Pratt & Whitney

Homogenous Metals, Inc. (HMI) Case Study:

A Case Study of the UTC ACE Operating System

George Roth
groth@mit.edu

Phech Colatat
pcolatat@mit.edu

Lean Advancement Initiative
Massachusetts Institute of Technology
292 Main Street – Bldg E38 Room 624
Cambridge, MA 02142

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Massachusetts Institute of Technology
Cambridge, MA 02139

Lean Enterprise Change Research Case Study Series

This case study provides an example of managerial and organizational changes that have accumulated into significant performance improvements. It is one of a series of case studies undertaken by researchers at the Lean Advancement Initiative (LAI) at the Massachusetts Institute of Technology. LAI focuses on developing, testing and studying the application of lean and other management principles in the aerospace industry. LAI's sponsors, and their improvement initiatives, have created a natural laboratory for studying lean enterprise efforts. The case studies in this series report on effective, interesting and novel applications of lean methodologies at enterprise levels in LAI-sponsoring and other organizations.

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Table of Contents

Introduction

Homogenous Metals Incorporated (HMI) is a pioneer in adopting and demonstrating value from United Technology Corporation's (UTC's) ACE operating system. ACE stands for Achieving Competitive Excellence. It is described by UTC's leaders as its "business operating system." In the same way that a computer's operating system gives instructions to the computer's operations, ACE provides the basis for how the UTC Corporation seeks to operate and eliminate waste across all of its processes. Introduced by Pratt & Whitney in 1996 and throughout UTC in 1998, ACE was originally conceived of as a core set of methods in an overall improvement program. Since that time it has evolved into the operating system meant to impact all aspects of running a business.

HMI, a wholly-owned Pratt & Whitney subsidiary, was among the first ACE Gold *cells* in 2001 and the first ACE Gold *sites* in 2003. Not only was HMI among the first organizations in UTC to achieve these ACE certifications, which require achieving and sustaining high operational performance *and* demonstrating the capabilities for ongoing improvement, but it was recertified as an ACE Gold site in April 2005 and May 2006. Based on its accomplishments, other facilities in Pratt & Whitney and UTC have sought to learn from and emulated HMI's results. It has hosted many visitors seeking to learn more about applying ACE and to benchmark themselves against HMI.

Accomplishments

HMI has received attention because of the changes it has made and sustained. Guided by ACE, it remained steadfast in its improvement activities through three general manager successions. The cumulative results of these continuous activities are more than incremental change. They have resulted in dramatic improvements across a broad range of business measures. From 1997 to 2006, inventory turns improved 81%, cycle time decreased by 75%, productivity increased by 32%, volume increased 24%, and HMI's bottom line (earnings before interest and taxes), increased by 28%. These figures represent a decade of continuous improvement. With HMI's process improvements, its managers have consistently collected and monitors detailed metrics since 2001. These business metrics, normalized to 2001 performance to protect the confidential information of the wholly owned Pratt & Whitney subsidiary, are shown graphically in Figure 1. Examining the information in this graph tells two different stories.

The first story is what we studied and report on this case: HMI's efforts and their results through 2006. We conducted interviews and collected data in May and June of 2006. Up through 2006, the graph confirms HMI's steady and consistent improvement progress. The exception is the drop in 2002 due to volume declines that HMI and others in aerospace experienced in the wake of 9/11/2001. What was experienced after 9/11 played out in 2002, and consistent improvements are shown through 2005. These are the benefits of ACE Gold, which HMI first achieved in terms of cells in 2001, and as a site in August 2003, with ACE Gold re-certification in April 2005 and May 2006. From 2002 to 2007, HMI's productivity and earnings grew at an average compound annual rate of 8.5% and 5.5% respectively, and its manufacturing cycle time decreased 75% while its volumes grew at a 5.9% compound annual rate. ACE focused on value the customer – customer satisfaction increased 33%, on time delivery went from 81% to 100% and stayed at 100% for two years, no significant customer quality escapes for 8 years, and the

cost of poor quality decreased 90%. These results are not at the expense of employees safety or satisfaction – EHS performance increased by a factor of 10, with the HMI logging 1,793,741 hours without a loss time injury, 3 of its cells going over five years without a recordable incident, having the highest employee participation rate across Pratt & Whitney's US operations, and a 73% favorability score.

The second story is what the figures show beginning in 2006, beyond the time of our study. While we continued to monitor HMI's performance, but can not report these changes in detail. What occurred in 2007, shown by the drop in HMI's EBIT, was a 70% increase in material and energy costs (oil, nickel, and other metals increased dramatically). This second story, which continued into 2008 and 2009, when economic conditions dropped dramatically, is less one of continuous improvement, but an adjustment and restructuring based on different market settings. This second story continues to play itself out now, and we report in the epilogue on indicators of HMI's progress in adapting to these new circumstances.
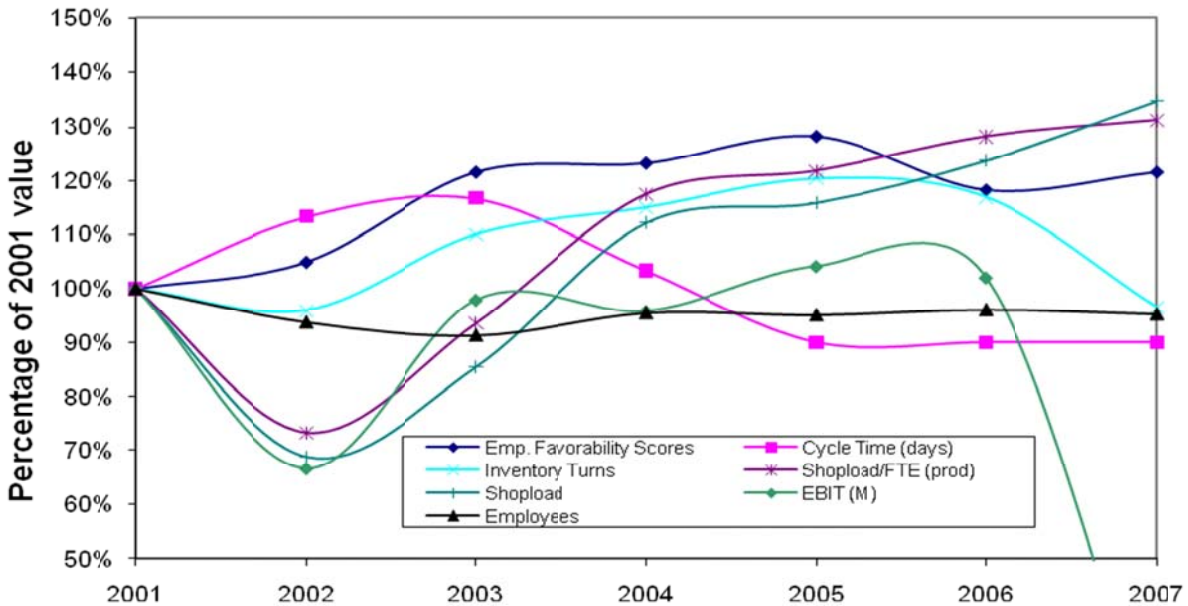
Figure 1 HMI's Historical Performance, 2001-2007
(Normalized to 2001 = 100%)

Time Frame & Methods

This case study was conducted in the first half of 2007. HMI was selected for two reasons; first, to examine ACE in a production environment, and second, with HMI's longstanding success in maintaining ACE Gold status, to examine the challenges in sustaining improvements at high levels of performance. This case study describes HMI's adoption of ACE tools and methods in 1996, improvement to "world class performance" levels in 2003, and then efforts continuing through 2006 to maintain improvement capabilities and sustain performance records.

In conducting this case study, we made visits in March and June of 2007 to Clayville, New York. During those visits we interviewed people, toured the plant, observed workers in their activities,

and collected data. We developed a time line of events and activities, used this in interviews to aid respondents' memories of what happened when, and to ask them how they associated improvement and change activities with overall performance changes. This time line provided a historical record of HMI's changes, and helps illustrate what company and ACE leaders were active in various periods (see Figure 2). People that had been part of changes at HMI but had since left were contacted and interviewed by phone or in person, depending on their new location. We interviewed twenty people in total, from front line workers to supervisors to managers, including three of HMI's general managers. Several people were interviewed multiple times. We followed up on questions with phone calls and email messages. Where we used quotes they have been reviewed and approved by the people that made them and HMI and UTC personnel reviewed the document as a whole.

After we had completed interviews and drafted this case study in the fall of 2007 HMI experienced several performance lapses. There was one loss time injury and four safety incidents, material cost and inventory increases, and delivery misses. Raw Material cost jumped 75% in 2007, driving a domino effect throughout the value stream including HMI. The resulting EBIT and inventory turn declines affected year-end 2007 metrics. ACE Gold requires a 12 month world-class performance, which meant that HMI decertified itself to ACE Silver. The ACE Gold recertification assessment planned for the summer of 2008 was rescheduled based on declining economic conditions resulting in a 30% drop in shop load in the 3rd and 4th quarters. Pratt & Whiney invested $3M in facility upgrades in 2008. Significant buffer stock was manufactured in the 1st and 2nd quarter to ensure customer requirements were maintained. In December 2008, the recertification was again postponed because of the impact of the market and economic conditions that began that summer. Many efforts were underway at HMI to improve and recover to its previous performance levels. While this case is focused on what HMI did and achieved from 1996 to 2006, the recent declines and recovery efforts are addressed in an epilogue.
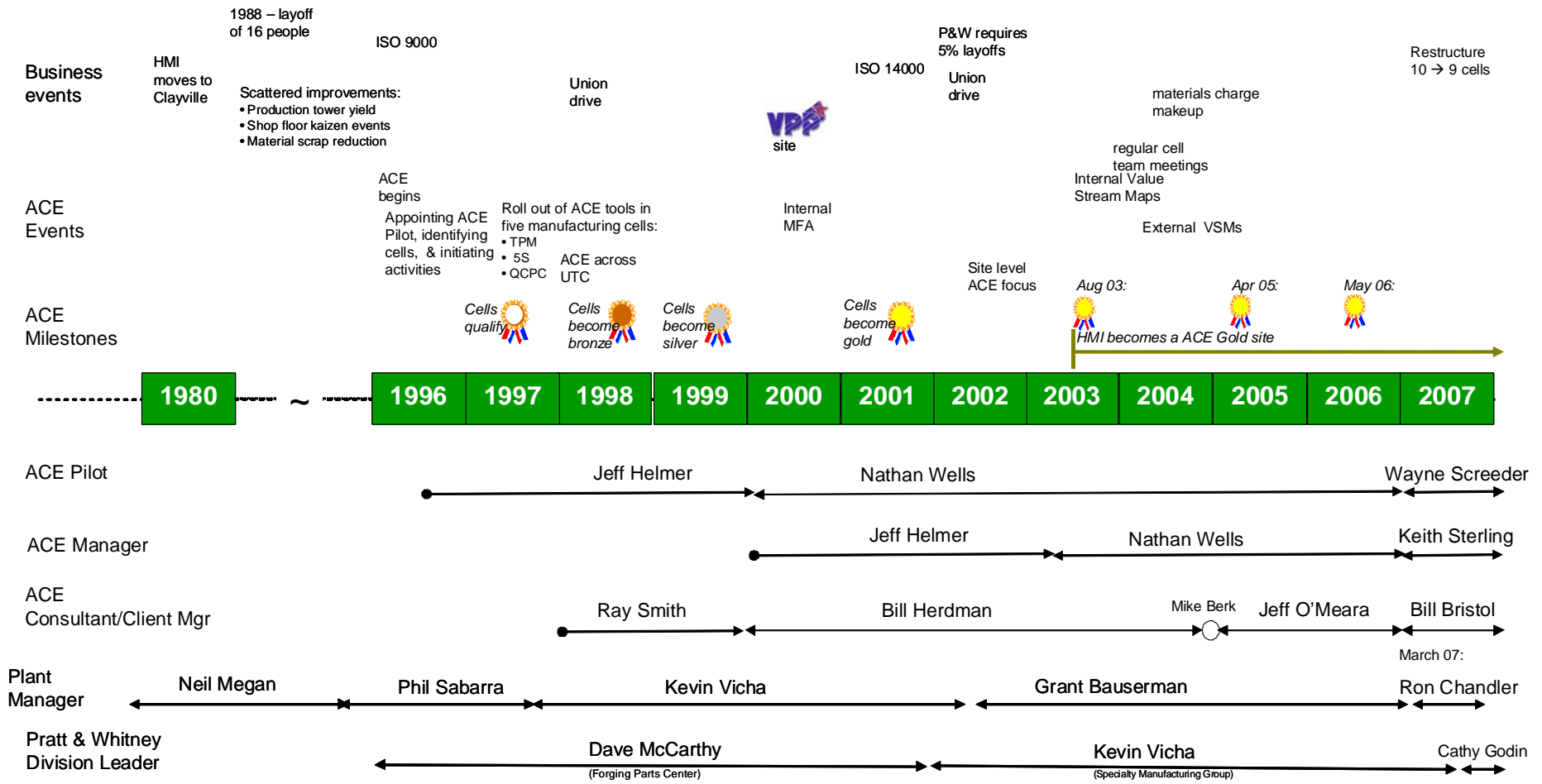
Figure 2 Time line of HMI's events, ACE milestones, and leaders

Case Study Organization

HMI's changes are described by five themes: first, to set a context, we describe HMI's history in terms of its products, operations, and culture in a background section. HMI's founder and the characteristics of its specialized metals set the stage for adopting ACE. Second, we describe leadership and its role in the adoption of ACE. HMI's general managers and the plant management staff set strategy and directly lead improvement efforts. Third, we focus on the dynamics of change. The local organization culture supported ACE tool use. The facility was divided into cells, each with a cell leader responsible for monitoring and reporting performance and identifying improvement projects. We describe important ACE events, which created the improvements that accumulated into overall performance gains. Fourth, progress was not along a straight path, and we focus issues of reaching a plateau and the reception of ACE by workers. There were setbacks that required retrenchment, but as more people become involved and people become more involved, improvements were sustained. The fifth theme reports on current and future challenges. After nearly a decade of success, issues have surfaced that present ongoing challenge, which will need to be addressed to enable continued progress. An epilogue describes recent events, which resulted in decertifying HMI from ACE Gold to ACE Silver and postponing Gold assessments.

1 Background

Products

HMI is a metal foundry that produces super alloy billets and specialized powders that are used in jet engines. Billets, made of a material called "IN100," require a precise mix of nickel-based alloys. HMI ships these billets to Pratt & Whitney's Georgia Forging operation (located in Columbus, Georgia), where they are pressed and prepared for precision machining. These parts then go to Pratt & Whitney's Module Center in Connecticut where they are machined into the parts that are in the hottest, most physically demanding jet engine sections.

