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Capturing and Sharing Learning in IPD Teams

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Background

Hamilton Standard, a subsidiary of United Technology, is an aerospace component manufacturer located in Windsor Locks, CT. Hamilton serves both commercial and military customers and its products appear in all types of aircraft from Cessnas to F-18s. The specific components are bundled into three main categories: engine & flight control systems, environmental control systems and propulsion. In addition to the domestic facilities, Hamilton owns a number of foreign businesses that manufacture primarily the same components for overseas markets.

Until the mid 1980s, Hamilton's engineering design was inefficient and unresponsive. A typical project would take 12 months in the design department, 6 months in drafting, 6 months in manufacturing engineering and another 12 months in the factory until suitable volumes could be achieved. This "over the wall" design process not only was slow because of the large number of engineering changes, but often developed products that could not be manufactured.

Strategy

In 1985, Hamilton did an analysis of a typical project for the Boeing 747 and determined the cycle time to be 20 months. Cycle time is defined as the time elapsed from initiation of the design to the first component to undergo testing. This long cycle time was brought to the attention of upper management who then approved the concept of Integrated Product Development (IPD.) To facilitate the process, a group received an off-site training program on the IPD process. This training was supplemented by a session on coordinating meetings and another on team building exercises. The IPD structure begins with an executive level that coordinates efforts of a steering committee. The steering committee consists of directors of the functional groups. Finally, a system team oversees the efforts of specific component teams and reports to the steering committee.

The component team is responsible for the actual design. The team consists of personnel from: manufacturing engineering, design, purchasing, quality, reliability, suppliers, factory foreman and others. These people communicate during weekly meetings, via e-mail and also through the minutes of each meeting that are distributed to all team members. The minutes are necessary because only those people that are specifically needed attend the weekly meetings. Overall, the goal of the team is to push responsibility to the lowest possible level. Team members are responsible for meeting customer requirements including cost, weight, schedule, maintainability and reliability. The teams are empowered to determine materials, vendors, capital requirements, make/buy decisions and the incorporation of new technology.

Hamilton found a number of key success factors when implementing IPD into the design process. While the personnel from different functional areas still report to those areas, the need for co-location at the manufacturing site was deemed critical. Having factory workers involved in the process also brought new ideas to the design table. The component teams also watched these assemblers to see problems and opportunities that were not recognized by the

assemblers. The system teams to which the component teams report are able to enforce commonality of design and hardware across component teams. This eliminates capital expenditure as well as setup down- times and associated quality losses.

In addition to the internal efficiencies achieved through IPD, a number of benefits to the customer are realized. With suppliers involved early in the design process, they are able to design using the knowledge of the component specifications. Because of the reduced cycle time over long product development lives, lower costs can be achieved. Also, service concerns, such as accessibility and modularity, are taken into account in the original design. The cohesive factor among all of the success factors is timely and accurate communication.

Results

IPD design first was attempted on two projects, one for the Boeing 777 and another for the F-18. These designs were not component modifications, but original designs. While a modified part for a Boeing 747 had a cycle time of 20 months, the new designs took approximately seven and six months, respectively. Because these were Hamilton's first attempts at IPD, similar if not better results are expected in future projects.

Because of the need for accurate and timely information for IPD teams to be successful, a company-wide database was developed for facilitating this communication. Based on a network of PCs and workstations, the database allows for key word, single and multiple field searches and is now required as part of the design review. This network also allows feedback from "non-traditional" areas such as quality engineering and assembly & test that eliminates similar problems from reoccurring. This user-friendly database is available to all company associates and is expected to contribute substantially to future successes with IPD.

Development and Implementation of "Design for Manufacturing"

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Background

General Dynamics' Land Systems Division is located in Sterling Heights, MI. The company manufactures heavy machinery primarily for defense applications. Because of its links to the military, schedules are driven by government schedules. Time to market is especially important to General Dynamics because of potential changes in funding appropriation.

