

**Self-Directed Work Teams**  
**at**  
**Texas Instruments**  
**Defense Systems & Electronics Group**

by

Richard D. Rosson

A.B. Economics,  
Dartmouth College, 1988

Submitted to the Sloan School of Management  
in Partial Fulfillment of the Requirements for the Degree of

*Master of Science in Management*

at the  
Massachusetts Institute of Technology

June 1994

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## Abstract

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Lean production is rapidly displacing conventional mass production at manufacturing companies in the US and throughout the world. Human resource practices play a critical role in any company's program to develop and institutionalize lean methods on the shop floor. One approach that has been successful at many companies involves organizing production workers into self-directed work teams. Teams of between five and fifteen workers take responsibility for an integrated, customer-driven production process. Team members cross-train in many of the tasks within the defined process, and gradually expand their capabilities to include administrative and support roles. As the team matures, it slowly becomes increasingly autonomous, until it functions with minimal supervision.

Texas Instruments Defense Systems and Electronics Group (TI DSEG) has pioneered the concept of self-directed work teams. This thesis presents a case study and analysis of two particular teams at TI DSEG: the Switch Filter/Beam Former Team, and the Diamond Point Turning Team. Both teams have achieved a high-level of maturity in terms of their degree of autonomy and the sophistication of their activities. The objectives in studying these two teams are to highlight the key factors that contributed to their success, to uncover the pitfalls and roadblocks they encountered along the way, and to document the organizational structures and operating procedures that support the self-directed team concept.



*Thesis Supervisor:*

Janice Klein  
Visiting Associate Professor of Management Science  
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*To my parents, Eileen and Bob Rosson*

*I am grateful for their constant support  
and the strength they gave me to pursue my dreams.*

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I would like to express my gratitude to Professor Janice Klein for her helpful guidance throughout the research and writing of this thesis. She contributed a host of invaluable insights related to the theory and practice of self-directed work teams, and offered many constructive suggestions to improve the written manuscript. In addition, Professor Klein showed unlimited patience as she waited for the author to finish a first draft.

I would also like to thank all of the people at Texas Instruments who participated in this project. In particular, Keith Weiss helped me greatly by identifying several potential teams that would illustrate the teaming concept well, and by arranging for me to meet with team members and development staff in the Dallas area. Mr. Weiss also provided helpful comments on the written report. Team facilitators Jani Cantu and Carl Young, and team coordinator Barbara McCuin, offered detailed and candid assessments of the team process at TI DSEG. I also acknowledge the assistance of Fred Eintracht, Jodi Rose, and Jana White of the High Performing Organizations Development staff. They outlined the history of teaming at TI and the systems realignment efforts that support the team initiative.

The most important contribution, however, came from the team members themselves, who endured hours of relentless questioning from an overzealous graduate student. Their honest and direct comments form the backbone of the case studies in this thesis. The table below lists the members of each participating team.

In addition, I would like to thank the Lean Aircraft Initiative at the Massachusetts Institute of Technology for coordinating and sponsoring my research.

Finally, I thank my sister, Julia Small, for proofreading the final draft and offering many excellent suggestions for improvement.

| <b>TI DSEG -- Team Rosters</b>        |                    |                                   |               |
|---------------------------------------|--------------------|-----------------------------------|---------------|
| <b>Switch Filter/Beam Former Team</b> |                    | <b>Diamond Point Turning Team</b> |               |
| Beverly Gideon                        | Carolyn McCandless | Frank Duran                       | Louis Rigney  |
| Birdie Blackwell                      | Juanita Webb       | Scott Moffitt                     | Mark Kempf    |
| Jay Romero                            | Debbie Emard       | Ken Brown                         | Rodney Hodge  |
| Sherri Pipkins                        | Sherri Baldwin     | Gerald Wester                     | Chris Martin  |
| Lori Carter                           | Donna Fields       | Delois Meredith                   | Troy Kardokus |
| Judy Jarrell                          | Darrell Breedlove  | David Davis                       |               |

## About the Author

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Richard D. Rosson will graduate from MIT's Sloan School of Management in June of 1994. During his time at Sloan, he concentrated in Operations Management with a particular emphasis on lean production and Total Quality Management. Rick served as co-president of the Operations Management Club during 1992–93. He also participated actively in the Sloan Outing Club and played for the school's intramural ice hockey team.

In addition to Sloan's regular management curriculum, Rick pursued additional coursework at MIT's Department of Electrical Engineering. Although he did not pursue a formal degree, he did complete a large part of the undergraduate electrical engineering core. His special interests include wave dynamics and semiconductor manufacturing.

Following graduation, Rick is planning to work for General Motors' Saginaw Division as a Senior Manufacturing Project Engineer. He will coordinate the cost and quality improvement efforts at Plant 4 in Saginaw, Michigan.

Before coming to Sloan, Rick spent two years as a Financial Policy Analyst at Stern Stewart & Company, a New York financial consulting firm. Stern Stewart advises senior financial executives at industrial companies on corporate finance issues, including mergers and acquisitions, financial restructuring, performance measurement, and incentive compensation. While at Stern Stewart, Rick served as a research assistant for G. Bennett Stewart, Senior Partner, in his writing of *The Quest for Value* (HarperCollins, 1991).

Rick graduated from Dartmouth College, Hanover, New Hampshire, in June of 1988 with a Bachelor of Arts degree in Economics. Before college, he attended the Loomis Chaffee School in Windsor, Connecticut.

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## Introduction

The members of the Diamond Point Turning Team (DPT) are seated around a long table in a conference room at Texas Instrument’s Forest Lane facility. They are having a slightly heated discussion. The issue centers around *A/E*, a measure of shop floor performance that DPT follows carefully. *A/E*, or Actual/Earned hours, measures shop floor productivity as the ratio of actual production time divided by the standard, or “earned,” time for any given activity.

“How useful is *A/E* to our business?” asks one machine operator. “How does it affect our business? Does anyone even care about *A/E*?”

“Hell, we don’t even know if the *standards* are right,” points out another operator. “We need to make sure the standards are right.”

The first worker perks up a little bit. “Look, JIT<sup>1</sup> has affected the standards. We don’t run as many lots as before, and the set-up times are screwing up the standards.” He stands up and starts pacing around the room. “It’s not fair to do a long set-up and then run only eight parts -- the *A/E* spikes up to five- or six-hundred percent. Besides, the set-ups take much longer than the standard. Look at this part -- the standard says 0.94 hours, but the actual time is more like six hours!”

“I don’t think it’s reasonable for them to give us half an hour to set up that job.”

Someone on the other side of the table disagrees. “We know this is an indication of how much it costs to make the part and we want to make it cost less.”

“OK, then let him spend the money to give us realistic standards. If we’re going to look at it, we might as well look at accurate data -- if it’s not accurate, why look at it?”

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<sup>1</sup>JIT stands for just-in-time. See pages 11-12 for a definition of this manufacturing concept.

This discussion is remarkable for two reasons. First, the team has raised a vitally important issue that has implications for not only how DSEG runs its business, but also how the company approaches the team concept itself. Second, the discussion betrays a level of sophisticated thinking that one might expect from company managers (or second-year business school students). Everyone in the room is participating, everyone speaks the same language, and everyone demonstrates an excellent understanding of the issues and tradeoffs in their full complexity. That the participants are actually shop floor workers pays tribute to the success of TI DSEG's efforts to empower its workers -- and the workers' ability to think for themselves.

The rest of this thesis presents a case study and analysis of two self-directed work teams at TI DSEG. Chapter 2 outlines the major principles of lean production, and describes the workings of lean production teams. Chapter 3 introduces the self-directed work team concept, and highlights a major distinction between lean production teams and self-directed teams. Chapter 4 outlines the history of teaming at Texas Instruments, and then presents the case study on the Switch Filter/Beam Former Team and the Diamond Point Turning Team. Finally, Chapter 5 identifies some of the key factors behind the success of teams at TI DSEG -- and some of the obstacles that the teams have had to overcome. Chapter 5 concludes with a few lessons and insights from the experience of TI DSEG with self-directed work teams.



## Lean Production

A revolution is sweeping manufacturing companies in the United States and throughout the world. A new manufacturing system, called lean production, is rapidly displacing Henry Ford's old paradigm of mass production. In 1990, the International Motor Vehicle Program at the Massachusetts Institute of Technology published the authoritative work on lean production, entitled *The Machine that Changed the World*.<sup>2</sup> In clear and simple language, the authors outlined the major principles of lean production, and described its origins at the Toyota Motor Company in the 1950s. Moreover, they argued that lean production holds the key to improving manufacturing competitiveness in the 1990s and beyond.

Lean production finds its origins in four well-known, but often-forgotten principles: (1) The goal of a business enterprise is to create wealth for its owners by *creating value for its customers*; (2) Resources are limited--they must never go to waste; (3) Intensifying competition demands that all business enterprises *continuously improve* - - by endlessly striving for ever higher quality, ever lower costs, and ever faster response times; and (4) People are intelligent and motivated to do a good job -- give them the right tools and adequate authority, and they will not only do their jobs well, but they will also make improvements on their own initiative.

### **Create value for the customer**

In Eliyahu Goldratt's allegorical novel *The Goal*, physicist-turned-manufacturing expert Jonah asks a simple question: "What is the goal of [a] manufacturing company?"<sup>3</sup>

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<sup>2</sup>Womack, Jones, and Roos.

<sup>3</sup>Goldratt and Cox, p. 32.

Alex Rogo, the plant manager and Jonah's protégé, labors over this question for several days, and finally comes to a startling conclusion: "The goal of a manufacturing organization is to make money."<sup>4</sup> It sounds obvious, but what's amazing is how often business managers forget this simple goal. Moreover, few managers really understand how to measure progress toward the goal, or how to link specific operating activities with achieving the goal.

Wall Street analysts and financial accountants have dominated this discussion for so long that it has become an unchallenged truth that making money is synonymous with increasing reported quarterly earnings. The owners of a corporation, however, are the shareholders, and shareholders do not take home the company's earnings. The only way for shareholders to make money is if the company pays dividends or if the price of the company's stock rises. Since dividends are really equivalent to forgone capital gains, the argument arrives at an inescapable conclusion: For a corporation, "making money" translates directly to *creating wealth for the owners* by increasing the company's market price. Reported earnings are, in fact, irrelevant.<sup>5</sup>

How, then, does a manufacturing company create wealth? The alarmingly simple answer comes directly from the principles of Total Quality Management, one of the cornerstones of lean production. A company creates wealth by *creating value for its customers*. In other words, the source of new wealth is the value that companies offer customers by delivering products that fulfill their needs. According to Shiba, Graham, and Walden, "TQM companies *focus on customers* and on satisfying their needs. Therefore, they must be able to react fast to changing customer needs and to focus their limited resources on activities that satisfy customers."<sup>6</sup> If the goal is to create wealth for the owners, then the means is to create value for the customers.

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<sup>4</sup>Goldratt and Cox, p. 40.

<sup>5</sup>Stewart.

<sup>6</sup>Shiba, Graham, and Walden, p. 28.

## **Relentlessly eliminate wasted resources**

The second principle derives from another cornerstone of lean production, the just-in-time management system (JIT). The central idea of JIT simply asserts that, because resources are limited and costly, companies must never allow any resource to go to waste. JIT imposes a new imperative on manufacturing managers and workers to eliminate all forms of *muda*, or waste, with a vengeance. Moreover, the definition of waste ties back to the concept of customer focus: JIT defines waste as anything that does not add value for the customer. Examples of wasteful activities abound in the mass production environment: inspecting products for defects, destroying excess and obsolete inventory, scrapping or reworking defective parts, or moving parts and materials great distances between sequential operations, to name just a few. None of these activities adds any value for the customer -- all of them, therefore, waste resources by definition.

The principal means of reducing waste is quite simple: the JIT factory constantly looks for ways to reduce lot sizes, where the ideal target is *a lot size of one*. As batch sizes decrease, the production process becomes more and more fragile -- that is to say, more and more vulnerable to a loss of control or an outright interruption. In other words, reducing lot sizes necessarily reduces slack in the system. For such a fragile process to work, the system cannot afford to waste any resource. As managers and workers successfully reduce the reliance of the system on excess resource consumption, then and only then can the process function with smaller batch sizes. Best of all, the company receives a big pay-off: less waste and smaller batches yield lower operating expenses, smaller inventory investments, shorter cycle times, faster response to changing market conditions, and higher final product quality. Not bad.

Goldratt offers an interesting twist on the JIT concept with his Theory of Constraints. Goldratt classifies all resources as either bottlenecks or non-bottlenecks. "A bottleneck is any resource whose capacity is equal to or less than the demand placed upon

it. And a non-bottleneck is any resource whose capacity is greater than the demand placed upon it.”<sup>7</sup> This distinction, while fairly elementary, has some far-reaching implications. First, since bottlenecks by definition constrain throughput, eliminating any waste in these operations must take the highest priority. Specifically, managers and workers must *never* allow bottlenecks to sit idle -- except for preventive maintenance.<sup>8</sup> Likewise, bottlenecks must never process defective or unneeded parts. In addition, improvement efforts should focus on reducing set-up times to increase each bottleneck’s capacity. Second, maximizing the utilization rate of non-bottleneck resources does far more harm than good. Allowing these operations to produce at a rate that exceeds the capacity of the most tightly constrained resource does nothing to increase system throughput; rather, the additional output simply piles up as work-in-process inventory, which in turn absorbs scarce capital investment and imposes additional carrying costs. Finally, because non-bottleneck resources operate below capacity, the plant can reduce lot sizes for these operations without incurring any additional cost -- the extra set-ups simply consume idle machine time. Furthermore, to the extent that workers can find ways to reduce set-up times on non-bottleneck operations, they can reduce batch sizes even further. And ultimately, smaller batches mean shorter throughput times and faster response to changing customer needs.<sup>9</sup>

### **Continuously improve the process**

TQM provides the third major principle at the heart of lean production: *kaizen*, or continuous improvement. Recognizing that manufacturing in most industries has become fiercely competitive, continuous improvement demands that managers and workers constantly find ways to improve all aspects of business and manufacturing performance.

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<sup>7</sup>Goldratt and Cox, pp. 137-138.

<sup>8</sup>In fact, it becomes exceedingly important to complete a regular schedule of preventive maintenance on bottleneck operations to avoid a breakdown, which would leave the machine idle.

<sup>9</sup>This paragraph adapted from Goldratt and Cox, pp. 157-158, 206-208, 228-229.

Workers apply standardized analytical methods to identify the root causes of problems and devise solutions that ultimately improve manufacturing and business processes. In addition to such reactive problem solving, workers also proactively seek out new and better ways to satisfy the needs of their customers. Continuous improvement sets out a moving target with which companies must try to keep pace. It is not enough to do as well as you have always done -- you must continuously do better just to keep up with your competition.

### **Empower workers to participate in the process**

The final principle takes the form of a belief on the part of managers in the capabilities of the shop floor workers. Under lean production, managers believe that production workers possess enough intelligence, education, skills, innovation, and self-motivation not only to perform their jobs well, but to do so without much supervision. Furthermore, workers are capable of discovering ways of improving productivity, quality, and profits on their own initiative. This faith in the abilities of factory workers contrasts sharply with the conventional wisdom under the mass production system:

“The problem with the American pattern is that it is extremely corrosive to the vital personal relationships at the core of any production process. Mass-production workers are under no illusions that their employer is going to stand at their side through thick and thin. Indeed, the most important function of mass-production unions is to bargain for seniority rights and for layoff compensation for those chucked over the side of the company ship. . . .the consequence is a distinct lack of commitment on the part of workers. . . .”<sup>10</sup>

Lean production, therefore, finds two virtues in empowering the shop floor workers: (1) empowerment leverages the talents and experiences of the workers in managing and improving the manufacturing process, and (2) it imparts a sense of identification and

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<sup>10</sup>Womack, Jones, and Roos, p. 248.

involvement to the workers that translates into a strong commitment to excellence in performing all of their tasks.

