Manufacturing Work Cell Design

v v v v v v v v v v v v v v v v v Participant Journal

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Introduction

Completion of production work in an area that is planned and designed to accomplish a specific sequence of tasks is an essential part of manufacturing operations. The area where the work is completed is known as a *work cell*. Effective work cell design considerations include safety, production takt time requirements, inventory levels, teamwork, ergonomics, time, and waste elimination. The demands of the marketplace are creating a need for more manufacturers to adopt cellular manufacturing systems.

Manufacturing Work Cell Design presents an orderly process for the effective design and implementation of work cells, with emphasis on the advantages cellular systems can provide. It introduces you to the fundamentals of work cells and how to bring these fundamentals together to support effective production. This module assumes you have completed prerequisite modules addressing process flow, lead times, work methods, kanban and pull systems, and just-in-time (JIT).

Manufacturing Work Cell Design provides you with an opportunity to pull together many of the fundamentals from several previous modules. Through guided activities, you revisit prior concepts and begin the process of integration. The Transfer Activity returns to Robotic Grippers, Inc., and addresses the final assembly of grippers at production rates required to satisfy the customer demand. Participation and interaction are critical parts of the work cell design process. This module is a "mini-capstone" module that should bring new credibility to the work completed in prior modules and prepare you to complete the *Manufacturing Facility Design* module.

ν ν ν ν Competencies

After completing this module, you should be able to demonstrate the following competencies:

- Present and discuss the significance of key terms and concepts related to work cell design and operation (Comp. 1).
- Create an effective work cell design using a structured methodology (Comp. 2).

- Construct and operate a work cell given a set of conditions including customer demand, operation time details, production volumes, and enterprise constraints (Comp. 3).
- Compare the theoretical design output of a production cell to its actual output (Comp. 4).
- Develop project plans for work cell implementation and operator training (Comp. 5).
- Perform an analysis of a business application of cellular manufacturing (Comp. 6).

The development of these competencies will be demonstrated through work completed both during the Authentic Learning Tasks (ALTs) and on your own time.

Many ALTs and the Transfer Activity require participants to work in teams. The importance of effective teamwork is reinforced throughout the module. After the Transfer Activity, you evaluate your own teamwork performance and the teamwork performance of the other members of your team.

Opportunities and criteria for the assessment of participant progress are provided throughout the module. Evaluation may be based on your performance, products of the activity, or materials produced after the activity. An instrument for collecting data is provided in each ALT and in the Transfer Activity.

v v v v Organization

This module provides separate materials for the facilitator and for the participants. The Participant Journal is primarily a workbook to guide the your learning through the activities in this module.

In the Participant Journal, the module is organized into six sections:

- **Introduction:** This section provides a first look at the material offered in the module, a list of competencies, and an outline of module organization.
- **Planning and Preparation:** This section includes participant prerequisites and general safety guidelines.
- **The First Session:** This section provides activities to help acquaint participants with each other, as well as an introduction to basic concepts you will learn during the module.

- **Authentic Learning Tasks:** Each ALT contains instructions for the activity, assessment instruments, and evaluation criteria.
- **Transfer Activity:** You apply the competencies developed through the ALTs to a practical situation—a scenario at the fictitious Robotic Grippers, Inc.
- **Closure and Generalization:** Structured discussion or an additional activity reinforces the competencies developed through the ALTs and helps you anticipate the application of these competencies to other situations.

Planning and Preparation

ν ν ν ν Participant Prerequisites

This module is designed for participants who have developed the following competencies and/or have completed the following modules:

Introduction to Just-in-Time (JIT)

- Describe throughput and calculate throughput for a manufacturing process.
- Identify the specific tasks that comprise a given manufacturing process.
- Classify tasks as value added or non-value added.
- Explain the effects of small lot size on a manufacturing process.
- Describe the relationships among cost, quality, and time in a manufacturing process.
- Identify potential sources of waste in a manufacturing process.

Process Flow and Lead Time Reduction

- Describe the importance of effective work flow and short lead times in manufacturing operations.
- Use process flow and lead time analysis and reduction techniques.
- Identify and eliminate waste in manufacturing systems.
- Analyze setup and changeover procedures.
- Design processes for rapid setups and changeovers.
- Use the "Seven Deadly Sins of Waste" model to eliminate waste in a manufacturing process.

Consistent Work Methods and Build to Demand

- Design standardized work methods (routers), processes, and motions in a cell environment.
- Propose a product process flow to meet customer expectations by considering materials, routing, lot sizes, shop processes, scrap rates, etc.

Kanban and Pull Systems

- Describe and compare push and pull production control systems.

- Apply techniques used in pull production control systems.
- Design and operate a kanban system.
- Identify specific constraints (bottlenecks) on throughput for a given manufacturing process.
- Propose and evaluate a plan to improve cost, quality, and cycle time in a manufacturing process.

v v v v Safety and Disposal

Each ALT includes specific information about appropriate safety procedures, as well as any necessary instructions for the disposal of materials used. You should always wear safety glasses when engaging in laboratory activities. In addition, anyone using equipment should be familiar with the operating instructions provided by the manufacturer of that equipment and should follow safe and proper operating procedures at all times.

The First Session

ν ν ν ν The Big Picture

The proper design of the work cell is an essential part of an effective manufacturing operation. Work cell design is part of the operational strategies introduced in several of the course modules in this series. This module concentrates on work cell design fundamentals that support the concepts of *just-in-time*, *synchronous*, and *lean* manufacturing. The work cell design fundamentals are based on proven industrial engineering practices.

ν ν ν ν Industry Profile

The following industry profile provides an example of a company which implements the competencies developed in this module.

Arvin Industries is located in Columbus, Indiana and employs over 14,000 workers. Arvin is a manufacturer of component assemblies for the automotive industry. These assemblies include exhaust system and suspension components for automobiles produced by the leading U.S. and international auto companies. Throughout its eighty year history, Arvin—like other manufacturing companies—has sought to adapt to changing industry standards and work methods, and to stay competitive in the market. In order to accomplish these goals, Arvin employs modern work methods, such as workplace organization, setup time reduction, cellular manufacturing, lot size reduction, and employee education and training programs.

Prior to the start of the implementation of modern methods, the following problems were often found in the Arvin production lines:

- workers with a limited understanding of standard work
- inefficient control of the flow of work
- overstaffing of workstations
- excessive waiting for machine cycles
- excessive overtime work to meet the demand for products
- unbalanced work for the employees (work expectations were not equal for all employees)
- lack of employee training or involvement with improvements
- excessive work-in-process inventories

Case Example of Improvements at Arvin Industries

In order to remedy the production problems, Arvin Industries and its employees began to develop work cells for many of their operations. They worked to satisfy the same work cell design competencies that are presented in this module, including:

Competency

> Develop project plans for work cell implementation and operator training.

Success Story #1: Arvin has implemented a program to educate all of its employees in the concepts of modern manufacturing. The first employees to complete the training course at the Gladstone Plant were members of a line that was working daily overtime and Saturdays. Through their own analysis, the participants in the course were able to convince the members of their work team that an operator could be removed from their cell by redesigning the work cell and improving the work methods used. Through careful analysis and change to the work cell, they were able to make it fit within defined "standard work" elements. They implemented new methods and layout changes, and were able to justify their analysis of the situation. The person that was no longer needed in that particular cell was relocated to another job within the plant.

Competency

> Construct and operate a work cell given a set of conditions including customer demand, operation time details, production volumes, and enterprise constraints.

Success Story #2: A team at the 17th Street facility realized after analyzing their current work methods that they were building huge amounts of work-in-process inventory and performing unnecessary work. The work methods and procedures they were using before the analysis actually jeopardized the team's ability to deliver quality parts to the customer. Their study showed that there was nothing to prevent them from implementing a one piece flow or pull system approach. The team is currently taking steps to implement the new methods and redesign the work cell to fit the new requirements.

Competency

Perform an analysis of a business application of cellular manufacturing.

Success Story #3: Arvin's workers benefited from a detailed line analysis. As work cells throughout the company were changed, the Arvin teams went back to the basics:

- Workers developed a new understanding of how many products their processes were capable of running.
- Workers compared the process capacity to the customer requirements.
- Through careful analysis and standardizing the work methods, and applying "best practice" techniques, effective changes were made to the design of the work cell and the flow of work.
- The company balanced the cell cycle times to best meet the daily production requirements and maintain the best interests of the employees.
- The improved cell layouts contributed to increased efficiency and productivity.

The manufacturing business has changed. In the past, Arvin could determine the cost of production, add in the desired profit, and charge that price to the customer. Today, the customer tells Arvin the price they will pay. It is up to Arvin to find ways to produce and deliver products that will generate profits. Work cell change can be done quickly, but it must be done properly. A careful analysis of the work cell requirements, including determining the takt time and defining the standard work elements for each operator, is a critical starting point. The careful implementation of modern manufacturing techniques based on just-in-time concepts, the Toyota Production System and lean manufacturing have helped Arvin to save millions of dollars and see its business grow. Effective work cell designs are found at the heart of all of these improvement initiatives.

ν ν ν ν Assignment

To prepare for Authentic Learning Task #1: The What and Why of Cellular Manufacturing:

- Read Information Sheet: The Development of Lean Production.

- Read Information Sheet: Manufacturing Education for the Work Force.
- Read Information Sheet: Arvin Industries Case Study.
- Review work from the module *Consistent Work Methods and Build to Demand*, ALTs #3, #4, and #5.
- Read the following articles or similar ones chosen by your facilitator:
  - Kinney, Hugh D., Jr., and Leon McGinnis. "Manufacturing Cells Solve Material Handling Problems." *Industrial Engineering*, August 1987.
  - Kinney, Hugh D., Jr., and Leon McGinnis. "Design and Control of Manufacturing Cells." *Industrial Engineering*, October 1987.

- Take a virtual tour of a manufacturing operation. Visit <http://forecast.umkc.edu/vtours/>. This site provides links to many companies producing a variety of different products. As you tour, look for cellular manufacturing examples and possible applications. Be patient! There are a many links here, and some are better than others. Have some fun, and enjoy your virtual visit.

Diagnostic Assessment Sheet: Manufacturing Work Cell Design

Participant:____ Date:_________________________

Although this is not a test, your responses will help your facilitator provide a learning experience that meets your needs and helps you attain your goals.

- Describe your previous industrial work experience.

- Was your industry experience in a cellular or non-cellular environment? Describe.

- Write a short definition of each term:
  - ☐ takt time
  - ☐ cycle time
  - ☐ one piece flow
  - ☐ work cell
  - ☐ standard work
  - ☐ Toyota Production System (TPS)

- Describe your previous experience with team problem solving.

Information Sheet: The Development of Lean Production

Manufacturing companies in the United States face competitive challenges that place demands on the workforce, including global competition, the information revolution, new materials and processes, and time-based issues. The quest for more competitive manufacturing operations has been going on for years. U.S. companies have lost major market shares—even whole product segments—to international competition that did not even exist just a few years ago. During the 1980s, companies scrambled to figure out what was happening in Japan and to try to replicate the Japanese systems in their plants. Hundreds of executives and managers made the trip to Japan to see first hand what was taking place. Programs in statistical process control (SPC), quality circles, and eventually total quality management (TQM) took over in many companies. In some companies, *everyone* was sent to SPC training class. Quality—and a system to implement it—is important, but these quality programs and classes do not make an entire manufacturing enterprise effective. The search for a "magic potion" continued. Companies were looking for something that could somehow transform traditional manufacturing employees into a highly effective and competitive manufacturing force.

During the late 1980s, the idea of *just-in-time* (JIT) production, a manufacturing concept developed in Japan following World War II, became the big idea championed in manufacturing operations across the country. The focus of JIT is on the elimination of all waste. Robert Hall's book, *Attaining Manufacturing Excellence*, presented many readers with their first summary of the "Seven Wastes" that are the target of elimination in a JIT process.

Waste of overproduction: Make only what is needed now—reduce setup time, synchronize quantities and timing between steps, compact layout.

Waste of waiting: Synchronize work flow as much as possible, balancing uneven loads by using flexible workers and equipment.

Waste of transportation: Establish layouts and locations to make transport and handling unnecessary. If possible, reduce what cannot be eliminated.

Waste of processing: Question why a part should be made at all—why is this process necessary?

Waste of stocks: Reduce stocks by reducing setup times and lead times. Reducing other wastes reduces stocks.

Waste of motion: Study motion for economy and consistency. Economy improves productivity. Consistency improves quality. Be careful not to just automate a wasteful operation.

Waste of making defective products: Develop process to prevent defects from being made. Accept no defects and make no defects. Make the process fail safe.

Many plants in the U.S., however, took a narrow view of JIT and placed emphasis on the timing of material deliveries. Parts were planned to arrive just in time, and in the proper sequence to support the production schedule. The just-in-time approach to manufacturing is, however, much more than just an ordering plan that schedules material deliveries at the time of need. Refer to the JIT definition from APICS: The Education Society for Resource Management.

just-in-time (JIT): A philosophy of manufacturing based on planned elimination of all waste and on continuous improvement of productivity. It encompasses the successful execution of all manufacturing activities required to produce a final product, from design engineering to delivery, and includes all stages of conversion from raw material onward. The primary elements of just-in-time are to have only the required inventory when needed; to improve quality to zero defects; to reduce lead times by reducing setup times, queue lengths, and lot sizes; to incrementally revise the operations themselves; and to accomplish these activities at minimum cost. In the broad sense, it applies to all forms of manufacturing—job shop, process, and repetitive—and to many service industries as well. Synonym: short-cycle manufacturing, stockless production, zero inventories. *APICS Dictionary, 9th Edition, 1998.*

Savings claims for the JIT manufacturing approach include reduced inventory levels, reduced work-in process inventory, shorter manufacturing lead times, and increased responsiveness to customers. Shorter lead times help compress schedules and lead to less work-in-process material. Elimination of any non-value added activity leads to spending less time and money. The streamlined processes work better and faster because the waste has been removed.

Implementing JIT has always been a challenge for manufacturing companies. Successful JIT manufacturing is the result of a lot of dull, boring, and methodical—but highly effective—work in the plant and with the material suppliers that support production. However, the savings and changes do not work if the management team only "announces" that the operation is now JIT. It is easy to start the change process to JIT and see significant improvements quickly, but it is more difficult to sustain the JIT philosophy over a longer period of time. By the mid-1990s, JIT was considered to be "old news," and the search for something newer and better continued. Nevertheless, the philosophy of JIT remains rock solid, supported by concepts of how work should be done and operations should be organized. These excellent ideas have been able to withstand the test of time and application in a variety of different environments.

