PARKER AEROSPACE

FLUID SYSTEMS DIVISION

PRODUCT SUPPORT FACILITY REDESIGN

By

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ABSTRACT

With growing popularity for commercial air travel and aerial military operations comes an increase in demand for innovative, technological solutions of aircraft system components. As OEM sales of these components rise, this creates a burden on the aftermarket side of the business when these parts and systems require service in order to continue functioning properly. Parker Aerospace, Fluid Systems Division, and its Product Support Team are experiencing this growth burden and want to reconfigure necessary means within the layout to succeed in accommodating new program areas on the aftermarket side. During this process, cost reduction opportunities will be explored and a systematic approach to facility design will be used. In this approach, the departments are initially defined before the relationships between them are to be analyzed. Space requirements are also recorded. Once these steps are complete, alternative layouts are constructed and analyzed before a final layout is chosen.

This systematic approach provides a fully analyzed facility design, taking into consideration the needs of the customer, the constraints of the company, and the total cost of implementation. Moreover, the increase in revenue due to new program areas along with cost savings provided by the layout is presented to show the economic justification of the facility redesign. Once the required steps of the facilities systematic approach are complete, the appropriate upper management at Parker Fluid Systems Division must be convinced before signing off on all necessary paperwork and eventually becoming implemented.

INTRODUCTION

The purpose of this report is to present and analyze the process leading to the implementation phase of a new facility design layout for Product Support. Parker Aerospace, Fluid Systems Division, located in Irvine, CA is experiencing considerable growth in all departments and is reconfiguring the layout of both facilities on site. This site consists of Building A and Building B. The Product Support Team (PST), the aftermarket side of this division, is located in Building B. Product Support would like to renovate their specific layout in order to accommodate space for new program areas, new business due to increased sales, pending product storage, as well as improved product flow. If space permits, they would also like to explore adding a few additional office cubicles and/or workstations to the shop floor.

In order to present a quality layout design, a variety of techniques were used such as 'Paper doll' figures, Visio Layout modeling, facilities planning, time studies, and financial analysis. Initially, paper doll cutouts were used to generate layout alternatives using an enlarged scale drawing of the space requirements per program area. Each section was cut out and placed into different configurations, like puzzle pieces, on the footprint layout model of the new Product Support area. Then, electronic layouts were created via Microsoft Visio in order to make design changes more efficiently and communicate proposed changes more effectively. Countless iterations of the overall layout as well as detailed cell layouts were made in Visio before a final layout was decided upon and approved. Next, Facilities Planning was used to analyze the flow of people, product and material through each area. Time studies are used to analyze the justification for rearranging and moving cells as well as shared resources. In order

to complete this project, concepts from several classes were used. These include Facilities Planning & Design, Human Factors Engineering, and Process Improvement Fundamentals.

The report will go into the background of the company and how the project is being applied, followed by the literature review. Next, the departments and space requirements will be analyzed in order to develop alternative layouts. Once developed, the alternatives will be closely analyzed and a layout will be chosen based on specific selection criteria and a multi-attribute analysis. The final layout and cost justification will then be summarized in the conclusion of the report.

BACKGROUND

Parker Aerospace is an entity of Parker Hannifin Corporation that designs, builds, and supports systems and components for virtually every aircraft flying today. Parker is a leading manufacturer of motion control technologies and systems. The Fluid Systems Division (FSD) in Irvine, California specializes in fuel, pneumatic and water valves as well as inerting systems, all of which help regulate the flow of fuel, air, and water within the aircraft to ensure its functionality. Parker's mission statement for its FSD site states "To be the aerospace global leader in the development, design, manufacture, and service of fluid systems and components for fuel, inerting, pneumatics, heat management, lubrication, and water applications through operational excellence while achieving our financial objectives and providing premier customer service." The Product Support division at FSD is where commercial and military product that has seen extended use in service return to the facility for maintenance, repair or overhaul.

A good analogy in understanding the function of the Product Support Team (PST) is a car dealer's service shop that directly supports the maintenance of new products they sell. After

you purchase a new car, you bring it in at different stages to be serviced; for example, a 30,000 mile check-up service. Upon dropping your car off you are provided an estimate and your car is repaired and maintained with a practical turnaround time. The PST operates similarly, only for aircraft components. Parts requiring service are taken off the aircraft and sent to Parker, as opposed to having an entire plane sent in like the car analogy. On the shop floor, there are approximately 40 technicians working in five different manufacturing cells, each dedicated to a particular type of part/process, and a machine shop that handles repair work in support of the cells. The area is managed and overseen by product support engineers, manufacturing engineers, customer support engineers, material planners, schedulers and contract administrators who ensure jobs are completed in a timely manner and abide by all federal regulations.

Speaking of timely manner, the incoming parts to be repaired are quite time-sensitive, especially for the commercial side of the business. An internal system component extracted from a plane means that the aircraft is essentially "grounded" and cannot fly. This is referred to as an Aircraft-on-Ground, or AOG. On the commercial side, an AOG contributes to decreased passenger revenue and, hence, company revenue. Thus, the PST greatly stresses a strict turn-around-time (TAT) in order to maintain customer satisfaction.

On the other hand, military components that are extracted and sent in for testing and repairs are not as urgent. This is because the military product is directly associated with the government who has a number of spare parts they can pull from while a contracted batch of parts are being serviced. The military cannot afford to have grounded aircraft that may jeopardize national security or other important aerial defense operations.

LITERATURE REVIEW

In order to put together an effective relocation plan, research must be performed of the literature pertaining to common techniques for facility design and implementation. Although facilities planning is part art and part science, it is beneficial to follow an organized, systematic approach when starting a design. This project follows the facilities systematic approach shown below in Figure 1. (Bozer, 2003)

Systematic Approach

1. Define Problem/Objective
2. Define Departments
3. Determine Relationships
4. Space Requirements
5. Generate Alternative Layouts
6. Evaluate Layouts
7. Select Layout
8. Redefine/Implement/Maintain

Figure 1: Systematic Approach

In using this step by step process, there is less chance that a critical aspect of designing the layout will be overlooked. The first step in defining the problem provides a powerful overview of the entire situation which makes it easier to achieve the desired goals. In defining departments, relationships between departments arise showing how each section of the company interacts with one another. In addition, the employees that are directly affected by a redesign change should be interviewed to gather information about their wants and needs. A cell-specific layout survey for technicians is shown in Appendix D. It is only after the gathering of information that alternative layouts are developed, evaluated, and selected. Once a layout is

decided upon, a cost analysis must be performed to justify changes. This allows management to critique problem areas and add useful insight before the project is actually installed.

In order to prove the value of reconfiguring a layout prior to implementation, proactive time studies identify potential issues earlier in the design process (Time-Study Guidelines). This type of time study has its advantages and disadvantages compared with a reactive time study which can only be used once the new facility is actually installed. Proactive time studies tend to be more abstract due to the limitations of using physical “clipboard and stopwatch” techniques which pose as an effective way to show improvements between actual and proposed layouts. Because of this, alternate techniques must be used to optimize the proposed layouts, such as string and relationship diagrams. Although time studies cannot be used to design new layouts, they *can* be used to show improvements between proposed locations. The change in locations of strong inter-dependent departments within Product Support will reduce the frequency of material transportation as well as the distance traveled for material and technicians. Time studies provide vital information about the location of actual departments within the layout itself even though they cannot show actual layout improvements (Time-Study Guidelines).

There are two basic measures that can focus a facility toward successful operation: throughput and capacity. These measures are dependent upon each other and the quicker the throughput of products, the more capacity the facility will have. The more demand we meet, the more money we make (Duggan, 31). When these measures are applied at Parker, the biggest metric of success concerning throughput is turnaround time (TAT). The inbound components received by this aftermarket shop are pulled from aircraft in service. When that part is away for servicing, much of the time, the plane becomes grounded. A plane that cannot

fly is inapt, especially for the commercial industry where passengers are the source of revenue. Therefore, Parker PST focuses on maximizing throughput through minimized TAT which will accommodate more service capacity and better customer service as a result.

One strategic approach utilized in meeting this demand and optimal TAT for its customers is the popular lean concept of cellular manufacturing. In order to do this, the products and process relationships must be understood to highlight similarities that can be grouped. The types of cells in a facility are not based on the products they produce, but the processes needed to produce or service those products (Duggan, 32). In Product Support, the cells are divided based on type – is the part military or commercial? From there, it is further specified as a fuel or pneumatic part. Once these variables are defined, the part can be placed into the appropriate cell where repair processes and resources are shared among parts. Shared resources are another key in allowing change to a facility layout. Independent workstations build flexibility into cells while shared resources can enhance efficiency and non-value added activities (Duggan, 33). For example, Cell 1 in Parker's PST shop services air turbine starters seen on helicopters and fighter jets. After a technician successfully repairs and assembles the part at their workstation, the unit must be tested. Rather than having a separate test machine at each of the 6 workstations within the cell, requiring more space and capital, a single test fixture is centrally located within the cell.