The billets that HMI sends to Georgia Forging come from powdered metal mixtures that have been extruded into alloy logs under high temperatures and pressures. These powdered metals made from precise mixtures of metal alloys at maximum particulate sizes. The alloy mixtures are packed under vacuum into extrusion cans that are shipped to Wyman Gordon in Houston, Texas. Wyman Gordon's press extrudes the cans into alloy logs, and these logs are then sent back to HMI for machining into the billets that are shipped to Georgia Forging. HMI has become the sole source provider of IN100 billets for Pratt & Whitney's military and commercial jet engines. In addition to making billets, HMI also produces powdered metal mixtures that are directly used as plasma sprays. These powdered metals are sprayed onto parts, usually those in the high temperature, caustic sections of turbine engines, to repair or mitigate wear.

HMI has three different production processes – a 60 foot tall argon gas-filled production atomization tower, a pilot plant atomization tower, and a rotary atomizer. Each atomization processes produces powdered metals in different quantities and particulate sizes. The powders are screened and blended to attain mixes with specific particulate sizes and alloy percentages. The screened powders are packaged in either extrusion cans for making IN100 billets or bottled for direct use as powdered metal in plasma sprays. As part of its improvement efforts, managers

organized all of HMI's activities into ten smaller units, which they called cells (see Table 1). The people in each cell used ACE tools and methods to organize, document, measure and improve their operations. For details on HMI's production processes, see Appendix A: HMI's Market and Product Value Streams.

Manufacturing Cells	*Support Cells*	*Business Process Cell*
CELL 1 Main Production Tower -Coil Room -Head & Tube Room	**CELL 6 MTS** -Maintenance -Electricians -Facilities -Tool Room	**CELL 10** - Financial - Administrative - Strategy - Technical Support - Customer Satisfaction - Overall Business Requirements
CELL 2 Main Screening		

**CELL 3 Machining &
       Can Fabrication**
-Weld Shop
	CELL 7 Materials
	-Charge Makeup &
	  Scrap Center	

CELL 4 Rotary Atomization Furnace	**CELL 8 Quality Control Labs** -Quality Control & Chem Lab	
CELL 5 Pilot Plant Atomization & Screening Room	**CELL 9 Non-Destructive Test** -Sonic & Etch	

Table 1 HMI's Cell Organization[1]

Company History

In what is an archetypal inventor-turned-entrepreneur story, Joseph Wentzell founded HMI based on a process he developed for producing super alloy metals in 1965. HMI's business with Pratt & Whitney started in 1970. It increased rapidly, and in 1975 Pratt & Whitney acquired HMI. HMI supplied Pratt & Whitney with IN100 alloy billets, which were used to make high components on the F100 engine (used in F-15 and F-16 fighter jets). Between 1975 and 1996, HMI operated independently, competitively bidding for Pratt & Whitney's contracts. HMI regularly won, based on price and performance, the maximum 80% award of IN100 contracts. The mid-1990s defense industry downturn required consolidation. Pratt & Whitney no longer had adequate volume requirements for two IN1000 suppliers, and it chose HMI as its sole source supplier. Thereafter, government contracting regulations allowed only fixed markups from wholly-owned subsidiaries. HMI began selling IN100 at a fixed price, which included a margin above its costs, to Pratt & Whitney.

While the sole source relationship solidified HMI's position with Pratt & Whitney, it also created an identity crisis. As with all its suppliers, Pratt & Whitney required year-to-year price decreases supported by productivity and quality improvements. It wanted HMI to adopt its methods, in particular, the ACE program. Pratt & Whitney treated HMI as a supplier and as an internal operation. For HMI's managers this situation created identity questions – where they integral to Pratt & Whitney or a supplier with autonomy and independence? These issues surface in HMI's powdered metal plasma business.

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[1] At the end of 2006 HMI restructured and merged Cell 8 and Cell 9, going from 10 to 9 overall cells.

The powdered metal plasma business, which represents about 20% of HMI's volume, is operated as a for profit line of business. Prices are set for plasma products based on market conditions. The majority of HMI's powdered metal plasmas are sold to Pratt & Whitney companies, but HMI is not a sole source supplier. HMI has other customers, and there are other companies that provide Pratt & Whitney powdered metal plasmas. HMI's ability to grow its plasma business is secondary by Pratt & Whitney's expectations for core HMI's IN100 and ME16 powder supply. For example, HMI must use the 60 foot production atomization tower exclusively for IN100 and ME16. It can not produce plasma in the larger batch sizes that would make it more price competitive than what is possible in its smaller rotary or pilot atomization production facilities. Strategic vision for HMI is IN100 and ME16, the 60 foot production tower is only used for IN100 and ME16 to eliminate any risk or cross contamination, thus limited the tower ability to produce alternative powders that might expand or grow the business.

Organization Culture

HMI's super alloy powdered metal production was developed by HMI's founder, Joseph Wentzell. Before HMI moved into its current Clayville, New York location in 1980, Wentzell ran operated in a number of other facilities. Production began in 1968, in a rented warehouse in Chadwicks, New York. Shortly after, HMI moved to a facility in Herkimer, New York, where it operated until 1980. The Clayville facility was initially a knitting mill, and had more recently housed a forging and tool company. Following it 1980 move, HMI has made regular upgrades to its Clayville plant and equipment. It added rotary atomization equipment and a pilot atomization plant to augment the 60-foot atomization tower. The workforce grew from a few people in 1969 to about 110 people by the mid-1990s, where it has leveled off. Much of the workforce that grew HMI's business throughout the 70s and 80s is still working there today.

Clayville is located more than 200 miles from Pratt & Whitney's headquarters and main production facilities in East Hartford Connecticut. Its remote location has enabled HMI to retain a unique and strong culture based on its history and founding. According to former general manager Grant Bauserman, it is a "small shop and very family-oriented." An example of the family-orientation is the creation of HMI's cafeteria. Clayville is a small, rural town with no nearby restaurants. The thirty-minute lunch period was not enough time for people to go out for lunch. With one hundred employees, HMI did not have enough people to economically justify a cafeteria. Nonetheless, HMI built a cafeteria and hired a cook to make a daily luncheon meal. Other examples of HMI care for its people includes an employee gym, a health and wellness program, organizing Weight Watchers programs, and supporting local schools and charities.

Many employees said HMI's policies contributed to a team-oriented environment. In a facility where employees view their business as captive to one customer, people do whatever is necessary to please that customer. For example, people in different areas of the plant work on teams that develop and implement improvements. One person we interviewed contrasted HMI with other Pratt & Whitney facilities he visited:

> *At other companies, in general, there is not a tendency of getting things done. There are union-promoted production habits, an atmosphere of just working my hours and going home, and not doing what needs to be done, fixed or improved.*

While a low turnover and distance from headquarters enables a local, family-oriented culture, it also limits people's opportunities. One worker noted, "As small as HMI is, there are not a lot of opportunities for advancement." Opportunities are almost exclusively from internal promotions, and leadership positions rarely become available. One of the few people who started at and then left HMI, its first ACE Pilot, Jeff Helmer, recounted his HMI career as follows.

> *I started at HMI in 1979, right out of high school on the ground floor at $3.66 per hour. I progressed up through the ranks to a management supervisory position and maintained that position from 1981 to 1996. In 1996, as the first ACE Pilot, HMI had the opportunity to learn about the ACE tools and apply them directly to our business. It was ingrained in out culture to embrace the ACE concepts and we became one of the first ACE Gold sites within UTC. With HMI being a wholly owned subsidiary with approximately 135 employees, there were not a lot of opportunities for movement within, which is one of the reasons I left. I had reached a professional plateau. I wanted to bring what I learned about ACE outside of HMI to other UTC divisions. I am the only employee hired here to leave HMI and work at another UTC site.*

Employees are encouraged to participate in the UTC Educational Assistance Program which pays for 100% of tuition and books for employees to advance their education and better position themselves for advancement within UTC.

2 Leaders' Roles in Introducing ACE

What companies need to go through to make and sustain process improvement efforts generally requires a change in "organizational culture." Organizational culture[2] is based on what people have learned and accepted as their company's way of operating. A change in culture associated with lean and continuous improvement is a shift from established behaviors and views. One of those shifts is from the notion that managers make decisions and workers follow their direction. Instead, managers and workers learn and use tools to collect data, examine operations, and together propose, make, and monitor changes. Although culture is shared among all organizational members, it is leaders' behaviors that creates and changes culture. Leaders' roles are important in process improvement efforts because it is often the leaders that must relinquish decision-making authority to engage workers in proposing, making, and monitoring improvements.

The Early Days of HMI: 1968-1996

HMI's founder, Joseph Wentzell, retired in 1981. Since then, HMI has had five general managers. The first was Neil Megan, general manager from 1981 to 1996. Megan is best remembered for instilling a work culture of order and cleanliness. Between 1996 and 1997, Phil Sabarra, previously the financial controller working under Neil Megan, served as general manager. Sabarra was the first HMI general manager to be involved in ACE. At the end of 1997, Kevin Vicha, a corporate Pratt & Whitney manager, became HMI's third general manager. The general manager had always been someone local who was promoted from within the plant.

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[2] A culture is defined as a pattern of shared basic assumptions that an organization's members learned as they solved their problems, which worked well enough to be considered valid, and, therefore, are taught to new members as the correct way to perceive, think and feel (Schein 1992:12).

With Vicha's arrival, leadership shifted from a local leader to a selected corporate manager. Vicha was followed by two other corporate managers: Grant Bauserman in 2002 and most recently, Ron Chandler, who started in the spring of 2007.

When people described HMI's "culture," they often referred to its long time general manager, Neil Megan. Megan had a military background; he insisted in order, discipline, and cleanliness. While the production facilitates in Herkimer were something from "the stone ages;" Megan had a vision that combined cleanliness and efficiency in producing the super alloy products. He was said to walk around with white gloves to see if there was dust. If he found it, people would be asked clean the area. He used slow periods and plant shutdowns to have production workers make facility improvements. Megan, as a worker commented, "Led by example, and showed people that they could make a difference." As such, he set a tone for other general manager and for worker responses to leadership initiatives. Under Megan, they cleaned, straightened, and painted plant areas, much like what the ACE 5S program later required.[3] To Megan, cleanliness reflected on a facility's production abilities. One person joked that you could eat off the floor at HMI. By the standards of many factories, that statement might not be surprising, but for a furnace and metallurgy operation housed in a 100-year old brick mill building, its cleanliness and order is exemplary. This culture, people's orientation, and HMI's historical practices, were a foundation for ACE efforts.

The Introduction of ACE: 1996

Pratt & Whitney began to promote ACE in 1996. While in position as General Manager, Sabarra was very supportive. People reported that his position was supportive, noting that he said, "HMI *had* to do this," and that he wanted to improve processes and efficiencies. Sabarra selected Jeff Helmer, then an operator on the atomization production tower, to become HMI's ACE Pilot. If people had sound improvement proposals, Sabarra had the reputation for finding needed financing. As a long time HMI employee, he was friends with everyone and maintained a sense of respect from peers at the working level.

ACE was HMI's first formal plant-wide program for continuous process improvement. Previous efforts were driven more as isolated projects organized by HMI's small, engineering staff. The acceptance of ACE was aided by several factors –Pratt & Whitney training for the ACE Pilot, and a general manager oriented to improvement, standard work, and workplace organization who supported the ACE Pilot. . Initial ACE activities, such as working with machine operators to implement Total Productive Maintenance (TPM) or Quality Clinic Process Charts (QCPC), resulted in improvements and found support from the workforce. Through the efforts of the newly trained ACE Pilot teaching and helping people, they implemented improvement practices and achieved ACE qualifying status in HMI's production cells.

A New General Manager: 1996-2002

While Sabarra was supportive of ACE, he did not actively "push" it. The leadership drive changed when Kevin Vicha became the new general manager. Vicha came from an overseas assignment, having just finished a three year assignment in Toulouse, France as Pratt &

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[3] For consistency in this case, we use the term 5S throughout. HMI was part of an original Pratt & Whitney 5S program, with became the "new 5S" with Mr. Ito's addition of human factors when ACE went UTC wide, and later was often referred to as a 6S program with the addition of safety procedures.

Whitney's representative to Airbus Industries. He understood customer requirements and brought that understanding with him as he became the HMI general manager.

The arrival of a new general manager from outside HMI created fear and uncertainty. Several employees led efforts to protect themselves and consider unionization. Specialty Metals, a company located only ten miles away in New Hartford, N.Y., was unionized and its union leaders attempted to persuade HMI employees join its ranks. Their propositions were appealing. HMI was remote, located far from Pratt & Whitney in Connecticut. Many local manufacturing firms had closed and those jobs had moved to other countries. Some workers felt they were underpaid, and others worried that without banding together, HMI could be closed. Adding to their fears was the fact that Pratt & Whitney sent in a corporate man, rather than promoting someone from within HMI.

Leadership for ACE

When Vicha came to HMI, he heard these concerns as, "Where is this business going? What are we doing? Are they going to shut us down? Why a new [outside] general manager?" He saw an organization made up of people that cared and wanted to "truly" do the right thing. Vicha described his efforts to calm employees as follows:

> *A lot of it was employee communication, employee engagement. The hardest part is getting leaders to believe in the leadership to make it happen... I found so much of it was listening to employees and getting their ideas. There seemed to be a backlog of ideas that for three years didn't get support. Not to say the previous management wasn't doing great things, but employees felt like they had not had enough of a voice to effect change.*

Vicha had no experience with ACE or other continuous improvement methods; "I was not real strong in the details of each of these tools; I learned a lot from the employees at HMI." He spent time on the shop floor, with an orientation to getting operations people involved. Vicha commissioned a market analysis. This analysis found that HMI was one of three companies in the world that produced these specialty metal alloys, and of the three, HMI was by far the largest. He created and shared his strategy as a "roadmap" for HMI. An element of that roadmap was the need to increase revenue through producing in greater volume. They developed an approach for increasing HMI's revenue by lengthening the extruded logs made in Texas' Wyman-Gordon Forgings. Receiving longer logs, however, required changes at HMI. Vicha described those discussions as follows.

> *Engineering came up with some plans to do it. They said, 'Here's what we see for the new layout of the machine shop.' I said, 'Okay, what do the guys on the shop floor think of this plan?' Well, they hadn't gone through that with them yet. How can that be? In that meeting, we took the drawing, walked down to the shop floor, and laid it out right in front of that large machine saw that cuts the logs. We gathered all the employees and said, 'this is what we are thinking, what do you think?' We went back out on the floor four to five more times before we finalized it.*
>
> *I think that was a step change in employee support of change. They put forth their ideas, right there, on the spot, and then six months later, the design was theirs. It was in place and working. And, it was very different from Engineering had come up with. They felt a*

part of the change. Their ideas were listened to. That is a lot of what I did at HMI. I listen to their ideas and incorporate them. I was going into that business not knowing powder metallurgy, not having detailed knowledge of ACE tools. It was a learning experience for me. But, I went in completely committed to ACE and never wavered from that.

Leading by learning and teaching

For Vicha, listening to employees was about more than engaging the workforce; He needed to learn from them the technical aspects of the business and the ACE tools and methods. Vicha learned about powdered metallurgy, HMI's production processes and business, and ACE from his employees as he led them. HMI progressed in ACE activities, and in August of 2001, was among the first Pratt & Whitney companies to have certified ACE Gold cells.

