacement of an Amdahl product just entering the marketplace. Time, cost, and quality goals were all set high, but were determined to be achievable based on past Amdahl experiences. In particular, this NPD used an existing phase management organizational and review approach, which provided a good sense of what could be accomplished in a given amount of time.

The 5890 was introduced on time, with all functional capabilities initially targeted, and at target costs. The organizational process already in place was improved upon with greater levels of simultaneous engineering between design and test/process engineering groups. This NPD was just one in an ongoing effort by Amdahl to cut new product development times and improve NPD processes.

The product was a tremendous success. It achieved record revenues and profits for Amdahl, and set new standards for reliability and customer satisfaction.

General Electric Aircraft Engine

General Electric Aircraft Engine began development of the CF6-80A commercial jet engine in late 1978. This product, based on a highly successful predecessor product, was to be sold to Boeing and Airbus Industries mainframe manufacturers for installation in 767 and A310 wide-body commercial aircraft. These airframe manufacturers in turn sold their products to commercial airlines such as American, and Delta who made purchase commitments for these new airplanes.

GE set very aggressive and explicit time targets. The engine had to be ready at a certain time for inclusion in the larger airframe systems. Hence, a traditional seven-year development cycle had to be cut to four years to achieve the market window. A very important interim milestone to be achieved was getting the first-engine-to-test (FETT) in 15 months rather than the traditional 42 months. Target FAA engine certification and entry into service was set for late 1982. GE felt additional pressure to achieve these short time frames to maintain its penetration in commercial engine markets. Sustaining representation in these markets was an important strategic necessity. Hence, this NPD was seen by all as a "bet-the-company" project, and so generally gained access to whatever talent and resources were required in the development.

The primary objective was product performance including low engine weight, high fuel efficiency, and short engine length. At the time, airlines and in turn the aircraft industry were booming due to great increases in air travel. Fuel costs were expected to reach $2.00 per gallon shortly, so the various design attributes contributing to fuel efficiency were deemed very important. In addition, the product performance objectives had to be met on time. Product life cycle cost and unit manufacturing cost had lower priority. Achieving the design objectives required some substantial changes to engine concepts employed in earlier products.

GE had an established matrix management NPD approach that was used here. A general manager and Program Control Board monitored and controlled program funding, determined time/cost/functionality trade-offs, and revised work assignments as necessary. A traditional GE work breakdown structure was employed. However, one major change to the organization structure was that engineering and management reported to the general manager for this project. There were hundreds of people working on this project at more than ten manufacturing sites. Accordingly, there was no colocation undertaken, but communication levels were high. Also, CAD, CAM, and CAE capabilities were implemented during the 1978 to 1983 timeframe. These tools assisted in communication efforts.

The project was managed closely with development cycle time in mind, and decisions were made such that product availability was mote important than cost. Manufacturability was not a major issue in early development stages. Two major problems arose during the development due to the booming industry: 1) vendors were operating at full capacity, so GE had to get part information to vendors early to negate the effects of extra-long lead times, and 2) the prices for certain critical raw materials went up substantially. The product did meet FETT and engine certification time targets in November 1979 and mid-1982, respectively.

In August 1981, the engine was determined by GE to have an excessively high unit manufacturing cost that required reduction. The early '80s saw airline deregulation, which dampened aircraft sales and led to lower production volumes for the CF6-80A, in turn increasing already high unit costs. A significant multifunctional cost reduction activity was undertaken. This activity was undertaken late because engineering and manufacturing resources were primarily focused on meeting engine certification requirements on time.

Time targets were specific and were set early in development due to the need to be ready in time to fit into a larger system product. In addition, regulatory approval time issues were incorporated into the time targets. Performance targets were specific, though they could have been achieved through a number of design approaches. Several design trade-offs were made to achieve the functionality required. Cost was never a constraint during the development, though later efforts were made to reduce unit costs.

The product met all interim and final target dates with the required levels of functionality. This was quite an achievement since earlier product development projects had taken almost twice as long. GE relied on an existing and reliable matrix management approach and experienced personnel. The organizational structure was new in that engineering and manufacturing reported to one manager. In addition, new CAD and CIM capabilities were put in place.

The product was considered a technological success, especially due to its high reliability. However, due to low production volumes, it was not considered a short-term financial success. Nonetheless, this engine served a strategic role in keeping GE in the commercial engine market. The CF6-8OA was used as a basis for a downstream product introduced three years later that was very successful and led to GE being the industry leader for commercial engines.

Implications for Future Research

These seven case studies, as shown in Table 1 provide insight into a number of interesting issues regarding time-based management. First, the setting of time targets is important. Six of the seven cases had explicit time targets. Without clearly stated time targets, it is difficult to consider managing with respect to time.