The typical method of design began after a design concept was presented to the company. To determine methods of production, component tolerances, etc., an expert in a product would set the entire structure and develop a process structure. Two problems plague this type of design; the process is inherently slow and design can develop tunnel vision. General Dynamics sought both to improve the speed with which products could be manufactured as well as combining new ideas and processes to develop a better design at the same time.

Strategy

The division adopted its Design for Manufacturing, or DFM, to realize two major benefits. First, the process was to be able to quickly design a product that met the specifications desired by the customer. Secondly, DFM was to prepare General Dynamics for actually producing the product. Core design teams were formed consisting of: systems engineering, quality, logistics, customer, manufacturing and subcontractors. These core teams were assisted by extended teams that encompassed all other areas, including health & safety, procurement and other liaisons. Essentially, the goal of the entire process was to link manufacturing processes to product design.

The product design is tackled first. Once the design concept report is received through the General Dynamic's network, the core teams meet in the DFM center. Because of the large size of the finished products, usually core teams are responsible for major components. The given parameters of the component are entered into a CAD system to enable engineers to familiarize themselves with the overall structure and its functionality. At this point, part processing is decided upon, including tool selection and tolerance specification.

The core teams utilize the necessary extended teams to make determinations at all points, and the team composition changes over the life cycle of the product. Once the basic design has been decided upon, all of the information to date is combined into a series of DFM documents. From these documents and with the assistance of suppliers and tooling operators, decisions such as where and how to inspect for quality and the optimum orientation of

SPC data should be collected and how this information can best be communicated. The final step in the design element is sending the model to a workstation that does a mathematical tolerance check and validates the recommendations of the core teams. The key benefit to this type of design strategy is that the manufacturing technologies and capabilities are known up front and therefore design changes can be made early in the process which saves time and money.

Preparing the organization for production is the second major stage. Through the use of a computer simulation, the impact the product will have on the intended facility is evaluated. In doing so, a CAD layout of the factory floor is processed with information about the estimated labor requirements and shift limitations as parameters. The model then routes the product through the production facility, taking into account other products and potential bottlenecks. Specific operations are then simulated, including welding, molding and stamping operations. This stage also involves writing the NC programs for automated tasks and finalizing any additional operational problems.

Results

Because General Dynamic's product specifications are set in governmental contracts, the DFM technique allows engineers to incorporate tolerances, materials, inspection requirements, etc., into the design and also provides a tool for documentation. General Dynamics has already used the DFM procedure in the redesign of six major applications, including a 70 ton vehicle capable of deploying a 26 m. temporary bridge, and has tentative plans for five additional vehicle redesigns.

Quantification of the benefits of the program have not been actively pursued. Only in one instance, when the original core team was attempting to secure funding for additional software, was a dollar estimate placed on the procedure. In a single machine operation within a large project the savings were estimated at $75,000. The rationale for not pursuing additional hard data was that the savings in time and manpower were patently obvious to those involved and that spending time collecting data would only take away from other more beneficial projects. Although General Dynamics decided not to quantify an entire project's savings, the DFM process is expected to be utilized in as many future projects as possible.

Development and Implementation of Concurrent Engineering for Complex Systems

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Background

Abbott Laboratories is composed of three business units: hospital products, pharmaceuticals and diagnostics. Although only 23 years old, the firm is a world leader in the development of new technologies for detecting and managing diseases, beginning with the breakthrough test for Hepatitis B in 1972. Principle customers include hospitals, commercial laboratories, blood banks and criminal justice facilities.

Many of the end products, while small in size, are extremely complex. Prior to the development of sophisticated measuring and monitoring devices, entire classifications of drugs were largely ignored by doctors because of the small range of concentrations within which they are therapeutic. However, through its innovative products, Abbott has increased the potential pool of cures for a number of diseases and ailments. Recent products include an amino acid testing system and an abusive drug testing process.

The development of concurrent engineering within Abbott Laboratories was in part the result of four external pressures on its design teams. In the industry, there is a great demand for new products that necessitates reduced cycle time and therefore development time for these new products. Secondly, competition has become much more innovative and are also copying products much faster. Of course with the changes occurring in the health-care industry, there is tremendous pressure to reduce costs. Finally, the complex requirement of such systems are difficult because development costs are high, capabilities are difficult to estimate initially, subsystems are difficult to integrate and the inclusion of multiple technologies brings increased risks.

