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Best Practices for Time-Based New Product Commercialization

Ray Meyer
3M Corporation

3M had nearly $14 billion in sales in 1992. Fifty percent of 3M's sales were outside the United States. The company has over 50 divisions within three sectors. Each sector has met at least 25% of its sales each year from new products. One of the three sectors has had 100% of its sales from new products over the last three years. A recent survey by *Fortune* magazine ranked 3M as the fourth most admired corporation in the United States, preceded only by Merck, Rubbermaid and Wal-Mart.

Ray's view of the product development process was very inclusive. It starts with need recognition and continues to meeting business objectives. The latter means maximizing the net present value of cash flow, which is much broader than just meeting an introduction date or shortening break-even time. Also, more attention needs to be paid to the "fuzzy front end" of the product development process. There is more potential for enhancing profitability here than during late phases of the process where recent efforts have focused, e.g., cycle time reduction.

Ray discussed the need for a paradigm shift in moving to time-based product commercialization. Some of the highlights of the paradigm shift include use of physically co-located, cross-functional teams with dedicated core members who remain together from project inception to commercialization and are rewarded by a common project-based incentive. These teams address all product and process-related issues concurrently rather than sequentially with less attention to functional goals than to contribution to overall project success. Also, new technologies are developed off-line through a separate infrastructure (sometimes years before commercialization) and introduced systematically into new products, which increasingly are improved incrementally rather than by radical breakthroughs. Top management focuses on prioritizing projects, allocating resources and reviewing project progress at only two project milestones ("project definition review" and "release readiness review"). Successful project management is based more on interpersonal and leadership skills than on technical skills and on keeping the focus on market and business objectives.

Ray visualizes the accelerated new product development process as relating two parallel time-based streams. One relates to corporate resources and core competencies that lead to the continuous, off-line development of new technologies, and the other to evolving customers' needs and market dynamics. The two streams become connected when new product ideas offer a good match between the two streams. These ideas can come from the market (pull), technology (push), employees or entrepreneurs. The strength and viability of the connection depends on the effectiveness of project selection and launch and on how well top management and the cross-functional development team play their complimentary roles. Continuous feedback between the team and customers (including making customers members of the team) assures that the connection will be maintained.

The first phase in accelerated new product commercialization involves thorough planning and information convergence around business objectives that take into account ecological, legal, marketing, and manufacturability issues. The second phase, concurrent product-process definition, tries to trade-off and optimize time, cost, product performance and related issues against the net present value of

cash flow. The third phase, parallel process implementation, includes process development and scale-up. As discussed earlier, top management usually conducts only two reviews: the first after completion of the first two phases and the second after the third phase. The latter review includes an assessment and control for risk due to deviation from the initial plan. Ray highlighted the value of 3M's software that development teams can use to assess the impact of trade-offs between time, cost, performance, etc. on the net present value of cash flow. The use of the latter measure encourages team members to de-emphasize functional rewards and to focus on one common measure of project success.

Project Sherlock: Action Research in New Product Development Design

Peter Gaarn
Hewlett-Packard

Peter is a member of an HP group called the Factory of the Future (FOF), which is part of a larger organization called Change Management. FOF views its mission as research, design and diffusion of organizational design and change. Because innovative organizational designs often fail to diffuse beyond experimental sites or to develop beyond ideas in written reports, FOF diffuses learning through networks of managers from different HP sites. FOF uses a variety of systems tools for system redesign that are based on sociotechnical systems analysis, system dynamics (Jay Forrester, MIT), organizational learning (Peter Senge, MIT), systems reengineering (Michael Hammer), etc.