For a facility to be viewed as lean, the value stream for its products must be understood. Continuous improvement and changes to match the value stream to the current product line are necessary. However, the facility must be designed to accommodate change. The following are guidelines insisted by Parker to remain forefront in any sort of facility design so that the

layout remains lean and efficient. One of the lists pertains to general layout principles while the other presents detailed cell layout guidelines. Some, not all, of the points were utilized in the creation of PST’s layout.

FSD Cell/Area Layout Process:

- Conduct 5S prior to layout effort
- Identify 80/20 Processes required in area
    - Focus on 80/20 Processes
- Follow Ergonomics Guidelines
- Use “Math” to determine # of operators and machines
- Engage teams to identify kaizen opportunities
- Avoid creating monuments – as processes/takt changes, the layout will need to be revised

FSD General Layout Guidelines:

- Build along superhighways/Value Stream
- Keep an open line of sight, over 5 ft. should be on a wall or monument
- Design for material FLOW through facility
- Incoming and outgoing work accessible to superhighway
- Cells replenished without interfering with workforce (material and tooling)
- Process flow focus – goal is to have leadoff and final step near each other
- Initial design should be for 1 person to flow
- Consider Point of Use Tooling/Components (kitting)
- 5 to 6 feet in between benches where techs are working back to back, 4 feet otherwise

- Eliminate areas where WIP can build up

Workstation designs within the cell are a more specific example of lean and continuous improvement. Modular workstations can be rearranged quickly to create new cell configurations. However, workstations need power, compressed air, and lighting. In many cases, these are supplied by utilities in the ceiling. To keep flexibility in workstation design, independent mobility must be incorporated. A workstation should have its own lighting, but it should be independently powered with electricity and compressed air. "One method for doing this is to supply each workstation with male/female connectors that can be chained together. One workstation powered from an existing drop in the ceiling could power the workstation next to it through electrical cords and rubber air lines. This station would then power the next station in the same manner, and so on" (Duggan, 32).

Facilities design is a continuous cycle that often repeats itself in order to meet the changing objectives of the company. As so, there are many obvious benefits to creating flexible cells. The drastic reduction of material handling, inventory, and manufacturing lead-time will all save substantial costs. However, the operational benefits to a lean facility design can yield more important benefits – those that impact future growth. By using the tools previously mentioned for lean facilities design, the foundation has been established for simple operational systems that can support it.

Designing an ergonomic workstation is part of keeping employees productive and healthy. Repetitive motion should be limited; however, if inevitable the motion should be within a comfortable reaching distance. Also, technology and more ergonomically friendly equipment can be used to reduce the effects of repetitive motion (Office Ergonomics

Handbook). Employees should be trained on techniques and suggestions on how to stay comfortable at work. For example, a person's knees should be bent at approximately 90 degrees with enough space between the back of their knees and the chair (Time-Study Guidelines). A technique like this will minimize lower back pain over an extended period of time and promote better posture. Placards with these suggestions are useful to have displayed around the workplace to serve as constant reminders of proper ergonomics. In addition to supplying ergonomic techniques, workers should be encouraged to take "Micro-Breaks" that last 10 to 60 seconds every 10-15 minutes (Rowh). During these breaks, employees have the opportunity to refocus or get up to stretch. In allowing workers to take these breaks, they are able to stay focused for longer periods of time and generally produce a higher quality of work (Ross 2008). By setting up ergonomic workstations, companies can save tremendous amounts of money in medical bills while keeping their employees happy, healthy, and productive.

In the process of undergoing significant facility or layout design changes, major opportunity to reduce costs arise – specifically, material handling costs and labor costs. There has been research done on workshop layout design based on the central point of material handling. An effective layout design will reduce the cost of material handling, shorten working hours, and accelerate the turnover rate of current asset, thereby raising the competitive ability of enterprises. It has been estimated that approximately 20 to 50% of manufacturing cost is spent on material handling and it is accepted that an effective layout design could reduce this cost by 10 to 30 percent (Xiaoguang). In order to simplify the optimization of workshop layout, equipment is divided to different rectangular production cells and from there is arranged inside the cell. Based on this idea, which is similar to operations research methods, the objective

function in aiming to minimize the cost of material handling is established and the genetic algorithm method is applied in optimizing a solution (Xiaoguang).

Traditional analysis of facilities design alternative layouts uses a multi-attribute analysis where characteristics of the layouts are given weights suggesting their relative importance. However, research supports a different technique in the analysis of alternatives. The Preference Selection Index (PSI) method was developed by Maniya and Bhatt (2010) as a decision making tool for material selection problems. The main benefit of the PSI method is that there is no need to assign relative importance between attributes. In addition, it is not required to compute the attribute weights involved in decision making problems (Maniya, Bhatt). The main steps of facility design selection methodology based on the PSI method are listed below. (Maniya, Bhatt)

Step 1 – Define the problem

Step 2 – Generate alternative layouts

Step 3 – Decide the facility layout design criteria

Step 4 – Formulate the decision matrix

Step 5 – Formulate normalized decision matrix

Step 6 – Compute the mean value of normalized data

Step 7 – Compute the preference variation value

Step 8 – Determine deviation in preference value

Step 9 – Compute overall preference

Step 10 – Compute facility design selection index

Step 11 – Select appropriate layout alternative for the given application

The result comparisons from numerous practical applications show good reliability of the proposed methodology for selection of optimal facility layout design alternatives from limited numbers of facility layout design alternatives. Moreover, the proposed methodology for selection of optimal facility layout design alternative using the PSI method is a relatively logical, systematic and simple approach. The proposed methodology is easily adopted and gives similar results without considering relative importance between attributes. The PSI method can consider any number of design selection criteria and facility layout alternatives. In addition, decision makers can consider and use the proposed methodology as an alternative approach if desired for solving facility layout design selection problems (Maniya, Bhatt).

After exploring and analyzing various methodologies and techniques relevant to complete Parker's Product Support layout, an aggregate plan must be set in place in order to implement these changes. We must first use the systematic approach to facilities design and outline the plans for the facility, both in its initial and future state.

PROJECT DEFINITION

Problem Defined

Parker Aerospace is experiencing considerable growth in all departments. As part of a larger redesign, Product Support would like to renovate their layout in order to accommodate space for new aftermarket program areas, new business due to increased sales, product storage, as well as improved flow within the department. If space permits, they would also like to look into adding a few additional office cubicles and/or workstations to the shop floor.

Project Scope

For the scope of this project, all other areas and departments within the site redesign, other than Product Support, are being disregarded. The only aggregate aspect that affects this project specifically is certain departments within PST that are being relocated elsewhere. This will increase our available square footage in accommodating growth and new program areas. The specific areas for improvement within PST are defined in the following section of the report. Additionally, the office area within PST for Engineers, Contracts, and Team Leaders will be ignored, simply because there is no need for change within this part of layout.

Objectives

A project of this extent is more manageable if it can be broken down into smaller pieces and set benchmarks accordingly. After extensive meetings with my boss, the Product Support Team Leader, in addition to PST Engineers, technicians, and Parker upper management I was able to get a sense of everyone’s needs and categorize the layout project accordingly into the following deliverables.