Strategy

The concurrent engineering process attempted to provide for some structure, while documenting processes and placing importance on time management. The first key element of the process is to institute standard phases of the process with

specific goals and requirements at each stage. Perhaps the most important element is a feasibility phase that attempts to identify, quantify and manage both technological and marketing risks associated with the project. The use of documentation and peer reviews are also encouraged throughout the process. Development teams are used during the design process, utilizing cross-functional members. Finally, enabling tools that promote communication within team members, assist design and promote recycling are utilized.

The product definition portion of the development phase used a number of tools and was based largely on QFD techniques. The cross functional development teams consisted of program management, marketing & sales, R&D, Quality, Manufacturing and Support staff. Each function's responsibilities wax and wane as needed. The definition process generally takes between six and nine months, depending upon whether the product is new or a rework. The team actively attempts to collect the "voice of the customer" and then transforms these needs into requirements or product specifications. Then problems are decomposed to generate a range of feasible solutions, which are then decided upon.

Another major task within the development process is managing risks. At each stage in the project a risk profile is developed because during the long development process, risks and their importance can shift. This profile describes the risk, formulates a risk reduction plan and contingency plans, determines decision points for when contingency plans should be enacted and finally quantifies each risk to the project. Risks are based upon four key elements of a process: time to market, R&D costs, product cost and product performance. As a tool for evaluating risks, a risk map is plotted using: probability of the risk creating a problem versus the consequences of that risk. This tool is then used to determine the priority with which the risks are managed.

Finally, the human element of concurrent engineering is managed with a variety of techniques. The multi-functional design teams are formed early in the process so that both "idea people," problem solvers and implementation groups have access to the same information. The different needs of groups are taken into account; idea people generally are less structured than the technical problem solving group. Post-launch reviews are also used to identify problems with the process and to formally document each stage for future review.

Results

Because the process is very new to Abbott, quantification of the results are not yet conclusive. In fact, the concurrent process was not defined until the midpoint of the design in question. However, because of the complex systems involved, design engineers intuitively knew the need for such a framework. While the product definition stage of a typical project for Abbott generally takes between six and nine months, the new process is expected to reduce this to three months for design reworks. As Abbott continues to develop innovative products such as drug detection systems, concurrent engineering is expected to be utilized to further reduce cycle time and product cost.

QFD as a Catalyst for Organizational Change

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Background

Dodge of Mishawaka, Indiana had been involved in the manufacture of wooden pulleys since 1873. By the time Reliance Electric acquired the firm in the 1960s, production had shifted to making power transmission components for materials handling equipment. Following a period of transition during which the company was involved with a management leveraged buyout, Reliance Electric was acquired by Rockwell Automation in 1994. While the organizational structure was characterized by the traditional functional silos, Dodge management felt it was a better internal communicator because all personnel were co-located and product focused.

Despite this feeling, there was an effort during the late 1980s to change Dodge's design process. Because of the stable market in which the company competed, an early product introduction usually resulted in higher market share and sales volume. In addition, the early entrant was able to secure a price premium and reduce costs faster through learning curve experience. The greatest impetus for change occurred after a redesign of the SAF-XT, a housing for mounted roller bearings. While the redesign propelled Dodge from an insignificant market share position to number three in the industry, the design was unable to fit both spherical and split sphere bearings. Therefore, although the

product was the result of a co-located design team and successful on the surface, serious problems in the design process were apparent.

Strategy

Adopting QFD was welcomed throughout most of the organization after the problems with the SAF-XT surfaced. Marketing was now supporting both the redesigned and original product, while unable to reduce price to the customer as a result. Engineering had designed the unit for use in the conveyer industry, but was informed through marketing that customers were using the products in applications requiring other design specifications. Manufacturing operations were then plagued with the downstream problems of marketing and design engineering. However, because the product on the surface was successful and upper management had reservations with investing more money into the project, the initial QFD attempts were primarily small in scale. Quality managers provided some training for marketing and engineering while teams gathered competitive products to begin investigating cost reduction opportunities.