Peter discussed work that the FOF group did with an HP division which employs 160 people, has $160 million in sales, and has grown 55% in the last four years. FOF helped managers in this division to investigate four previous projects that they viewed as failures; hence, the investigation was called Project Sherlock. Failures included projects that didn't meet forecast expectations, burned too many resources during development or were cancelled late (after lab release). FOF and the managers experimented with a variety of diagnostic and analytical tools to generate information. A common theme from this effort related to problems of organizing around functions versus organizing around core processes such as order entry, product generation, and delivery. It was very difficult for cross-functional product development teams to perform well within the context of the division that was organized on a function basis with its associated metrics, rewards, and goals. Only the commitment and quality of personnel from product development teams can overcome this context.

A study team of key functional representatives undertook a retrospective analysis of the four failed projects. Their investigation was guided by the vision of what it would be like if they could operate without function-based "silos," but still retain some function-based identity and expertise. Their vision consisted of co-located product development teams whose members had profit-and-loss responsibility, real-time access to business strategy and operations data, and were rewarded on a project basis. The product development teams were to be led by top management and serviced by technical support centers that would provide consultation to the teams.

The study team then developed what FOF calls "organization process maps" (OPMs) which are retrospective tracings of how decisions were made over the life of the four projects. The team identified 16 common themes that characterized the division. When they searched for root causes

for their themes, they recognized that they were highly interdependent without a single cause. They were, however, able to reorganize the 16 themes into "high impact themes" and "root cause error types."

Peter illustrated issues that were related to some of the common themes. For example, marketing data tended to get discounted when R&D dominated a team. Boundary management between functions (internal) and strategic partners (external) was hampered by lack of conflict resolution and negotiation skills. Conflict was avoided by using general and vague terminology and by relying on a "champion" to fix the team's problems. Also, the teams tended to concentrate more on problems than on what they did right. Finally, the teams felt that the division always required them to hit "home-runs" rather than consistently to hit "singles."

The common themes were subjected to a "root cause" analysis to discover "error types." Peter characterized the errors that were identified as "system errors." The latter limited the ability of the teams to control themselves effectively. For example, teams cannot succeed if their goals are bad (misaligned with business strategy), if their conflict and negotiation skills are limited (ineffective boundary management), with a bad reward structure (based on function rather than project) and resources that were limited or constrained by decisions made at the division level.

Peter summarized the team's key learning from the investigation. The team developed a "systems dynamics model" or "influence diagram" that related the 16 themes positively or negatively to each other. The teams also learned the importance of a clear product definition and of strategic alignment between the team's goals and the division's business strategy. They realized the importance of having a "project historian" who could provide feedback frequently during the project on managerial and social dynamics. They also realized that the presence of the general manager at their meetings inhibited their openness to explore issues, so they asked him not to attend them.

The study shifted from investigation to design and implementation. The team tried "cross-functional mapping," which looked at the activities that were essential to efficient product development and eliminated those that were unnecessary. FOF wanted to help the teams develop and implement an organizational vision, and to learn through continuous improvement. The team used the cross-functional maps to help it think in terms of core business processes rather than functions, e.g., the product generation process. When the team thought this way, it was clear that no one function owned the process; but there was continual pressure to revert to functional dominance because of the over-arching function-based structure and daily pressures. The teams could counter this pressure by using product development checkpoints. Even still, there was often a divergence between formal and informal achievement of checkpoints. Peter introduced the "wedge" concept as a way to understand this divergence and manage risk. For example, in the early stages of product development, the R&D group was at the leading edge of the wedge. It is all right for other functions to be a little behind the leading edge during concept development, but not too far behind without risking project success.

ISO 9000 Quality Standards: Prerequisities and Guidelines for Exporting to the European Community

Hugh Thuerk
American National Standards Institute

The American National Standards Institute (ANSI) is playing an increasingly significant role both nationally and internationally because of the proliferation of quality standards and organizations that certify conformance with quality standards in the United States and in the growing number of countries in which the United States competes. ANSI is a not-for-profit membership organization that coordinates the U.S. system of voluntary standards development. More than 1,300 company members, 250 organization members and 30 government agencies convene under the ANSI umbrella to participate in national and international standardization initiatives. As the U.S. member to the ISO and IEC via an ANSI committee, and through ties to many counterpart international bodies, ANSI is the avenue for U.S. participation in global standardization.

