

**ANALYZING THE BOEING 777 LINK THE FLOW PROCESS FOR VALUE
STREAM FLOW REDUCTION AGAINST THE LEAN AEROSPACE
INITIATIVE'S ENTERPRISE LEVEL ROADMAP**

by

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Submitted to the Sloan School of Management and the Department of Aeronautics &
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ABSTRACT

This thesis is the result of research conducted at The Boeing Company working specifically with 777 operations at Everett, WA.

As the component supply business units (like the Interiors Responsibility Center/IRC) and final assembly production line (like the 777) implement lean practices within Boeing, various standard practices develop that locally optimize the system for the individual organization. The IRC has started to work with their suppliers to lean out the supply interface and would in turn like to develop a standard Just In Time process for all aircraft line customers they serve. The 777 would like to develop a standard process for their suppliers' deliveries that supports the factory mechanic. As the customer, the 777 should lead the determination of the interfaces and subsequent processes, however they want to consider and incorporate, where possible, the supplier preferences.

Both the IRC and the 777 factory have been actively and successfully reducing flow within the bounds of their operations and have started to work throughout their value stream to further improve and reduce flow time. The organizations had worked with other suppliers/customers previously and had developed conflicting processes that both wanted to make standard. To resolve these interface issues, the 777 flow reduction process was used as a means of uncovering the issues, roadblocks, and next steps necessary to improve the process for a single commodity, the outboard stowbin. Specifically, the process was applied to the outboard stowbin logistics and design portions of the value stream. The lessons learned from the logistics and engineering workshops will be presented. These lessons can be applied to flow reduction efforts for other IRC interiors commodities in the future. The 777 flow reduction process will be analyzed and evaluated against the Lean Aerospace Initiative's model for an aerospace company transitioning to a lean enterprise. This model is in development at the Massachusetts Institute of Technology.

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The conclusions of this thesis are those of the author and do not necessarily reflect The Boeing Company strategy and policy.

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EXECUTIVE SUMMARY

In 1993, The Boeing Company began an initiative to implement lean manufacturing throughout its production facilities (Reference 1). On the 777 program, factory lean implementation began with a program initiative called Make It Flow (MIF) (Reference 4). MIF focused on the reduction of waste in factory processes, and involved personnel from the director to factory floor. From 1998 to 2000, MIF successfully reduced factory flow days by 50%. Following this success, the 777 program launched Link The Flow (LTF) to reduce waste and flow days in the supply chains of the program's top 20 suppliers by cost. One of these suppliers was the Interiors Responsibility Center (IRC), an internal Boeing supplier. The IRC had implemented lean in many processes within their factory and were interested in working with their customers, the aircraft production lines, to gain further flow reductions.

The LTF workshops with the IRC focused on the outboard stowbin value stream, one of the commodities assembled by the IRC for the 777 factory. Implementing a pull process for logistics was the first focus. The challenges in logistics workshops consisted of merging 777 and IRC flow reduction processes, something both organizations had previously successfully achieved on similar projects. Using the customer's process for the workshops and including the supplier's previous learnings as input, the organizations were able to work together, although determining the best way to improve the logistics process was a challenge. Implementing and maintaining a pull process had proven difficult in past attempts, but this time the team used the criticisms of each new process draft as motivators for improvement. As a result, the team was able create a process that was better for everyone involved. Successful implementation of the new process resulted

in no more than one half a day of inventory for the outboard stowbins and the center stowbins, sidewalls, and ceiling panels as well.

The second focus for the LTF process with the outboard stowbin was the engineering processes. This was the first time the LTF process was used to enable flow reduction with engineering processes. While the workshops were successful in discovering a means for achieving the flow reduction goals, there were several barriers to implementation. The first was a commitment by management to use dedicated engineering resources for specified days during the engineering flow. Two dedicated engineers can finish a process step in five days that would take one non-dedicated engineer fifteen days. To achieve shorter flows dedicated engineers are necessary. The second barrier was the assemblies that attach to the stowbin. Lights, wiring, and ducting attach to an outboard stowbin sub-assembly. The flows for these items exceeded workshop goals and prevented the realization of outboard stowbin flow reduction. However, by highlighting these long flow items a list was developed of the next workshops necessary to meet flow reduction goals.

The Lean Aerospace Initiative (LAI) at the Massachusetts Institute of Technology has developed a guide for aerospace companies to follow when implementing lean practices throughout their organizations. The Enterprise Level Roadmap (ELR) is a top down guide that coordinates corporate strategy with the aspects of the company where lean could be implemented (Reference 12). The manufacturing, the financial, or the supply chain organizations all fall within the scope of the ELR.

When comparing the ELR and the LTF process several differences can be seen including:

- The LTF process maps the physical value stream while the ELR process includes the mapping of decision and information flows. By mapping these flows in addition to the physical value stream, hidden organizational problems and additional waste elimination opportunities can be located.
- The LTF process does not focus on developing metrics that support implemented leaner processes. The metrics that measured the previous logistics process rewarded suppliers that delivered parts to the factory more than one day early. Pull or kanban process do not meet this metric and result in strikes against the suppliers who use these delivery methods. The ELR includes a step to align metrics to reward the lean processes assisting in implementation.
- The LTF process does not incorporate a structured incentive system for the team members involved. While there are incentives available to managers to reward employees, the ELR suggests using a separate structured incentive system that rewards teams more as the number of flow days removed increases.
- The LTF process includes an adjusted cost model that translates flow reduction into value asset reduction. As a result the LTF projects can be assessed on a financial basis. This reduces the chance that a lean idea is implemented that is not in the company's best financial interest and enables the 777 program to realize one-time cost savings as a result of the projects. This is not included in the ELR.
- The LTF process includes a tool set of various methods that can be used to implement flow reduction ideas. This highlights the LTF process focus on implementation.

In conclusion, while there are several differences between the LTF process and the ELR, the two methods could be complementary. The top-down focus of the ELR establishes and coordinates corporate support. It also enables the support organizations to transition to lean while the manufacturing processes transition. However, it is not presently focused on the implementation aspects of lean. Though future versions of the roadmap may include this, the LTF process already accomplishes it. LTF has repeatedly proven its ability to realize the reduction of flow in processes as different as manufacturing and engineering. However, LTF is limited to the organizations not under the control of the 777. Finance, human resources, and information systems are examples of organizations under corporate, not program, control. As a result, changes to organizations like these are difficult for the LTF process to initiate. However, by using the two processes together, a more complete model for transitioning an entire enterprise into a lean organization could be developed.

1. BACKGROUND

In 1993, Boeing Commercial Air Group (BCAG) started a corporate Lean Enterprise initiative (Reference 1). The focus of the initiative is the continuous elimination of waste in processes throughout the company. The initiative will assist The Boeing Company in meeting its internal goals to reduce costs, cycle time, and defects while delivering more value to their customers (Reference 1). Business units and production lines throughout Boeing are implementing the elements of lean in various ways, but always with these goals in mind. The ideas for the improvements are started and implemented by the people who are part of the process, while personnel from Boeing's lean office support their efforts. As Boeing continues to reduce their process flows, the business units that supply the parts and the production lines that assemble them will develop closer working relationships.

1.1 777 Background

In 1998 Boeing's 777 program started a program plan titled Make It Flow (MIF) (Reference 4). The purpose of this program plan was to implement lean principles in the 777 manufacturing plant. The basic assumption underlying MIF was eliminating waste and maximizing current process, significantly reducing the days of factory flow and man-hours per aircraft. These reductions would lead to a reduction in the cost to build each aircraft. The work statement for MIF focused on the four main value streams of the factory: Aft Bodies, Mid Bodies, Forward Bodies, and Joins (Appendix 1). The 777 then used a tiered methodology to focus their time and labor resources on these value streams (Figure 1).

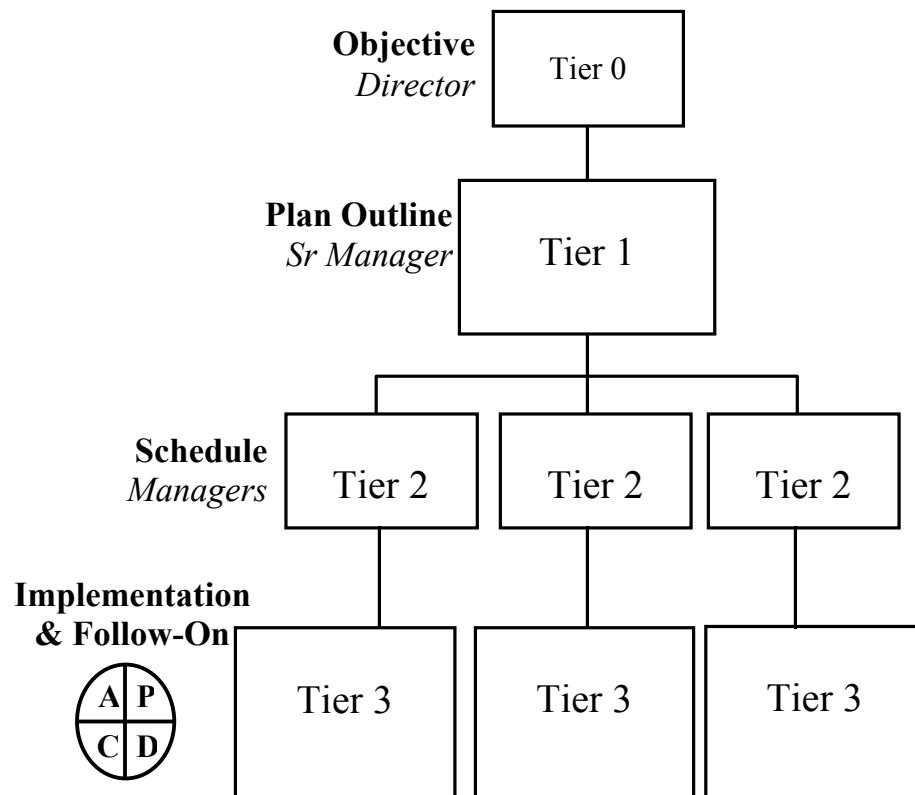


Figure 1 Make It Flow and Link The Flow tiered methodology from Tier 0 goal setting to Tier 3 implementation.

The Tier 0 workshops involved directors from all of the areas within a given value stream. They were the leaders for change within the organization. Their responsibilities included the commitment of resources required for the implementation of the plan, to provide project visibility to management, and to set high level targets for flow. The Tier 0 goals included:

- Map out the “as-is” process at a macro level.
- Understand what the “to-be” vision is and define the goals, objectives, and targets to achieve that vision.
- Determine the scope and boundaries for the project.
- Outline the project management structure and identify core team participants and commitments.
- Determine the project timeframe.
- Identify the participants for the Tier 1 activities (Reference 2).

These results became the baseline for the Tier 1 workshop. During this workshop the senior managers identified in the Tier 0 develop a “to-be” macro process that met the directors’ flow targets. The Tier 1 goals included:

- Expand participation in the project.
- Orient the new participants and get them engaged and excited in the project.
- Validate the vision, goals, and objectives and work statements for each element of the project.
- Map out the “to-be” process or proposal for each project element.
- Identify and document the major steps that must be taken to get to the “to-be” macro process.

- Review the plan or schedule for the Tier 2 workshop.
- Identify participants for the Tier 2 activities and determine the first meeting day, time and location (Reference 2).

The managers then developed a detailed process flow, implementation plan, and schedule in a Tier 2 workshop. The Tier 2 goals included:

- Expand participation in the project.
- Orient the new participants to the project.
- Review and validate the macro “to-be” process/proposal for the element of the project they will be working on.
- Map out the “to-be” process at a lower level of detail and identify issues/tasks to achieve the goals and objectives.
- Prioritize issues/tasks and determine time frames for resolution.
- Sort tasks into phases and develop a step-by-step implementation plan/schedule that links issues/tasks to specific process changes.
- Assign individuals to each issue/task and identify additional participants for Tier 3 activities (Reference 2).

The implementation of the new process and the follow up to implementation, the Tier 3 activities, occurred during weekly or bi-weekly meetings where issues were worked through and progress was tracked. These activities followed the Plan-Do-Check-Act (PDCA) cycle promoted by Total Quality Management. The goals for this phase included:

- Expand participation in the project.
- Orient the new participants in the project.

