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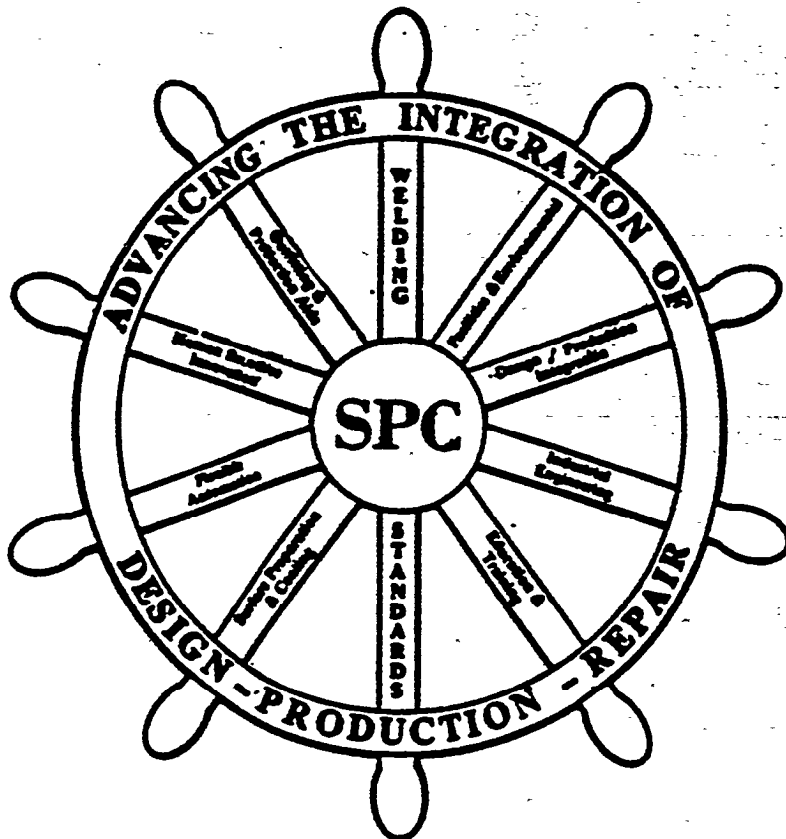
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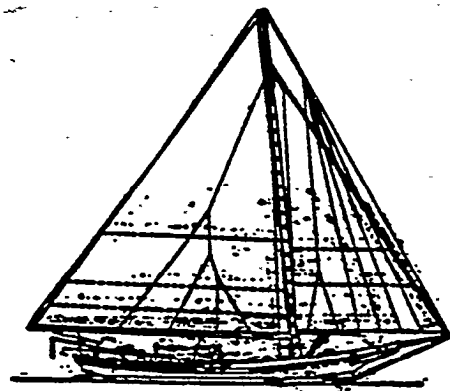
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Product Work Breakdown: An Essential Approach for Ship Overhauls

No. 6B

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ABSTRACT

Some North American shipyard managers have successfully adopted a product work breakdown structure for ship construction. Adoption by those who would compete is inevitable. But, none have applied the same product-oriented approach for ship overhauls. Yet, significant such progress is being made by a naval shipyard.

In yards which accept both challenges, continuing to employ a system work breakdown structure for overhauls while applying a product work breakdown structure for construction, doesn't make sense. Two different management information systems are required.

Thus, this paper identifies how the same product-oriented logic successfully applied to improve construction productivity, also applies for overhauls.

INTRODUCTION

Many are familiar with or at least aware of the logic revolution irreversibly established in some North American shipyards. Basically, information that had been grouped only by system, e.g., as on a system arrangement and detail drawing, is now grouped in the design process to exactly anticipate the parts, subassemblies, and assemblies, i.e., the interim products, required to build ships. In each case, the build strategy which guides designers in so grouping information, is imposed before contract design starts!

When the interim products are grouped by the problems inherent in their manufacture, even for different ships being built simultaneously, production lines can be organized which are just as effective as counterparts in the automobile manufacturing industry. This.. approach which examines required interim products with different eyes so to speak, looks for manufacturing commonalities and ignores differences in design details. The organization of

alike work in this manner is called Group Technology (GT). GT is the most ideal way to process interim products of different designs in varying quantities as required for ships and for many end products other than ships. [2]

For certain interim products, production lines sometimes constitute real work flows wherein materials are conveyed from work station to work station. In contrast, when a team of workers is moved from site to site and the work category at each site remains the same, the effort is regarded as virtual work flow. The impact on people is the same as if they were at fixed work stations and a conveyor was transporting the materials being worked. The objective of work flows, both real and virtual, is to avoid the greatest single loss in any industrial endeavor, i.e., people waiting for work.

Rationalizing virtual work flows is extremely important because they are means for effectively organizing very much of the ship production effort. Particularly outfitting and painting, and because they are the means for bringing unprecedented order to nearly all shipboard overhaul activities. Whereas, traditional methods which feature system-by-system work packages assigned to different supervisors are always issued with the inferred management cop-out, "Somehow coordinate among yourselves."

As work on one system conflicts with work on other systems in an infinite number of ways, traditional supervisors are preoccupied with reacting to day-to-day changing circumstances. such disruption is significantly reduced with the product-oriented (also called zone-oriented) approach because all work of one type, say gas cutting, is planned to be performed in a specific zone during a specific stage. No two work teams doing different types of work are unintentionally scheduled to be in the same zone at the same time.

In the absence of conflicts, productivity indicators, such as, man-hours per weight of material ripped out or man-hours per lineal feet of gas cutting, become very meaningful. Work performances become predictable. This association of man-hours with a discrete product is essential for true compliance with the U.S. Department of Defense cost/schedule control systems criterion for a work breakdown structure to "...define the product to be produced as well as the work to be accomplished...." [3]

Equally important, each envisioned interim product, i.e., what is to be worked in a specific zone during a specific stage, becomes a focal point for organizing prerequisite work instructions, materials, and manpower. Already, some overhaul strategies are being expressed in terms of zones/stages. As a consequence, the preparation of work instructions and the procurement and marshaling of materials, including materials overhauled in yard shops, proceeds in accordance with the exact same strategy to be applied by production people on board for each unit of work.

Also, because their system-oriented work packages are usually large and scheduled for implementation over relatively long periods, traditional supervisors become skilled at retaining unspent budgeted man-hours from one-system in order to charge them to another system for which they would otherwise have a budget overrun. Usually, their intent is not deceit. More often, they want to avoid having to make explanations when they are preoccupied with reacting to more unforeseen problems. The consequence is experience vested in supervisors only, i.e., inadequate Corporate experience.