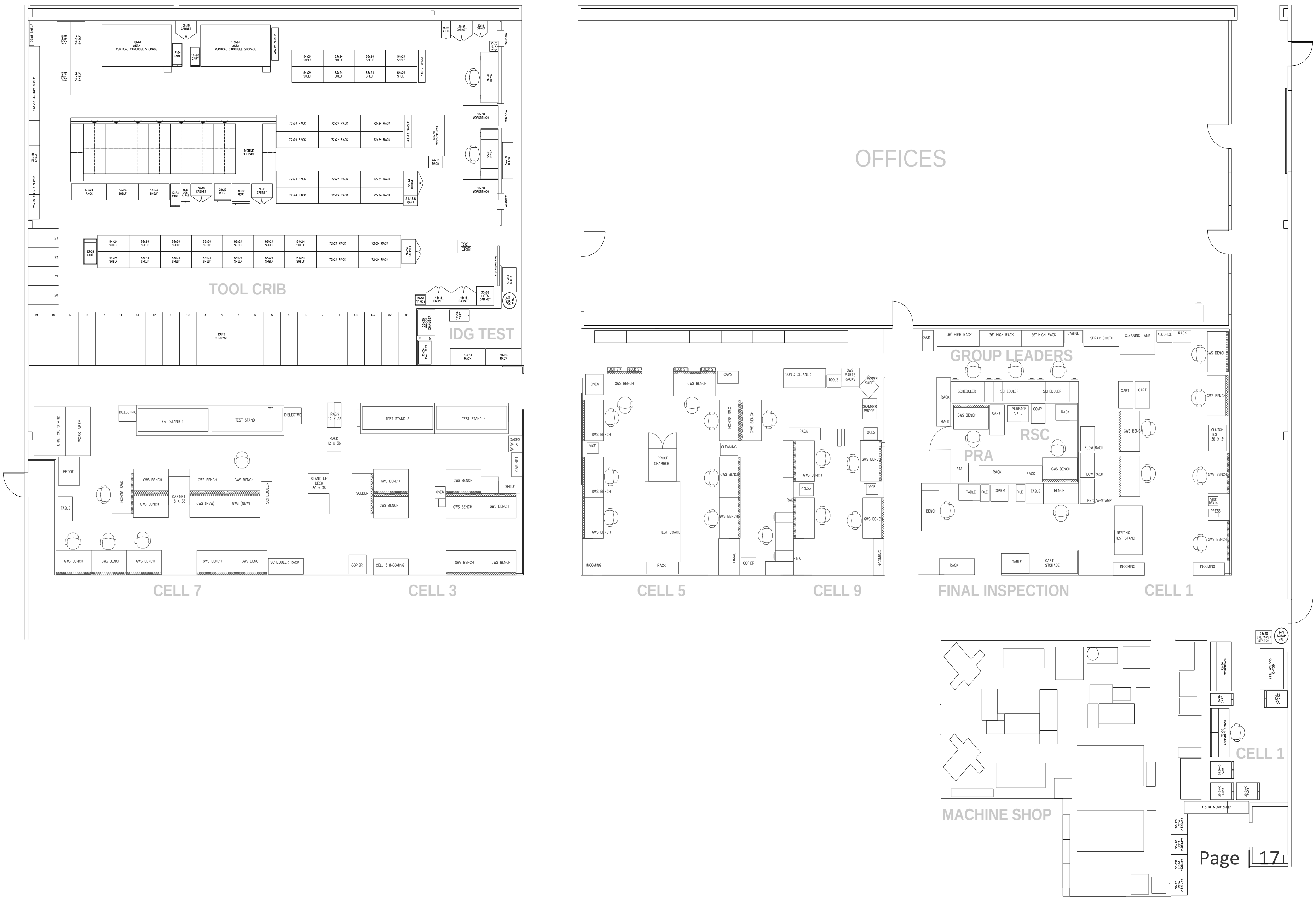
1. Incorporate the footprint location and detailed design of new program areas for Dewars and FMU (never in PST area before).
2. Incorporate approximately 600 sq. ft. as “growth” for future aftermarket programs and expansion space.
3. Accommodate and establish storage area for Pending Parts located inside or nearby appropriate manufacturing cells.
4. Find alternative location for the Machine Shop (current location to be used by another department at FSD).
5. Analyze current cell configurations and explore whether they are truly optimal.
6. Uphold current lean, kaizen, and 5s manufacturing standards.

INITIAL STATE

Layout

The initial state of the PST layout has a completely different ‘footprint’ layout than the requirements of the future state. In Figure 2 on the next page, notice how the Machine Shop and an extension of Cell 1 are segregated from the rectangular territory PST primarily encompasses. One of the major constraints with the future state is that everything must fit within the rectangular area, as the external square footage is being taken over indefinitely by a different department. However, the tool crib in the initial state is being relocated to another department’s layout within the building and is no longer the responsibility of Product Support. As a result, PST will gain this square footage in the future state layout in order to house the machine shop move, Cell 1 extension, new program areas, and growth among existing cells.

Figure 2: Initial State Layout



Departments

Let us first define the departments in the initial layout to gain an understanding of department additions and subtractions between the two states. Much of this will look familiar in the next section where the *future state* departments are defined. See Figure 3 for the PST initial state departments.

Initial State

1. Tool Crib
2. Cell 7
3. Cell 3
4. IDG Test
5. Cell 5
6. Cell 9
7. Final Inspection
8. Group Leaders
9. Cell 1
10. Machine Shop
11. Cell 1 (Extension)

Figure 3: Initial Departments Defined

DEFINE DEPARTMENTS

Defining future departments in the Product Support facility redesign is one of the most important stages in order to gain a solid foundation and basic understanding of what each area encompasses. Many of the departments within this specific layout are broken up into manufacturing cells in order to group common processes and product mixes.

There is a decent amount of change between the defined departments of the *initial state* compared to those of the *future state*. Changes include additional program areas such as a Fuel Metering Unit (FMU) cell and a Dewars Repair & Overhaul cell. Another major change is

that the Tool Crib has been removed from the final state as it is being relocated elsewhere in the facility. The revised departments of the Product Support Team future state are shown in Figure 4 below.

Future Departments

1. Machine Shop
2. FMU
3. Dewars
4. PRA
5. RSC
6. IDG Test
7. Final Inspection
8. Group Leaders
9. Cell 1
10. Cells 3 & 7
11. Cell 5
12. Cell 9

Figure 4: Future State Departments Defined

In order to gain a better understanding of how the future departments operate individually and interact together, let us take a closer look into the function of each.

Machine Shop: Supports all cells and new program areas; performs required reworks on commercial and military product to minimize scrapping of parts. Quick fixes and custom jobs are also frequent.

Fuel Metering Unit (FMU): This area is dedicated to the aftermarket side of these units since increased sales have been seen on the OEM side. These units deal with tiny circuits and other intricate electronic parts, so this area is especially sensitive to FOD.

Dewars: Dewars is a fire suppression system onboard the military C-5 aircraft. This area is for the repair and overhaul of these 500-gallon tanks and the system as a whole.

Preliminary Review Authority (PRA): This is a small area within the layout that inspects a variety of incoming parts from customers, vendors, and suppliers.

Repair Service Center (RSC): This area inspects flawed customer product to determine whether a rework is feasible or the part should be scrapped. If a rework is required, the engineer responsible writes up a set of work instructions or corrective action to the machine shop.

IDG Test: Upon completion of repair, this area contains test equipment for IDGs – a large part that is serviced in Cell 5.

Final Inspection: Every part or system that has been serviced by PST must pass through final inspection before it is eventually sent to shipping. Checks and balances, as well as last minute documentation, are completed here to insure the integrity and quality of the service provided.

Group Leaders: There are two group leaders responsible for all of the cells who act as the liaison between the shop floor technicians and PST management. They support the workers with proper training and help promote a collaborative work environment.

Cell 1: This is a military product cell that primarily services turbine starters for Black Hawk helicopters. They also service a part called a 'Climb & Dive' valve that is a component to the C-5.

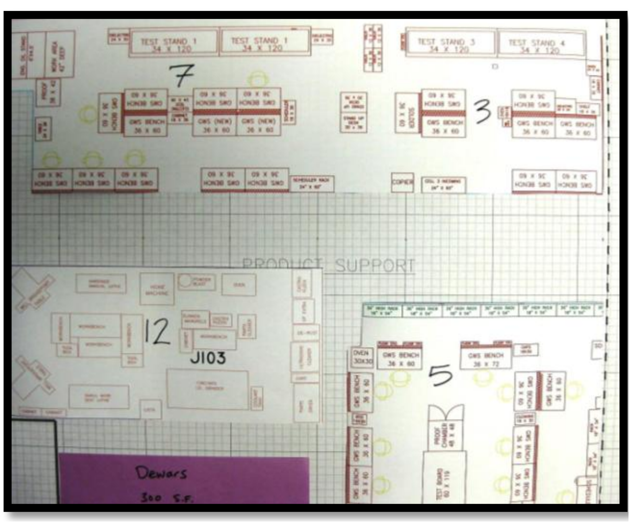
Cells 3 & 7: These cells are blended together within the layout and both service commercial fuel components. They share similar processes and test equipment.

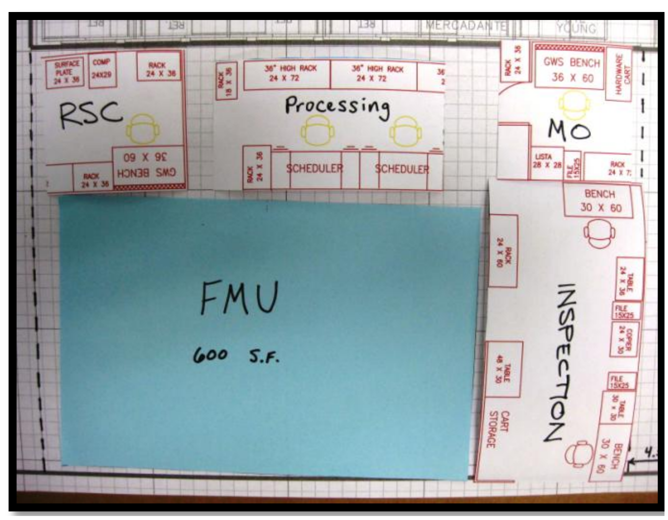
Cell 5: This cell services a variety of pneumatic commercial product and contains the largest volume of parts both incoming and outgoing.