### **The Three Manufacturing Paradigms<sup>11</sup>**

These ideas about empowerment and participation define a major difference between lean production, and each of the two previous manufacturing paradigms -- the Ford/Taylor mass production system, and the original craft production system. As Exhibit 1 illustrates, the difference centers on the classic trade-off between depth of expertise and breadth of functional capabilities. Under the craft system of the eighteenth- and nineteenth centuries, individual workers -- carpenters, metal smiths, fabric makers, bakers, and so on -- mastered the complete set of skills in their respective trades (see the top panel of Exhibit 1). Each artisan achieved, through lifetime training and practice, an extreme depth of expertise in a single industrial activity. Although the craft system produced goods of exceptionally fine quality, it suffered from certain inherent limitations: small production volumes, a low degree of standardization, and very high manufacturing costs.

Henry Ford and Frederick Taylor, among others, developed several innovations in the early twentieth century to address the limitations of the craft system. The Ford/Taylor mass production system took Adam Smith's division of labor to its logical extreme. The middle panel of Exhibit 1 illustrates how Taylor's scientific management concept broke down the manufacturing process into minute production tasks small enough for one worker, with minimal skills, to perform repetitively. This idea worked quite well with Ford's new moving assembly line and highly standardized parts. Mass production divided the factory into separate functional silos -- fabrication, assembly, inspection, purchasing,

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<sup>11</sup>This section adapted from Klein, pp. 9-12; and Womack, Jones, and Roos, pp. 21-51.

shipping, and industrial engineering. The factory assigned workers within each function to perform a particular task over and over again, hundreds of times each day. Industrial engineers studied the tasks in great detail, and spelled out precise work standards. And first-line supervisors watched over the shop floor workers carefully, to make sure they didn't slack off. For more than four decades -- roughly 1920 through 1965 -- mass production served the needs of the rapidly growing, consumer-oriented US economy exceptionally well.

Enter Toyota and the Lean Production System.

### **Lean Production**

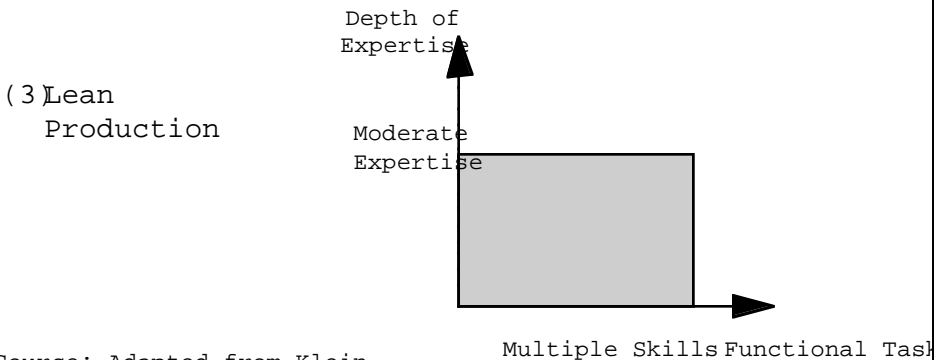
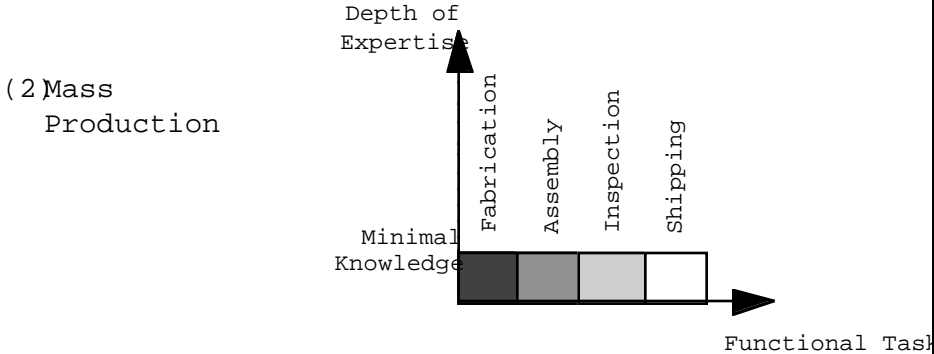
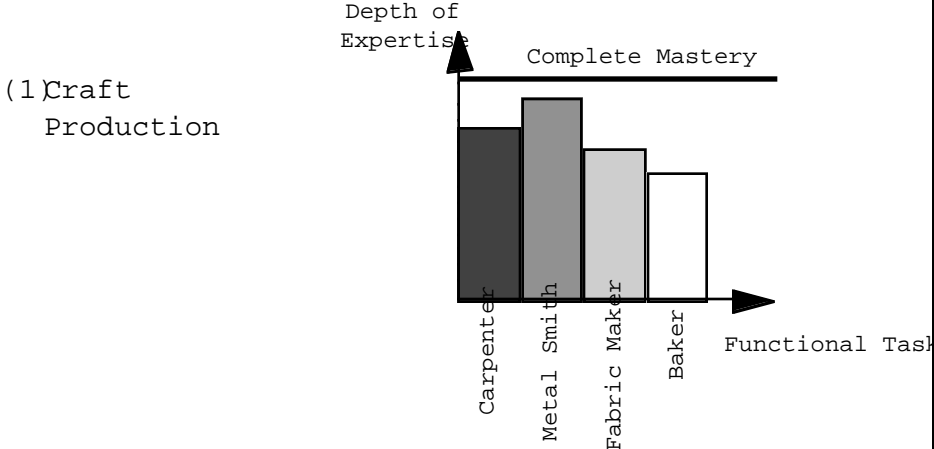
Rising from the ashes of World War II, the Toyota Motor Company devised an entirely new approach to manufacturing. During the 1950s, Taiichi Ohno, Toyota's brilliant production chief, developed and later perfected the Toyota Production System. Ohno literally invented the concept of JIT, and pursued Total Quality with a vengeance. As the Big Three automakers soon discovered, much to their dismay, Ohno's new production system had become a potent competitive weapon. Toyota exploited its advantage masterfully as the company began to invade foreign markets in the late-1970s and through the 1980s. Superb product quality and customer service, combined with low costs and lightening fast response to rapidly changing markets earned Toyota a strong and improving position in North America and Europe.

The Toyota Production System soon became the model for a third manufacturing paradigm, what we now call lean production. As other manufacturing companies have gradually awakened to the new competitive reality, they have begun to emulate Toyota's lean production techniques. As a result, lean production is already rapidly displacing mass production at manufacturing companies in the US and throughout the world.





**Exhibit 1**  
**The Three Manufacturing Paradigms**  
**Skill Sets of Individual Workers**



Source: Adapted from Klein.

Worker participation and empowerment, as we have already discussed, provide a large part of the foundation for lean production. In fact, Krafcik, one of the original IMVP researchers, includes the idea of empowered work teams in his definition of lean production:

Lean production is a system “taking the minds + hands philosophy of the craftsmen era, merging it with the work standardization and assembly line of the Fordist system, and *adding the glue of teamwork for good measure*. Management did not think of workers as replaceable cogs in a great production machine; each worker was trained for a variety of jobs and skills -- not just production tasks but maintenance, record keeping, quality control, and more. Rather than delegating the task of work standardization to a stopwatch-toting industrial engineer, management trained the shopfloor workers themselves in that task and gave them the responsibility to continuously improve performance. Scientific management techniques were not thrown away; they were just performed by different, more appropriate employees. Finally, *management organized workers into teams -- teams that were largely autonomous, did not require large white-collar staffs, and were more capable of reacting to shifts in production content than were the rigidly standardized Fordist laborers and supervisors.*”<sup>12</sup> (emphasis added)

The bottom panel of Exhibit 1 illustrates Krafcik’s point. Lean producers assemble workers into small teams with a defined set of production-related responsibilities. Each member of the team cross-trains in all of the activities within the team’s boundaries. As a result, each worker achieves a moderate level of expertise in a wide variety of functional tasks. Teams may periodically rotate assignments among their members, and workers participate actively in process and quality improvement activities. Supervision, while lighter than mass production, does not disappear entirely. Team leaders coordinate the activities of each team, and group leaders facilitate interactions between related teams. Moreover, lean production uses scientific management techniques even more fervently than mass production -- only instead of industrial engineers, it is the workers themselves who devise the standardized procedures and measure the standard production times.<sup>13</sup>

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<sup>12</sup>Krafcik, p. 43.

<sup>13</sup>Klein, pp. 10-11; and Adler.

## **Lean Production Teams**

At the heart of the lean production team concept lies a chain of six inter-connected management practices: (1) teamwork, (2) participation, (3) flexibility, (4) empowerment, (5) the just-in-time system, and (6) cooperative labor relations. Exhibit 2 presents this concept of a cross-linked chain of management practices.

### **Teamwork**

Lean producers organize their entire workforce into several hundred work teams. Each team encompasses anywhere from five to fifteen members or so, and sometimes a team leader, a team facilitator, or rotating leadership. Leaders come from the ranks of the shop floor workers, not plant management. Each member of a particular team learns all of the jobs within that team's responsibility, and team members rotate jobs periodically among themselves. Team responsibilities often cross functional boundaries, and include many tasks that in typical factories would fall within the exclusive purview of management or engineering.

### **Participation**

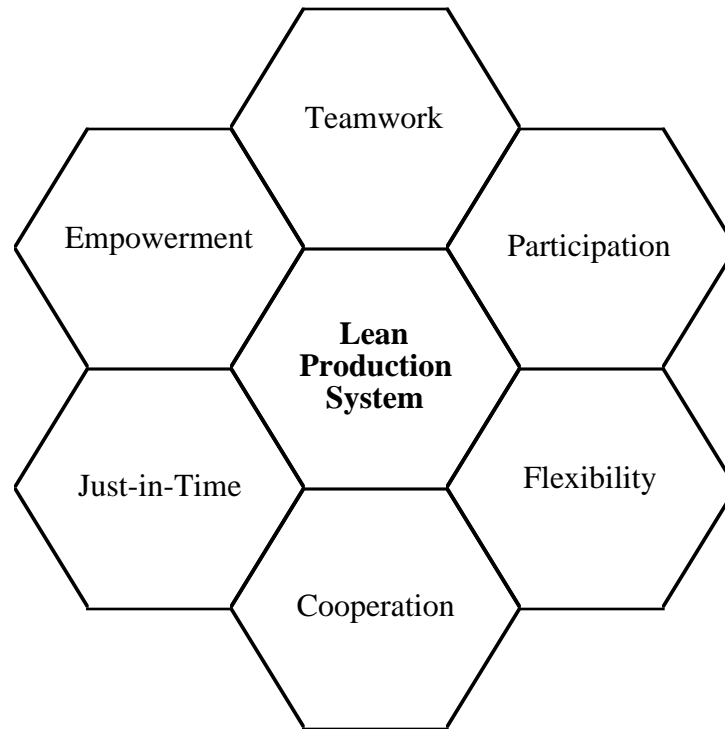
In a typical mass production environment, managers assign a single production task to each worker, who repeats that same activity hundreds of times each day. These factories also employ armies of salaried support workers and industrial engineers to help keep the production line running smoothly and without interruption. The Lean Production System, in contrast, handles things much differently. In addition to their regularly assigned production tasks, shop floor workers perform a host of production support tasks. These additional assignments include scheduling shifts, assuring quality, maintaining and repairing equipment, redesigning and improving processes, measuring performance, and ordering supplies.

This approach offers two major advantages: First, the variety of assignments helps to motivate the workers, prevents boredom, and improves morale. Second, it allows managers to tap the wealth of experience and knowledge of the manufacturing process that only shop floor workers possess. This concept of worker participation embraces two important Japanese principles: *kaizen*, and *jidoka*:

- *Kaizen*, or continuous improvement, implores managers and workers to pursue relentlessly ways of improving business and manufacturing processes through better quality, higher productivity, lower cost, safer work methods, and less waste. Contrary to the conventional wisdom of mass production, improving quality almost always automatically improves all of these other dimensions simultaneously.
- *Jidoka*, the quality principle, maintains that the only way to guarantee the quality of the final product is by guaranteeing the quality of the production process itself. The quality of a product is only as good as the quality of the process that manufactured it.

The need for workers to participate actively in managing and improving the production process raises a thorny issue. Workers know that if they take the initiative to make process improvements that increase efficiency, the company might find that it can get by with fewer workers. The only way that workers will help to improve efficiency is if they know that management won't "reward" their efforts by eliminating jobs. Some companies -- NUMMI, for example -- have addressed this problem by offering guaranteed job security in exchange for active worker participation.

**Exhibit 2  
Lean Production Teams:  
Management Practices**



**Flexibility**

Another important difference between lean production and mass production relates to the flexibility of the workforce. In a typical mass production environment, the Taylorist production system enforces a rigid system of hundreds of job classifications for unskilled hourly workers, and dozens of classifications for skilled tradesmen. The Taylor approach imposes strict rules defining a narrow set of allowable tasks for each classification, and violations on the part of management invariably leads to a grievance, or worse.

The Lean Production System scraps this complex web of tangled classifications and work rules in favor of a highly simplified and flexible system: *one* classification for all unskilled production workers, and just a handful for skilled trades. Instead of rigidly assigning each worker to a narrow and fixed task, lean producers have a flexible force of multi-skilled workers that move fluidly from one task to another, as needed. Lean producers provide extensive training of their workers in a variety of job-related skills, and workers often use their own judgment in deciding when and how to apply those skills on the assembly line.

### **Empowerment**

The process of empowering the workforce involves two steps: first, the company breaks down barriers between management and workers by eliminating manager's special privileges, and second, the company literally *empowers* the workforce by transferring decision-making authority from the exclusive control of managers down to the shop floor workers themselves.

Management perquisites at most American factories have always irritated hourly workers. Workers resent feeling like second-class citizens as they watch supervisors and senior plant managers take advantage of reserved parking spaces, posh executive dining rooms, and comfortable, private offices. Not so under lean production. Lean factories offer none of these special privileges for managers, and the system tries to put everyone - - from the plant manager to the shop floor worker -- on an equal plane. In some companies, managers and workers even wear identical uniforms.

Workers also resent management by fiat -- arbitrary command decisions handed down from the all-powerful foreman. Again, the Lean Production System has turned the old mass production logic on its head. Lean factories have no swarm of white-coated industrial engineers watching over the work flow and telling workers how to do their jobs. Rather, the workers themselves, who are intimately familiar with the tasks they

perform each day, design their own process flows, discover their own process improvements, measure their own standards, and evaluate their own performance.