While Sabarra had built the base, Vicha's active leadership accelerated the ACE adoption. People said that he visibly showed commitment, pushed hard, and was excited and ambitious about making progress. He encouraged people to be creative and focus on how-can-we-do-it alternatives rather than dwell on why-we-can't-do-it responses. The difference in leadership, one worker speculated, was that Vicha wanted to establish himself both at HMI and Pratt & Whitney. He was an outsider and he had to be proactive. That worker also noted that the "program worked out very well for Vicha," implying that HMI's accomplishments and recognition helped advanced his Pratt & Whitney career.

As Vicha spent time on the shop floor to listen to employees, employees also listened to and learned from him. Vicha taught people how to sell HMI's results to Pratt & Whitney. Vicha had a knack for marketing. He knew who to call and what to say in order for HMI to become a part of the bigger Pratt & Whitney picture. As one HMI manager commented, "he brought us into Pratt & Whitney." Vicha identified and guided HMI's efforts in winning two Pratt & Whitney leadership awards and the UTC Rentschler Award (for significant achievements in the quality of products, services or processes that directly benefit customers). This recognition, one employee noted, "Was a wild ride." HMI's accomplishments resulted in numerous requests from other companies to visit, benchmark, and learn from their experience.

Another New General Manager: 2002-2006

At the end of 2001, Vicha was promoted to a director-level position at Pratt & Whitney's East Hartford headquarters. He oversaw the Specialty Manufacturing Group, a group of six manufacturing companies that included HMI. Vicha was involved in picking his successor and the next HMI general manager. His primary consideration was finding someone that would continue to lead HMI's improvement efforts. Many candidates applied, attracted by HMI's recognition within Pratt & Whitney. Vicha's priority was communication skills, rather than the strongest candidate with hard-core operations experience. That next general manager, Grant Bauserman, came from a Pratt & Whitney joint venture company in Indianapolis that helped start up over the previous two years. Bauserman wondered, given its reputation, what he could do to improve HMI's improvement record. Vicha challenged him to take ACE further and become Pratt & Whitney's first ACE Gold site.

Making an entrance

Shortly after Bauserman had accepted the position, he received a phone call asking to start immediately. He was shocked, given what he expected, to hear that HMI was in the midst of a union drive. His first days at HMI, he recalled as follows: "We had our industrial relations people, engaged a local law firm, and camped out in a conference room. That was our headquarters for providing an alternative view to what the union was proposing."

With a gap in time of several months from when Vicha left and Bauserman arrived, International Association of Machinists union leaders collected signatures from seventy percent of HMI's workforce requesting information. Earlier that year, Pratt & Whitney had required all facilities, including HMI, to make five-percent workforce reductions. HMI had made these cuts by work area rather than worker seniority, which resulted in a "popular" employee being laid off.

The employee unrest was compounded what Bauserman identified as three key issues: supervisors' treatment, pay and benefits, and identity. Supervisor issues occurred because there were too many bosses – twenty-five percent of the workforce held supervisory titles. After a study by Pratt & Whitney's HR department, a new Technical General Coordinator position was created. This new position recognized a person's competence, but did not give him supervisory authority. Pay and benefits were questioned relative to Pratt & Whitney union workers in East Hartford Connecticut. Identity was the issue of whether HMI was treated as a supplier or as a Pratt & Whitney facility.

Bauserman put together a plan to address these issues, talking to employees, making frequent speeches, and sending out mailings. Thirty-six hours before the vote was to take place, the union withdrew its action. Reflecting on this contentious start, Bauserman saw the silver lining, noting, "It gave me a chance to come in, establish myself because, clearly, there must have been some concerns and issues. It gave me a great opportunity to get the doors wide open, even though HMI had a great reputation and was performing pretty well. Without that, I might not have wanted to tinker."

Plans beyond the immediate

Bauserman carried out many of the plans that he drafted during this inauspicious start of his four-year general manager tenure. He initiated employee councils to plan company events and support community activities. They had guidelines and were empowered to spend within them. If employees put in sweat equity, HMI provided financial support for these activities. HMI became a title sponsor for the Utica College science fair, which attracted high profile people such as congressmen and astronauts. The company sponsored a regional air show. Employees created a golf tournament that became the American Cancer Society's largest regional golf fundraiser. Employee engagement improved dramatically. HMI won the 2004 Pratt & Whitney Leadership Award for employee fulfillment.

ACE provided an opportunity around which to focus business change, which Bauserman expressed as follows,

> *I saw ACE as a great way to do what we wanted and build around these other activities. ACE is a platform for driving significant change. Not just change in one business area, because ACE requires a kind of balanced scorecard. EH & S [Environment, Health and*

Safety] had to progress as rapidly as the financials. Financials go as quickly as employee and customer satisfaction.

Going for Gold

When Bauserman arrived in October 2002, HMI had four gold cells, five silver cells, and one bronze cell (see Table 1 for listing of HMI's ten cells). ACE criteria were changed to assess sites, rather than cells. To become an ACE Gold site all cells had to be at ACE Gold. The site assessment was planned for the first half of 2004. Vicha challenged Bauserman and HMI to pull the assessment up into 2003 and become UTC's first Gold site. Bauserman expected that this goal would help show employees that their long-term security rested in performance, customer satisfaction, and manufacturing excellence, rather than in paying union dues.

Bauserman recalled, "We didn't know any better. We did not see barriers or any reasons why we could not become one of the first Gold sites." They asked for a consultant from Pratt & Whitney's ACE office to help them. That consultant's analysis was that HMI's biggest challenge was the business cell, which was then only ACE Bronze. Improvements to business cell became a priority for the whole organization.

HMI became one of the first ACE Gold sites in August, 2003. Making the needed changes required everyone in the organization to rally. Bauserman noted that that HMI, given its history and experience to date, had a "resident understanding of the tools and how to use them." His predecessor "cleared the field of all the trees and stumps" and he "went in and had the bumper crop." In a 2003 presentation of its ACE accomplishments, relative to its 1998 Bronze performance, HMI's sales increased 19%, return on sales improved 11 points, inventory turns increased 61%, on time delivery improved from 91% to 99.8%, customer satisfaction improved from 4.5 to 6.7 (on 7 point scale), and lead time decreased 78% (to 27 from 120 days). Achieving ACE Gold also addressed employee concerns. There was "no question about it," Bauserman said, "that recognition really helped us deal with employee concerns." When Pratt & Whitney President Louis Chênevert came to Clayville to present HMI their ACE Gold plaque, a local television new crew covered the event and shared the news with the local community.

Leadership at Multiple Levels

ACE Pilots

What people at the top of organizations do and say is often viewed as leadership. That perspective is important because people in top positions enable or constrain many others' actions. Leadership behaviors that impact a facility's improvements also come from workers, managers, supervisors, including ACE Pilots. For example, the ACE Pilot's treatment of people affects the attitude that workers and supervisors have for ACE and its requirements. Regarding HMI's ACE Pilot Nathan Wells, Bauserman noted, "I would set overall expectations and drive them through my leadership team, through the operations manager, and through my personal involvement on the floor; but Nate [Wells] was out there holding people's hands and keeping it going."

Choosing an ACE Pilot is an important decision that HMI has made three times. Sabarra selected HMI's first ACE Pilot, Jeff Helmer, in 1996 from his role in production tower operations. When Helmer was promoted in 2000, Nathan Well was selected as the new ACE Pilot. Wells started as

a welder in mechanical maintenance at HMI. He attended college and earned an engineering degree part-time while working at HMI. Succeeding Wells, in 2007, was Wayne Screeder. Screeder was long-time HMI employee, and at the time a senior screener who had been a member of numerous ACE teams. HMI's ACE Pilots were well known to other workers. They learned, used, and taught ACE tools and methods in leading improvement efforts with colleagues. A manager involved selecting the ACE Pilot described the criteria: "the ACE Pilot needed to have some ACE experience from being on project teams. He had to be someone willing to learn, and having gone above and beyond their regular job. For overall morale, they were promoted internally. By promoting a shop floor worker, the Pilot would know the people, their thinking, and their problems."

Each ACE Pilot learned on the job. Helmer used what he had just learned in training and applied it by teaching his colleagues. Pratt & Whitney experts also came to HMI to lead training and events. Helmer taught what he learned to Wells, who also attended formal ACE training at Pratt & Whitney. Wells described his ACE Pilot role as combining ACE criteria, HMI business goals, and knowledge of the culture, people, and cells to ask questions and help people implement changes that improved performance.

When the ACE focus shifted to a site level in 2002, HMI's plant staff managers' responsibilities shifted from efforts in their cells to understanding value streams across HMI and taking collective action to improve them. The weekly plant staff meetings, which Wells attended, were used to review ACE efforts in cells and at the site level. Bauserman noted that Wells was a good leader, "he had the respect of supervisors and [cell] leaders because of his expertise, and he had the respect of hourly associates because he was a welder."

Cell leaders, supervisors, and workers

While HMI's managers influence the ACE Pilot's activities, it was how those activities affected where changes were made that determined what gains were realized. ACE Pilots' activities created insights that were the basis for changes led by cell leaders and workers. HMI's ACE Pilots – Helmer, Wells and Screeder – were all drawn from the rank-and-file. They then understood broader employee concerns and ongoing needs for overall business improvements. The method for making changes started with defining the area for improvement, forming a team involving the supervisor and area workers, using ACE tools and methods, collecting data, developing improvement options, and planning, implementing and tracking changes. As the ACE Pilot applied ACE tools and methods, they taught them to the improvement team, and helped these people make and track changes. The ACE Pilots facilitated a great many ACE events, which built an understanding of ACE and process improvement in the workforce, who implemented the changes that accumulated into performance gains.

Workers comments on improvements were that they depended largely on supervisors' and cell leaders' acceptance and enthusiasm. The actions that were taken to address an ongoing late delivery situation illustrate the improvement process. After forming a team, the members examined causes of delivery misses. They found the key factor to be the time it took to changeover the production tower. The team members, who worked on the production tower, used several ACE methods – point of use tooling, efficient cleaning, visual queues and color coding – to improve reduce the changeover time by a factor of four. These gains were achieved

and sustained, the manager said, because "employees that came up with ideas were educated on the tools."

Supervisors' leadership was important in employees using ACE tools. The supervisors initially identified ACE projects, then provided employees with guidance, help, and time they needed to accomplish these projects. Supervisors sought funding to buy materials or equipment and requested training. This leadership required new skills, namely that supervisors be facilitators of workers' learning rather than experts on what to do.

Before changes were made, current processes were documented enabling tracking of improvements, particularly whether they achieved expected gains. Documenting the current state was seen as bureaucratic, not adding value, and said to be a deterrent to improvement. To gain acceptance, supervisors documented the current state rather than assigning workers to do it. For example, in the material cell, it was the supervisor who identified, documented, and wrote the standard work for all of the cell's processes. He recalled that what had been "tribal knowledge" then became formal. When problems occurred, such as when failed materials were returned, they used the QCPC process, turnback reporting, and root cause analysis to diagnose problems. Previously they would have made a knee-jerk reaction to those failures. For example, they found some failed materials returns due to mislabeling. The root cause was in a process they had followed for 25 years. They changed that process, type-tested all materials before shipping, and documented these procedures in their standard work. This approach, however, required more work. The materials cell supervisor noted that his vigilance was required to maintain documentation, because "if you don't do it all the time, then you'll never be able to do it." The accumulation of many small changes in the material cell charge make-up resulted in one person doing forty percent more work than what was previously done by two people.

Executive leadership

The active involvement of HMI's General Manager affected the pace of change. People repeatedly mentioned that while ACE started with Sabarra, activities accelerated as Vicha and then Bauserman, each in their own unique ways, pushed ACE efforts forward. Initially, General Manager Vicha stimulated improvement activities and gave the ACE Pilot the authority to make changes. Later, when most cells were ACE Silver, Vicha promoted Helmer and funded Wells to as HMI's new ACE Pilot. Helmer's management role was needed when HMI became one of the first ACE Gold sites in 2002. HMI hosted visits from other UTC companies and Helmer helped with training at these companies. In supporting those visits, Helmer and HMI learned about other improvement methods. Helmer could do this because he mentored Wells as HMI's ACE Pilot. When Helmer left HMI for a position at another UTC company in 2003, Wells provided continuity in HMI's improvement efforts.

The strategy behind Vicha's thinking was that once you get people using tools, making improvements, and experiencing benefits, you create a cycle from tool use to activities to results that reinforces itself. He commented as follows

> *The guy that runs the production tower could give a presentation on any one of the ACE tools. He is an advocate for ACE, and he gets such benefits. That attitude flows down to his employees. All of his employees know that, hey, my cell leader, my supervisor, is a*

believer and passionate. Much of it is passion. What you saw when you went into that shop is that they had passion, they were committed.

To sustain this reinforcing cycle, Vicha held his managers accountable for ACE tool use. What encouraged Vicha and enabled his efforts was the visible and vocal commitment from corporate leaders, which he described as follows.

ACE was the way that we were going to improve our businesses, and UTC is all about process improvement. During the dot.com boom, many companies were buying these businesses. Not UTC. George David was not lured by that, he said many times that UTC's strength is in process improvement. There was resistance for quite a few years. But, it's the senior management of UTC and Pratt that has been absolutely committed. That is a key strength. Without that, it wouldn't happen. Steve Finger, the president of Pratt during this time,was even more committed. When he moved into the role as president at Pratt, he said one of the first things he wanted to do was visit all of these ACE Gold sites. And he did it within four month of coming into his new job… Every visit was incredible. He stood up in front of employees and recognized the accomplishment and pushed appropriately and respectfully for more progress. It was so powerful for him to do that. It really sent the message that this new president is committed, just as Louis Chênevert was. There should be no mystery, or no employee that could say there is no commitment… That commitment is what allows me, as a general manager, to stand up there with credibility when I say that management is committed. I know above me there's commitment. It's pretty powerful.

3 The Dynamics of Implementing ACE

When ACE was first introduced in 1996, activities focused on laying a foundation for continuous improvement. ACE was a new name for a program that integrated improvement methods that had been practiced individually at different Pratt & Whitney facilities, including HMI. An important aspect of ACE was the commitment of Pratt & Whitney's management to promote a systematic and widespread effort to these continuous improvement methods in all its facilities. In that time, and before, consultants came in and led kaizen (rapid improvement) events. Techniques like 5S and TPM were taught and used throughout the plant. The manufacturing floor was divided into cells, processes were identified and defined, and metrics were established and tracked for those processes in cells. Those efforts provided the foundation for numerous improvement projects. ACE activities also created organizational-level feedback, helping to identify and direct improvement activities (see Figure 2 for time line of HMI's improvements and Figure 3 for graph of events over time).

A tentative start

When Pratt & Whitney's leaders began promoting ACE in 1996, it found a receptive audience at HMI. Before 1996, HMI's improvement efforts had not been systematic. For instance, in 1995, two HMI managers were looking at the melting process to find ways to reduce scrap. Another team was working to increase yields in the production atomization tower, and several kaizen events had been held to overall improve plant work flow and productivity. These efforts were largely done by an engineers and managers. ACE engaged workers and gave them an influence in changing their work processes.