Cell 9: Supports the repair of military pneumatic valves seen in fighter jets and helicopters.

As mentioned, there are two entirely new departments, FMU and Dewars, created due to the accommodation of new program areas that have been taken on by the aftermarket side. The specifics and space requirements of these areas will be discussed later on. In addition, notice how Cells 3 & 7 were grouped as a single department; this is due to their departmental relationship. This will be explained in the following section as well.

When dealing with this many departments it would be beneficial to visualize all of them with a scaled model representation of their actual square footages. In defining these departments, the management at Parker had an old-fashioned method that proved to be quite effective. 'Paper doll' cut-out figures of each department were created and scaled down to represent their respective sizes. The cut-outs were retrieved from a blown up CAD drawing of the PST layout. An example of the paper doll cut-outs can be seen in the figures below. Since new program areas were non-existent in the initial state, they were created here with different colors and scaled to their projected square footages based on space requirements.





Figures 5 & 6: Paper Doll Figures

Now that the departments have been clearly defined and visualized from a size perspective, the next step of the systematic approach is to define the relationships between departments.

DEFINING RELATIONSHIPS

In order to increase efficiency in a facility, the relationships between departments should be carefully defined. The relationship of the new layout to overall facility must be taken into consideration as well. The departmental relationships were generated through process observation and documentation in addition to surveying managers, group leaders, and technicians. Starting with the cells, Cell 1 should be located along the East (right) side of the facility because the parts they repair must all be tested outside on the test pad. This area in the layout is the closest to the door that leads to the test pad and will minimize travel times. Also, the Cell 1 extension that was segregated in the initial state must *absolutely* be a part of the original cell which, in effect, will create a much larger Cell 1. Cells 3 & 7 must be located adjacent to each other since they both service commercial product and have many shared resources, such as tools and test stands, within their cells. Separating the cells would create increased test and travel times. Cells 5 & 9 have a similar strength of relationship in that they both service military product in both locations so strong consideration should be made to keep them united. Additionally, the IDG Test area should be within close proximity of Cell 5 because the IDGs to be tested come out of here. Strategies to place the small test area inside of Cell 5 were explored, but deemed infeasible due to space requirements. The Repair Service Center (RSC) evaluates air and fuel parts on the basis of a required rework, so it should be located near the machine shop. Final Inspection should be located on the East side of the facility, near Cell 1,

for the fact that all parts must pass through here before they are released to shipping. Shipping is located down the way (South) from Final Inspection so placing it on this side would achieve a U-shaped flow through the facility. Also, the Group Leaders should be as centrally located among the cells as much as possible. They serve as the liaison between the shop floor technicians and team leaders, or management. Being central will increase their communication and visibility of process activities, in addition to quickly aiding with any issues that arise. With a large number of departments comes a considerable amount of relationships to maintain in successfully establishing the future state layout. A relationship matrix can be seen in Appendix A which shows the strength of inter-dependencies among departments.

SPACE REQUIREMENTS

Now that the departments have been established and the relationships between these departments defined, the space requirements for each department need to be gathered in order to develop a preliminary layout using Microsoft Visio. Since most of the areas in the layout are already well established, it was decided to keep their square footages the same, more or less. However, with the tool crib moving Product Support has gained approximately 3,000 sq. ft. in order to accommodate the new program areas and area deemed for “growth”. The precise space requirement breakdown is shown below. These values are predefined by the Facilities department and include accurate estimates for the space and capital required by the new areas.

<u>PST Assembly & Testing</u>

- Current 4,963 sq. ft.
- Future
  - Existing 4,963 sq. ft.
  - FMU 600 sq. ft.
  - Dewars 300 sq. ft.
  - Growth 600 sq. ft.
  - Total 6,463 sq. ft.
- Actual 6,720 sq. ft.

<u>PST Machining</u>

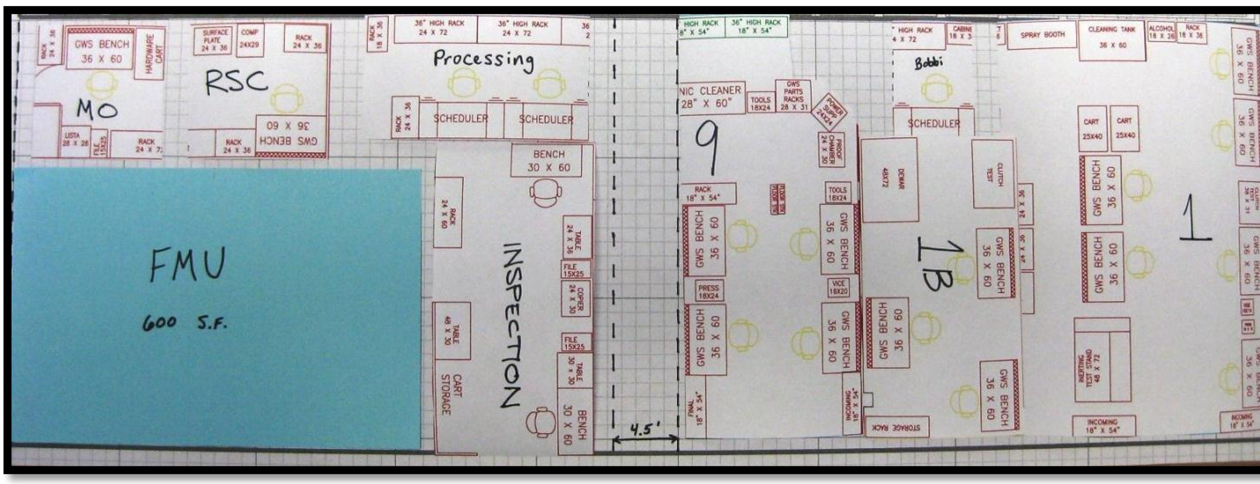
- Current 935 sq. ft.
- Future 935 sq. ft.
- Actual 935 sq. ft.

Keeping these space requirements and the defined relationships in mind, alternatives are ready to be prepared and analyzed.

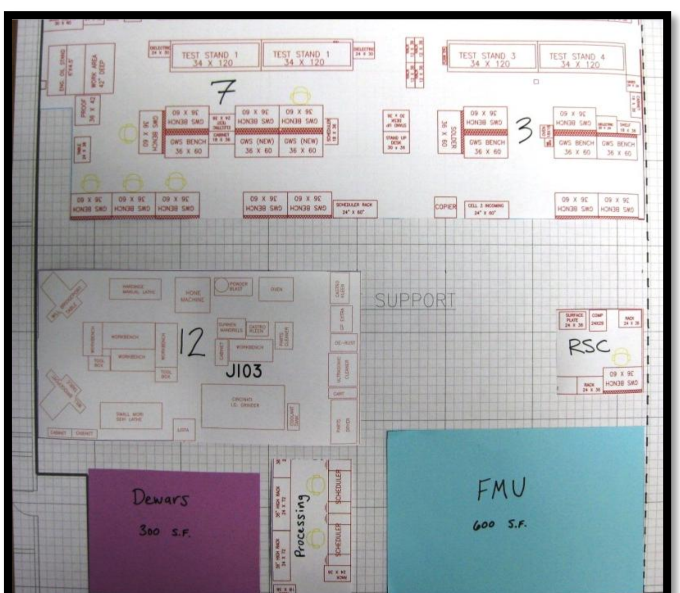
ALTERNATIVE LAYOUTS

Approach

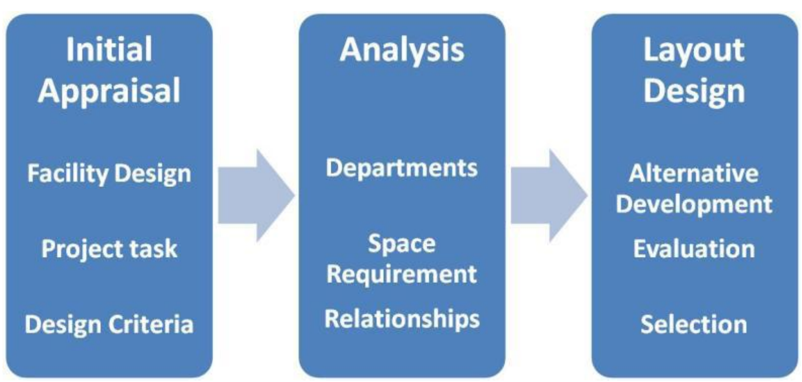
When brainstorming alternative layouts for Product Support, my initial approach was to utilize the paper doll method and square footages to create a physical model of the layout that allowed for ease of change as new ideas arise. This concept is similar to a puzzle that can be put together in various ways, where the goal is to find the best way everything fits. Initial iterations using this concept are shown in the Figures below.