One of the currently popular trends in manufacturing is *lean production*, *lean manufacturing*, or some other adaptation of the production system made famous by the Toyota Motor Manufacturing Company. On the surface, the Toyota system seems to be just a collection of the best ideas about manufacturing from the past 25 to 30 years, including JIT. But, there is more to this latest collection of techniques.

The comprehensive system for manufacturing created at Toyota in Japan by Taiichi Ohno is commonly known today as the *Toyota Production System*. When pressed by American executives about the source of this revolutionary system, Ohno is reported to have laughed and said he learned it all from Henry Ford's book, *Today and Tomorrow*, first published in 1926. Take a look at this manufacturing classic, and you will see the similarity between the visions of Ford and Ohno.

Ford's factories implemented a new system of production and produced quality automobiles at prices that nearly every worker could afford. The Ford system led to fantastic productivity improvements that allowed car prices to be cut in half and worker wages to double. Norman Bodek of the Productivity Press commented in the preface to the new printing of Ford's book:

> (Ford) insisted that work environments be spotlessly clean; that business leaders think in terms of serving their communities and society at large; that production techniques not be taken for granted but continuously change and improve. He said that primary industries should help their suppliers and service industries to produce cheaper and better products in less time; and that managers should not remain in their offices but should walk around, know their workers, and be capable of doing the work themselves. He emphasized that workers should be trained and have the opportunity to better themselves and make product improvements.

These sound operational ideas have withstood the test of time.

James Womack and a team of educators from MIT completed a major study of the automobile industry and published their findings in a landmark book, *The Machine That Changed the World*, in 1992. This book provides a look at the history of the auto industry and the tremendous changes that have taken place since 1975, and most significantly collects the various tools and philosophies together under the popular title of "lean manufacturing." The heart of lean manufacturing is the careful control of resources to eliminate waste throughout all parts of an operation and its organization. This concept is exemplified by Toyota.

lean manufacturing: A philosophy of production that emphasizes the minimization of the amount of all the resources (including time) used in the various activities of the enterprise. It involves identifying and eliminating non-value adding activities in design, production, supply chain management, and dealing with the customers. Lean producers employ teams of multi-skilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in potentially enormous variety. Synonym: lean production.
APICS Dictionary, 9th Edition, 1998.

James Womack and Daniel Jones teamed up again in 1996 to write a follow up book titled *Lean Thinking* that has helped to package and organize the important concepts about the Toyota approach to manufacturing. *Lean Thinking* lays out five fundamental principles that summarize the lean production concept.

1. Precisely specify the value of a specific product.
2. Identify how the value is actually realized by the customer.
3. Make value flow without interruptions.
4. Allow the customer to pull value from the producer.
5. Pursue perfection. Continuously improve.

Womack has since founded the Lean Enterprise Institute. Through the Institute, Womack and his followers are leading the crusade for lean production. They are concerned with the way many companies approach the implementation of the lean principles. Americans are notorious for searching for the quick fix, and not taking the actions to assure problem elimination. Too often, American companies skip over the critical work of describing or mapping the value stream and really understanding it. The Lean Enterprise Institute develops training materials to help people implement "lean" the right way. The latest information from the Lean Institute can be found at their web site: <www.lean.org>.

Information Sheet: Manufacturing Education for the Work Force

Companies have seen some short term savings by quickly applying the tools of lean production. However, an important key to long term success is to truly understand the product's value and the related value stream—from the customer back to the producing company and even the company's suppliers. The concept of *lean thinking* leads to ongoing improvements and savings that are not possible any other way.

American companies tend to be impatient with process changes. They often omit the critical steps of understanding a product's value and mapping the *value stream* for all product families. The value stream includes all the actions required to bring a product from conceptual design to the hands of the customer:

- problem solving
- design analysis
- the transformation process
- procurement
- distribution
- all related information systems

APICS—The Education Society for Resource Management (formerly known as the American Production and Inventory Control Society) reported in 1993 that too often companies do not invest in the development of their people or teach them about new innovations in manufacturing. Workers need to learn and understand more about the techniques and fundamentals of manufacturing that impact them. Companies must face the challenge of teaching their employees about new approaches to manufacturing that may rattle the foundation of traditional manufacturing.

In central Indiana, more than 30 companies have formed an education and development network. The network participants meet monthly for training presentations to share their lean production experiences and to learn from each other. Some companies have been working on implementing the principles of lean manufacturing for several years, but most want to learn how to do it in order to gain the long term benefits of lower cost, less inventory, and faster response times demanded by the customers. The lean principles seem so logical, but they can be difficult to implement and sustain.

The APICS report contends that education and training should be "embedded in the workplace." Perhaps this is where the current lean movement can make a lasting impression. Hands-on education and learning by doing is at the heart of the Toyota system and lean production. The modern manufacturing environment provides workers with education, training, and tools, and empowers them to evaluate their operations and implement meaningful changes. Companies that have been successful implementing the new methods, whether they are called "lean," or "synchronous," or something else, have gotten their employees actively involved in learning and in implementing the changes. A skilled workforce that understands the issues and techniques of effective manufacturing is the critical basis for proper implementation of changes needed in manufacturing. As increasing complexity of the production environment places new demands on workers, workforce development becomes a necessity for manufacturing companies.

Information Sheet: Manufacturing Education for the Work Force, page 2

The following list presents actual course topics that could be part of a company's employee education and development program supporting modern manufacturing practices:

- statistical process control (SPC), total quality control (TQC), and continuous improvement
- production measurements
- work cell design and cell design parameters
- material management and procurement
- supplier development and communications
- production scheduling preventative maintenance and maintenance management

Companies need to learn how to create and sustain a work environment that develops employee skills and empowers them to change and improve their processes and procedures. Employee education and training helps develop the skills needed to select the right tools to solve a problem.

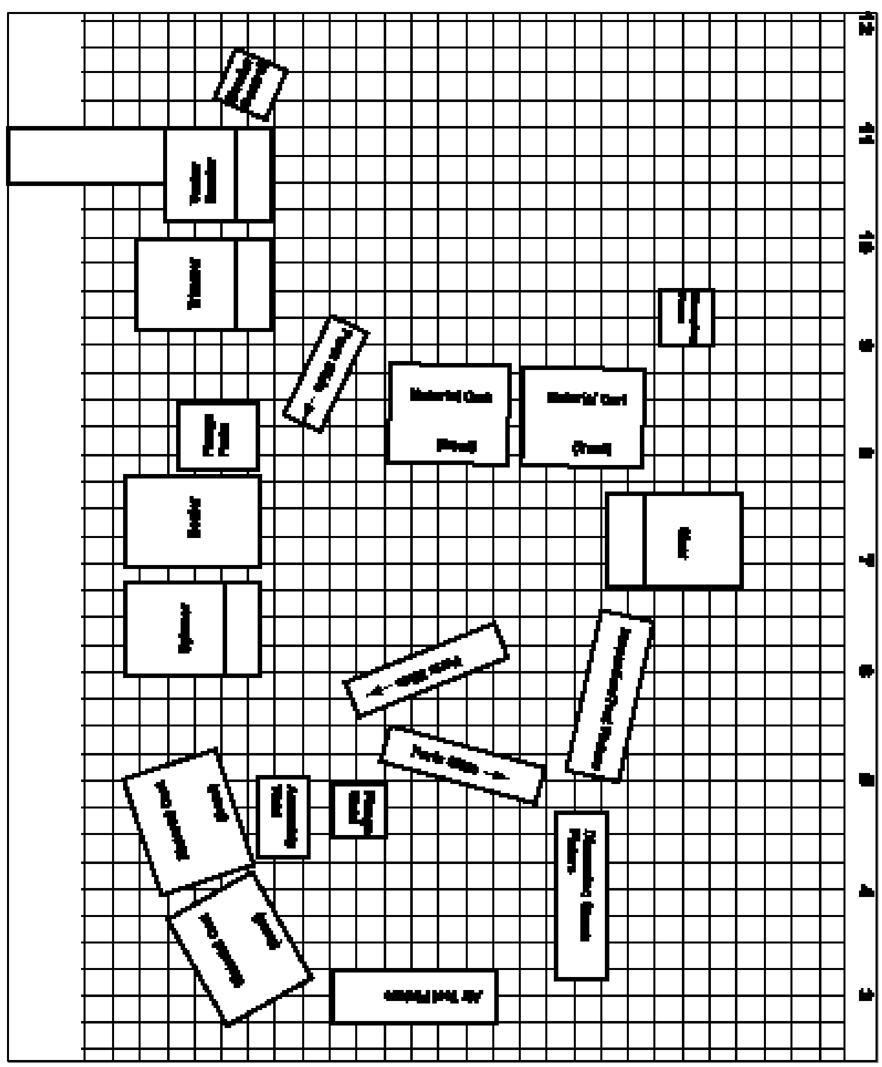
The roles of workers and supervisors in the work place are continuing to change. In the past, workers were encouraged to "leave their brains at the door" and just do what they were told. Production operations went on for many years without the benefit of the experience and knowledge of the people that made the processes work. Today, the supervisor plays a more important leadership and support role in a manufacturing operation. She or he must do much more than give orders. The supervisor in a modern operation works as a "facilitator" and "coach," working *with* the production operators and helping them do their jobs. This approach can unlock new potential and capabilities in workers and production operations.

Information Sheet: Arvin Industries Case Study

Arvin Industries, now a division of ArvinMeritor Corporation, is a supplier of exhaust systems to all the major automobile companies. In the early 1990s, the company was faced with rising costs and a shrinking market. The crisis led to a new management team and a major initiative to implement new manufacturing methods to reduce labor content, work-in-process inventory, and throughput times in an effort to reduce costs. Arvin management used these examples to help them sell the need for change and demonstrate that the new changes really worked. These stories are evidence of the spark that started the fire of change and ongoing improvement in work cell design at Arvin.

A typical exhaust systems work cell before the crisis is shown in the figure below.

- The work to bend, flare, assemble, weld, and test an exhaust system is done by six operators.
- Chute type conveyors are used to slide material from one operator to another.
- Each square in the grid represents one square foot.

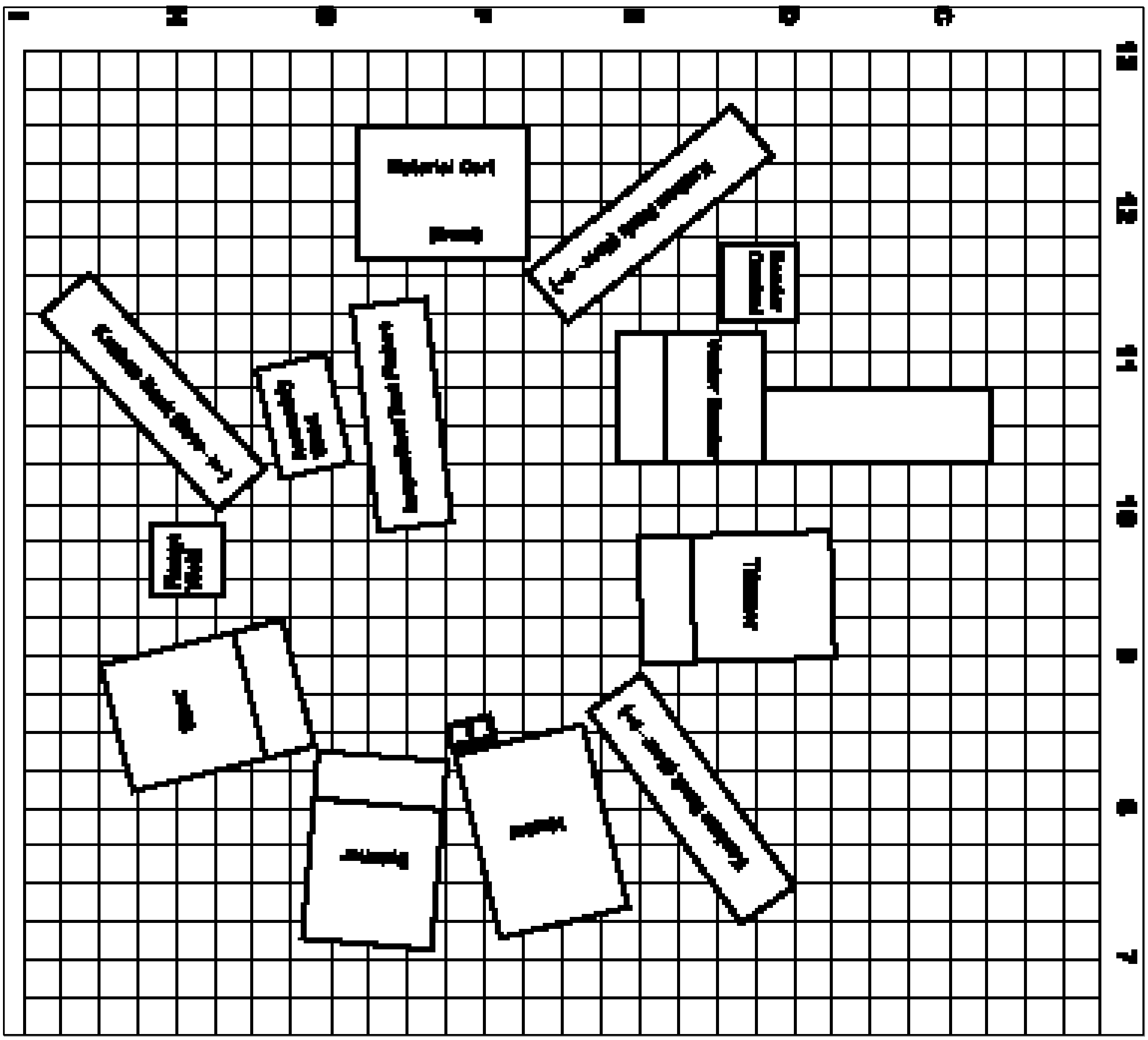


initial layout

Information Sheet: Arvin Industries Case Study, page 2

The work cell layout on the previous page had been used at Arvin for years. Workers were conditioned to expect large containers of work-in-process inventory in their work areas. The operators assigned to the cell actually worked more as individuals than as a team. Workloads at each of the six workstations were not well balanced. The result was a work area that had high inventory and fairly low output.