The most important thing in any industrial enterprise is how to analyze. Corporate experience is crucial for accurately estimating future overhauls, for budgeting man-hours based on workers performing normally in a statistical sense, for scheduling with certainty based on mean values and standard deviations, and for constantly setting targets for improvement. As overhauls become more complicated, particularly overhauls of warships, their successful implementation with 'traditional system-by-system grouping of people, information and work, is becoming impossible. Adequate corporate experience can only be delivered from a product work breakdown structure with people and information grouped accordingly. Work organized by zone/stage which is also classified by problem area per GT logic, is susceptible to statistical analysis. When work is so organized,, Dr. W. Edwards Deming's fourteen points for management become alive even for overhauls.

Some traditionalists will remain skeptical. "Overhauls are different from construction!", they will say and they are right. In two very significant aspects, -overhauls are much easier! Most overhauls are not encumbered with having to integrate structural work to the degree encountered in construction. Also, management, supervision, and the workforce as an entity, knows an infinite amount more about a ship due to arrive for overhaul than does an organization awarded a shipbuilding contract know about the ship to be built. More Often than not, an overhaul activity has previously overhauled a ship of the same type if not of the same class.

"What about open and inspect work?", traditionalists will counter. The lack of definitive information upon contract award is what both construction and overhauls have most in common! In the world's most effective shipyard, contract design is part of the shipbuilding process. With just preliminary design input, production engineers document a build strategy which will guide subsequent design-stages. Before, the contract protected only the owner's ship performance characteristics. Now, with incorporation of a build strategy in the contract design, the yard's manufacture system is also protected. This vigilance guarantees that the manufacturing system will retain its flexible nature and, through management by target, will continue to improve. Without such flexibility and constant improvement, competitiveness is jeopardized. The yard's very existence is at stake. A major production engineering effort, i.e., planning well before the fact. must Commence with less information than is usually available when a contract is awarded for overhaul work. Devising an overhaul strategy in terms of zones/stages for a known ship type is much easier.

As shown in Figure 1, the design process for construction is organized in phases. The first, contract-design, is preceded by a product-engineered build strategy. As the progress of contract design makes more information available, production engineers refine the build strategy in time to guide the next design phase, i.e., functional design, and so on. By the time the last design stage is reached, the information being produced by the production-engineering effort is tactical in nature, e.g., it advises designers where to show on sketches of hull blocks, the reference points and lines needed to facilitate hull erection, it includes specific instructions for drilling and tapping fillet Welds in portions-of blocks that will form oil-tight bulkheads so that such welds may be air tested in the shop, it includes instructions for dividing material lists in order to obtain

work packages of about 40 man-hours each, etc.

In the process depicted by Figure 1, information is first grouped in a large-frame sense, then in an intermediate-frame sense, and thereafter in a small-frame sense corresponding to work packages. In other words data always exists for the entire construction effort but in different degrees of refinement as time goes by. The process is the same for large overhaul endeavors as shown in Figure 2.

The boxes and flows shown in Figures 1 and 2 are identical only for discussion purposes. Open-and-inspect on board and open-and-inspect in Shops does not occur in distinct phases as shown in Figure 2. They occur bit by bit as various equipments are opened regardless of their locations. But, the effect is the same as in construction projects. Information describing required work is being refined as time goes by.

Overhaul traditionalists will persist, "What about materials? We don't know what is needed until open-and-inspect takes place!" To the uninitiated it would seem that similar overhauls have never been accomplished before and that contingent work cannot be planned and scheduled.

CONTROL THROUGH CONTROL OF MATERIAL

One of the neatest things about a product work breakdown is that it facilitates production control through control of material. Man-hours required are always related to some physical characteristic of material regardless of whether something is to be ripped out, overhauled, fabricated, or reinstalled. With obsessive focus on identifying all material including contingent material at the bid stage, with rough assessment of where in the ship and when materials are to be processed, and with productivity indicators which reflect corporate experience, man-hours required are obtained and schedules are derived. The initial man-hour budgets and schedules so obtained do not make sense unless they are in a large-frame sense commensurate with the grouping of information available. As the materials to be processed become more definitive, the man-hour budgets and schedules are refined accordingly. At first some materials can be counted from an overhaul work list and from a list of ship alterations (shipalts). Other requirements have to be estimated per material classification, e.g., so many lineal feet of medium-diameter pipe.

What is required is a more effective material management approach which recognizes that material procurement and marshaling are production control func-

tions equivalent to man-hour budgeting and scheduling. It is for this reason that in the World's most effective shipyard, the material procurement manager reports to the production control manager and the production control manager is subordinate only to the general manager. Further, a prerequisite for being a production control manager is having been a production department manager. With procurement so drawn into production control, a much greater sense of urgency emerges about material.

With such emphasis it becomes clear why the most effective shipyard managers regard the computer program which maintains the material required status as the most important computer program, that for payroll not withstanding. For all projects underway, i.e., shipbuilding, overhaul, and other, the computer assimilates all material requirements which are the result of counts of some items and estimates of others. As work is more definitized by open and inspect reports and the development of shipalt detail design drawings, a sorting and collating function immediately asks:

- o "Were materials just designated anticipated in the initial material assessment in sufficient quantities?". if not
- o "Are they long lead-time materials, materials that must be fabricated either in-house or by a subcontractor, or are they short lead-time materials?"

If any materials are newly discovered, management is immediately alerted to the fact that the current man-hour budget and schedule are incorrect. If long lead-time materials are newly discovered, management is immediately alerted for procurement action commensurate with the problem.

An essential technique not generally employed by managers outside of Japan is use of a third material classification to supplement allocated material (often called "direct material") and stores stock. The third classification is called allocated-stock because it combines features of the first two classifications. Allocated-stock pertains to relatively expensive long-lead-time materials which are required in at least moderate quantities. Too many of them are required to conveniently regard them as allocated material and they are too expensive to be treated as stores stock.

The requirements for each item of allocated-stock are assessed periodically, usually monthly and for all contracts underway at the same time (ship overhaul, ship construction and other). Per allocated-stock item, questions that are answered each month are:

- o How many are in the yard's warehouse today?
- o How many are on order that are expected to be received in the coming month?
- o How many new requirements surfaced in the past month due to open and inspect reports, design development and/or change orders?
- o How many are scheduled for issue during the coming month?