Moreover, empowerment is more than just an abstraction; it really happens. At NUMMI, for example:

- The company initiated an employee suggestion program in March of 1986. Not only do employees participate actively -- they generated over 10,000 suggestions in 1991 alone -- but NUMMI's managers actually listen. The company implemented over 80 percent of employee suggestions.<sup>14</sup>
- NUMMI granted work teams the authority to purchase their own supplies, and backed them up by providing each team with its own account.<sup>15</sup>
- The plant allows and even encourages individual workers to stop the assembly line whenever problems arise -- not just for safety reasons, but also to prevent installing defective parts or making errors in assembly. The contract guarantees workers against discipline for stopping the line as needed.<sup>16</sup>

The success of this approach to empowerment depends critically on changing the entire purpose and outlook of the middle-management hierarchy at all of the company's plants. Overall, the management structure is somewhat flatter than the typical mass production plant. More important, however, is the role that middle managers and engineers play at a lean producer. Their job is not to command workers to work harder, or to watch over their every move, but rather to coach workers, to support them, to motivate them, and to teach them whenever they need assistance. The first-line supervisor, in particular, becomes less of a master, and more of a team leader or facilitator. Managers and engineers provide assistance and expertise, almost like internal consultants, to the lean production teams, but only when the teams cannot work things out by themselves.

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<sup>14</sup>“New United Motor Manufacturing, Inc.”; and Adler.

<sup>15</sup>Adler.

<sup>16</sup>New United Motor Manufacturing, Inc.”; and Adler.

## **Just-in-Time**

Managers at US factories have long misunderstood the Japanese notion of just-in-time management (JIT). To most American executives, the central principle of JIT is to minimize factory inventories at all costs, particularly by coercing suppliers into holding onto inventory longer and delivering parts and materials more frequently. The supposed benefit of this practice is twofold: (1) it reduces inventory carrying costs, and (2) it exposes problems and weaknesses in the manufacturing process by eliminating the protection of large inventory stocks.

The reality is that the Americans have it all backwards. The Japanese understand that JIT doesn't *begin* with inventory reduction (although it does *end up* there). Rather, the central idea is to eliminate *muda*, or waste, in all forms. By persistently attacking and destroying all sources of waste, and by breaking any constraints or bottlenecks, workers actually *enable* the factory to get by with much lower levels of inventory. The true benefit of JIT, however, comes from the higher quality and lower costs that result from eliminating wasted resources, and from the much faster response time to changing market conditions. Thus, the American view of JIT reverses cause and effect.

Lean production, having grown out of Toyota's revolution in production management, embraces the Japanese approach to JIT. Production teams actively seek out new ways to improve the process and reduce wasted material and effort. Each production station takes responsibility to assure that its work meets the quality standards of the next station in line. Special teams devoted to *kaizen* activities also work with production teams to discover additional process improvements. As a result of this never-ending quest for improvement, lean production factories do in fact operate with significantly less work-in-process inventory than the typical mass production plant. Lean producers also devote much less space to reworking and repairing defective products, because the system simply does not allow quality problems to persist.



## Cooperation

Lean production makes a conscious commitment to promoting an atmosphere of cooperation and reconciliation between managers and workers. That commitment begins with the labor contract itself. As discussed above, one key provision in many such labor agreements is a guarantee that the company will not lay off workers except in dire circumstances. Actions, of course, speak louder than words, and NUMMI, for one, has proven that it means what it says. In 1988, when sales of the Chevy Nova dropped substantially and NUMMI's Fremont plant was running at only 60 percent of capacity, the company did not lay off a single worker. Rather, the factory re-deployed workers from the assembly line into additional process improvement teams. NUMMI also sent some to extra training programs.<sup>17</sup> The willingness of NUMMI to live up to its word *earned* the company the respect and trust of the workers.

Managers at lean producers also consult with the leadership of the local union on a regular basis on matters of mutual concern. The union can play an active role in assisting management evaluate and select new workers from incoming applications. The end result is that the union and its members feel that the company really cares about creating a positive working relationship and a cooperative atmosphere in the plant. They believe that management deserves their cooperation and their best efforts.

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<sup>17</sup>Adler.

## Self-Directed Work Teams

Self-directed work teams are quite similar to lean production teams. In fact, many students of shop floor organization have failed to make a distinction between the two. Exhibit 3 clarifies the difference between lean production teams and self-directed work teams by highlighting the similarities and differences. Although separate and distinct concepts, the two have many principles in common, notably teamwork, empowerment, participation, flexibility, and cooperation. There are two important distinctions, however. First, participation for lean production teams focuses heavily on continuously improving the process (TQM) and relentlessly eliminating waste (JIT). For self-directed work teams, in contrast, participation focuses on allowing shop floor workers to take on administrative and managerial tasks, in addition to regular production activities.

Second, lean producers expect team members to cross-train in all of the skills within the team's boundaries (refer back to the bottom panel of Exhibit 1, page 16). As a result, team members cannot ever achieve more than a moderate level of expertise in any one activity, and the team may end up with excessive redundancy. Self-directed teams, on the other hand, recognize that human limitations place a cap on the number of different competencies that any one individual can master. Self-directed teams do not expect every team member to learn every skill within the team's boundaries. Rather, the team leverages the diverse and complementary skills of all of its members to ensure that the team-as-a-whole has all of the needed competencies with just enough redundancy.<sup>18</sup>

Exhibit 4 summarizes the differences between self-directed work teams, lean production teams, and shop floor organization under the two earlier manufacturing paradigms. Notice that of the four systems, only self-directed work teams expand into the

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<sup>18</sup>Klein, p. 12.

third dimension, “Administrative & Managerial Activities.” Furthermore, the cube representing self-directed teams covers the skill set of the team-*as-a-whole*, whereas the regions representing the other three systems cover the skill set of any *individual* worker.

Lean production and self-directed work teams developed historically at different times and in different parts of the world. Nevertheless, given that the two concepts share so much common ground, many lean producers have begun to expand the boundaries of their work teams to encompass not only *kaizen* activities, but also administrative and managerial tasks; as a result, they have created truly self-directed work teams under the lean production banner. For the remainder of this paper, we will refer exclusively to self-directed work teams that fit this expanded definition.

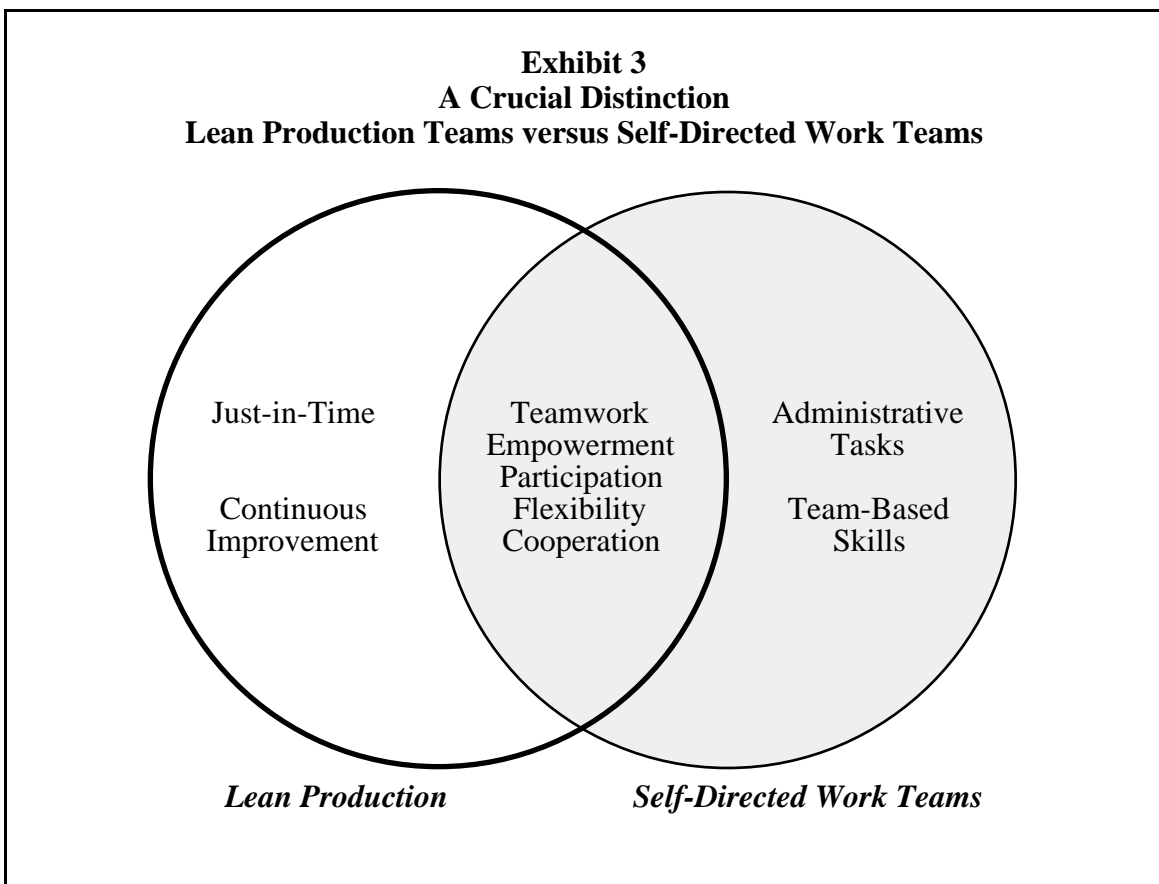
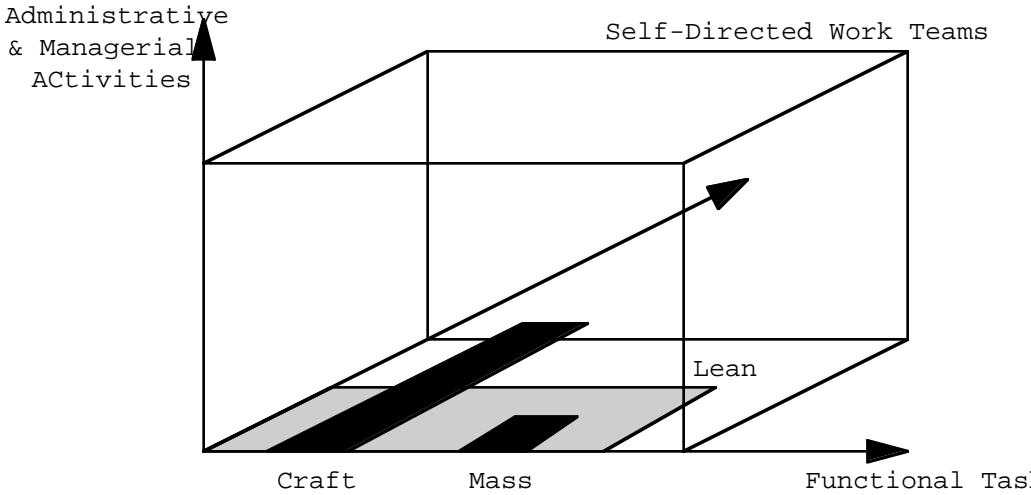


Exhibit 4  
Self-Directed Work Teams  
Skill Set of the Team-as-a-Whole



Source: Klein.

## Implementing Self-directed Work Teams

Creating self-directed work teams is an evolutionary process consisting of four major steps: (1) cross-training, (2) enhancing teamwork skills, (3) participating in proactive improvement efforts, and (4) developing administrative skills.

- *Cross-training:* Workers must learn how to do many but not necessarily all of the production tasks within the mission of their team. Cross-training not only allows team members to substitute for absentee workers on a moment's notice, but it also enables the team to realize job rotation. Rotation has the advantage of adding variety to workers jobs and thus relieving boredom.
- *Teamwork:* Workers must enhance their ability to work with others, by learning or improving such skills as cooperation, conflict resolution, communication, negotiation, and consensus formation.
- *Proactive Improvement:* Management must empower workers to begin diagnosing and analyzing production processes, and to develop and implement ideas for improving quality, increasing productivity, and reducing waste.
- *Developing Administrative Skills:* Team members need to develop production support and administrative skills, including maintenance and repair, quality control, scheduling, purchasing, inventory control, personnel management, performance measurement, and personal computer skills.

In addition, a smooth transition depends heavily on securing management commitment, preferably early in the process. Senior managers can provide the vision and leadership needed to spark change throughout the organization. Equally important, the buy-in of middle managers can help overcome their natural fear of organizational change, and prevent any counter-productive resistance from developing.

Managers and team members alike must remember that this process takes a great deal of time, and teams may experience setbacks en route to full self-direction. Teams that attempt to take on too much responsibility too quickly are destined to fail miserably. Moreover, when things don't work out well for a specific initiative, as is bound to happen occasionally, it is important to pick up the pieces, learn from the mistakes, and move on.

Assigning blame is a counter-productive effort in futility, and managers and workers must overcome this temptation, which is so common under the mass production system.

## **Performance Measurement**

The performance measurement system in a manufacturing company should serve three important objectives. First, it provides information that links specific operating actions and decisions to the goal of the company -- to increase shareholder value. Second, it provides a way of identifying specific problems that the company may need to address, and a way of tracking the progress and success of continuous improvement activities. Finally, the choice of performance metrics sends a message to the shop floor that indicates the particular dimensions of performance that the company considers important for its success.

Performance measurement systems under the traditional mass production regime generally served these objectives rather poorly (although they did serve the objectives of mass production quite well). Managers at mass production firms typically placed great emphasis on metrics such as labor and equipment utilization rates, fully-absorbed manufacturing cost and its variance against the standard, and actual versus standard production hours. Unfortunately, these types of metrics encouraged managers and workers to maximize output and minimize cost without regard to other vital parameters such as process quality, lot sizes, defect rates, inventory levels, or customer satisfaction. Furthermore, managers would often use performance results as an opportunity to assign blame for what went wrong rather than to find opportunities for improvement.

Once a company adopts lean production and empowered work teams, managers may find that the company's performance measurement system undermines the objectives of these new initiatives. Developing a comprehensive and standardized system

of performance measurement across teams would solve this problem. One approach might follow the example of Analog Devices Incorporated (ADI), which pioneered the “performance scorecard” as part of the company’s TQM efforts during the 1980s.<sup>19</sup> The scorecard presented on a single page a handful of key metrics that together painted a comprehensive picture of ADI’s performance along several dimensions. The company followed a few important principles in designing the scorecard system:

- Taking an idea from TQM, the scorecards “focus on the vital few.” Rather than presenting a laundry list of every imaginable performance metric, the scorecards present only the few measurements that have the biggest bottom-line impact.
- The list is nevertheless comprehensive and balanced. It includes both financial and non-financial metrics, internal manufacturing and external customer satisfaction metrics, current production and product development metrics.
- The financial measures focus not on reducing costs, but rather on increasing revenues and profits, for two reasons. First, the goal of the company, as we have said, is to make money, not to minimize costs.<sup>20</sup> Second, the opportunities to increase revenues are almost always far greater than the possibilities to reduce costs.
- The scorecard presents each item as it evolves over several periods, either monthly or quarterly. The page also compares actual performance against targets or benchmarks.
- The clear purpose of the scorecards is to stimulate improvement, not to assess blame. The report highlights problems and weaknesses that the company needs to address, and it tracks the progress of continuous improvement over time and against fixed benchmarks.

The exact details do not make much difference. What does matter, however, is that the company aligns its performance measurement system with the goals of lean production and the team concept.

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<sup>19</sup>Kaplan., pp. 6 & 21.

<sup>20</sup>A decision that reduces costs does not always increase profits. Likewise, a decision that increases profits may sometimes also increase costs.

## Cultural Dependence: A Common Myth

Lean production, like any revolution in thinking, has its detractors in both industry and the university. Many critics often argue that, although lean production clearly works exceedingly well in Japan, where it originated, it is doomed to fail in the United States because of the vast cultural differences between the two countries. Especially in the vital areas of cooperation and consensus, many argue, the lean production practices hinge critically on the culture and traditions of Japanese society. Such a system has no chance of taking root in the individualistic and anti-authoritarian society of the US.