In launching ACE, each facility was to name an ACE Pilot. General Manager Sabarra suggested Jeff Helmer. Helmer was a shift supervisor on the main production tower. Helmer was not sure why he was selected, although he had demonstrated interest in improvement methods by collecting data on atomization yields. He accepted the offer on Thursday and the following Monday he was in Hartford for a week of training. Armed with new knowledge from a week of training, on the following Monday Helmer began organizing improvement initiatives.

People recalled the trials that marked HMI's ACE start; they resisted what was new and unfamiliar not because of what it is, but how it was introduced. The initial approach was different from how HMI later practiced ACE. A machinist recalled, "ACE was introduced very poorly. It was, 'this is what you're going to do and this is how you'll do it.' It was put across as a threat." Another worker commented that when ACE was launched, "we didn't understand the concept; we had to figure out what we were doing." A manager's comment reflected similar experiences, "When the ACE program was introduced people complied with it." It was either the ACE Pilot or a manager that defined improvements and "the cell leader would be co-opted."

People were initially repelled by the introduction process, but their experience with its tools drew them into ACE. Exposure created an understanding for ACE that went beyond their treatment. Comments, from workers reflecting back, were as follows:

> *ACE started off as checking the box for headquarters. This process of documenting the benefits, however, helped to build momentum. What was required to check the boxes sold ACE to the people. 5S came in, and we did it, no one asked us. After we got it, it was accepted immediately, even before we became bronze.*

With its mixed introduction, the utility of ACE tools and work area benefits was sufficient to keep worker interested.

Restructuring into work processes and cells

An important change that set in place a structure for improvement was the reorganization of HMI's operations into cells. HMI divided its manufacturing into five cells; each cell was responsible for its improvement efforts. The ACE Pilot was available to help or guide efforts, but responsibility for improvement rested with those who had the operational expertise, the cell leaders and workers. Table 1 shows the division of HMI's operation into cells and the progression of those cells (note that initial ACE efforts focused on cells, at the end of 2002 ACE shifted from cells to site-level assessment). As illustrated by the ACE cell progress, HMI's improvement efforts initially focused on its manufacturing areas. In 2000, cells for non-manufacturing processes were established, and improvement efforts began in those areas.

Manufacturing Cells	Support Cells	Business Cell
CELL 1 Production Tower - Coil Room, Head & Tube Room CELL 2 Production Screening CELL 3 Can Fabrication & Machining - Weld Shop CELL 4 Rotary Atomizer Furnace CELL 5 Pilot Plant & Screen Room	CELL 6 MTS - Maintenance , Electricians, Facilities, Tool Room CELL 7 Materials - Scrap Center & Charge Makeup CELL 8 Quality Labs - Q.C. & Chemistry Lab CELL 9 Non-Destructive Testing - Sonic & Etch	CELL 10 - Financial, Administrative, Strategy, Technical, Customer Satisfaction, Overall Business Requirements
1996 – Cells established 1997 – Prerequisite 1998 – Bronze 1999 – Silver 2001 – Gold 2002 – Recertified as Gold 2003 – Part of Gold Site 2004 – Assessment waived 2005 – Recertified as Gold Site 2006 – Recertified as Gold Site	2000 – Cells established 2000 – Prerequisite & Bronze 2001 – Silver Site level assessment 2003 – Part of Gold Site 2004 – Assessment waived 2005 – Recertified as Gold Site 2006 – Recertified as Gold Site	2000 – Cells established 2000 – Prerequisite 2001 – Bronze 2003 – Silver, Part of Gold Site 2004 – Assessment waived 2005 – Recertified as Gold Site 2006 – Recertified as Gold Site

Table 1 HMI Cells and progress of ACE certifications

ACE assessment and improvement criteria

Between 1996 and 2002, cells progressed based on meeting the line items of the ACE Criteria[4]. The ACE Pilot interpreted the requirements of each criterion and translated it into specific changes to be made in each cell. Fifty percent of the items on the list had to be complete for a cell to reach the prerequisite (later renamed as "qualifying") level.

For ACE Prerequisite, the cell had defined key metrics, identified its value stream, and begun using ACE tools. The next level, ACE Bronze, was achieved by demonstrating the use of ACE tools in improvement events. In the fall of 1997, in the push for ACE Bronze, HMI rolled out three tools – 5S, TPM, and QCPC (see tool descriptions below) – across the five manufacturing cells. For a cell to reach the next ACE level, it had to demonstrate the knowledge of all ACE tools and show performance improvements (for ACE Silver), and sustain improved performance levels for twelve consecutive months (for ACE Gold). The progression through ACE levels built knowledge first within and later across cells.

Tentative acceptance turns to steady progress

The ACE introduction focused on applying a combination of tools: Total Productive Maintenance (TPM), 5S (visual factory), and Quality Clinic Process Charts (QCPC). As people participated in events and used tools, the results from these activities created enthusiasm. For

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[4] After 2002, the Pratt & Whitney ACE criteria changed so that cells were no longer awarded ACE levels. Rather, an entire site, comprised of multiple cells, would be assessed for its level of ACE achievement.

example, machine operators were trained and asked to be involved in TPM.[5] Many HMI workers interviewed brought up and discussed the implementation of TPM. Operators did not initially like doing preventative maintenance tasks. These tasks, which were previously done by maintenance people, required them to do cleaning and initialing of sheets indicating that they had checked machine status. To lessen their extra efforts, workers rotated who did what tasks on each shift so, as one worker commented, "you weren't always cleaning the same part, but you were always cleaning." Operators noted the value in TPM it that it reminded them how dependent they were dependent on their machines being ready and running properly. The result, as an operator reflected, was "that you could come onto a shift and find machines good to go… there is nothing worse than starting your shift having to fix or clean." TPM became second nature. One employee noted, "We once visited a company in Binghamton. They do not do preventive maintenance. They ran to failure. How can you even admit to that [not doing maintenance]?"

5S was the method people recalled most vividly at the start of ACE. 5S was an efforts required to advance cells from ACE Prerequisite to Bronze status. The implementation of 5S took place in people's "spare time," which meant between production runs or when production volume was down. 5S produced highly visible outcomes, consistent with HMI historic orientation toward order and cleanliness.   To people on the production floor, 5S made a lot of sense; the fact that it was a part of ACE gave them the time and support to clean up their work areas and buy new tools and equipment. For example, storage cabinets replaced open shelves and newly purchased mobile work kits kept tools closer to where they were used. "I was skeptical at first," a worker commented, "but followed what was asked. 5S helped people with their tools and where to find them. Once we had done 5S, the workplace was more organized. It took about six months." The machine shop supervisor said that 5S helped his operators take greater ownership of their workplace, and along with daily TPM activities, machines was always ready. An ACE Pilot commented that people needed "to participate and engage to see the value to the activities." His enthusiasm helped to overcome resistance, "if you are active, if you use the tools, they help you, you see that things are getting corrected and getting corrected sooner, and you see that ACE is working."
ACE requires upfront work for subsequent benefits. Work, such as documentation, was burdensome. For example, QCPC involved process charting, documenting process steps, and continuous efforts for tracking "turnbacks." A "turnback" is anything that inhibits or prevents the timely completion of a work step. Tracking and analyzing turnbacks prevents reactive fixes that later fail and enables identifying root causes. Turnback data helped focus improvement efforts on actions with the biggest impact. In the machine shop, "it used to be that 75% of their parts came back from testing needing some work. After improvements, they got about 1% of parts back."

Although it is difficult to measure quantitative improvements caused by 5S, TPM, or QCPC, implementing these methods broadly had multiple benefits. First, these methods laid foundations for subsequent, often more systematic, efforts. The results, however, were often local, and benefits created on one area do not necessarily get passed on to another area or show up on the "bottom line." Local use, however, created interest, engagement, and experience. People could

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[5] TPM is a method for achieving greater equipment utilization and effectiveness through operator involvement in maintaining, cleaning, and tracking the use of their machines.

more readily see work flow, the readiness and supply of materials or tools needed to complete tasks, and the status of operations relative to expectations. ACE methods created a new language that provided a new means for communicating across business units. The workplace, what people did, and how they interacted with one another changed.

Achieving the critical mass that sustains change

People noted a point in time where ACE no longer required a continuing direction from managers or the ACE Pilot. ACE instead began to sustain itself from the energy of workers using it. One person commented that this turning point was when "it shifted from learning tools to becoming a way of life." A sign of this turning point was when team members and cell leaders no longer waited for direction, but they themselves identified problems, proposed projects, and took action. The turning point occurred at different points in time, depending upon specific cells' working environment.

In describing the transition, Wells drew a bell curve for ACE acceptance over time, noting it was between the first ACE Gold cells in 2001 and becoming an ACE Gold site in 2003. To be ACE Gold, people across HMI were involved in one or more improvement activities. Examples of these activities included weekly cell meetings where tools and methods were taught, process turnback data and updates on current improvement projects were discussed, and new projects were initiated. An employee suggestion program and project review committee reviewed and initiated new efforts. The plant manager and management team members had an open door policy, inviting people to talk about improvement ideas.

Identifying improvement opportunities

There were two approaches to applying ACE tools and methods to create improvements. One approach relied on top-down direction, in the form of mandates to initiate improvement activities by learning and applying specific methods. The strength of this approach is that it allocates and applies resources to the areas that managers identify as most in need of improvement. A top-down approach was character of HMI's first few years of improvement activities. HMI's managers and the ACE Pilot promoted specific 5S, TPM and QCPC improvement activities in cells.

As cell leaders, supervisors, and workers understood and accepted ACE, a bottom-up, worker-led approach became the common. ACE projects generated information on each cell's process capability and operational performance. That information provided feedback on changes and direction for future improvement activities. For example, quality clinics, process certification, and root cause analysis create data that are used to identify new improvement opportunities. In bottom-up efforts, projects are identified and led by workers and supervisors, and reviewed and supported, as requested, by cell leaders, managers, or the ACE Pilot. The strength of a bottom-up approach is that it is based on the initiative of people closest to the work, who then learn to not only to identify issues as they arise, but also to take action and monitor progress.

The taper pin improvement projects in Production Screening (Cell 2) illustrate this shift in ACE efforts. The taper pin refers to the type of seal used in the extrusion cans filled with powdered metal. The extrusion can is 24" in diameter and ranges between 52" and 75" in height (later there was just one "common" can design). The can is filled with powder, evacuated, and then pressurized. The evacuation process involves an adapter that covers the can's top as a pump

creates a vacuum. A valve is slowly opened (over 6 to 8 hours) to avoid drawing out any powdered metal. The powered metal is under vacuum for 8 to 12 hours to remove any gases. Next the can is pressurized using nitrogen for 78 hours. It is then sealed and shipped out for extrusion. The operation has to be restarted from the beginning if there are any leaks before the can is sealed.

Initial improvement efforts required Cell 2 workers to apply ACE methods – TPM, 5S, and QCPC among others. A focus taper pin problems was initiated once these methods were in place. The QCPC team examined these work processes, focusing on what caused evacuation and pressurized to be repeated. The most frequent failure came from dislodging the taper pin in the final sealing operation. In investigating what caused the pin to dislodge workers found that the electrical tape holding the pin in position was at times contaminated by the grease used to create vacuum seals. The Cell 2 team created an engineering service request for a new adaptor design. The new design used a cotter pin to hold the taper pin in place. A subsequent improvement team later made further improvements by replacing the cotter pin with a double O-ring seal that altogether replaced the taper pin. These series of improvements started with requirements by managers to use ACE tools that over time created involvement and understanding by workers, which lead to multiple improvement team efforts led by people in the cell to make further improvements.

People described many improvements that evolved in way that were similar to the taper pin projects. Managers oversaw the initial implementation of ACE methods. Initial team efforts used data generated to identify and make some changes and subsequent team activities created further improvements. As people gained sufficient experience with improvement projects and their results, they initiated and sustained these activities without direction from managers or the ACE Pilot.

Cumulative efforts need to be sustained

Figure 3 provides historical HMI event activity[6] and shows two ACE activity peaks in 2000 and 2008. ACE activities, measured in total man-hours invested, increased until 2000, after which time there is a gradual decline in the total man-hours invested until 2005. The number of ACE projects increased through 2002. In terms of overall involvement and activity, there is an increase again in 2006 which grows to a larger increase in 2007 and 2008. The broad involvement seen in HMI's total man-hours invested, peaking between 2000 and 2002, is consistent with the ACE activity tipping point described in interviews. These activities corresponded with cell-level efforts based on 5S, kaizen, set up reduction, and TPM methods. In 2001, manufacturing and support cells became, respectively, ACE Gold and Silver. In 2003, with efforts focused on the business cell, HMI achieved ACE Gold at the site level. The ACE Gold site assessment requested value stream mapping efforts to be conducted with suppliers and

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[6] These numbers are derived from retrospective estimates. Given that the estimates go back several years, there is reason to question its detailed accuracy. Records of events and their duration and participation had to be reconstructed from various sources, including the memory of people involved in them. Event records were not systematically kept until 2007. In 2007, people recorded their participation in activities for their ACE qualification levels. Records did not include total time invested in improvement projects, so these figures were created from estimates. Based on people's event descriptions, for events that took several days, we estimated 100% (basically full time), for events of one or two weeks, we estimated 80% (4 days out of a week), and for events over months, we estimated 20% (one day per week).

customers, which are shown as the VSM ACE projects in 2003 and 2004. An increase, if not resurgence, of ACE activities took place in 2007 and 2008, in both the number of projects and involvement of people.
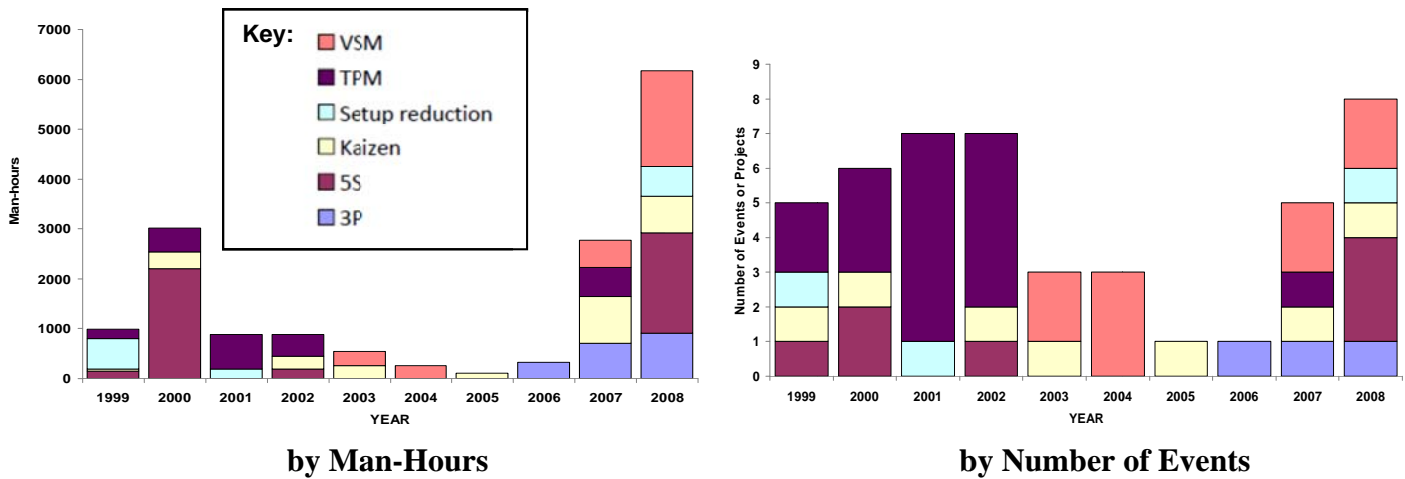

by Man-Hours   **by Number of Events**
Figure 3 Estimates of Annual ACE Efforts

What is notable in the activities records is that HMI was recertified as an ACE Gold site in 2005 and 2006. This data shows that recertification was achieved with only a few selected and focused ACE activities. The new General Manager Ron Chandler drove the increase in ACE activities in 2007 and 2008. Current HMI performance levels validated that sustaining ACE Gold Performance was even a bigger challenge than achieving ACE Gold levels. Based on financial performance (a result of 75% cost increase in raw material) and increase in recordable injuries, the management team decertified HMI from Gold to Silver in April of 2007. Although HMI implemented significant capital improvements for facility upgrades in 2008, including installing a new production tower in Cell 1 and increasing production by 30% to accumulate sufficient inventory so as to not disrupt supply during the needed shutdown, the Gold site recertification originally scheduled for 2007 was rescheduled into 2008.