When the net requirement is determined, a margin is added by the production control organization as an allowance to offset unforeseen needs, loss, damage, defects, etc., as determined from the yard's experience with that particular item. A purchase order amendment is issued accordingly, usually to an open-end purchase order which specifies a bulk quantity estimated when information existed in a larger-frame sense. Reduced to logic, the process is similar to that traditionally applied by shipyard managers for ordering structural steel. A mill reservation is placed based on bulk tonnage and as the design develops, the mill is instructed regarding specific-size plates and shapes and delivery dates.

Another necessary material practice includes limiting the number of suppliers to two or three for each item, i.e., just enough to maintain competitive pricing while keeping a practical limit on the amount of data to be maintained in a computer data bank regarding suppliers products and past performances. Each such supplier's catalog item becomes, in a sense, shipyard standard. In the absence of such "standards" with which to guide the people performing material definition, effective sorting and collating as material requirements are refined and management of allocated stock, are elusive. In the absence of "standards", the use of computers for material management is inherently impractical.

If similar great emphasis on material was suddenly applied for complete overhauls of U.S. Navy ships, the first thing to emerge would be general awareness that planners are adversely handicapped. For each overhaul, they necessarily focus on the officially described ship configuration (list of components in a ship) for the purpose of ascertaining needs for technical manuals, replacement parts, and test equipments. The problem is that each official configuration intentionally lists only about 70% of what is purported to be in a ship. Of the 70%, reportedly, as much as 30% of the components listed are incorrect even for submarines. In other words, the basic records which planners rely on are both incomplete and inaccurate.

In traditional functional organizations which characterize most public and private shipyards outside of Japan, problems of this nature do not demand resolution commensurate with their adverse impact on productivity. In product organizations which control through control of material and focus on Cost per product, the disciplines imposed would contribute to correcting this grave situation while clearly identifying the nature and scope of the problem with the utmost sense of urgency.

PRODUCT ORGANIZATIONS

People who have acquired overhaul experience only in traditional functional organizations will have a hard time accepting all of the foregoing. There are prerequisites for success that are unknown to them. One is a product organization in which people specialize differently. Another, is greater investment in the planning effort where planning consists of both production engineering and design engineering for integrated hull construction, outfitting, and painting. Production engineering becomes more professional, ultimately, with college graduates or people having equivalent ability to think analytically, assigned as generalists in all levels of the production organization and design becoming literally an aspect of planning.

Much is written in North American college textbooks about product organizations. Their great advantage is their obsession with cost per product, or more clearly in shipyards, per interim product. Initiatives by Panel SP-2 of the Society of Naval Architects and Marine Engineers for the National Shipbuilding Research Program, disclosed reliance on product organizations by Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) of Japan for ship construction, overhaul, and other work in order to maintain leadership as the world's most effective manager of shipyards.

At the time of the disclosures, IHI people concerned with outfitting in both design and production were grouped in accordance with the following specialties for both construction and overhaul work: deck, accommodation, machinery and electrical. For warships a fifth specialty was added: weapons. Thus, all disciplines required to perform work in a machinery space, for example, were under a common boss. The same applied to the other specialties with deck designating all spaces that were not accommodation, machinery or weapons spaces. At that time electrical was still functionally organized but electrical outputs were product oriented.

Design people were so organized in counterpart organizations. Each design

speciality and its counterpart in production was only concerned with costs per parts, subassemblies, and assemblies for the region for which it was responsible. The analogous organizational divisions for hull construction except for erection work, applied to flat-panel blocks, curved-panel blocks and superstructure blocks with all further subdivided in both design and production by parts fabrication, subassembly, and block assembly. The distinct products of each group were identifiable. This is product orientation. A separate product-oriented group in design and its counterpart in production were concerned with the virtual work flows needed for effective hull erection.

Recently, in response to unprecedented pressure to become more productive, IHI's Kure Shipyard shifted to a purer form of product organization. For example, its Hull Fabrication Shop is still responsible for producing all hull blocks. But, the Hull Fabrication Shop is now also responsible for outfitting and painting all forebody blocks. Thus for merchant-ship forebodies the Hull Fabrication Shop now specializes by blocks which represent perfectly integrated hull construction, outfitting and painting. Outfitters (people who work with stick welders and spanner wrenches), electricians, and painters are assigned to the Hull Fabrication Shop accordingly. Already shipfitters and painters are being trained to perform outfitting. This is one of the strengths of a product organization. When work is organized differently, labor will adjust to suit just as predicted by the head of the AFL-CIO Metal Trades Department a few years ago. [4]

A simultaneous initiative resulted in a target to reduce the total number of components to be purchased and parts to be fabricated for a very-large crude carrier (VLCC) from more than 70,000 to less than 40,000. In the first 10 months the number was reduced to less than 60,000. Now, square-steel tubing which doubles as ventilation duct is used in place of H-beams for support of engine-room flats. In many cases separate flanges have been eliminated by extending webs and forming flanges by bending. Wherever possible, holes are punched in the flanged surfaces before bending to accommodate U-bolts so as to eliminate need for separate pipe hangers. (Note: Reportedly, there are approximately 1,150,000 separate pipe hangers in a Nimitz-class aircraft carrier.)

The initiative to reduce the total number of components combined with the purer form of product organization will eventually force designers to reorganize so that in the future, the same people performing detail structural

design for forebody blocks will be simultaneously producing the forebody outfit details. Not only is there an analogy for overhaul work, the analogy is well underway in the U.S.

APPLICATION IN KITTY HAWK

Following precedent established by at least eight private U.S. shipyards to acquire benefits by either retaining IHI consultants or having floating drydocks built by IHI, the Philadelphia Naval Shipyard retained IHI to assist in planning a major portion of the Ship Life Extension Program (SLEP) overhaul of the aircraft carrier KITTY HAWK. As a consequence, about 400,000 man-days of work are being controlled by a product work breakdown. The areas being so controlled exclude the carrier's island, hanger deck, main machinery spaces and magazines. Included are pump rooms, air-conditioning machinery rooms, electronic spaces, storerooms, accommodation spaces, tanks, voids, steering-engine room, anchor-Windlass room, chain locker, etc. The application is purposely limited commensurate with resources available.

The specialities designated are faithfully in accordance with GT but are necessarily different from what IHI has applied to date for merchant-ship and destroyer construction and overhaul work. As shown in Figure 3 the specialists in design with counterpart specialists in production, are for:

- o electronic and accommodation spaces between the flight deck and the hangar deck,
- o accommodation spaces below the hangar deck,
- o pump rooms, air-conditioning machinery rooms, storerooms, etc., and
- o tanks and voids.