Considering the U.S. history of decentralized, regional and sectoral approaches to standards development and assessment, ANSI plays an important role in helping the U.S. to develop national standards. The U.S. will be helped by such development as its companies seek entry into Europe, which itself is moving toward regional standardization. ANSI provides the medium by which countries can communicate about standards. The ISO 9000 series is fast becoming the standard that all companies must meet if they are to compete in global markets, especially those within the European Community. Both the European Commission and the American Society for Quality Control have adopted the 9000 series to assure consistency of product quality and reliability. Their regional designations are EN29000 and Q90, respectively.

One of ANSI's main activities is development of accreditation programs that accredit test laboratories, certification bodies that evaluate and certify products, processes and services, and registrars that assess and register supplier quality systems. In the latter case, ANSI started a joint program with the Registrar Accreditation Board (RAB) in 1991 to accredit registrars that audit companies for compliance with ISO 9000 standards. The RAB (which is part of the ASQC) focuses on training, selection and accreditation of auditors, while ANSI focuses on program reviews, approval of procedures and appeals for accreditation denial. ANSI and RAB mutually develop accreditation criteria. The program is very advantageous to U.S. industry and government agencies because it provides one nationally accepted, internationally recognized body to turn to for accreditation of quality registrars. The accreditation process is rigorous and is followed up by annual audits and periodic surveillance.

ANSI's continuing cooperative efforts with European counterparts is facilitating the move toward worldwide quality standards. Their discussions have helped ease apprehensions in the U.S. that European markets might close themselves to outside interests. Their discussions also have stimulated an exchange on how conformity assessment in the U.S. and Europe could cooperate in the interests of promoting trade and reducing duplicate testing in their respective markets. For example, ANSI has urged the European Commission to allow U.S. testing, registration and certification organizations to perform work that could be accepted in Europe.

New Product and Process Developments in Pager Lines

Ken Wasko
Motorola

Ken provided an overview of the Bandit project that began in 1987. The project started as an experiment to put an existing product line (Bravo) into an automated setting to prove that manufacturing in the U.S. was feasible. What emerged was a philosophy concerning attitudes and related practices that has been diffused to many subsequent pager projects. The name Bandit was chosen to emphasize that ideas should be taken from anywhere for use in the project; no NIH (not invented here) syndrome was to be permitted. The ambitiousness of Bandit's goals and the magnitude of the task would not permit such a restrictive attitude. They not only sought ideas from electronics companies, but even from McDonald's, Wal-Mart, Woolworth's, Benetton, etc.

The completed Bandit line was able to begin producing a product within 17 minutes of receiving an order from Chicago. A finished pager was ready for shipment two hours later. The line was capable of producing pagers in lot sizes of one. It had 20 linked robots and 34 work stations. The project developed a new order entry system, sourcing strategy, manufacturing accounting system, materials control system, and was committed to achieving six-sigma quality and total customer satisfaction. With the help of Motorola Corporate Technology Transfer Center, most of Bandit's innovations have been diffused to 10 other sites, e.g., France, New York, Phoenix, Austin.

Some innovations included a catastrophe plan to recover from failures that might arise from so many robots and operating stations being linked. Another innovation was structured—time-based goals for introduction of prototypes into factory. All prototypes (four in all) were run on production equipment that was to be used in the factory so that the best product-process match would be developed. The number of suppliers was reduced from 600 to 30 and the remaining ones were involved early in the product design process. All incoming parts were vendor certified. The product parts, e.g., boards, were designed by suppliers for convenience for automation. Technology and parts were taken off the shelf whenever possible to minimize risk, especially technology that Motorola wasn't the best at developing. The product was subjected to accelerated testing so that problems could be discovered early in the development cycle. Managers led empowered, co-located development teams on a mission rather than micro-managed basis. To discourage engineers from thinking only about invention for its own sake, the company provided "Reuse 1991 Awards" to engineers who adopted technology from other sectors.