Operators were given training in work cell design and modern manufacturing methods that eliminate waste and give workers more control of the process. As a result, the work area was redesigned based on the worker recommendations. The revised work cell is shown below.



improved layout

The results are clear! The work is now done with only three operators. The space between machines has been reduced. Most of the containers holding the excess work-in-process inventory have been eliminated along with conveyors that had become a barrier to the flow of work through the cell. There are still opportunities for additional changes that will continue to reduce the distances and amount of handling. The three person cell was much more effective and helped create products at a competitive cost.

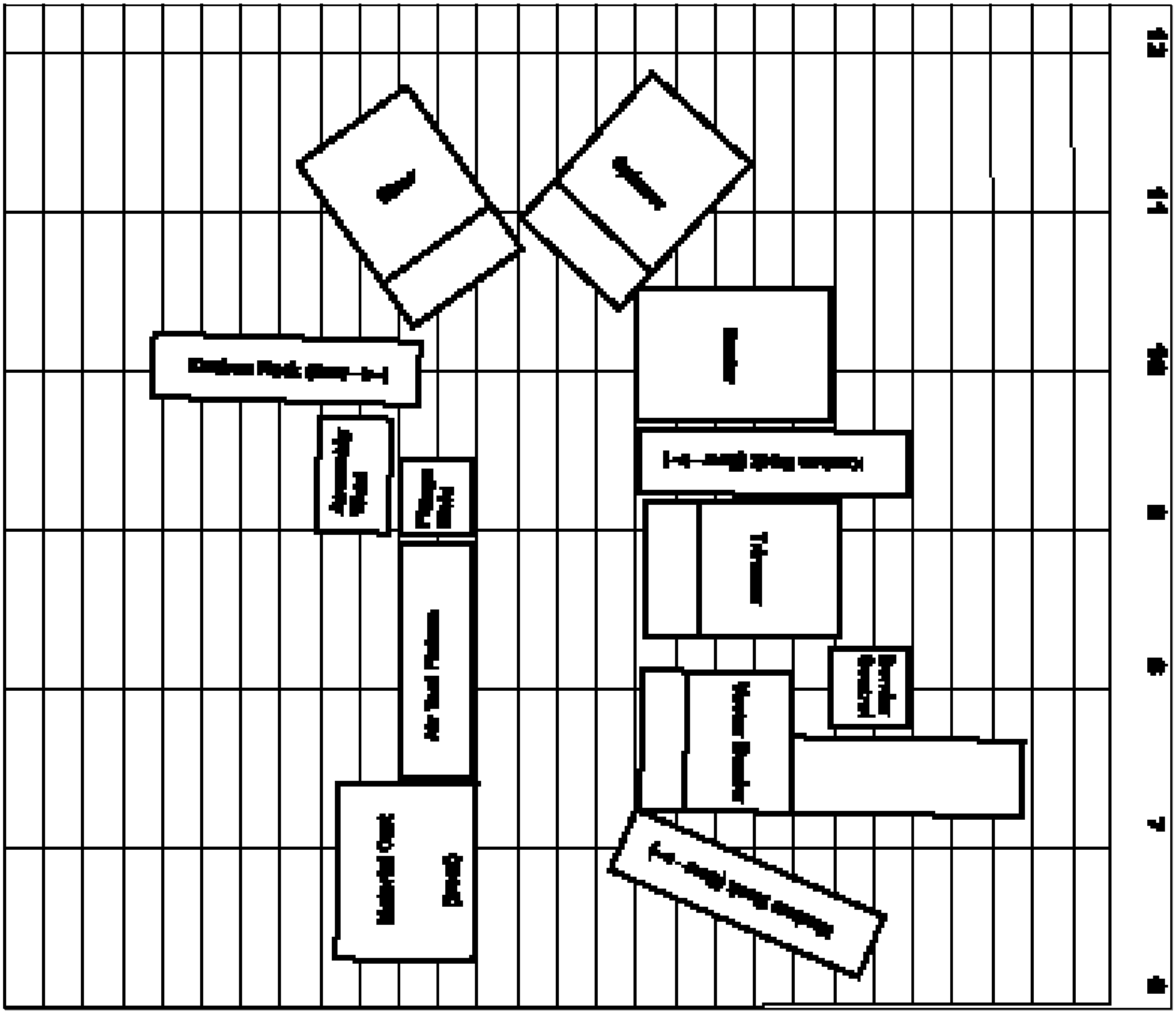
Floor space reductions: Note the significant savings—almost 50% reduction in floor space—that result from the improvements to the work cell design. Nearly half of the original space is now open for new work.

The space that was made free as a result of the more compact layout is now available to be filled with a new production cell. Without the space reductions, any new business would have required a significant investment in new manufacturing space. Following the changes to the current work cell, a new cell producing new products was installed in the existing free space. The key is to use the space no longer needed for the original work cell to generate new revenue and new profits.

The Arvin case study illustrates how a company in a desperate situation was able to make a significant turnaround in operating performance through the redesign of its work cells. It also demonstrates that real improvements can be achieved through the development of the employees and their careful redesign of the areas they work in every day. The changes made did not change the physical processes used to produce the parts. The primary focus of the redesign was to eliminate wastes of motion, transportation, and waiting. Operator workloads were balanced at a level that satisfied the takt time determined to meet the customers' requirements and address the waste of overproduction. The example presented brings the cell staffing down from six to three.

Has the cell been optimized with three operators? NO. There are still savings to be made with additional analysis and work. The industrial engineers working on this project came up with some additional changes that, with some additional expense, would reduce a critical machine cycle time and simplify the handling and positioning work required.

The diagram on the following page shows the result of these additional changes and improvements that led to a cell design that could be operated with one person and still satisfy the takt time.



one person layout

The improvement at Arvin was significant, and Arvin is not unique. The problems faced at Arvin are very common in industry. The implementation of work cells provides a sound solution to production problems not only in manufacturing, but also in many other types of business. Effective work cells are an important part of the competitive potential for many companies, and manufacturing professionals can expect to see this trend continue into the future.

Authentic Learning Task #1: The What and Why of Cellular Manufacturing

ν ν ν ν Overview

In the business world, having a great idea is not always enough. It is also imperative to have the skills to describe the idea, explain its benefits, and identify the means to realize it.

In this Authentic Learning Task (ALT), you develop a more specific understanding of the critical characteristics of a work cell. Through direct involvement in stating the case for cellular manufacturing methods, you develop an understanding of and commitment to the principles of cellular manufacturing. In addition, you connect your experiences by sharing your perspectives with others.

After completing this ALT, you should be able to demonstrate the following competency:

- Present and discuss the significance of key terms and concepts related to work cell design and operation (Comp. 1).

ν ν ν ν Safety and Disposal

No special safety or disposal procedures are required.

ν ν ν ν Activity

1. Your facilitator will form teams of four participants.
2. With your team, develop a list of *work cell details*, answering the question: "What are the defining characteristics of a manufacturing cell?" Record your work on a flip chart. Refer to the assigned readings and record important terms and concepts you find on Data Sheet: Work Cell Related Terminology.
3. With your team, construct a *list of the benefits* provided by work cells. Make sure you record them on the flip chart and on Data Sheet: Benefits of Cells, as well. Also, discuss possible challenges to work cell implementation and complete Data Sheet: Work Cell Implementation Challenges.

4. Your facilitator will bring teams back together for a group discussion.
5. With your team, complete Instruction Sheet: Extending the Use of Cells at Arvin.

ν ν ν ν Assignment

Completing This ALT

To demonstrate achievement of the competency from this ALT:

- Give a six minute team presentation about extending the use of work cells at Arvin Industries.

Preparing for Next ALT

To prepare for Authentic Learning Task #2: Work Cell Design:

- Read Information Sheet: Seven Steps to Successful Cellular Design.
- Read an article or chapter from *Making Manufacturing Cells Work*, by Lee R. Nyman, editor (1993), or other appropriate source.

ν ν ν ν Assessment

Your facilitator may use Assessment Sheet: The What and Why of Cellular Manufacturing to evaluate your performance and record whether you have adequately demonstrated the competency developed in the ALT.

The Classic Seven Wastes are:

- waste of overproduction
- waste of waiting
- waste of transportation
- waste of processing
- waste of stocks
- waste of motion
- waste of making defective products

The Benefits of JIT are:

- reduced inventory
- high quality
- shortened product lead time
- reduced production floor space
- lower total cost

Information Sheet: Work Cell Definition

A manufacturing work cell is a small group of machines and/or work centers, grouped together physically and tooled appropriately to accomplish the production of a family of parts or end products. Often, a cell is designed to accommodate a range of output rates via flexible staffing levels and task assignments.

A manufacturing cell relies upon the ingenuity and problem solving skills of its workforce to maintain high levels of productivity and quality. Those who make plant-wide scheduling decisions regard the cell as a single resource or department. Movement of material within the cell is controlled by simple visual signals.

Data Sheet: Work Cell Related Terminology

Participant:____ Date:__________________________

Create a list of work cell related terminology based on group and team discussions and your prior reading and experience.

Data Sheet: Benefits of Cells

Participant:____ Date:__________________________

Create a list of benefits of work cells based on group and team discussions and your prior reading and experience.

Data Sheet: Work Cell Implementation Challenges

Participant:____ Date:__________________________

Create a list of possible challenges to work cell implementation based on group and team discussions and your prior reading and experience.

Instruction Sheet: Extending the Use of Cells at Arvin

Refer to the Industry Profile and Information Sheet: Arvin Industries Case Study from "The First Session."

Using PowerPoint® (or equivalent software), prepare a six minute presentation to deliver a persuasive and well organized case for why the company should extend its use of cells.

Presentation guidelines:

- Include no more than six slides.
- Incorporate details specific to Arvin Industries, including specific benefits and challenges that are potentially important for the company.
- Include how the experiences at Arvin can be related to other companies. Consider similar waste issues in other manufacturing cells and processes.
- Identify the issues that may be most common, and comment on how the Arvin model can be used as a guide to improvement planning in another company.

Assessment Sheet: The What and Why of Cellular Manufacturing

Participant:______________________________________ Date:________________________

Use the following rubric to evaluate the participant's performance.

Participant Deliverable	Highly Competent	Competent	Needs Improvement
Instruction Sheet: Extending the Use of Cells at Arvin, team presentation (Comp. 1)	Presentation is complete, accurate, and detailed, and shows a high level of understanding of work cells and the benefits and limitations of using cells in a specific environment.	Presentation is complete and accurate, and shows a basic understanding of work cells and the benefits and limitations of using cells in a specific environment.	Presentation is incomplete or inaccurate, and does not show a basic understanding of work cells and the benefits and limitations of using cells in a specific environment.

Comments:

Authentic Learning Task #2: Work Cell Design

v v v v Overview

A manufacturing cell is a group of work operations that are tightly sequenced and have highly coordinated work assignments. Manufacturing cells are typically, but not always, arranged in a U shape. Manufacturing cells ideally work with single piece, unidirectional flow and have a cross-trained, flexible work force.

In this Authentic Learning Task (ALT), you are introduced to the seven step model for designing a work cell by reviewing the complete design of a manufacturing cell that produces a retractable tape measure or a similar product.

After completing this ALT, you should be able to demonstrate the following competencies:

- Present and discuss the significance of key terms and concepts related to work cell design and operation (Comp. 1).
- Create an effective work cell design using a structured methodology (Comp. 2).
- Compare the theoretical design output of a production cell to its actual output (Comp. 4).

v v v v Safety and Disposal

No special safety or disposal procedures are required.

v v v v Activity

1. If possible, your facilitator will form seven teams, one for each step of the seven step process. For a smaller group, fewer teams could represent more than one step each.
2. Refer to:
    - Information Sheet: Seven Steps to Successful Cellular Design
    - Information Sheet: Sample Time Collection Form
    - Information Sheet: Sample Sequence of Events Form

3. Review the seven steps of cellular design while your facilitator demonstrates how an example product is produced using these steps.
4. Your facilitator will introduce a second example product and assign one or two steps of the seven step process to each team. With your team, present your step(s) to the entire group and describe how this seven step model can be applied to work cell design for that product.
5. With your team, complete Data Sheet: Using the Seven Step Model for Work Cell Design.

v v v v Assignment

Completing This ALT

To demonstrate achievement of the competencies from this ALT:

- Give a team presentation describing one or more steps of the seven step model.
- Turn in Data Sheet: Using the Seven Step Process for Work Cell Design.

Preparing for Next ALT

To prepare for Authentic Learning Task #3: Designing a Work Cell for Simulation:

- Locate an article or case study from the library or the Internet that describes how a company implemented effective redesign of their work cells. Write a brief summary of the article and bring it to the next session.

v v v v Assessment

Your facilitator may use Assessment Sheet: Work Cell Design to evaluate your performance and record whether you have adequately demonstrated the competencies developed in the ALT.

Information Sheet: Seven Steps to Successful Cellular Design

Manufacturers of items from small toys to huge locomotives strive to improve their operations by relentlessly seeking quality improvements and cost reductions. One method and philosophy that has been extremely successful is the trend toward using manufacturing cells instead of long assembly lines.

Converting to manufacturing cells is something that any manufacturer can accomplish by following steps successfully accomplished by many others. In order to design a successful work cell, these steps, used to group work operations into tightly sequenced steps and coordinate work assignments, should be followed as closely as possible. When completed, the manufacturing cells typically result in a U-shaped layout, with the operating end of machines facing toward the inside. Workers load and unload machines and operate the processes from the space inside the U. Support personnel work on the outside of the U to stock material and move finished items away from the cell. Communication among the operators on the inside of the U is improved through the elimination of the physical barriers that have kept them separated. Workers inside the cell can now work better as a team. Congestion and confusion related to the movement of raw materials, components, and finished products is also eliminated by getting these tasks out of the way of the production workers. A well designed work cell produces products using a single piece pull system, with a unidirectional flow that supports a cross-trained flexible work force.

The advantages of a cellular manufacturing environment over a traditional batch manufacturing environment are:

- reduced manufacturing cycle time
- reduced overall lead time
- improved product quality
- reduced material handling costs
- reduced material handling personnel
- decreased inventories with comparable output
- reduced floor space required for equivalent output
- more involved, multifunctional work force

The seven steps to successful cellular design are:

1. Rationalize the products into families.
2. Map the processes required.
3. Collect the discrete tasks required to manufacture.
4. Calculate the design takt time.
5. Calculate resource requirements.
6. Define the work operations.
7. Balance the operations.