Two specialities involve accommodation spaces because work in those between the hangar deck and the flight deck has to be carefully coordinated with work in various electronic spaces, including the combat information center, which are located in the same region. The same problem does not exist for accommodation spaces below the hangar deck.

The grouping of miscellaneous spaces, such as pump rooms, storerooms, etc. into a single specialty illustrates something that people do not at first understand. Product orientation is often called zone orientation and perhaps for this reason traditionalist immediately envision major divisions of a complete ship that usually coincide with transverse bulkheads. They then contemplate subdivision that coincide with compartments. But, per GT logic separations are

different because they are by problem category. It doesn't matter where in a ship work of the same problem category is located for organizing virtual work flows. Thus, as shown in Figure 3, the spaces that are assigned to each speciality do not comprise neat geographical divisions of the ship. In fact, the spaces for the miscellaneous speciality are not even contiguous with each other. Treating them as a single group is like gerrymandering in politics. Geographical boundaries, grouping of classes of problems and needed horizontal communication were all factors in developing the specialities for KITTY HAWK in addition to applying the basic GT principle, i.e., matching classes of problems to sets of solutions.

An additional concept that is hard for the uninitiated to understand is the nature of zone/stage. It is possible to control by divisions in geography, i.e., by zones. It is also possible to control by divisions in time, i.e., by stages. But, the most effective and flexible way to control large industrial endeavors is by combinations of both. Thus if a particular zone scheme is optimum at one point in time, as soon as time changes it can be abandoned for a different zone scheme that is more opportune. For example, planners are entirely free to organize an on-board zone/stage work package that straddles a bulkhead during hot work on the bulkhead, knowing full well that later in time, zones that coincide with the compartments on both sides of the bulkhead make more sense for painting. Zone/stage designations are synonymous with opportunities. The greater degree of control afforded should be extremely attractive to people involved in nuclear submarine overhauls because specific systems must remain active during certain stages and because work durations must be limited in the vicinities of certain active systems.

Just as designers in IHI's Kure Shipyard are now focusing on all requirements of merchant-ship forebody blocks, Philadelphia Naval Shipyard planners focus on all requirements for overhaul work in each space within their assigned speciality. In one case the product is conversion of a pump room that needs overhaul to one that is overhauled. In other words, value added is synonymous with designation of an interim product. With such focus it became immediately apparent that 80% of the pump-room's components had to be ripped out. After evaluating various overhaul strategies, the team consisting of designers and people performing production engineering, determined that the most productive option was to redesign the pump room so as to facilitate zone/stage reassembly.

Because of the team's prudent decision, the redesign is likely to combine

some foundations, show some pipe runs in parallel-under walkways sharing common supports, have a greater percentage of straight pipe pieces, limit a greater percentage of pipe bends to 90 and 45 degrees, and increase average pipe-piece length. All such features enhance productivity. [5]

Significantly, the output of the design process now includes preparation of detail part drawings eliminating the need for such effort by production people. This is a clear example of a major design effort being geared to support production overhaul work. The benefits expected are assembly and painting of many outfit packages in shops, a significant reduction in rework, and perhaps less volume occupied and less weight in the overhauled pump room. On-board man-hours and the overall duration required should be much less than that for the traditional system-by-system approach. Based on first-time experiences observed elsewhere, the associated production man-hours should drop by about 30%.

Another example of significant benefit being obtained arises from focus on the replacement bulbous bow as a distinct interim product by a team formed to integrate production and design engineering. Line heating was adopted for curving shell plates so as to reduce the number of separate shell pieces from 14 to 9. This action caused a 30% reduction in seams and butts to be welded. Significant savings should be reported, including savings in fitting, weld-inspection, and distortion-removal man-hours. As a further indication of more investment in planning, the team exploited a photogrammetric survey to insure accurate fit of the bulbous bow to the as-built ship.

Virtual work flows can be more readily visualized in the speciality for the more than 900 tanks and voids shown in Figure 3 than in any other speciality. About five different piping systems have to be ripped out and replaced. The zone/stage work packages by types of work are controlling the different teams like rolling waves one after another in the following sequence: tank cleaning, ripping out all pipe, blasting, holding-coat painting, inspecting structure, ripping out structure, replacing structure, touch-up blasting and undercoat painting, outfitting, and final painting. Each zone/stage work package consists of 6 or 7 sheets of 8-1/2" x 11" or 8-1/2" x 17" paper that are readily reproduced on photo-copy machines. Typically, that for tank cleaning conveys to a work team:

- o location of the zone in the ship,
- o safety instructions,

- o job description,
- o a sketch showing the locations of tank manholes,
- o routing instructions for temporary services.

No other drawings or references are required.

For the work involving reinstallation of piping, all fittings including pipe pieces regardless of system are fitted in a zone during one stage. The pertinent work instruction contains composite arrangement and detail sketches and an applicable material list limited to the zone. Shop personnel are relieved from all bother such as associated with hold-ups and revisions. Such problems are absorbed during the interaction of production engineers and design engineers.

For the product-oriented approach to the SLEP overhaul of KITTY HAWK, a project office has been created to direct, monitor, and expedite implementation of the overall strategy by all facets of the hierarchy in Philadelphia Naval Shipyard. The production part is shown in Figure 4. A group superintendent, i.e., the highest-level civilian manager second only to the Production Officer, has been assigned. The product for which he is responsible is converting spaces that need overhaul and modernization into spaces that are overhauled and modernized within the boundaries of the four specialities shown in Figure 3. Because the workload is so great, about 400,000 man-days, he is assigned two assistants called zone superintendents, one of whom has charge of the two specialities with accommodation spaces and the other having cognizance of the miscellaneous specialty and the tanks and voids specialty. This grouping reflects some commonalities in work problems and the proximity of the specialities for resolution of interface problems.

At the third level there are four zone managers, each of whom is assigned a speciality. Each is assisted by as many as five general foremen per product trade. The teams of foremen and workers that report to the general foremen are made up of mixed crafts as required to produce specific products. People, information and work are grouped in the same product-oriented manner. Throughout the hierarchy all managers and supervisors are generalists equivalent to factory managers for the products assigned. As maintaining the coordination of all work flows is of ultimate importance, every level has been delegated authority to transfer manpower as required. The degree of such authority is of course commensurate with the level.

Already, as has happened in IHI shipyards and as predicted by the head of the AFL-CIO Metal Trades Department, people of different trades are beginning to assist one another toward common objectives. For the first time they have something that is realistically measurable, i.e., cost per product. Now, much of the managerial advice expounded by Peter F. Drucker is coming into focus in Philadelphia Naval Shipyard.