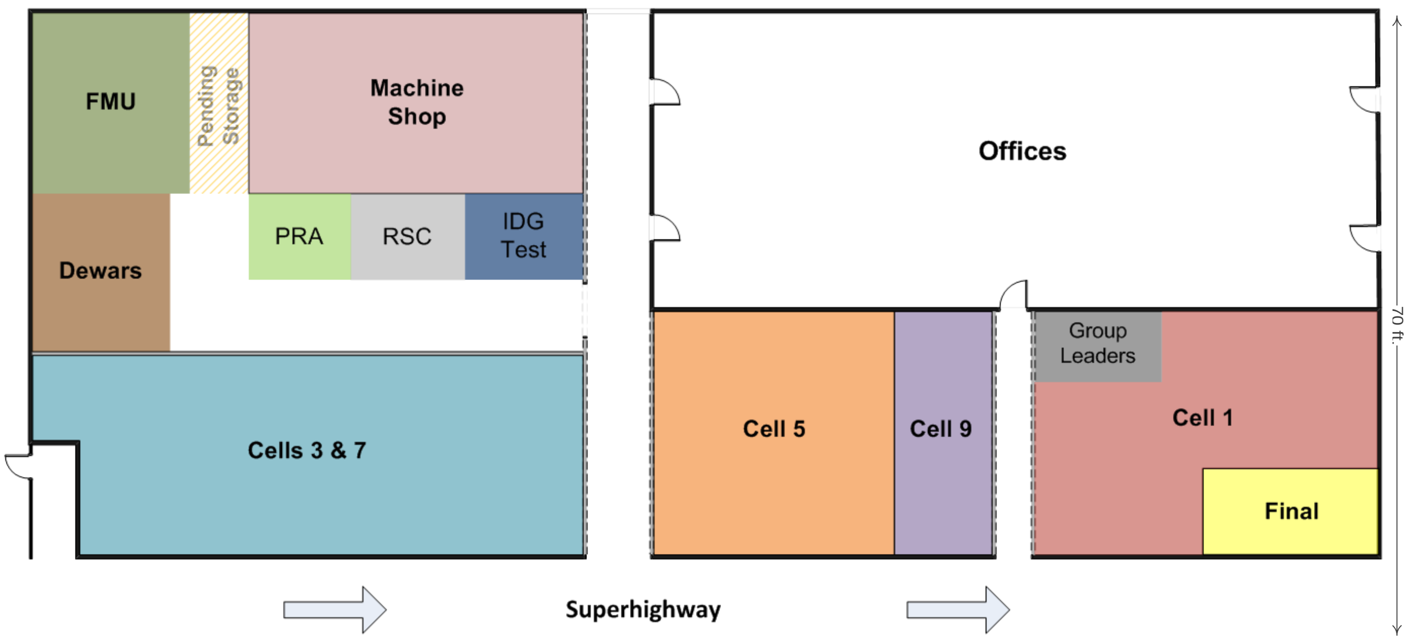
Figures 7 & 8: Generating Alternative Layouts via Paper Doll Concept



In addition to space requirements, the department relationships must also be kept in mind. These relationships are what drove the decisions in putting certain areas near each other in the paper doll model as well. Once ideas were flowing using the physical model, it was decided to transfer our ideas to Microsoft Visio so they could be managed digitally. This effective strategy allowed for ease of change along with the capability of saving different versions we came up with. Moreover, when status meetings on the layout project were held each week, proposed alternative layouts could be efficiently shared via the conference room projector. A downfall to the physical model is when a good layout was created, the only way to save that idea was to take a picture of it. Also, transporting the large piece of cardboard that served at the backbone to the layout meant that the individual cutout pieces, the departments, would move around freely and occasionally get lost. Moving things into Visio was a much more secure way to manage these documents and save changes as the project progressed. Once ideas were moved into Visio, five primary alternative layouts were produced.



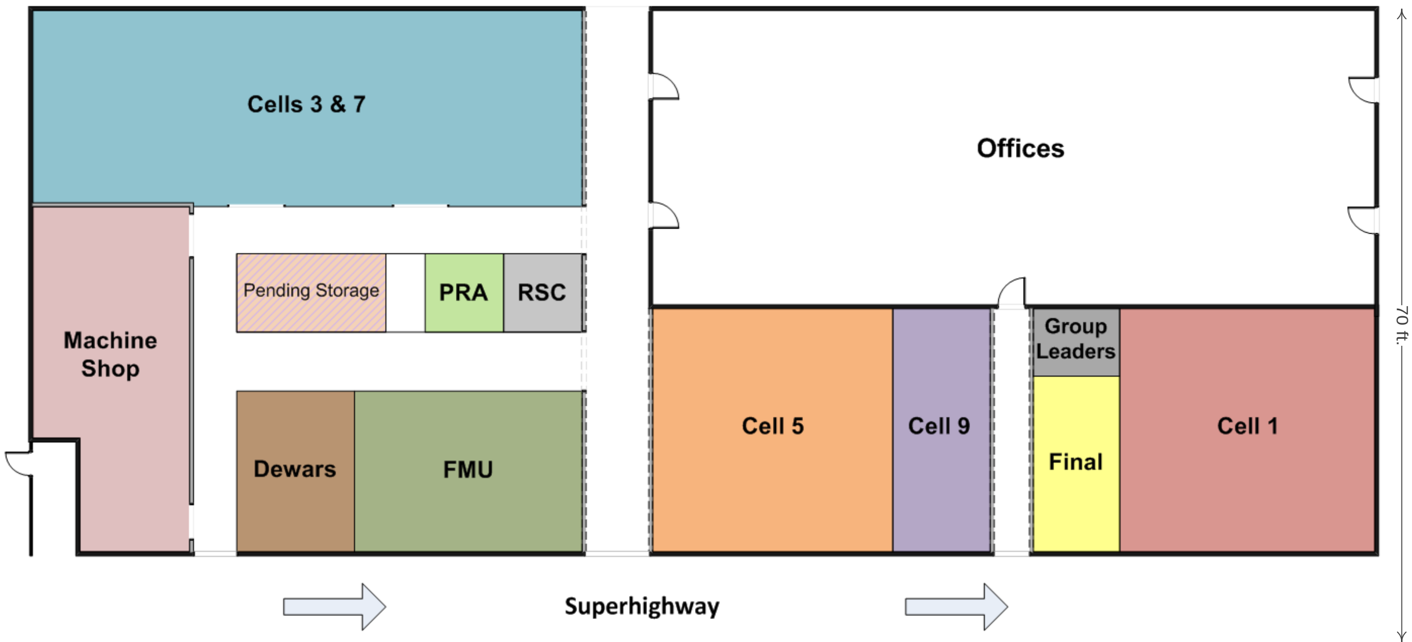
Layout #1



Alternative layout 1 focused to achieve effective material and product flow. It places the machine shop in a region where the tool crib previously resided. This is partly due to its rather large space requirements for all of the machinery. Cell 1 and its extension have been seamlessly integrated together with the movement of final inspection pushed against the wall. Product leaving final inspection, which is eventually *every* product, is now a bit closer to shipping whose path perpendicularly intersects the superhighway. Notice how all of the cells have been basically left in the same position, all being placed along the superhighway which will allow for ease in replenishing material. This is essential since the cells are where the primary value-added activities occur. Group leaders were also left in place since they are fairly central in location among the manufacturing cells and there was no practical area to place them within Cells 5 or 9. The IDG test area was placed as close to Cell 5 as possible since it is used to test their parts.

RSC and PRA are directly adjacent to the machine shop to allow easy handoff of parts in both directions. The new program areas, Dewars and FMU, were placed against the back corner wall along with pending storage.