- Review and validate the work statement, detailed implementation plan/schedule and issues/tasks they will be working on.
- Create detailed action plans for each issue/task and initiate activities/teams to complete tasks.
- Work the plan.
- Hold regularly scheduled meetings for progress checks and continuously refine the implementation plan/schedule.
- Prepare status reports and participate in report-outs to senior management (Reference 2).

Participation and cooperation were crucial to the success of each workshop and the overall plan. The greater the number of people involved, the wider the influence of the workshop results. Within three years the tiered methodology used to implement change in the factory had reduced the critical path days of flow from 71 days to 36 days. With the success of Make It Flow the 777 started to look at further opportunities for flow reduction and their supply chain was a logical next step (Figure 2, Reference 15).

In 1999, the 777 initiated Link The Flow (LTF) as its method for reducing flow with their suppliers. They decided to focus their resources on the 20 largest suppliers by commodity cost since these suppliers could leverage the greatest savings. They followed the same tiered methodology as in MIF, but expanded the participation to include the supplier, logistics personnel, and any other organization that accounted for days of flow for the given commodity. Early successes included floor grids, struts and nacelles, flap supports, and the 41 section. The focus for flow reduction was on two areas. The first was on supporting the supplier with flow reduction within their factories with cost

savings shared between the 777 and the supplier. The second was on the logistics between the supplier and the 777 factory. This portion became more critical as the factory continued to reduce flow. If the parts were not at the aircraft when it was time for installation, the repercussions could be felt immediately since the flow “buffers” had been removed with Make It Flow.

777 CTR/Link The Flow Strategy

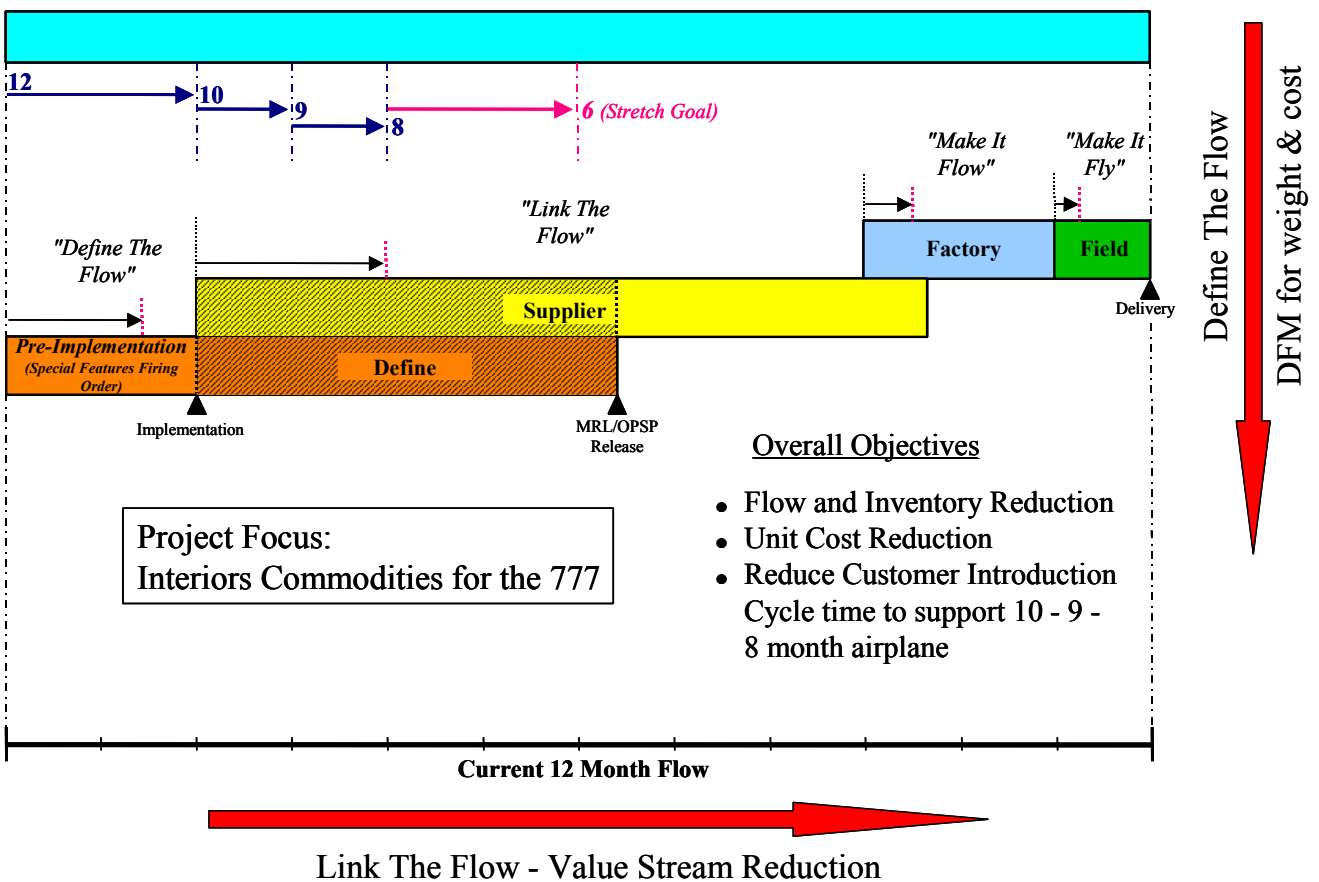


Figure 2 777 flow reduction strategy starting in the factory and expanding into the value stream. CTR (Cycle Time Reduction) is the group within the 777 factory that leads the MIF and LTF projects.

Even with this progress of working with suppliers, one area that was excluded was the engineering and design flows. In many cases these flows were several times longer than the factory flow. Additionally, efficient and accurate designs could enable

easier, quicker installations in the factory. In the fall of 1999, the 777 10-9-8 month airplane initiative was reinstated putting additional pressure on flow reduction efforts. The 10-9-8 month airplane initiative's goals were to reduce the total aircraft flow from customer kick off to delivery of the aircraft to 10 months initially, then 9 months, and eventually 8 months. The start date for each phase of this directive was attached to a particular aircraft on the production schedule. This initiative suddenly shifted everyone's focus from factory flow reduction only, to engineering and supplier flow reduction, since several aircraft parts had greater than a twelve-month flow. This sense of urgency motivated the various organizations associated with the 777 to assist in the Link The Flow effort.

1.2 Interiors Responsibility Center Background

The Interiors Responsibility Center (IRC), like various areas throughout Boeing, began applying lean thinking to its operations in the mid 1990's. The IRC operates as a supplier to most of the Boeing aircraft production lines providing the interiors commodities such as ceiling panels, sidewalls, partitions, and stowbins (Figure 3). Each of the commodities is produced in separate areas of the factory in a job shop manner. As pressure from external competition surfaced, the IRC decided to implement lean principles as a means of becoming competitive. There are several successes to date. The 737 stowbin line now operates on takt time with the bin moving between stations until it is finished and lifted onto hand pushed tex tube carts and brought to the 737 factory in response to the production line's kanban card. Future possibilities include conducting experiments with working cells that could exist next to the aircraft. Another implementation of lean is in their inventory. The IRC is moving their parts ordering to one of two systems: a min/max reordering system for frequently ordered parts and a quick turnaround supplier for rarely ordered items. The quick turnaround suppliers are screened and tested before written agreements are established. The combination of the two processes is reducing the average days of inventory and ensuring that the parts are available when they are needed. The next step for the IRC to becoming competitive is the 3-month interior vision. In this vision, the IRC would have a 60 manufacturing day turnaround for interior commodities measured from the day the customer finalizes their interior to the day the interior commodity is delivered to the aircraft production line. If successful, the IRC will not only have reduced flow days by as much as 75%, but they would be able to support the 777's 10-9-8 month airplane initiative and maintain

competitiveness with external suppliers. However, the IRC could not achieve a 60-day flow without extensive coordination with the engineering, procurement, logistics, and operations organizations. The result was the IRC looking for a way to initiate work with the 777 at the same time the 777 was ready to begin working with their supplier.

The scope of this internship included initiating the involvement of an internal Boeing supplier, the IRC, with the 777 LTF methodology and applying this methodology to a single commodity in a manner that could be easily applied to all of the IRC's commodities. The focus of the work was to provide the team leadership centered on applying the methodology to the logistics (Chapter 2) and design (Chapter 3) flows. In the final two chapters the LTF process is analyzed against the Enterprise Level Roadmap created by the Lean Aerospace Initiative at the Massachusetts Institute of Technology. This model is a work in progress and the feedback can be incorporated into future Roadmap versions.



Figure 3 A representative picture of the some of the commodities the Interiors Responsibility Center provides the 777 factory. Pictured above is the 777 –200.

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2. LINK THE FLOW

Prior to June 2000, the IRC and the 777 factory had made initial contact expressing interest in each other's flow reduction plans. Following this contact, a meeting with the 777 factory Critical Process Reengineering group and the IRC's director to gauge the possibility of meshing both organization's improvement goals enabled them to work together. During the meeting the goals of both organizations were presented with two positive results. The 3-month interior directly supported the 10-9-8 month airplane directive and the LTF process was the right method to reduce flow throughout the interiors value stream. A point-of-contact within the IRC was given by the director to ensure the proper attendance at the tiered workshops. Additionally, possible dates for the Tier 0 workshop (see chapter 1.1) and necessary invitees were also discussed. The invitees for this workshop (the directors) were a crucial part of the Tier 0 workshop who signed on to support the project with information, personnel, and resources for their organization.

The focus of the next three weeks was the extensive information and data gathering for the upcoming workshop. To focus the workshops on a single interior commodity, the outboard stowbin, was selected based on cost and flow metrics. Other commodities like the sidewall would have been easier to work with since it is an assembly. As a result the flow of the sidewall is affected by only its design and part flows. In contrast, the outboard stowbin is a sub-assembly and in addition its flow also depends on the flows of electrical wiring, lights, and other assemblies that attach to the bins. However, the lessons learned from this commodity were to be transferred to the other interiors commodities to speed up improvement implementation. As a result the

lessons learned from the sidewall would not transfer to the outboard stowbin as easily as it would the other way around. For these reasons the commodity selected to initiate the LTF process was the outboard stowbin. Starting with the factory, discussion began with first line supervisors to determine the average flow, the maximum flow, and problems encountered with the outboard stowbins. Additional information gained included an understanding of the value added by the factory and the key personnel to talk with in interfacing organizations. By discussing the same part of the process with adjacent organizations, discrepancies in the number of flow days included in each step became apparent. In many cases these could be resolved by gathering more information. In other cases these discrepancies were carried into the Tier 0 workshop to be resolved when all participants could state their opinions. Step by step the physical value stream map for the outboard stowbin was created as a baseline for the Tier 0 workshop (Appendix 1, Reference 7). Also by documenting on the same document the problems encountered, the workshop team could also look for ways to improve the process. Eliminating the problems encountered by personnel throughout the value stream is a way of gaining momentum for the project that is a fundamental part of the LTF process. Other activities that occurred during this time period included scheduling the exact date and location of the workshop; continuing to locate organizations and key personnel necessary for workshop success; and setting up the agenda and information packets for the participants. The information packets contained the agenda (Appendix 2), process layout, the initial value stream map, and a visual of the personnel present grouped by organization. All data and visual information gathered was put into an electronic format as a means of documenting and presenting the information at the workshop. Also a value stream cost

model of the outboard stowbin was created using the flow data gathered to document the project starting point. The day before the workshop changes to the value stream map were frozen and a 4 feet by 3 feet page of the map was printed. This became the working version of the map for the Tier 0 workshop (Appendix 1).

2.1 Tier 0

The Tier 0 workshop occurred at an offsite location (Appendix 2). The choice of location was intentional. It required that attendees commit to spending the day at this workshop focusing on the result instead of other obligations and meetings they needed to attend. The workshop began with an icebreaker; a fun game that introduced everyone and lightened the atmosphere. The next step was to level set the group with a discussion of the history of Make It Flow and Link The Flow providing everyone with an understanding of past successes and the process they would be using that day. The IRC also discussed the 3-month interior plan and the progress that had been made to date. All of this occurred to set the stage with the participating organizations and create a common baseline of knowledge throughout the group.

