IMPLEMENTATION OF FUNCTIONAL BUILD IN THE VEHICLE DEVELOPMENT AND LAUNCH PROCESS

By

Peter T Haughton

B.S. Mechanical Engineering, North Carolina State University, 1995
A.B. Mathematics, A.B. Public Policy Studies, Duke University, 1993

Submitted to the Sloan School of Management and the Department of Mechanical Engineering in partial fulfillment of the requirements for the degrees of

Master of Science in Management
AND
Master of Science in Mechanical Engineering

In conjunction with the Leaders for Manufacturing Program at the
Massachusetts Institute of Technology
June 2004

Signature of Author____
May 8, 2004
MIT Sloan School of Management
Department of Mechanical Engineering

Certified by____
Daniel Whitney, Thesis Advisor
Senior Research Scientist
Center for Technology, Policy and Industrial Developments

Certified by____
Jan Klein, Thesis Advisor
Senior Lecturer
Sloan School of Management

Accepted by____
Donald Rosenfield
Senior Lecturer
Director, Fellows Program, Leaders for Manufacturing

Accepted by____
Margaret Andrews
Director of Masters Program
Sloan School of Management

Accepted by____
Professor Ain Sonin,
Chairman, Graduate Committee
Department of Mechanical Engineering

Abstract:

Prior to production of an automotive assembly, the individually fabricated components must be validated or "tuned in" in order to produce an acceptable assembly. This validation or tune in process must be done before the product can be sold, and is generally a major step in the launch process. Mean shifts and variance within normal production processes result in differences between design intent (specifications) and actual parts. These differences are unavoidable in most processes. During launch processes manufacturers must have strategies for dealing with these differences.

One traditional strategy to product launch processes is build-to-print methodology. The basic assumption of this methodology is that by working to make individual parts as close as possible to specification, the assemblies of these parts will also be to specification. In others words one can achieve an optimized assembly by focusing on the individual parts. An alternate methodology to build to print is functional build. A functional build methodology involves focusing on the completed assembly rather than the individual parts. The basic idea is to examine if the overall assembly meets customer requirements. If it does not then the launch team can analyze the individual parts to determine the best way to solve the problem. This solution may or may not involve forcing a part to design intent.

In the recent past a major American auto manufacturer has used functional build methodology in the tune-in of the body structures. This auto manufacturer is currently implementing a change to vehicle development process called the craftsmanship initiative. A major part of the craftsmanship initiative involves extending the functional build methodology to a higher level of assembly. Functional builds will be extended to include not only body structures but also interior and exterior parts typically installed on a typical vehicle assembly line.

This thesis will first examine both the technical and corporate reasoning behind this fundamental change to one of the core processes within the auto manufacturer. Second the thesis will study the underlying challenges surrounding implementation of this change and recommend possible solutions to some of these challenges. The major focus of the internship has been participation on the pilot program that is implementing this change. There are three main areas of difficulty facing the pilot program. These are process design issues, organization structure challenges, and development of appropriate metrics to measure the impact of the change.

Acknowledgements

First I would like to thank the LFM program for the opportunities presented to me during my two year stay at MIT. The facility, staff, alumni, and students of the program have made my experience wonderful. This has been a life changing experience and I have grown tremendously from it.

Next I would like to thank the host company, General Motors. Their generous sponsorship of my internship made my made my education possible. I would like to thank them for their continued support of the Leaders for Manufacturing Program.

There are several people at the host company I would like to thank in particular. My supervisor Bob Scott provided constant guidance during my internship. I learned a tremendous amount about leadership from him. Lou Julien was always available to give me advice and support, and helped my transition into a new organization. When I got to GM I was completely new to company and the auto industry in general. Scott Therrien had the time and patience to teach me about the company, the change initiative, and the company culture.

Next I would like to thank my MIT faculty thesis advisors, Dr. Jan Klein and Dr. Daniel Whitney, for their time and efforts. Their help and guidance got me through the process of completing the thesis and the internship itself.

Finally I would like to thank my family for their support. Throughout my life my parents have provided me with constant guidance and the freedom to make my own choices. Without them I would not have gotten as far as I have. I would also like to thank my significant other, Yoon Kim. She has been incredibly kind, patient, and supportive of me throughout my time in the LFM program.

Table of Contents

List of Figures

List of Tables

Chapter 1 – Introduction and Background

1.1 Industry Background and Competitive Market Forces

The current situation in the worldwide automotive market has created huge challenges for all major auto manufacturers. In 2002, sales of vehicles in the US represented approximately thirty percent worldwide production.[1] Of all of the various segments of the worldwide auto market, the US auto market has is one of the most stable and mature. Since 1999 the total annual sales of vehicles in the US has hovered around seventeen million units. During the last five years the annual number of vehicles sold in the US has grown at an average rate of only 2.11%. During the last forty years this average growth rate is only 2.87%.[2] Given this lack of growth, gains in market share must occur at the expense of the competition. During the last three decades foreign auto manufacturers have made tremendous inroads to the US market, taking market share away from the traditional "Big 3" US automakers (General Motors, Ford, and Chrysler – now Daimler-Chrysler). For the first time ever in August of 2003, the Big 3 sellers of vehicles in the US consisted of GM, Ford, and Toyota (which slightly outsold Chrysler).[3]

Given the increased competition and the lack of growth in total market size, auto manufacturers in the US are being forced to use a variety of strategies to succeed. These strategies can be summarized by three major categories: price, quality, and proliferation. Most manufacturers are concentrating on all three of these areas with varying degrees of success.

Price competition is one of the most visible areas to most consumers. In recent years major US manufacturers have used aggressive pricing incentives and rebates to attract customers. These incentives have helped maintain healthy volumes of sales during a sluggish period in the US economy, but have had some negative consequences.

---

[1] Wards AutoInfoBank: World Output Share – Selected Regions. WardsAuto.com
[2] Wards AutoInfoBank: US Sales 1980-2002. WardsAuto.com
[3] Reuters NewsWire: Toyota Chief sings GM's Praises, October 21, 2003

Incentives have led to erosion of already slim profit margins for the manufacturers using them. They have also forced some (but not all) of the competition to replicate the offers to avoid losing precious market share, thus creating downward pressures on overall industry pricing. Furthermore these incentives are difficult to get rid of once implemented. Consumers come to expect them and without them sales (and thus production) volumes could drop. There are two commonly accepted possible solutions to the problems created by the incentives. Either the manufacturer can produce products that sell in acceptable volumes without the need for large price discounts, or the manufacturer can lower costs to offset the reductions in sales price.

During the last couple of years there has been an explosion of new vehicle introductions. Consumers are demanding more options. Manufacturers are responding with new categories of vehicles, while at the same time trying to create "must-have" vehicles that can attract demand without price incentives. However, new product development takes time and resources. This is especially true in the automotive industry because of the complexity of the products and the capital intensive nature of the manufacturing processes. The ability to develop and launch new vehicles quickly is a huge competitive advantage. Manufacturers are putting tremendous efforts into reducing the cycle times for vehicle development. At the same time they are putting into place aggressive new standards for vehicle quality.

The combination of new quality standards, reduced development cycles, and increased number of new products is forcing new approaches to manufacturer's core processes. The paper examines one such change. This change effort has been labeled the craftsmanship initiative and is a change to the auto manufacturer's vehicle development process. The following section discusses how some of the market forces created the need for the craftsmanship initiative.

1.2 Challenges Addressed by Change Initiative

Below is an excerpt from a recent Bob Lutz (auto manufacturing company Vice Chairman) interview, given to Edmunds.com:

...So the reality is we've closed the quality gap but the lag in customer perception is still huge. The average person still believes that the Japanese cars' quality and reliability is head-and-shoulders above General Motors, and it simply is no longer the case.

It's going to take a while for that to get through. I would say the onus is on us to produce vehicles, which we're now doing and the Chevrolet Malibu is the first concrete example, vehicles with a much higher level of visual quality. Better panel fits, closer gaps, better door-closing sounds, better-tailored seat covers and more precise knobs and switches. Soft, low-gloss plastic parts instead of hard, shiny ones. All of those things are part of what the customer registers as a quality perception, which is why we call it 'perceived quality.' And your real quality can be outstanding, but if your perceived quality is off, the customer says, "Gee, I don't know, this is a pretty lousy-looking interior. I can't believe this is a good car." And you turn them off. That part we still have to fix across our whole product line and do interiors and exterior fits and finishes that tell the customer, "Wow, this thing was put together with great attention to detail and love of craftsmanship." That's really the Volkswagen and Audi secret. If you look at J.D. Power, their cars are not even average, but the way they are finished is so good that the customer thinks, "This is done with such care and love. I must have this car."

This excerpt summarizes the industry pressures that created the craftsmanship initiative. The craftsmanship initiative is a change to the vehicle development and launch process. The goal of the change is simply to improve the fit and finish of the interior and exterior of the vehicles, without impacting the timing of launches. Furthermore the development cycles of new vehicles have shrunk dramatically in recent years. With the pressure to quickly introduce new products into the market the challenge of improving fit and finish is significantly more difficult. The next section provides an overview of both industry-wide and internal metrics for vehicle fit and finish.

1.3 Major Internal and Industry Metrics

As stated in the previous sections, there exists tremendous market pressure forcing change upon vehicle manufacturers. The two main factors that created the need for the craftsmanship initiative are improvements to the fit and finish of new vehicles (quality pressures) and reduced times to market (timing pressures). Each manufacturer has their own internal methods of judging their quality and time to market. However there also exist many external metrics for both areas. This section examines the internal and external quality metrics and concepts used in the auto industry.

The annual JD Power and Associates Initial Quality Study (IQS) is one of the major external ratings that automakers strive to perform well in. High marks in the IQS are highly sought after by manufacturers. JD Power awards get significant media attention and are often used extensively in manufacturers advertising and marketing campaigns. IQS is a measurement of the number of problems reported per one hundred vehicles by consumers after ninety days of ownership. JD Power ratings are based solely on extensive consumer surveys and not on internal evaluations. The JD Power IQS is generally regarded as a good metric for the overall quality of a new vehicle. Major areas in which consumers are surveyed by JD Power for the IQS are listed in Table 1 below:[4]

[4] JD Power and Associates Consumer Website (www.jdpower.com/cc/index.html)

Table 1: Components of JD Power and Associates Initial Quality Study of New Vehicles

Mechanical Quality	Engine
	Transmission
	Steering
	suspension
	braking systems
Feature and Accessory Quality	exterior paint
	wind noise
	water leaks
	interior fit and finish
	squeaks and rattles
Body and Interior Quality	Seats
	windshield wipers
	door locks
	Heater
	air conditioner
	stereo system
	Sunroof
	trip computer

Consumer Union, publisher of *Consumer Reports*, is another organization that provides testing and information to consumers on a variety of products and services, including autos. This is a non-profit organization that derives all of its funding through subscriptions to its published content (*Consumer Reports* magazine and its website ConsumerReports.org) and various other noncommercial sources such as grants and donations. No advertising is accepted by Consumer Union. Data gathered by Consumer reports is done using two methods, in house testing and subscriber polling. This is a key difference from the JD Power ratings, which are solely gathered from independent consumer surveys and not internal testing.

Auto manufacturers must also have metrics used internally to measure the fit and finish of a vehicle. At the auto manufacturer studied, the major internal metrics are the Dimensional Technical Specifications. Dimensional Technical Specifications, or DTS, are a collection of allowable measurements for the gaps between mating parts and the flushness of mating parts. Gap specifications have requirements for mean distances between parts and tolerance ranges for these distances, along with parallelism requirements along the gap. For example there could be a specification for the gap between a vehicle hood and front headlamp of 6 mm plus or minus 2 mm with a parallelism requirement of 1.5 mm (fictional examples, actual information is confidential). Flushness specifications similarly have a target mean and acceptable variation tolerances. For example there could be flushness requirement for between the deck lid of the vehicle trunk and the rear quarter panel of 1.0 mm plus or minus 1.5 mm (again not actual specifications). This would result in a deck lid that sat above the rear quarter panel by 1 mm for a nominal vehicle, with an acceptable range of up to 2.5 mm above to –0.5 mm below the rear quarter panel. DTS exists for all cosmetic surfaces and interfaces of a vehicle. The actual DTS numbers vary by vehicle and are proprietary information.

1.4 Thesis Objective and Research Approach

The basic objective of this thesis is to evaluate the implementation of the craftsmanship and provide recommendations for implementation of the change on future programs. There are three basic aspects to this evaluation:

- Process – How has the craftsmanship initiative changed the development and launch processes? What lessons have been learned and how can those be used to improve the process in the future?
- Organizational Structure – What is the organizational structure of the development and launch teams? How does this structure affect the outcomes of the change?
- Metrics – How should the status of the change be measured? What are the appropriate metrics to use, and how should they be used?

In order to complete this evaluation the author took on the role of craftsmanship facilitator for the pilot program implementing the change. This role involved working with a vehicle development team to understand and implement the change. Less than a year before the author started the internship the idea of the change was hatched within the auto manufacturer. The high level goals and processes for this change initiative were developed. Company executives decided to implement this change as quickly as possible. A vehicle program in the middle of the development cycle was selected as the pilot program before all the details of exactly how to implement the change were developed. The main role of the craftsmanship facilitator was to thoroughly understand the goals and thinking of the change and guide the pilot team in implementing the change. Much of the work centered on developing working level plans for implementing high level concepts.