The first focused stage of the QFD project involved investigating competitive products to enable the group to be able to ask informed questions of its customers. A range of personnel was involved in the process, from marketing and design engineers to machining operators and pattern makers. During the process, other products were disassembled to determine process technology as well as reasons for differences in the commodity-like products. Another purpose of the disassembly exercise was to enable marketing and sales personnel to ask better questions of customer expectations. The QFD group felt that customers may not have a frame of reference to compare the entire range of product or be able to conceptualize what features would exceed product expectations.

Once a database of information was compiled about the market offerings, the QFD group hoped to gain non-biased customer opinions. Because of the weight of the products and the possibility that brand names may alter answers, physically bringing the products to Dodge's customers was rejected. However, photographs of disassembled products were used in the hope of eliminating the brand name recognition. In addition, preferences for individual components of the product could be extracted. The questionnaire was continually updated as additional information was revealed. From this information, a House of Quality was developed to set target values, make technical comparisons between products and to find correlations between specifications. The entire QFD team was involved in the process.

Results

The positive results of the QFD team were apparent both internal to Dodge and in the marketplace. Internally, the group gained experience to use on other projects and the data to more effectively market its products. Based on the costing methods used, a 22% reduction in cost was achieved, while reducing cycle time by 35%. Although Dodge maintains a slightly higher finished goods inventory because of the stocking of English and metric products, WIP was reduced through the use of common parts. Finally, the process enabled design to realize the opportunities for future uses with "smart" bearings that return information on temperature, vibration and wear to the operator.

The redesign of the bearing housing was also successful in the marketplace. Although products in the market are difficult to differentiate, Dodge used customer statements in its marketing brochure to show its customers that "it was [their] idea." In the relatively stagnant market, the SAF-XT gained significant market share in the US, while enabling the company to enter the European market.

Customer Driven Innovation in Design Practices

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Background

The Jervis B. Webb company was founded in 1919 after the development of a forged rivetless chain conveyer. The company, headquartered in Farmington Hills, MI is a world leader in design and manufacturer of material handling systems. Products include automated electrified monorails, baggage handling equipment and integrated sorting and packaging equipment. Webb supplies most types of manufacturing industries, including primarily domestic automakers, but also airlines, and paper, appliance and steel manufacturers.

During the past five years, there have been two major changes in the material handling systems industry that has prompted Webb to restructure its design process. Because of the reduced cycle time of

the products its customers provide, there has been increased pressure for Webb to also reduce cycle time to facilitate product introductions. Secondly, Webb's customers want to drastically reduce the amount of time facilities are inoperable while changeovers are performed. As an additional goal, these customers want the material handling equipment operational prior to the product launch stage.

Strategy

Although the Webb company was a relatively technically advanced manufacturing company, utilizing computer-aided design for almost two decades, the process was incapable of meeting current customer requirements. Therefore, as a first step in revamping its operations, Webb switched from a mainframe platform to a PC system using AutoCad. This change enabled Webb engineers to tie into the design plans of its customer base.

Secondly, a different methodology was taken with respect to standardization of operations. Prior to the change, every single component of a project was kept in a separate file from the others. Therefore, similar or even identical parts would have different part numbers, based upon the project it was linked to. Although some standardization was attempted, of the over 13,000 components standardized, only 500 were used at the time of the standardization audit. The structure of the design process was then changed to operate around components that together built a design, instead of a design that comprised many components. At the same time, the proliferation of almost identical components was halted and the overall product line somewhat reduced.

Webb management decided that the organization of the company was also preventing the design process from being responsive. While each department was computerized, each used a different database to collect information and inter-department information was performed manually. A completely paperless system was instituted, utilizing a centralized database that was accessible by all departments. This centralized system eliminated much of the time spent on correspondence paperwork while allowing project leaders to assess the progress and cost of an entire project on-line.