The historical ACE activities chart (Figure 3) also shows changes in HMI's ACE methods emphasis over times. Efforts in 1999 to 2002 utilized TPM, 5S, set up reduction, and kaizen methods. From 2003 to 2006, HMI ACE efforts used only VSM, 3P, and kaizen improvement methods. In 2007 and 2008, ACE efforts again included TPM, 5S, and set up reduction methods.

Figure 4 shows the history of ACE efforts by cells. An examination of methods by cells shows the appropriate use of methods based on the nature of the work in that cell. Within production and support cells, initial activities were focused on the use of 5S, Setup Reduction, and TPM methods. Later, VSM was applied across manufacturing and support cells and within the business cell. When 3P (Production Preparation Process) was promoted as a method, it was applied in the Materials and Production Tower cells. The increase in ACE projects in 2007 and 2008 included a focus on manufacturing cells and the use of 5S, Setup Reduction, and TPM methods.
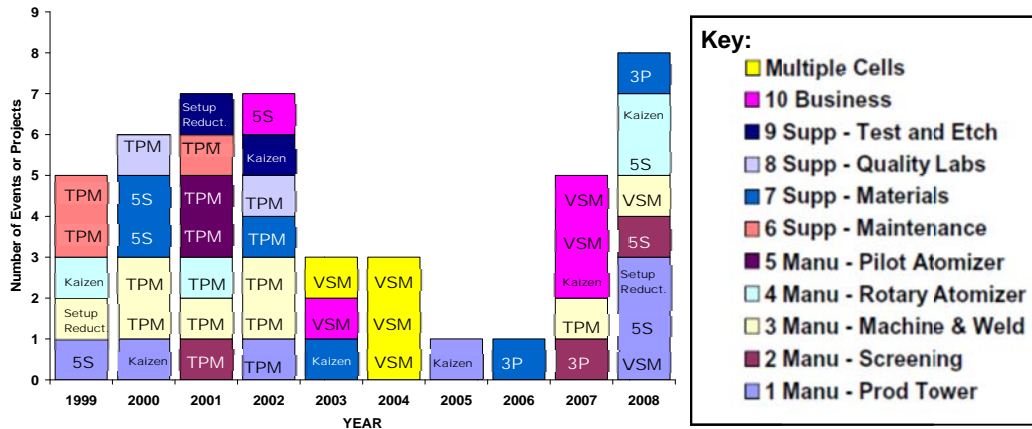
Figure 4 Estimates of Annual ACE Events by Cells

Assessing and rewarding improvement progress

HMI's improvement activities resulted in both better financial and operational results as they achieved ACE certifications. The focus on ACE certification was a collective goal established by managers which gained popular support. Many people commented that becoming ACE Silver or Gold, in cells and then at the site level helped to focus their collective energy. A supervisor, commenting on activities in 2000, noted that, "Everyone could see the goal. You saw more managers on the shop floor. It seemed that everyone was on board."

In 2003, UTC's criteria for ACE certification shifted from assessing cells to achieving results at site levels. At that time, HMI's five manufacturing cells were certified as ACE Gold, its four support cells where certified ACE Silver, but the business cell (Cell 10), then at the Bronze level, lagged the other cells and held HMI back. Achieving a Silver or Gold site level certification required all cells to be at that performance and improvement level. Focused attention and effort in the business process cell was needed. With help and focus, the business cell attained ACE Silver status. HMI was thus positioned to be one of UTC's first ACE Gold sites. There were three other advanced ACE sites, an international Pratt & Whitney site, international Otis Elevator site, and a domestic Carrier site. The goal to be UTC's first ACE Gold site created friendly competition among the sites and spurred local efforts. In the end, the UTC ACE department announced HMI as among the first four UTC ACE Gold sites in August 2003.[7] On the basis of its performance and its demonstrated improvement abilities, HMI had passed the ACE Gold site assessment, although it was required to undertake several "homework" assignments.

Feedback systems highlight opportunities

The progression in ACE certification in cells and then as a site made information available and visible on how units and then HMI as a whole was performing. ACE methods required defining processes, collecting data, and using these data to monitor performance and make improvements. Implicit in ACE was valuing data and using it as feedback. In addition to data about product quality and production processes, data was collected on internal and external customer data and

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[7] The goal of improvement across UTC is what had the corporate ACE group announce a set of initial sites to be certified as ACE Gold. The choice was made to lessen competition and increase cooperation across sites.

employee satisfaction. Each cell maintained a set of metrics, which were rolled up into an overall site level report, called a "control tower."[8]
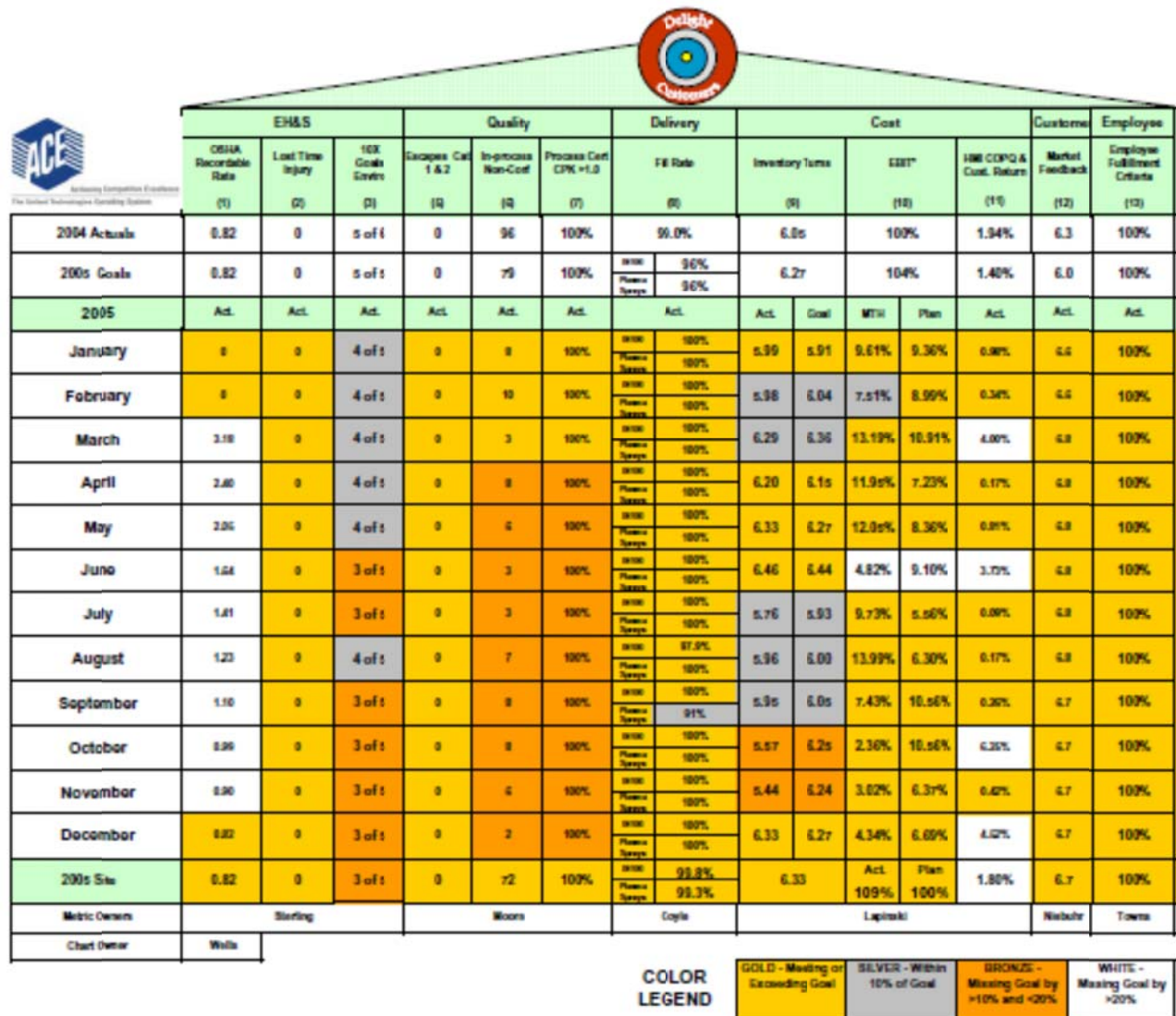
Figure 5 HMI's ACE control tower[9]
(Source: HMI 2006 ACE Gold recertification presentation,
*note: EBIT normalized based on 2004 actual = 100% baseline)

The control tower is one page table that is updated monthly to provide key operational, financial, quality, delivery, health & safety, customer and employee metrics against goals. Background

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[8] The term "control tower" is used for its high level metrics dashboard in keeping with Pratt & Whitney's aviation heritage. In Carrier the overall site metric dashboards are called a "thermostat," and in Otis they are called "control panels."

[9] There were thirteen items on HMI's control tower. There are three measures of Environment, Health and Safety (EH&S) – OSHA recordable rate, lost time injuries, and 10x Environmental goals; three measures of quality – category 1 and 2 escapes, in-process non-conformance, and process certification, one measure of delivery – fill rate, three measures of cost – inventory turns, earnings before interest and taxes (EBIT), cost of poor quality (COPQ) and customer returns, one measure of customer satisfaction – MFA (Market Feedback Analysis, from customer survey scores), and one measure of employee satisfaction (based on an employee survey).

color codes allow for a quick visual indication of metric status (see Figure 5 – often the colors green, yellow and red are used; HMI used Gold, Silver, Bronze and white backgrounds to indicate performing at those levels, or in the case of white, missing the metric; see note on color coding in Figure 5).

Achieving ACE Gold and Silver level certification requires good measures across all these dimensions. This multiple metric approach, similar to a balanced scorecard,[10] reflects UTC's

improvement philosophy – ACE is not an instrument for achieving cost reductions; it is a way to do business. According to Grant Bauserman,

> *ACE really does move the business forward. At the same time, this progress does not come at the expense of the employees or the expense of EH&S.*

Along with the control tower, each site has a "roadmap" that lists on a single piece of paper the goals for the next year and on another single page its vision for the next five years. The roadmap contents are updated annually and cascaded up and down the organization to link Pratt & Whitney's corporate goals to HMI goals to specific cell goals and finally into individual performance goals.

By viewing Figure 5, HMI's historical monthly performance is evident. The white boxes show an OSHA recordable incident in March, and several misses of more than 20% in cost and quality targets in 2005. Also, boxes with bronze and silver backgrounds are indicative of better performance, but not up to the ACE Gold standard. In the certification process, HMI needed to discuss what happened areas that missed Gold performance, and how they had put in place improvements to address the causes of those missed metrics.

The road map and control tower are publicly displayed on HMI's ACE Boards. Each cell has an ACE Board where its performance status, including the site control tower, is regularly updated and posted. ACE Boards also display ongoing improvement project status and completed project results. In visiting UTC sites, ACE Boards provide people with an immediate sense of the area's performance and improvement history. The vibrancy of improvement initiatives can quickly be assessed by noting whether or not the ACE board is up-to-date and designed for actively use.

4 The Challenges of Reaching a Plateau

"There is no end to this, you can always look at what you are doing and find ways to make improvements," one engineer noted. There were, however, indications when we conducted our interviews in 2007 that HMI reached a plateau. One indication was people's comments that the enthusiasm and energy had slowly declined since achieving ACE Gold. Another indication was HMI's 2005 ACE Gold recertification assessment. The assessors found several lapses and nearly decertified HMI. There were many explanations of what happened, including concerns on the part of HMI people that the ACE criteria had changed and become more stringent. HMI's lapse,

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[10] The term "balanced scorecard" was developed by Harvard Business School Accounting Professors Kaplan and Norton to give managers a more "balanced" view of their organization's performance by adding non-financial measures to traditional financial metrics. See "The Balanced Scorecard: Measures That Drive Performance" by Kaplan and Norton, January 1992, Harvard Business Review.

according to an UTC assessor, was due to their own decline in efforts, which he expressed as follows:

> *They were getting flat, running for two years as ACE Gold, not looking at opportunities, starting to get a bit of atrophy, saying we are the best. I had to stir the pot, and told them, yes, you are good but others are getting better.*

The assessors recommended changes, which if completed in 90 days, would allow the assessors to return and recertify them. The assessor commented on what happened next,

> *For six weeks that place was in turmoil. They were beside themselves that they hadn't received their second round of Gold. After that Grant [Bauserman] said, 'You know what? We have pulled ourselves up on our bootstraps. We realized it wasn't you, it was us. You guys did an awesome job. You made us look inside where we hadn't looked before. And lo and behold, we found what you found.' And they came through with shining colors.*

The realization was that recertification, which involves sustaining improvement activities once you have attained and been acknowledged as world class is more difficult than initially achieving that designation. Once you have shown you are among the best in you industry, the question shifts from what you can do to prove yourself to what can you do to continue to improve?