This line of thinking really misses the whole point. Of course some of these practices have their foundation in Japanese culture and traditions. But that does not exclude the possibility that they can succeed in the West. Innovative managers can learn lessons from the exceptional performance of Japanese manufacturing companies, and invent ways of shaping and adapting these practices to fit Western culture and traditions. Moreover, real-world experience clearly refutes the notion that culture alone determines success or failure in adopting lean production. Toyota's Georgetown and Lexington, Kentucky, assembly plants; Honda's Marysville, Ohio, factory; NUMMI, the GM-Toyota joint venture in Fremont, California; and GM's Saturn operation in Spring Hill, Tennessee -- all of these facilities have successfully applied lean production methods on American soil with American labor, in some cases with American *unionized* labor. In addition, Krafcik's survey of dozens of auto-assembly plants demonstrates that plant performance -- both quality and productivity -- depends not on country of location, but rather on the type of production system employed.<sup>21</sup> *The Machine that Changed the World* summarizes the argument quite well: "the fundamental ideas of lean production are universal -- applicable anywhere by anyone. . . ."<sup>22</sup>

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<sup>21</sup>Krafcik, pp. 41-42.

<sup>22</sup>Womack, Jones, and Roos, p. 9.



## Texas Instruments Defense Systems & Electronics Group

Texas Instruments Defense Systems & Electronics Group stands alone. No other defense contractor has ever won the Malcolm Baldrige National Quality Award. TI DSEG, along with four other companies, won the prestigious prize in 1992. At the awards ceremony in December of that year, then-President George Bush commented, “This TI subsidiary has grown to become the nation’s eighth largest defense electronics contractor. And we know from the success of Desert Storm that in matters of advanced weaponry, quality is absolutely essential. . . .we know too from the success of Desert Storm that TI’s contributions to this effort were absolutely invaluable.”<sup>23</sup> TI DSEG manufactured many of the weapons systems, including the HARM missile and the Paveway guidance system, that the US Navy and Air Force deployed against Iraqi targets during Operation Desert Storm, the Pentagon’s code name for its campaign in the Persian Gulf War.

Despite winning the Baldrige Award in 1992, the business outlook for DSEG was not all that bright. When the people of East Germany toppled the hated Berlin Wall in 1989, the world celebrated the end of the Cold War and the triumph of freedom over oppression. Although these events offered great hope for peace and prosperity, they also brought with them a certain amount of pain for the US defense industry. With the reduction in tensions between the superpowers, the US military could at last begin to downsize from its huge build-up during the 1980s. These force reductions, coupled with a deep recession during 1990 and 1991, had a devastating impact on many defense contractors. Although the downturn did impact the performance of TI DSEG, the

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<sup>23</sup>Reuters, December 14, 1992.

company remained profitable throughout the period and ultimately emerged with a strong position in the defense market. Exhibit 6 shows financial results for TI's Defense Electronics Systems Sector, which includes DSEG.

The Defense System Sector's turnover ratio (sales/beginning assets) dropped from 2.06x in 1988 to 1.73x in 1991. Simultaneously, the sector's profit margin (operating profit/sales) plunged from above 10 percent to below 6 percent. As a result, return on assets -- the product of turnover and profit margin -- collapsed, dropping from nearly 21 percent in 1988 to below 10 percent in 1991. These fluctuations, to be fair, may exaggerate the true situation -- the sales figures are highly sensitive to the timing of specific individual contracts, which often involve large sums of money.

As we will discuss in the next section, it was around this time that senior managers at DSEG began to consider making some major changes in the structure and operation of the division. The crisis that defense cutbacks and recession had precipitated may have given DSEG's managers all the motivation they needed to seek organizational change.

DSEG staged a remarkable comeback in 1992: the turnover ratio bounced back to 2.1x, profit margin reached nearly 10 percent, and return on assets recovered to better than 20 percent. Moreover, the results for 1993 continued to show improvement. Although many factors may have contributed to the turnaround, including the end of the recession, there is little doubt that organizational change played a significant role. Self-directed work teams have reduced manufacturing costs, slashed cycle times, increased product quality, and improved on-time delivery.

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**Exhibit 5**  
**TI DSEG at a glance**

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|                              |  |
|------------------------------|--|
| <i>1993 Revenues</i>         | \$1.86 billion.  |
| <i>Share of TI's Revenue</i> | 22 percent.  |
| <i>Employees</i>             | 14,000.  |
| <i>Products</i>              | Precision-guided weapons<br>Radar systems<br>Navigation systems<br>Infrared surveillance systems<br>Fire control systems<br>Electronic warfare systems |
| <i>Headquarters</i>          | Dallas, Texas.   |
| <i>Locations</i>             | 11 facilities in north and central Texas.  |
| <i>Activities</i>            | Research, design, and development;<br>Manufacturing, testing, and distribution.  |
| <i>Customers</i>             | US Department of Defense<br>Foreign governments allied with the US -- 10% of sales   |
| <i>Officers</i>              | Dean Clubb, President  |

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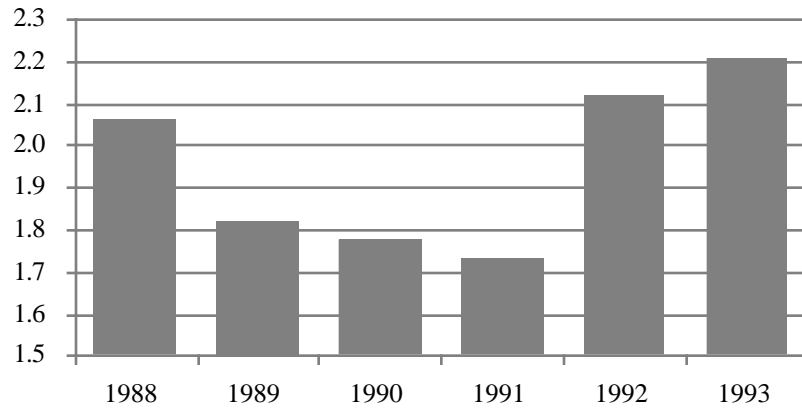
Source: Business America; Texas Instruments *Annual Report to Shareholders* (1993); Texas Instruments Defense Systems and Electronics Group.

**Exhibit 6**

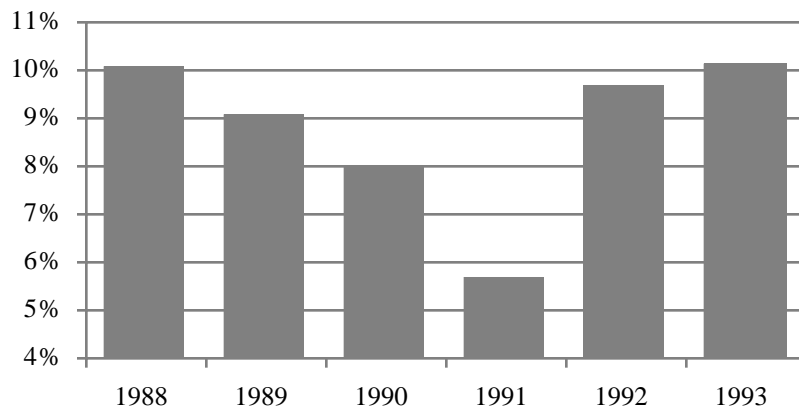
**Texas Instruments  
Defense Systems and Electronics Group**

**Summary of Operating Performance**

*Turnover  
(Sales/Beginning Assets)*



*Profit Margin  
(Operating Profit/Sales)*



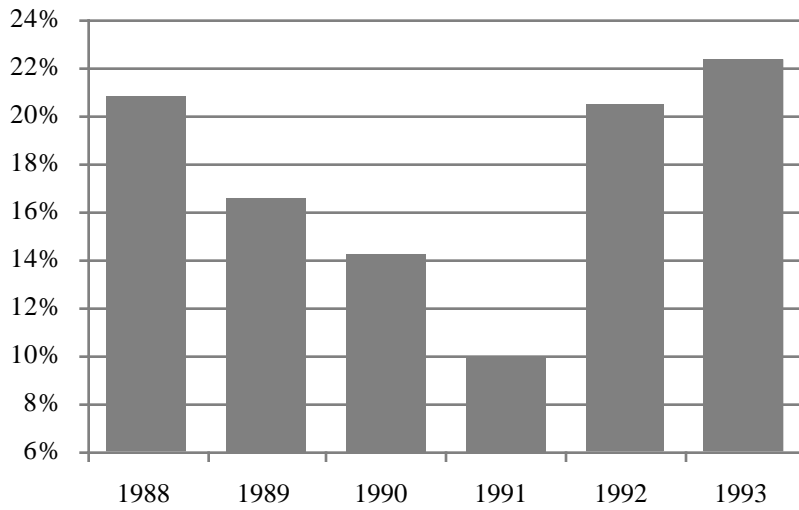
*Continues --->*



**Exhibit 6 -- Continued**

*Return on Assets  
(Operating Profit/Beginning Assets)*

*Return on Assets = Turnover x Profit Margin*



Source: Texas Instruments *Annual Report to Shareholders* (1988 - 1993).

## **History of Teaming at TI**

Throughout much of its history, TI has taken a team approach in many situations. Originally, the company created teams around a specific project or program, and structured the teams in a conventional fashion, as functional blocks that fit nicely into the standard organizational hierarchy. The teams, perhaps emulating a military ethic, operated under a rigid command and control philosophy. Separated into neatly arranged functional silos, these teams were not especially effective and tended to arrive at sub-optimal solutions.

Some time later, TI began dabbling in problem-solving teams. A big problem or hot issue would surface, and the company would assemble a team of experts from management or engineering. The team would then set out to analyze the problem and develop solutions for the people who did the day-to-day work. These teams often succeeded in correcting the problem in the short term, only to have the same problem return six months later, after the team had either moved on to the next problem or disbanded. This type of team often eliminated only short term symptoms rather than the true long term root causes.

### *Effectiveness Teams*

In the early 1980s, the Japanese concept of the quality circle became quite popular in the United States. TI introduced its own version, called Effectiveness Teams, or ETs. For the first time, the company included shop floor workers as team members, and provided them with training in teamwork and problem-solving skills. Management, however, did not allow the ETs to consider business problems; rather, they would focus only on solving narrowly defined production issues. The program kept participation on a voluntary basis. That decision sent a signal that ETs were not all that important to the

company, and it polarized people into two camps. Nevertheless, shop floor workers did become involved in solving problems, running meetings, and working with other people. As a result, ETs succeeded in addressing certain production problems. Moreover, the program created a foundation for understanding the team process among managers and workers alike.

A few years later, US companies began experimenting with JIT and SQC. Factories began shifting away from batch production and toward continuous flow production. Managers noticed that JIT required production workers to start becoming involved in higher-level decisions, and it required people to take ownership of the process. The more people participated, the more they could improve the processes. The shop floor workers understood how things worked on the line far better than the supervisors and manufacturing/industrial engineers. Once they understood the objectives of JIT, they figured out how to make it work in practice.

#### *Self-directed work teams*

In 1987, middle managers at a few business units -- including DSEG -- began looking at the self-managing concept. They brought in some outside experts to teach them more about this idea, and established a few pilot teams at the grass-roots level. Unlike the earlier experiment with ETs, the new self-directed teams focused not only on production problems, but also on broader business issues and customer needs. Senior managers began to take notice of the positive impact that worker participation was having on productivity. Self-directed work teams had taken root and were beginning to spread.

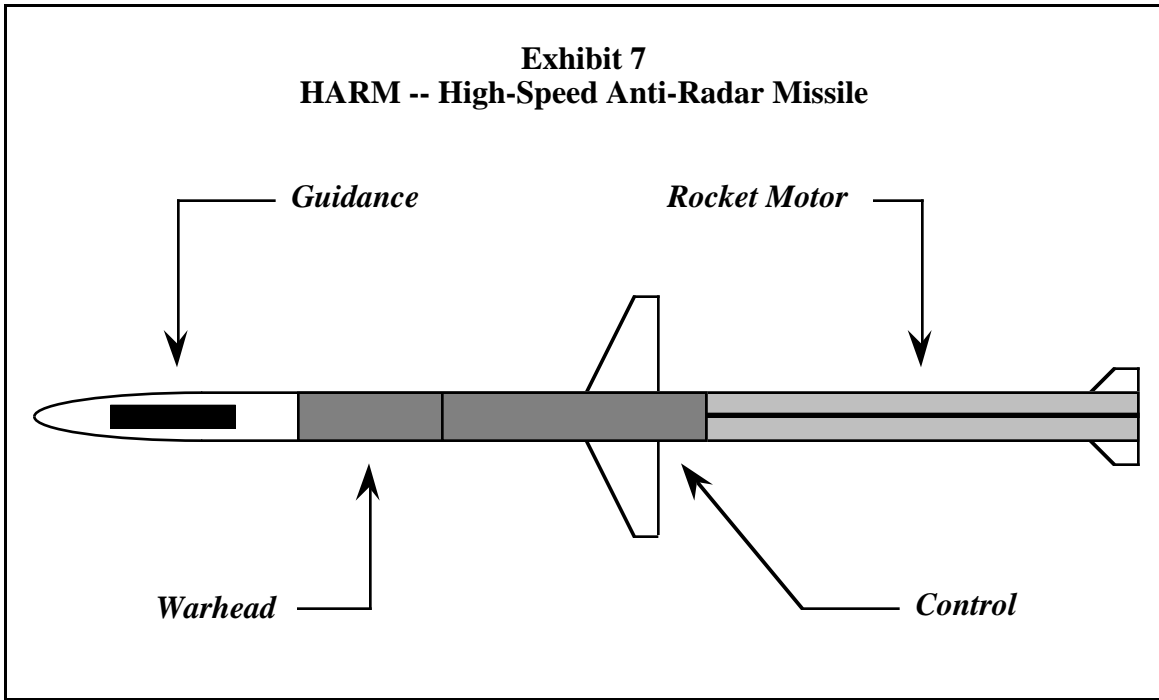
In 1991, DSEG formed a new staff group called High Performing Organizations Development. HPOD's charter was to take the successful concepts and practices from the depths of the division and disseminate them to the organization-at-large. HPOD would help DSEG move toward team-based empowerment and participation. The group would also begin aligning the company's systems to the team concept.



One of HPOD’s initial tasks was to create a database of all teams within DSEG. The database would simplify the team registration process, help teams communicate, and allow teams to share success stories. Currently, the database includes more than 1,100 teams. The following table categorizes the teams by general business function:

| <b>Business Function</b>                     | <b>Number of Teams</b> |
|--|------------------------|
| Product Production Process                   | 395                    |
| Customer Support, Material Service Suppliers | 264                    |
| Product Development                          | 184                    |
| Technology                                   | 72                     |
| Miscellaneous                                | <u>185</u>             |
| Total  | <u>1,100</u>           |

The next two sections present a case study of two specific teams at TI DSEG. The Switch Filter/Beam Former Team assembles microwave circuit boards for the HARM missile program; the Diamond Point Turning Team manufactures precision optical components for military and industrial applications. Both teams have achieved a high level of maturity and enjoyed great success as self-directed work teams.