The next step was the explanation of the value stream. It was presented step-by-step starting with customer configuration; continuing through engineering and logistics; and concluding with the factory, paint, fueling, pre-flight and delivery. The problems encountered were included and revised with information the group was encouraged to offer. The discussion concluded with the establishment of the workshop boundaries. Flow reduction for customer configuration and the field, including flight test and the paint shop, were not included in the boundaries of this workshop. The reasons for this are simple. Customer configuration decisions are made based on entire matrices of options that include all of the interior choices available to a customer. The availability of all of these options and the impact on downstream organizations were something that surfaced in the workshop, but the ability to change this process lay at a strategic level. The field already laid out their flow reduction goals and was working on achieving them.

Therefore the field's goals were transferred to the map as baseline information. By the end of this step the group gained a thorough understanding of the process and problems involved. Additionally, personnel had started to look beyond their individual piece of the organization to see the cause and effect relationships that existed.

With this new insight into the present value stream, the group began brainstorming ways that processes or systems could be changed to reduce flow. These ideas were categorized by the step of the value stream it affected. The four categories used were engineering, the IRC factory, logistics, and the 777 factory. Every idea was read aloud to the group, and the determination was made whether the idea was in or out of the box. In the box ideas could be implemented in the next 6 months to one year, and were within the realm of control of the participating organizations. Once all of the ideas were discussed the group voted on the best ideas within each of the four categories. The top ideas were then transferred onto the four feet by three feet working map, the in-the-box ideas in the interim strategies section and the out-of-the-box ideas in the vision strategies section. With this information the negotiation phase of the workshop began.

The overall goal of 60 manufacturing days had to be achieved through the coordination of the organizations present. By examining the interim and vision strategies the representative directors estimated the number of flow days their organization would span if the ideas were implemented. Once all organizations volunteered their flow reductions, the total interim and vision flow goals were calculated. If these flow goals were greater than the preset 100 days interim and 60 days vision necessary to meet the 3-month interior, an iterative process of negotiation between the organizations began until the preset goals were met. In the case of the outboard stowbin flow, the initial estimate

of the new flow was less than the preset goals. This can be attributed to the already existing flow reduction work of the individual organizations. This agreement for flow reduction was added to the enlarged value stream map and the participants signed their names to the map establishing accountability for their participation.

Normally this would conclude the Tier 0 workshop, however, by reducing the critical path flow, a new critical path was uncovered. Initially the installation part flow was less than one third the critical path flow, but too long to meet the 3-month interior goal. The installation part flow would need to be addressed before the agreed upon flow reduction goals could be achieved. To work through this discovery the group agreed that a Tier 0 for the installation parts path would need to be scheduled. This workshop was dubbed the Tier 0a, and the results are found in section 3.1. The final Tier 0 agreement can be found in Appendix 2 (Reference 9). At the conclusion of the workshop the organizations volunteered the personnel from within their organizations that would be supporting the follow on workshops.

The workshop succeeded by gaining support for the project, establishing realistic goals, and identifying the two areas of the value stream to focus on for improvements. The first area was the engineering flow that encompassed the define stage and the installation part flow. The installation part flow involves the engineering drawings that interface the commodity to the aircraft and includes the part flows of the installation parts. Many members of the workshop stated that the engineering organizations were interested in developing a simpler process with a shorter flow. See chapter 3 for documentation of the engineering workshop results. The logistics flow was the second

area on which to focus resources. The rest of chapter 2 explains how the LTF tiered methodology was used to improve the logistics process while drastically reducing flow.

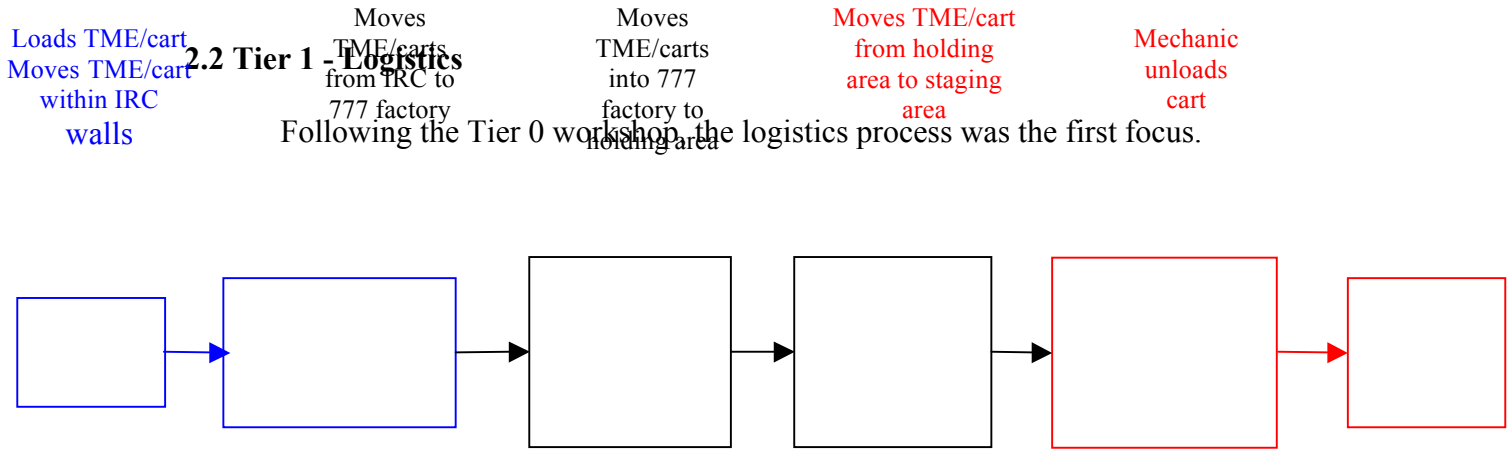


Figure 4 Process Steps of the present logistics process from the IRC assembly line to the 777 factory installation. TMEs are Transportation Mechanical Equipment used to transport interiors commodities from the IRC to the 777 factory.

In previous LTF workshops logistics improvements proved to be achievable. This early success would create momentum for the engineering aspects of the project. To prepare for the Tier 1 workshop, the detailed process steps needed to be researched and documented. By following a shipment of outboard stowbins from the end of the assemble line in the IRC to the 777 factory floor, the multiple handlings and inventory holding positions could be located. Additionally, discussions with personnel from the three logistics organizations completed the description of the present process. These discussions also revealed the fact that a pull process was implemented two years before and fell into disuse due to miscommunication and a lack of trust. With these insights the logistics Tier 1 was scheduled and the managers from the organizations involved in the IRC interiors logistics process were invited. The final workshop preparation involved laying out macro blocks of the present process steps onto a timeline. Each macro block consisted of one step in the logistics process, the length of time the step spanned, and who was accountable for the completion of the step (Figure 5).

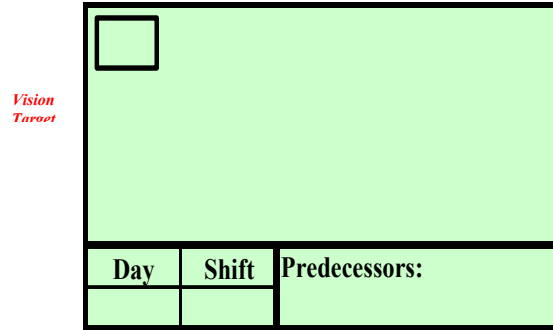


Figure 5 Macro block used to document a single step in the logistics process

The macro blocks were then placed onto a large timeline according to the typical days the individual step occurred. This timeline would be used to constrain the new process within the Tier 0 goal of ½ of a flow day or one shift for logistics. Suggestions in the Tier 0 included using a kanban process, a pull process, or a pulsed process. Figure 6 is an example of a timeline with the macro blocks prepared by the different organizations involved in the process.

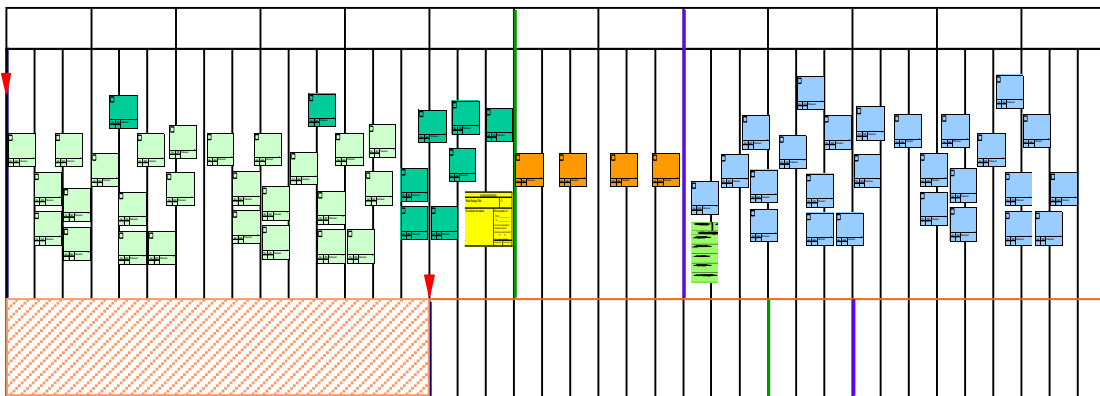


Figure 6 An example of a Tier 1 process map used to derive a new process flow

The macro block timeline with the new process was intended to be the outcome of the Tier 1 workshop. However, once the Tier 0 results were presented to the managers everyone immediately agreed that the goal was achievable. All steps of the present

logistics process (Figure 4) could occur in one shift with coordination and cooperation without mapping the new process onto the timeline. This realization led the team to support a Tier 2 Accelerated Improvement Workshop (AIW) to redesign the logistics process. Included in this workshop would be the communication link, method of transportation, and the means of transportation. The names of the specific team members to support the AIW and the implementation (Tier 3) were volunteered.

During this workshop the difficulty of coordinating people's effort became apparent. The previous failure of a pull process two years before left people disillusioned about 'process improvements'. Additionally, employees from the various organizations spent a lot of time blaming the others organizations for the failure. In order for the project to succeed this time everyone would need to move past his or her differences. If they would be willing to replace their individual ideal process with a new process that benefits all organizations then implementation and continuation of the new process could occur. The function of the Tier 2 logistics workshop would be to align the interests of the employees within the participating organizations.

2.3 Tier 2 Logistics

Once the directors and managers agreed on the ½ day goal for logistics between the IRC and the 777 factory, the Tier 2 AIW would involve the personnel accountable for the successful completion of the logistics process. Without the support of these personnel any improvement effort would fail. A two-day AIW was scheduled to examine how the pull process would behave, what the responsibilities of each individual would be, and how the outboard stowbins would be transported. Baseline information for the workshop included the other LTF logistics processes and the IRC's 737 logistics process previously implemented. When this workshop occurred, it was initially thought to be a success. The two-day workshop concluded with the following results:

- A kanban process should be used to communicate which shipment of stowbins the factory needs at which time. The initial process was a push system in which the IRC shipped over the stowbins as soon as they were finished. The IRC did not know if the factory was ahead or behind schedule and the factory had no access to the present status of the IRC assembly line. The lack of communication and the push process together resulted in the work-in-process inventory between the organizations.
- The present TMEs should not be used in the new process. TMEs were the storage and transportation containers used to move the interiors commodities to the 777 factory (Figure 7). They were heavy, making it impossible to move one without a tug or forklift, and their size prevented them from maneuvering anywhere near the aircraft. As a result the factory mechanics would have to unload the stowbins onto tex tube carts, move the carts to the aircraft, unload the

carts for quality control to check the part numbers, and finally move the stowbins by hand onto the aircraft and into position. With the weight of an 84” long stowbin exceeding 80 pounds, ergonomic issues and mechanic injury were a concern.



Figure 7 TMEs used in the logistics process

- Instead of TMEs, a tex tube cart moveable by one person down the final assembly ramp to the aircraft should be used. Ideally the carts would be capable of rolling onto the aircraft at the systems installations control codes where the aircraft is in cross-wise sections. TMEs were large and heavy, hindering their placement anywhere near the aircraft. The workshop designed and built the prototype cart for testing by the mechanics.
- All of the interiors commodities built by the IRC should be moved onto the pull process to reduce the number of processes employees had to follow and reduce the likelihood of reverting to the push process.