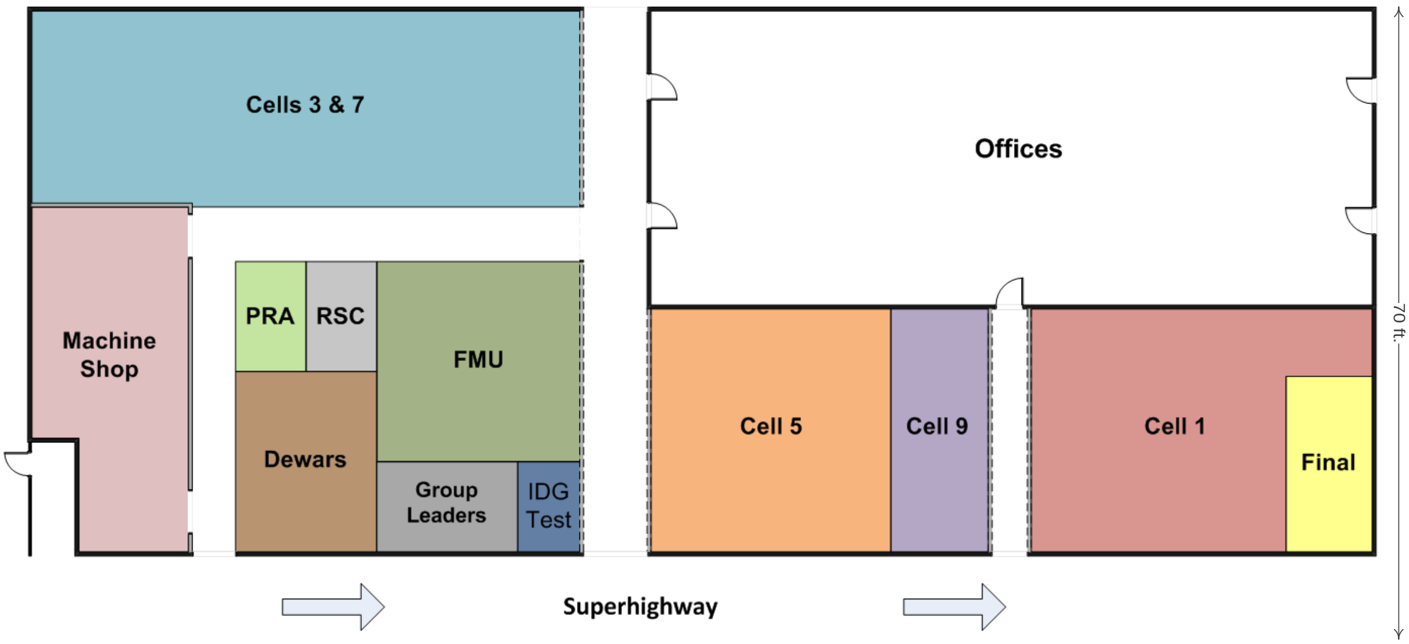
Layout #2



Alternative layout 2 primarily focuses on allowing greater access to personnel and equipment within all areas of the layout. As you can see above, an aisle way was created to allow greater access to the more isolated regions, Cells 3& 7 and the machine shop. This idea stemmed from reducing travel time from the perspective of someone that is standing directly below the machine shop; instead of having to walk all the way around FMU to enter through that side, they could now walk straight through. Safety was also a major concern in generating layouts, and these new aisle ways increase the number of exit points for technicians situated in these deeper areas. Moving Cells 3 & 7 against the back wall is justified by what is on the other side of that wall. These cells test and repair fuel parts and the according testing stands and fixtures require fuel lines that originate on the other side of this back wall. A major concern and complaint when interviewing technicians was vibration issues in the pipes overhead, since the “raceway” (collection of pipes) had to extend all the way out to the superhighway. Moving the

cells against the wall minimizes the distance these fuel lines have to go, which will decrease and possibly eliminate the noise and vibration issues that seem to distract the workers' ergonomics. However, moving these cells against the wall from their original location along the superhighway would be very costly to execute. Dewars was placed on the superhighway in order to efficiently accommodate the large 500 gallon tanks that will be frequently wheeled in and out. There is a roll up door located directly adjacent to the machine shop so this was seen to be a good in and out access point for these enormous tanks. Cells 5 & 9 were untouched, and final inspection was simply rotated and pushed against the left side this time so that Cell 1 could have more of a 'block' layout with definitive space all for them. Remember, Cell 1's parts are tested on the pad located directly out the doors to the right, so close proximity is key.

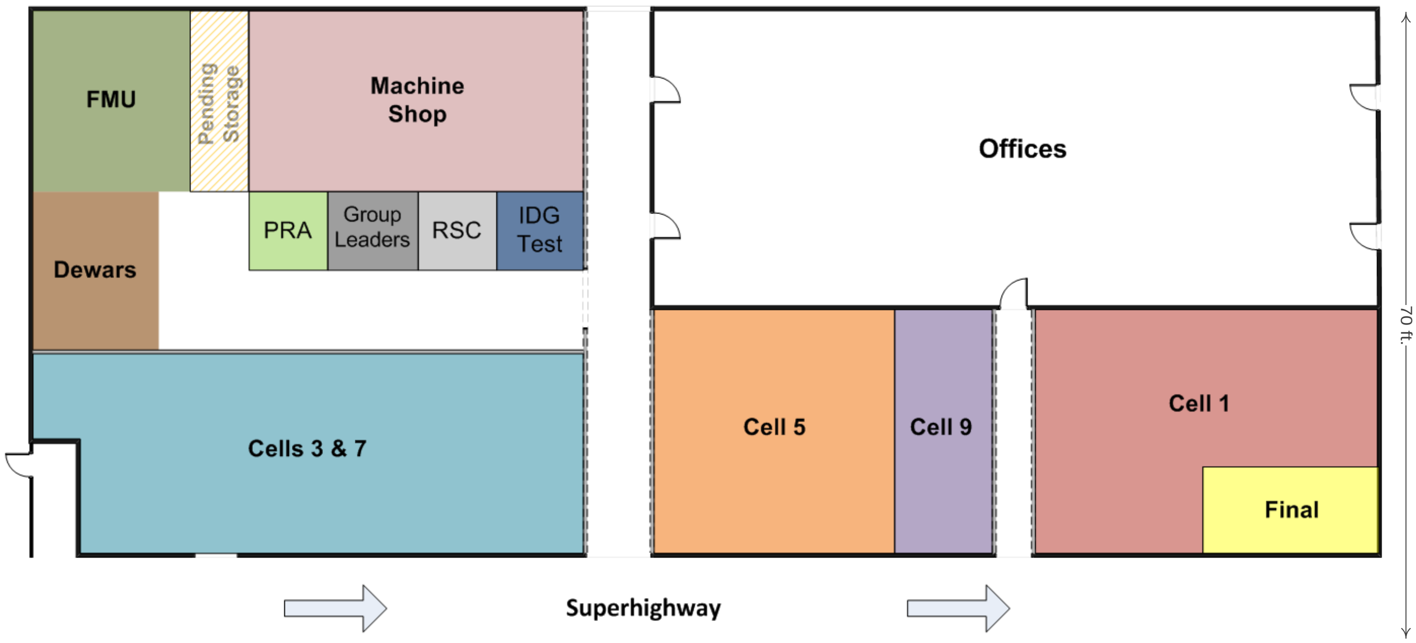
Layout #3



Alternative layout 3 differs from layout 2 in that it eliminates one the aisles near the machine shop and restructures this entire region. Having two aisles here was seen by some as wasted square footage, which is why this alternative was explored. Pending storage was also eliminated from this layout. Here, PST had the option of placing their pending product within another department's layout due to extra space. Visually, the pending storage was placed in the upper right-hand corner behind the office walls, but was not shown here since Product Support does not incorporate that area. Again, PRA and RSC were placed very close to the machine shop. Dewars was left in place due to the superhighway and roll-up door vicinity for its large components. The group leaders here were taken from their previous location and placed on the other side of the layout. Since Cells 3 & 7 were moved back, keeping them central required a change. In looking at the overall layout, the group leaders definitely appear central to the cells with this move. Since group leaders are now away from Cell 1, this area is able to be

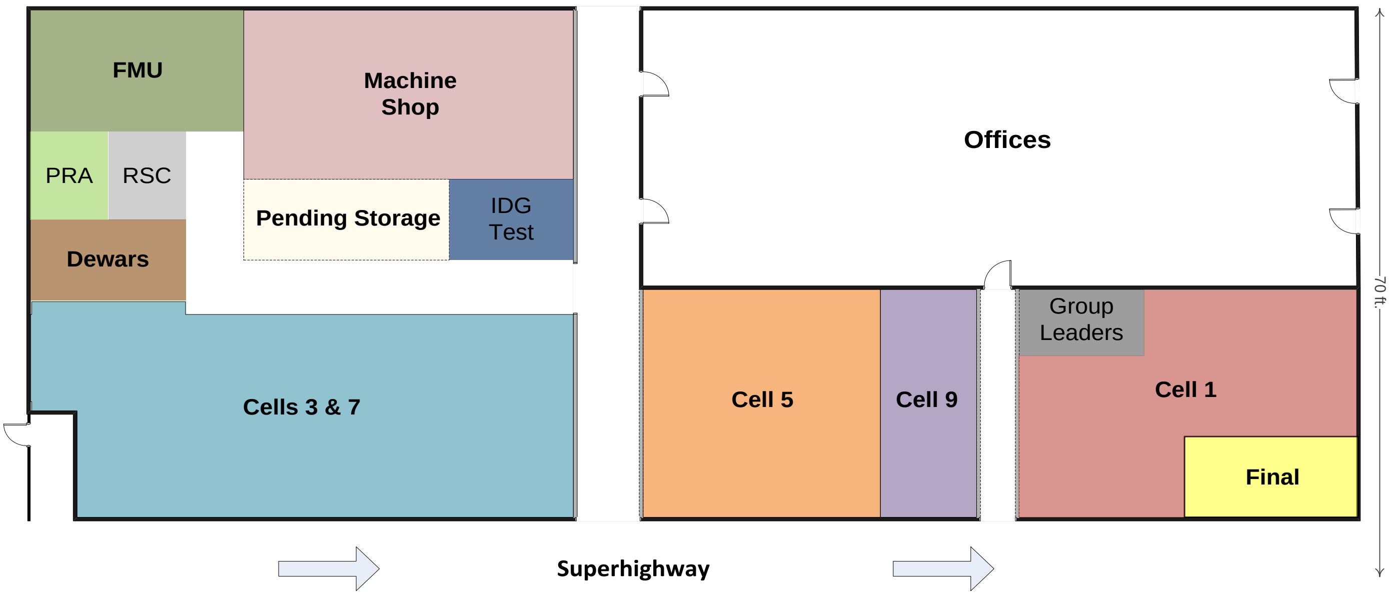
completely occupied by Cell 1 with the rotation of final inspection against the East side of the facility. In theory, the flow of this layout seems very beneficial with deliberately placed access points that capitalize on material flow and safety.