Shipyards with less resources are well advised to venture into product orientation in a more modest way. The course taken by some other naval shipyards, so far mostly for shipalts, is also good guidance. Applications were purposely limited. Puget Sound Naval Shipyard employed an ad-hoc product team as shown in Figure 5. The figure indicates the maximum number of possible incumbents, but positions are only filled commensurate with the needs of the product being contemplated.

On the production side, the team members were the actual general foremen who were to immediately manage the work. In a one hour meeting each week, they conveyed a strategy to the designers and constantly refined their strategy as designers were able to make more information available through design development. The results were dramatic. One case involved seven "electronic" shipalts in a confined region of a submarine which had been implemented in other submarines with traditional system-by-system work packages.

The shift to product orientation focused on everything in each zone at once, caused the different foundation requirements to be combined, and resulted in multi-system foundations that were completely fabricated, machined and drilled ashore. In one case, for a job on the critical path, the duration for on-board foundation work was reduced from seven weeks to three work shifts in one day! While the overall saving in man-hours was not reported, it is likely to be at least 30%. Really, all that has been applied is just common sense. That is, for the detail design and arrangement of anything that is part of a complex, everything in the vicinity should be considered regardless of the system it is part of. Similarly, for efficient implementation of on-board work, all work of one type in a region should be accomplished at the same time regardless of the different systems represented.

PERTINENT EXPERIENCES

Review of some experiences in U.S., U.K., and Canadian shipyards which have successfully shifted to product orientation for construction work and those which have not, is helpful for applying product orientation to overhauls. Most

problems to be overcome are people problems.

Only three types of managers have succeeded:

- o those who are practical, have a solid production background, and are confident enough to refrain from appeasement of traditional middle managers,
- o those who have financial/business educations and experience who regard how to analyze as the most important aspect of any industrial endeavor, and
- o those who have engineering degrees, but whose educations are not limited to applied engineering, who appreciate manufacturing as a system and who accept the obligation to constantly develop the manufacturing system while producing end products.

All employed IHI consultants to accelerate the transitions to product orientation. [6]

Others, have been either disappointed with progress made or have failed completely. In one case a manager whose predecessor was deposed for insufficient tact in an attempt at more formal organization for the purpose of obtaining useful corporate data, overreacted with cancellation of everything his predecessor invoked. This was followed by a directive which exempted the structural shop from effective material control. Both acts were politically motivated as they were concessions to hard-nosed traditional middle managers. The shipyard was committed to a downhill course from which it has yet to recover.

Elsewhere the first application was extremely large in scope and was soon overlapped by an even greater application. At the same time another revolution was being attempted to computerize the design process. Had the first attempt at product orientation been limited to one complicated space, the affect on all management information systems would have become known without people being overwhelmed by masses of data in different formats. Other Achilles' heels were the failure to shift to a product organization commensurate with the transformation being attempted and both inadequate build strategies and insufficient standardization for the purposes of directing designers in grouping information and defining materials.

In still another case, a manager listened to a different drummer for at least two critical years before making a concerted attempt to shift into a product-oriented mode. IHI consultants were retained to assist in accelerating

the transition. But the investment was too little too late. A contract critical for the shipyard's survival was lost. A competitor had discovered the same need three years earlier and at that time made a far greater investment in IHI services. The message is loud and clear. It is not enough to be managing a transition to product-oriented methods with focus on constantly developing the manufacturing system, a firm must be making such progress ahead of its competitors!

In more than one instance, top managers were obsessed with acquiring expensive facilities s means to improve productivity without first developing product-oriented manufacturing systems. The corporate data produced by the latter would have provided a sounder basis for making decisions and would have resulted in less costly, if any, facility investments. Relative to competitors, they assumed increased overhead costs while losing valuable time for manufacturing-system development.

The most pitiful experience occurred in a shipyard where the top manager seems to have been preoccupied with other matters. The move toward product orientation was sparked by a few middle managers. Although applications were limited, significant amounts of assembly and painting work were organized zone per stage and performed in an orderly fashion in shops. Traditionally, the work would have been done on board with people assigned to various systems competing with each other for access to work. But, the yard's archaic management information system did not report all savings. When common sense should have prevailed because people were obviously working smarter and savings were manifest, the absence of pertinent interest from the top permitted die-hard traditionalists to wine out the move toward modern management. Impact on the morale of those who dared to innovate, was devastating. Traditionalists 16 power might *just* as well have said to the innovators, "How dare you improve productivity?"

"The innovator has for enemies all those who have done well under the old conditions." [7]

In a category by itself, is the shipyard management team which rapidly and successfully abandoned its traditional methods in favor of a product work breakdown approach. Impressive command of integrated hull block construction, zone outfitting, and zone painting has been clearly manifest for more than one shipbuilding program. But, the same group has not adopted statistical accuracy control applied for production control purposes. With regard to levels of technology development, they have reached a plateau. Their manufacturing

system will never acquire the characteristic of constant self development until the Statistical approach is appreciated and adopted.

Regardless of the nature of work, e.g., overhaul work of the same problem category in a virtual work flow or construction of multiple ships of the same class, demonstration of a learning curve by itself is no longer an impressive achievement nor is it sufficient for survival. What is required now is bit-by-bit constant improvement which has the effect of constantly displacing the learning curve downward for product after product as shown in Figure 6.

For the benefit of people who have yet to appreciate the significance of statistical accuracy control, the advice of the world's most effective shipyard managers is reiterated:

"Statistical control epoch makingly improved quality, laid the foundation of modern ship construction methods and made it possible to extensively develop automated and specialized welding." [8]

Overhaul specialists in considering the foregoing should dwell on the problems they encounter with disassembly and reassembly of high-pressure pipe systems, particularly in submarines. The use of large-capacity chain falls to make up such pipe joints is common. Because of locked-in stresses they are more susceptible to failure during high-impact shock and are dangerous to disassemble. Statistical accuracy control applied for manufacture of new and replacement pipe pieces would greatly minimize such problems.

Regarding middle managers, not all having had only traditional experience were obstructionists when their yards began to transform. Some found that, despite the erudite terminology and the different organizations of people, information and work, a great undercurrent of common sense is inherent in product orientation. The many photographs published of IHI people working smarter-not harder appealed to them. Some of these middle managers fitted in quickly and graciously. Others wanted very much to participate but had never been educated in how to shift gears.