Though these results were positive, several roadblocks prevented the implementation of the pull process at this stage. The first was a conflict within the team about the mode of

transportation for the stowbins and all interiors commodities. The 737 process used a truck to move over shipments of tex tube carts requested by installation. The IRC preferred to use this method again for consistency and for protection of the commodities from the weather elements and jolting. The transportation organizations only wanted to drive forklifts and therefore wanted the tex tube carts mounted onto a base strong enough to be pulled across roadways by a forklift. The base also needed to withstand the forces of linking 6-8 carts together in a train to reduce the total number of trips per day between the buildings. The 777's view was to have lightweight point-of-use carts. If the carts could be linked in a train it was an added benefit, but not at the expense of the point-of-use cart. Several weeks were spent attempting to find a base and/or cart to meet the needs of the organizations in the leanest way possible. When a base lightweight enough for one person to push, but strong enough to withstand pulling by a forklift across roads could not be found, the decision to mimic the 737 process was made. This decision led to another roadblock in the IRC. An employee who was experienced with the loading of outboard stowbins into the TME's at the IRC was not at work the week of the workshop. Though another employee participated in the workshop, the first employee's concerns about the changes in the process carried considerable weight. Management was similarly concerned. This resulted in several more organizations stating they would not allow the pull process to be implemented. Simultaneously, the other commodities managers within the IRC realized they knew nothing of the goals their director signed in support of the project. With all of the problems arising, the success of the project was doubtful. In response, the solution the key stakeholders rallied around was to redo the Tier 2 with a larger team and an expanded focus.

Due to the larger scope and the greater number of people involved, the workshop was scheduled for an entire week. To overcome all of the short-comings of the previous Tier 2 AIW, the focus of this Tier 2 would be all of the major interiors commodities: ceilings, sidewalls, center stowbins, and outboard stowbins. If all of the commodities were to be implemented together then the workshop should work on all of the issues simultaneously. This idea was initially proposed by the Tier 2 team for simplification for everyone involved. With the scope expanding, all of the IRC's commodity managers were given the opportunity to air their views at a separate meeting. During this meeting they approved the team's suggestion to implement the new logistics process for all of the major commodities simultaneously. At the conclusion of the meeting their support was solidified with their signing of the AIW work proposal. Additionally, the dissenting organizations and personnel that were creating roadblocks to prevent change were invited to and participated in the workshop. Their criticisms of the previous Tier 2 were viewed as valuable opportunities for improvement. This mentality contributed to the success of this workshop. At the end of the week a report went out to management presenting the results of the workshop. All of the issues and roadblocks that had prevented implementation were resolved and ergonomically friendly point-of-use carts were designed and tested. Tex tube material was ordered to support the cart building, and implementation would occur when the carts for an individual commodity were completed.

2.4 Tier 3 – Logistics and Results

Implementation for the new logistics process is occurring in stages throughout the spring of 2001. The critical step is the manufacturing of the tex tube carts. As of March ceilings and sidewalls are operating on the new process with no major implementation problems. Stowbins, both outboard and center, will follow in April. The improvements in logistics for outboard stowbins alone will result in approximately \$1.3 M savings in asset value. This was calculated using a cost model developed for the MIF and LTF projects. This model accounts for the value of the assets removed from the value stream by translating flow reduction into cost savings. This allows for the flow reduction projects to be justified on a net present value basis while accounting for lean improvements. Additionally, the tex tube carts have reduced multiple handling and ergonomic issues the 777 factory mechanics encountered.

This success establishes the value of flow reduction within the LTF framework. Through starts and pauses, a new pull process for the logistics between the IRC and the 777 factory was created. The employees who expressed concerns or reservations proved to be valuable since it was their opinions that pushed the team to constantly improve their ideas. Additionally, encountering the issues before implementation enabled a smoother transition making change easier for everyone involved.

One of the IRC's concerns that was not addressed within the process was the counter issue. Counters are a metric used to measure suppliers. When a supplier receives a counter it is a negative strike noting a late delivery of the specified part. Built into the counter metric is the measurement of late: parts are considered late if they are not in the factory 24 hours ahead of loading onto the aircraft. With pull processes the parts would

never be in the factory 24 hours early. If the metric is not changed, it will be measuring the exact opposite of what the new process intends. Changing the counter metric and creating new metrics that support the proper use of the pull process would reinforce the implementation and sustainability of the new process. If these changes do not occur, it will encourage the supplier to revert to the old logistics process.

A second issue that arose centered on incentives. As a team leader I did not have many options available to reward the team members. They are saving Boeing money and improving the way the organization operates, yet they do not share in the benefits. Giving the team members a stake in the success of the project is another way to ensure success and it could simultaneously raise morale within the Boeing workforce.

At a Tier 0 level the critical success factor is the support of all the participating directors. The future support of the project was dependant on their enthusiasm and support. The workshop sparked a sense of possibility in the organizations and created momentum for the next workshops.

At a Tier 1 level the ease with which the project could fail became apparent. The previously instituted pull-process fell into disuse and each person was convinced everyone else was responsible. Developing relationships with the participants and encouraging interaction between team members enabled the members to overcome past experiences.

During the Tier 2 the team's determination to implement a better process ensured the project's success. The members knew the process they created would improve an aspect of their own positions. As a result the members continued to discover how to deal

with each snag that hindered implementation. The project's success was a result of the efforts of the individual team members involved.

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3. ENGINEERING

Installation Drawings (777)

777 Factory

The initial Tier 0 (see chapter 2.1) highlighted opportunities for flow reduction

within the engineering processes for the outboard stowbin these engineering processes

include:

Engineering Data Check (EDC)

Mechanical Engineering (ME)

Computer Processing (including MAIDS)

Panel Maintenance

Install at control code (cc)

(IRC)

Engineering Data Chart

Mechanical Engineering (ME)

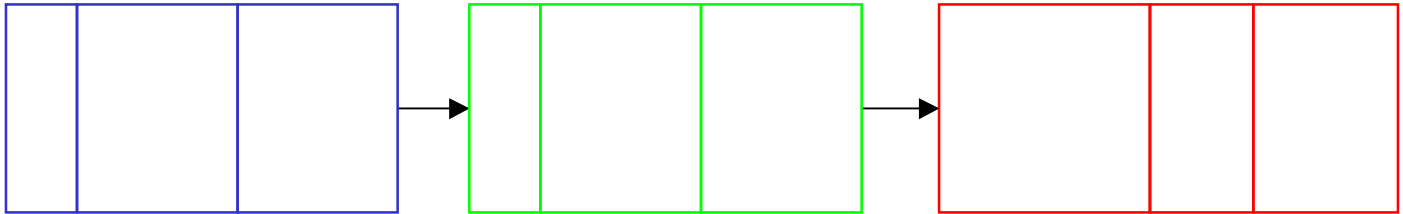


Figure 8 Engineering process including the installation part flow

In the define stage, engineering creates the drawings for the outboard stowbins and the endcap bins. The stowbin drawings themselves do not change, but the items that attach to the stowbins vary between customers. Next Engineering Data Check (EDC) verifies the part numbers and interfaces. The define stage concludes with manufacturing engineering (ME) which creates the document that describes how the bin is to be assembled in the IRC and how the assemblies attach to it. The installation drawing stage is organized similarly, however, the drawings and ME Operations and Inspection Records (O&IR's) refer to the installation of the stowbin subassembly into the aircraft. These drawings contain the information factory mechanics use to install the outboard stowbins. Before installation occurs, the drawings and documents must be processed by a collection of legacy computer systems (Figure 8, 777 Factory). The MAIDS system is the system that controls the interfaces between the legacy systems. To simplify the workshop, the flow days associated with all of the legacy systems were assigned to MAIDS. After

computer processing, panel maintenance receives the O&IR documents and organizes them by control code, delivering them the day before installation.

Several years earlier, define and installation engineers were co-located and worked together to produce the drawings. This cooperation deteriorated with the creation of integration teams. Interiors commodities were grouped with the Main Cabin Integration Team (MCIT). This team consisted of the define engineers for all main cabin items to increase coordination and reduce interface issues. A consequence of MCIT, however, was the increase in flow days between the IRC and 777 engineering groups as the work was scheduled to occur serially. The goal of the Tier 0a workshop was to gather the outboard stowbin engineers from the various processes to determine the feasibility of reducing the engineering process flow to fit within the Tier 0 goals.

3.1 Tier 0a - Engineering

Prior to the Tier 0a workshop, the engineering value stream map and process problems encountered were researched in the new critical path of the installation part flow. There were several more flow discrepancies between the interfacing organizations. This may be a result of the reinstatement of the 10-9-8 month airplane directive between the Tier 0 and Tier 0a workshops, which resulted in no one wanting to be held accountable for more flow days than necessary. There was an interesting discovery made during the research. The combined flow for the legacy computer systems was longer than the total aircraft factory flow. This flow drove the master schedule dates for the engineering work to be several weeks earlier than necessary. The hidden buffer had built up over time. However, the legacy computer systems were corporate wide and outside the sphere of control of the 777 program. The value stream map and information discovered were the foundation for the Tier 0a workshop. The key discovery during this process was each individual's definition of flow. An example is panel maintenance. Since panel maintenance only worked for two days with the information, they assumed they should only be assigned two days of the flow. However, their process called for one day of work the first week, $\frac{1}{2}$ of a day of work the second week, and $\frac{1}{2}$ a day of work the third week on the day before installation. This resulted in 15 days of flow not the two days of work performed. The concept of days of work not days of flow was ingrained in several employees mindset.

The Tier 0a workshop followed a similar agenda to the Tier 0 workshop. A major difference between the two workshops was the inclusion by managers of representative engineers, involving the engineers at an earlier stage. As a result, the brainstorming ideas

were detailed and addressed specific problems the engineers encountered. These ideas fed directly into the Tier 1 workshop and established the possibility of concurrent engineering achieving the Tier 0/0a flow reduction goals.

At the end of the half-day workshop, a realistic vision of how the Tier 0/0a goals could be met was established. The key personnel necessary to work through the complex processes were defined and committed by management. The detailed interim and vision strategies established a clear direction for the Tier 1 workshop (Appendix 4, Reference 10). However, the workshop could have been improved if the information and decisions flows were mapped in addition to the process flow. These additional maps would capture the iterative processes and the rework that occurred in the engineering processes. They would also highlight the weeks of flow attributed to information and computer processing. Future workshops should consider mapping this information too.

3.2 Tier 1 - Engineering

The detailed ideas and information provided by the Tier 0a workshop created a solid foundation for the Tier 1 workshop. Having ideas and information at the start was crucial due to the complex and interrelated process flows involved. This workshop was the first attempt to apply the LTF process beyond logistics and successful results would build momentum for the process in several organizations. The personnel attending the Tier 1 workshop on October 27, 2000 were asked to bring their color-coded macro blocks detailing the steps in their process (see 2.2, Figure 5). The color-coding clarified the timeline as each group's processes were added to the present process timeline. Each group presented their process blocks and discussed what occurred during the associated flow. This led to an open question and answer phase that assisted the team's ability to understand each other's demands. As all the processes were placed on the timeline, it became clear that many of the group's processes could occur concurrently without reducing the time allowed for the engineers to complete the step. When this became obvious to the team, the engineers in attendance became increasingly motivated to see the workshop succeed. The idea of 'working smarter, not faster' eased some of the tension the phrase 'flow reduction' had created before everyone had arrived at the workshop. With this new momentum the team began to layout the to-be process on the timeline. Starting with the first step, customer kickoff, the group evaluated what processes could start immediately and which depended on the completion of other process steps. Block by block all of the process step for all of the groups were discussed and rearranged. Sometimes a process needed to be changed before the order of the steps could be rearranged. These changes were collected and added to the brainstorming ideas from the

Tier 0a. The team also discovered the concurrent engineering “to-be” process fit within the Tier0/0a goals on one condition: when the master schedule signaled a process step, dedicated engineers were required until the step was completed. This was a cultural change that needed management support for implementation. Normally engineers worked multiple tasks simultaneously, which increased the flow of each process step. Without this change the stowbin engineering process could not meet the 3-month interior and the 10-9-8 month airplane.

Coming out of the Tier 1 engineering workshop was a timeline of the to-be process that fit within the Tier 0/0a goals. A list of 15-20 improvement ideas and process changes necessary for the flow reduction realization was compiled. The engineers were anxious for the Tier 2 workshop to occur so they could structure the implementation plan for these changes. However, one major roadblock existed. The flows for the interfacing assemblies like the lights, wiring, and ducting exceeded the Tier 0/0a goals. These flows would need to be worked separately; as a result of the success of the LTF workshops, MCIT was considering working the flow reduction for these assemblies. The new value stream including these interconnects as part of the initial work MCIT will conduct.