1. Rationalize the products into families:

Understanding the products that an organization produces is always important and sometimes taken for granted. When considering a product, it is useful and educational to list all the models and options of the particular product because it demonstrates the complexity of a product and how model proliferation can complicate manufacturing operations.

Rationalizing products into like families is essential for manufacturing cells that build multiple products in the same cell, often called *mixed-model manufacturing.* The steps for grouping products into families are:

- **Group like products according to the raw materials required:** In a manufacturing cell, having the right materials in the right place at the right time is essential. When products are grouped by their requisite raw materials and subassemblies, the material supply process is more efficient and cost effective. Also, within the cell, team members who are familiar with common raw materials are more productive.
- **Group products according to the processes or skills required:** Determine the machines that are needed to perform each process required for product assembly. For example, a printed circuit board assembly cell requires soldering, and an automatic wave soldering machine may be very expensive to acquire. In that case, grouping products around that machine is more cost effective and will require less movement within the cell. In the same way, certain processes must be accomplished by highly trained personnel. Grouping processes around highly skilled people optimizes their utilization.

Rationalizing product families according to similarities in materials, processes, or skills works best when looking at the products with intuition or experience in mind.

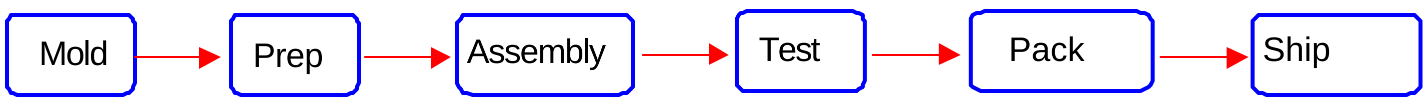
2. Map the processes required:

To understand and be able to communicate how the manufacturing process works to convert raw materials to finished products, a map of the processes is needed. A process map is a pictorial diagram, and it is a valuable tool when completing the cellular manufacturing line design because it captures the flow of material, shows the order of processing, and documents the sequence needed to complete processing.

Although there are many techniques for process mapping, a simple technique is recommended. Start with a diagram that can be revised as needed and use a medium that facilitates revision. Your diagram becomes a "living picture" subject to many iterations as analysis of the process continues. Suggestions for mapping are:

- Map the processes from left to right.
- Be sure that the *processes* are noted, not the functional departments. Use the definition of "process" as the conversion of materials—for example: mold, assemble, pack, and ship.

- Keep the diagram as simple as possible with nine or fewer processes per page.
- If further depth of process definition is required, break up processes and diagram them on other sheets, keeping the general rule of nine processes per page. Often it is helpful to print a very large, poster size picture of the process, and post it in a meeting room where all team members can study it.
- Use flow arrow symbols to map the connection of the processes from left to right. Each process should have at least one input and one output for proper material conversion to occur.
- Avoid right to left flow arrows that normally are displayed to refer to repair or rework loops. As in the example below, the best and most understandable process flows are single in direction from left to right.



example diagram of a process map

3. Collect the discrete tasks required to manufacture:

It is important to know the discrete tasks that are required to convert all the raw materials into finished products in the manufacturing operation.

The information needed includes:

- a way to identify and keep track of all the tasks as they are listed, such as a sequence number
- the logical process where the task is currently being completed
- a description of the task itself
- whether the task is value added or not from the perspective of the customer
- whether the task is a person task or a machine task, a setup to prepare to complete a task, or task that does not convert raw material, but just moves it (Designate these tasks as person, machine, setup, or move.)
- the amount of time the task takes (Depending on the manufacturing process, the units used should be minutes; however they can be seconds or hours. It is important to be consistent and accurate for all operations.)

A proven way to collect data is by observation and a simple "time collection" form. Tasks are listed along the left side along with sequence numbers. Observation numbers are listed along the top. A single piece being built follows the task list from top to bottom. This method makes it quite easy for a pair of timekeepers to take many sample time readings while a cell is operating without disrupting the cell. One person watches the process and the task list, while giving commands to take time readings to another person reading a watch and documenting the time.

After a sufficient number of samples is taken, usually more than ten and less than twenty, the elapsed time for each task can be found by subtracting the time reading for the next task minus the time reading for the current task.

Once accurate times for each task have been collected, listing them on a *sequence of events form* is valuable to understand what category the times fall into and whether or not tasks are value added or non-value added. In order to determine this, ask yourself, "Would the customer be willing to pay extra for this task?"

Three things to remember about perceived value:

- It is always from the perspective of the customer.
- It is illusive and difficult to pin down.
- It is constantly changing.

For an example, refer to Information Sheet: Sample Sequence of Events Form.

4. Calculate the design takt time:

In order to design a cell to work smoothly, and make sure the work in each operation is balanced, you need to use the demand information and available time resources to calculate the pace that the manufacturing cell must operate.

A very important quantity needed to properly design the manufacturing cell to work correctly is the takt time. *Takt* is the rhythm, or the beat on which the cell should operate. It is calculated as the amount of available time over the demand quantity. The amount of available time is the period that workers work, or machines operate. The demand is the agreed upon quantity that the manufacturing cell is designed to produce. Some cyclical or seasonal businesses may calculate takt time quarterly, or over some fixed period.

Occasionally, organization management cannot agree upon what the volume of a new product should be. In order for manufacturing to design an effective work cell, the forecast demand must be agreed upon and locked down for the future. This is usually a joint decision by the sales team, marketing, product management, and manufacturing. After the aggregate annual demand is decided and agreed upon, the number of production days in the year is counted so an average daily demand (ADD) can be calculated.

For example, a manufacturing operation building a single product, with a marketing department estimated volume of 75,000 units, plans to manufacture in a cellular environment. With a typical production schedule of 250 workdays a year, the daily requirement is 300 units per day. Also, in this production schedule, the team will work 7.3 effective work hours each day.

Yearly demand	75,000 units
Daily demand	300 units
Effective work time	7.3 hours/day

Takt time is the interval of time between successive units produced.

takt = available time / demand

takt time = available time / demand

takt time = (7.3 hours x 60 minutes/hour) / 300 units

takt time = 1.46 minutes per unit

In the example above, for a properly designed manufacturing cell to operate, the designed takt time would be 1.46 minutes. That means every 1.46 minutes another tape measure will come from the manufacturing cell on its way to the customer. Or, approximately every 1.46 minutes an in-process product will move from one operation to the next through the cell. Remember, this is a line design quantity, and the actual rate that the cell builds tape measures will depend on the actual customer orders.

5. Calculate resource requirements:

Every cell must be effectively resourced with the right number of people and the correct number of machines to complete the work at each operation to takt. This level of resources is not estimated; rather the number of resources is calculated with mathematic formulas using the takt, amount of labor and machine time, and the average daily demand.

In order to calculate resource requirements, sum up the times that have been documented. Refer to the example presented on Information Sheet: Sample Sequence of Events Form. In that example, the total of the setup times is 6.84 minutes. The total of the labor times is 24.32 minutes. The total of the machine times is 4.7 minutes, and the move time for each tool is 0.75 minutes. The total time requiring an operator is 31.91 minutes (the sum of the setup, labor, and move times).

Number of operations (workstations):

For the manufacturing cell, the designer must calculate the number of *operations* (workstations) that will be required in the cell. Later, the work content will be divided as equally as possible among these workstations.

number of operations = labor time / takt time = 31.91 / 1.46 = 21.85 (round up to 22 operations)

Always round up the number of operations to assure that there will be a sufficient number of work areas in the cell to handle the daily production requirements that come from the takt time. This is the number of workstations required to produce to the takt time and satisfy the demand.

People calculations:

The number of people needed to staff the operations and complete the work is calculated similarly.

people = labor time / takt = 31.91 / 1.46 = 21.85 people (round down to 21 people)

Always round down the number of people, so 21.85 rounds down to 21 people. The reason that we round down the number of people, is that people can move to the workstations where work is required, practicing their flexibility, to meet the daily rate of the cell.

Machine calculations:

For products that require machine time, the same equation is used.

machines = machine time / takt = 4.7 / 1.46 = 3.21 machines required

The astute observer will notice that when different machines are needed for different purposes, the cell designer must take care to keep track of different machines used and their associated times. Since the calculation above has a remainder, 0.21 machines, further analysis is required to justify the cost of the additional capacity to cover the 0.21 machine shortage if the decision to have four machines is taken. An alternative to this would be to have only four machines, but operate at least one machine more time each day to keep up with a daily rate of approximately 300 units.

6. Define the work operations:

After accurate times have been collected for all the tasks required to convert the raw material to finished products, and the takt time has been calculated, the tasks must be divided into takt-sized operations. This is most easily accomplished by making a copy of the sequence of events form tasks and combining by circling tasks to most closely equal takt. The result of combining and collecting of tasks into operations is pictured on the following page.

Detail from Information Sheet: Sample Sequence of Events Form

Seq	Task Description	VA	Setup	Labor	Machine	Move	TQC Information
28.0	Place top on assembly fixture.		0.3				
29.0	Set spring band onto winder; wind, clamp with temp clamp.			1.0	0.3		Winding count=22.
30.0	Remove spring, clamp, and place into wheel bottom.	Y	0.2	1.5			
31.0	Place spring and wheel, and spring onto top.	Y		1.0			
32.0	Attach measure tape.	Y		0.25			
32.5	Place corner hook (30-0450).	Y		1.05			
33.0	Place wristband assembly.	Y		0.1			
34.0	Wrap stop button over measuring tape in hold in-place with small spring.	Y		1.0			Verify button motion.
35.0	Remove level glass from carrier and place into top half.	Y	0.2	0.7		0.1	
36.0	Remove clamp, place bottom onto top and release measuring tape.		0.1	1.25			Tape must retract into body. Check wrist strap movement and pull tape out, and press button to retract to base.
37.0	Place 4 screws and drive into base.	Y	0.4	1.5			Torque setting to 6 in.-lb.
38.0	Clip level window over base.	Y		0.25			See that window fits flush with base.
39.0	Pull custom label from dispenser and place in recess on body top.	Y		0.2			Label must not extend outside recess.
40.0	Verify bubble level, tab movement, pull on wrist strap and rotate, pull tape out to 72" mark, press button to retract.			0.6			Wipe off any debris from body.

The result of the combining and collecting of tasks into operations is summarized in the table below.

Sequence range	Sum of time
28.0 – 29.0	1.6 min
30.0	1.7 min
31.0	1.0 min
32.0 – 34.0	1.5 min
35.0	1.0 min
36.0	1.35 min
37.0	1.9 min
38.0 – 40.0	1.05 min

Frequently, a company performs tasks in the same sequence for years. The sequence simply becomes a habit. It may be necessary to move or reorder tasks to more closely approach the takt time in order to achieve the needed operation balance.

7. Balance the operations:

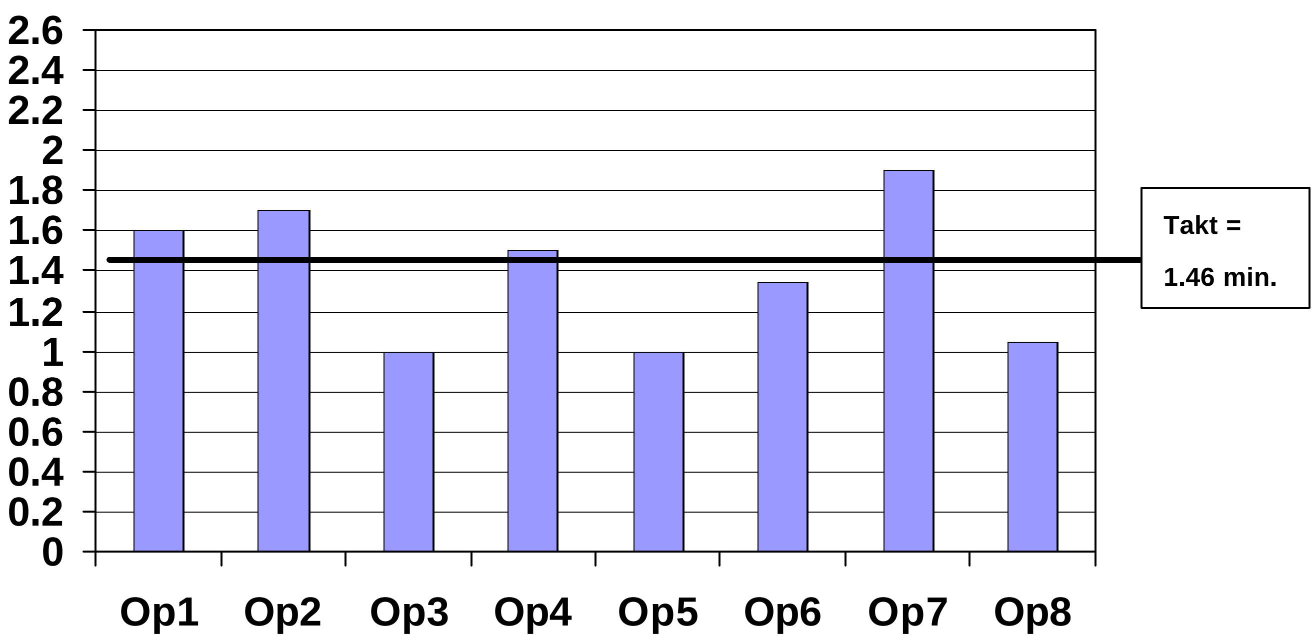
The goal is to have the amount of work in each operation as close to takt as possible. In other words, the amount of work, as defined by the cell design, must fit as closely as possible to the takt time. In order to accomplish this, the following are suggestions in the order of preference.

1. Eliminate tasks that are non-value added.
2. Move the work tasks from one operation to another.

   If the work is still not balanced at a level equal to or below the takt time:

3. Add additional work time (hours) in the day.
4. Add capital, machines, or operations, only if absolutely necessary. If you choose to add them, you must justify your decision (unless production volumes have increased significantly).

In the example on the preceding page, all the combinations of tasks exceed the takt of 1.46 minutes. Additional analysis and movement of work to different operations is required to achieve balance. In the case of the first and second tasks, a logical change is to move work from Operators 1 and 2 to Operator 3, who only has 1.0 minutes of work. (Refer to the table below.) Work from Operator 4 may shift to Operator 5, and some of Operator 7's load can move to Operator 8. This will balance all operations so they do not exceed the takt time of 1.46 minutes.