The final stage of the process was changing the basis of the Webb design process. Project engineers were co-located on-site with customers to be better able to anticipate problems with either the Webb product or the customer's facility. The actual design was also begun earlier with conservative assumptions about the impact of the assumptions on downstream design changes, timing and cost. Components were also designed more flexibly; bolts were used instead of welding when possible. Teams of engineers were also assigned to large repeat customers so that the teams would become more acquainted with the facilities and expectations of that customer. Finally, many repetitive procedures were automated that allowed for both placing material orders electronically and also obtaining cost estimates during different phases of the design.

Results

The techniques utilized by the Webb design teams have been successful from a number of assessment points. Of primary importance, the time during which Webb was involved in a customer's facility changeover was reduced from 18 to nine months, while enabling customer projects to be reduced from 24 to 13 months. In each of the projects to date, the Webb machinery was also operational prior to its customers' product launches.

The new techniques have also benefited Webb in other ways. By centralizing the information flows, the engineering design teams are more productive and spend less time on paperwork or redundant designs. Because many of the modular components are finished prior to the customers' facility being ready to accept them, Webb is able to debug the systems and therefore provide more reliable equipment. The new design sequence has enabled the Jervis Webb company to provide its customers with higher quality, flexible products in half as much time.

Use of Concurrent Engineering in Redesigning the V-22

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Boeing Corp.

Background

The Boeing Defense Space Group–Helicopter Division is located in Ridley Park, PA. The division designs and produces helicopters and airplane components. Many of the projects are large, complex systems requiring the work of between 500 and 1000 designers. With the level of outsourcing reaching almost 50% with some projects, the need for

coordination of efforts is becoming increasingly important.

Prior to the development of Integrated Product Teams (IPDs), Boeing was characterized by the typical "over the wall" design process. As each function was responsible for the profit of its component, the sub-optimization that followed resulted in increased rework costs. With the scale and length of projects, the costs of rework following design and fabrication of tooling and parts was burdensome. Therefore, in 1985 Boeing began the IPT process that sought to eliminate these difficulties by focusing teams on a single product.

Strategy

The IPT design structure consisted of four basic elements: IPT teams, Digital Product Definition, Digital Pre-Assembly and Concurrent Product Definition. The IPT teams consist of approximately 30 members who are assigned a product or component, depending upon the scale of the project. These teams consist of tool design, wiring design, manufacturing engineering, quality, customer representatives, stress analysis, etc. The team leader acts as a facilitator, while decisions relating to technical performance, budget, organizational structure and schedule are the responsibility of the group. In fact, the only responsibility of the company at large is the initial staffing of the group.

With the Digital Product Definition portion of the design, the intent was to produce a single source of all information. Beginning in 1990, all functions supporting the design were linked to a common database. From this database, communication between functions such as engineering designers and tooling designers may occur early within the design cycle. All design elements are drawn from this centralized database, including the NC programming, bill of materials, etc.

As early as 1987, Digital Pre-Assembly was used to facilitate the design process. While a regular CAD system does allow for visualization of the design in progress, the complexity of Boeing's projects left some ambiguity in the process. Using the Digital Pre-Assembly, engineers are able to check for more elusive elements such as manufacturing space requirements and potential maintenance problem areas. The modeling has progressed, using limited amounts of the specific geometry to allow for a virtual flyby of the project. The equipment has also been used for presentations to Congress.

Finally, Concurrent Product Definition attempts to coordinate the interactions of engineers on the design in progress. Because each of the hundreds of engineers working on the project make changes daily that will affect elements such as load requirements of other designers, there is the need for a sequential release of data. The data sets are coordinated into three main groupings; each requiring a progressively more exacting degree of accuracy. For instance, after the first grouping is released, enough information is available for tool design to begin. After the final release of data sets, the design is essentially complete.

Results

The IPT process was described using the design of the V-22 helicopter/aircraft; a vertical takeoff "airplane." In order to reduce both the design-to-cost metric and also fuselage weight by over 20%, the IPT groups reduced part and fastener counts, rework and scrap, while utilizing new composite materials and production processes. Through using new technologies and the virtual flybys, the IPT groups also reduced the tooling complexity while increasing machine utilization.