3.3 Tier 2 - Engineering

One month after the Tier 1 workshop the team met again to structure an implementation plan for the ideas. The Tier 2 meeting organized the ideas from the Tier 0a and Tier 1 workshops. The easiest, most realistic ideas were placed in the first phase of implementation and the most difficult ideas were placed in the third phase of implementation. Individuals volunteered to work on specific ideas and a bi-weekly meeting was scheduled to start in January of 2001. This meeting was the first that the IRC engineering point-of-contact organized and led. From this point forward the IRC was the lead organization in the effort. The IRC was in the position to leverage the engineering workshop results into the other interiors commodities through cooperation with MCIT.

3.4 Results

Proving the applicability of the LTF process to engineering flows was further validation of the method's worth. The process was flexible enough to organize and sort through the engineering processes in a way that enabled greater coordination and concurrent engineering. However, the effectiveness of the LTF process as applied to engineering could be improved with the additional mapping of the information and decision flows. Though the implementation of the engineering flow reduction depends on management decisions and further flow reduction on other assemblies, the team was able to construct a new, simpler process that achieved the Tier 0/0a goals and the engineers supported. The workshops re-ignited cooperation between the engineering organizations.

Appendix 5 depicts the workshops for the logistics and design processes. The Tier 0 triggered two separate sets of workshops. The first set was the Tier 1-3 focused on the logistics process between the IRC and the 777 factory. The second set was the Tier 0a-2 encompassing the engineering involved in the design processes.

4. ANALYSIS

The LTF process has initiated a focus on flow reduction that has produced results for the 777 program. To measure how well this method meets the needs of the 777 program, it must be compared against some standard process. The Lean Aerospace Initiative's Enterprise Level Roadmap (Reference 5) is the standard process chosen for its focus on the aerospace industry and is a company wide vision.

The Lean Aerospace Initiative (LAI) began in 1993 to address the needs of the government to promote lean processes throughout the military aerospace industry (Reference 8). It has grown to encompass the United States' aerospace industry including government, military, and civilian organizations. The aerospace industry has unique needs concerning lean implementation. Aerospace systems are orders of magnitude more complex than cars or other assembly line items. Frequently new technologies are used and manufacturing processes for these technologies are untried. Additionally, the sheer size of a stealth fighter makes a Toyota-like moving line difficult to implement and a reconnaissance satellite may be built only once. However, these are the same reasons why lean is so important to the industry. For many aerospace products failure is unacceptable. You only have one chance to succeed in your mission. Lean provides a way to reduce the chance of failure, increasing the protection of human lives, enabling the government mantra of 'faster, better, cheaper' to be realized.

The Enterprise Level Roadmap (Figure 9) is a culmination of the work of researchers at the Massachusetts Institute of Technology (MIT) and companies throughout the aerospace industry (Reference 12). It was compiled to answer questions

Enterprise Level Roadmap

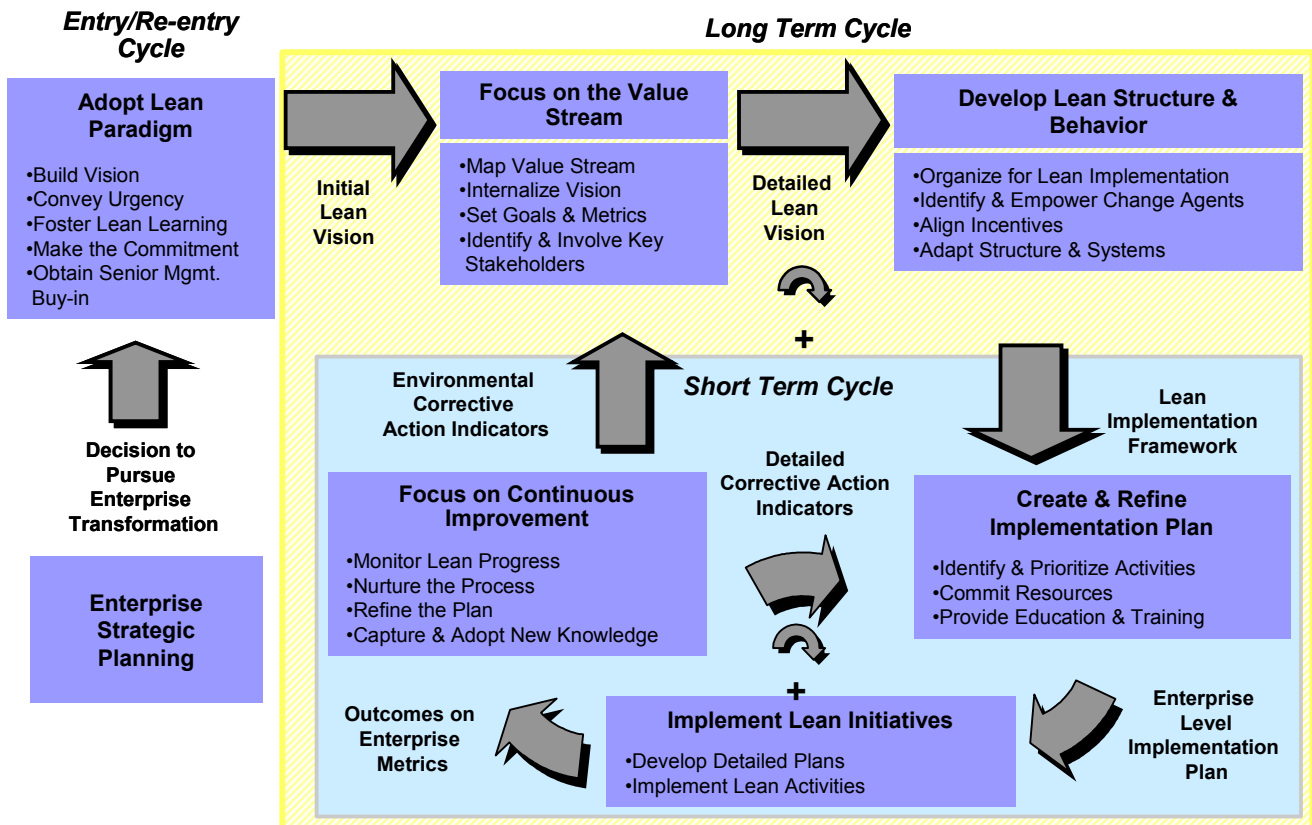


Figure 9 The Lean Aerospace Initiative’s process for transitioning a company into a lean organization. Deborah Nightingale © 2001 Massachusetts Institute of Technology

concerning how lean can be implemented throughout the entire enterprise. Most literature on lean focused on factory implementation (Reference 16). The enterprise level roadmap expands the concept of lean to include all elements of an organization and its supply chain. No one company has successfully transitioned their entire company into a lean enterprise, but many have successfully transitioned portions of their organizations. The knowledge gained from these successes, along with knowledge gleaned from “change management” literature, was employed to develop the roadmap. It is important

to remember that the roadmap is a work in progress. As more aerospace companies become lean enterprises, it will be refined with the knowledge gained.

In analyzing LTF against the Enterprise Level Roadmap, a table was constructed to highlight the major differences using a detailed guide (Reference 6) written by the LAI (Table 1). The analysis is based on a six-month internship experience in the 777 factory. Working on the 777 program level, an accurate view of how Boeing Corporate policy on lean influenced the 777 program was not observed. As a result the analysis will be limited to the influences of the program level and below. Five major differences between the Enterprise Level Roadmap and the Boeing flow reduction process were noted. The underlined points in the spreadsheet are aspects that are found in the 777 LTF model and not found in the roadmap. The italicized points are aspects that are found in the roadmap but are absent from the 777 LTF process. The following two sections will highlight these aspects. The last section of this chapter addresses the orthogonal value streams within Boeing and how a strategy for lean implementation could resolve boundary issues in the future.

ADOPT LEAN PARADIGM

Build Vision	1993 Corporate initiative to become lean (Reference 1). <i>Make Lean vision integral part of company's strategic business plan. Create new mental model of how new lean enterprise would function.</i>	3 days one bay.	
Convey Urgency	Airbus competition.		
Foster Lean Thinking	Organized a 'Lean' office w/ trained personnel. Hire personnel from lean organizations for transition. <i>Senior mgt site visits to lean companies and training in lean.</i>	777 team focused on flow reduction.	
Make the Commitment	9 step plan. <i>Commit the significant resources required.</i>	Make it flow (Reference 4). Commit the significant resources required.	
Obtain Senior Management Buy-in	All a/c organizations implementing. <i>In depth education and training required.</i>	Program, ops, etc support.	Tier 0

FOCUS ON VALUE STREAM

Map Value Stream		Map of process flow for Tier 0. <i>*Map information flows and decision flows.</i>	Tier 0
Internalize Vision	Create Value for the customer. Pull Value (Reference 2).	Set expectations at Tier 0.	Tier 0
Set Goals and Metrics	Eliminate waste.	Goals of flow reduction. <i>*Metrics - changes/additions.</i>	Tier 0
Identify and Involve Key Stakeholders		At end of Tier 0 identify Tier 1 participants. Include potentially affected stakeholders.	Tier 0

DEVELOP LEAN STRUCTURE AND BEHAVIOR

Organize for Lean Implementation	Lean office. Establish IPPD teams.	777/IRC Lean personnel.	
Identify and Empower Change Agents		At end of Tier 0 & 1 identify personnel for next level.	Tier 1
Align Incentives	<i>Structure incentives to reward lean behavior. Tie incentives & executive compensation to lean performance metrics. Remove disincentives.</i>	Cost/ flow reduction including cost savings sharings. <i>*Align incentives - monetary & non-monetary/individual & team.</i>	
Adapt Structure and Systems	<i>* Reduce the complication of communication & information systems. Make financial & accounting statements compatible w/lean paradigm.</i>	Cost model adjusted to account for intangible benefits.	Tier 0

CREATE & DEFINE IMPLEMENTAION PLAN

Identify & Prioritize Lean Initiatives	Time-phased schedule of collective Enterprise lean initiatives.	Transition plan for MIF and top 20 list for LTF prioritized.	
Commit Resources	Plan to meet all production requirements during lean transformation. <i>Make firm commitment to all resources needed.</i>	The time of human resources is the major commitment.	
Provide Education & Training	<i>Establish comprehensive program of education/training for enterprise.</i>		

IMPLEMENT LEAN INITIATIVES

Develop Detailed Plans		Implementation plan and business case built on adjusted cost model. Incorporate needed education & training into plans. <i>*Adjusted cost model to include intangible benefits and still justify NPV.</i>	Tier 2
<u>Choose Means of Fostering Lean</u>		<i>*Kaizen, AIW, CQI Teams, Six Sigma, Etc. (Reference 2).</i>	Tier 2
Implement Lean Activities		Personnel assigned to complete each taks of implementation plan. Challenge senior management & change agents to remove barriers.	Tier 3

FOCUS ON CONTINUOUS IMPROVEMENT

Monitor Lean Progress		PDCA as part of Tier 3 bi-weekly ->bi-monthly follow-ups. Roll-up updates & results into 777 cost models.	Tier 3
Nurture the Process		PDCA as part of Tier 3.	Tier 3
Refine the Plan		PDCA as part of Tier 3.	Tier 3
Capture and Adopt New Knowledge		Personnel training. Electronic knowledge capturing.	

* Described in chapter 4 analysis

italics - missing from or incomplete in 777 process
Underline - Missing from or incomplete in LAI Roadmap

Table 1 Comparison of the Enterprise Level Roadmap to the Link The Flow process. It highlights items that are not found in both models. The * items are focused on in sections 4.1 and 4.2. The difference between the Boeing Corporate and 777 Program columns segregates the level in the company the items are found.

4.1 Link The Flow Process

While there are several areas at a corporate level that appear to deviate from the LAI roadmap, only three are significant to the 777 program. The first area involves the mapping of processes, the second area discusses necessary changes to metrics, and the last area focuses on employee incentives. These three deviations from the roadmap provide an opportunity for the 777 to improve an already successful change process.