HMI's abilities to sustain improvement continue to the current day. People acknowledge that it is harder to maintain ACE Gold than to initially attain it. It was easier to get people focused and participating in ACE efforts when there was a goal to achieve ACE Gold and be among the first to achieve it. Once Gold certification was attained, people's attention and desires drifted back to past habits. Improvements were also more difficult because operations were already performing at higher levels. The new ACE Pilot, Wayne Screeder, worried about this challenge he accepted his new position. HMI had made so many improvements, and it was unclear how much further could they go. They were meeting production schedules and cost reduction goals, so the basis for more changes was uncertain. HMI's early ACE efforts had put them in a position of greater hardship later. When Pratt & Whitney mandated an across-the-board five-percent manpower reduction in 2003, HMI, like other organizations, had to comply. These cutbacks, its leaders said, were more difficult for HMI than other Pratt & Whitney facilities because of the changes that they had recently made to achieve ACE Gold. For example, their ability to decrease IN100 costs was constrained by corporate inventory goals. These goals limited the materials that HMI sent to Wyman Gordon in Texas for extrusion. Wyman Gordon's press had considerable set up costs, so increasing the cans extruded per lot would reduce unit costs. Increased lot size, however, meant greater work-in-process inventory, as well as decreased delivery flexibility. Both of these metrics were two closely watched Pratt & Whitney corporate measures and a part of HMI's performance goals.

People mentioned that Pratt & Whitney continued to hold HMI on a tight leash, despite their demonstrated process capabilities and ACE achievements. As a sole source of a critical component in Pratt & Whitney's jet engines, the historically tight constraints were understood and accepted. With its success, however, and requirements to show continued year over year improvements, HMI managers expected greater flexibility, and considered Pratt & Whitney's

constraints as limiting possible future performance gains. In talking about these constraints, one person questioned whom these improvement efforts really benefited:

> *ACE has increased bureaucracy. There is a lot of paperwork to document turnbacks, do Pareto charts, and fulfill corporate requirements. This is opposite to what was taught and done in the original kaizens, where were to do work rather than to do paperwork. Many of the wall charts are produced for visitors and ACE assessors; people in the cells know how they are doing, and maintaining those charts is just more paperwork.*

From a limited number of interviews, it is difficult to assess whether dissenting views are wide spread and representative. The logic of the argument had merit: too many metrics over constrain possible courses of action. However, as earlier efforts showed, forcing people to use tools is what engaged them, and through the results that they achieved, created the understanding and commitment to continuous improvement that sustained changes. In terms of wide spread measures, HMI's employee satisfaction survey showed constant and steady progress in job satisfaction and people embracing improvement initiatives. An engineer that was an ACE advocate commented on changes as follows,

> *The enthusiasm for ACE has changed, and now ninety-five percent of people are positive and enthusiastic, and 5% not so much. There will always be some people that you can not reach.*

UTC learned that every cell needed to be at the same performance and improvement level to achieve desired business, customer and organizational benefits. This learning resulted in a focus on ACE at the site, rather than cell, level. At an individual level, is acceptance by every employee needed to sustain improvement activities? How many employees need to actively participate and promote improvement initiatives for there to be organizational results? Since true acceptance is volitional, how is it best achieved? The following section on workers' reception for ACE examines these issues.

ACE Reception by Workers

Having worked with ACE for some time, people did not always recall in 2007 what historical changes had gotten them to their current performance level. People did say that HMI was not always been as it now was. The incremental nature of continuous change makes it difficult to remember the steps taken that contrast present conditions with those of the past. The change dynamic is that of subtle but significant shifts in behavior and thinking that happen over time. These changes did not result from marching to a fixed schedule, but as came about as cumulative efforts provided people with time to soak in changes and reflect upon what happened. Conducting interviews for this case study seemed to provide people with an opportunity for reflection. Many people described how things were currently relative to how they had been in the past. These workers' descriptions provide insight the evolution and dynamics of ACE-related changes.

The way we do things

The acceptance of ACE methods by HMI's workforce was described by ACE Pilot Wells as follows.

When we introduced ACE in 1996, only a few people were interested. When we reached four gold cells in 2001, interest was approaching a 50% level. When we achieved ACE Gold site in 2003, we then got the critical mass to build momentum. People were seeing the results. Now, we are definitely above critical mass, we have common knowledge and buy-in. The culture is there and it is definitely sustainable.

While Wells described a cumulative adoption process, other people mentioned declining activities after achieving ACE goals. That difference might come from the physical effort initially needed to develop process charts, establish a visual workplace, and write standard work. Establishing these efforts required more explicit activity than did later activities to use and maintain these methods. Initially, it was not apparent what benefits these methods would provide, while the extra effort was immediately apparent. The regular use of these methods are initially salient, and later they are less noticeable as they become "the way we do things." For example, in 2007, while they had previously railed against it, people accepted the documentation required in certifying and control processes. One worker said, "You are doing your job, plus documenting it," and another commented, "You are still here for eight hours; what difference does it make if you do your work or you document your work?"

The success of ACE has come from UTC, Pratt & Whitney, and HMI staying committed it. The continuing promotion and development of ACE enable its adoption to progress before it is replaced by another priority. Looking back, a worker noted the following:

Most of the workforce has accepted ACE. Part of the reason is that it has been around long enough. With other programs, they changed frequently, like every year. People were skeptical initially. Now, people are working with ACE tools, and using them without thinking that they are tools. People are convinced over time. It has helped that the company has stayed with ACE. It is not a program that will go away.

Adoption and acceptance has been encouraged is by adding new, complementary elements to ACE. In the last two years, each cell holds weekly toolbox meetings. This meeting lasts 15 to 30 minutes. While never "required," cell leaders are encouraged to hold these meetings. When HMI's new general manager, Ron Chandler, arrived, he started attending toolbox meetings. Toolbox meetings raise issues beyond daily operations and ACE. The cell supervisor leads discussions on such topics such as safety, injuries, departmental notices, updates on improvement activities, and short tutorials on ACE tools and methods. These meeting include a time for employee ideas and suggestions.

Employee engagement

Getting people involved in a broad range of improvement activities is an explicit ACE goal. Implicit to ACE are tools and methods that seek to engage people by learning to apply tools and methods, such as team-based approaches in 5S, quality clinics, and TPM. The role of the ACE Pilot is not only to lead improvement activities, but also to teach, inspire, and facilitate teams to initiate, implement, and sustain improvements in their work. The reception by the workforce is measured in an annual Pratt & Whitney survey, which is administered voluntarily and anonymously. HMI employee's overall favorability toward ACE has steadily increased since this information was captured and reported (see Figure 6). The requirements for ACE Gold certification are that the site has a favorability score of 70% or above.
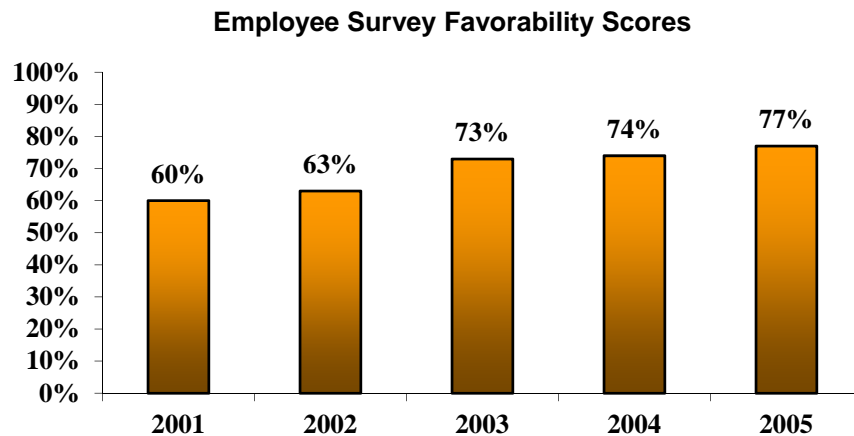
Employee Survey Favorability Scores

Figure 6 Employee Survey Favorability Scores
(Source: HMI ACE Gold Recertification Presentation, May 16, 2006)

To maintain and improve employee satisfaction, HMI developed numerous programs. A "voice of the employee" program provides opportunities for people to meet with and give feedback to managers. Ron Chandler, the general manager, has an open door policy, inviting people to come to talk to him at any time. HMI, because of a historical situation in supervisors' treatment of workers, conducts leadership training for team improvement activities. As part of managers' and supervisors' job evaluations, HMI uses a 360-degree feedback process. These efforts complemented other programs that strive to engage employees in their education and improving their workplace and the local community. Short descriptions these programs – HMI's creative solutions, safety, community involvement, and UTC education program – follow.

Creative Solutions
HMI's Creative Solutions program invites employee suggestion to reduce cost, increase efficiency, or improve safety. A committee of managers, engineers, and accountants reviews suggestions and respond to the person who made the suggestion within 90 days. Employees whose suggestions are implemented receive rewards of either $100 or $300 based on the impact of their idea. Five to six $300 awards, with additional $100 awards made annually. There is also a single $1000 award given to the most impactful idea in that year. Creative Solution suggestions have been the basis for improvements implemented cells (see Appendix B).

Safety
HMI's "catch a near miss" program promotes safety improvements. If an employee sees an unsafe situation, he writes it up and submits it to the Environmental Health and Safety (EH&S) Manager. Each employee receives a $25 gas card for his first submission and a $10 card for subsequent suggestions. HMI has a good safety record, and on the basis of its record and practices, achieved OSHA-certified Voluntary Protection Program (VPP) star site certification in April 2000. This program requires management and employees to work cooperatively with OSHA representatives to establish a comprehensive safety and health management system. Once a facility is designated as a VVP site, OSHA no longer makes annual inspections but instead reviews the site every five years to insure the continuation of good safety practices.

An element of its "behavior based safety" approach has HMI employees observe a peer's normal work procedures. In those observations they look for possible safety risks and then write a report, keeping the person observed anonymous, summarizing their observations. This activity heightens the safety awareness of the person doing the observations and the person being observed. As a regular safety reminder, at 11 AM and 3 PM each day, HMI plays a 30 second sound clip of a 1970's era rock song the facility's public address system. What initially might be an intrusion, a rock song suddenly playing the PA system, does cause people stop momentarily and remember that this is broadcast to remind them about safety.

Community Involvement
HMI is a significant employer in the local economy, where many manufacturing companies have closed as their jobs moved to lower cost countries. HMI employees are encouraged, with financial underwriting for charitable groups, to contribute to local community activities. Past involvements include participation in American Heart Association Greatest Heart Run and Walk, Crusaders for Cancer Golf Tournament, United Way Campaign, State University of New York (SUNY) Technology Showcase, Utica College Science Fair, Take Your Child to Work Day and Earth Day.

Education
As part of a UTC's Employee Scholars program, HMI supports it employees' educational advancement by paying for tuition and books for any employee pursuing any accredited degree program, whether or not that degree is related their job. When employees complete college degrees, UTC gives them stock awards that vest over five years. UTC spent over a half billion dollars in its employee scholars program between 1996 and 2007.

UTC's educational benefit is very important, according to HMI's general manager Ron Chandler. He advanced his education through the UTC program, and said that it "stimulates peoples' minds and gives them energy, makes people think about tools and applications of what they have learned, and is a great recipe for success." Nathan Wells, HMI's second ACE Pilot and currently it engineering department, earned his engineering Bachelor of Science degree through this program.

5 Current and Future challenges

Given it history, HMI's learning and change efforts have proven themselves to be long-lived. As one of the first ACE Gold cells, and later one of the first ACE Gold sites, HMI has been able to maintain its performance and improvements standards as long as any other UTC organization. To continue its success, however, HMI faces several challenges. We identified three sets of challenges in 2007 – 1) those that are unique and specific to HMI's product, technology, and supply chain position, 2) those related to Pratt & Whitney's relationship with HMI, and 3) those that related to broader process improvement and change issues. Each challenge area is described in the following sections.

HMI's unique conditions

HMI faces challenges unique to its products, industry, and customer base. HMI creates value by atomizing and blending alloys as powders with precision and quality. Some of the resulting powders are sold directly and other powders are packed, compressed, extruded, and machined to make billets. Wyman Gordon in Texas extrudes the compressed powders in can to make metal logs, which HMI then tests and machines into billets. Its sole customer for billets is Pratt & Whitney's Georgia Forging (where billets are made into stamped parts that are then machined into engine components at Pratt & Whitney's module centers in Connecticut). While HMI has leveraged ACE in its improvements, its efforts and results have been constrained by two factors.

Constraints in working with other organizations

One factor is what HMI is capable of doing in within its own organizational purview, which is its Clayville factory. HMI's abilities to optimize its own process depend upon its inputs and outputs, or its abilities to influence its ore suppliers, Wyman Gordon, and other Pratt & Whitney organizations. Wyman Gordon's Houston, Texas operation is 1.2 M square foot facility with a 35,000 ton press that can extrude metals at high temperatures. HMI's compressed powder cans are a small part of their business. With its large capital investments in expensive equipment, Wyman Gordon's willingness and ability make changes, such as improved machine set up and turnover time for HMI, is limited. Wyman Gordon is owned by Precision Castparts Corporation, a maker of complex metal products with over $5 B in revenue in 2007. Some improvements have been possible, largely by changes in HMI's methods. HMI worked with Wyman Gordon to make new extrusion dies for its common extrusion can. The larger can allows for more material per extrusion can, resulting in longer logs, from each press operation.

Improvement efforts with other Pratt & Whitney facilities – Georgia Forging and the Combustor Module Center – have been more successful. However, there relationships among the Pratt & Whitney companies are not easy as each organization has its own priorities and efforts underway to improve its operations. Each site seeks to improve its own related metrics, such as inventory levels and turnover. In 2007, at the time of this study, Georgia Forging was outsourcing work to two different suppliers in an effort to satisfy customer demand. The additional material required was unique; demand was heavy and impacted HMI's daily operation. However, as these other suppliers failed to produce, they returned material to Georgia Forging, which created inventory surpluses. HMI's inventory consequently increased as it was asked to not ship and wait for Georgia Forging to first process the returned material.

An issue that crosses HMI and Georgia Forging is at what stage and location to hold inventory. As each organization undertakes improvement activities, it measures, reports, and seeks to improve its performance, including its inventory turnover ratio. Allowances to operational measures, such as holding some inventory for contingency purposes, are made at a Pratt & Whitney level. The Pratt & Whitney preference is to hold inventory closer to the customer, or to have billets in inventory at George Forging. HMI would like to hold more inventory as it would allow larger extrusion lots at Wyman Gordon. Larger lots would lower overall unit costs because of the significant press set up cost charged by Wyman Gordon. The example was that it costs $1 M to extrude the typical current run of eight to ten IN100 logs. With that same set up charge and a longer press run it would only cost $1.5 M to extrude up to twenty-four IN100 logs.[11] Corporate inventory goals, however, prohibited the greater work-in-process inventory that HMI would hold in going to longer press runs. The constraints have evolved over time from cells to sites, and more recently to the entire value stream. The current focus for HMI is to use the ACE operating system and its tools across the value stream to establish an ACE Gold performance level.

Working from what customers value in making improvements

The second factor is related to the question, "Does where you start determine what you can ultimately do?" A premise of lean production methods is to improve customer value by implementing changes based on ideas such as eliminating non-value adding operations, developing single-piece flow, and using pull systems with just-in-time material delivery.[12] Ideally, improvements start from the customer and what is valued to work back through all associated operations activities.