Layout #4



Alternative layout 4 places Cells 3 & 7 back in their original location. An alternative 'L' shaped walkway was created in accessing Dewars, FMU, etc. with no other entry points from the superhighway. The machine shop is placed against the back wall in this layout which also promotes access from the intersecting walkway. Pending storage here is placed in the extra space between FMU and the machine shop. This actually serves as a functional placement because FMU cannot be susceptible to foreign object debris (FOD) that is commonly generated by the machine shop. Group leaders were, again, moved away from Cell 1 to see the effect it would have after the change to Cells 3 & 7. The right half of the layout remains predominately unchanged, with the exception of final inspection rotating once more to be parallel to the superhighway.

Layout #5



Alternative layout 5 exercises sufficient flow with access and is also the layout of least change. Cells 3 & 7 remain in their original positions, putting FMU and the machine shop against the back wall. PRA and RSC are integrated together, separating the Dewars area from FMU, but still close to the machine shop. In order to minimize FOD going into FMU from the machine shop, a solid wall placement is added between the two areas. Pending storage is placed adjacent to the IDG test which is still in close proximity to Cell 5. Cells 5 & 9 remain unchanged, again, and group leaders have been placed back into Cell 1. Final inspection is parallel to the superhighway and at its closest possible point to shipping just down the way (South).

EVALUATE & SELECT

Evaluation Metrics

In order to analyze the five alternative layouts, the evaluation metrics must be developed to effectively meet the needs of the shop technicians and Product support management. Once this is done, each metric is assigned a weight that corresponds to its significance in the overall layout. These were gathered through a variety of methods including weekly cell meetings, interviews with senior technicians, management and facility experts within Parker FSD. In addition, the 'Lean Team' was consulted in order to uphold and maintain current lean, kaizen and 5S practices. The evaluation was split into six attributes with the following weights:

Attributes	Weight
Travel Time	20%
Safety	15%
FOD Restrictions	10%
Shared Resources	20%
Promote Cell Synergy	20%
Cost of Implementation	15%
Sum	**100%**
Maximum Score	**10**

1. **Travel time** – the time it takes an employee or other resource to travel with or without time sensitive material between interdependent locations within the layout.
2. **Safety** – In the event of an emergency, how well the layout is designed to allow rapid yet calm access to an exit point.
3. **FOD restrictions** – How well the layout attempts to minimize foreign object debris (FOD) from conflicting areas (e.g. machine shop and FMU).

4. **Shared resources** – the extent to which resources used by more than one cell or production area are placed effectively within the layout. This largely involves the product type(s) serviced by a cell.
5. **Promote cell synergy** – the placement of cells combined with group leadership promotes an interactive, team-building work environment and active communication.
6. **Cost of implementation** – the additional cost to implement layout changes from Product Support's initial state. The higher the score in this metric, the lower the cost.

Now that the weights of the evaluation metrics are assigned, each layout can be analyzed and scored. Each layout will receive an attribute rating for each of the evaluation metrics. The attribute rating is on a scale of one to ten with ten being the best and is assigned relative to each of the layouts being analyzed.

Select Layout

Alternative layouts were analyzed and scored based on a multi-attribute analysis. This is shown in Table 2. Although very close in score between weighted indices, layout 1 scored the highest in this analysis method and was the selected layout to be implemented by Parker. A detailed version of layout 1 can be seen in Appendix B which includes workstations, test equipment, machinery, and all other furniture aspects that are a part of the final layout configuration.

As an aside, it is important to note that once a "footprint" layout was selected and future department locations were finalized, alternative *detailed* layouts of each specific department were explored in depth. Input needs were gathered from the respective areas'

team leader as well as technicians and management. Generating alternative detailed layouts of each department became especially challenging because so many requests were trying to be met in a single, effective configuration. A great deal of time was spent validating furniture measurements and examining alternative detailed layouts, however, for the scope of this report, will not be discussed in any further detail.

Table 2: Multi-Attribute Analysis

Attributes	Weight	Layout Alternatives				
		1	2	3	4	5
Travel Time	20%	7	9	9	6	7
Safety	15%	7	8	8	6	5
FOD Restrictions	10%	6	8	8	6	5
Shared Resources	20%	8	6	6	8	8
Promote Cell Synergy	20%	8	7	8	7	8
Cost of Implementation	15%	9	5	4	8	9
Sum	**100%**	45	43	43	41	42
Weighted Indices	**10**	**7.6**	7.15	7.2	6.9	7.2

DEWARS MATERIAL MANAGEMENT

In addition to the general Product Support layout redesign, I was asked to help with managing the material in the Dewars cell while on my co-op. A Dewars tank is a vessel manufactured entirely from stainless steel for use with liquid nitrogen in a wide range of applications.

This Dewars program is a Proof of Concept project taken on by Parker FSD as a contract with the U.S. Air Force to service approximately 26 of these units annually. They fly aboard the military C-5 cargo plane which contains two tanks per aircraft (one in each wing). They serve as a fire suppression system in preventing flammability within the wings (fuel tank) by eliminating oxygen and replacing it with liquid nitrogen. In doing this, chances of explosion and internal combustions are greatly reduced. A visual of the Dewars system can be seen below in Figure 8.

Figure 8: Dewars System Assembly

The goal in designing this new program area was for me to establish a way to organize and streamline material components of the system assembly in order to optimize technician performance and usability, while also contributing to minimized search times. There are over 100 different parts in the system assembly of one unit, so attention to detail was key in proposing an efficient solution. The primary concern during assembly with this many parts is search time. As a solution, I managed to come up with storage bins organized by item number. The item numbers were taken from the exploded assembly drawing that technicians will use during build up. Next to the item number would be the unique Part number to serve as confirmation that this is the correct part. All of this information was displayed on custom made labels that were placed on the front of the bins like name tags. The bins are then organized chronologically by item number on a series of racks to be quickly located when the technician is searching for parts. Pictures of this proposed organization method are shown in Appendix C.

COST ANALYSIS

The cost analysis is perhaps the most important factor in the determination of which design alternatives and possibilities to recommend to the client. In order for a business to seriously consider implementation of any proposed ideas, they must be shown that the time and money spent on implementation will be worth the investment. Numbers and percentages speak wonders to upper management in selecting the preferred choice. Ideally, analyzing a facilities design will eventually yield multiple avenues toward changes that will make a positive financial impact for the customer.

The first aspect by which the selected layout will be measured is new business. The new layout supports two new aftermarket program areas, Fuel Metering Units and Dewars, without hindering the production or capacity of existing cells and departments. This is beneficial in that Product Support is significantly increasing their revenue and profits with the same amount of square footage. It is executing better usage of the space it already had and maximizing its value-added activities per unit area. Based on company forecasts and projected volumes, refer to Table 3 to see the increase in monthly sales and profits due to the new layout. Monthly profits increase by $6,900 which comes out to $82,800 annually.

Table 3: New Sales & Profit due to Layout Redesign

Program	Monthly Sales ($)	Profit Margin	Monthly Profit ($)
FMU	15,000	6%	900
Dewars	100,000	6%	6,000
Total	115,000		6,900

The next aspect by which the selected layout will be analyzed is cost reduction. As mentioned, in order to show the improvements from the initial state to the proposed future state, time studies were used to present a financial savings basis. In this situation, like many in facilities design, time studies cannot be performed to compare the *actual* savings of the two layouts because the new one has not been implemented yet. Thus, distances were measured to the eventual location of these areas within the layout while recording the travel time at an average walking pace. These times and distances are summarized in Table 4. Notice that these were only measured between areas that are different from the initial state and that have strong departmental relationships.