### **Switch Filter/Beam Former Team**

The Switch Filter/Beam Former Team is one of seven work teams that together comprise the Microwave Circuit Board Shop at Texas Instruments' Lewisville facility. Located about 15 miles north of Dallas on a lonely stretch of Highway 121, the sprawling, two-story Lewisville complex manufactures advanced guidance, detection, and weapon systems for the US Air Force and US Navy. The Microwave Circuit Board Shop, or MCB, produces components for the guidance system of the highly successful HARM missile program.

HARM, or High-Speed Anti-Radar Missile, gives tactical aircraft the ability to destroy ground- and sea-based defensive radar systems, rendering enemy installations unprotected from air attack. A sophisticated electronic guidance system detects the enemy's outgoing radar signal, and exploits these radio waves to maneuver the missile directly to its intended target. Exhibit 7 presents a schematic diagram of the fully assembled HARM missile.

The HARM guidance system is a complicated sub-assembly that consists of several inter-connected microwave circuit boards and a broadband radio frequency antenna and receiver. The MCB shop assembles ten different circuit boards that together make a complete HARM guidance system. Organized as seven self-directed work teams, MCB has piloted many new initiatives as the team concept has evolved at TI DSEG. As a result, the MCB work teams are among the most mature within the division.

Except for the Prep Cell team, each of the seven work teams manufactures one or two of the ten circuit boards for the HARM's guidance system. The Prep Cell team assembles kits of parts for each circuit board, and distributes the kits to the production teams. The Switch Filter/Beam Former Team, as its name suggests, assembles two of the ten microwave circuit boards. The team has twelve members.

### **Production Process**

The members of the SF/BF team work together as an integrated work cell to assemble the two circuit boards front-to-back. The team members occupy individual workstations that are all located contiguously in a single area of the MCB shop. Target production for the HARM missile is currently nine units per day. Each unit requires one switch filter and one beam former. MCB uses the line of balance, or LOB, method to keep track of parts production. The LOB for any given part measures the cumulative difference between planned and actual production volume. For example, suppose the LOB for switch filters starts out one morning at +2. If target production is 9 units, and the team produces only 6, then the LOB falls to -1 by the end of the day.<sup>24</sup>

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<sup>24</sup>The calculation proceeds as follows:

|            |   |              |   |               |   |               |
|------------|---|--------------|---|---------------|---|---------------|
| Ending LOB | = | Starting LOB | + | Actual Volume | - | Target Volume |
|            | = | +2           | + | 6             | - | 9             |
|            | = | -1           |   |               |   |               |

After the part kits arrive each morning from the Prep Cell Team, the team follows a process flow (see Exhibit 8) that involves about seven distinct operations, some in series and some in parallel:

- *Flow Line:* Manually place and solder integrated circuits and discrete devices onto the switch filter or beam former circuit boards.
- *Potting:* Fill in gaps between components with a putty-like substance to isolate each electronic device from the others.
- *Metal Foil and Auto Weld:* Place metal foil over each integrated circuit and manually weld the four corners of each piece in place. Deliver the boards to the Auto Weld area. Complete the welding on each board using CNC equipment.
- *RF Washers:* Place and attach metal washers at certain positions on the boards.
- *Assemble Flex, Tray, and Cover:* Enclose board and flexible interface cables within tray and cover assembly.
- *Wire Flex:* Connect flexible external ports to circuit board.
- *Additional Potting:* Cover key components with potting to shield them from electromagnetic interference.

A central computer system tracks all of the production-related paperwork. A production data sheet, including appropriate bar coding for easy data-input, travels with each circuit board through the process. All of the workers have a terminal at their workstation, and they retrieve their own reports right on-line. In particular, team members can see the current production status of every team in the MCB Shop -- and every team's Line of Balance. Other on-line data includes inventory, quality, defects, and actual/earned hours.

Team members work eight-and-a-half hours each day, including a half-hour lunch break and two ten-minute coffee breaks. MCB has adopted a flextime policy: workers generally start at 6:30 am and leave at 3 pm, but they are free to start as late as 8:30 am

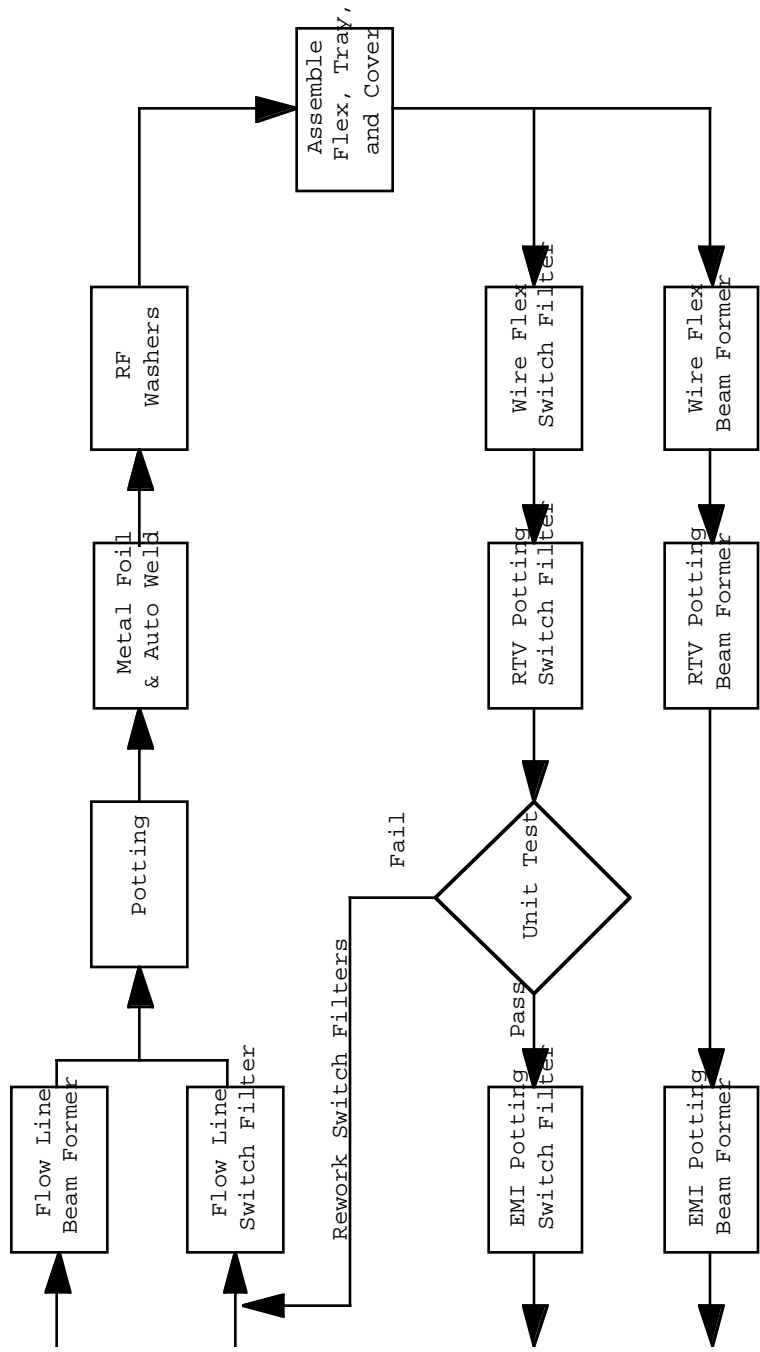
(and stay until 5). If workers need to miss work and have a legitimate excuse, they can call in by 8 am and ask other workers to cover their tasks.

This process differs significantly from the system that reigned before TI DSEG adopted self-directed work teams. Each worker simply completed a handful of assigned production tasks on each board as it went by on a continuous flow line. The same assembly line produced all ten of the microwave circuit boards for the HARM missile. Although each worker performed the same task repetitively, they worked on many different types of boards. TI had to keep some additional workers, called ‘floaters,’ on the payroll. These workers knew how to do every job on the line, and could fill in for any absentee workers.

One worker, looking back and comparing the old system with the current team concept, said, “I miss the variety of boards, but everyone gets to know what they’re doing real well.”

Before self-directed work teams, the supervisor stood watch over the line, and workers were not supposed to even talk to each other on the line. As one team member put it, “You had someone down the other end of the line cracking the whip.” And the supervisors weren’t always even-handed: “That’s the problem with supervisors, you always get favoritism.”

Exhibit 8  
Switch Filter/Beam Former Team  
Process Flow



## **Incentive Compensation**

All of the workers in the MCB area are participating in a pilot program for Pride & Share, a new initiative that provides both pay-for-knowledge and pay-for-performance components. The performance awards relate to the performance of MCB-as-a-whole, rather than individual teams. As part of Pride & Share, MCB is also working on Job Class Consolidation. MCB is trying to move toward just three job classifications (for more information on Job Class Consolidation and Pride & Share, see pages 70-73).

## **Administrative Tasks**

Each worker has responsibility for one or two production tasks, plus several administrative and support tasks, called starpoints (see Exhibit 9). Each starpoint carries with it certain daily and weekly responsibilities. More important, workers keep each other up-to-date on any issues or problems that arise related to their individual starpoints. Starpoint tasks include staffing, safety, line of balance graphs, tooling, methods improvement, mail, and checks. DSEG makes training classes available to provide workers the skills they need to handle starpoint tasks. Moreover, the team cannot assume all of the supervisory responsibilities all at once. Gradually, over a period of time, the team takes on greater and greater responsibility. Team members rotate periodically through different starpoints to learn new skills and to avoid getting stuck with unpopular tasks.

The MCB team coordinator estimates that administrative tasks take an average one-and-a-half hours each day, and meetings an additional half-hour; that leaves six hours-a-day for production work. In addition to starpoints, the MCB has created four resource teams: Cost Resource Team, Six Sigma Team, Cycle Time Team, and People Involvement Team.

**Exhibit 9**  
**Switch Filter/Beam Former Team**  
**Task Assignments**

| <b>Team Member</b> | <b>Years at TI</b> | <b>Production Tasks</b>                                    | <b>Starpoint Tasks</b>   |
|--------------------|--------------------|--|--|
| 1                  | 7                  | Flow Line -- switch filter                                 | Team Representative<br>PB Autoload<br>Parts                              |
| 2                  | 11                 | Flow Line -- switch filter                                 | Mail<br>Checks<br>Teaming for Excellence<br>Tooling Back-up              |
| 3                  | 6                  | Flow Line -- switch filter<br>(Trainee)                    | (none)   |
| 4                  | 4 $\frac{1}{2}$    | Flow Line -- beam former<br>Wire Flex -- switch filter     | Cost,<br>Tooling<br>Cycle Time   |
| 5                  | 6                  | Flow Line -- beam former<br>RF Washers                     | Safety<br>Shop Process Book  |
| 6                  | 11                 | Flow Line -- beam former                                   | Methods Improvement<br>Staffing<br>Tooling Requests                      |
| 7                  | 7                  | Metal Foil   | Line of Balance Graphs<br>Quality Graphs                                 |
| 8                  | 7 $\frac{1}{2}$    | Auto Weld<br>RTV Potting -- switch filter                  | Sale Team Book   |
| 9                  | temp               | RTV Potting -- beam former<br>EMI Potting -- switch filter | (none)   |
| 10                 | 7                  | Assemble Flex, Tray, & Cover                               | Labor Approval   |
| 11                 | temp               | Potting  | (none)   |
| 12                 | 3 $\frac{1}{2}$    | Unit Test  | Conflict Resolution<br>Assembly Instructions<br>In-process Quality Graph |

Source: Switch Filter/Beam Former Team.



## Quality Control

The quality control process provides an excellent example of how worker participation can not only support, but actually advance progress toward the company's objectives. Prior to adopting self-directed work teams, TI DSEG relied heavily on inspection to ensure quality. After completing their assigned tasks, workers simply passed each board down the line to the next production station without any mechanism for detecting production defects. MCB controlled quality only at the end of the line, during final assembly and test. Here, quality inspectors rejected any guidance system that failed to meet the product's specifications. Rework specialists would then try to find and fix the problems in rejected units. If they could not do so successfully, they would have to scrap the bad unit.

This approach suffered from several critical flaws that the teaming concept has since corrected. First, the old quality control process depended entirely upon inspection rather than prevention. Catching defects at the end of the line did nothing to prevent defects from occurring in the first place -- it was already too late. Second, it was much more difficult to pinpoint and correct specific defects for a completed system than it would have been for any individual circuit board. The Assembly & Test group relied heavily on trial-and-error to identify a bad part or weak solder joint. Rework specialists might replace a part on a rejected circuit board in the hope of fixing the problem. It didn't always work. As a result, rework could take a long time and become very costly. Third, scrapped systems represented an enormous heap of wasted resources. Every resource that the rejected unit had consumed since the process first introduced the defect went completely to waste. If workers had detected the problem earlier, they could have either fixed it right away or avoided wasting any additional resources down the line. Finally, inspection is inherently limited because it merely *controls* final product quality while it offers no means for *improving* the quality of the underlying process.

### *A New Approach*

The arrival of self-directed work teams at MCB brought with it an entirely new quality control process. MCB has taken advantage of three key attributes of the team concept -- total participation, continuous improvement, and the quality principle -- to overhaul its quality control methods. First, total participation has allowed MCB to make QC an integrated part of the overall production process. One of the earliest steps in developing self-directed teams was to certify team members in quality control, thereby allowing them to perform QC on their own work.

The Switch Filter/Beam Former Team has already achieved 100 percent QC certification -- all twelve members have completed the three-day training course and passed the required practical test. Upon completing any production task, workers inspect their own output to identify any defects that might exist. As a result, the workers uncover most problems at their source, and can immediately correct the problems before they snowball during continued processing -- and waste additional resources.

Second, total participation opens the door for continuous improvement. By eliminating the long delay between production processing and final inspection, integrated quality control allows workers to begin seeing patterns of cause and effect between processing conditions and the occurrence of specific defects. Furthermore, the intimate knowledge of the production process that resides with shop floor workers gives them an ideal perspective to identify and implement process improvements. TI DSEG has provided workers a mechanism -- the Method Improvement Report, or MIR -- to propose and document potential process improvements. Process engineers study and usually approve these MIRs; the new methods then not only become standardized for the team where they originated, but also disseminate to other teams as well.

Third, the new QC process embodies the Japanese concept of *Jidoka*, the Quality Principle (see page 19 for the definition). In the MCB shop, the responsibility for fixing a problem resides with the person who created the problem; as a result, workers have an excellent incentive to do things right the first time. Their direct involvement in QC provides them with a clear understanding that building quality into the production process in the first place eliminates the need to inspect the final product for defect later on.

### *Customer Focus*

Organizing the production process into self-directed work teams has created an interlocking network of customer-supplier relationships among all of the shops involved in manufacturing the HARM missile. The MCB shop, for example, receives blank circuit boards from TI's Austin facility. The Austin crew sends people to visit MCB about once-a-month to see if the shop is having any difficulties in processing the circuit boards. As a result, Austin can develop a good understanding of the needs of its customers, the MCB production teams, and can respond quickly as those needs change or as specific problems arise. If something major comes up, of course, the Austin people come up to Lewisville right away -- the earlier they can correct the problem, the less likely it becomes that MCB will generate a pile of defective circuit boards.

Likewise, the Switch Filter/Beam Former Team (and other MCB teams) maintain close contact with their own customers. For example, as the SF/BF team finishes a batch of circuit boards each day, one member typically delivers the boards to the guidance system assembly area upstairs. "If there are any problems with the boards, believe me, I'll hear about it," says the worker. The team receives customer feedback immediately and frequently.