1.5 Thesis Structure and Organization

The thesis is organized into six chapters. Chapters one and two provide background information on the auto industry and the vehicle development process. The details of the craftsmanship initiative are described in chapter 3. Chapter 4 summarizes and evaluates the new functional build process implementation. Chapter 5 focuses on the organization issues and challenges surrounding the change initiative. Finally chapter 6 provides lessons learned during the project and recommendations for possible future improvements.

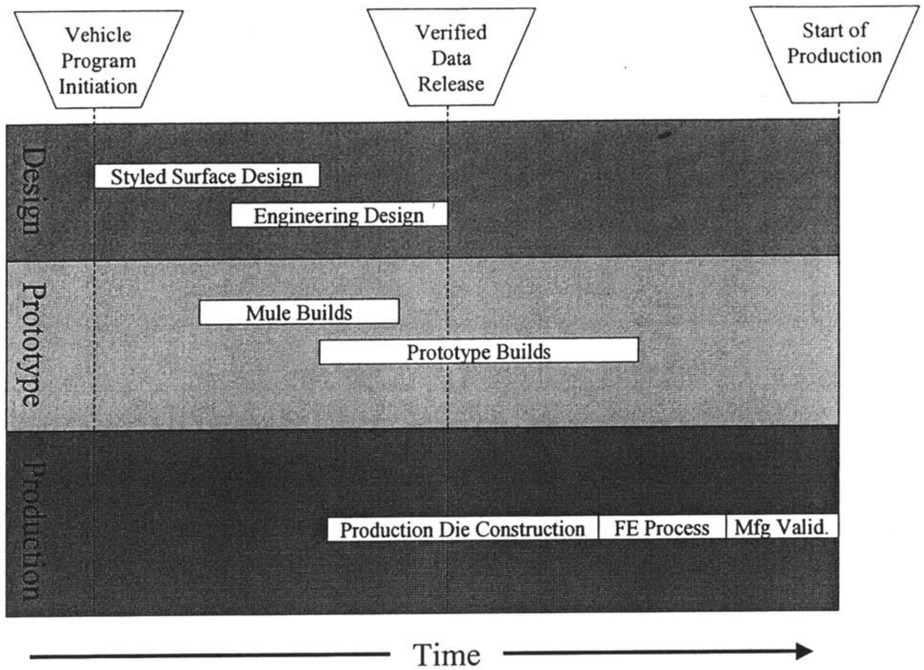
Chapter 2 – Vehicle Development and Production Launch

In order to understand the craftsmanship change initiative, a basic understand of the vehicle development process is required. This chapter provides a high level overview of this process, including a more detailed look at the manufacturing validation process that existed before the change. It then discusses some of the challenges faced in the pre-craftsmanship process.

2.1 Overview of the Global Vehicle Development Process

As stated in the introduction there exists tremendous market pressure to reduce new vehicle development cycles. A short development cycle is viewed as a significant competitive advantage in the auto industry. The auto manufacturer's global vehicle development process (GVDP) is a process that uses a common set of best practices to facilitate concurrent development in multiple geographies. To put it simply the GVDP is a process that defines what is done when in order for a new vehicle to be designed and brought to market. The GVDP is architecture based. New vehicles are designed and built around common platforms used for a family of vehicles. It is a coarse to fine process with a combination of virtual and physical builds and evaluations. The company has several different length templates for vehicle development depending on the complexity of the project. For example a mid-cycle enhancement of an existing program takes significantly less time to bring to market than the first vehicle built on a new platform. The exact number and timing of these templates is confidential. Figure 1 below shows a brief timeline of the major events in this process.

Figure 1: Basic Timeline of the Global Vehicle Development Process



The process officially begins with vehicle program initiation (VPI). At VPI a single theme for the vehicle has been defined, a charter for the vehicle has been approved and a detailed document with the statement of requirements for the development program has been completed. The timing of this event varies depending on the extent of the development project and is confidential information. The next steps in the process involve development of BOM, styled surface design by studio based on single theme definition, and engineering design. This culminates in a milestone called the verified data release at which the complete vehicle exists virtually.

There exists a detailed process for the both the studio and engineering design. In this process production dies and tools are started at various points throughout this process. The construction of these dies has significant lead times and lie on the critical path to the start of production. Therefore the process has been created to allow dies to be started as soon as possible, as opposed to starting all dies at once when the entire design is complete. This is referred to as a staged release. Some of the last parts to have fabrication tools kicked off are the styled surfaces parts such as the interior (dashboard, door panels, etc) and the exterior panels (body sides, hood, fenders, etc).

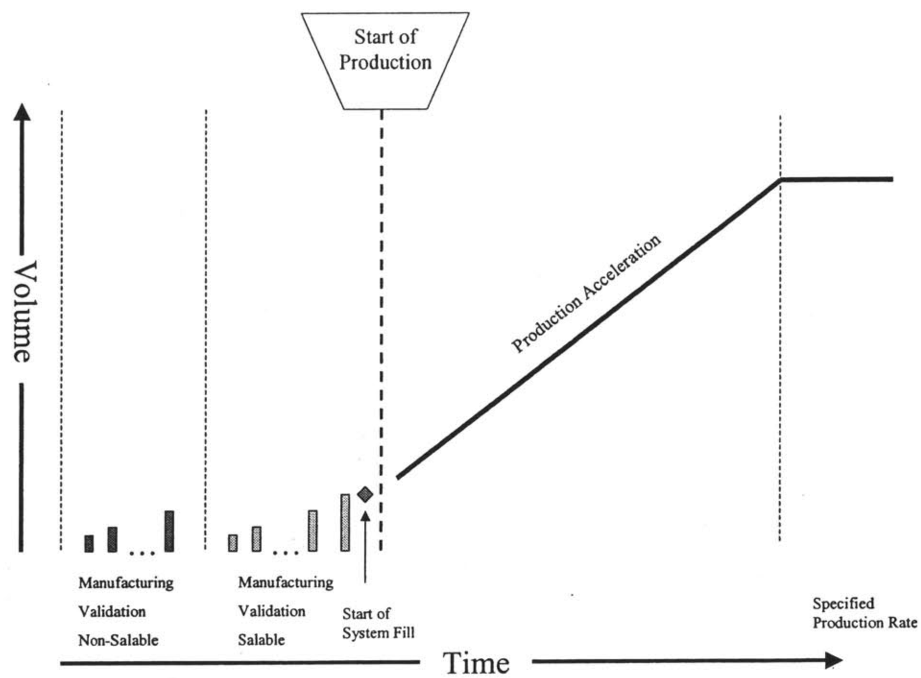
Running in parallel to the staged release of production dies are several other key events and processes. These include fabrication of mules, virtual builds, and prototype builds. Mules are very early prototypes built using components from existing programs (modified as needed) and a minimum of prototype parts. These are very rough prototypes built very early in the process. Three dimensional computer aided design (CAD) software is used in the design of the vehicle. The three dimensional capabilities of this tool are used to complete various design reviews, and later in the process virtual build events without the resources associated with physical builds. Prototype builds are also a significant part of the development process. Design validation and product testing are the main uses of the prototype vehicles. Significant numbers of complete prototype vehicles are fabricated during process. As with most development projects, prototyping in the auto industry is quite an expensive process. The goal is to move towards more virtual builds and fewer physical ones. Accomplishing this shift is a significant undertaking and prototypes still play a significant role in development. There are several pre-production facilities at the auto manufacturer that fabricate and assemble the prototype parts for these early builds.

Once the dies for the production parts are completed the process of tuning-in the parts and assemblies begins. Prior to craftsmanship this was done using a process called functional evaluation (FE). It involved a series of builds of early production tooled body structure parts, screwed together (as opposed to welded). All parts used in these screw bodies were metal body components, the majority of which were produced by internally by the company's metal fabrication division (MFD). The FE process consisted of several iterative builds. First sub-assemblies were built and analyzed. Then complete bodies were built from the subs and analyzed. The goal was to diagnose any part issues that arose during the first build and fix these for the second build. The second build would validate the fixes, and raise new issues to be fixed before manufacturing validation. The FE builds were completed in a pre-production facility by an internal organization solely responsible for these events. The next steps in the process are both part of the GVDP and the global production launch process (GPLP) includes the last stages development and ramp to full speed production.

2.1.1 The Global Production Launch Process

Similar to the GVDP, the launch process is intended to be a common process for all plants. The underlying goal is meeting program quality and timing requirements while minimizing production costs and maximizing profit. Many of the events and deliverables in the launch process are also key steps in the development process. The launch process could almost be viewed as a subset of the development process. Although this is a very well defined process with numerous steps, only the major events will be covered in this summary. Figure 2 below shows a simplistic overview of the launch process. This figure begins with the manufacturing validation process shown in the lower right corner of Figure 1 (Basic Timeline of the Global Vehicle Development Process).

Figure 2: Overview of the Production Launch Process



The first major events in the launch process are the manufacturing validation builds (MVB). These are builds that occur in the production plant with the purpose of training production operators, validating the production process, working out any problems that arise. Not only do these builds occur in the plant, but they also occur on the main line at the plant at production speed. If the plant is already producing other models, these builds must be phased into the regular production. Prior to the start of these events the product design should be complete and validated. Groups of vehicles are built over a set period of time with the same vintage parts. A group of vehicles of the same level is referred to as a bucket. The strategy of the manufacturing validation builds is to complete iterative buckets in order to quickly find and resolve manufacturing issues. The exact quantity of buckets and number of vehicles per bucket is based on program specifics, such as program complexity and length, and plant specifics. These builds are also major events in the development process and are defined very early in the program.

There are two main types of manufacturing validation builds, non-salable and salable. As the name implies non-salable builds are not intended to be sold to customers but rather to be used in testing and captive internal fleets. As the name implies, salable builds are meant to produce vehicles that could be sold to consumers. Salable vehicles must meet all engineering, regulatory, and safety specifications. The main difference between salable and non-salable is that all parts for salable must be approved for production. A common process called PPAP (production part approval process) is used by the big three to review and approve all production parts. To the casual observer the main difference between salable and non-salable are cosmetic differences. Body panels may not meet flush and gap requirements, certain plastic parts may not be grained or textured. Grain or texture is the surface treatment done to plastic dies to add a defined appearance and feel. After texturing of a plastic die it is significantly more difficult and expensive to make changes to the die. With the current importance of look and feel in new vehicles, texturing of parts is a major step in the part approval process.

Soon after the completion of the final bucket of manufacturing validation salable vehicles the start of regular production begins. The start of regular production marks the end of the vehicle development process, whereas the launch process continues until the plant can produce the vehicle at full line rate at the required quality level. There are a couple of major events in the launch process after the manufacturing validation builds. The first of these is the ship to commerce gate review. This involves a rigorous review of the final salable vehicle to determine that the quality levels are met and the plant is ready to begin acceleration of regular production. The next is the start of system fill, which is the point in time at which the plant production system is filled with salable parts. For example the body shop must be filled with salable metal. After system fill the plant begins the acceleration ramp, which culminates in the plant producing vehicles at the required line rate and quality level. This ends the production launch process.

2.2 Challenges of the Pre-Craftsmanship Development and Launch Processes

In response to changes in the auto industry and the increasing quality standards, the auto manufacturer decided to make significant changes in their development and launch processes. There were specific areas of these processes that presented opportunities for improvement. Prior to the craftsmanship initiative there were three main areas with opportunity for improvement. The first of these areas involved the functional evaluation (FE) builds. Section 2.2.1 will outline some of the basic shortcomings of the old FE process. The second area with opportunity for significant gains was improvements in the implementation of the functional build methodology. Section 2.2.2 will define both the functional build and build to print methodologies and briefly describe some of the challenges with implementing functional build. Finally section 2.2.3 will describe some the challenges presented by the timing of early production builds in the old vehicle development and launch process.

2.2.1 Function Evaluation Process Overview and Opportunities

Prior to the implementation of the craftsmanship initiative, first shots off of production sheet metal dies were validated, or tuned in, initially with in the Functional Evaluation process. As previously described this process involved several iterative builds of first metal sub-assemblies and later a complete vehicle body. In order to understand the process, one must understand the key stakeholders and their roles in the process, and the timing of the FE builds.

There were four main stakeholders involved in the old FE process. The first was the Functional Evaluation group. This was the department responsible for ordering the parts, creating the schedules, conducting the actual builds, and distributing the results. The second major stakeholder was the metal fabrication division (MFD). Another key player in the process was the product engineering groups responsible for the design of the parts used (i.e. the design engineers who designed the metal parts). Finally the body in white group (the team responsible for installing new vehicle body shop manufacturing lines in plants) was the fourth main stakeholder.