Second to no other problem are the dyed-in-the-wool traditional middle managers and design engineers. Advising of them cannot be better stated than in the following:

management must make commitments necessary to make it work. Commitments must transcend management hierarchy, trade boundaries, curators of ivory towers and traditionalists who

balk at new concepts. Failure to attend these considerations make it fairly easy for a single disbelieving or disinterested person or group to scuttle successful utilization." [9]

SUCCESSFUL ACTIONS

The implementation actions which follow are the most effective of those employed in U.S., U.K., and Canadian shipyards which have successfully shifted to product orientation for construction work and, more recently, for overhaul work.

Top managers, including a naval shipyard commander, made some judgement calls. Are shipyard operations, particularly for modern naval ships, now so complicated that they overwhelm traditional system-by-system based management? Does a management information system based only on a system work breakdown structure produce accurate enough corporate data and does it truly comply with the U.S. Department of Defense cost/schedule control systems criterion for a work breakdown structure to "...define the product to be produced as well as the work to be accomplished...."? Are competitors benefiting enough from product-oriented approaches to threaten traditionally operated shipyards? If so, is there time to self-develop a product-oriented approach or should special assistance be obtained to accelerate transition as has been done, or is being done by a number of private yards and Philadelphia Naval Shipyard?

After deciding to shift to modern product-oriented operations, the most effective top manager worked persistently on implementation. Senior and middle managers-were advised of his decision and were then indoctrinated in basic logic and principles. Afterwards, each was interviewed separately so that the top manager could identify:

- o the majority that was willing to cooperate and was capable of cooperating,
- o those who were sincere in their willingness but who needed special assistance to make the transformation, and those few individuals who had to be weeded out because they were disbelievers, disinterested, dyed-in-the-wool traditionalists, or curators of ivory towers who constituted a threat to successful implementation.

When the management team was so conditioned, a second indoctrination effort was directed at people who perform design engineering. Similar interviews were conducted for the same purposes.

With assurances thus obtained, only then were workers immediate supervisors

and union leaders indoctrinated in pertinent logic and principles. They were also advised of the progress made by competitors in applying product-oriented methods for constructing and overhauling ships of all types and sizes and various end products other than ships. Thus, workers were not exposed to how people could work smarter before management was fully prepared to follow through. Part of the preparations addressed trade-union leaders' concerns even when they were expected to be just political in nature.

The managers who determined that they had to rapidly move ahead of their competition in commanding more effective methods, retained IHI consultants. Their common objective was to supplement their resources with people having extensive pertinent experience. This assistance is especially needed by designers when a "computer" revolution is undertaken simultaneously with the logic revolution, i.e., the shift from system to product orientation.

In one case where time was not critical and only modest resources were available, the first application was limited per advice proffered by Dr. H. Shinto, former President of IHI. For the first attempt he suggested selecting a single complicated space such as a tanker pump room within which product orientation would be applied exclusively. He further recommended relying on advice from everyone involved in that experience to suggest how fast and where else to expand the product approach. People were not overwhelmed by the limited size of the first such challenge and at the same time were obtaining-knowledge of how all aspects of the yard's management information system were being affected. The experience instilled-confidence and the people involved wanted to expand product orientation to all work s soon as possible. Those in the work force who were not involved wanted to work the new easier way.

For a few additional applications, continued employment of ad-hoc product teams is reasonable. But, each top manager has to watch carefully because traditional managers who are unsure of their abilities to become more generalized can be expected to try to preserve their roles as functional specialists regardless of the top manager's objective. Thus, changing the entire organization to a product organization should be planned and scheduled lust as for key events during any overhaul or construction project, i.e., in the context of the shipyard's master schedule. If not a high-priority concern to the top manager, the transition, if effected at all, will be agonizing for many people and unnecessarily prolonged.

CONCLUSION

Obstructionists should be informed that in the U.S., abandonment of functional organizations by many successful non-shipyard firms, e.g., IBM and Exxon, started about 40-years ago. By 1960, IHI was actively managing a logic revolution and in 1963 started operations in the world's first shipyard rationalized to exploit product orientation for both construction and overhaul work. For many shipyards elsewhere, the time for adopting product organizations is long overdue. [10]

In North American shipyards, only one top manager provided thorough continuing education in the logic and principles of product orientation to his managerial staff, design engineers, first-line supervisors and union leaders. He retained IHI consultants to accelerate what turned out to be a very successful transformation. He weeded out uncompromising traditionalists. When asked why he personally attended all of the many pertinent seminars, he replied, "I want everyone in this yard to know how important this subject is to me!" Any commitment less than that will not suffice.

[1] The logic and principles of what is described herein reflect the very effective management system employed by Ishikawajima-Harima Heavy Industries co., Ltd. (IHI) of Japan as published by L.D. Chirillo Associates, P.O. Box 953, Bellevue, Washington 98009, U.S.A., in a series of booklets for the National Shipbuilding Research Program (NSRP). Some of the material so published is incorporated in "Ship Production" by Storch, Hammon, and Bunch; Cornell Maritime Press, Centreville, Maryland (ISBN 0-87033-357-71), Chapters III, IV, VI, VII, and VIII. Other pertinent booklets based on IHI methods and published for the NSRP by L.D. Chirillo Associates are: Precontract Negotiation of Technical Matters - December 1984, Product Oriented Material Management - June 1985, Shipyard Organization and Management Development - October 1985, (Reprinted in the May 1986 issue of The Society of Naval Architects and Marine Engineers' Journal of Ship Production, pp. 74-79.), Flexible Production Scheduling System - April 1986, Product Oriented Safety and Health Management - May 1986, Analytical Quality Circles - September 1986, and Flexible Production Indices - April 1987.

[2] In U.S. naval shipyards the term "Zone Logic Technology" is sometimes used in place of "Group Technology". The latter is preferred because of its general use in literature.

[3] U.S. Department of Defense Instruction 7000.2.

[4] Responding to a shipyard manager's statement that labor imposed trade separations impeded productivity advances, Paul J. Burnsky, President of the AFL/CI0 Metal Trades Department said in effect, "We are not your problem. If you do not like the way we are organized, change the way you organize work. If you do, you will cause problems for people like me. but we will get to where you want to go. It won't be as fast as you want, but we will get there. Management infers leadership so act like leaders, take the first step."

[5] There is also great opportunity to achieve such benefits during ship construction. In at least four-countries, frigates are currently being built in follow yards with less productivity than is achievable because the lead-ship design was not developed in the context of a product-oriented build strategy. Two such follow shipbuilders are using the product approach for other shipbuilding projects while having to revert to a corruption of the product approach in order to achieve some productivity increase for the frigates. To say-the least, they are frustrated. There is much to be gained from a policy of constantly enhancing productivity by design changes in follow ships. Naval administrators should work to-create practical approval procedures which would encourage follow shipbuilders to submit proposals that would, in ship after follow ship, constantly result in more combined foundations, more pipe runs in parallel, more straight pipe pieces, etc. Such benefits are achievable with nominal changes in machinery arrangements, focus on piping runs, and without changing any components which require spare-part provisioning.