Once these seven steps are complete, the next step is to make a sketch of the U-shaped cell, developing a picture of how the workstations should be positioned.

Information Sheet: Sample Time Collection Form

Operation		Time Collection Form												
Sequence	Task Description	1	2	3	4	5	6	7	8	9	10	11	12	Time

Information Sheet: Sample Sequence of Events Form

The sequence of events form below is for the retractable tape measure.

PART NUMBER: 500-0001

Seq	Task Description	VA	Setup	Labor	Machine	Move	TQC Information
1.0	Retrieve material from shelf and load dispenser, 35-0500.		3.5				
2.0	Cut band strap with heavy scissors.			0.5			Measure length to 12" +/- 0.25".
3.0	Load new clamp into clamping machine, 30-0700.		0.25				
4.0	Overlap band over clamp and press button.	Y	1		0.2	0.1	Must be 0.25" to 0.5" overlap.
5.0	Inspect band, fold, and place in container.			0.15			
6.0	Pull required length of spring band, 25-0200, and cut.			1			Measure 72" +/- 0.5".
7.0	Insert into end prep machine 1 and press button.			0.5	0.1		Check for rounded end.
8.0	Insert other end into prep machine 2 and press button.			0.4	0.1		
9.0	Insert into notching machine 3 and press button; hang on transport hook.			0.3	0.1	0.1	
10.0	Insert measuring band (25-0001) into end prep machine and press button.		0.2	0.25	0.1		Check for rounded end.
11.0	Hold band over rivet machine 1, press button to insert annular rivet, 30-0110.	Y	0.25	0.25	0.1		Verify continuous rim on both sides of tape.
12.0	Insert tape tap (30-0020) into rivet machine 2 along with two rivets, 30-0100 and press button. Hang on carrier rack.	Y	0.4	2	0.2	0.2	Verify continuous rim for both rivets on bottom side of tape.
13.0	Load steel band stock into cutting machine, turn machine on, run to fill bin (30-0700).		0.01	0.02			Measure sample of 3/8" length.
14.0	Load steel band stock into cutting machine, turn machine on, run to fill bin (30-0450).	Y	0.02	0.03			De-burr as required.
15.0	Insert flat stock into angle press, press button to shape part (30-0450).	Y	0.01	0.02			

Table continued on the following page.

Information Sheet: Sample Sequence of Events Form, page 2

Table continued from the preceding page.

Seq	Task Description	VA	Setup	Labor	Machine	Move	TQC Information
16.0	Press activation button.			0.5	0.5		Verify correct material in hopper.
17.0	Unload top (65-0011) frame; break out pieces.			0.75			Trim any excess.
18.0	Press activation button.			0.5	0.5		Verify correct material in hopper.
19.0	Unload bottom (65-0013) frame; break out pieces.			0.75			Trim any excess.
20.0	Press activation button.			0.5	0.5		Verify correct material in hopper.
21.0	Unload wheel top (65-0211) frame; break out pieces.			0.75			Trim any excess.
22.0	Press activation button.			0.5	0.5		Verify correct material in hopper.
23.0	Unload wheel bottom (65-0251) frame; break out any excess.			0.75			Trim pieces.
24.0	Press activation button.			0.5	0.5		Verify correct material in hopper.
25.0	Unload stop button (65-0300) frame; break out pieces.			0.6			Trim any excess.
26.0	Press activation button.			0.5	0.5		Verify correct material in hopper.
27.0	Unload bubble window; break out pieces.			0.5	0.5		Trim any excess.
28.0	Place top on assembly fixture.		0.3				
29.0	Set spring band onto winder; wind, clamp with temp clamp.			1.0	0.3		Winding count=22.
30.0	Remove spring, clamp, and place into wheel bottom.	Y	0.2	1.5			
31.0	Place spring and wheel, and spring, onto top.	Y		1.0			
32.0	Attach measure tape.	Y		0.25			
32.5	Place corner hook (30-0450).	Y		1.05			

33.0	Place wristband assembly.	Y		0.1			

Table continued on the following page.

Information Sheet: Sample Sequence of Events Form, page 3

Table continued from the preceding page.

Seq	Task Description	VA	Setup	Labor	Machine	Move	TQC Information
34.0	Wrap stop button over measuring tape and hold in place with small spring.	Y		1.0			Verify button motion.
35.0	Remove level glass from carrier and place into top half.	Y	0.2	0.7		0.1	
36.0	Remove clamp, place bottom onto top and release measuring tape.		0.1	1.25			Tape must retract into body. Check wrist strap movement and pull tape out, and press button to retract to base.
37.0	Place 4 screws and drive into base.	Y	0.4	1.5			Torque setting to 6 in.-lb.
38.0	Clip level window over base.	Y		0.25			See that window fits flush with base.
39.0	Pull custom label from dispenser and place in recess on body top.	Y		0.2			Label must not extend outside recess.
40.0	Verify bubble level, tab movement, pull on wrist strap and rotate, pull tape out to 72" mark, and press button to retract.			0.6			Wipe off any debris from body.
41.0	Open box, fold in lower tab, insert guarantee, and caution into box.	Y		0.4			
42.0	Wrap wrist strap around outside of body, hold inserts to one side, and insert body into box.			0.3		0.25	
43.0	Close box tightly.			0.1			
44.0	Place unit in shipping box until full.			0.25			Verify qty 50 per shipping box.
45.0	Close box with shipping tape.			0.1			
46.0	Print shipping label and place on shipping box.			0.25			Place on lower panel; center.
	TOTALS:		6.84	24.32	4.7	0.75	

Product Totals **2,196.6 sec**

36.61 min

0.61 hr

Data Sheet: Using the Seven Step Model for Work Cell Design

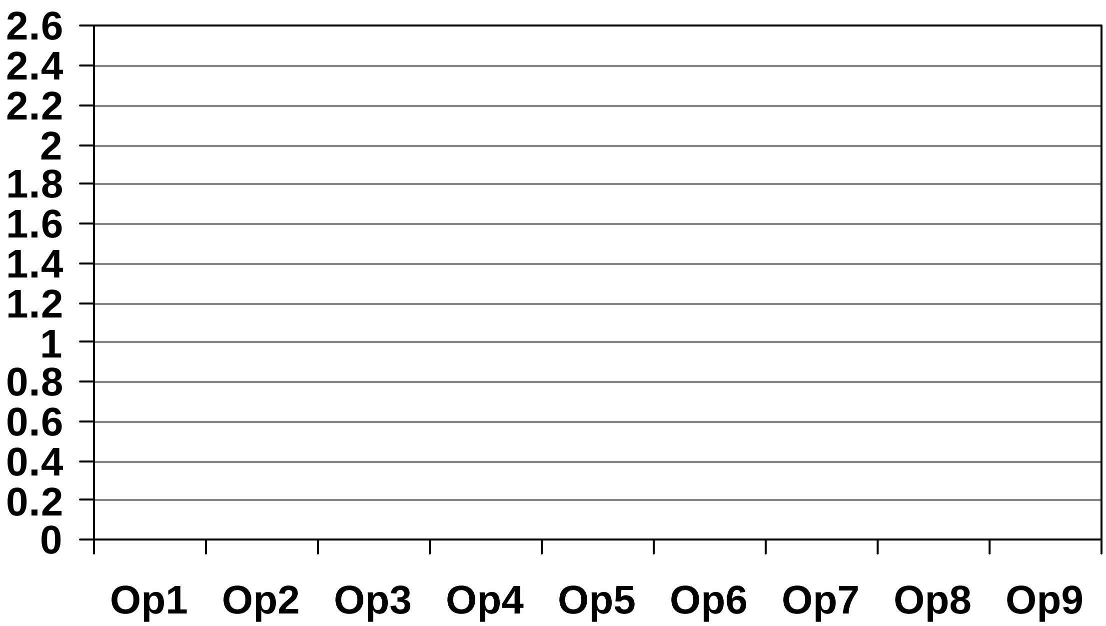
Participant:____ Date:_________________________

Refer to tasks #28–40 on Information Sheet: Sample Sequence of Events Form.

- If takt time is 1.46 minutes, combine tasks to optimize performance of the work cell.

Sequence range	Sum of time

- Balance the operations and fill in the graph below.



Data Sheet: Using the Seven Step Model for Work Cell Design, page 2

Participant:____ Date:_________________________

Briefly respond to the following questions. Support your answers by using specific examples related to either the tape measure assembly process or another example product.

- Why is it advisable to employ a step-by-step process for cell design?

- What would be the consequences of not following the steps in the process?

- What defines a sound manufacturing cell design?

Assessment Sheet: Work Cell Design

Participant:____ Date:_________________________

Use the following rubric to evaluate the participant's performance.

Participant Deliverable	Highly Competent	Competent	Needs Improvement
Team presentation (Comp. 1, 2, 4)	Presentation demonstrates a thorough understanding of the seven step model for work cell design and specific product example demonstrates ability to apply the model to a variety of products.	Presentation demonstrates a basic understanding of the seven step model for work cell design and relates specific product example appropriately.	Presentation does not demonstrate a basic understanding of the seven step model for work cell design and/or does not relate specific product example appropriately.
Data Sheet: Using the Seven Step Model for Work Cell Design (Comp. 1, 2, 4)	Answers are complete, accurate, and detailed, and demonstrate a thorough understanding of why and how work cells can be used in a variety of applications.	Answers are complete and accurate and demonstrate a basic understanding of why and how work cells can be used in a variety of applications.	Answers are incomplete and/or inaccurate and do not demonstrate a basic understanding of why and how work cells can be used in a variety of applications.

Comments:

Authentic Learning Task #3: Designing a Work Cell for Simulation

ν ν ν ν Overview

The previous Authentic Learning Tasks (ALTs) have presented research and examples of manufacturing work cell design. To begin this ALT, it is appropriate to summarize the definition of a work cell as a group of work operations that are tightly sequenced and have highly coordinated work assignments. Manufacturing cells work with single piece, unidirectional flow, and have a
cross-trained, flexible work force. The advantages of a cellular manufacturing environment over a traditional batch manufacturing environment are:

- reduced manufacturing cycle time
- improved product quality
- reduced material handling costs
- decreased inventories with comparable output
- reduced floor space required for equivalent output
- more involved, multifunctional work force

In this ALT, you create a manufacturing cell for a specific product by applying the concepts learned in previous ALTs and using the seven step model for successful work
cell design.

After completing this ALT, you should be able to demonstrate the following competencies:

- Present and discuss the significance of key terms and concepts related to work cell design and operation (Comp. 1).
- Create an effective work cell design using a structured methodology (Comp. 2).
- Construct and operate a work cell given a set of conditions including customer demand, operation time details, production volumes, and enterprise constraints (Comp. 3).
- Compare the theoretical design output of a production cell to its actual output (Comp. 4).

v v v v Safety and Disposal

No special safety or disposal procedures are required.

v v v v Activity

1. Your facilitator will form teams of four participants.
2. Review Information Sheet: Seven Steps to Successful Cellular Design from ALT #2.
3. With your team, complete Data Sheet: Work Cell Design, which includes:
    - Data Sheet: Time Collection Form
    - Data Sheet: Sequence of Events Form
    - Data Sheet: Grid Paper

4. Give a team presentation demonstrating and discussing your work cell designs. Explain the choices you made to balance the work operations. Discuss which options are the most efficient, or have the greatest or least cost.

v v v v Assignment

Completing This ALT

To demonstrate achievement of competencies from this ALT:

- Turn in article summary.
- Turn in Data Sheet: Work Cell Design.
- Turn in Data Sheet: Time Collection Form.
- Turn in Data Sheet: Sequence of Events Form.
- Turn in Data Sheet: Grid Paper.
- Give a team presentation to demonstrate and discuss your work cell design.

Preparing for Next ALT

To prepare for Authentic Learning Task #4: Comparing Theoretical Output to Actual Output of a Cell, read:

- Information Sheet: Calculations
- Terms and Definitions: Work Cells

v v v v Assessment

Your facilitator may use Assessment Sheet: Designing a Work Cell for Simulation to evaluate your performance and record whether you have adequately demonstrated the competencies developed in the ALT.

Data Sheet: Work Cell Design

Participant:____ Date:__________________________

Apply the seven step model to the K'nex® wagon or similar product.

1. Rationalize the product into families. Your job is to create a cell that produces two models of the wagon. The two models are identical, except that one model uses the long length and large wheels, and the other uses the medium length and the small wheels. Explain your rationalization.

2. Map the processes required. (Hints for some possible processes to be mapped: handle assembly, body assembly, bracket assembly, final assembly, inspection 1, wheel assembly) Refer to the example on Information Sheet: Seven Steps to Successful Design, page 3 from ALT #2.

3. Collect the discrete tasks required to manufacture the wagon. Use Data Sheet: Time Collection Form. Once accurate times for each task have been collected, list them on Data Sheet: Sequence of Events Form, and designate each task as value added or non-value added.