A build event in the old FE process was designed to take approximately six weeks. FE builds involved only sheet metal parts. These events involved either a build of all of the major subassemblies, or a build of the complete body from the sub-assemblies (completed in a previous FE build). Each build had specific rigorous submission requirements for each of the parts used. Typically these requirements included extensive measurements of key dimensions, repeatability studies, and supplier warrants (paperwork describing tooling level, source, etc - required for approval of parts). A typical FE involved review of the submitted parts, fabrication of the required assemblies, and diagnosis of any issues arising from either the parts submission or the assemblies. All issues were tracked and stored on an internal website that all key stakeholders had access to. Issues that arose and were tracked ranged from parts not meeting submittal requirements to major interferences in assembly. Generally during the builds the main participants were the FE group and MFD. Almost all diagnosis and corrective actions created during the events were done either by the FE group or MFD. At the conclusion of each build event the FE group organized and hosted a wrap up meeting in which all major issues were reviewed and handed off to the other stakeholders. All issues and corrective actions were kept on the FE website for future review.

This process and organization of the old FE process presented many opportunities for improvements. It should be noted that although these opportunities for improvement existed, the FE process was still a vital part of the validation of new sheet metal parts and assemblies. Without this step in the vehicle development process there would have been little to no opportunity to evaluate new production tooled sheet metal assemblies before a vehicle program entered the launch phase in the production plant.

There were two main problems with the FE process. First, although the process did uncover the majority of part and assembly issues, quite often these issues were not fixed. For example, the process would document and uncover interference between a front fender and door. This problem would be documented on the FE website and a solution such as "make part to print" would be listed as the corrective action. The process did not include steps for prioritization and follow-up on corrective actions. Furthermore the process documented every single part, so the database of issues became quite crowded with information, making it more difficult to see what the major issues really were. Another factor adding to this problem was the fact that often the product engineering community was only involved at the very end of the event during the wrap-up meeting. Product engineering is responsible for the design of the parts and assemblies. Without their input and help, no changes could be made to designs, and the only real possible corrective actions would have been to make part match the specifications. In summary the old FE process did not have the all the key stakeholders involved at the correct times during the process. Product engineering was not very involved in creating the solutions to build problems (thus severely limiting the possible solutions to a given build problem). Instead solutions to build problems were presented to the product engineering community at the end of the FE process. Solutions were pushed upon a key stakeholder, instead of developed by that stakeholder.

The second main problem with the old FE process was the length and timing of the process. As previously mentioned each build was designed to last six weeks. Even if the builds went like clockwork and finished on time, there was inadequate time left to incorporate changes into tools and dies and then run new parts for the next build.

The goal of the functional evaluation process was to functionally tune new sheet metal body assemblies (rather than using a build to print methodology). Because of the organizational and process challenges presented by the old FE process implementation of a new tune in methodology proved difficult. Often these builds reverted back to build to print solutions. In the next section these two methodologies, build to print and functional build, will be defined and some of the problems of implementation discussed.

2.2.2 Function Build versus Build to Print (Net Build)

Because there is variation in manufacturing processes, parts produced rarely perfectly match the design intent. When parts are used to create assemblies this presents problems. Prior to start of production, parts must be evaluated and validated to insure an acceptable final assembly. During this validation, some methodology must be used to approve the individual parts and sub-assemblies that comprise the top level assembly. There are two main methodologies for this validation. The first of these is build to print or net build. The second is functional build.

The build to print (or net build) methodology is a quite simple concept. The basic idea of build to print is that each new part to be validated is compared to its technical specifications and the tooling or dies are reworked until it meets them. In the simplest terms the newly fabricated physical part is compared to the dimensions and tolerances on its engineering print. Once the part meets the specifications, it is approved and used in the next higher level of assembly. Each subsequent assembly is evaluated in the same manner until the final assembly is approved. The underlying assumption of this methodology is that you will optimize final product quality by insuring that all individual components meet all specifications.

There are many advantages of the build to print (BTP) methodology. BTP is a straight forward sequential validation process. If followed to the letter, very few subjective or engineering decisions need to be made. This is a huge benefit in terms of repeatability and process design, especially in an ISO 9000 organization. It is also a methodology historically used by American car manufacturers to tune in their sheet metal body assemblies. Although this has been changing in recent years, the methodology is somewhat engrained in the engineering culture. Any attempt to change this cultural trait is going to be slow and arduous. Finally there are certain types of assemblies that are more suited than others to this type of validation process. Products with complex moving parts and interfaces, or products with multiple sources for the same part number may be ideally suited for build to print. An engine is an ideal example. It may have parts that are fabricated by multiple sources. Each of these sources must deliver parts that match each other within the specified tolerances. Furthermore the specifications for individual engine parts are tremendously important to the function of the complete assembly.

There are two main disadvantages of build to print. It could be argued that a build to print validation process wastes both resources (money) and time. Tools and dies constructed to fabricate large sheet metal parts have very long lead times and are very expensive. The time and resources required to rework these dies is similarly very expensive. Using a build to print validation process will result in reworking of all out of specification areas of a new part. Some of this rework may not be necessary because the assembly fixtures and processes may be able to accommodate some of the out of specification conditions and produce acceptable results. For certain assemblies, such as an automobile chassis and body, a validation process that allowed the manufacturer to identify the required rework areas would be ideal.

A functional build methodology allows manufacturers to identify and fix only the out of specification conditions in parts that actually create problems in higher level assemblies. The basic methodology of functional build is also quite straightforward. Using this methodology, manufacturers still compare the early production parts to the technical specifications. However the specifications are viewed more as targets than rigid guidelines for part approval. These parts are then used to create higher level assemblies which are in turn evaluated. The approval process then depends on building acceptable assemblies, as opposed to technically correct parts. Assembly approval is based on the needs and viewpoints of the customer. There are several basic assumptions of the functional build methodology. The first assumption is that an assembly processes can accommodate for mean shifts and variations on individual parts and produce acceptable assemblies. The second assumption is that customers really only care about the final product, or assembly, not the individual parts, and this should drive the manufacturers' processes during product launch. For example, people looking to purchase a new car probably do not really care about how the body side inner sheet metal panel fits to rear inner quarter panel. The customer cares about the smooth look of the exterior of the vehicle and the operation of the doors and trunk.

The advantages and disadvantages of functional build are just about a mirror opposite of build to print. First functional build can save time and resources in the validation or tune in process. In the competitive market of automobile manufacturing today this is a huge advantage. In functional build processes when an assembly issue is discovered, the launch team looks at the parts involved and decides the most effective way to resolve the issue. Most effective can mean a number of things. It can mean that the problem is solved in the quickest or least expensive manner possible, regardless of how closely the individual parts match their original specifications. This is a huge advantage over the build to print process. In that process all parts must match the specifications, regardless of how costly or expensive the rework. In functional build a decision can be made to take a simple inexpensive part to an off-nominal measurement to avoid reworking a huge expensive die to tool. However as previously mentioned there are certain types of assemblies that are suitable for each type of validation process. Vehicle bodies are ideal candidates for functional build validation. They are generally compromised of sheet metal parts that are sole sourced. Many of these parts are very large in size and non-rigid (which can allow assembly fixtures and processes to compensate for individual part problems). On the other hand there exists types of parts and assemblies that are not suitable for this methodology such as the engine block example previously described.

Many major auto manufacturers have been using functional build tune in for years. There exist many academic articles and studies extolling the virtues of functional build. One such study by the University of Michigan Transportation and Research Institute

(UMTRI) claims that functional build can lead to the following cost and time savings over a build to print tune in process:

- 90% time savings on body die tryouts.
- 48% cost savings on the dies for the total body.
- 50% time and cost savings on tryout, automating, and process validation of body dies.[5]

Although these figures do seem a bit extreme, another article published in 1996 by the Office for the Study of Automotive Transportation at UMTRI claimed that one US auto manufacturer "has suggested that over twenty million dollars may be spent on a major vehicle launch to unnecessarily rework 10% of the stamped part dimensions..."[6]

At the auto manufacturer there has been a push to validate vehicle structure and closure assemblies (car bodies with doors, hood, and deck lid) functionally, rather than nominally, for several years. This process has met with some success, but still has room for improvement. As previously mentioned the functional evaluation (FE) builds were intended to be functionally driven tune in events. However the organizational structure of these build events and teams were not ideally suited to implement functional build. These teams had a tendency to revert to a build to print mindset. Furthermore the idea of a functionally driven validation has only been applied to the unpainted vehicle body at the auto manufacturer, and not to any of the other interior or exterior components.

2.2.3 Integration of General Assembly Components

As mentioned in the previous section, the FE builds were design to validate only the sheet metal parts of the vehicle body. Most auto manufacturing plants have three main sections, the body shop, paint, and general assembly (GA). The FE process really only attempted to validate parts for the body shop. After the FE process new sheet metal parts are brought into the plant body shop. At this point the assembly and weld tools on the body shop lines are tuned and the first sets of production tooled bodies are run through the

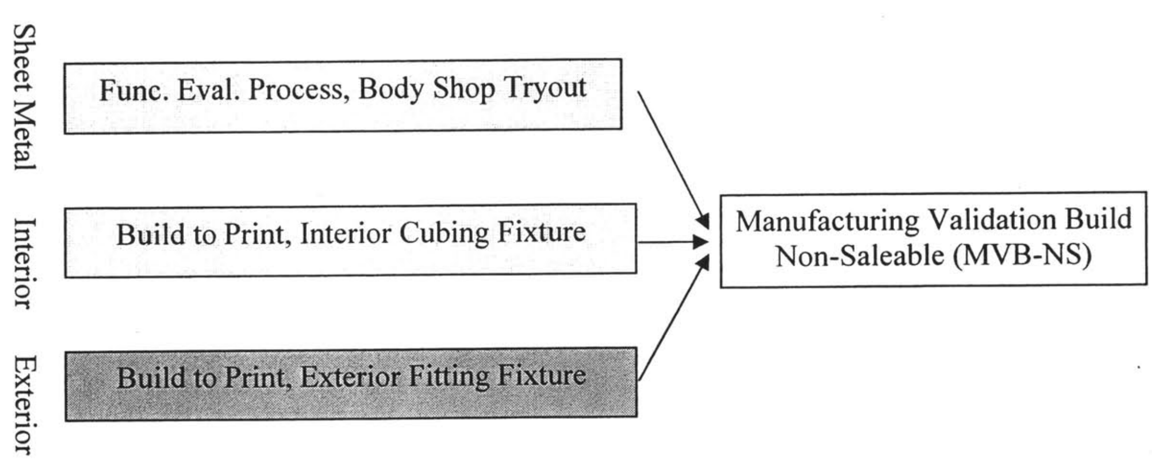
[5] Building Better Vehicles Via Functional Build, Gary S. Vasilash. *Automotive Design and Production, http://www.autofieldguide.com/articles/020002.html*

[6] Functional Build: No Longer an Unconventional Body Development Practice, Pat Hammett, OSAT – Manufacturing Systems Group, OSAT's Focus on the Future (Quarterly Newsletter) Fall 1996.

lines. Tuning in a body shop consists of running a batch of parts through the line and making adjustments to both the body shop weld tools and the parts themselves to achieve an acceptable end product. This event is called body tryout. This was an iterative process in which adjustments were made to both parts and weld tools over a period of time until an acceptable body was achieved. The intent of an acceptable body was also design nominal. However this was almost never reached.

Interior and exterior parts followed a separate tune in process from the sheet metal parts prior to the craftsmanship initiative. In the old process the interior and exterior parts were validated using a build to print methodology. First parts off production tools were evaluated against the specifications and installed on interior cubing fixtures (ICF) and exterior fitting fixtures (EFF). These fixtures are assembly jigs that allow parts to be assembled on them just like the parts would be installed on the real vehicle. All interface points for parts on the fixtures are machined to nominal design specifications. Figure three below shows the parallel paths taken by these parts during the old tune in process. The first point at which production tooled (as opposed to prototype) interior and exterior parts were installed in production tooled body was at the manufacturing validation non-saleable builds (described in Section 2.1.1). Up until that point these three critical areas of the vehicle were following parallel tune-in processes.

Figure 3: Pre-Craftsmanship Validation of Interior, Exterior, and Body Structures



These parallel processes have one flaw. The metal vehicle body is the foundation upon which all the general assembly parts are mounted. When the a complete vehicle is first assembled using all production parts in MVB-NS, the interior and exterior parts have all been tuned to design nominal using a nominal fixture with nominal locating and attachment points. On the other hand the metal vehicle body has been tuned functionally and the interface points may or may not meet the exact design specifications. This can create major problems because the GA parts match design intent but may still not fit on the vehicle body. MVB-NS is also quite late in the overall vehicle development process, and there is not much time left before launch to fix problems that arise. Quite often this late integration of GA components onto production bodies gives rise to significant fit and finish problems. This in turn creates significant challenges to the launch team trying to release the vehicle on time at specified fit and finish level.

2.3 Chapter Summary

In this chapter a brief overview of the auto manufacturer's production launch process was given. Part of this launch process is the validation or tune in of new assemblies. The functional evaluation (FE) process was used prior to the change initiative to validate new sheet metal parts and assemblies. However the FE process had several weak points.
The FE process attempted to employ a functional build methodology. However the organizational structure and process design really only allowed for build to print solutions to problems because the product engineering community was not involved in the decision making. Furthermore problems with the FE process were amplified by timing and length of the events. The FE assemblies did not really achieve functionally tuned bodies and many of the parts still had out of nominal conditions. As a result the problems were then tackled in the body shop when the vehicle began launch in the plant. Finally the FE process only included metal body parts, and the interior and exterior parts followed a separate parallel tune in process. The underlying assumption of the interior and exterior part tune in was that the body would eventually get to nominal. However this often did not happen. The first integration of the interior and exterior parts to a production vehicle body was so late in the process that by the time problems were discovered they were

difficult to fix in the available time.