The Link the Flow (LTF) process maps the physical value stream, but does not map the information flows and the decision flows. This is highlighted in the Focus On Value Stream section of Table 1. The physical build-up, movement, and installation of parts are not the only processes where energy is expended. The information that passes between people working throughout the process and the decisions made with that information are the primary focus of not only management but manufacturing engineering as well. Entire support organizations like panel maintenance, expedite, and MAIDS (a legacy computer system that interfaces with tens of other legacy computer systems) exist for the sole purpose of gathering and distributing information. In fact, the engineering functions involved in design rely heavily on information and decision flows. By mapping out the information and decision flows with the physical product flows, greater opportunities for process improvements exist. This is illustrated in the former method the factory used to track down a shipment of stowbins needed for installation. The typical process for locating them follows:

- The factory first line supervisor first sent out mechanics to look in the usual inventory holding places throughout and outside the factory.

- The factory first line supervisor located the factory shop floor control person to see if the shipment had been received yet.
- The factory shop floor control person and/or first line supervisor contacted factory expedite to have them locate the shipment.
- Factory expedite contacted IRC expedite to have them check on the status of the shipment.
- IRC expedite routed the message to the person within their organization who handled interior commodities for the 777.
- The expedite person for 777 interiors contacted the IRC internal logistics employee to see if the shipment left the assembly line.
- The expedite person contacted the IRC first line supervisor for 777 stowbin assembly to find out the status of the shipment and, if incomplete, estimated the date and time of completion.
- The information was then passed back through these processes until it reached the factory first line supervisor who then needed to rebalance their crew work assignments.

The organizations and gates the information needs to pass through are cumbersome. At any point in time in this chain of events the bins could be located, but the full search has occurred. With the new logistics process a factory request includes pre-notification of late shipments. With pre-notification the IRC first line supervisor will contact their factory counterpart if they have the choice to ship late or ship short (missing parts). The factory supervisor can then make the decision based on factory drivers and adjust the workforce accordingly. The elimination of the middle steps makes it possible for large

amounts of time and energy to be saved. Now to incorporate this new logistics process with every part that the factory first line deals with would over load their already busy day. There must be a simple way for information to pass between the organizations. By mapping out these decision and information flows, the time, energy, and resources absorbed by these flows can be identified, and the opportunities for improvement can be identified. This opportunity to lean out the support organizations that handle information should be examined and, if resources permit, explored.

The LTF process explicitly sets the goals for each value stream project, but it does not incorporate a method to address and implement the necessary metric changes. This item is also highlighted in the Focus On Value Stream section of Table 1. A change in performance metrics for the factory had already occurred. Production lines are measured by days of flow and flow reduction in addition to traditional metrics of person-hours per aircraft and unit cost. However, the metrics for the suppliers have not been changed. Suppliers are evaluated not only by quality, but by ‘counters’ as well. Counters are negative strikes against a supplier given if their parts are not in the 777 factory one day before aircraft installation. For suppliers that compete for Boeing’s aircraft business, counters pose a threat to future bid proposals and awarding. If a supplier participates in the LTF workshops and inventory between the supplier and factory is drastically reduced, more counters can result. For the IRC this was a particular risk for future competitiveness with external suppliers. With the new IRC-777 logistics process, the IRC commodities would rarely be in the factory one day in advance. In fact the designed worst-case scenario is sixteen hours. Until the counter metric is changed to incorporate pull processes, suppliers bear a greater risk with lean logistics process implementation.

An examination of the metrics used throughout the value stream will assist in the location of other metrics that actually work against the success of lean processes.

The LTF process does not incorporate a 777 standard system for monetary, non-monetary, individual, or team-based incentives for flow day reduction as found in the Develop Lean Structure & Behavior section of Table 1. The people involved are going the extra mile and receiving no incentives for the extra work. All that is required of a unionized workforce is that they complete their job according to job description. Current job descriptions do not cover much of the improvement activity associated with MIF and LTF. It is the responsibility of the team leader to pull everyone together. All that can be given in return is personal thanks and hopefully a process that they can be proud of. However, individual managers have the tools available to incorporate incentives. To this end, management needs to make the best use of the available incentive tools to encourage the creativity and teamwork necessary to meet desired goals. In an age when Boeing, like many companies, is rethinking their human resource strategy, a variety of different incentives should be considered. These incentives could be as simple as a structured vacation policy: for every 20% of flow reduced out of the system 2 hours of paid vacation will be granted to the Tier 2 team members. Other options include:

- The team that reduced the greatest percentage of flow from their value stream in a given year would get to fly along on a test flight in a 777.
- With a 10% reduction in flow, team members could trade jobs for a day to see the process from a different viewpoint.
- The three teams to reduce the most asset value annually would receive a catered lunch.

Incentives should be a consideration for future projects when a company is trying to establish better relations with their workforce.

4.2 Enterprise Level Roadmap

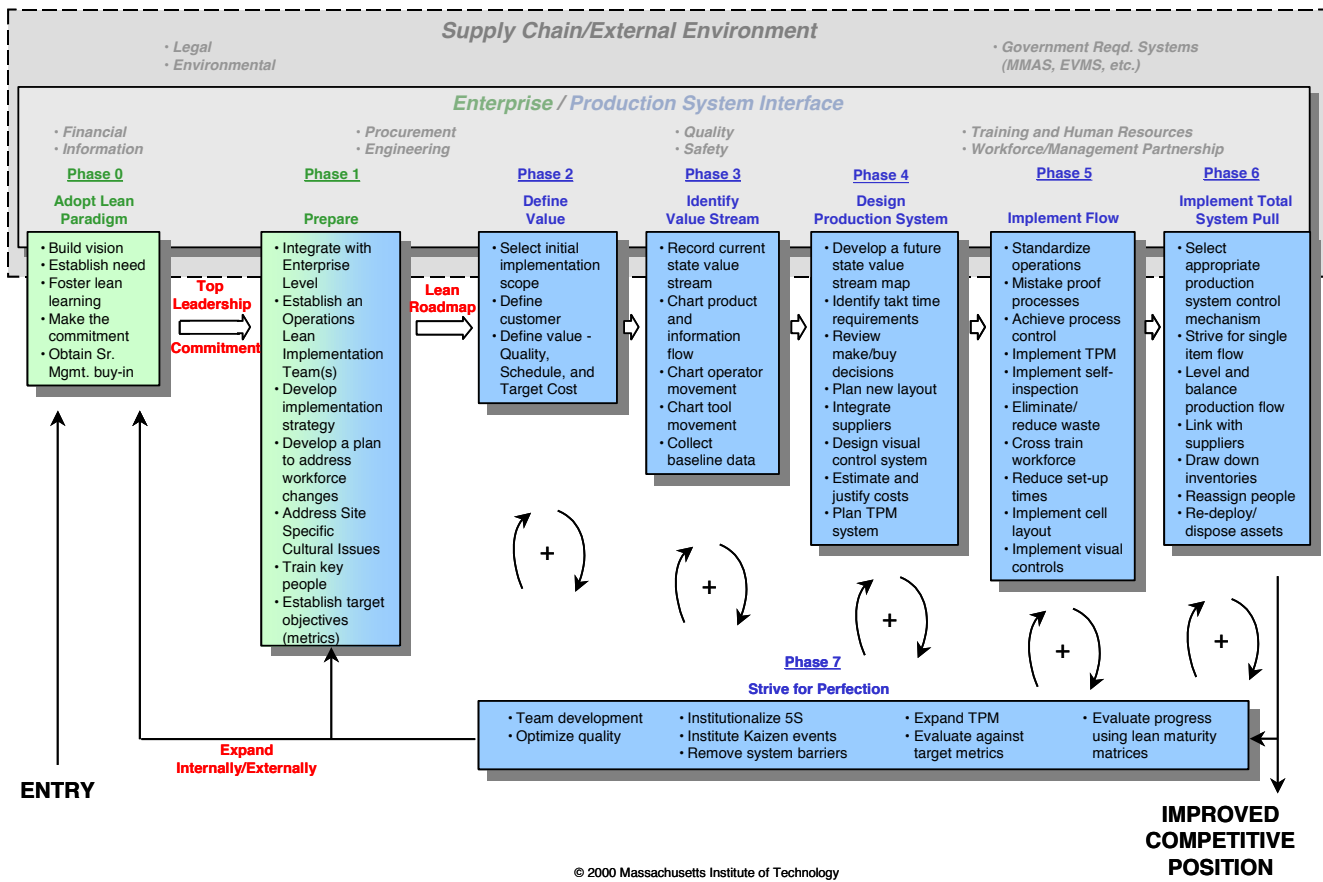
The two aspects missing from the LAI roadmap are both associated with the Implement Lean Initiatives phase of the roadmap. The first concerns the use of a financial measure to determine whether implementation of a lean idea makes business sense. The second addresses the various ways lean processes can be implemented. Both are highlighted in the Implement Lean Initiatives section of Table 1. One final observation concerning the roadmap's focus on management will conclude the last half of the analysis.

At a high level the roadmap includes transitioning the organization's financial systems to a lean system; however, it does not address the financial aspects of lean implementation. A basic principle of lean is the reduction of inventory, but present financial measures of return on investment and net present value do not incorporate the intangible benefits of lean processes throughout an organization. Additionally, implementation of ideas just because they are 'lean' may not be in the company's best interest. An example of this is the lean concept of a moving line. Transforming 777 production to a moving line may not make business sense. Presently, 777 factory production is broken up into work areas called control codes. The idea of the control code is that a specific number of jobs are to be completed within each control code before the aircraft body moves to the next control code. Presently, work travels from one control code to the next without being completed on a regular basis. A moving line would not eliminate this. Conversely, if no work traveled to the next control code then a moving line is no longer necessary to signal the end of the control code's tact time. The only savings would come from the cost reduction of crane moves. This savings may not

realistically be justified against the cost of restructuring the entire plant and adding factory space to accommodate the lengthwise dimension of a 777. The 777 developed a cost model for the LTF process that incorporates some of the intangible gains flow reduction offers. Though it presently does not incorporate all of the intangible benefits, it does enable some of them to be captured in a variation of a cost model that can be used to justify implementation. The adjusted cost model calculates the asset value reduction, a one-time financial write-off that can occur after the removal of flow days. This value can also be weighed against the resources needed for implementation. A corporation like Boeing must fulfill the needs of all of its stakeholders. The company's profits affects each of these stakeholders. Using adjusted financial measures to justify implementation of lean ideas is necessary for the protection of the stakeholders' interests.

The roadmap does not explain the various ways to implement lean initiatives. It includes the ideas of 'develop a detailed plan' and 'implement lean activities' (Reference 5), but does not give guidance about the various activities that can be used to make a process lean. Boeing presently uses various methods tailoring the method to the process under assessment. Accelerated Improvement Workshops (AIWs), Kaizens, Six Sigma, and Continuous Quality Improvement teams (CQI teams) are some of the methods used in implementation. Job shops differ from production lines, which differ from supply chain issues. Having a toolbox of several methods that can address the various needs of a given situation can improve the project's chance of success. Presently, LAI is developing an Enterprise/Production interface map that includes some of these concepts in Phase 7 (Figure 10).

Production Operations Transition-To-Lean Roadmap



6/5/00

Figure 10 The beta version of the transition-to-lean roadmap for production operations. It is one level more detailed than the enterprise level roadmap (Figure 9).

One final observation concerns the roadmap's focus on executives and management. While high-level support is essential for any corporate wide change effort to succeed, the roadmap does not address the roles and responsibilities of the mechanic or the electrician who actually executes the processes. If change efforts are forced on personnel, they have no personal stake in the success of the new processes. The LTF's hierarchical structure deals with this point. It leaves the leadership aspects like vision, goal setting, and resource support for management while the process restructuring occurs

within cross-functional teams of the personnel. The road map needs to address ways in which the mechanic, electrician, or assistant can become involved within its framework.

Assembly 747 IRC

4.3 Orthogonal Value Stream

767 Corporate Boeing needs a lean incorporation strategy to guide the management of the various boundary interfaces that exist between support, supplier, and production

organizations. This project addressed the interface between an internal Boeing supplier

and one of the aircraft production lines. In most lean concepts the customer dictates the nature of this interface and processes should conform to the customer's needs. However,

Assembly organization an internal supplier serves many internal customers within the company. The resultant interface creates an orthogonal value stream (Figure 11).