In its enthusiastic and initial ACE efforts, HMI began improvement efforts from its position near the beginning (close to raw materials) in Pratt & Whitney's value chain. After HMI made internal improvements, it sought to influence its suppliers and customers. This change sequence was not guided by end customer value but by what HMI and its intermediate customers valued. The 2003 and 2004 value stream mapping initiatives with raw material suppliers, Wyman Gordon, Georgia Forgings, and Module Centers have provided a cross-organization perspective and overall customer value orientation. The reality of improving the value stream is difficult, which HMI's general manager Ron Chandler described as follows.

> *The value stream has many challenges. Customer satisfaction will be a direct result of how well the entire value stream delivers. The value stream is only as good as its weakest link. For HMI to sustain long term ACE Gold performance the value stream will need to be in sync every step of the way. HMI's focus is to partner with suppliers, share best practices, and ultimately achieve an ACE Gold value stream.*

Pratt & Whitney and HMI rely upon one another at company and product levels. That interdependence creates unease in the autonomy of improvement initiatives. While HMI is wholly owned by Pratt & Whitney, it is a separate company, and its managers and employee identify with and seek to maintain its competitiveness. As a parent corporation, Pratt & Whitney

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[11] These numbers, the $1M for 8 to 10 logs to be extruded and $1.5M for up to 24 logs to be extruded, were provided to illustrate relative costs. They are not actual costs or numbers, as the actual figures are confidential and proprietary to HMI.
[12] These principles of lean production are described in Womack and Jones, <u>Lean Thinking</u>, 1996.

challenges HMI with goals for its performance and improvement, prescribes tools and methods that it should be using, and imposes constraints on the variation from these goals that it will allow. HMI is a sole source of supply and its major product, IN100, is unique and proprietary to Pratt & Whitney. The components made from IN100 are an essential part of Pratt & Whitney's commercial and military engines. These conditions buffer HMI from market forces but also limit its growth opportunities.

As HMI became more efficient and its managers became savvier about their business and its value stream, external constraints were more evident. There was particular concern with making continued productivity improvements. Labor costs could not be decreased without producing more or eliminating people. Producing more was constrained. To be more competitive in powder metals sold directly to customers, HMI would have to produce in large lots sizes. Larger lots could be made using the main production tower, but this was not allowed because of its sole source arrangement with Pratt & Whitney for IN100. Downsizing or eliminating workers was constrained by not only HMI's family culture but also a recognition that improvements depended upon people's acceptance of ACE.

Pratt & Whitney's priorities

It is difficult to implement process improvements across facilities, particularly when improvements in one facility come at the expense of gains, or impose costs, at another facility. For example, HMI's financial goals and operational metrics depended upon its shipments, and its shipment was based on Georgia Forging's forecast and schedule. In effort to improve this situation, value stream mapping events involving HMI and Georgia Forging people took place in 2003 and 2004. An HMI participant made the following comments.

> *Getting a good production schedule from Georgia Forging has been one of our biggest challenges. We will ramp up, work Saturdays, and then find out that they do not need the parts. That hurts our metrics.*

Meeting customers' expectations and changing customer schedules created direct conflicts between HMI and Georgia Forging. This challenge developed because of the long lead time raw materials with specific IN100 chemistry, size, and weight. When these changed on particularly short notice, it caused problems and missed metrics for HMI. Some premises of lean production, such as single piece flow and pull systems, were difficult to implement with the batch processes necessary in using Wyman Gordon's extrusion presses.

Chandler, the new HMI general manager in March 2007, identified three capital expenditures as priorities: controllers for the pilot atomization plant, upgrades to dehumidification equipment in the powder screening room, and, the most significant, replacing the 60 foot production atomization tower. These investments, said Chandler, would "take the facility to the next level for the next twenty-five years... allowing HMI to expand its product lines and double business in two to three years." Replacing the production tower could take up to two months. In addition to the capital required for a new tower, HMI would have to increase its production to build up billet inventory to carry them through the shutdown period. These capital expenditures and inventory increases had to be approved by Pratt & Whitney.

Several people expressed concerns about Pratt & Whitney treating HMI as a closely managed subsidiary; one person commented that HMI was "managed on a tight leash." As part of ACE, HMI collects, rolls up, reports and manages to a set of financial, operational, customer, employee, safety and environmental metrics. These measures capture both process capability and organizational performance, and HMI has consistently delivered results and demonstrated its process capabilities. Pratt & Whitney, as the parent company into whom HMI's performance and asset metrics roll up into, authorizes head count, monitors inventory and cash flow, approves capital expenditures, and expects certain EBIT (Earnings Before Interest and Taxes) returns. HMI's managers expected, however that since they have consistently delivered results and demonstrated their process capabilities, they should gain greater latitude in making decisions to upgrade facilities that would enable revenue growth and secure employment stability.

Broad improvement challenges

Many of HMI's challenges are generic issues that any organization would encounter in its improvement efforts. People asked how long they could keep on improving. HMI had demonstrated significant progress, achieved best-in-class performance status, and been certified and then twice recertified as ACE Gold. Across those assessments, ACE criteria had become more rigorous, and HMI met standards. When would they be able to relax? People sought the comfort of a status quo anchored in equanimity and stability rather than turmoil and continued change. This desire goes back to observations made by an assessor in HMI's 2005 ACE Gold recertification, who noted that they had slipped and lost a lead they once held in UTC. Vicha, then a group manager, noted the following.

> *HMI rested on the laurels of past success and it is a challenge for them. They need to recognize that some shops have surpassed them, go see what they have done, and incorporate it. The beauty of the friendly competition is every site should want to be better than the rest.*

The reality of an ever changing global economy is that is no enduring competitive advantage. The challenge for managers is to recognize their own and subordinates human tendencies to seek comfort and stability despite an ever changing external environment. An environment of ongoing change cast against human desires for stasis and stability raises important considerations. What should be kept stable and what should be required to change? What will be the impetus for change come that keeps HMI competitive?

Relevant to this case, and the understanding of ACE, is whether the change impetus for HMI can come through the ACE Operating System from UTC? If history is a guide, Pratt & Whitney's and UTC's overall development, direction, and guidance around ACE did produce many desirable changes and outcomes at the local HMI level. HMI's ACE activities were combined with its existing corporate culture to create a context that provided an impetus to promote improvements, sustain change, and achieve desired business results. As has been noted, there were and are limitations to HMI's abilities to sustain changes. However, the changes related to ACE are still ongoing at HMI and ACE itself is continuing to develop. While for typical corporate improvement efforts, the study of ACE at HMI over 12 years is extraordinarily long-lived, it is not the end, but seemingly the middle of the story. Improvements continue to take hold, and greater and deeper understandings of continuous improvement are being learned. It is not just HMI, but its also suppliers and intermediate customers that need to act in concert to

improve value delivery to end customers. For example, as issues across HMI, Georgia Forging, and Pratt & Whitney Module Centers become more salient, their local ACE efforts provide a common language and tool set to build new understanding.

This examination of the multi-organizational value stream would suggest that a large corporation not buffer but instead strive to equip and expose its subsidiaries and facilities to market forces. Yet, as described by HMI managers relative to their relationship with Pratt & Whitney, as a parent organization it buffers HMI from market conditions while also constraining HMI's range of possible actions. Of Pratt & Whitney's actions, managers' comments focused on the constraints imposed upon them. An approach to resolve these issues might come from considering who is responsible for learning and change. If that stewardship is to come from within the organization, then it raise the question of who has control over HMI's destiny and to what extent people will have a say in decisions that affect employment, strategy and governance? These issues become prominent when considering improvements across a value stream.

To date, cross value stream efforts have been conducted by involving representatives from constituent organizations. Together these teams collect and analyze data to propose changes. While it was not openly discussed, beyond logical decisions based on data, there are parochial and political issues affecting changes across the value stream. For example, in HMI's value stream, the lean principle of reducing material movement would suggest that the machining of extruded logs into billets take place at Georgia Forging, rather than returning from Wyman Gordon in Houston, Texas to Clayville, New York before being sent to Columbus, Georgia. HMI mangers hold tightly to the proposition that their machining of the logs gives them feedback and quality control information on their atomization and screening of powdered metals. Also important is that cutting and machining logs into billets and conducting material tests keeps people in Clayville employed. Given the historical employment sensitivities, combined with Pratt & Whitney's constraints on new business growth, some improvement alternative out of bounds, as they would undermine HMI employee's commitment and engagement. These factors are often difficult to quantify and objectively include in logical, data-driven value stream analyses. Not being able to address employment issues creates conditions were people avoid conversations or situations where they might be raised.

What considering hypothetical improvement opportunities illustrates is a range of options whose evaluation goes beyond process data. The idea that all sites along the value stream develop and implement process and other improvements is important, particularly given the use of a common ACE toolset, as it helps people to think and talk from similar ideals and relevant data. As more data is surfaced, it also requires greater personal and organizational security.

Epilogue

The second half of 2007 turned out to be difficult for HMI. While it achieved a 10% increases in production volume and productivity over 2006, other factors worsened. Profitability (measured in EBIT) declined to its lowest value in ten years. Raw materials, which make up half of HMI costs, have risen in price industry-wide. HMI had its first lost-time injury in over eight years, and there were four other safety incidents. The OSHA recordable injury rate rose to its highest value in a decade.

These incidents were "red flags" as noted on HMI's metric control tower. The ACE Gold criteria requires metric goals be consistently met for 12 consecutive months. In seeking site recertification, any variance from the ACE criteria requires a written exception explanation addressing what happened, why it happened, what was done to resolve it, and what would be done to avoid related future problems. In light its performance and the challenges in writing exception packages for safety incidents and missed metrics, the general manager, Ron Chandler, in consultation the with the Pratt & Whitney manager in Module Center Operations that he reported to, decertified HMI to ACE Silver. The requirement for twelve months of consistent performance had them shift the scheduled June 2008 ACE Gold assessment to December 2008.

In June of 2008, HMI recovered in its 2007 performance troubles, and consistently met all its metric targets since January 2008. That accomplishment is significant, since production volume in 2008 ramped up considerably in preparation of a plant shutdown. Pratt & Whitney had approved the funding needed to replace the 28 year-old production atomization tower. Beginning in January 2008, HMI began 24 hour per day operations on the existing production tower, running two twelve-hour shifts either six or seven days per week. Twenty-three temporary workers were hired to staff the operations. With the increased work schedule and new workers, productivity declined and inventory levels increased. Its customer for IN100 billets, Georgia Forging, outsourced a part of its operations improving its lead time. HMI began delivering billets to Georgia Forging and the two other pressing facilities.

In July 2008, HMI shut down to replace its main production tower. The whole plant was closed for a week, and it took at total of four weeks to get the new production tower installed and operating. The upgrade and transition went smoothly, and HMI was again operating at normal, full production capacity in August 2008. Market conditions had, however, changed dramatically. The high oil prices of 2008 impacted airlines and flights, and the financial, banking, and economic crisis in August and September resulted in dramatic business changes for HMI. The demand for IN100 for commercial applications essentially "fell off a cliff" and there were only requirements for the military engine grade IN100 materials. From it earlier 2008 production schedule and inventory build up, HMI had accumulated a finished goods inventory that was not what its customers needed. These inventory levels and additional expenses associated with capital upgrades meant that HMI was off from its expected financial targets. The ACE Gold assessment scheduled for December 8, 2008 was postponed into 2009.

These recent developments raise important future questions for not only HMI, but all UTC's sites, and how they are measured, goaled, and given ACE certification. At one level, HMI took what most managers would consider prudent and appropriate action to prepare for a major facility upgrade, building inventory to provide uninterrupted supply to their customer during that

disruptive facility shutdown. In that timeframe, unprecedented changes took place in global financial markets. Is the result that HMI is no longer operating at world class levels, as postponing the ACE Gold assessment would suggest? Or, does its ACE Silver status signify that performance and improvement ability level, but the operational and financial results, because of sharp demand changes, simply mean that HMI needs to continue its operations for the next twelve months to be able to post the expected performance record?

The answer to these questions will not only be determined in time, but will also depend upon what happens over time. The market change at the end of 2008 was not incremental nor gradual, but a sudden and dramatic, arguably unforeseeable, "step" change. In times of significant economic and market change, even Toyota, known for reliable performance and year-over-year performance, has had difficulties and shown financial losses. In talking to Toyota people, they acknowledge that the size and scale of the downturn exceeds what the range of variance for which they designed their production system and organization. The same is undoubted true for HMI.

The design of an organization's processes to accommodate and perform well across a range of economic conditions is just one outcome of a business operating system. HMI's ACE Gold achievement and multiple re-certifications are indications of its abilities to perform well within an expected range of economic conditions. The other element, while often untested but highly necessary, in the use of the operating system to redesign the organization and its processes to operate effectively under new conditions. This is what HMI has been doing, using ACE to redesign its operations to the new economic conditions. Once again, time will show whether they have been successful in adjusting to new conditions. The indications to date show promising results. In 2009, HMI shop load dropped by 31%. However, HMI's return on sales is up 2%, productivity has increased 4%, there have been 28 consecutive months of 100% on time delivery, 500,000 hours without a recordable injury, inventory reductions of $6M, implementation of projects saving over $3M annually, and employee survey results improvements of six percentage points. Even with the 31% drop in shop load, HMI's earnings before interest and taxes (EBIT) is within 10% of its plan. Under new conditions, HMI is performing at the ACE Gold level, and over time, it will apply for, and seem likely to achieve, ACE Gold certification.

Appendix A – HMI's Customer and Product Value Streams

Jet Turbine Engines

Gas temperatures in jet engines can exceed 1400° C. In the hottest part of the engine, engine parts have to maintain their shape and tolerances as the temperatures exceed the metal's melting point. Sophisticated engineering and materials science make this seemingly impossible feat a routine and even dependable occurrence, as jet engines must be able to operate safely and reliably. The critical rotating and high-heat components – disks, spacers & seals, shafts and bearings – in Pratt & Whitney's jet engines are made from a special alloy, IN100, produced by Homogenous Metals Incorporated (HMI) in Clayville, New York. IN100 is a super alloy metal that is formed when microscopic metal powder is extruded under heat and pressure. The process for creating the powder was invented by HMI's founder, Joseph Wentzell. The advantage of using powdered metal is that material defects are limited by the size of the largest granules in the powder. For the most demanding military engine applications, the granules are no larger than 80 microns in diameter, while for commercial engineers, the granules are no larger than 260 microns. In addition using powdered metal alloys to make engine parts, powdered metal can also be applied directly as plasma to provide corrosion resistance, abrasion seals, or thermal barriers in jet engine parts. IN100 and powdered metals comprise HMI's two lines of business.