Chapter 3 – The Craftsmanship Change Initiative

As discussed in Chapter 1, the competitive landscape of the automotive market has been changing. In response to these market challenges, the auto manufacturer's leadership wanted to see not only improvements in manufacturing efficiencies and overall quality, but also a specific focus on the fit and finish of the vehicles. Chapter 2 outlined some of the shortcomings of the existing development and launch process. A corporate team was put together to find a way to improve the fit and finish of the vehicles by addressing some of the shortcomings of the existing process. The result of this team was the craftsmanship change initiative. The following sections outline the goals and details of the change initiative.

3.1 Goals of the Change Initiative

The high level goals of this change initiative are fairly simple. First the change seeks to improve the overall fit and finish of newly developed vehicles. Fit and finish is generally measured by an evaluation of the vehicle relative to its dimensional technical specifications (DTS). Recall that manufacturers use dimensional technical specifications to dictate the acceptable gaps and flushness between mating panels and parts of the assembly. The specifications are a function of the vehicle's intended market and competition. The auto manufacturer has been pushing hard to improve the flushness of mating parts and reduce the gaps between mating panels. The second major goal of the craftsmanship initiative was to avoid launch delays in aggressive new vehicle development cycles. Launch delays are extremely costly as tremendous capital is invested in bringing new products to market. Again there has been a push to drastically reduce vehicle development cycles, while at the same time meeting aggressive new dimensional specifications. Craftsmanship is meant as a change to the existing process to attain both of these corporate goals.

In order to achieve these two main objectives, several lower level goals must first be met. One of these is to achieve a dimensionally stable vehicle body much earlier in the launch process. In the old process the tune-in of the body shop was an iterative process in which the targets were the nominal design intent dimensions. Many iterations were made (including changes to both parts and assembly tools) in attempts to achieve a repeatable (aka stable) nominal vehicle body. Only very late in the launch process were decisions made to move away from nominal. This created difficulties for the GA components (interior and exterior parts) that were assembled to the vehicle body. Until the late decision was made to move away from nominal, all of the interior and exterior part fit up was based on nominal interfaces with the metal body. Many of the interior parts have a cosmetic textured surface finish on them. This texture is added to the tooling for parts in a process called either graining or texturing. After a tool has had texture or grain added, it is extremely time consuming and expensive to make changes to the tool. For this reason it is obviously critical to have a stable body before graining parts. The next section will discuss in detail the comparison between body stability in the old process versus the new.

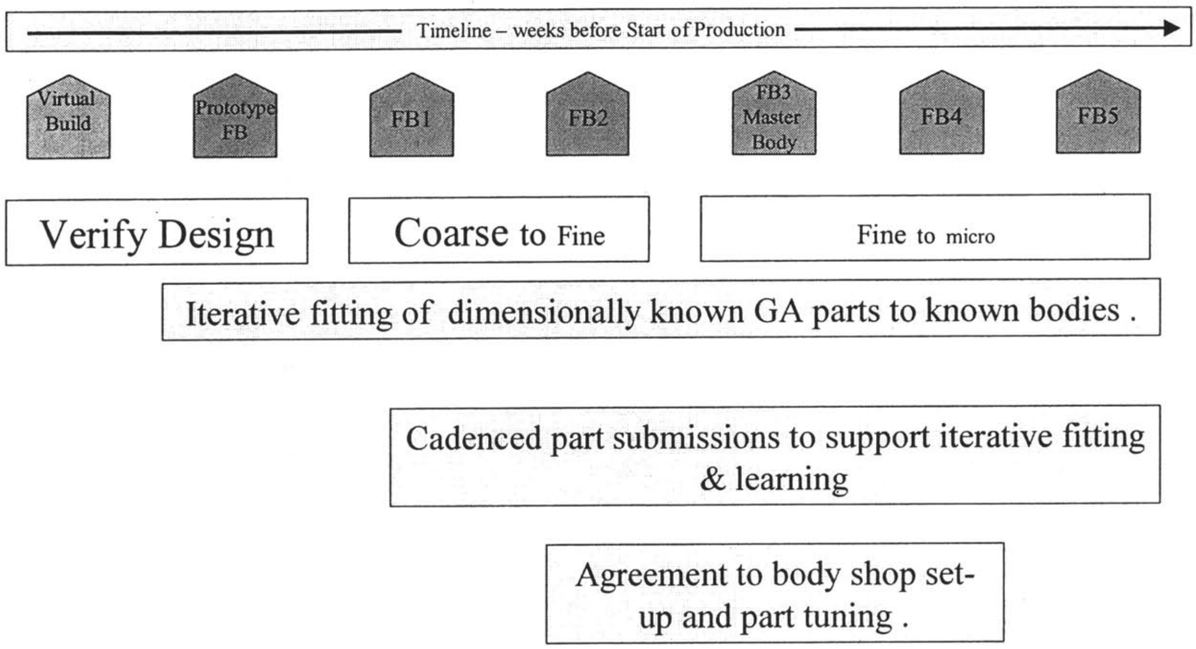
The second sub-goal of craftsmanship is to drive part tune in around new functional build events. As mentioned previously the old process had functional evaluation events. The purpose of these events was to functionally evaluate and drive the tune in of the sheet metal parts only. These FE events met with only limited success. In the new process the goal will be to have iterative functional build events in which dimensionally known GA components are fitted to a dimensionally known body. Dimensionally known parts are simply parts which have been measured and evaluated against their dimensional specifications. The tune in of both the sheet metal body as well as the interior and exterior components avoids the past problem of late integration of the GA components and is a key to the new functional build process. Furthermore the organization and process for the new functional builds was designed to overcome some of the shortfalls of the old FE process. Specifically the new functional build process involves the product engineering community throughout the process and gives ownership of resolving build issues to them.

Finally craftsmanship will seek to create a launch team mentality earlier in the process. A launch team mentality is one in which all the team members and stakeholders involved are focused on the manufacturing and launch of the vehicle, rather than the engineering and design. In the old process the launch of the vehicle began when the plant started producing vehicles. This started in the body shop during the body try-out stage, which is followed by the non-saleable manufacturing validation builds. By moving the start of launch earlier in the process, this will hopefully avoid problems commonly seen in the late stages of previous launches (like a dimensionally unstable body combined with grained interior parts).

3.2 Details of the Change Initiative

To accomplish these objectives a detailed plan had to be created and implemented. Figure 4 below shows an overview of the new craftsmanship specific events that were added.

Figure 4: Craftsmanship Events[7]



The purpose of the first two events is to verify the design, as opposed to tune in a production process. The vehicle design is broken up into many different functional areas such as structures and closures (the body), interior, exterior, etc. Each functional area, known as a system management team (SMT), has its own engineers and management hierarchy. The virtual CAD build is a design review in which the design engineers from each of the SMT's come together and review the CAD assembly and interfaces between mating parts. The goal is to verify that the design meets the desired dimensional technical specifications. Following the virtual build there is a prototype functional build. The purpose of this event is to verify the design intent in a physical build. This event is a replication of the virtual build with physical prototype parts, again as design verification

[7] Company internal documents (presentation) – modified to remove timing

(i.e. do parts fit together, are there no interferences or large gaps, do doors open and close, etc).

Tune in of production parts begins with the first functional build event. This is where the launch of the new vehicle will officially commence in the new process. Starting with the first functional build, the intent is to use dimensionally known (measured with capability studies) production parts. These events are builds of the vehicle structure and closures, the interior, the exterior, and a handful of miscellaneous parts from other functional silos. The basic idea behind these events is to complete several iterative builds and use the time between each to fix problems uncovered during the previous event. In order to accomplish this, these build events have to be completed quite quickly (much quicker than the old FE builds, and with about twice as many parts). Each subsequent build is meant to resolve issues to a finer level of detail. During FB1 first shots off production tools are used. The intent with this build is to uncover and resolve any major build issues. FB2 is used to validate changes made during FB1 using new material. At the end of FB2, the goal is to have a contract between the structures and closures and the interior and exterior groups defining the interfaces between the body and the interior and exterior parts. This contract will be used by to tune in the body shop, which involves making adjustments to the weld tools and insuring that all agreed upon changes to the parts themselves were completed satisfactorily. This contract is the method for achieving the stable body much earlier than in previous launches. Any part changes or agreements not to achieve nominal achieved during FB1 and FB2 are to be included in this contract. The FB3 build is then a validation of the FB1 and FB2 changes and agreements and should be the master body that is described in this contract. FB4 and FB5 are further iterative builds completed in the plant with parts off of the production body shop and the production general assembly line. Theses builds are just normal launch builds that are pulled off line and extensively measured to further fine tune part fit up and validate previous decisions.

This change initiative has many risks associated with it. First, it was not clear that builds could be completed as scheduled. The builds involve twice as many parts as a FE build in significantly less time. Second as these builds are being added to midstream programs, many of the production tools will not be ready to supply parts for many of the early builds. Finally it was also unclear exactly how the new functional build process will create more involvement from the product engineering groups. Although the intent of the builds is to get product engineering much more involved, this a major change to the previous process and a shift of responsibilities. How will the stakeholders react?

The main technical challenge is going to be achieving the dimensionally stable body immediately after functional build two. The definition of the body-GA contract is still somewhat nebulous. Furthermore the process for tuning in the body shop using this contract is also up in the air.

3.3 Chapter Summary

There are four main goals of the change initiative. These are to meet the aggressive DTS for the new vehicles, achieve a stable vehicle body after FB2 using a body-GA contract, to use the FB events as the primary tune in process for body and GA components, and to move ahead the start of the launch to the beginning of FB1. There are many parts to this change initiative. The functional builds were the major new steps in the process. These functional builds were intended to be quick iterative builds of body and GA components. The builds were scheduled so that changes could be made to dies in between builds and new parts fabricated and delivered to the build site. The implementation of these functional builds is the focus of the next chapter.

Chapter 4 – Functional Build Implementation

Chapter 3 provided an overview of new events added to the vehicle development and launch processes under the Craftsmanship Change Initiative. This chapter will focus specifically on the implementation of the functional builds. The auto manufacturer's executives had to make a decision as to when to implement all of the various aspects of the craftsmanship initiative. It was decided to first implement the functional builds in a program already in the middle of the development process, rather than start on new program (which would have taken several years to see to completion). A decision was made to try to make these new events work in an existing program (despite so obvious challenges). Section 4.1 will provide some background on what elements are required for implementation of these new build events. Section 4.2 will discuss the process roadmap for these events. Key enabling metrics will be reviewed in section 4.3. The final two sections will discuss the results of the initial implementations and review some of the remaining challenges to be overcome.

4.1 Pre-Requisites for Functional Build

These new events involve the assembly of approximately three hundred sheet metal body and structure parts along with approximately three hundred interior and exterior parts. The goal of the event is to complete the body structure in about two weeks and the complete build in a total of four weeks. This is about two weeks less than the old Functional Evaluation (FE) build with approximately twice as many parts. In order to accomplish this many details of the new event must be resolved. These details fall into four main areas: resources, material, process, and leadership.

4.1.1 Resources Required

The resources required are quite simple. A suitable location and space had to be determined for the builds. Secondly, people to actually put the vehicles together and to organize and run the builds had to be identified. It was decided to utilize the internal resources and facilities of the pre-production operations (PPO) group. As the name indicates, PPO is the division within the auto manufacturer that is responsible for manufacturing the pre production vehicles. These are generally fabricated from prototype or non production tools and are assembled in designated PPO facilities (slow build manufacturing plants). These PPO sites had the necessary space and equipment to complete these new functional builds. The department that formerly managed the functional evaluations was selected to run the new functional builds. This department was renamed the Dimensional Fit Function and Appearance team (DFFA). DFFA handled the planning and daily management of the builds. Skilled tradesmen (members of the United Auto Workers union) completed the assembly and measurement work.

4.1.2 Material Planning and Acquisition

Material planning and acquisition was another major pre-requisite for success of the new functional builds. Appropriate parts for each build had to be determined and a bill of material (BOM) created. The DFFA build engineer became responsible for creation of the BOM for each functional build. This BOM was then ordered from external suppliers (for interior and exterior parts) and from MFD (for sheet metal body parts) through the PPO special order group. The timing of the new dies and tools that create the parts had to be incorporated into the planning and timing of each functional build. Appropriate parts had to be available for each scheduled build, and that there had to be adequate time to make changes to these dies between builds if necessary. Without the appropriate timing of the build events, cadenced part submissions would not be possible. The corporate craftsmanship team decided to implement five functional build events as shown in Figure 4. As scheduled, these events allow time for some changes in between builds. Finally a process for submission and acceptable of parts had to be designed. This submission process provided suppliers details on what they are required to provide along with the parts prior to each build (dimensional requirements, capability study, measurement plan, warrant showing part information such as level, part number, and production location, etc). This submission process also had to incorporate a method for tracking and documenting submissions to insure all the parts and information are available to support an aggressive build schedule. The DFFA department created a parts submission process, and took the responsibility of training suppliers on this new process. The existing PPO systems were used to track and accept material deliveries from suppliers.