Table 4: Distance and Time Savings

Departments		**Old**	**New**	
From	To	Distance (ft.)	Distance (ft.)	Time Savings per day (min.)
PST	Pending Storage	850	250	8
PRA/RSC	Machine Shop	25	10	10
Final	Shipping	200	172	2
Cell 1 integration		20	0	8
	Totals	1,095	432	28

With this savings in time from the initial state to the future state, obviously, comes a cost savings. The new layout was found to save an average of 28 minutes per day, or 0.47 hours. A shop technician working at an average wage of $24/hr, combined with an average operating cost of $95/hr for the PST shop, totals an expense of $119/hr for *one* employee. Taking the savings in time per day from above and simply multiplying it by the total expense per hour will yield the daily cost savings. These values and calculations can be seen in the Cost Savings Table 5 below.

Table 5: Cost Savings

Cost	Avg. Hourly Rate	Units	Time Saved	Daily Savings ($)	Monthly Savings ($)
Technician	24	USD	28 min.	-	-
Operating	95	USD	28 min.	-	-
Total	119	USD	0.47 hrs.	55.53	1,110

Finally, the calculated sales profit acquired from the increase in revenue due to this new layout must be combined with the total cost savings to understand the overall value of the new layout. Taking a monthly profit of $6,900 from new sales, in addition to a monthly cost savings of $1,110, results in an overall monthly value of $8,010. Annualized, the new layout is valued at $96,120 per year. The value breakdown is shown in Table 6.

Table 6: Overall Layout Value

Breakdown	Monthly ($)	Yearly ($)
New Sales	6,900	82,800
Cost Savings	1,110	13,320
Total	8,010	**96,120**

Another method by which the selected layout will be judged is the payback period. As the name suggests, the payback period is the amount of time it takes to be paid back on an investment. For example, if an investment requires $50 up front, and yields a return of $10/month, the payback period for the investment would be 5 months. While the exact cost of implementation was unknown at the completion of this project, the *estimated* implementation cost for the new layout was $150,000. At an overall value of $96,120 per year, the proposed future state layout has a payback period of 1.56 years. This is a pretty fast recovery considering other major renovations and investments.

CONCLUSION

The primary goal of this project was to find the best way to accommodate more business in the same space while also exploring cost reduction efforts. Minimizing travel time and distances without hindering the production capability of the other departments was one example. It was equally important to analyze the product flow through the facility as a whole and examine whether the existing configuration of the original departments was truly optimal. Furthermore, the detailed layouts of each department were specifically examined one by one and changes were made accordingly. Furniture and equipment validations were completed in this elaborate process as well. Referring back to the problem statement in the beginning of the report, there was not adequate space to add additional office cubicles and/or workstations to the shop floor. Nonetheless, this was not a concern to the Product Support Team.

There was no precise constraint on the cost of implementation, but minimizing the cost was a key driver in the decision among alternatives. The total profit due to new sales revenue from the layout is approximated at $82,800 per year while the total cost savings is $13,320 per year, providing an overall value of $96,120.

After the design phase of this project ended along with my co-op in December 2010, I am pleased to report that this layout redesign of Product Support was officially implemented in April 2011. This redesign proves to be an essential step in the continued growth of Parker Aerospace Product Support. It provides cost reduction in a time of economic recession while significantly increasing department revenue and enduring the success of Parker Hannifin Corporation.

RELEVANT COURSEWORK

- **IME 443** - Facilities Planning and Design
- **IME 314** - Engineering Economics
- **IME 223** - Process Improvement Fundamentals
- **IME 303** - Project Organization and Management
- **Microsoft Visio** – Computer Design

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APPENDICES

Appendix A

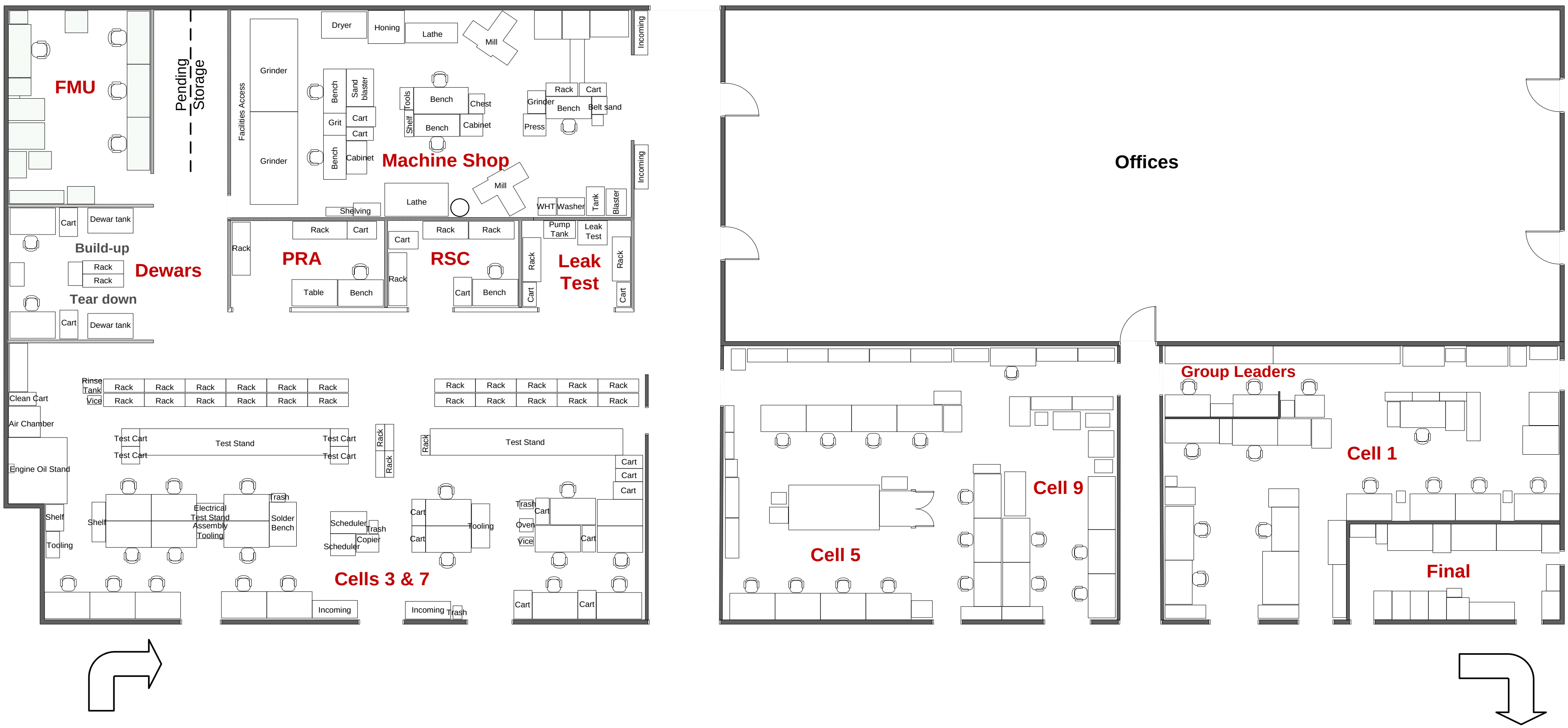
Relationship Diagram

From \ To	Machine Shop	FMU	Dewars	PRA	RSC	IDG Test	Final Inspection	Group Leaders	Cell 1	Cells 3 & 7	Cell 5	Cell 9
Machine Shop		U	O	E	E	U	U	O	O	O	O	O
FMU	U		U	O	O	U	O	E	U	U	U	U
Dewars	U	U		O	O	U	O	E	O	U	U	U
PRA	E	O	O		O	U	O	U	O	O	O	O
RSC	E	O	O	E		U	U	O	O	O	O	O
IDG Test	U	U	U	U	U		U	U	U	U	A	U
Final Inspection	U	O	O	U	O	U		O	I	I	I	I
Group Leaders	U	I	I	U	O	U	O		E	E	E	E
Cell 1	O	U	O	O	O	U	I	E		O	I	I
Cells 3 & 7	O	U	U	O	O	U	I	E	O		I	I
Cell 5	O	U	U	O	O	A	I	E	I	I		A
Cell 9	O	U	U	O	O	U	I	E	E	I	A	

Key	
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary
U	Unimportant

Appendix B

Selected Layout 1 – Detailed



Appendix C

Dewars Material Management – Storage Bins/Racks

Appendix D

Technician Input - Cell Layout Survey

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1. What do you like about the current layout?

2. What do you dislike about the current layout?

3. What changes would you like to see in the new layout (cell specific)?

4. As a team, what do we want the layout to achieve?