Second, time is not always the primary objective for a development project. In only two of the seven cases was time the most important priority. In other cases, cost or functionality were deemed to be of greater importance. These cases show that a firm in a competitive industry need not have time as a first priority. In addition, the relative priority of time varies across product development projects within a given company. It is important to understand what the relative priority of time is, and how it trades off with the other priorities management must deal with.

Third, the measurement of performance has a multidimensional flavor. Our cases have shown that it is possible to obtain market and technological success for a project that does not meet its time target. Also market success may be elusive even when time targets are met. And yet, even when market performance is disappointing, meeting the technological requirements can set a base for future development successes.

Our research in this area is continuing. Because we found that setting cycle time targets for the introduction of a new product is a critical managerial act, we believe this phenomenon is worthy of further study. Understanding the source, relative priority, and implications of such targets will help explain the dynamics of product development performance. In particular, project managers need to be aware that the perception of urgency can vary greatly across different functional groups involved in the NPD.

Furthermore, we found that a wide variety of factors may combine to drive the setting of such time targets (see Fig. 2). Time targets are directly affected by some combination of forces external or internal to the company and are also influenced by the availability of required technical and managerial capabilities. Some of the external forces are common to more than one company in an industry- regulatory mandates with associated dates for compliance, the timing of a newly announced competitor's product, or the date of an annual industry trade show. A more localized external force is a lead user telling a company that they have a need for some new product capability by a particular date. Forces internal to a company may result from a strategic plan to introduce new products at in prespecified frequency (NPD rhythm), to make some new technology available for commercial use, or to take advantage of some type of manufacturing capacity. Sometimes a senior executive will simply announce a particular product introduction date that then serves as the target for that reason alone.

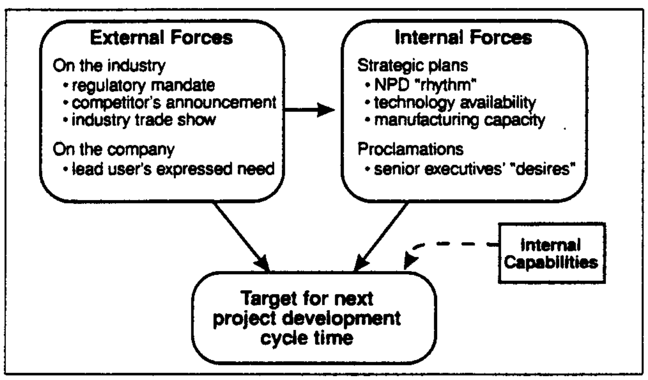

Fig. 2. Time targets can have multiple sources.

An appreciation for all these factors will indicate how ambitious the cycle time target should be and the relative priority of achieving it. Examples of a high priority include the development of a component (or subsystem) of a larger system with a pre-established delivery date (e.g., GE's new jet engine), or product introductions where time is a critical element in a strategy of technological leadership (e. g., Amdahl's new mainframe computer). Examples of situations where time-to-market is not the primary consideration range from the introduction of path-breaking new technology (e.g., NeXT's debut computer) to a replacement product where quality considerations will dominate customer choice (e.g., Interlake's improved Selecta-Flo shelf or Motorola's Keynote pager). These findings regarding the variety of influences on time-to-market can serve as a basis for more structured research on the setting of time targets.

Whatever the urgency, the ability to set achievable time deadlines is a desirable planning skill. Our case studies identified a natural tendency for project planners to overlook the realities of resource availability, most notably those that require the hiring of additional specialists or the procurement of special materials or components. We also observed that projects often get delayed because planners inadequately appreciate the time required to comply with regulatory requirements, to meet design specifications involving unfamiliar technologies, or to coordinate successfully the development work of separate groups including suppliers. A systematic survey of such individual sources of cycle time variability would improve our ability to predict the aggregate time variability inherent in such projects. Further, outputs of such research would assist managers in avoiding variability and/or developing contingency plans to prevent delays.

Our findings to date suggest the dual importance of: (1) specifying the relative urgency of product development cycle time for each new project of this type: and then (2) planning and managing the project with the reduction of time variance in mind. Project management, once targets have been set, is another topic worth more analysis and discussion. For example, of all factors affecting time variance within a project, the one that seems most in need of further study is working with unfamiliar technology. Many companies (including the ones that we studied) are trying to plan technology development so that any one NPD project contains only a limited amount of novelty. Rather than absorb unnecessary risk of late product introduction, these companies place a heavy premium on the use of ready technology. Doing this successfully requires an ability to introduce families of new products with a controlled amount of technology reach in any single introduction. In any event, the management of technological risk within each project is an operational challenge that needs to be better understood.

While increasing its focus on the reduction of development cycle times, management also needs to be more precise especially at early phases of a project, with considerations of quality, cost, and customer satisfaction. Balancing these considerations is easier said than done (as discussed in Ref. 4). Additional research along these lines would lead to useful managerial diagnostics.

Time-based management is here to stay. In the field of new product development, the issue is not whether to reduce cycle time, but how to do it effectively.

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