### *The Remaining Role for Inspection*

The new QC process has not eliminated inspection entirely. The last step in the process for assembling switch filters, for example, involves testing the units. One member of the SF/BF team devotes his time to the task of measuring the frequency response and other electronic characteristics of the circuit boards. If a board fails to meet tight specifications, the technician can often pinpoint the exact problem right away. In fact, the testing procedures themselves provide a wealth of diagnostic information that helps him locate the root cause of the defect. Furthermore, he can in some cases fix the problem himself, or in other cases simply hand the board back to the appropriate team member for a quick rework job.

Although this step still qualifies as inspection, it is a clear improvement over the end-of-the-line inspection in the old flow-line days. Now, the unit test takes place much closer, both physically and in time, to the source of the defect than under the old method. As a result, the team uncovers systematic defects much earlier, before the process spits out a pile of rejects. More important, the new system provides the team with an opportunity to improve the process in ways that will avoid defects in the future.

### **Performance Evaluation**

The SF/BF Team has recently adopted a new method of evaluating each worker's performance. Team members first seek feedback from their peers. Based on this information, they then write up their own evaluations, including areas of good performance, areas that need some improvement, and plans for taking action. Finally, they present the evaluations to the team facilitator.

Before adopting this new system, members of the team received performance evaluations once-a-year, although some workers wanted to receive feedback more frequently, perhaps quarterly. The evaluation process depended on the same evaluation

forms that supervisors wrote-up under the old Taylorist production system. These questionnaires were long and tedious -- filling them out could take two or three hours. The criteria for evaluating performance included dependability, productivity, safety, teamwork, and quality.

MCB is also discussing a proposal for yet another evaluation method. The whole team would sit together in a conference room and evaluate the performance of one worker. Going around the table, each member would comment on the worker's performance during the most recent few months. One week later, the person would present a corrective action plan to the team; a week after that, the team would discuss the worker's progress toward the plan. Meanwhile, the team would have started evaluating the performance of a second and third worker. Repeating this process for each member of the team in turn, the team could evaluate all twelve members once each quarter.

One vital consideration is the purpose of the evaluations. MCB intends to use this technique only as a method to allow people to improve their performance. The evaluations will not have any impact on base pay or bonuses. Round-table evaluations offer two key advantages: first, they allow people to learn from their own mistakes and successes; and second, they allow people to learn from the mistakes and successes of others as well. To increase the effectiveness of the program, workers attend classes to learn how to give constructive criticism -- and how to avoid attacking each other.

## **Training**

TI will make 32 hours of training available to each employee during the current year, up from 24 hours last year. The plan next year calls for 40 hours per employee. Training includes certification in production tasks, safety procedures, quality improvement process, teamwork skills, communications, and other management skills. Training serves two objects: (1) to certify each team member in all of the team's production tasks, and (2) to give team members the skills they need to deal with business

and administrative issues. Each team works out a training schedule for all of its members. Teams then schedule additional work hours as needed to keep up with the Line of Balance during training courses.

### **Weekly Production Meeting**

The team has a regular production meeting once-a-week. All members of the team, plus the team facilitator, attend these meetings. Discussion centers around both production and administrative issues. The team can review the schedule and make plans for the coming week regarding work hours, training sessions, the Line of Balance, and any planned absences or vacations. Workers can bring specific production, quality, or inter-personal problems to the attention of the entire team, and discussion can focus on finding appropriate solutions. Each member also makes a brief presentation to update the team on each of the Starpoint activities.

### **Helping Other Teams**

Workers in the MCB shop can monitor the current Line of Balance of all of the MCB teams. The computer system makes the data readily available at every work station. If one team falls behind the LOB, workers from other teams will pitch in to help the team catch up. This kind of cooperation is possible because the workers know how to do more than just a single job. Moreover, MCB provides strong incentives for teams to cooperate in optimizing the performance of the shop-as-a-whole rather than individual teams.

### **Performance Measures**

MCB places great emphasis on reducing manufacturing costs. The SF/BF Team focuses on one metric in particular, A/E, or Actual/Earned hours. A/E measures the ratio of actual time divided by earned, or standard, time for any given activity. SF/BF tracks A/E for production time, queue time, touch time, scrap, and overhead. Earned time

includes not only the target time, but also break time and personal breaks. Workers log their hours onto the computer system, which then calculates and records A/E for each component.

The process has changed greatly since SF/BF originally measured the target times. The team coordinator is currently updating new targets to reflect the current process. As the teams continue to improve the processes in the future, they will need to measure the target times on a regular basis, perhaps once-a-year.

MCB's management looks at A/E very carefully. The group believes that A/E influences manufacturing costs. DSEG receives fixed revenue regardless of its costs. As a result, keeping costs in line has become exceedingly important.

### **Production Decline and Layoffs**

Spending reductions at the Pentagon continue to take a toll on TI DSEG. The Line of Balance for HARM missile production used to be thirteen per day. Currently, it stands at nine. And DSEG is already planning to cut back again, to just six per day. The company also has plans to reduce the HARM program's workforce by 30 percent in the third and fourth quarters of 1994. That amounts to approximately 100 people.

## **Diamond Point Turning Team**

The Diamond Point Turning Team manufactures high-precision optical components for various DSEG programs. DPT team members operate a sophisticated machine shop located in the Optics Department at the Forest Lane production complex in Dallas. DPT delivers both standard and custom-made components primarily to other groups or programs within DSEG, although the team occasionally fills orders for external customers as well. The team uses diamond point machining technology to impart specific surface geometries onto bulk materials within extremely precise tolerances. Customers use these components -- including custom lenses, flat and curved-surface mirrors, and snap-together housings -- as the optical elements in a variety of devices for both military and commercial applications. DPT makes elements that operate at either infrared or visible wavelengths. Materials include germanium, gallium arsenide, silicon, aluminum, copper, and gold. As an example of the DPT's work, Exhibit 10 shows a schematic diagram of a Schmidt-Cassegrain telephoto assembly. DPT manufactures the precision-machined primary and secondary mirrors for this device.

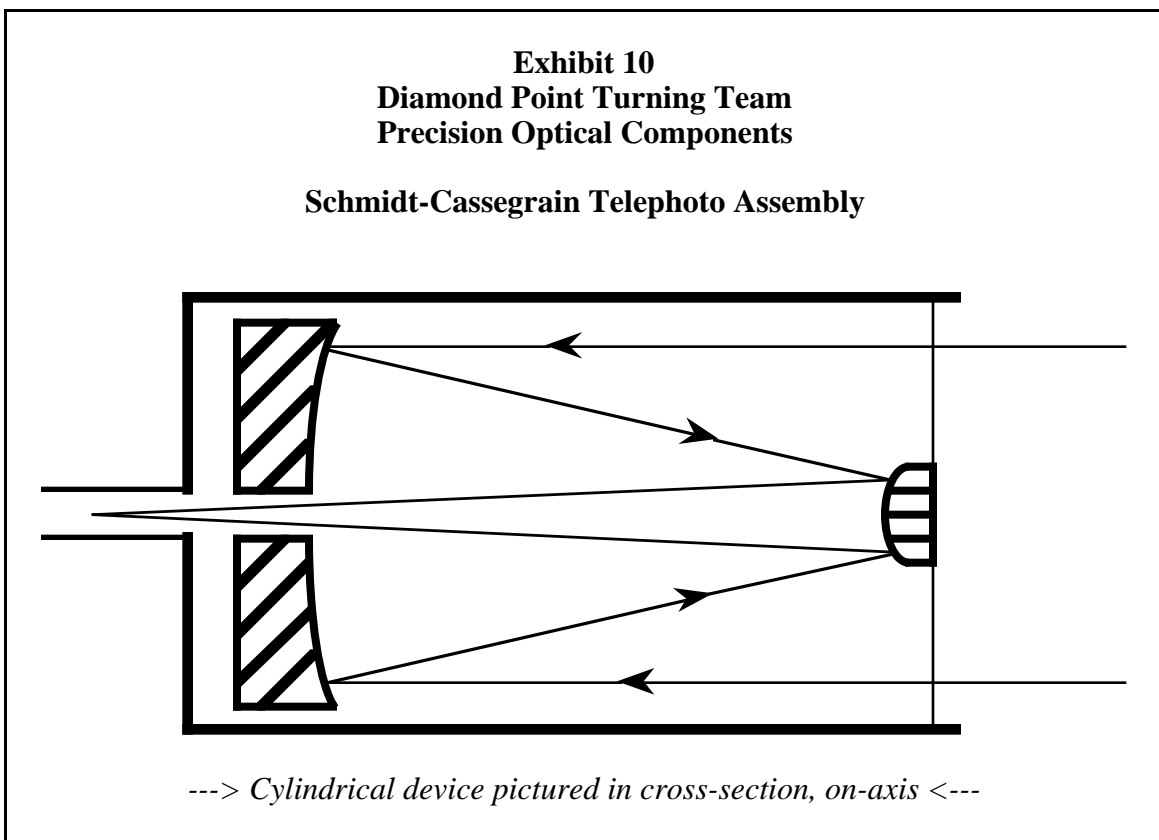
### **Production Process**

Producing a large variety of parts in low-volume runs, DPT structures its work flow as a simple job-shop. The shop occupies a 3,200 square foot clean room and an adjacent support area. A controlled environment in the clean room maintains a constant temperature of  $68^{\circ} \pm 1^{\circ}$  F. and humidity of  $55\% \pm 5\%$ . The room houses many large machines, including three diamond-point lathes (two- and three-axis), three diamond-point flycutters, a conventional CNC lathe, a small engine lathe, and a boring mill. In addition, DPT uses any of several interferometers and profilometers located in the shop to measure the dimensions and characterize the optical properties of finished components.



The diamond-point equipment uses single-crystal diamonds mounted on vibration-free frames to cut geometries at a resolution of 1 microinch.<sup>25</sup>

Many parts that DPT produces are custom, one-time runs. Some are standard production part numbers for which the team maintains process sheets, last-run data sheets, and stock tooling. In addition, some customers may periodically re-order small quantities of some particular custom-made part. When DPT introduces a new, standardized component into production, the team usually experiences a definite learning curve -- unit costs often decrease dramatically over time as the team accumulates experience with the new component.



<sup>25</sup>One microinch is approximately 250 Ångstroms. This resolution is 20 or 25 times smaller than the wavelengths of visible light!

TI DSEG established the diamond point turning operation in 1981. The DPT work group had always maintained a strong level of independence within the Optics Department, for two reasons: (1) The need to work in a certified clean room kept the group physically separated from other production groups; and (2) the highly skilled, specialized nature of the diamond point machining process gave the group a large degree of organizational freedom as well. As a result, the DPT work group stood out as a clear candidate to transition from supervised group to self-directed team. In June of 1992, after spending six months redesigning its manufacturing activities, the Optics Department officially designated DPT as a self-directed work team.

DPT has eleven members -- seven machinists and four opticians. All of these workers are highly skilled specialists and craftspeople. In addition, the team has the support of a team facilitator and a process engineer. The DPT shop operates two shifts-a-day, five days-a-week. Team members rotate machines periodically, about every two or three years. Changing machines often requires additional training and skill upgrades, particularly on more advanced machines.

Soon after its initial inception, the DPT team adopted a formal transition plan to become self-directed. The transition plan sets out goals for starting team activities and taking on additional responsibilities, as well as a time frame for the completion of each item. These goals include:

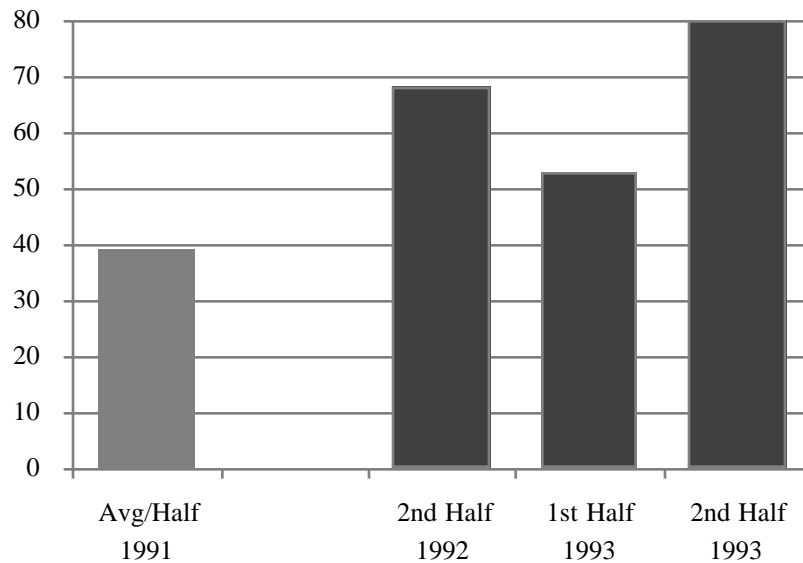
- establishing regular team meetings
- creating a process for setting goals
- documenting all shop processes
- developing SQC methods and measuring progress toward six-sigma
- building infrastructure and support systems to
  - track key performance metrics
  - analyze variances
  - interface with customers
  - keep records on attendance and MIRs
  - set annual budgets

Every month, DPT submits a written report to the department manager outlining the team's progress relative to the plan. In addition, DPT (along with other teams) makes a presentation to the Quality Improvement Thrust, which the manager chairs.

### **Process Improvement**

Among the earliest tasks that DPT completed as a team was to document the shop's entire production process as a comprehensive set of flow charts. Although this exercise took a lot of time and effort, it proved a worthwhile investment. Once completed, the process flow diagrams became a valuable tool in uncovering wasteful processes and identifying potential improvements. As one machinist described it, "It's kind of funny when the people who actually do the process sit down and say, 'What can I do to improve this process?' " Exhibit 11 shows the result. The number of Method Improvement Reports that DPT implemented in 1993 was 70 percent higher than in 1991. During its first year as a self-directed team, from June of 1992 through June of 1993, DPT adopted 121 MIRs -- and created \$140,000 in annual savings. MIR participation was not limited to just a few operators; rather, every team member contributed ten or more MIRs during 1993. In addition, the team initiated thirty-eight safety improvements in 1993, which proactively reduced the likelihood of an accident.

**Exhibit 11  
Diamond Point Turning Team  
Method Improvement Reports**



***36% increase in participation since team formation  
Realized \$140,000 Savings from 6/92 to 6/93***

As an example of the impact that involving workers in process improvement can have, consider Exhibit 12. The top panel shows the original process flow for one high volume part, while the bottom panel shows a redesigned process for the same part after the team developed several improvements. Team members simplified the process by eliminating two of three queuing delays and consolidating processing from four operations to just two. The team's effort paid off big -- the new process yielded annual savings of \$43,400, and simultaneously improved quality.



## Quality Control

Like the SF/BF Team, DPT has achieved 100 percent certification of its members in TQC. Operators perform QC on their own work -- DPT has no need for a separate QC person to inspect finished parts. "Doing your own QC cuts out a whole operation," said one team member. "We QC our own work. That cuts down wait time, cuts labor costs and cycle time. Most people know when they're doing a good job."