It is important to note that the intent of the functional builds was to use only production tooled parts. However as it was decided to implement this change in the middle of an existing development program (rather than from day one) this was not possible on the pilot programs (other any other of the initial implementations). To achieve production tooled interior and exterior parts by the first scheduled functional build, the readiness dates for the production tools for the interior and exterior parts would have to be significantly earlier in the cycle. As a result the pilot program had to use a significant percentage of prototype interior and exterior parts.

4.1.3 Process Design

Many details of the build process itself must also be resolved. The method for attaching sheet metal parts together must be defined for each build. The goal of the builds is to accurately replicate the production build process. However the body shop weld tools and fixtures are not available during the early builds. It was decided to use sheet metal screws to assemble the parts. Some method of fixture to hold the parts in the correct relative positions had to be determined. On the pilot program check fixtures were used to hold the parts as they were assembled. However the long term decision was to use pre production weld fixtures to fixture these builds. These are the fixtures used by PPO to create the prototype vehicle bodies. However the PPO weld tools were not available for the pilot program. Finally the events must be organized such that key stakeholders have incentives to be involved and participate. This required appropriate methods for conveying information and making timely decisions. The company internal DFFA website was to be used to track and disperse all information on the functional build. This included daily build schedules, material tracking, build issues, and corrective actions.

Another major build process detail to be resolved was the measurement plan. In order to evaluate assemblies, these assemblies had to be measured and compared to the design intent. A detailed plan of exactly which areas to measure and how to measure them was required. The selection of the correct points to measure was critical to the analysis of the build by the engineers. Without good data to determine the root causes of build issues (such as gaps or interferences) it would be impossible to analyze the problems and create useful action plans to resolve the problems. There are several methods for measuring parts and assemblies. Given the level of accuracy required (tenths of millimeters or smaller), the approximate number of points to be measured, and the nature of build process; it was decided to use portable coordinate measuring machines, or FARO arms.[8] These portable measuring machines could be set-up on the build plate and could be used to measure assemblies without moving them to a more traditional fixed coordinate measuring machine (CMM). The advantage of fixed CMM's is that they are automated rather than manual. FARO arms require users to physically move the sensor at the end of the arm and touch it to all of the specified measurement points. The manual operation of the FARO arms is susceptible to operator error when attempting to place the sensor on the specified measurement point. An automated fixed CMM machine will move the sensor automatically to all the specified points. CMM's can measure the same number of points in much less time than a FARO arm. Both the FARO arm and the CMM required a routine for which points to measure and translated CAD data to use as a basis for these measurements. The measurement of the assemblies is a slow time consuming part of the functional build process. It should be noted that it is very difficult to predict in advance exactly which points need to be measured. During the build unforeseen issues arise and require additional measurement points.

4.1.4 Leadership and Management of the Change

The final pre-requisite for successful implementation of several new functional build events was leadership. Someone has to help the pilot team understand the vision and goals of the change initiative. Furthermore there are many programs in the pipeline behind the pilot program. The auto manufacturer's aggressive release of new vehicles is no secret. Each of these new programs has its own development and launch team. The head of one of the body in white departments took the role as executive champion of the

[8] Faro Technologies is the company that produces this equipment. FaroArm is a registered trademark. www.faro.com

change initiative. A high level person within the body in white organization took on the temporary assignment as a change agent working for the executive champion. Both the executive champion and the change agent worked with the corporate craftsmanship team to design the change as well as with the program teams to implement it. The intern also reported to the executive champion and eventually took over the lead implementation role on the pilot program, allowing the change agent to shift his focus to the next several programs in the pipeline that were implementing craftsmanship. The goal of the executive champion, the change agent, and the intern was to institutionalize these changes into the development and launch processes such that their roles were not necessary. However in a large corporation with a very strong culture, institutionalizing a change of this magnitude will take considerable time and effort.

4.2 Key Stakeholders

In order to understand the challenges associated with successfully implementing functional build one needs to understand who the key stakeholders are in the process. Table 2 below gives a basic outline of the main stakeholders involved with implementation of the craftsmanship and functional build. As one can see there are approximately many overlapping people or groups involved with this change initiative.

Table 2: Key Stakeholders

Stakeholder	Description
BIW Group (Body In White)	Group that designs and installs body shops in manufacturing plants. Part of larger manufacturing engineering organization
. Process Executive Champion	Director of PPI, one of the departments within BIW
. . Change Agents	Temporary Assignments for two people to help implement the craftsmanship change initiative
. . PPI Department	Products and Process Integration, one of the departments within BIW
MFD (Metal Fabrication Division)	The company division that produces the vehicle's sheet metal panels
Suppliers (Interior and Exterior Parts)	Integrated and non-integrated suppliers who produce the some of the parts used on the general assembly (GA) lines

PPO (Pre Production Operations	The division that produces all pre production (prototype) vehicles in slow build manufacturing plants
. DFFA Department	The department that is responsible for managing and running the functional build events (Dimensional Fit Function and Appearance)
. SOG (Special Orders Group)	The department within PPO that places the orders to suppliers for many of the early builds, including the functional builds
Manufacturing Plant	The plant that produces the saleable vehicles
. GA (General Assembly portion of plant)	This is the part of the plant that installs all components to the painted body and produces a finished vehicle
. Body Shop	This is the part of the plant that produced welded vehicle bodies and delivers them to the paint shop
UAW Skilled Tradesmen	The union labor that assembles and measures the functional build assemblies
SMT's (System Management Teams)	Product Engineering Departments divided by functional area
. Structures and Closures (Body)	Product Engineering group that designs the vehicle body
. Exterior	Product Engineering group that designs the vehicle interior
. Interior	Product Engineering group that designs the vehicle exterior
Vehicle Program Team	Team that designs and launches a new vehicle
. PEM (Program Engineering Manager)	Team leader throughout the life of project
. PLM (Program Launch Manager)	Team leader, more of a role later in the program
. . Lead System Engineers	Lead engineer for each SMT
. . . Design Engineers	SMT design and release engineers - report to lead system engineer
. . Dimensional Program Manager	Lead dimensional person for design and development
. . Dimensional Launch Manager	Lead dimensional person during launch at the plant
. . BIW PPI	Responsible for interaction between product engineering and the manufacturing plant
Corporate Craftsmanship Team	Team tasked with developing the change initiative
DQ&V	Design Quality and Verification - group that validates interior parts using nominal fixtures

There are ten main groups of stakeholders. Starting from the top of the chart the first is the body-in-white (BIW) division. This is the group that designs and installs body shops into the manufacturing plants. Within BIW there are several key players. The executive champion of the change initiative heads one of the departments within BIW. This department is Products and Process Integration (PPI). PPI serves as the liaison between the design and development engineers and the manufacturing plant. This group is very busy during vehicle launches and is represented on the vehicle program team. The two change agents responsible for helping early programs implement craftsmanship also report directly to the executive champion.

The second and third major stakeholders are the suppliers of the parts used in the functional builds. The first of these is the auto manufacturer's metal fabrication division (MFD). MFD is an internal division but is still considered a supplier. MFD has its own management chain. MFD supplies the majority of the sheet metal parts for the vehicle body, including all of the larger panels. Various other suppliers provide the smaller sheet metal parts and interior and exterior parts. The suppliers range from completely separate bidding only suppliers to supplier-partners who design and build whole sub-systems such as cockpits.

The next major stakeholder is the pre production operations (PPO) organization. This is the division that fabricates all of the vehicles before the program enters the production manufacturing plant. Within PPO there is the dimension fit function and appearance (DFFA) department that manages and runs the functional builds. There is also the special order group (SOG) that orders and tracks the parts for the functional build, based on a bill of material from the DFFA build engineer.

Obviously the manufacturing plant has to be a key player in functional build if it is going to accomplish improvements to the fit and finish of vehicles produced in that plant. The plant body shop and the general assembly (GA) line are the two main sub groups within the plant that must have roles in the change initiative.

The UAW skilled tradesmen are the folks who actually assemble and measure the functional build vehicles. They play a major role in the success or failure of the implementation of the functional builds.

The seventh major group of stakeholders is the system management teams, or SMT's. These are the engineering organizations responsible for the design and development of major sub systems of the vehicle. The three main SMT's involved with functional build are structures and closures (welded metal body plus doors, fenders, hood, deck lid, etc), interior, and exterior. Each of these SMT's is a separate silo with its own management hierarchy. The engineers on the SMT's own the design of the parts and assemblies, and control any changes to these designs. The SMT's also play a major role on the vehicle program team.

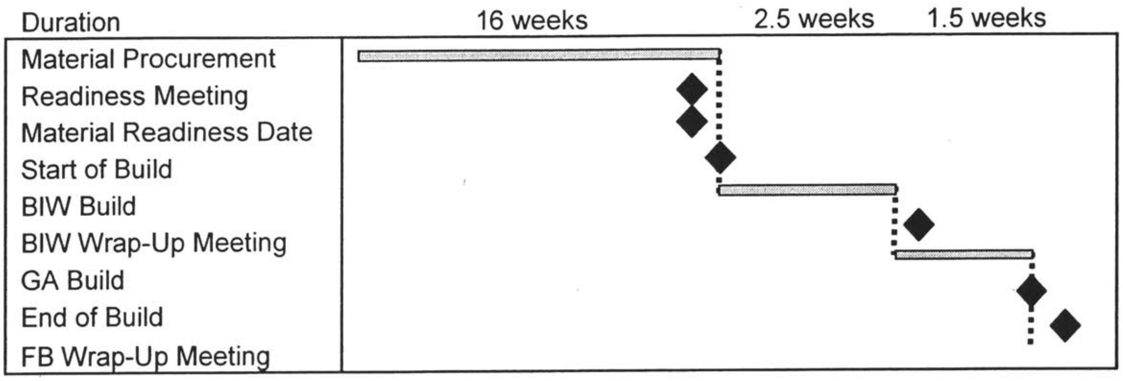
The eighth main player in the implementation of functional build is the vehicle program team. This is the group that designs and launches a new vehicle. That team is led by a program engineering manager (PEM) and a program launch manager (PLM). The SMT's and PPI, as mentioned before, are also part of this team. Also part of this team are the dimension program manager (responsible for the dimensional requirements of the new vehicle) and the dimensional launch manager (responsible for the meeting the dimensional requirements during the launch).

The final two main stakeholders are the corporate craftsmanship team and the dimensional quality and verification (DQ&V) department. The corporate craftsmanship team is the group that created the whole change initiative. DQ&V is part of one of the partner-suppliers that provides the interior of the vehicle. DQ&V is the group that validated the interior parts prior to craftsmanship using nominal cubing fixtures. These cubing fixtures are jigs used to install interior parts at the design nominal locations and evaluate their fit and function.

4.3 Description of the Functional Build Process

Once the key stakeholders of the new functional build process are understood, it is possible to define the steps within the actual functional build process itself. Table 3 below shows the timeline and progression of the major steps of the process.

Table 3: Functional Build Gantt Chart for a Single FB Event



The functional build process begins with the ordering of material. Orders are placed approximately sixteen weeks before the material readiness date in order to give the PPO SOG enough time to enter the order and suppliers enough warning to provide the requested parts with the requested information (per the submission requirements). A week before the official start of the build a readiness meeting is held. This purpose of this meeting is to determine readiness to begin the build and includes such items as material, labor, facility availability, measurement plans in place, information communication and distribution plans in place, and fixtures, jigs, and assembly instructions availability. The readiness meeting is organized and led by one of the change agents and attended by the DFFA, MFD, and the vehicle program team. The material readiness date (MRD) is set a week before the official start of the build.

The build itself is composed of 2 main parts, the body-in-white build and the general assembly build. As Table 3 shows the BIW build requires 2.5 weeks and the GA build requires 1.5 weeks. The BIW build includes all the screwed together or welded body components plus the doors, hood, fenders, and deck lid. The GA build includes the interior and exterior components as well as a handful of other SMT's components. During each of these builds brief morning meetings are held by the DFFA build engineer. The purpose of these meetings is two-fold. First, all new build issues that have arisen since the previous meeting are explained and assigned ownership. The second purpose is to present root causes and corrective actions (with implementation dates) for previous build issues. The goal is to have root causes and corrective actions with implementation dates presented to the meeting the day after the build issues are assigned ownership. Although individuals are assigned ownership, the intent is to reach team resolutions. Each meeting is intended to just be a brief summary of new items and a brief summary of resolved issues. The goal is to have representation from the all the SMT's, from dimensional management, from MFD and the suppliers, and from PPI. Issues owners can then quickly talk with the appropriate team members, work out root causes, and collectively create an action plan for resolving the problem. The DFFA build engineer tracks all build issues on an open item tracking list which is presented to the team every morning. When open issues have resolutions, they are then entered into the DFFA database as functional evaluation disposition reports, or FEDR's. The database, including the FEDR's, is available internally to all company employees.