Data Sheet: Work Cell Design, page 2

Participant:____ Date:__________________________

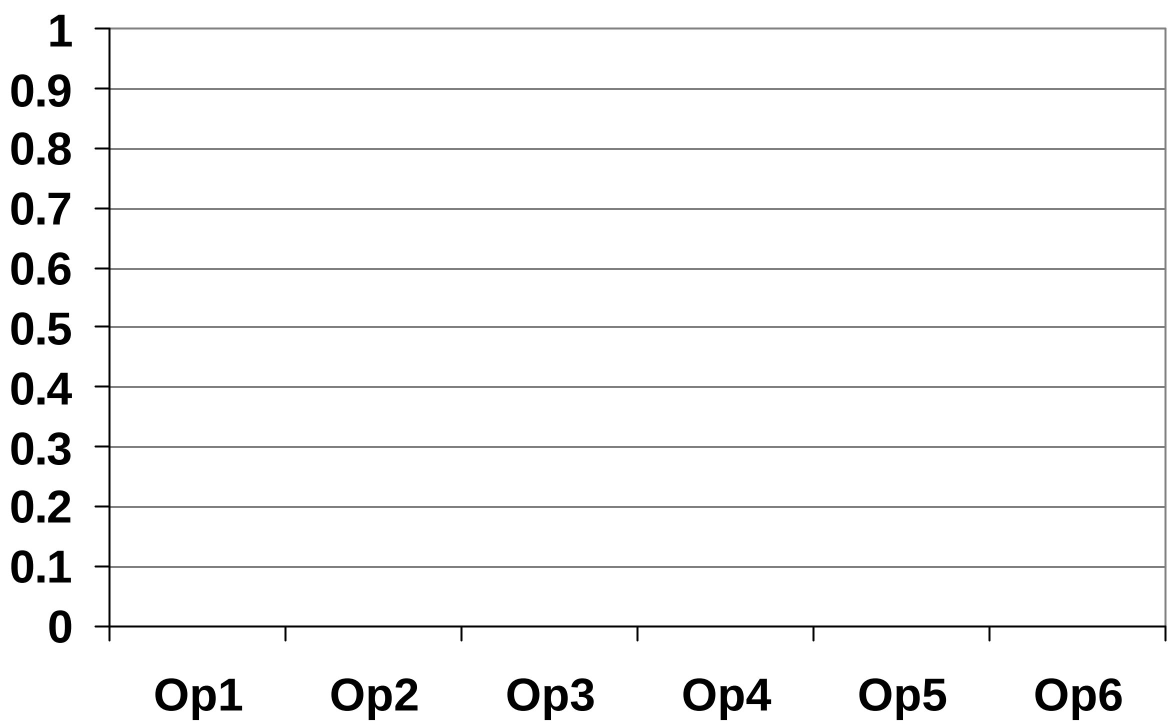
4. Calculate the takt time. Show your calculations.

Yearly demand	150,000
Daily demand	600
Work days per year	250
Effective work time	7.3

5. Calculate resource requirements. Show your calculations.

Participant:____ Date:_________________________

6. Define the operations. Refer to completed Data Sheet: Sequence of Events Form.
   a. Circle the tasks to capture the amount of time in each operation to equal takt as closely as possible.
   b. Use the rules for balancing work time, if needed.
   c. Create a graph showing the amount of work time in each operation. Then plot the takt time on the graph as a horizontal line. Identify any problem areas.



   d. Compare the time “buckets” to takt and balance as closely as possible.

Data Sheet: Work Cell Design, page 4

Participant:____ Date:_________________________

7. Balance the operations (work allocation of each operator). The goal is to have the total amount of work assigned to each operator be close to (but not over) the takt time. Use the graph below to record the assigned work sequence numbers and the total time allocated for each operator.

   Keep the following suggestions in mind as you assign the required operations to the calculated number of operators in the cell:

   a. Eliminate tasks that are non-value added.

   b. Move the work tasks from one operation to another.

   If the work is still not balanced at level at or below the takt time:

   c. Add additional work time (hours) in the day.

   d. Add capital, machines, or operations, only if absolutely necessary. If you choose to add them, you must justify your decision (unless production volumes have increased significantly).

Operator	Sequence Range	Sum of Time

8. Draw the manufacturing cell using Data Sheet: Grid Paper or a separate sheet of graph paper. After the initial drawings of the cell are complete, consider what changes could be made to improve the cell design before actually moving furniture around and building the cell. On a separate sheet of paper, describe your proposed changes and explain your choices.

Data Sheet: Time Collection Form

Participant:______________________________ Date:____________________

Operation		Time Collection Form												
Sequence	Task Description	1	2	3	4	5	6	7	8	9	10	11	12	Time

Data Sheet: Sequence of Events Form

Participant:____ Date:_________________________

PART NUMBER:

Seq	Task Description	VA	Setup	Labor	Machine	Move	TQC Information

Table continued on the following page.

Data Sheet: Sequence of Events Form, page 2

Participant:____ Date:_________________________

Table continued from the preceding page.

Seq	Task Description	VA	Setup	Labor	Machine	Move	TQC Information

Table continued on the following page.

Data Sheet: Sequence of Events Form, page 3

Participant:____ Date:_________________________

Table continued from the preceding page.

Seq	Task Description	VA	Setup	Labor	Machine	Move	TQC Information

Data Sheet: Grid Paper

Participant:____ Date:_________________________

Draw the manufacturing cell. Indicate the flow of production.

Title:
GraphPaper
Creator:
Aldus Freehand 4.0
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

Assessment Sheet: Designing a Work Cell for Simulation

Participant:____ Date:_________________________

Use the following rubric to evaluate the participant's performance.

Participant Deliverable	Highly Competent	Competent	Needs Improvement
Article summary (Comp. 1, 2)	Summary clearly describes the methods used by a company to implement effective work cell design, and comments on how the seven step model has been applied or altered to meet the company's needs.	Summary clearly describes the methods used by a company to implement effective work cell design.	Summary does not clearly describe the methods used by a company to implement effective work cell design.
Data Sheet: Work Cell Design (Comp. 1–4)	All steps for designing a work cell are complete; calculations are accurate; cell design is realistic, practical, highly efficient, and cost effective.	All steps for designing a work cell are complete; calculations are accurate; cell design is realistic and practical.	Not all steps for designing a work cell are complete, or calculations are inaccurate; cell design is not realistic or not practical.
Data Sheet: Time Collection Form (Comp. 1–4)		Times are recorded completely and accurately.	Times are not recorded, or are not complete and accurate.
Data Sheet: Sequence of Events Form (Comp. 1–4)		Form is complete and accurate. All tasks are listed and designated as value added or non-value added; times are recorded and descriptions are detailed.	Form is incomplete or inaccurate. Not all tasks are listed, and/or they are not designated as value added or non-value added; times are not recorded and/or descriptions are not detailed.
Data Sheet: Grid Paper (Comp. 1–4)	Work cell design demonstrates effective use of collected data and excellent application of work cell concepts such as workspace allotment, operator assignments, and balance of operations.	Work cell design demonstrates effective use of collected data and application of work cell concepts such as workspace allotment, operator assignments, and balance of operations.	Work cell design does not demonstrate effective use of collected data and/or application of work cell concepts such as workspace allotment, operator assignments, and balance of operations.
Team presentation (Comp. 1–4)	Presentation is clear, professional, and demonstrates excellent understanding of work cell design.	Presentation is clear and demonstrates essential understanding of work cell design.	Presentation is not clear and/or does not demonstrate essential understanding of work cell design.

Comments:

Authentic Learning Task #4: Comparing Theoretical Output to Actual Output of a Cell

ν ν ν ν Overview

A manufacturing work cell is designed to perform effectively and efficiently. Cell designers strive to build manufacturing cells that perform in practice very close to the theoretical, or estimated, output of production. However, since most designs are done on paper before they are actually put to the test, it is important for designers to know how to use data to predict the real output of a work cell. It is also important to be able to understand and explain probable reasons why or why not the theoretical and actual results are sometimes different.

In this Authentic Learning Task (ALT), you use data to compare the theoretical output of a cell to its actual production.

After completing this ALT, you should be able to demonstrate the following competencies:

- Present and discuss the significance of key terms and concepts related to work cell design and operation (Comp. 1).
- Compare the theoretical design output of a production cell to its actual output (Comp. 4).

ν ν ν ν Safety and Disposal

No special safety or disposal procedures are required.

ν ν ν ν Activity

1. Your facilitator will form teams of four participants.
2. Work with your team to complete Data Sheet: Comparing Theoretical and Actual Output.

Assignment

Completing This ALT

To demonstrate achievement of competencies from this ALT:

- Turn in Data Sheet: Comparing Theoretical and Actual Output.

Preparing for Next ALT

To prepare for Authentic Learning Task #5: Change Management for Cellular Implementation:

- Read the following articles, or similar ones chosen by your facilitator:
  - □ "Competing Ideas: Team Based Manufacturing" by Wayne Chaneski in *Modern Machine Shop*, September 1998. Online at <www.mmsonline.com/articles/0998ci.html>
  - □ "Competing Ideas: Implementing Work Cells" by Wayne Chaneski in *Modern Machine Shop*, February1999. Online at <www.mmsonline.com/articles/0299ci.html>
  - □ "Competing Ideas: Manufacturing Cells Support Lean Production" by Wayne Chaneski in *Modern Machine Shop*, October 1998. Online at <www.mmsonline.com/articles/1098ci.html>

- Locate and read one article (or a chapter in a book) on the subject of implementing cellular manufacturing. Write a brief summary or outline (1 page) of the article, noting important concepts. Make one copy of the summary for each participant, and bring to the next session. Bring a copy of the article as well.

Assessment

Your facilitator may use Assessment Sheet: Comparing Theoretical Output to Actual Output of a Cell to evaluate your performance and record whether you have adequately demonstrated the competencies developed in the ALT.

Calculating the difference between theoretical and actual output:

- difference = daily rate – actual production

- percent difference = (daily rate – actual production) / daily rate * 100

Terms and Definitions: Work Cells

actual output: The actual number of units produced by the operation over a specific time period. This is the output of the cell that has actually been demonstrated by the production department.

backlog: The accumulation of negative difference for a specified period of time.

actual production: The quantity produced during a specified period considering external influences. These influences sometimes limit production and may include machine down time, people shortages due to illness or vacation, material shortages, power outages, etc. When actual production does not meet the required **daily rate**, hours may need to be extended and overtime paid to catch up. For prolonged periods, additional cells can be added.

daily rate: The amount of production required each day to satisfy customer requirements. For example, a total production quantity of 25,000 units that is to be completed in 20 workdays results in a required daily rate of 1,250 units each day. The rate at which the cell must operate to meet customer requirements.

design rate: The rate that the cell was designed to produce based upon sales forecasts and documented work from the time analysis.

new daily rate: Prior days' **backlog** + today's **daily rate**. Changes in demand may require the **daily rate** to be recalculated and a new takt time determined. New production requirements and any unsatisfied requirements from a prior contract or production order may need to be added together to get the new total requirements. These total requirements are then divided by the scheduled number of workdays to determine the new **daily rate**.

theoretical output: Another description for the **design rate** of the cell. Represents the maximum output expected from a process during a specified period of time. It does not consider delays or other quality problems. It is a true maximum value. In actual practice, this value will probably never be achieved.

Data Sheet: Comparing Theoretical and Actual Output

Participant:____ Date:_________________________

- Complete the following tables from the information provided.

Yearly demand	150,000 units
Average daily demand	600 units
Effective work time	7.3 hours/day

DAILY PRODUCTION REPORT			
	Daily Rate	**Actual Production**	**Cause**
Day 1		555	
Day 2		580	
Day 3			
Day 4			
Day 5			

- Transfer data from the Daily Production Report to the Production Planning Report.

PRODUCTION PLANNING REPORT							
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Week 2**	**Week 3**
Design Rate	600	600	600	600	600	600	600
Daily Rate	560	575	610	580	575	550	560
Actual Production							
Difference							
% Difference							
New Daily Rate							

Data Sheet: Comparing Theoretical and Actual Output, page 2

Participant:____ Date:_________________________

- Determine the new daily rate required to make up for any production shortcomings by the end of the week.

- What are some possible reasons for a difference between the daily rate and actual production?

- What can be done to reduce the difference between daily rate and actual production?

Assessment Sheet: Comparing Theoretical Output to Actual Output of a Cell

Participant:____ Date:__________________________

Use the following rubric to evaluate the participant's performance.

Participant Deliverable	Highly Competent	Competent	Needs Improvement
Data Sheet: Comparing Theoretical and Actual Output (Comp. 1, 4)		Calculations are complete and accurate. Reasons are identified, and solutions are realistic.	Calculations are incomplete and/or inaccurate. Reasons are not identified, and/or solutions are not realistic.

Comments:

Authentic Learning Task #5: Change Management for Cellular Implementation

v v v v Overview

Creating a successful cell requires more than a solid technical design. It also requires expanding the skills and orienting the attitudes of the cell operators. The truly successful project also requires new methods of performance measurement, new scheduling practices, and new approaches to problem solving.

In this Authentic Learning Task (ALT), you develop a more specific understanding of the implementation issues for work cells.

After completing this ALT, you should be able to demonstrate the following competencies:

- Develop project plans for work cell implementation and operator training (Comp. 5).
- Perform an analysis of a business application of cellular manufacturing (Comp. 6).

v v v v Safety and Disposal

No special safety or disposal procedures are required.

v v v v Activity

1. Your facilitator will form teams of four participants.
2. Refer to the three articles you read. Working on the flip charts, create a list of the major tasks required to implement cells within a business. Generate a set of broad categories (for example, training, equipment purchase, communication) and also identify subtasks (for example, training a cell team on the use of their performance measurements).
3. Your facilitator will bring the entire group back together and have you compare your outcomes.
4. Distribute the copies of your article summaries to one another. Present a brief (two minute) summary of your article.
5. During these presentations, add to your flip chart task lists. Then reassemble in your teams, and review your lists and consolidate key points.

6. Your facilitator will bring the entire group back together and review and expand the list of tasks and subtasks needed for effective cell implementation.
7. With your team, develop an outline for a project plan for implementation and training using realistic time estimates for each task.
8. Complete Data Sheet: Effective Cell Implementation.
9. Present your project plan outline to the group with justification for your time estimates.

v v v v Assignment

Completing This ALT

To demonstrate achievement of the competencies from this ALT:

- Give a team presentation to present your project plan outlines with justification for time estimates.
- Turn in Data Sheet: Effective Cell Implementation.

Preparing for the Transfer Activity

To prepare for the Transfer Activity:

- Read and review the Transfer Activity, including all information sheets and data sheets.
- Consider the given data and identify the critical issues you will need to address in order to design an effective work cell for this assembly. Identify the information you can use and also what new information you will need to complete the job.

v v v v Assessment

Your facilitator may use Assessment Sheet: Change Management for Cellular Implementation to evaluate your performance and record whether you have adequately demonstrated the competencies developed in the ALT.

Data Sheet: Effective Cell Implementation

Participant:____ Date:_________________________

Refer to your project plan outline for implementing cells within a business and answer the following questions.

- Are there tasks for which the duration seems difficult to estimate? Why?

- What are the most likely problems during a cellular implementation project?

- Will some tasks require specialized expertise? Explain.

- Who must be involved in each task? Explain.

Assessment Sheet: Change Management for Cellular Implementation

Participant:____ Date:_________________________

Use the following rubric to evaluate the participant's performance.