777 Value Stream

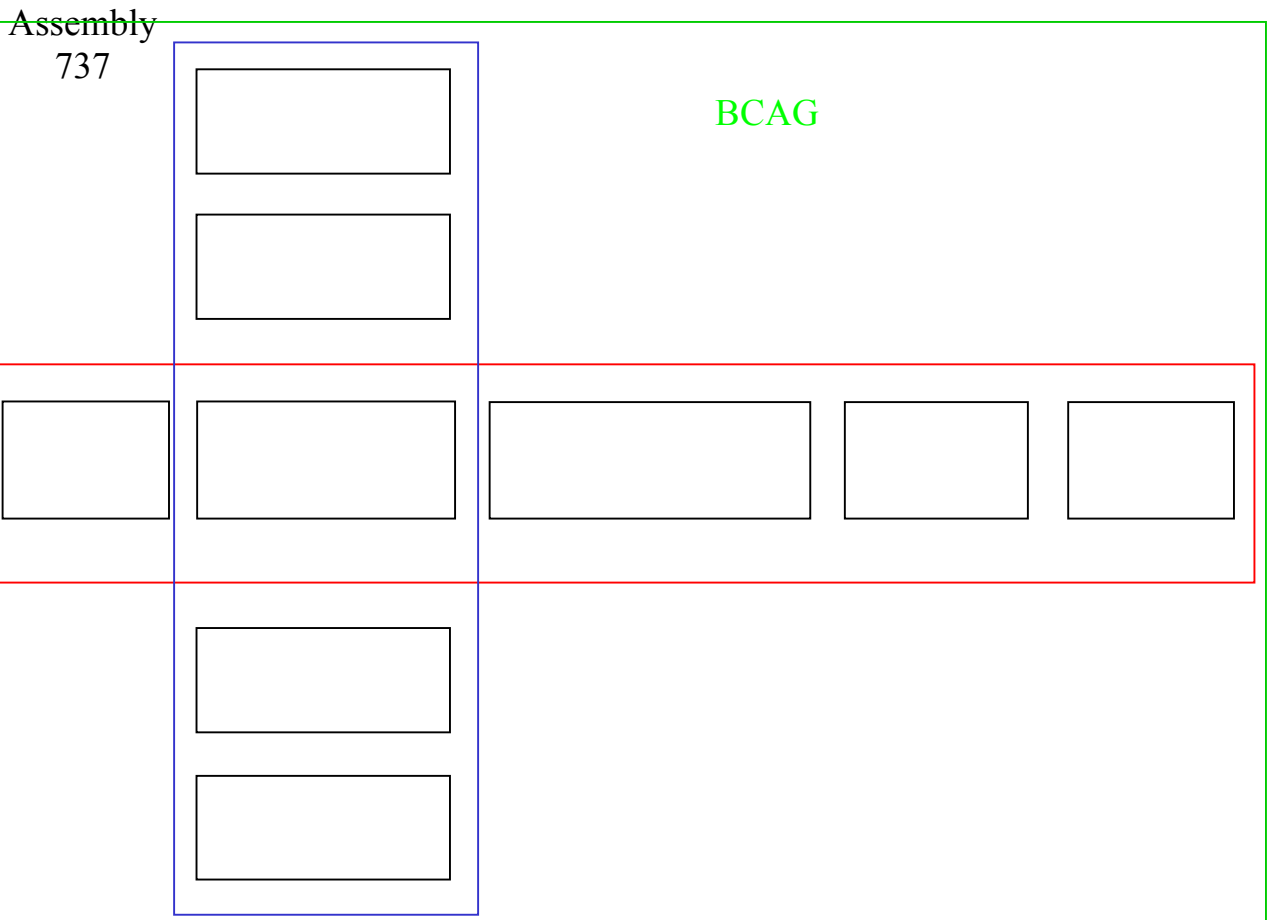


Figure 11 An orthogonal value stream within Boeing. The IRC serves multiple aircraft production lines attempting to implement lean throughout its process. Meanwhile, the 777 program is implementing lean throughout its value stream resulting in conflicting needs that must be considered to avoid sub-optimization.

With an orthogonal value stream, if either organization optimizes the process for only their value stream, sub-optimization for BCAG could occur. In this project, the IRC had already created a logistics pull process for interiors commodities with the 737 line. Although this process was the basis for the 777 process, it is not identical. In fact the long-term logistics vision for the 777 varies greatly from the 737 process. As a result the IRC will be managing two different pull processes. As the other production lines work with the IRC to reduce inventory between organizations, several more processes could be designed (Figure 12). Each process presently used different carts or transportation

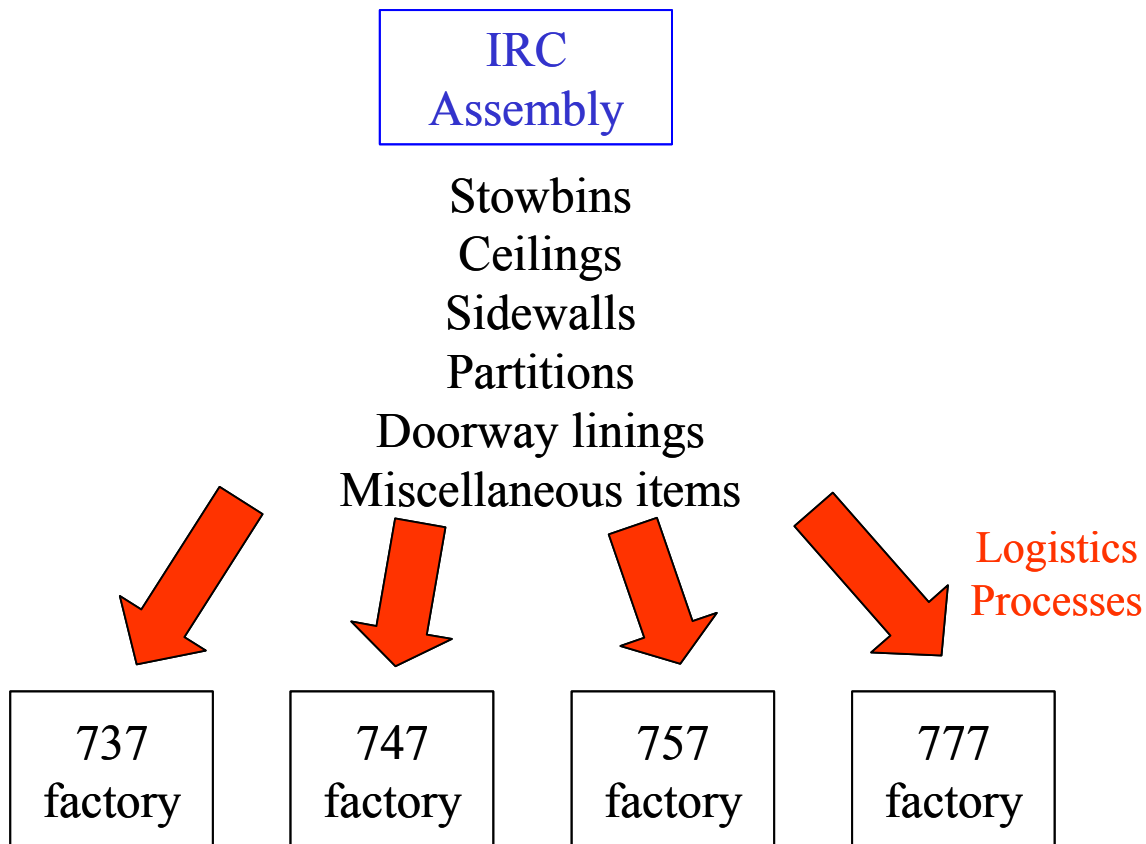


Figure 12 Depicting the commodities the IRC supplies to the aircraft production lines.

containers. Additionally some aircraft lines used a push process while others had implemented a pull process. Forklifts, tugs, and trucks were all used to move the commodities from the IRC to the production line. All of these variables created a

different logistics process for each production line. If the IRC was the only internal supplier then maybe sub-optimizing their logistics processes to optimize each production line would be better for BCAG. However, the IRC is not the only internal supplier. Additionally, support organizations will encounter the same problem. Finance, receiving, MAIDS, and other support organizations could end up with various processes across aircraft production lines creating waste of resources and energy. With all of the internal supplier and support organizations Boeing controls, it is possible that optimizing for the productions lines would create vast amounts of waste and sub-optimize BCAG. The logical conclusion is BCAG must be responsible for the management of these boundaries. Creating a corporate lean implementation strategy would do this. This boundary interface concept should be included in the top-down LAI Enterprise Level Roadmap. Presently, the roadmap only requests that lean become part of the corporate strategy without going into detail of which parts of corporate strategy it should affect. The bottom-up 777 flow reduction processes will also encounter it as the boundaries of the project continue to expand and encounter more processes out of their control. An example of this type of boundary process is the legacy computer systems, including the MAIDS system. These systems absorb one to one-and-a-half months of design flow. This is over 10% of the 8-month airplane flow in computer processing, making it difficult to meet this directive. However, the 777 does not have the authority to change a corporate-wide system for its production line alone. Corporate support on this issue is needed for improvements to occur. A BCAG lean implementation strategy would resolve issues like this.

5. CONCLUSION

While the Link The Flow (LTF) process and the Enterprise Level Roadmap contain several differences, the striking realization comes when one considers meshing the two views together. This is possible since the roadmap is a top-down implementation process and the LTF process is a bottom-up process. The roadmap's strengths lie in its ability to develop corporate support and strategy for lean implementation. The Lean Aerospace Initiative (LAI) is now developing the details of how this is implemented in supporting layers such as the Production-Operations Transition-To-Lean Roadmap (Figure 10). However, the 777's flow reduction initiatives, such as LTF, give them a proven process to use in further development. Where the roadmap leaves off is the exact point that the LTF process has reached up to: the program level. This result makes the LTF process complimentary to the LAI's continued work in documenting a comprehensive lean implementation map.

The 777 program from customer kick off through customer delivery has used the LTF and Make It Flow processes to reduce flow, cost per aircraft, and man-hours per aircraft. However, there are further opportunities for flow reduction that are outside the program's control. Boeing Commercial Air Group (BCAG) controls the standards of the supporting organizations and only they can commit to the changes across aircraft lines. This is where the Enterprise Level Roadmap comes in. Corporate Boeing does support leaning out their assembly and operations processes, but has not integrated leaning out supporting organizations into their strategy. If corporate followed the roadmap to direct the company's lean efforts, the 777 would have the support needed to expand their work into boundary systems like information tracking and processing.

In conclusion, the LTF process is an effective way to “lean out” a value stream that is adaptable to various company processes. The next step is to incorporate the LTF goals into corporate strategy while continuing with the operations, field, and supplier work occurring within the 777.

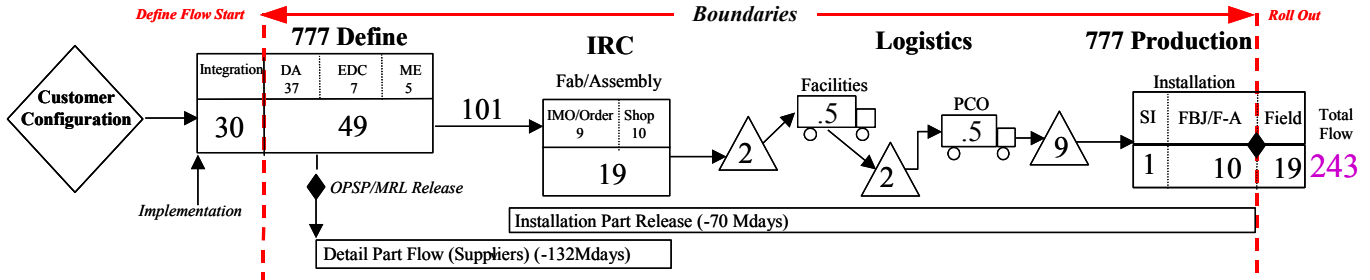
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Appendix 1 Value stream map before Tier 0 workshop

The following map was developed before the Tier 0 workshop through interviews with individuals in the organizations represented. These individuals estimated the number of flows days for their processes and the problems they encounter. The vision goal was set by the IRC's 3-month interior goal.