Through the use of such digital tools, significant savings were realized throughout the project. Within the fuselage project, the outer "skin" was reduced from 9 mechanically spliced, hand mounted pieces to a single composite. This redesign contributed in reducing the overall weight by 322 pounds. In addition, the number of structural stiffeners was reduced from 157 to 17 while an overall 36% decrease in parts for the three part fuselage system was achieved. Finally, the number of engineering drawing changes was reduced 80%, helping Boeing to reduce costs while improving the response time to customer requests.

Product Development Team Effectiveness

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Background

A study performed by Gerald I. Susman and Judith M. Ray attempts to confirm several hypotheses relating to the success of product development teams. Specifically, it was presumed that integrative mechanisms such as participative decision-making,

team leader strength and project-based awards would positively affect the outcome of a project. Secondly, the attitude and behavior of the members of the product development teams were expected to affect the relationship between integrative mechanisms and the outcome of the project. Finally, mechanisms such as participative decision making were expected to be more helpful in the successful completion of high risk projects versus low risk projects.

Methodology

In order to test the three hypotheses, a questionnaire was distributed to a sample of 55 product development teams, including commercial companies, defense contractors and the US Armed Forces. Each of the respondents answered questions relating to the organizational structure of the group, evaluations of success of the project and the level of risk posed by the project. The questions were compiled from previous studies relating to integrative mechanisms as well as from published literature on group effectiveness. The sample received was pared to include only those team members who had devoted at least 30% of their time on the particular project in an attempt to secure more reliable responses.

A number of indices were then developed to relate responses for key parameters. The index relating team leader strength included such aspects as: budget authority, relative clout and final decision making ability. A participative decision-making index was compiled from answers relating to: extent of involvement in budget and schedule decisions, nature of decision making and relative team leader influence in decision making. An index characterizing the group processes included such items as: level of agreement on goals and priorities, percent of team members influencing decisions of the group and how satisfied members were with regard to their influence on the group as a whole. Finally, special care was taken to secure unbiased estimates of the risk associated with each of the projects. Different types of risk were incorporated, such as the risk of designing a new product as opposed to a modification as well as using new materials or processes.

Results

A number of insights were gained from the analysis of the questionnaires. In none of the groups were many of the decisions made without the group leader, although both functional managers and group leaders appear to utilize more decentralized decision making. Awards systems were different for high and low risk projects and expectations of rewards were more likely to be good publicity and higher salary versus the possibility of a promotion, bonus or non-monetary rewards. As expected, participative decision-making and award systems were significantly and positively related to the outcome of a project and therefore in partial support of the first hypothesis.

The second hypothesis was to test whether attitude and behavior of the group members affected the relationship between integrative mechanisms and project outcome. However, of the three integrative mechanisms, only the project-based awards showed a significant relation. Therefore, the hypothesis is not statistically supported. Finally, while the relation between risk and participative decision-making was significant, the relation proved stronger when the risk is lower. Therefore, such techniques do not appear to assist group effectiveness as much as in high risk projects; counter to the third hypothesis.

Conclusion

The study does have some implications for group management. Incorporating participative decision making and project-based reward systems seems to enable teams to be more successful, while the impact of a strong team leader is not as stringent of a requirement. The study also indicated that behaviors and attitudes of group members were not as significant in defining the success of the group, as were integrative mechanisms. An explanation for integrative mechanisms being less effective in high risk projects was also posed. In these types of projects, expertise is perhaps concentrated in a smaller percent of the members, thus mitigating the benefits of participative decision making.

The results may then be used in practical applications. The use of project-based reward systems can be expected to contribute positively to both high and low risk projects. However, participative decision making is expected to be useful only in the normally encountered lower risk projects. Reasoning for this difference may lie in different levels of dissemination of information; high risk projects may entail some additional strategic information not released by the leader to the members of the group, while less risky projects are less likely to encounter the problem.