Participant Deliverable	Highly Competent	Competent	Needs Improvement
Project plan outline team presentation (Comp. 5, 6)	Presentation is complete, accurate, and detailed, and shows a high level of understanding of issues and problems related to implementing work cells including training needs, physical facilities, utilities, ergonomic considerations, equipment selection, cross-training, etc.	Presentation is complete and accurate, and shows a basic understanding of issues and problems related to implementing work cells including training needs, physical facilities, utilities, ergonomic considerations, equipment selection, cross-training, etc.	Presentation is incomplete and/or inaccurate, and does not show a basic understanding of issues and problems related to implementing work cells including training needs, physical facilities, utilities, ergonomic considerations, equipment selection, cross-training, etc.
Data Sheet: Effective Cell Implementation (Comp. 5, 6)	Answers are accurate and explanations are clear and detailed. Demonstrates a thorough understanding of issues related to cell implementation.	Answers are accurate and explanations are appropriate. Demonstrates an understanding of issues related to cell implementation.	Answers are inaccurate or incomplete and explanations are not appropriate. Does not demonstrate an understanding of issues related to cell implementation.

Comments:

Transfer Activity: Cells Rock!

ν ν ν ν Overview

As the culminating activity of the module, the Transfer Activity provides an example of a typical situation you may encounter in your career.

Designing an effective work cell requires a lot of attention to detail and a fair amount of digging for all the necessary information. Your challenge now is to demonstrate your work cell design abilities for a product you may be familiar with—the AF-H-2000 end effector by Robotic Grippers, Inc. (RGI). In this Transfer Activity, you apply what you have learned to design a work cell for the assembly of the RGI gripper assembly AF-H-2000.

You apply the following competencies developed in the Authentic Learning Tasks (ALTs):

- Present and discuss the significance of key terms and concepts related to work cell design and operation (Comp. 1).
- Create an effective work cell design using a structured methodology (Comp. 2).
- Construct and operate a work cell given a set of conditions including customer demand, operation time details, production volumes, and enterprise constraints (Comp. 3).
- Compare the theoretical design output of a production cell to its actual output (Comp. 4).
- Develop project plans for work cell implementation and operator training (Comp. 5).
- Perform an analysis of a business application of cellular manufacturing (Comp. 6).

ν ν ν ν Safety and Disposal

No special safety or disposal procedures are required.

ν ν ν ν Activity

In this Transfer Activity, you design a work cell for the assembly of the AF-H-2000. Your deliverables are:

- Data Sheet: Equipment Templates and Work Floor Grid, including sketches of any fixtures, tools, or material handling devices not included in the templates
- Data Sheet: Work Cell Specifications
- team presentation

1. Your facilitator will form teams of up to four participants.
2. Refer to:
   - Information Sheet: Robotic Gripper Assembly Drawing (The parts list from the title block is shown on the page following the drawing. CAD drawings are available in the Robotic Grippers, Inc. information at <www.aimcenter.org>)
   - Information Sheet: Parts List
   - Information Sheet: Production Structure for the AF-H-2000 Gripper Assembly
   - Information Sheet: Estimated Assembly Operation Times in Seconds
3. With your team, review the data and identify the critical issues you need to address in order to design an effective work cell for AF-H-2000 gripper assembly.
4. Develop a plan for the most effective work cell design based on a streamlined flow of materials, workers, and information. This plan should be specific for the AF-H-2000 gripper and the specified production rate.
5. Refer to Data Sheet: Equipment Templates and Data Sheet: Work Floor Grid. Define the design specifications for the new RGI assembly cell by working with the templates to balance the work at each workstation, consistent with takt time and your estimates for material handling.
6. Given a takt time of 200 seconds, calculate the number of operators needed in the cell.
7. Prepare a sketch, drawn to approximate scale, of any fixtures, tools, or material handling devices not included in the templates provided.
8. If time permits, prepare standard work instructions for each operator.

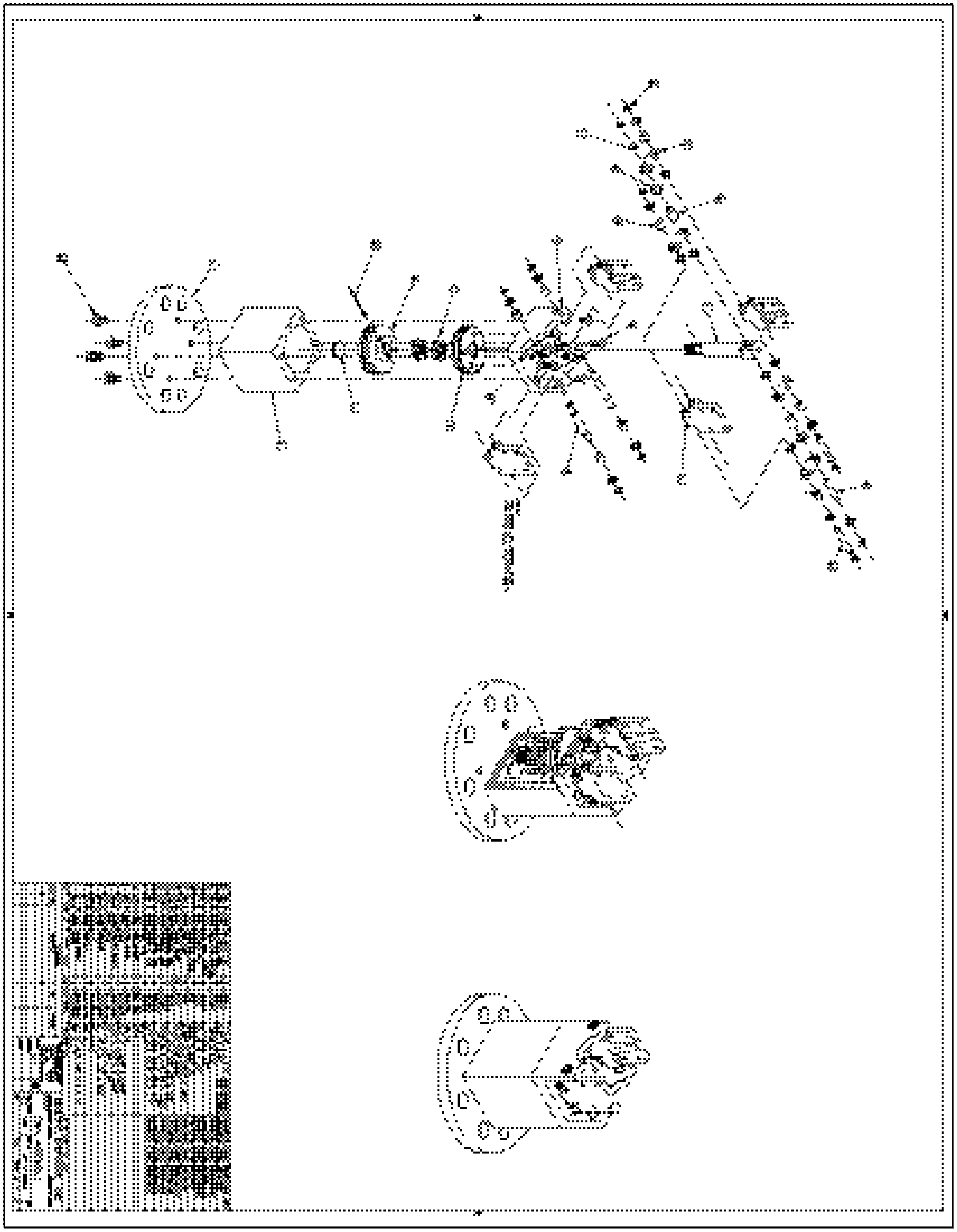
9. Create a scale drawing of the work cell Data Sheet: Equipment Templates and Data Sheet: Work Floor Grid.

10. Complete Data Sheet: Work Cell Specifications.
11. Give a brief presentation of your work cell design to the group.

ν ν ν ν Assessment

During the Transfer Activity, you work in a team to apply competencies developed in the ALTs. Your facilitator will use the rubric provided to evaluate the application of competencies. Use the assessment sheets provided to evaluate your own teamwork skills and those of your team members.

Information Sheet: Robotic Gripper Assembly Drawing



NO.	PART #	PART NAME	QTY	MATERIAL	DESCRIPTION	PURCHASE ITEM NO.
23	[illegible]	O-RING, LRG	4	VITON	1 3/4" X 1 7/8" (NOT SHOWN)	McMASTER-CARR #[illegible]
22	[illegible]	O-RING, SML	2	VITON	3/8" X 3/4" (NOT SHOWN)	McMASTER-CARR #[illegible]
21	[illegible]	HEX CAP SCREW	4	NYLON	10-32 X 3/8"	McMASTER-CARR #[illegible]
20	[illegible]	HEX CAP SCREW	8	NYLON	1/4-20 X 1/2"	McMASTER-CARR #[illegible]
19	[illegible]	COTTER PIN	1	STEEL	Ø1/16" X 1 1/2"	McMASTER-CARR #[illegible]
18	[illegible]	WASHER, HEX	1	PVC	Ø.832" X .320" HT	McMASTER-CARR #[illegible]
17	[illegible]	SIL. RING	2	PVC	Ø.489" ID X .515" X .201"	McMASTER-CARR #[illegible]
16	[illegible]	SNAP RING	10	STEEL	10 FOR 1/4" SHAFT	McMASTER-CARR #[illegible]
15	[illegible]	WASHER, SML	18	NYLON	1/4" ID X 3/8" OD X 1/32"	McMASTER-CARR #[illegible]
14	[illegible]	WASHER, LRG	8	NYLON	5/16" ID X 1/2" OD X 1/32"	McMASTER-CARR #[illegible]
13	[illegible]	BEARING, SML	8	BRONZE	1/4" ID X 5/16" OD X 1/4"	McMASTER-CARR #[illegible]
12	[illegible]	BEARING, LNG	2	BRONZE	1/4" ID X 5/16" OD X 1/2"	McMASTER-CARR #[illegible]
11	CT-N-2002	PIN, MED	1	303 SS	Ø1/4"	
10	CT-N-2001	PIN, SHORT	3	303 SS	Ø1/4"	
9	CT-N-2003	PIN, LONG	2	303 SS	Ø5/16"	
8	FA-L-2001	LINK	4	ALUMINUM	3/4" X 1 5/8" X 3/16"	
7	CA-P-2002	PISTON SHAFT	1	ALUMINUM	1/2" X 1/2" X 3 3/16"	
6	FA-A-2001	ARM	2	ALUMINUM	2" X 2 1/8" X 1/2"	
5	BA-D-2001	CRADLE	1	ALUMINUM	2 1/2" X 2 1/2" 2 5/8"	
4	CA-C-2001	CAP	1	ALUMINUM	Ø2" X 1/2"	
3	CA-P-2001	PISTON	1	ALUMINUM	Ø2" X 1"	
2	BA-B-2001	MAIN BODY	1	ALUMINUM	2 1/2" X 2 1/2" X 2 3/4"	
1	BA-S-2001	BASE	1	ALUMINUM	Ø5" X 1/2"	

ROBOTIC GRIPPERS, INC.

FINAL ASSEMBLY

DJR

NTS

AF-N-2100

SHEET 2 OF 2

Information Sheet: Production Structure for the AF-H-2000 Gripper Assembly

Assembly structure combining transient levels of the BOM:

Item Number	Description	Qty Req	
AF-H-2000	**Final Assembly**		**Note**: AV-B-2002 is a transient in AF-H-2000
AV-P-2001	Piston Cradle Assembly	1	
DA-S-2001	Base	1	
BA-B-2001	Main Body	1	
VS-Q-2001	Screw, hex cap steel	4	
VS-G-2001	Snap Ring	4	
VB-E-2001	Bearing, long	4	
DN-W-2001	Washer, thin	4	
CT-N-2003	Pin, long		2
AV-P-2001	**Piston Cradle Assembly**		**Note**: AV-D-2001 is a transient in AV-P 2001
AU-A-2001	Arm Piston Shaft Assembly	1	
SR-T-2002	Top Stop		2
CA-P-2002	Piston	1	
VR-O-2002	O-ring	4	
SR-T-2001	Bottom Stop	1	
VT-N-2001	Cotter Pin	1	
BA-D-2001	Cradle	1	
CA-C-2001	Cap	1	
VR-O-2001	O-ring, small	2	1/2 x 5/8 #AS568A014 from McMaster
VN-Q-2002	Screw, socket cap	4	
AU-A-2001	**Arm Piston Assembly**		
FA-A-2001	Fingers	2	
CT-N-2002	Pin, medium	2	
VB-E-2001	Bearing, short	4	
DN-W-2001	Washer, thin	8	
VS-G-2001	Snap Ring	4	
CT-N-2001	Pin, short	2	

Information Sheet: Production Structure for the AF-H-2000 Gripper Assembly, page 2

Assembly structure combining transient levels of the BOM (continued):

SU-L-2001	**Link Piston Shaft Assembly**	
CA-P-2002	Piston Shaft	1
FA-L-2001	Link	4
VS-G-2001	Snap Ring	2
DN-W-2001	Washer, thin	4
DN-W-2002	Washer, thick	2
VB-E-2002	Bearing, long	2
CT-N-2002	Pin, medium	1

Information Sheet: Estimated Assembly Operation Times in Seconds

SU-L-2001 subassembly step description—refer to Link Piston Shaft Assembly.	**Est. Time in SECONDS**
1. Pick up piston shaft and insert in fixture.	4
2. Insert Pin (medium) into fixture and apply snap ring.	5
3. Build stack up onto pin.	
a. Washer, thin	5
b. Link	3
c. Washer, thick	3
4. Slide bearing onto the pin and fit through hole in the washer and the link.	3
5. Slide another link onto the bearing.	3
6. Add a thin washer to the pin.	3
7. Insert the pin through the hole in the piston shaft.	5
8. Add a thin washer.	3
9. Add a link.	3
10. Insert a bearing onto the pin and through the hole in the link.	5
11. Add a thick washer.	3
12. Add the last link sliding it onto the bearing.	3
13. Add a thin washer.	3
14. Install retaining clip.	5
15. Aside into rack.	4
	63
AU-A-2001 subassembly step description—refer to Arm Piston Assembly	
1. Insert link piston assembly (SU-L-2001) into holding fixture and position links as in drawing.	4
2. Insert pin (medium) into fixture and apply snap ring.	5
3. Build stack up onto pin.	
a. Washer, thin	5
4. Slide bearing into the hole in the link.	5
5. Insert pin stack up through hole in the bearing.	5
6. Slide on a thin washer.	5