Outboard Stowbins - "Link The Flow" Tier 0 Agreement



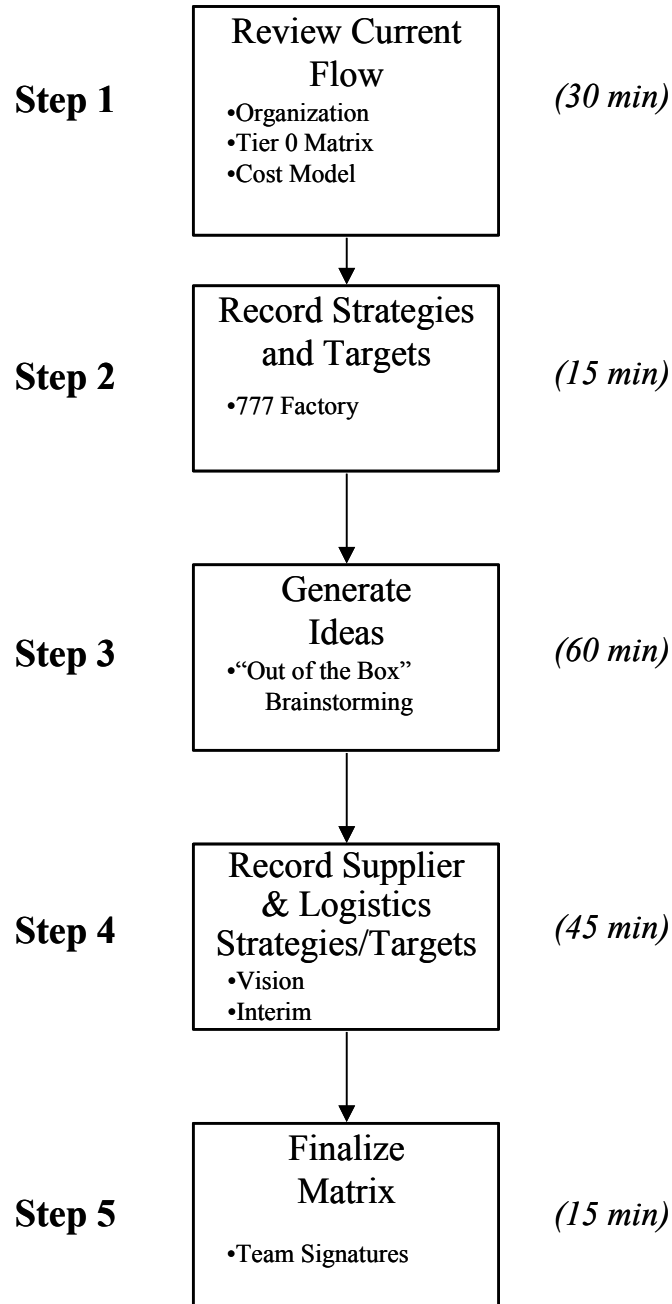
	Totals										
Current Process Issues	•Some customer options offered are difficult to build •Customer has ability to change options after design process has begun	•Engineering drawing must be complete before detail parts are ordered •No standard offerings •Detail part lead times are excessive if not ordered using Simplified Materials Management	•Order system flow time is too long (9 days) •Layers of systems prevent IRC and 777 factory 1 st line supervisor interaction	•Pull system initiated with factory has fallen into disuse •New scheduling system 'work to date' is better than previous process, but installation delays still exist	•Occasionally, when control code is ready to install stowbins, they can be difficult to locate •All staging areas not at point of use	Baseline Between Boundary Flow 194					
Vision Strategies											
Interim Strategies											
Interim Targets	Target flow 100 days Define to Rollout By:									Interim 100	
Vision Targets	Target flow 60 days Define to Rollout By:									Vision 60	

Signatures:

Appendix 2 Tier 0 Workshop Process

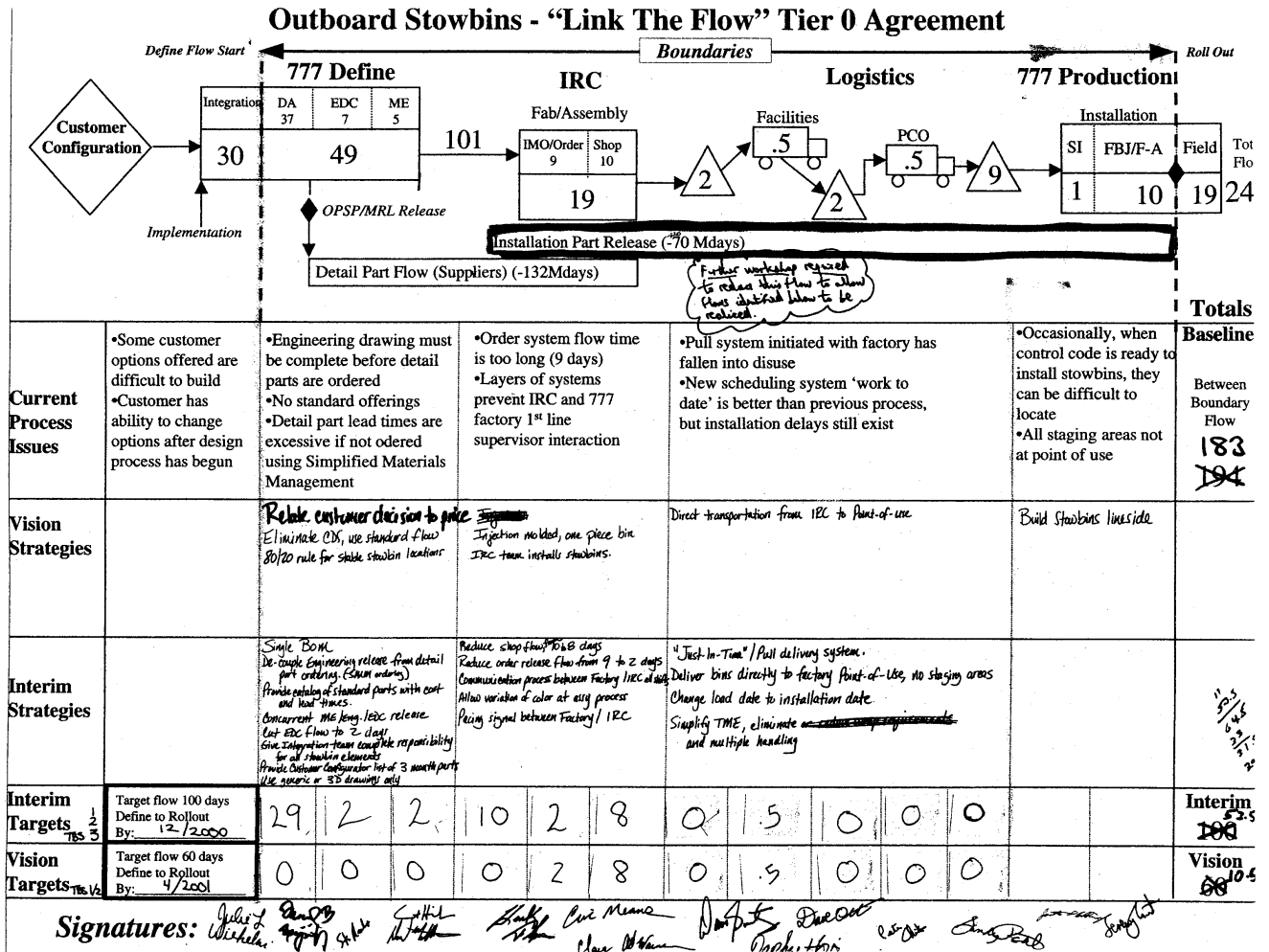
This process flow was used as a guide for the Tier 0 workshop.

“Link The Flow” Tier 0 Workshop Process



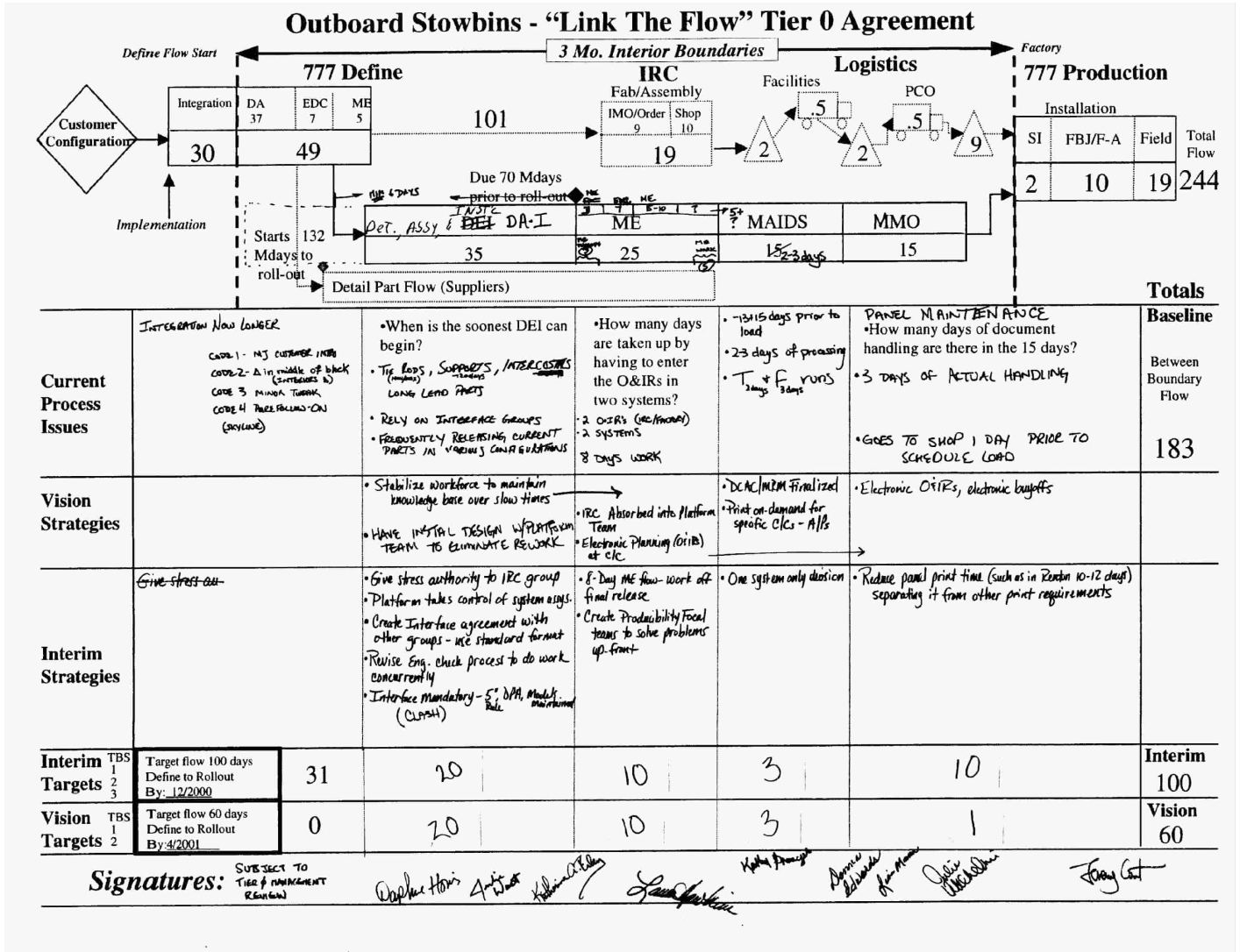
Appendix 3 Value stream map after Tier 0 workshop

This is a scanned version of the final Tier 0 agreement. The installation part release flow is highlighted since it is greater than the IRC's 60-day goal. This discovery resulted in a Tier 0a workshop focused on the engineering processes including the installation part flow. The summation of both the interim and vision goals meets or is better than the target.



Appendix 4 Value stream map after Tier 0a workshop

This is the final scanned version of the Tier 0a workshop. This workshop was necessary due to the discovery in the Tier 0 workshop that the installation part release was greater than the IRC's 60-day goal. The summation of both the interim and vision goals meets or is better than the target.



Tier 0

New Critical Path

Tier 0a

•New critical path process map

•New reduction goals for design

Appendix 5 Map of workshops for logistic and design processes

The workshops began with the Tier 0. The results trigger two workshops: the Tier 1 for logistic and the Tier 0a for design and engineering. From this point forward the workshops followed these two distinct paths.