The last Bandit pager was produced in December 1990. Three days later the space where the Bandit line was produced was empty and the technology moved to another area to be used for the new Speedy line (internal name) or Bravo Express (commercial name). Seventy-five percent of the depreciated capital was re-used for the Speedy line. The first prototype was developed by the end of January 1991 and was run on production equipment by the end of February. The product was ready for volume production by June 1. During the six months between December and June, production of the Bravo pager (the commercial name for the Bandit product) continued on a second line. The product on the second line differed only internally. The boards within the Bandit pagers had been redesigned to accommodate state-of-the-art automation.

The learning from Bandit has been carried over since to several new lines, e.g., Mermaid (wristwatch pager), Echo Neptune (four line alphanumeric display), Cobra, etc., and improvements have continued in manufacturing and managerial practices. Some of these continuing innovations include computer-integrated manufacturing (CIM), cross-functional development teams, and modular robotic cells. The Bandit was the first project in which all project personnel were co-located. Also, "front-end" activities (populate boards with chips) and "back-end" activities (placement of boards into housing) are done in a single site. Front-end activities used to be performed overseas and back-end activities in Boynton Beach.

The Bandit line led to a paradigm shift in manufacturing. Before the Bandit project, pagers were made in batches of 50. Now pagers can be made in lot sizes that match a customer's order. The 20 robot cells used for the Bandit line has expanded to 200. Modular robot cells can be used to produce Bravo Express, Mermaids and Cobras by only changing the end-of-arm tooling. This permits the product mix to shift based on varying demands for these products. The original capital investment for Bandit was $7 or $8 million, but new lines can be started now for half that amount. The Bandit line changed the way that the Pager Division did business. The Corporate Technology Transfer Center is focusing on ways to transfer the learning worldwide to sites in the Americas, Asia and Europe.

Concurrent Engineering Overview

Jim Ridings
Westinghouse Electric Company

Jim emphasized that concurrent engineering (CE) requires a shift in focus from product to process. Citing Lester Thurow's recent book "Head-to-Head," Jim suggested that leading companies in the 21st century may be those that can use their manufacturing capability to quickly reverse engineering products and market them rather than those that rely on their capability to create new products.

The first major question that Jim raised was what is CE? Concurrent engineering is more than integrating design and manufacturing. It includes all activities from product idea to product retirement. It includes redefining the boundaries of a company to include suppliers and customers and reorganizing around information flows or key customers. Jim cited the collaboration between Westinghouse and Boeing that allowed them to share geometric data and text without having to seek approval first from the contract office. Jim also cited Bose, the speaker manufacturer, which permits 10 suppliers to perform activities that Bose's purchasing department once performed. They order supplies, pay themselves for delivery, and control their own quality. Bose has taken a link out of the value chain and created a "virtual organization" that includes its suppliers. CE requires all traditional "walls" or boundaries that separate internal and external units to be re-examined and redefined.

Jim's second major question was why is CE important? He cited Motorola which estimates that nonmanufacturable product and process designs cost as much as 15% of total sales, which in 1987 amounted to nearly a billion dollars. Jim also showed some General Motors data indicating that 70% of manufacturing cost is influenced by product and process design, which itself only involves about 5% of total product cost. By Motorola's criteria, Westinghouse would lose about $1.5 billion a year in manufacturing costs. The leverage implied by GM's criteria is that investments in concurrent

engineering can yield a return of 14 to 1 (70% to 5%). A McKinsey study suggests that concurrent engineering can lead to a 30% reduction in total product development costs, 50% to 80% reduction in development time and throughput time, and a 30% improvement in quality. Westinghouse has verified some of these numbers with "process mapping," a technique that it has used to streamline operations and reduce throughput time by 50%, reduce development costs by 24% and increase quality by 30%.