7. Position a finger between the links and push the pin into the finger, but not through.	5

Information Sheet: Estimated Assembly Operation Times in Seconds, page 2

AU-A-2001 subassembly step description—refer to Arm Piston Assembly (continued)	**Est. Time in SECONDS**
8. Insert a thin washer on the opposite side of the finger and push the pin through the washer and into the hole in the next link.	7
9. Add another bearing onto the pin and through the hole in the link.	5
10. Add a thin washer to the pin.	5
11. Install retaining clip.	5
12. Rotate the piston shaft assembly 180 degrees and repeat the process to add the remaining finger.	4
13. Repeat.	52
	112
AV-P-2001 subassembly step description—refer to Piston Cradle Assembly	
NOTE: *AV-D-2001 Cradle Assembly is a transient in AV-P-2001*	
1. Insert O-ring in to groove on the circumference of the Cap (CA-C-2001).	6
2. Assemble Cap to Cradle using 4 nylon screws (VN-Q-2002) to complete the cradle assembly (transient).	16
3. Pick up Arm Piston assembly AU-A-2001 position it on the bench with the shaft end pointing up.	4
4. Insert the top of the cradle assembly on to the shaft. Make sure the U is pointing toward the fingers.	6
5. Insert 2 rib rings (SR-T-2002) onto the shaft.	7
6. Insert the piston (CA-O-2001) onto the shaft.	5
7. Visually align the hole through the side of the piston and the hole through the end of the shaft.	4
8. Insert the cotter pin through the holes. Make sure the key end of the pin is seated inside the outer edge of the piston. Flair the opposite end of the cotter pin into the groove in the perimeter of the piston.	10
9. Install bumper (SR-T-2001) onto the end of the shaft.	5
	63
AF-H-2000 final assembly step description—refer to Body Cradle Assembly and Final Assembly	
NOTE*: AV-B-2001 Body Assembly is a transient in AF-H-2000*	
1 Assemble the base (DA-S-2001 and the main body (BA-B-2001) using 4 steel screws (VS-Q-2001) to complete the body assembly (transient).	20

2. Insert the Piston Cradle Assembly (AV-P-2001) into the body.	6

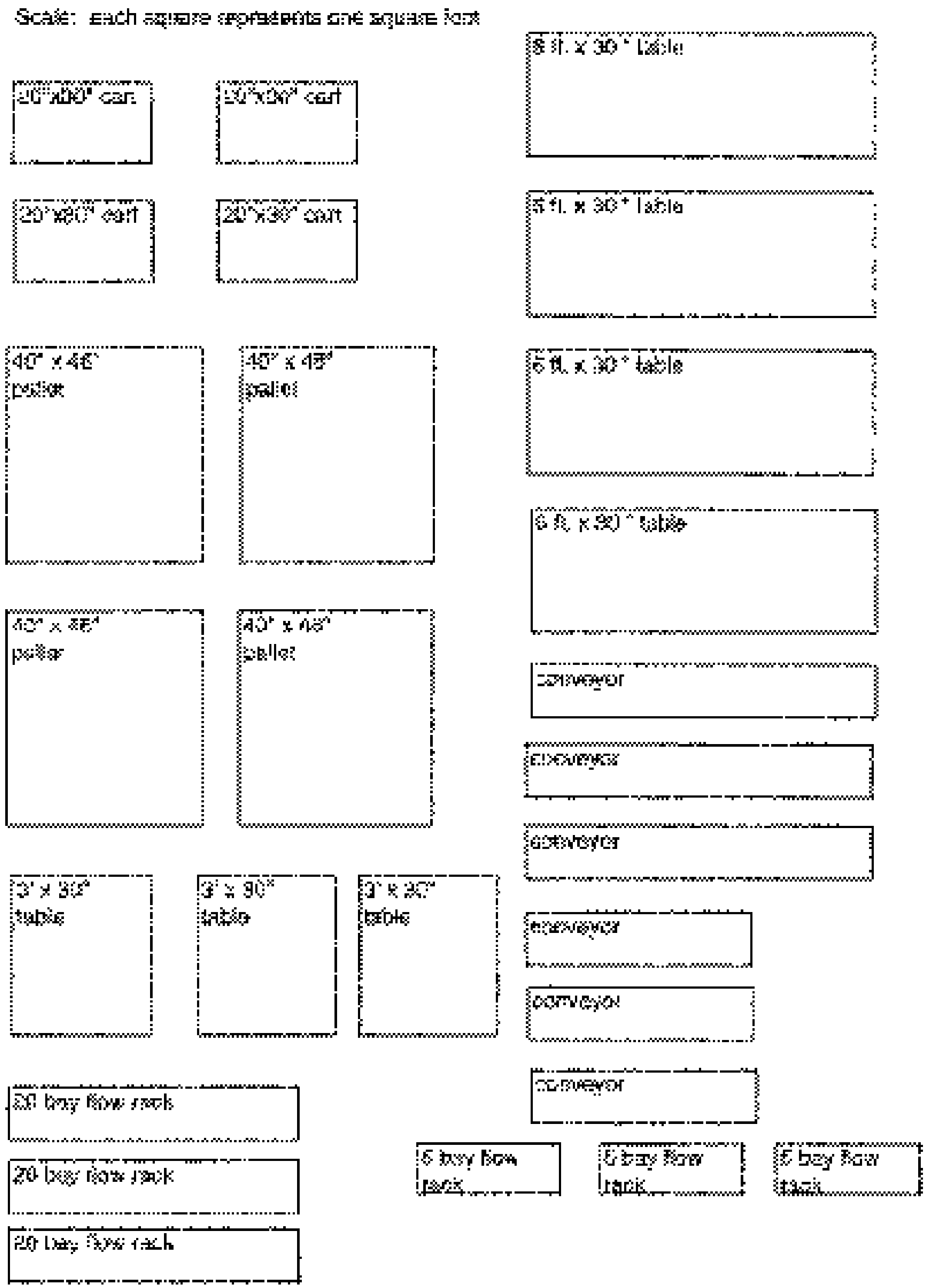
Information Sheet: Estimated Assembly Operation Times in Seconds, page 3

AF-H-2000 final assembly step description—refer to Body Cradle Assembly and Final Assembly drawings (continued)	**Est. Time in SECONDS**
***NOTE**: AV-B-2001 Body Assembly is a transient in AF-H-2000*	6
3. Pick up a long pin (CT-N-2003) and insert one end through a bearing. Add a thin washer and complete with the installation of a snap ring into the end groove. Repeat with another pin, bearing, washer, and snap ring.	10
4. Insert the open end of one of the pin assemblies into the hole at the top of the U of the cradle.	
5. Repeat on the opposite side of the gripper assembly.	16
6. Aside the finished assembly into a tote pan and move to the cell transfer station.	8
	66
Total Estimated Assembly Time	**304**

Data Sheet: Equipment Templates and Work Floor Grid

Participant:____ Date:__________________________

Cut out the equipment templates and arrange on the grid to describe the work cell. Each square on the grid represents one square foot.



Data Sheet: Equipment Templates and Work Floor Grid, page 2

Participant:____ Date:__________________________

Cut out equipment templates and arrange to describe the work cell.

Data Sheet: Work Cell Specifications

Participant:____ Date:_________________________

Team #_____________ Product: ____

Team members: ____

Annual production rate: ____________________________ Takt time: ________________

Number of workers: ________________________________ Cycle time target: __________

Brief task description:

Worker: Cycle time:
Worker: Cycle time:
Worker: Cycle time:
Worker: Cycle time:
Worker: Cycle time:
Worker: Cycle time:
Comments:

Data Sheet: Work Cell Specifications, page 2

Participant:____ Date:_________________________

- List time estimates, theoretical output calculations, and performance measurements recommended for the cell.

- In a short paragraph, describe your team's theoretical design output for this cell and the expectation you have for the actual output. Discuss where and why these two values may differ.

- Where do you see potential problems in your cell? Create a bulleted list of challenges that are specific to this assembly project. Include an assessment of the potential problem areas that might affect the cell's ability to produce at the desired rate.

Data Sheet: Work Cell Specifications, page 3

Participant:____ Date:_________________________

- Outline your team's plan for the implementation of this work cell. Identify the critical issues that need to be resolved to implement the cell and prepare the operators to run it effectively.

- What would be the consequence if the product requirements for the last half of the year doubled and the takt time dropped to 100 seconds? How could you adapt your cell to meet these new requirements?

Rubric for Evaluating the Transfer Activity

Participant:____________________________________ Date:_______________________

Participant Deliverable	Participant Task with Competency	Highly Competent	Competent	Needs Improvement
Data Sheet: Equipment Templates and Data Sheet: Work Floor Grid	Create an effective work cell layout for AF-H-2000 assembly. (Comp. 2)	Layout is complete and design is thoughtfully conceived. Presentation is professional and comprehensive. Floor space, handling, and WIP are minimal.	Layout is complete and reasonable. Use of appropriate design method is clear.	Layout is incomplete. Basic concepts of cell design have not been followed.
Data Sheet: Work Cell Specifications, work cell	Construct and operate a work cell given a set of conditions and constraints. (Comp. 3)	Specifications are complete and appropriate, and include detailed comments and a thoughtful assessment of any open issues or problems that could be addressed in a future project.	Specifications are complete and appropriate, and include an assessment that recognizes some opportunities for future enhancement.	Specifications are incomplete and/or inappropriate, and do not demonstrate an understanding of line balance.
Data Sheet: Work Cell Specifications, calculations	Compare the theoretical design output to actual output. (Comp. 4)		Calculations are complete and correct.	Calculations are incomplete and/or incorrect.
Data Sheet: Work Cell Specifications, plan	Develop a plan for work cell implementation and operator training. (Comp. 5)	Plan is well designed, complete, and presented professionally, and goes beyond the initial startup and considers ongoing improvements.	Plan covers critical elements of implementation and a basic operator training plan.	Plan is incomplete and/or explanations are not appropriate.

Rubric continued on the following page.

Rubric for Evaluating the Transfer Activity, page 2

Participant:_______________________________ Date:____________________

Rubric continued from the preceding page.

Participant Deliverable	Participant Task with Competency	Highly Competent	Competent	Needs Improvement
Data Sheet: Work Cell Specifications, time estimates, theoretical output calculations, performance measures, and challenges	Analysis of production environment and appropriate work cell design. (Comp. 1–4, 6)		Calculations, performance measures, and list of potential challenges are complete, accurate, and demonstrate a basic understanding of work cell design and function.	Calculations, performance measures, and list of potential challenges are incomplete, inaccurate, and/or do not demonstrate a basic understanding of work cell design and function.
Team presentation	Discussion and analysis of a work cell for production. (Comp. 1, 6)	Presentation demonstrates a superior command of work cell design vocabulary, terms, concepts, and applications.	Presentation demonstrates understanding and appropriate use of work cell design vocabulary, terms, concepts, and applications.	Presentation does not demonstrate understanding and appropriate use of work cell design vocabulary, terms, concepts, and applications.
Overall Assessment		**Highly Competent**	**Competent**	**Needs Improvement**

Comments:

Assessment Sheet: Participant's Team Evaluation

Participant:____ Date:__________________________

For each of the items below, circle the number that best represents your evaluation.

1. Effective Use of Time:						
7	6	5	4	3	2	1
no wasted effort; stayed on target		did well once we got our ideas clear		got off track frequently		much time spent without purpose
2. Development of Ideas:						
7	6	5	4	3	2	1
ideas encouraged and fully explored		friendly session but not creative		ideas imposed on the group by a few		little done to generate ideas
3. Ability to Decide Issues:						
7	6	5	4	3	2	1
genuine agreement and support		made compromises to get the job done		let one person rule		poor resolution of differences
4. Overall Productivity:						
7	6	5	4	3	2	1
highly productive session		just did what we had to do		barely accomplished the job		did not accomplish our goal

Team members (include yourself):	**Individual contributions to this team project:** (Allocate 100 points to your team members; be sure to include yourself. Base the allocation on your opinion of individual performance. The sum of all points allocated must equal 100.)
1.	
2.	
3.	
4.	
5.	

Suggestions and comments to the facilitator:

Assessment Sheet: Teamwork Self Evaluation

Participant:____ Date:_________________________

Read each statement below, then circle the number that best represents your experience as a team member.

(3 = agree completely; 2 = agree somewhat; 1 = disagree somewhat; 0 = disagree completely)

1. I felt comfortable working with this team.	3	2	1	0
2. I was an active participant on my team.	3	2	1	0
3. I listened to everyone on my team.	3	2	1	0
4. I encouraged and praised others on my team.	3	2	1	0
5. I explained/helped someone who didn't understand.	3	2	1	0
6. I asked for an explanation or help when I didn't understand.	3	2	1	0
7. I felt encouraged by people on my team.	3	2	1	0
8. My role was ____________________________ I felt comfortable in this role.	3	2	1	0
9. I found this group activity to be a worthwhile experience.	3	2	1	0
10. I enjoyed working with the other participants on teams.	3	2	1	0

Suggestions and comments to the facilitator:

Assessment Sheet: Facilitator's Team Evaluation

Participant:____ Date:_________________________

Read each statement below, then circle the number that best represents your evaluation of the participant as a team member.

(3 = agree completely; 2 = agree somewhat; 1 = disagree somewhat; 0 = disagree completely)

1. Is an active team participant.		3	2	1	0
• Initiates and maintains task-oriented dialogue.		3	2	1	0
• Works for constructive conflict resolution.	3	2	1	0	
• Strives for meaningful group consensus.		3	2	1	0
• Supports other team members.		3	2	1	0
• Initiates and participates in group maintenance.		3	2	1	0
2. Is responsive and effective in completing team assignments.		3	2	1	0
• Works to define the problems.		3	2	1	0
• Investigates problems.		3	2	1	0
• Works to define solutions.	3	2	1	0	
• Works to document solutions.		3	2	1	0
3. Effectively performs assigned team role.	3	2	1	0	
4. Exhibits good listening and speaking skills.		3	2	1	0

Suggestions and comments to the participant:

Facilitator:____

Closure and Generalization

After concluding the Transfer Activity, this section completes the module.

A general discussion about this module should recall and reinforce your experience of hands-on, participant centered activities and real world manufacturing as reflected in real life products. You are encouraged to look at the whole module process and consider how it is meaningful to your individual goals.

About the Authors

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