The team focuses heavily on building quality into the process rather than merely inspecting the final product for defects. DPT routinely uses the tools of Statistical Quality Control to monitor and control the production process. In fact, DPT has adopted a very aggressive target for one key SQC metric: defects per million opportunities. The transition plan explicitly sets out the objective to achieve a process quality level of six-sigma, which corresponds to just 3.4 defects per million opportunities. Given DPT's current volume and product mix, the process experiences only 150,000 opportunities each year<sup>26</sup> -- leaving room for only *half-a-defect* per year! To achieve six-sigma, therefore, the team has in effect accepted Phillip Crosby's challenge to aim for *zero defects*.<sup>27</sup>

In practice, of course, no process can ever eliminate defects entirely, but it is a worthy goal nonetheless. As Exhibit 14 demonstrates, DPT's quality has made a dramatic improvement over the last few years -- defects per million opportunities have dropped from 2,000 in 1988 to less than 200 in 1993, a decrease of more than ten-to-one in just four years. The team tracks the trailing six-week average DPMO and the corresponding sigma on a weekly basis. Exhibit 13 shows the calculation of DPMO and sigma for a six-week period in late-1993 and early-1994. During this period, DPT incurred only two defects on the 600 parts that the team processed, yielding 128 defects per million opportunities or 5.2 sigma. For all of 1993, DPT's weekly sigma hovered between 4.7 and 5.3, and averaged about 5.1 sigma for the year.

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<sup>26</sup>This figure assumes approximately 26 opportunities per part on average.

<sup>27</sup>Crosby.

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**Exhibit 13**  
**Diamond Point Turning Team**  
**Statistical Quality Control**  
**December–January, 1993–94**

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| <b>Shop week</b> | <b>Defects</b> | <b>Parts processed</b> | <b>Defects per 1000 parts</b> | <b>Defects per million opportunities<sup>a</sup></b> | <b>Sigma</b> |
|------------------|----------------|------------------------|-------------------------------|--|--------------|
| 49               | 1              | 121                    | 8.3                           | 318  | 4.9          |
| 50               | 0              | 98                     | 0.0                           | 0  | 6.0          |
| 51               | 0              | 84                     | 0.0                           | 0  | 6.0          |
| 52 <sup>b</sup>  | 0              | 0                      | (n.c.)                        | (n.c.)   | (n.c.)       |
| 1                | 1              | 132                    | 7.6                           | 291  | 4.9          |
| 2                | 0              | 165                    | 0.0                           | 0  | 6.0          |
| <b>Total</b>     | <b>2</b>       | <b>600</b>             | <b>3.3</b>                    | <b>128</b>   | <b>5.2</b>   |

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<sup>a</sup> assumes 26 opportunities per part on average.

<sup>b</sup> Christmas & New Year holidays.

Source: Diamond Point Turning Team.

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*Maintenance*

In addition to QC, operators also take care of routine equipment maintenance on a daily basis. According to one team member, “We try to keep these machines pretty clean. We do a pretty good cleaning job everyday -- just general-type maintenance.” Ensuring the quality of the production process, of course, depends critically upon carrying out a regular schedule of preventive maintenance. Including maintenance among the regular day-to-day tasks of the shop floor operators frees up staff Repair & Maintenance specialists (external to the team) to deal only with major equipment failures. As a result, the department can reallocate a number of maintenance specialists and their associated overhead expense. Furthermore, self-directed maintenance eliminates the perverse

incentives inherent in standard cost accounting systems that actually *penalize* profit- and cost center managers for investing in preventive maintenance.

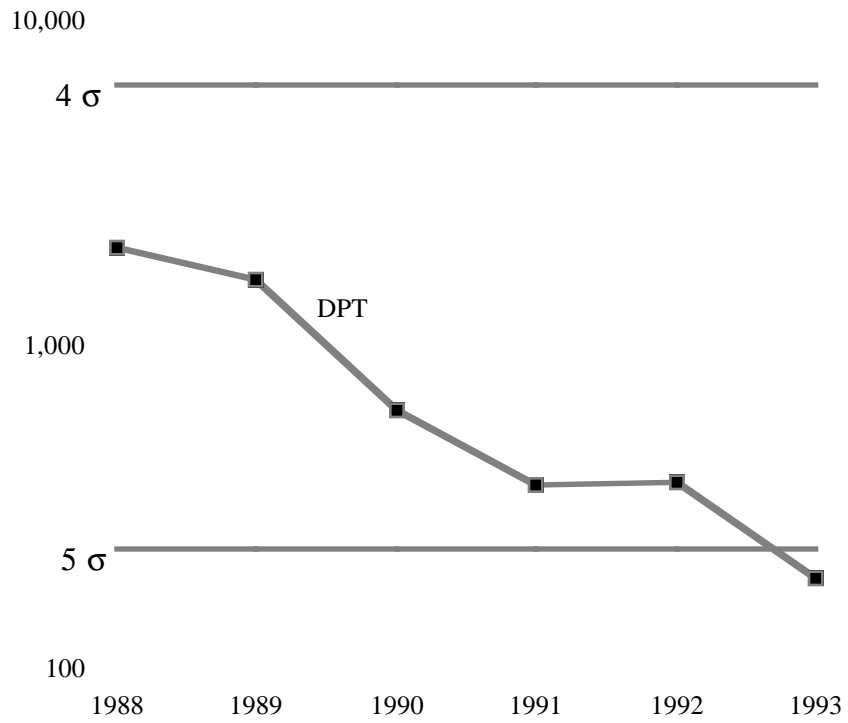
### *Customer Focus*

DPT's members have embraced the customer-focus idea in virtually all of their activities. DPT makes custom parts primarily for internal TI manufacturing programs, although on occasion the team fills orders from outside companies. Order volumes are typically small, and customers expect a quick turnaround. DPT understands what its customers want: high quality, low cost, and on-time delivery. In fact, to gain a better understanding of customer needs, one team member is planning to create a customer survey that he will send out quarterly to receive feedback from end-users.

Because of the extremely tight tolerances on the precision optics that DPT manufactures, final product quality is absolutely paramount. "You can't afford to let anything out that doesn't meet quality standards," says one team member. For all of 1993, the team released only a single part that failed during customer use. DPT had placed its quality stamp on a part they could not check fully. As a result of this failure, the team changed its policy and no longer places the stamp on any part it cannot test.



**Exhibit 14**  
**Diamond Point Turning Team**  
**Defects per Million Opportunities**



Source: Diamond Point Turning Team.

## **Administrative Process**

Like the SF/BF team, DPT assigns starpoint tasks to each of its members. Starpoint duties include Production Control, Methods & Tooling, Administration, Quality, and Safety. Exhibit 15 describes the specific responsibilities and the needed qualifications for each starpoint. Each starpoint task follows one or two relevant metrics, and tracks them on graphs and charts. “Everything a supervisor would do, we do by ourselves, within our boundaries,” says one team member. The team set up a front desk that everyone shares for administrative tasks. Located at the front desk is a 486 personal computer with a laser printer. The team keeps track of time usage carefully; records indicate that starpoint tasks take about six minutes of every available hour (Exhibit 17). The team rotates starpoint tasks every year, but never forces anyone to learn skills they don’t want to know. Nevertheless, DSEG requires every team member to complete a certain minimum number of hours of training each year. Training often takes the form of business or management classes.

DPT has personal computers at many, but not all, of its work stations. Although the department originally installed the PCs to control the lathe machines, some team members now use the computers for administrative tasks as well. “While you sit and watch your machine run you can do a whole lot of stuff between cuts. It actually helps your productivity. You couldn’t watch your machine and go over to the central computer at the same time -- your machine would have to sit idle.” The team has set a goal to put a PC at every work station. Meanwhile, everyone is taking PC training classes, and the team is investing in additional software tools. DPT is also considering a networking connection to Forest Lane’s central file server, which has a large collection of software.

Every Wednesday, the team meets with the Optics Department managers. They discuss the current situation in DPT, and present the team’s metrics to the first-level manager, the cost center manager, and the manufacturing people.

## **Hiring Process**

The administrative activities of a self-directed work team can even include hiring new members. Some time after its inception, DPT went to the department manager with a request for an additional person. The team needed more help, and justified it to the manager. He agreed, but asked the team to consider only candidates from inside the optics organization.

DPT developed an entire hiring process. The team created a list of questions for candidates, and asked Human Resources to look it over. The team then interviewed candidates. Each applicant met with three team members one-on-one. The entire team then met to discuss the three best candidates. They hammered out a consensus decision during a four-hour meeting. The team chose the person based not only on production skills, but also on personality characteristics and on how well the candidate would fit in with the rest of the team.

## **Performance Metrics**

As we discussed in the previous section, team members track one or two performance metrics related to their specific starpoint tasks. The team pays particular attention to defects per million opportunities and the associated sigma, on-time delivery, cycle time, output, MIR participation, attendance, and safety.

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**Exhibit 15**  
**Diamond Point Turning Team**  
**Starpoint Task Descriptions**

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**Attributes**

**Responsibilities**

*Administration*

|  |  |
|--|--|
| <p>Good communication skills<br/>         Computer literate<br/>         Knowledge of products &amp; processes<br/>         Knowledge of TI policies &amp; procedures<br/>         Understand statistical principles</p> | <p>Team communications<br/>         Present weekly status meeting<br/>         Overhead charge number control<br/>         Team metrics -- charts &amp; graphs<br/>         Liaison for overtime scheduling<br/>         Monitor budget -- 2nd shift</p> |
|--|--|

*Methods & Tooling*

|   |   |
|---|---|
| <p>Good communicator<br/>         Good organizational skills<br/>         Understand product flow<br/>         Computer literate<br/>         Understand tooling design &amp; function<br/>         Understand calibration procedures</p> | <p>Research proposed routing changes<br/>         Instigate valid routing changes<br/>         Update current routers<br/>         Help design, build, &amp; modify tooling<br/>         Monitor diamond cutters<br/>         Monitor equipment calibration schedules</p> |
|---|---|

*Production Control*

|   |   |
|---|---|
| <p>Good communicator<br/>         Good organizational skills<br/>         Understand product flow<br/>         Familiar with PCS/DXS<br/>         Computer literate</p> | <p>PCS/DXS training<br/>         Track cycle time &amp; delinquencies (graph)<br/>         Daily hot parts meeting<br/>         Liaison for scheduling work</p> |
|---|---|

*Quality*

|  |   |
|--|---|
| <p>Good communicator<br/>         Familiar with operating procedures<br/>         Familiar with shop processes<br/>         Familiar with part testing procedures<br/>         Familiar with statistical indices</p> | <p>Interface with customers on quality issues<br/>         Monitor compliance with shop processes<br/>         Quality statistical data (6-sigma graph)<br/>         Liaison for quality updates (QOI, TQC)</p> |
|--|---|

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*Continues --->*

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**Exhibit 15 -- Continued**

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**Attributes**

**Responsibilities**

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*Safety*

Good communicator  
Safe role model  
Knowledge of requirements (OSHA)  
Trained in emergency response, first aid,  
and CPR

Housekeeping & safety audits  
Age control audits  
Chemical handling audits  
Render first aid as needed  
Monitor degreaser and solvents  
Flow Gemini Control (on 2nd shirt)

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Source: Diamond Point Turning Team

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**Exhibit 16  
Diamond Point Turning Team  
Mission & Vision Statements**

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*Mission Statement*

The mission of the Diamond Point Turning Self-Directed Work Team is to create an environment which supports and encourages self-management, versatility, innovation, involvement, and commitment in each one of its members.

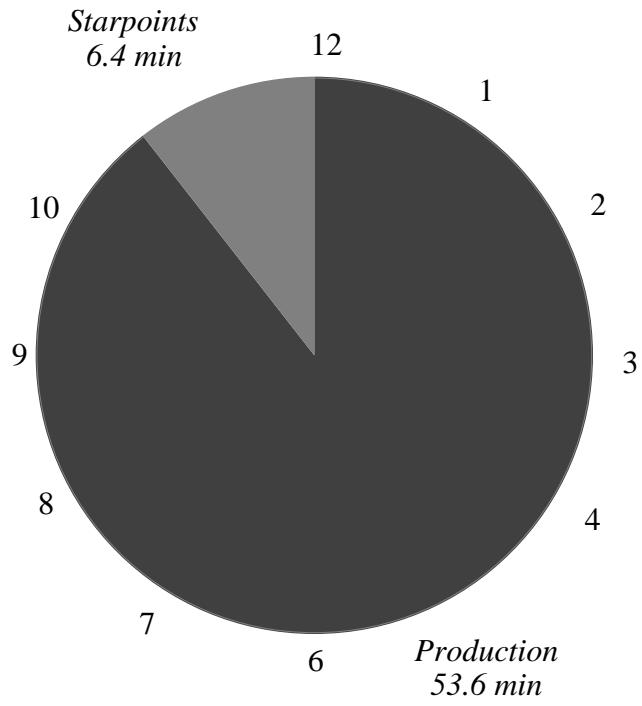
*Vision Statement*

The vision of the Diamond Point Turning Self-Directed Work Team is for the Diamond Point Turning Shop to be a world class supplier:

- Totally committed to customer requirements
  - Whose people have ownership and involvement in the work process
  - Using cross-functional teamwork to achieve customer satisfaction
  - Contributing to company profitability
- 

Source: Diamond Point Turning Team.

**Exhibit 17**  
**Diamont Point Turning Team**  
**Average Hourly Time Usage**



## **Incentive Structures**

Implementing self-directed work team brings about a wholesale change in organizational culture. Any complex organization, such as a large manufacturing company, depends on a number of key support systems -- information technology, policies and procedures, rewards and recognition programs -- to function on a daily basis. Such infrastructure evolves over a long period of time and largely reflects the company's culture and traditions. Systems, however, can take on a life of their own, and may not respond very quickly to sudden changes in the environment. As the self-directed team concept has taken root at TI DSEG, the old infrastructure has remained in place. DSEG's High Performing Organizations Development Group (HPOD) recognized the existence of a disconnect between the systems and the culture, and began considering ways of developing infrastructure to fit the new reality.

### **Job Class Consolidation**

TI DSEG has historically assigned each worker to any of more than 100 different job classifications -- production, maintenance, administrative, quality control, and so on. Within each classification, the company further grouped workers into one of several job grades (anywhere from five to eleven grades per classification). All told, DSEG maintained more than 500 different combinations of classes and grades for its employees. Naturally, pay scales depended largely on job classification and grade. Unfortunately, the classifications and job grades no longer served any useful business purpose. Worse, the excessive complexity and petty jealousies of the old classification scheme could potentially undermine the objectives of the self-directed team program.

To address these issues, HPOD set up a new initiative called Job Class Consolidation. JCC reduces the number of job classifications to just a handful, and eventually eliminates job grades altogether. For example, JCC classifies all members of

manufacturing teams under a single title -- Production Associate. As a result, the company no longer differentiates people by something meaningless like job class. Instead, the focus has shifted to the knowledge and skills each person brings to the table, and the performance of the team as a whole.

### **Alternative Reward Systems**

Rewards and recognition programs can have a dramatic impact on the behavior of managers and workers alike. The success of any new initiative, especially one so fragile as self-directed work teams, depends critically on installing effective incentives that encourage constructive behaviors and discourage destructive ones. For teaming to succeed, HPOD needed to devise an *alternative reward system* for TI DSEG. The result of this effort is the Pride and Share program.

Pride and Share combines elements of pay-for-knowledge and pay-for-performance into a dual program that creates incentives supporting a variety of objectives at a variety of organizational levels. Where job grades once determined pay scales, now the Pride and Share program will take over. HPOD is currently piloting the program in three limited work areas, including the MCB shop. The pilots involve approximately 180 people in total. At the end of a year, HPOD will fully evaluate the pilots, make revisions, and begin to spread Pride and Share to additional work areas. The design and development of the philosophy and methods will take about three years.