The third major question concerns how to measure CE. Jim again cited Motorola which discovered in 1987 that its defect rate was approximately three-sigma (66,810 parts per million). It set its goal at six-sigma (3.4 parts per million) by 1992, which required a 10-fold improvement in 1989 and more than a 100-fold improvement in 1991. One of the ways to pursue six-sigma is by understanding its relationship to design tolerance and process capability. This relationship can be quantified by a Capability Index (C_p). C_p is the ratio of "specification wide" or design tolerance to process capability or process variation. Product designers own the numerator or specification width, while process designers own the denominator or process capability. This ratio encourages the two functions to do concurrent design by giving them a communication medium and a common goal. Motorola aims at a robust design in which the C_p ratio is 2.

The fourth major question concerns what needs to be done to achieve CE. Jim indicated that CE concepts should extend beyond engineering and manufacturing. For example, Westinghouse has reduced customer orders from 56 days to 10 days, reduced time to close accounting books from 14 days to 3 days, and reduced time to complete patents from two years to 90 days. Jim suggests that achievements like these require very ambitious goals of an order of magnitude change (10-fold) to be achieved at clearly specified dates (six to twelve month intervals).

No two companies will start at the same point. Westinghouse began offering courses in value analysis and statistical methods in 1985, courses in process analysis, variance reduction and Taguchi Methods in 1986-87, and courses in design for customer value in 1989-91. It is now studying ways to measure six-sigma. It is looking at adapting or developing tools and methodologies to be utilized throughout the entire product life cycle. For example, Westinghouse has developed a methodology called "Value Edge" which can help customers articulate their product attribute preferences (as a supplement to QFD). They also have developed methodologies to improve configuration management and to track a product's field history. They continue to work on ways to improve team dynamics, especially when design and manufacturing differ significantly in educational background.

Sources of New Product Development Capability

Gerald I. Susman
Penn State University

Gerry's presentation was based on the epilogue he wrote for the book he edited, *Integrating Design and Manufacturing for Competitive Advantage*, which was published last year by Oxford University Press. The epilogue introduces a framework that summarizes the ideas of the book's 21 contributing authors. The framework assumes that the new product development process is information intensive, whereby information in the form of ideas and knowledge is converted into saleable products.

The product development process can be improved by simplifying and clarifying information, by developing the capability to process information, and by facilitating the ability to learn.

Tools and techniques like design for assembly simplify information by reducing the number of parts in a product, simplifying the interfaces between parts and generally making the parts easier to assemble manually or by automation. Information also can be simplified by designing whole families of products that can be derived from a single product platform. The families share common parts that don't have to be redesigned whenever a new product is developed from the platform. Xerox's highly successful 9900 Series shared about 60 to 70% of parts with its predecessor product. Sony developed more than 180 different products from only three basic platforms. Each platform was developed to serve very different types of markets. The products produced from these platforms were designed to meet the needs of market niches around the world.

If subsystems are self-contained with a standard interface between them, then each can be worked on independently so that two or more subsystems can be designed simultaneously. Innovations in any one subsystem need not lead to the redesign of other subsystems as long as the interface between the subsystems remains the same, e.g., personal computers. Modularity is not cost free, however, in that interface connections add costs to a product, but the benefits in development speed and market responsiveness tend to make up for the cost.

Introducing only proven technologies into products and introducing them serially simplifies information processing. The temptation to "hit a home run" with a new product can lead a product development team to add too much technical risk into the new product. The uncertainty introduced during the development process complicates problem-solving and can lead to unacceptable delays in product introduction.

Codification and computerization of manufacturing data and design guidelines can simplify and clarify information. The ability to codify and computerize such data depends, in part, on taking some of the actions cited earlier. Research conducted at Penn State suggests that too much relevant data and guidelines still reside only in the heads of experienced manufacturing and design engineers or can be found only in relatively inaccessible engineering handbooks.