During the functional build there are two wrap up meetings. The first of these is for the BIW build and follows soon after the build is completed (within a week). The second of these is a complete vehicle wrap up and includes the body, the interior, and the exterior components. This meeting is intended to fall within a week of the completion of the build. The purpose of these meetings is to present to the team and upper management a brief summary of the issues resolved, a more detailed summary of the un-resolved issues, and an evaluation of the dimensional results relative to the design targets.

4.4 Results of Initial Implementation

At the conclusion of the internship the first two functional builds had been completed on the pilot program and three subsequent programs had completed their first functional builds. The results of these builds were mixed. Not all of the targets for the builds were met. It was commonly agreed by members of the vehicle program team that the functional builds were very helpful to the program, but it was unclear exactly how to measure this positive impact. Section 6.1 offers recommendations on in-process metrics that could be used for judging the progression of the implementation and the progression of the vehicle programs themselves. Below is a bulleted list of the main results of the implementation of the early functional builds.

- *Build Length* - The builds ran longer than the four week target length. On the pilot program, functional build one took more than seven weeks and functional build two took more than six weeks. One of the main goals of functional build was to have quick iterative builds with strong participation from MFD, the SMT engineers, dimensional management, and the vehicle program team. Because the builds ran longer than expected it became difficult to maintain the participation and focus on the daily build meetings. Furthermore the delays jeopardized the ability to make changes to dies and tools between builds. There were several reasons behind the delays. The main ones were delays due to late parts, additional time required for root causing of problems or special side builds or studies, longer than expected time required to measure assemblies, and shortages of skilled trades labor to put together and measured assemblies.
- *Purpose of Daily Meetings* - Early in functional build one of the pilot program, the intended purpose of the daily meetings was unclear. Often during these early meetings a lot of time was spent discussing material submission issues that added very little value to the goal of improving the fit and finish of the vehicle. Missing submission information was more of a loss of opportunity to learn something than it was a build issue. As the build progressed the team leadership made it clear that the purpose of the meetings was to use what information was available and not waste excess time worrying about lost opportunities.
- *Production versus Prototype Content* - The functional builds were implemented midstream on all of the early programs. The availability of production tooled parts (as opposed to prototype parts) was dictated by the production part approval process (PPAP). For the interior and exterior parts PPAP required submission of early production parts well after the functional build two. Because of this many interior and exterior production parts were not available for the first two functional builds. When production parts were not available prototype parts from earlier builds were used in their place. Fortunately the production tooled metal body panels were mostly available by functional build one. MFD built their tool trial schedules around the FE material schedule, which was very similar to FB. In order to achieve 100% production tooled parts for functional build one the

program must put this material requirement in its program charter and definition. This will dictate when designs must be complete and when suppliers will start and complete the production tooling, which will have to be different from the current process.

- *Material submissions* - In the first functional build on the pilot program there was a significant problem with incomplete submission packets. Many parts were missing capability studies, measurement details, part markup, or supplier warrants. This improved in the second pilot program, partly because the suppliers better understood what was expected and partly because the functional build team better understood what was really necessary.
- *Turnover of Key Engineers* - On the pilot program between the first and second functional builds many of the key engineers from the SMT's were replaced. Approximately 75% of the design and release engineers were replaced. The new engineers on the program were very capable and dedicated, but simply did not have the experience with the new process or the design of this particular vehicle that the outgoing engineers had. A lot of the learning about the parts and the process was lost because of this switch.
- *Loss of Focus During FB2* - Towards the end of the second functional build on the pilot program, the daily status meetings began taking four times as long as originally intended and the number of issues resolved dropped. This drop in productivity was probably a result of the replacement of many of the original engineers or a result of the build running so much longer than intended. During this time the PEM and the PLM had many conflicts that forced them to miss many of the meetings. Without the PEM or PLM attending these daily meetings the meetings were even less productive.
- *Common Implementation* - There were problems with common implementation of the new builds between vehicle programs. Each program team interpreted aspects of the functional build slightly differently. Each team understood the goals and steps within the new process slightly differently and implemented the build in different ways. At one point there were four functional builds going on at the same time in the build facility with only two temporary change agents assigned to

support the four program teams. As this change initiative was implemented very quickly this is not unexpected. One of the big challenges of the implementation was to work out the details of a change initiative in which only the high level processes are well defined.

- *FEDR Usage* - A key example of differentiated implementation was the use of functional evaluation disposition reports, or FEDR's. As the name indicates FEDR's were used during the old functional evaluation (FE) process. In the FE process every part had a FEDR written against it. During the FE process, the purpose was to completely document the status of every part, including submission requirements met, and any problems encountered assembling the part. A database of FEDR's was maintained on the build group's website, which was accessible to all company employees. Documenting every single part was quite time consuming and made tracking changes on the FEDR database quite tedious. The initial tendency during the first functional build was to use FEDR's in much the same way as in the FE process. However it was quickly decided that this was not the most valuable use of time and resources. Changes to the purpose and use of the FEDR's were implemented (see next bullet) on the pilot program. However these changes were not universally accepted by each of the early programs implementing functional build. Each team had a slightly different opinion on the uses of FEDR's as a tracking tool, and some tended to lean more to the old FE usage.
- *FEDR definition* - During the first functional build it was decided to only use FEDR's to track build issues that actually required corrective action. This corrective action also required an implementation date to be entered into the database. Any build issue that arose was documented on the open issues list. Possible solutions to open issues include: 1) physical part changes required (i.e. changes to a die or tool), 2) changes required to engineering documentation (such as an engineering drawing, tolerance, or specification), 3) changes to an assembly fixture or tool required, 4) closing of issues because it did not present a problem. Only the first three solutions were documented and tracked as FEDR's.

- *Stakeholder Involvement* - Involvement by key stakeholders became an issue as the build events continued beyond their original finish date. The key stakeholder list was quite sizable, and in order to efficiently reach consensus on solutions to build issues, many of these stakeholders had to attend the daily meetings. However the demands on the time of many of the stakeholders were very high, and as the events dragged on, it became increasingly difficult to devote the necessary time to these builds. A case in point is the program team leadership. The program engineering and launch managers have tremendous pulls on their time. Without the program leaders engaged in the daily meetings the attendance and productivity of these meetings dropped significantly.
- *Timing of Problem Resolution* - The original goal was to have action plans for each build issue presented the day after ownership was assigned. This level of fast decision making proved to be very challenging for a number of reasons. Sometimes the impact of problems on sub-assemblies could not be determined until a higher level assembly was completed. The assemblies in question were also quite complex and the engineering problems quite challenging. In some cases arriving at a solution involved a lot of engineering judgment and was quite risky. The tendency in these cases was to get more and more data and continue the root causing efforts.
- *Early Discovery of Build Issues* - One commonly agreed result on the pilot program was that several major build issues were discovered a lot earlier as a result of the builds than they would have been in the old process.
- *Collaboration* - The collaborative effort between the structures and closures SMT and the interior and exterior SMT's was much improved. In this new process there was required interaction and decision making between these groups during the build process.
- *Functional Build Tune-In* - The implementation of functional build (versus build to print) methodology met with mixed results. At the end of the second functional build on the pilot program, the goal was to create an agreement between the structures and closures SMT and the GA SMT's that created a stable vehicle body. This agreement took the form of definitions of where the key interface

points would be relative to the design intent (i.e. at nominal, within tolerance, or off nominal). It turned out that the goal at the end of the second functional build was to tune the assemblies to reach all the nominal targets for key interfaces. It proved difficult to tune points on top level assemblies to off nominal and still achieve the dimensional technical specifications. However the ability to use functionally driven tune-in proved valuable when changing lower level assemblies and parts to achieve the top level targets. Although the goal was to be at nominal for the top level assembly, several of the parts were tuned off nominal to achieve this result.

Although the initial attempts at implementing functional build were quite varied, there were several results that stood out as key positive and negative outcomes. The main positive results were the early discovery of major build issues and the successful collaboration during the builds between separate engineering teams (SMT's). In the old process these many of the build issues would likely not have been discovered until the manufacturing validation builds in the plant much later in the process.

However the list of problems with the initial implementation was quite long. The build ran considerably long. As the builds dragged on there was the team lost focus and productivity. There were problems with a common definition and implementation of process details including usage of FEDR's and the daily build meetings. Root causing and decision making took considerably longer than intended. Finally turnover of key engineers in between builds resulted in a loss of project and process knowledge and further hurt the pilot implementation.

4.5 Chapter Summary

This chapter provided a brief overview of the implementation of functional builds in the vehicle development and launch processes at the auto manufacturer. Prerequisites for this change initiative included material acquisition, resource planning, process design, and leadership requirements. The implementation of the builds was a very broad change and involved approximately twenty seven key stakeholders (who were defined and reviewed in section 4.2). A Gantt chart for the functional build process was presented in section 4.3 and the main steps in the process were reviewed. Finally the results of the initial implementation were presented in section 4.4. These results were quite mixed and leave lots of room for future improvements. Chapter 5 will attempt to uncover some of the organization problems causing some of the failures of the early implementation. Chapter 6 will attempt to provide some suggestions for future changes to the process that may alleviate some of the problems.

Chapter 5 – Organizational Issues

This chapter examines the process of implementing change in a large organization. It attempts to evaluate the success or failure of the craftsmanship initiative and the reasoning behind the organization's reaction to the change. The chapter examines what aspects of the change initiative were pushed or forced upon the organization, and what aspects where pulled or sought out by the organization. In the first section the process roadmap of the functional build is re-examined to determine what the roadblocks were at each step. The next section presents a stakeholder commitment chart that models the necessary and actual commitment from each of the stakeholders. Next the timing and reasoning behind acceptance or rejection of the change are examined. Finally section 5.4 presents some leadership examples in which change was successfully pulled by rather than pushed upon the organization.

5.1 Output, Goals, and Roadblocks to the Process Roadmap

There are nine main steps in the functional build process. Each of these steps has fairly specific outputs. During the pilot program it became clear that achieving these steps in the time intended was not always possible. This section seeks to review the goals and outputs of each step and examine what roadblocks exist that may prevent successful completion. Table 4 below shows the specific outputs and roadblocks at each of the main steps within the functional build process.

Table 4: Output and Roadblocks of the Functional Build Process

Material Procurement	Meet Material Readiness Date	Ownership/Responsibility, BOM creation, process learning curve, material receiving process
Readiness Meeting	Establish readiness to start build	None
Material Readiness Date	All parts received 1 week before start of build	1 week buffer is commonly known and used up by suppliers
Start of Build	Assembly work begins per DFFA build schedule	Labor availability, material availability
BIW Build	Complete in 2.5 weeks	Root causing, material submission, decision making, labor incentives to finish
BIW Wrap-Up Meeting	Summary of DTS, unresolved issues, brief review of action plans and implementation dates	Ownership, purpose, incentives to make a public commitment
GA Build	Complete in 1.5 weeks	Root causing, decision making, labor incentives to finish
End of Build	All assembly, measurement, and root causing complete	Delays due to BIW/GA problems
FB Wrap-Up Meeting	Same as BIW with additional body/GA contract review	Ownership, purpose, incentive to make a public commitment

The first step in the process was material procurement. The output of this step is to have all the required material at the build site with all submission requirements complete by the material readiness date (MRD). As previously discussed this proved to be a challenge. There were a number of reasons this proved to be a challenge. First there was no single ownership of this responsibility. The DFFA engineer created the bill of material (with help from the SMT's and the change agents), the PPO special order group (SOG) placed the orders to the suppliers, and the receiving dock at the PPO build site accepted and received the parts. The interface with the suppliers producing the parts was shared between the SMT design engineers and the PPO SOG personnel. When delivery of a part was a problem, it could be quite unclear who was responsible for resolving the problem. Furthermore timely creation of the BOM proved to be difficult. This BOM was a selective subset of the overall vehicle BOM. The DFFA build engineer is responsible for creation of the BOM, but the real understanding and knowledge of the vehicle parts and assemblies lies with the engineers from several different SMT's. Another challenge was the fulfillment of submission requirements. As previously mentioned this was due mainly because of the learning curve by both the suppliers (as to exactly what was required of them) and the build team (as to exactly what was really important). Finally the material receiving process at the build sites was not the most efficient system. All parts were received by the build facility and then placed in a holding area before the start of the build. The flow of information about which parts had arrived was sporadic and sometimes inaccurate. It was quite difficult to actually confirm what parts had been received and what parts were still outstanding at any point prior to the start of the build.

The readiness meetings were scheduled for approximately a week before the material readiness date. These meetings were more of a help to the whole process rather than a roadblock. The material readiness date was not usually met because it has a built in one week buffer before the start of the build. This buffer is commonly known by the team members and the suppliers. Missing the MRD is not a major concern as long as the parts arrive before the day they are required on the build schedule.

The start of build date is published well in advance and the DFFA engineers publish a detailed schedule of daily builds during the event. Sub-assemblies are built first, which are in turn used to create higher level assemblies later in the build. Delays in early builds create delays in later higher level assembly builds. These delays are difficult to impossible to recoup. During the early implementations of functional builds a lack of labor and material delayed the start of the build on several occasions. The material shortages were explained above. The labor shortages were simply a matter of not enough skilled tradesmen available for the required builds. There was a general shortage of experienced skilled tradesmen available to support the builds, especially when there were four functional builds occurring at the same time. These skilled tradesmen were also required for several other build events occurring at the PPO facility at the same time. The DFFA build schedules were published well in advance and clearly showed the labor requirements for each of the programs. However there were just not enough experienced skilled tradesmen available to put together these assemblies. This was both an issue of lack of availability and of constant re-prioritization of a limited resource.