[6] The consultants were made available to U.S. and Canadian shipyards by IHI Marine Technology, Inc. of New York City.

[7] Machiavelli.

[8] The Society of Naval Architects of Japan, 1967.

[9] Similar resistance to change was also noted by John F. Kenefick. JFK Inc., Indialantic, Florida, in "Transfer of Photogrammetric Technology to the U.S. Shipbuilding Industry. a presentation-to the U.S. Naval Shipyards' Structural Group Superintendents Workshop. 3-5 November 1987. Paradoxically, in certain shipyards photogrammetric surveys are being beneficially applied in more and more repair and ship-alteration situations while in other yards which have identical work-

loads, there is no such response. Managers are well advised to investigate the motives of their people who do not pursue opportunities to exploit innovations that have been proven elsewhere. Some of the latest such photogrammetric surveys are for creating accurate data for manufacturing replacement gravity davits for which existing as-built drawings are useless, dimensioning foundation bolt-hole locations in rebuilt arresting-gear engines (about 6'x50') before they are landed in aircraft carriers, and determining required interface dimensions of as-built multi-leg masts before new mast tops are fitted.

[10] See "Shipyard Organization and Management Development", R.D. Chirillo, I. Inuki, and I. Kobayashi, SNAME Journal of Ship Production, May 1986, pp. 74-79.

FIGURE 1: A build strategy starts the shipbuilding process. Contract design describes the ship with information grouped in a large-frame sense. Functional design describes the ship system by system, i.e., with information grouped in an intermediate-frame sense. Transition design groups information zone/stage for the purpose of preparing work instructions, i.e., information grouped in the smallest-frame sense.

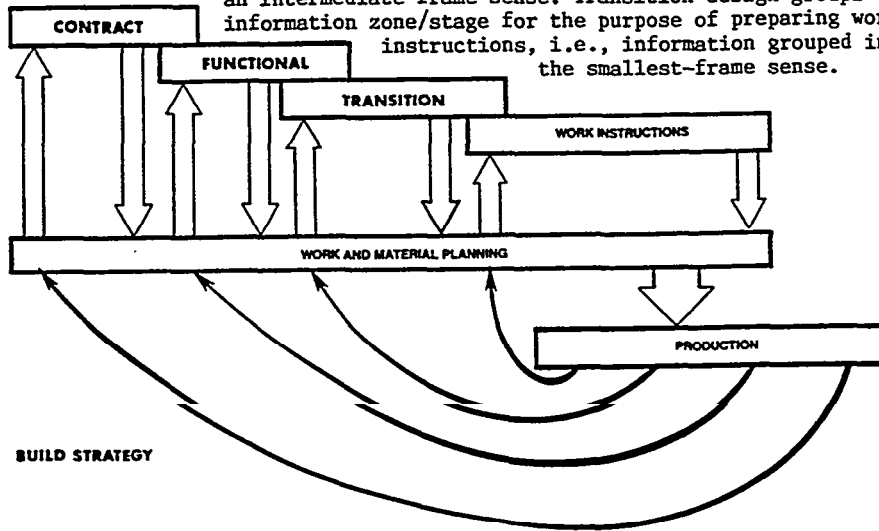


FIGURE 2: An overhaul strategy starts the overhaul process. While the information development phases are not as distinct as in shipbuilding, the process is the same. As more becomes known due to open-and-inspect reports, information is refined until it is the form of work instructions, i.e., in the smallest-frame sense.

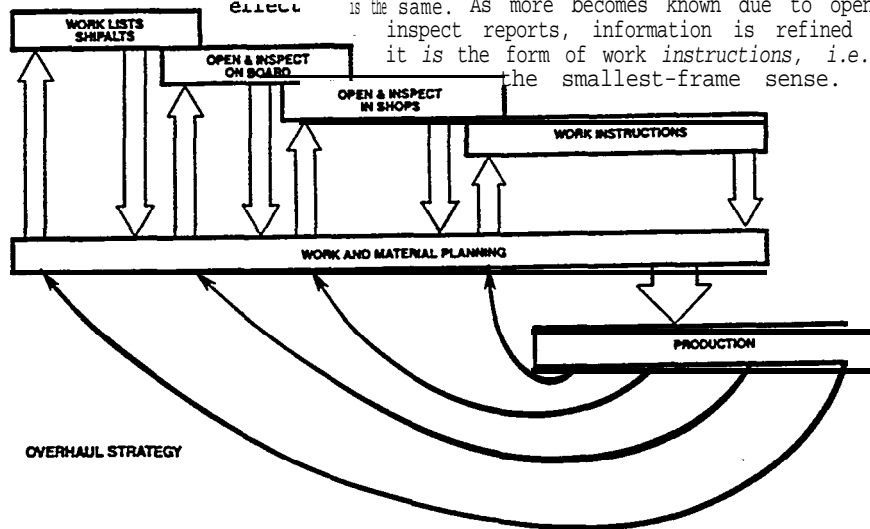


FIGURE 3: Specialities applied by Philadelphia Naval Shipyard for overhaul of the aircraft carrier KITTY HAWK are: (1) Electronic and Accommodation Spaces, (2) Accommodation Spaces, (3) Pump Rooms, Air-Conditioning Machinery Room, Storerooms, etc., and (4) Tanks and Voids.

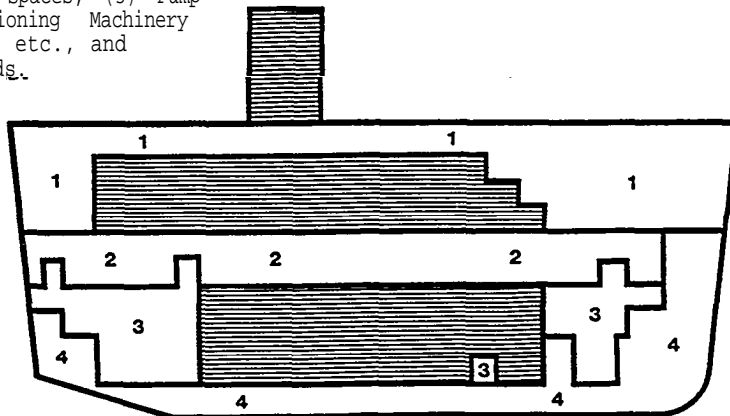


FIGURE 4: Product-Oriented Production Organization applied by Philadelphia Naval Shipyard for overhaul of the aircraft carrier KITTY HAWK.