Finally, Quality Function Deployment can clarify information by facilitating internal integrity, i.e., the fit among all product's contributors, and external integrity, i.e., the congruence between the product and its intended use. Also, a concept champion can help the team keep its problem-solving consistent with the agreed-upon product definition.

Three mechanisms for coordinating product development projects were introduced. Integrative mechanisms, include organization-wide policies and practices that are designed to overcome the potentially negative effects of functional specialization. Although functional specialization is desirable for many projects, it can lead to misunderstanding and conflict between project personnel. Integrative mechanisms to discourage such dynamics include status parity between functions, strong program managers, project-based evaluation, rotation between functions, top management support and co-location of design and manufacturing personnel.

Group processes include specific practices and behaviors of project managers or team members that affect work team structure and dynamics. Examples include consensus of project goals, time spent in meetings, integrative problem-solving, percent time spent on the project, and turnover of project personnel. Codification and computerization consists of manufacturing data and design guidelines that are used to integrate product and process design. Data and guidelines vary in degree of codification and accessibility to team members as well as in their applicability to other projects being undertaken in the company.

Group processes and codification/computerization are assumed to be alternative means for processing information that integrate design and manufacturing inputs. Group processes are assumed to offer more effective means to process information when technical risk is high, and codification/ computerization to offer more effective means to process information when technical risk is low.

Questionnaire data collected from over 100 product development projects suggest that integrative mechanisms contribute positively to first-of-a-kind projects, while codification and computerization contribute negatively to them. The results also suggest that integrative mechanisms contribute weakly or negatively to routine enhancement projects, while codification and computerization of data contribute positively to them. Effective management of product development projects requires recognition and selection of the coordination mechanism that is appropriate for each type of project.

The ability to learn requires willingness to reflect on experiences, to share information and revisit old problems. Most team members are anxious to move on to the next project, so they devote little time to reflecting back on what went right and wrong on their last project. There is seldom any documentation available that members of future projects can use to avoid making the same mistakes as their predecessors. By contrast, Hitachi keeps "problem logs" in which problems and solutions are recorded and made available to present and future project personnel.

The manner in which senior management assigns project personnel to projects often fails to take advantage of learning opportunities. There clearly is benefit to having designers remain assigned to their projects until pilot production, yet designers are often reassigned to new projects as soon as their drawings are released to manufacturing. There also is a clear benefit to assigning designers to work on derivative products within the same product family, yet too often the reassignment is based on criteria that do not take learning into account.

A substantial portion of the Japanese advantage in development lead-time for new cars is based on the speed with which prototypes are developed. This speed is due in part to the involvement of key suppliers in the product development process, which reduces bureaucratic slip-ups and delays. As a result, the same or a greater number of prototype cycles are possible earlier in the development process, permitting more opportunities to improve the product when it is less expensive to do so.

Prototyping capability contributed to Motorola's success with the Bandit pager. The Bandit team generated four prototype cycles during the product's development, with integration between functions being a key team objective from the start. Prototypes were scheduled by the calendar rather than by completion of development phases. Each function was expected to make contributions to every prototype cycle or to document what remained for it to contribute to the next cycle and when it expected its contributions to be ready. The generation of four prototype cycles increased opportunities

to improve the final product and increased awareness among team members of each function's contributions to the development process.

The type of learning discussed above is learning by doing; that is, learning from the experience of designing and developing products. Learning opportunities are available also from listening carefully to customers who use the product, either preproduction units at "beta-sites" or units of the first generation of the product. The knowledge gained from "learning by using" can be incorporated into subsequent production runs or into the next generation of the product. Lastly, one cannot overlook the learning opportunities that arise even from failed products. The engineering literature is replete with examples of companies that introduced an unsuccessful product, but acquired capabilities from their development experience and gathered sufficient intelligence from the marketplace to produce remarkably successful successor products.