The BIW and GA builds were scheduled to take a total of four weeks. It was important to have quick iterative builds in which a large team could be brought together to solve build issues quickly and the tool and die makers could have time between builds to make changes to large and expensive equipment. However this four week goal was not met. Labor shortages, labor incentives, material submission problems, additional time for root causing, and a longer than expected decision making processes kept these dates from being met. The DFFA build schedules were based on a set number of skilled tradesmen working a given number of hours per week. When the skilled tradesmen were not available or could not work the required number of hours (or both) the schedules slipped. Furthermore the incentives of the unionized skilled tradesmen did not align with the goal of a quick four week build. The skilled tradesmen were paid premium wages when overtime work was required. Early in the build there was little reason to assign overtime work. However as the build progressed and got further behind the need for overtime work increased. The further behind the build was, the more overtime work was required. The other factor creating delays in the process was the decision making process. The build problems encountered by the team were often very complex engineering issues with no clear and obvious solution. Furthermore these issues revolved around high capital investment dies and tools. Changes were risky both from a capital and timing standpoint. These complex problems often led to additional root causing efforts, which were not in the original build schedule. These root causing efforts included such things as additional measurements, additional information from suppliers, and offline sub-assembly builds and studies (all requiring more time and resources). From the perspective of the individual and the team facing the challenging decision, the incentive is to be risk averse, and gather as much information as necessary to make a sound engineering decision. The costs of making an incorrect decision far outweigh the benefits of making a quick decision for the sake of the functional build process.

Finally the wrap up meetings at the end of the BIW and the GA builds were quite difficult to implement. At first the purpose of these meetings was not clearly defined. The purpose and definition of these meetings evolved with the functional build. Each meeting was intended to provide a summary of the dimensional results of the build relative to targets (DTS), a list of open or unresolved issues, and a brief summary of the corrective actions and implementation dates. The intended audience was the next level of management for each of the key stakeholders. The premise was to create a public contract between the functional build team and management about what was committed to be resolved and when. The complete wrap up meeting following the GA portion of the build also had the added topic of the body/GA contract that defined what the goals were for the body and GA interfaces. This topic became more critical in the second functional build wrap up. Several roadblocks existed to implementing these meetings. First of all it was unclear who was responsible for organizing and running the meetings. Second the information on open issues, actions plans, and implementation dates was difficult to summarize because it was spread out across many different stakeholders. Finally the team lacked incentives to make public commitments to management to fix build problems. Again the costs of making a commitment in such a public forum and failing to achieve it far outweighed the benefits of making the commitment. The GA wrap meeting had the added conflict of the DQ&V health check meeting to compete with. This health check meeting was another wrap meeting mandated by the interior SMT and organized and hosted by DQ&V to review and approve proposed interior changes resulting from the functional build. Its purpose and audience somewhat overlapped that of the functional build wrap up meeting. This additional meeting made it even more difficult to clearly define the purpose and organization of the end of build wrap up meeting.

5.2 Stakeholder Commitment Chart

As useful tool for analyzing the relationship between change efforts and stakeholder involvement was given by Beckhart and Rubin in their work Organization Transitions – Managing Complex Change. In this work they develop the idea of a commitment chart. This chart lists all of the key stakeholders involved in the change. It then breaks down the levels of possible involvement in the change into 4 categories, listed below[9]:

- No Commitment
- Let It Happen
- Help It Happen
- Make It Happen

[9] Beckhart and Rubin, Organization Transitions – Managing Complex Change p. 94

The X's in a commitment chart represent the current state of the commitment from each particular player. The O's represent the minimum required level of commitment for each of the stakeholders in order to make the change successful. In boxes where both the X and O are present no further action is required. However when the current and required levels of commitment do not match this allows one to create a strategy to fix this.

This section provides the authors opinion on current and required levels of commitment for each of the major stakeholders, along with some background on relationships between stakeholders. Chapter 6 will attempt to provide some strategies for aligning current and required involvement in mismatch scenarios.

Table 5 below shows the commitment chart for all of the major stakeholders. The following list describes the roles and relationships of the key stakeholders and briefly describes their involvement in the change initiative. Please note this chart is just the opinion of the author and is somewhat of a simplification and generalization, as there are many stakeholders and people involved with the change.

Table 5: Change Initiative Commitment Chart

Stakeholder	No Commitment	Let It Happen	Help It Happen	Make It Happen
BIW Group (Body In White)	X		O	
. Process Executive Champion				O,X
. . Change Agents				O,X
. . PPI Department		X	O	
MFD (Metal Fabrication Division)		X		O
Suppliers (Interior and Exterior Parts)		O,X		
PPO (Pre Production Operations)	X		O	
. DFFA Department			X	O
. SOG (Special Orders Group)		X	O	
Manufacturing Plant	X	O		
. GA (General Asm portion of plant)	X	O		
. Body Shop	X	O		
UAW Skilled Tradesmen	X			O
SMT's (System Management Teams)		X	O	
. Structures and Closures (Body)		X	O	
. Exterior		X	O	
. Interior		X	O	
Vehicle Program Team		X	O	
. PEM (Program Eng. Manager)			X	O
. PLM (Program Launch Manager)			X	O
. . Lead System Engineers			O,X	
. . . Design Engineers		X	O	
. . Dimensional Program Manager			O	X
. . Dimensional Launch Manager			O	X
. . BIW PPI		O,X		
Corporate Craftsmanship Team	X		O	
DQ&V	X	O		

- *BIW Group* – BIW is a division within the company responsible for installing body shops in the plants. This is a fairly large group with a range of responsibilities in the change effort. There are several departments within BIW, including PPI and body shop execution. The required level of involvement for this group was list as help it happen because overall there are several groups/departments within BIW that are critical to making this change a success. One of those is the body shop execution group. This is the team that is responsible for tuning in the new body shop lines in the plant. Several members within BIW were very involved, including PPI, the change agents, and the executive. However BIW was listed as currently having no commitment because one key member (body shop execution) was not involved, and overall the group as a whole has not been very involved.

- *Executive Champion* – The executive champion was part of the corporate craftsmanship team, and maintained an excellent working relationship with MFD. This individual was very involved with the builds throughout the pilot and follow on programs. Without the leadership and guidance of the executive champion completing the pilot functional builds would not have been possible.
- *Change Agents* – The change agents reported to the executive champion and interacted with all of the key stakeholders to get the change implemented. Their role in the organization made them proponents of the change initiative. The senior change agent developed almost all of the process details for the functional builds. Again without the senior change agent this process would not have happened.
- *PPI Group* – PPI was an integral part of the old FE process. They were responsible for creating the BOM for that build and insuring the parts arrived on time. All rework of structures and closures parts was managed by PPI. However this stakeholder probably did not completely understand their role in the new process, and was therefore not able to be as committed or involved as needed. As the liaison between the plant and the engineering community this group plays a critical role in the helping the design engineers' impact on functional build resolutions is understood once the vehicle starts production in the plant. Furthermore the head of this department is the executive champion for the functional build implementation. PPI is part of the vehicle program team and had close ties with MFD.

- *MFD* – The metal fabrication division has been traditionally at odds with design engineering. The groups have very different objectives and points of view. Fabrication of the dies and tools that make the body panels is a long and complex process. The goal of any tool maker is to get a stable part design early and run with it. Changes to part design are huge headaches for a tool or die maker. Design engineers want to create the best possible design, which requires iterations and tweaking of part designs. This puts the two groups naturally at odds with each other. Success of this whole change initiative requires a constructive working relationship between the design engineering community (who control the designs) and MFD (who control the equipment that produces the designs). During the pilot program there was a constructive relationship with MFD. In order for the change to succeed MFD must be completely committed and involved. As owners of the dies and tools, they must make the change happen. However the current relationship between MFD and the product engineering community makes this a challenge and prevents this stakeholder from being as involved as needed (although MFD was very supportive of the pilot builds, more is required).
- *Suppliers* – The external suppliers are also important to the success of the change effort. The difficulty in the early programs will be for the interior and exterior suppliers to have production parts available for the functional builds. Once the program definitions include requirements for production parts from these suppliers, the suppliers will start the fabrication of the tooling of these parts in time to make this possible.
- *PPO* – This group owns all pre production vehicle builds. They control the facilities, resources, and allocation of labor. As it stands the early builds were very short on labor and often had problems with use of the CMM room. If the change is going to succeed PPO will have to help it happen by improving availability of labor and support through services like the CMM room.
- *DFFA Group* – The main purpose of the DFFA department was to organize and run the functional builds. This is probably the most central stakeholder of all of the players. This department naturally interacted with almost all of the stakeholders. In order for this change to accomplish its goals DFFA is going to

have to make it happen. During the initial builds not all of the details on the process had been worked out. The use of FEDR's changed from the FE builds. Several DFFA build engineers led the various early builds and not all of them shared the same viewpoints on the details of the process. In future builds the process ought to be better defined and the build engineers can implement the process in the same manner. The vehicle program team and dimensional management worked closely with the DFFA engineers during the build to gather information and resolve build issues. PPI worked closely with the DFFA engineers on structures and closures material issues. The head of the DFFA department was a member of the corporate craftsmanship team.

- *PPO SOG* – The PPO special order group orders and tracks the parts for the functional builds. This group did everything they could to process and track the orders, but was having trouble keeping up with the volume of parts ordered as the numbers of programs planning to complete functional builds increased. In the near future this group will probably need one or two additional people to be able to keep up with the volume of work.
- *Production Plant (GA and BIW)* – There was little involvement during the functional builds by production plant personnel (from either the GA or body shop portions of the plant). As one of the stated goals of the functional build was to achieve a stable vehicle body after functional build two, the lack of involvement from plant personnel, or the execution team that installs the body shop lines, was a major loss. If the change is to have a last effect there will need to be more commitment and participation from these groups.
- *PPO Labor (UAW Skilled Tradesmen)* – This group was a key player in the change initiative as they actually put the assemblies together and measured they parts. Unfortunately their compensation structure created incentives for them to make the build go on for as long as possible. This delay in the long run could be devastating to the institutionalization of the change. It should be noted that this group is a proponent of keeping the functional builds in house. It could be difficult to have these builds done outside of the PPO facilities because they are now viewed as union jobs. It should also be noted that there was little interaction

between this group and any of the other stakeholders. Only the DFFA group interacted directly with the labor. Occasionally engineers would seek information, or help from the skilled tradesmen, but in general there was no interaction between PPO labor and anyone other than the DFFA build engineers. The daily meetings were timed to coincide with the morning break of the skilled tradesmen (in an attempt not to bother them during builds). In the long run the people that put together the assemblies need to be an integral part of the team resolving the issues. These people will naturally have insight and opinions on why problems exist and how to possibly solve them. In the current state this knowledge is not being used.

- *Structures and Closures SMT* – The engineers and leadership within the body SMT were in general very supportive of the change. Often these engineers were owners of build issues and led teams to resolve them. These teams were comprised of people from MFD, dimensional management and PPI. Timely decision making was a challenge but participation was very good. The timeliness of decision-making was more a product of the challenging problems and the incentives to present risky solutions, rather than a function of the ability of the teams. This group could have been better utilized if they had not changed most of their personnel between the first and second builds. This SMT also used different tools to track build issues (as opposed to using the FEDR database). These engineers had a list of ongoing issues they had to track to closure so they just added the functional build issues to this list. While this did make perfect sense to that SMT, it made tracking of all issues more challenging for the team in general because there was no single master list of build issues and resolutions.
- *Exteriors SMT* – The exterior SMT was somewhat indifferent toward the change initiative. It was difficult to convince them to actively participate in the pilot functional build at first. However once the exterior engineers began participating in they were very supportive of the build. The exterior SMT worked with a supplier partner to design and develop their parts, unlike the body SMT which designed all parts in house and had MFD manufacture them. It should be noted

that most of the exterior parts were prototype parts so it was more challenging to tune in a production assembly using non production parts.

- *Interiors SMT* – Members of the interior SMT on the pilot vehicle program team were very supportive of the change and seemed to think these builds were great opportunities. These engineers participated in the functional builds and worked well to try to resolve build issues. Again tune in was difficult because many of the interior parts were prototypes. However the interior SMT also had people on corporate craftsmanship team who at the same time were pushing an alternate agenda. Like the exterior SMT, the interior group worked with a supplier partner to develop their designs. Prior to craftsmanship the tune in of interior parts involved the use of interior fitting fixtures. These fixtures represented the interface points between the interior components and the vehicle body. These fixtures were set to nominal design intent. The group responsible for assembling the interior parts to the fixtures was DQ&V, design quality and verification. With the addition of the functional builds, it was unclear what the role of DQ&V would be, how the interior parts would be tuned in, and what the use of the interior fitting fixtures would be. Members of the interior group on the corporate craftsmanship team came up with the idea of the interior health check event, which was to follow each of the first two functional builds. Although the purpose of this health check changed during the process, its initial intent was to compare the interior parts on the functional body against the interior parts on the interior fitting fixture, and to mock-up and approve any changes required to these parts. Given the time available between the functional build and the health check the proposed initial purpose was not realistic. There was simply not enough time or resources available to mock-up and install all proposed changes. Also one of the premises of the iterative functional builds was to validate previous changes on the next build, so this health check was somewhat redundant. However the DQ&V group had significant role in the pre-craftsmanship process, and the interior SMT seemed unwilling to change this.
- *Vehicle Program Team (pilot program)* – This team was told by their upper management that they were going to be the pilot program for the change initiative.