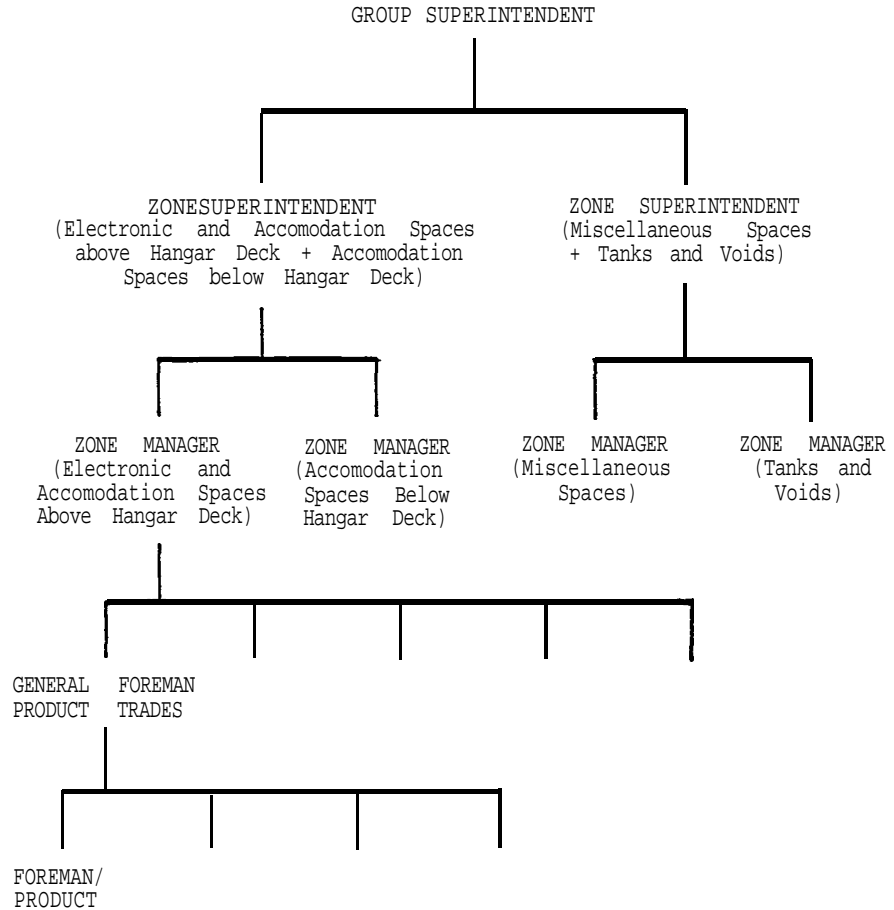


FIGURE 5: Ad-Hoc Product Team applied by Puget Sound Naval Shipyard for alterations, e.g., a close-in weapons system in the aircraft carrier RANGER, an outfitted and painted grand block for a Tomahawk-missile system in the cruiser TEXAS, and modification of electronic systems in 637-class submarines.

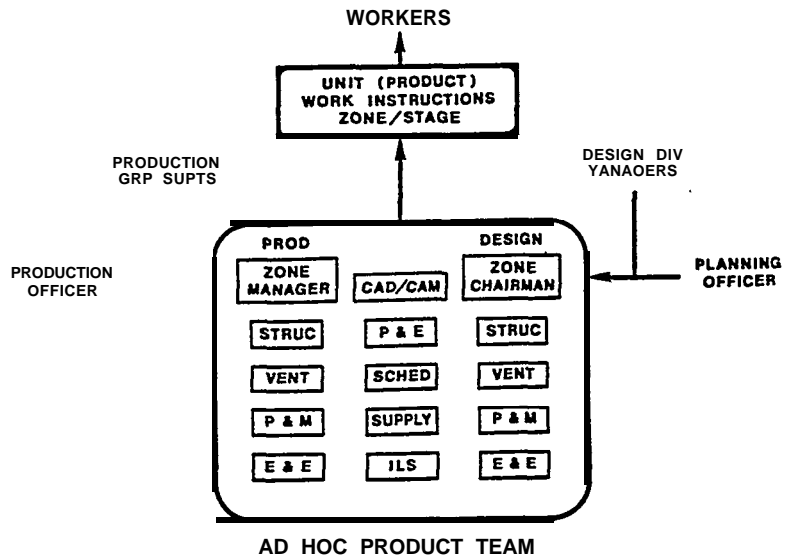
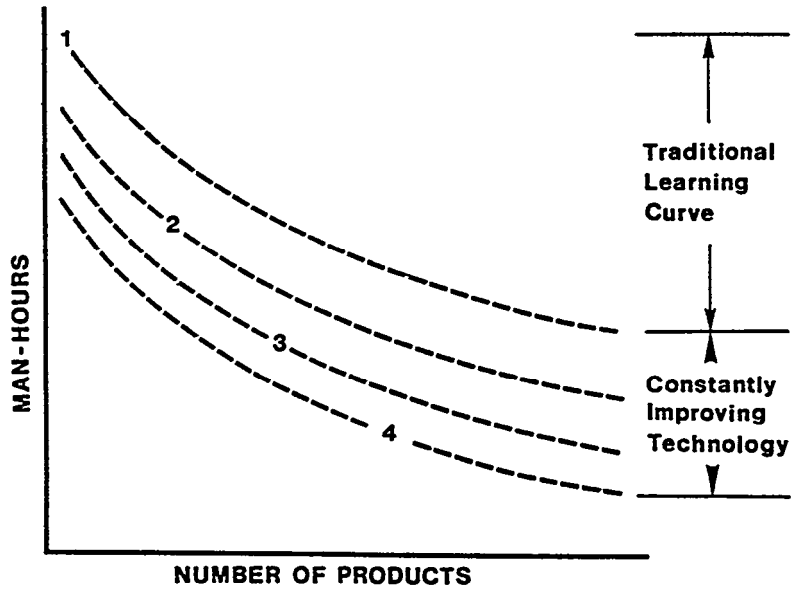


FIGURE 6: Modern manufacturing systems supplement learning-curve benefits with savings derived from constant improvements in technology. The effect is constant displacement of the learning curve downward. Per Dr. W. Edwards Deming, "The obligation to improve the system never ceases."



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