#### *Pride Model*

Pride, or “process for investing in development,” uses a pay-for-knowledge model to encourage individual workers to develop their technical and management skills. The purpose of the program is twofold: (1) to empower workers with the skills they will need to contribute effectively as team members, and (2) to develop the capability of every team to function without direct supervision and to manage its own operations.



Pride follows a straightforward pay-for-knowledge model. First, as we mentioned in the previous section, JCC eliminates needless distinctions between team members by folding the myriad job classes into one -- Production Associate. Second, the Pride model establishes a matrix of competencies related to regular production activities plus the new administrative and support tasks for which the team will gradually take responsibility. The Team Level -- consisting of team-specific core knowledge, general business knowledge, and basic support skills -- provides the minimum foundation of competencies necessary to certify as a Production Associate. The remainder of the matrix divides skill blocks into three advanced levels -- Support, Coordination, and Strategic. At each level, specific competencies fall within one of five categories -- Leadership & Development, Administrative, Planning, Process Improvement, and Output (technical skills). The hourly wage of an individual worker will then depend on the depth and breadth of skills and competencies that person masters through training and certification. As members of the team grow individually, and as the team itself becomes more competent and mature, it gradually absorbs additional supervisory and support functions. After a moderate period of development and growth, the team eventually evolves into a fully mature, self-directed work unit.

### *Share Program*

Share, or “shared achievement and reward,” adds a pay-for-performance component to the Pride model. Share differs from Pride on three important dimensions. First, pay scales under Pride depend on skill levels and knowledge, whereas Share pays out depending on business performance. Second, Pride determines hourly base wages, whereas Share offers periodic lump-sum bonuses. Third, Pride links wage levels to actions of individual workers, while Share’s pay-out depends on the performance of integrated work areas comprising many self-directed teams. This last distinction is by far the most important. Share creates incentives not only for individuals to work together as

teammates, but also *for teams to work together as integrated business units*. In so doing, Share tries to pick the correct optimization point. It accounts for the complex and dynamic dependencies that exist across teams, and avoids driving a wedge between teams. Finding the right optimization point takes a careful balance. Paying bonuses for individual performance often causes sub-optimization and destructive petty rivalries. Paying bonuses for performance company-wide, on the other extreme, leaves people with no understanding of the outcome or any sense of control over performance. Finding the right middle ground between these two extremes is difficult.

Share pays out a lump-sum payment to each business unit for achieving certain quarterly goals. The business unit sets the goals in terms of four key metrics -- total cost, quality, cycle time, and on-time delivery. Managers, team members, and customers negotiate with one another to determine by consensus six levels of goal attainment. The lowest level is a step above the baseline trend, and the highest level a true stretch goal requiring dramatic improvement. At the end of each quarter, the business unit calculates a weighted scoring of the four measurements, which teams track on a weekly basis, and compares the results to the previously determined levels of attainment. The Share program then pays a bonus to the business unit; the size of the pay-out depends on which level the department attained. Each person receives an equal portion of the pay-out. Business units can choose to change the weighting factors on each of the four metrics. If the unit wanted to focus on a specific problem related to, for example, defect rates, it might choose to increase the weight of the quality metric and reduce the weight of the others.

### **Teaming for Excellence Award**

The Teaming for Excellence Award, another HPOD initiative, serves two important purposes: (1) the award gives teams some added incentive to achieve higher levels of excellence in business performance; and (2) much like an internal version of the

Malcolm Baldrige Award, Teaming for Excellence provides teams with a ready-made framework within which to measure their progress in several critical areas. The selection process asks each applicant team to rate itself in each of five categories -- planning and strategy, customer and supplier relationships, process improvement, resource management, and team development. The application consists of a questionnaire asking seventy questions. Teams check off yes/no responses, and provide data to back up their answers. HPOD judges the applications, and invites teams scoring better than 50 points out of the possible 70 to participate in interviews. The group then awards Gold, Silver, and Bronze prizes to teams showing strength in four of the five categories. In addition, teams can earn awards for excellence in a single category.

Teaming for Excellence is currently in its third year. The Diamond Point Turning Team received the Bronze award in the first year, and Gold in the second. Although teams receive no monetary reward, the Gold winner attends a banquet dinner with the company president and other managers. Gold team members may also attend a one-day seminar of the team's choice. All award recipients receive individual trophies, plus a team plaque.

## Conclusion

The SF/BF and DPT teams have enjoyed great success in transforming from a traditional organizational structure to the self-directed work team concept. Nevertheless, both teams have certainly had their share of ups and downs along the way, and the work is by no means complete. Moreover, not all teams at TI DSEG have achieved quite the same level of maturity as SF/BF and DPT -- at least not yet. DSEG has a vision of where the organization is going, and the teams are working toward realizing that vision. In fact, successful lean producers understand that their work is never done. Continuous improvement and workforce flexibility enable companies to respond quickly as markets change quickly. As a result, the hallmark of lean production is *permanent change*.

The next two sections will present, in concluding this paper, some of the key success factors that helped the SF/BF and DPT teams transition to the self-directed model, and some of the obstacles they had to overcome along the way. Finally, the last section will offer a recommendation regarding performance measurement.

### **Key Success Factors**

Self-directed work teams offer a number of advantages to manufacturing companies. Success, however, is by no means guaranteed. Transformation from a traditional hierarchical organization to self-directed work teams depends on many critical success factors. The shop floor workers and team facilitators at TI DSEG have identified three particularly important factors from their own experience: (1) management commitment, (2) highly motivated workers, and (3) wide open communication.

## **Management Commitment**

Self-directed work teams cannot happen unless upper- and middle-level managers support the concept fully. First, senior managers set out the vision and provide the leadership that the organization needs. The direct involvement of the CEO and the other top executives sends a clear message to everyone that the success of the team initiative is of paramount importance to the organization. Second, the fledgling teams need the coordination and support of good middle managers to get started and to keep going, especially in the face of temporary setbacks during the initial phase-in. “Management supported us, they really did. We could come to them with anything, and they were there for us,” recalls one member of the SF/BF team. “If something didn’t work out the way we planned, they’d come in and support us.” Another worker describes how the former supervisor helped the team out: “She got us on the right track. She figured out the target times, who needed to do what, and distributed the work load evenly.”

After the teams are up and running, they still need management to support their ideas for improvements. “If we go to [the department manager] with a big proposal, and show him we need it, he’ll look at it, and if it’s good for everybody, we’ll get it,” says a member of DPT. “Sometimes, of course, he does turn us down.” The key point is not that the manager simply approves every idea, but rather that he *listens* carefully and considers all ideas fully.

## **Highly Motivated Workers**

Management commitment is important. But it is the team members themselves who make the teams a reality, and that takes a lot of hard work. The program can only succeed with a highly motivated group of workers. Setting up a new team can require long hours each day, involves a lot of training, and can lead to a certain amount of conflict and stress. The SF/BF and DPT teams owe their success in part to the high levels of motivation of the team members. “Our team just wanted it to work. It helped that

everyone was dedicated to getting it done. We did whatever it took -- worked ten hour days, came in on Saturdays -- we wanted to make it work,” said one SF/BF team member. Another worker agreed: “We were the pilot team -- we were determined to make it work . . . It was a challenge. When you’re handed a challenge, you want to make it.” One DPT member described something similar: “What really holds the team together is we got one heck of a group of good conscientious people.”

### **Wide Open Communication**

The success of self-directed work teams depends critically on open, direct, and honest communication, not only among members of a given team, but also among teams within the same department, and between teams and department managers. Some of the reasons for the importance of open communication include its role in coordinating the operating activities of inter-dependent work teams, and the need to alert everyone when specific problems arise. “We communicate so much that if there’s a problem, we know it,” says one member of the SF/BF team. Workers also need to receive feedback on their performance. Says one team facilitator, “I tell ’em all day long how they’re doing -- good or bad. They don’t wonder how they’re doing at the end of six months.” Most important, openness undermines the formation of bad blood between people whenever conflicts arise, and conflicts will always arise. “People do not hold grudges -- they got something to say, they say it,” explains a shop floor worker.

### **Obstacles or Barriers**

Any company attempting to initiate self-directed work teams cannot underestimate the importance of nurturing these success factors. Nevertheless, a number of obstacles or barriers can potentially block the path of even the most carefully planned

implementation plan. These obstacles include excessive workload and resistance to change.

### **Excessive Workload**

The SF/BF team piloted the self-directed team program for the MCB shop. The team was understaffed at the beginning. Management expected eight hours of production work from each worker, plus completion of the needed training classes. “They supported us, but they didn’t really understand what we had to go through until we explained it to them,” recalled one worker. Another agreed, “Trying to keep up with production and go to classes all the time, that was the biggest frustration we had. We survived, it doesn’t seem like nothing now.” Management explained the team process to the SF/BF team, but left the rest of MCB in the dark for several months. The team members initially worked twelve hours-a-day to keep up with the workload, and management allowed them to take as much overtime as needed. Some of the other workers became jealous of all the overtime they were taking. “You still have to get the product out so it’s hard to find the time for all the other stuff.”

The Diamond Point Turning Team also had some difficulty adjusting to the workload initially. “It was a whole new way of life. It was difficult to make the transition, to do your job and all the extra stuff now that goes along with it,” said one team member. The team adjusted quickly, however, and found some relief in better cooperation. “We can tell who’s overloaded. All you gotta do is say in our meeting you’re overloaded and someone will jump in to help -- it works real well. You gotta spread the load.”

### **Resistance to change**

People always find change inherently threatening or uncomfortable; as a result, people at all levels of the company will throw obstacles in the way of organizational change. Shop floor workers resist moving to new jobs. “I didn’t want to do flow line,”

remembers one member of the SF/BF team. “I couldn’t see myself doing flow line work, but now I do it.” This obstacle typically appears early in the implementation phase. The best remedy involves offering strong management support to the teams, and providing adequate training to allow workers to change jobs with ease.

Once teams begin redesigning the production process, they face a whole new round of hurdles. “Why do you want to change what you’ve been doing for 10 years?” asks one worker. He answers his own question, “Just ’cause we’ve done it for 10 years doesn’t make it right.” This barrier is a little more difficult to surmount. Part of the solution involves strong leadership and changing the company culture from accepting business-as-usual to expecting continuous improvement. Another part of the solution lies with the company’s incentive structures, both formal and informal. Devising effective pay-for-performance and pay-for-knowledge systems, offering high-profile awards, and emphasizing the right performance metrics can all have a dramatic impact on the willingness of people to participate in improvement activities.

Supervisors, perhaps more than the team members themselves, feel highly threatened facing the prospect of self-directed work teams. “When a manager or supervisor resists empowering the workers, it becomes almost impossible to get it done,” asserts a team facilitator. Managers and supervisors have a great deal invested in maintaining the status quo. Often, they owe their positions of power and authority to their ability to excel within the very organizational model that self-directed work teams aim to overthrow -- traditional corporate hierarchy. Moreover, to the extent that they perceive a threat to their own power and influence, they will find ways to undermine and destroy the source of that threat. In the case of self-directed work teams, supervisors who fear losing their influence -- or worse, their jobs -- may quickly transform into wolves dressed in sheep’s clothing. While openly espousing the principles of empowerment and



participation, they covertly do everything in their power to torpedo all attempts at actual implementation.

The wolves, however, cannot hide forever. If senior management fully commits to the success of organizational change, resistive supervisors and middle managers will either leave the company on their own initiative, or risk losing their jobs. Supervisors who embrace the team concept, on the other hand, and who can adapt to a new and different role, will often become excellent team facilitators or coordinators. DPT's experience illustrates this point quite well.

Before DSEG adopted self-directed work teams, DPT had three supervisors. As the team began to take on administrative responsibilities, DPT lost two of the supervisors to attrition, while the third became a team facilitator. Some of the team members suggested that this particular supervisor survived the transition because of his willingness to embrace organizational change and to adapt to the new role that facilitator represented. "We couldn't have a better facilitator," said one worker. "He's not at all threatened by anybody getting credit for anything." Another machinist called the facilitator "a hands-off kind-of-guy. He's an ideal facilitator. [He] didn't have any trouble letting go of his authority." The facilitator described his new role as follows:

"I realized these guys knew what they were doing. They don't need me to tell them what to do. If I had to carry a big stick, I would -- but I don't have to.

"They've taken over a lot of my tasks. I feel like I'm a resource for them more than anything. Maybe I need to give them a suggestion but not tell them what to do.

"I always try to give them the credit. I don't try to ride their coattails. When they do peer reviews, I think they're harder on each other than I am. We have a really good working relationship -- we understand each other.

"I had some apprehension [at first]. But this is something we wanted, something that will help them. We'll just make the most of it."

A good facilitator strikes a careful balance between maintaining excessive control over the team versus allowing the team to take on too much responsibility too soon. “You’ve got to have [a supervisor] willing to turn you loose,” says one DPT member. “If he doesn’t want it to work, there’s just no way. We’ve been fortunate to have that. He’s there, but he’s not there. They’ve got to let you do it or it’s just not going to work.” Facilitators do not dominate their teams, nor do they simply walk away and leave the workers to fend completely for themselves.

### **Lessons Learned**

Lean production has revolutionized the way managers and workers think about manufacturing activities. Many companies in the US and Europe are attempting to adopt the principles of lean production -- focusing on customer needs, relentlessly eliminating wasted resources, continuously improving the process, and empowering shop floor workers to participate in production decisions. Self-directed work teams offer an excellent avenue by which companies can transform from a traditional mass production environment to lean production. The self-directed team concept shares several important principles with lean production teams -- teamwork, participation, flexibility, empowerment, and cooperation. Self-directed teams, however, broaden the concept of participation to include not only production tasks, but also the administrative and support activities that traditionally fall under the exclusive purview of management or engineering.

Texas Instrument Defense Systems & Electronics Group (TI DSEG) has developed a highly successful program of self-directed work teams. This thesis explored the implementation and organization of DSEG’s team initiative by presenting a case study of two particular teams -- the Switch Filter/Beam Former Team and the Diamond Point Turning Team. Both teams have achieved a high level of maturity and enjoyed

great success as self-directed work teams; as a result, their collective experience offers many valuable lessons and insights for other companies wishing to organize their own self-directed teams. These lessons include the following:

- ***Continuous Improvement:*** Managers and workers must never lose sight of the fundamental purpose of adopting self-directed work teams -- to continuously improve the quality of manufacturing and business processes. Eliminating defects, reducing costs, improving on-time delivery performance, promoting safety, and providing stimulating work not only add value for the customer and reward workers with greater job satisfaction, but they also create wealth for the shareholders.
- ***Management Commitment:*** Implementing self-directed work teams is a difficult and painful process. The success or failure of the initiative may well depend on the degree of management commitment. Senior managers need to provide the vision and active leadership, and middle managers need to buy-in to the concept fully, to make the transition happen.
- ***Motivated Workers:*** Likewise, the active participation of team members demands a lot of hard work and persistence. Periodic setbacks will inevitably hold up the transition, and only highly motivated workers will show the persistence needed to stay on track.
- ***Overcoming Resistance to Change:*** Organizational change by its very nature threatens the established order, and creates fear and discomfort among workers and managers alike. The natural reaction of entrenched interests and those who fear change is to resist. Proponents of change must keep a constant vigil against subterfuge aimed at derailing the team initiative.
- ***Appropriate Incentives:*** One of the most effective means of promoting all of these efforts is to develop incentive structures that reward the right behaviors and undermine resistance to change. Pay-for-knowledge, pay-for-performance, excellence awards, business performance scorecards, job performance evaluations -- any or all of these programs can provide strong incentives that support the self-directed team concept.

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