IN100 - Super Alloy Metal for Jet Engine Parts

The first step in producing the super alloy powder is to combine and melt several "virgin" high-purity metals together in specific proportions. This molten alloy is atomized in a 60-foot tall tower filled with argon gas (see Figure A for process steps in producing powered metal billets). A vacuum is created in the tower, which then pulls in and violently sprays molten alloy into the tower chamber. As the molten alloy falls in the tower, it cools and solidifies into small particles. These particles are collected and screened in a clean room. The screening processes uses different mesh sizes, ensuring particles in the processed powder that are no larger than specifications. Larger particles are reused in subsequent melt and atomization cycles. Screened powder is packed into cylinders. Air is vacuumed out and the cylinder is repressurized with nitrogen over a four-day period.
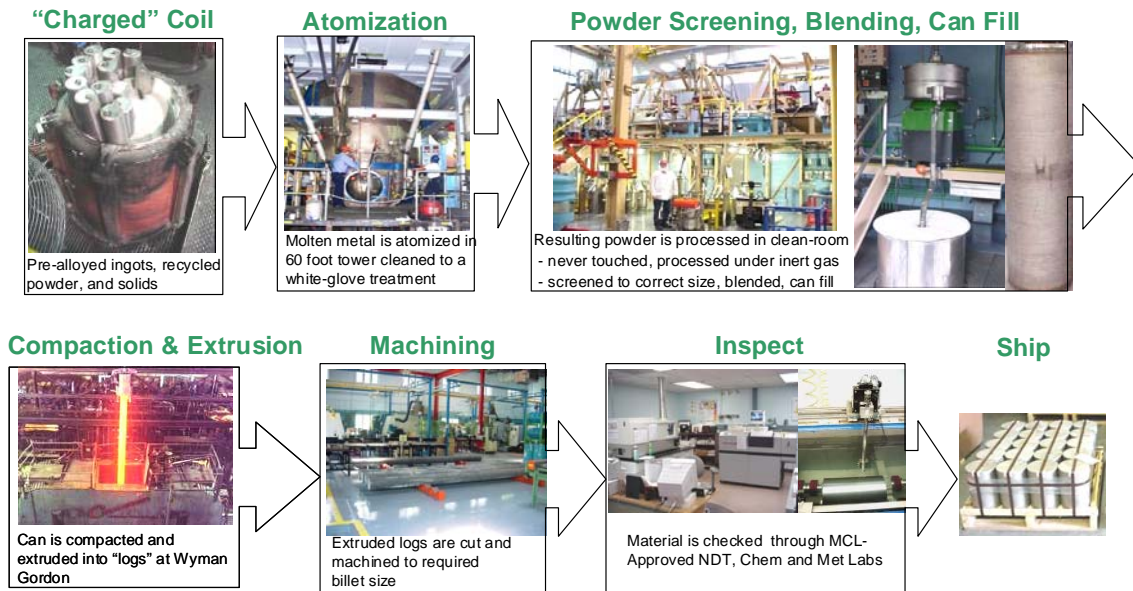
Figure A. HMI's process steps in producing powdered metal billets
(Source: HMI internal presentation)

The compacted powder cylinders are sealed and shipped to Wyman-Gordon in Texas, a third-party facility where the cylinders are extruded under extreme heat and pressure. This Texas facility uses an enormous press, and is one of only two facilities in the world capable of this type of extrusion. The product of the extrusion process is 30 foot long cylinder, referred to by HMI as a "log." Logs are shipped to HMI, where they are cut, ground, and milled into IN100 small cylinders "billets." The billets will eventually be shipped to another Pratt & Whitney facility, Georgia Forging, where they will be pressed and heat treated into semi finished parts. But before they are shipped, they are non-destructively tested for defects and certified by HMI (see Figure C). While the billets are heated, pressed and formed into parts ready for machining at Georgia Forging, the majority of the machining takes place at the Compressor Systems Module Center and Turbine Module Center in East Hartford, Connecticut. Finished parts are assembled into new jet engines or sent to field locations to be used in engine refurbishment or repair. In 2006, HMI shipped over five million pounds of IN100 billets; IN100 billets form the majority of HMI's business, accounting for 80% of its production volume and revenue.

Plasma - Metal Powders for Coating Engine Parts

Another use for super alloy metals is in the application of powdered metal plasma directly to jet engine parts. The powders are applied using thermal sprays to coat to engine parts. The powdered metals are produced in one of HMI's two low volume plant areas – a "pilot plant" or the "rotary atomizer." The pilot plant uses an atomization tower analogous to, but smaller than, the 60-foot production tower and the rotary atomizer uses a rotational process to atomize melted metal in powder (see Figure B for metal powder plasma production process steps). The powder from both these facilities is also screened, but instead of being packed into cans that are extruded, it is packaged in plastic containers for direct shipping to customers.
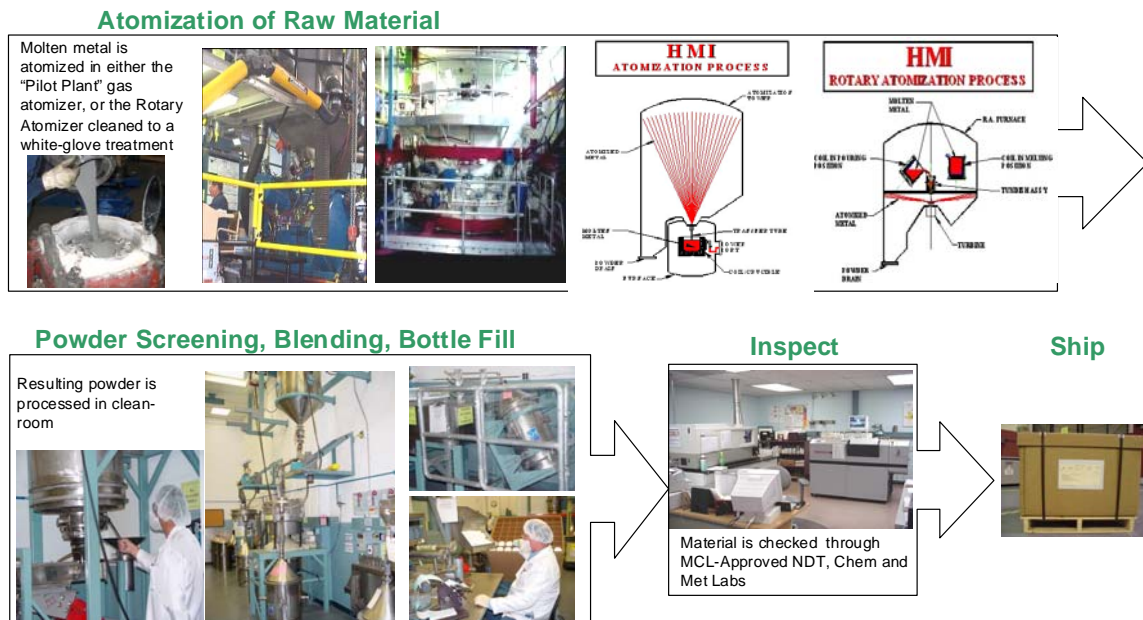
Figure B. **HMI's process steps in producing powdered metal plasmas**
(Source: HMI internal presentation)

Appendix B – HMI ACE Events History

Year	Cell #	Project Name	Focus & Activities	# People Involved	Length of Project (in months)	Est. Annual Man-hours	Results
1999	1	Coil room	5S improvements, standard work, set up reduction	6	3 days	144	Clean work are, more thru-put
1999	6	MTS Piranha	5S, increase uptime	6	2 days	96	Created daily walk around, identified critical spares. Replaced worn parts
1999	6	MTS Bridgeport	5S, increase uptime	6	2 days	96	Created daily walk around, identified critical spares. Replaced worn parts
1999	3	Machine Shop 7 1/2" to 10"	reduce set up time from going from 7 1/2" mults to 10" mults	6	6 months	1210	Reduce change over time from one part to next part. Came up with a face driver
1999	4	Sprays & Coatings Inventory reduction	consolidate and reduce inventory	6	1 day	48	Improved inventory turns
2000	7	Materials South 3rd Floor	5S, standard work flow and set up reduction	10	12 months	4032	Clean work area and shorter walking distance, more thru-put
2000	7	Material First Floor cage	5S improvements, standard work	6	1 week	192	Clean work are, more thru-put

Year	Cell #	Project Name	Focus & Activities	# People Involved	Length of Project (in months)	Est. Annual Man-hours	Results
2000	3	Weld Shop Welder	5S, increase uptime	6	3 days	144	created daily walk around, identified critical spares. Replaced worn parts
2000	8	QC Cut-Off Saw	5S, increase uptime	13	2 days	208	created daily walk around, identified critical spares. Replaced worn parts
2000	3	Materials Roto-Blast	5S, increase uptime	8	2 days	128	created daily walk around, identified critical spares. Replaced worn parts
2000	1	Lead Time Reduction Team	325 Final Screening process	7	6 day	336	Improved lead time through the process.
2001	3	Machine Shop Savage Saw	Increase machine uptime	10	3 days	240	5S machine, created TPM Schedule, identified critical spares, created daily walk around
2001	2	Clean room - Hydraulic Pump	Increase machine uptime	8	2 days	128	replaced worn parts, TPM Schedule, identified critical spares
2001	6	Tool Room 3H Lathe	5S, increase uptime	5	2 days	80	created daily walk around, identified critical spares. Replaced worn parts
2001	5	"O" Ring & Bucket	setup reduction, 5S, kitting	6	2 days	96	kitting boards, standard workbooks

Year	Cell #	Project Name	Focus & Activities	# People Involved	Length of Project (in months)	Est. Annual Man-hours	Results
2001	5	RA Screening	TPM area and cleaning of cans	4	2 days	64	TPM work area established, 5S area, reduced turn around time on cans.
2001	4	Lower Chamber Alloy Change	TPM on equipment	5	2 days	80	TPM Schedule, identified critical spares,
2001	9	Daily Tank Set Ups		6	4 days	192	
2002	10	Process Development	5S improvements, standard work	6	1 week	192	clean work area, more thru-put
2002	7	Materials Stud Welder	5S, increase uptime	8	1 day	64	Created daily walk around, identified critical spares. Replaced worn parts
2002	1	Hydraulic System Furnace #3 & #4	TPM Furnace Equipment	8	2 days	128	Clean organize and inspect Equipment, identified critical spares. Replaced worn parts
2002	3	Mori-Seiki Timing Belt Pulley	TPM on Lathe	6	2 days	96	replaced worn parts, TPM Schedule, identified critical spares

Year	Cell #	Project Name	Focus & Activities	# People Involved	Length of Project (in months)	Est. Annual Man-hours	Results
2002	3	Daewoo "Headstock Shaft"	TPM on Lathe	6	2 days	96	replaced worn parts, TPM Schedule, identified critical spares
2002	8	Automatic Grinding Machine	TPM on equipment	6	1 day	48	replaced worn parts, TPM Schedule, identified critical spares
2002	9	Dual Scans	increase throughput	8	1 week	256	increased through put
2003	7	Charge Make Up area	eliminate use of forklift	8	1 week	256	removed wall, eliminated use of fork truck, recessed scale in floor, FIFO lane
2003	multi	IN100 Internal to HMI	map the IN100 process)	6	3 days	144	current & future state maps and action plans
2003	10	Sprays & Coatings	map the IN100 process	6	3 days	144	current & future state maps and action plans
2004	multi	IN100 HMI and Georgia	map the IN100 process	6	2 days	96	current & future state maps and action plans
2004	multi	IN100 HMI, Georgia and CSMC	map the IN100 process	6	2 days	96	current & future state maps and action plans

Year	Cell #	Project Name	Focus & Activities	# People Involved	Length of Project (in months)	Est. Annual Man-hours	Results
2004	multi	Extrusion (Wyman Gordon)	map the IN100 process	4	2 days	64	current & future state maps and action plans
2005	1	Head & Tube Room Work Flow	better workflow, mistake proof	7	2 days	112	To improve any/all aspects of the Head & Tube room process, with special attention on mitigating safety conditions while improving 5S visual factory and flow.
2006	7	Material Elemental charges	Setup reduction, material flow, work instructions	10	1 week	320	developed new standard work for each alloy, reduced distance traveled, ergonomic concerns,
2007	2	Production Screening	Improve yields Reduce processing times, Improve working conditions	14	3 months	1411	5 future Kaizen Bursts Identified for '08-'09 Future Screen Room Layout Proposed Future Screen Flow Simulation Model 3D Model of New Floor Layout Capital Budget Plan for 2009/2010 Implementation Scheduled- 2009-2011 in phases
2007	3	Machine Shop	Improve Tooling and Lighting	6	3 weeks	576	Tailstock recentered new light placed in lathe Window replaced and sludge removed and parts cleaned. Oils where changed.
2007	10	Business Process	Value Stream Map, Increase Speed, Reduce Input Times	6	3 days	144	Value stream map created. Eliminated paper copies. Eliminated 4 clocks, have reduced input time by cell leaders.
2007	10	Business Process	Value Stream Map, Increase Speed, Reduce Input Times	6	4 months	806	Value stream map created. Eliminated paper copies. Eliminated 4 clocks, have reduced input time by cell leaders.
Year	Cell #	Project Name	Focus & Activities	# People Involved	Length of Project (in	Est. Annual Man-	Results

					months)	hours	
2007	10	TED Clocking System	Focused this event from VSM	14	4 months	1882	Eliminated 4 clocks , reduced input time by cell leaders, and resulted in 100% electronic data
2008	1	Rotary Atomization	Lead Time, Cost, Machine Set Up Reduction	18	3 months	1814	Reduced process times by eliminating unnecessary steps
2008	7	Stock Room - Material Tracking System	Automated Reporting Reduce manual labor 85%	9	6 months	1814	Reduced manual labor by 85% and controls inventory of consumables and critical parts to a mid / max reorder system. Eliminated paper waste and implemented electronic entries and withdrawals.
2008	4	Coil Room	Automated processing techniques utilizing	11	4 months	1478	Reduced manual labor by automating a special vacuum system to help remove material from the crucibles. Decreased process time and made the work environment safer and cleaner.
2008	3	Machine Shop	Lead Time & Cost Reduction, Set up Reduction	12	On Going	2016	Future State Map to align cells for a robust flow to decrease process times. 3P Event scheduled for 1st qtr 2009 to bring NDT & Sonics to the area of the machine shop for a streamline flow
2008	1	Rotary Atomization	Reduce & standardize the assembly process from VSM event	7	On Going	1176	Eliminated task times in installing tundish from 15 minutes to 7.75, the removal of 15 minutes to 5.56 minutes, the teardown from 30 minutes to 15.83 minutes. Updated standard work.

Year	Cell #	Project Name	Focus & Activities	# People Involved	Length of Project (in months)	Est. Annual Man-hours	Results
2008	4	Coil Room	5S for safe and productive environment	7	On Going	1176	clean working environment, healthier working conditions, with robust point of use tooling
2008	1	Production Tower	5S for safe and productive environment	8	On Going	1344	clean working environment, healthier working conditions, with robust point of use tooling
2008	2	Weld Shop / Machine Shop	5S for safe and productive environment	9	On Going	1512	clean working environment, healthier working conditions, with robust point of use tooling

Assumptions	168 Man-hours per month	Est. Man-hour Conversion calculation	
	40 man-hours per week		Assumed % effort
	8 man-hours per day		
		Days	100%
		Weeks	80%
		Months	20%