This team was responsible for the design and launch of the vehicle and was a cross functional team with membership from many of the key stakeholders. Being a pilot program on such a major change initiative gave the pilot program a lot of visibility within the organization. The team embraced the change and the team's leadership made the functional builds an important part of their already busy schedule. Support of the program team leadership is critical to getting the support of the team as a whole. In the long run as the process gets a more clearly defined more commitment will be required of this team. This team will be the team that launches the vehicle in the plant and must take overall ownership of the functional build process. Especially important will be the leadership (the PEM and PLM) to the process. In the hierarchical company culture, team leaders have a tremendous influence on team performance. If the PEM and PLM buy into and understand the change, then the rest of the team is likely to follow their lead.

- *Dimensional Management* – One of the main goals of the functional builds was to meet the program's aggressive dimensional technical specifications. The main responsibility of the dimensional management group is to insure that the DTS are met. The goals of dimensional management and those of the change are so well aligned that these team members were invaluable in the pilot program. As part of their normal responsibilities the dimensional management team worked closely with all of the SMT's, the DFFA build engineers, MFD, and with the production plant. Dimensional management was also a key part of the vehicle program team with both a program dimensional manager and a launch dimensional manager on the team.
- *Corporate Craftsmanship Team* – This team developed the change initiative but had surprisingly little involvement with the day to day implementation during the pilot program. Their position could best be described as interested, but not involved. Part of this could have to do with changes in the make-up of the team during this time period. The leadership of the team changed. At times the weekly team meetings were extremely lengthy and not tremendously productive. After the change in leadership the group became more focused on the interior SMT over some of the other stakeholders.

- *DQ&V* – As mentioned above, this group had significantly more responsibility in the pre-craftsmanship process. Considerable effort was put forth by this group and their proponents within the interior SMT to make this health check part of the craftsmanship change initiative. This health check event detracted from the focus on the functional build and generally confused things. Furthermore the very premise of using a design nominal fitting fixture to tune in parts supports a build to print methodology, rather than a functional build methodology.

5.3 Institutionalization of Change

Overall the craftsmanship initiative could be described as a top down change. The auto manufacturer has a very hierarchical culture. Position and title are very important and provide significant ability to influence and give direction. The impetus for the change initiative came from quite high up in the organization. Although the corporate craftsmanship team is not primarily made up of executives, it was formed by a directive of executives. Furthermore this team had the authority and directive to make changes to the template for the vehicle development and launch process. The decision to implement this new template on the pilot program and every following program had the support of upper management. The early adopters had little choice but to implement the change.

However this is not to say that the change has been accepted and institutionalized. Although it is possible to dictate change from above in this culture and organization, the success of the change is far from guaranteed. In this organization, people can be required to implement a change, but they can not be forced to agree with it. In order for the change to become institutionalized, the organization must not only implement the change, but must buy into and accept the change. To achieve organizational buy-in the goals of the change must align with the goals of most of the stakeholders. The change must make sense and must help the stakeholders accomplish their goals. These goals are often dictated by the items upon which the stakeholders are evaluated by their management. Alignment of the goals of the change with the incentives of the stakeholders is critical to its success.

The craftsmanship initiative has many supporters and functional builds have been completed with varying degrees of success for several vehicle programs to date. However this change is still a long way from being institutionalized into the organization. As section 5.2 indicated the process has many committed supporters who see the benefits, or possible benefits of the new process. However more participation and commitment will be required of several of the key players as outlined by the commitment chart. Section 4.4 points out the results of the initial implementation still leave lots of room for improvement. Chapter 6 will outline some steps and recommendations intended to solve some of the challenges faced and help insure the change initiative institutionalized.

5.4 Leadership Lessons and Examples

During the course of the project, there were several situations that occurred that provided valuable leadership lessons. Two of these in particular stand out. These situations stand out because they are clear examples of the difference between pushing change upon an organization, and having the change pulled by the organization. Furthermore these examples allow one to look at the different perspectives of company insiders versus outsiders, such as the change agents.[10] The first of these examples involves the actions of the executive champion during the early days of the first functional build of the pilot program. The second of the examples centers on attempts by the intern to organize the wrap up meetings for the pilot functional builds. Both these examples provide intuition into how better to implement the change in future implementations. The leadership section of Chapter 6 will refer back to these examples.

5.4.1 Executive Champion Example

During the early period of the first functional build there was a lot of participation and attention given to the event. Most of stakeholders were present and involved during the kick-off and daily build meetings. This was a high profile change initiative that was very important to organization and upper management. However it became clear very quickly

[10] © J.A. Klein, "*How Outsiders on the Inside Make Things Happen in Organizations*" Jossey, Bass. 2004.

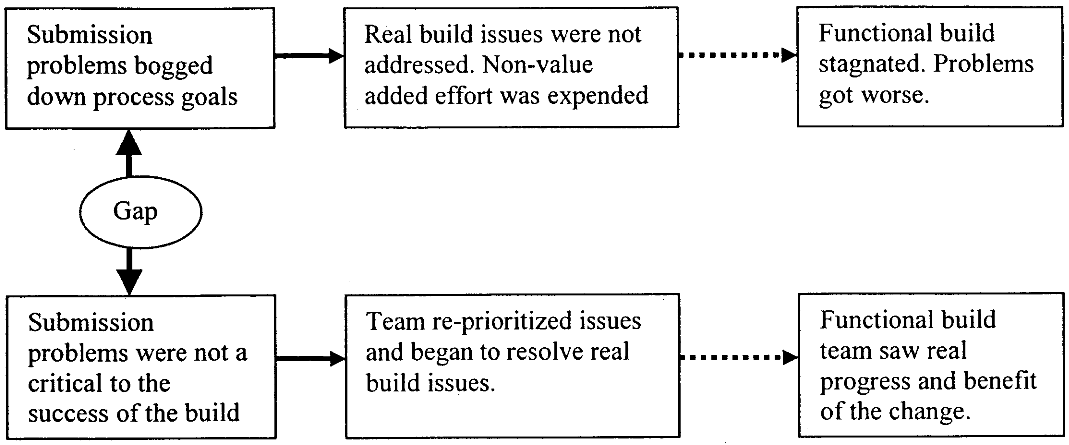
that most of effort was focused on problems with submission requirements, not build issues. There was very little discussion and debate of build issues and no resolution of these assembly problems. There was lots of heated debate about why this part was late, not marked up correctly, did not have the source warrant, did not have a complete capability study, or did not meet the dimensional criteria. For every daily meeting a list was compiled of the all current issues with assigned owners. This list became clogged with mostly submission issues that were discussed in detail during the limited time for the daily meeting. Most of the effort of the group was focused on what we did not have instead of building an assembly and solving build issues. All of the key stakeholders were insiders, long time company employees, prone to see problems with the cultural, structural, and political bias of the organization. These insiders were approaching the new functional build events much like they approached the old FE builds. However these new functional builds were to be completed in one third of the time and there was lots of executive attention on them. The team quickly became frustrated and some of the responsible leadership (DFFA group) was becoming almost panicked.

The intern change agent had just joined the group and was very much of an outsider to the organization. From the outsiders perspective it seemed that the team was spinning its wheels fruitlessly. There was no lack of effort or time commitment, but there was very little to show for it. However as an outsider the intern did not have the credibility or authority to just push a change to this behavior on the team.

On the other hand the executive champion was very much of an insider with credibility and authority within the organization. If the team continued to approach the functional build using their current practices very little would be resolved and the change would most likely fail. However to just give explicit directions on a new approach would have been pushing a change on the team. Although the team would most likely have accepted the new approach, the change would have been pushed upon them, and the team most likely would not have bought into the new approach. The executive champion intentionally allowed the team to continue on its current approach for a couple of days, knowing what problems they were encountering. Then he went to one of the daily meetings, which by then had become quite contentious, and asked a couple of questions of the team. The questions were initially centered on how many build issues had been found and resolved. The answer to this question was almost none because all of the effort had gone into tackling submission problems. Instead of then asking how to get these submission issues resolved, the executive champion then started asking the team why these submission issues were really a problem, and why they had not been focusing their efforts on the information we did have, rather than what we did not have. Instead of telling the team to focus on build issues, the leader allowed the team to figure that out for themselves with the line of questioning. Then with a little prodding the team reprioritized what issues to actually focus on during the daily meetings. The submission requirements were handled offline, were mostly removed from the daily issue list, and the team accepted a new method of approaching the builds and the daily meetings.

The following figure models the difference in viewpoints about the problem and the differing end results of these viewpoints. The outsider (intern) could see the gap but do little about it. The insider (process champion) got the team to see this gap. He got the team to create the change (pulling) rather than telling them to make the change (pushing). The team accepted a different view of the problem. This changed the process for the pilot functional build and made good progress toward the goal of finding and resolving real build concerns.

Figure 5: Pilot Functional Build Gap Analysis



The main takeaway from this example is the need for credible insiders to actively participate on in the change efforts but take the viewpoint of an outsider. The executive champion took the viewpoint of an outsider and spotted the root causes of the problems of the early pilot functional build. Then instead of just forcing a change in behavior, he used a couple of well placed simple questions to get others to look at the problem from a different point of view. There will be many more attempts at functional builds in upcoming programs. Each team will need a credible insider to look at problems they encounter along the way from an outsider's point of view and steer the team back on course.

5.4.2 Change Agent (Intern) Example

The intern had the opportunity to experience a classic example of the differing results from pushing versus pulling change. This example centers on the organization and execution of the functional build wrap up meetings.

The first wrap up meeting required for the new process was the body in white meeting following the pilot program functional build one. During this build no one was quite sure what the purpose of this meeting was and who was responsible for organizing it. As the change agent on the pilot program, the intern took the responsibility of working with several of the key stakeholders to define and organize the meeting. Definition of the event was accomplished simply by getting several of the key players to sit down and discuss what they hoped to accomplish in the meeting. The executive champion provided a lot of the vision for this discussion. This discussion provided a basic purpose and format for the meeting.

All that remained was organizing a meeting that fulfilled this purpose. Having a good understanding of the format and goals of the meeting, the intern created an agenda and a detailed presentation that would serve as a template for the meeting. The goal of the template was to make life easy for the team by creating structure and format for the meeting. All they had to do was fill in the details on their particular section and present it. This template was given to the team with the idea they would review, revise, and complete it before the meeting. However this did not work well at all. Although the team understood the purpose of the wrap up meeting, the attempt to push the meeting template on them was rejected. Instead the agenda of the meeting was agreed upon by the vehicle program team and each presenter came up with their own set of slides, which did not always completely meet the intent of the meeting.

When organizing the second wrap up meeting (for the end of the complete functional build one) the intern approached the team differently. A date was selected and invitations were sent out to a large audience, thus setting the date in stone. The intern then created a proposed agenda that was reviewed with the team. At this point the intern offered to help organize the meeting, but did not push a specific template for the meeting. This offer for help was well received and accepted. A lot of the team members needed help pulling together data for the presentation and the intern was much more able to influence the structure of the event to insure it met the intent.

The takeaway from this example is the difference in effectiveness of pushing versus pulling change. The intern attempted to push a change on the team by creating a presentation template and just telling people to use it, with very little success. If the need for a change was instead made clear, the team was more likely to request help with the presentation. As the craftsmanship change initiative continues it will be a lot more success with if the change is designed so that key stakeholders pull the change rather than have it forced upon them.

5.5 Chapter Summary

This chapter initially outlined the output and goals of each of the major steps within the new functional build process. The existing roadblocks to completion of these goals were explained. The major roadblocks during the early builds were availability of labor to complete the builds, the inability to quickly make require decisions, and general details and ownership of the functional build process. Next the current and required level of commitment from each of the major players was examined. In general this showed several key stakeholders that will need to be considerably more involved and committed in the future to institutionalize the change effort. Finally the last section of the chapter provided a couple of examples of effective and ineffective leadership lessons.

Chapter 6 – Recommendations

During the course of the project many lessons were learned and possibilities for future improvements created. The goal of this section is to summarize some of the lessons learned and suggestions. These recommendations are broken up into four sections. The first section covers tools for improving the process and metrics for gauging the success of the builds. The second section covers process lessons and improvements, including such areas as material acquisition, process design, and resource requirements. The third section provides recommendations focusing on stakeholder involvement, incentives, and training. The final section provides suggestions for long term leadership and vision of the functional build.

6.1 In Process Tools and Metrics

During the implementation of the functional build one and functional build two on the pilot program, it was not completely clear as to how to judge success or failure of the new builds. Metrics were needed to evaluate the progress of the vehicle relative to the goals of the change initiative. In addition, metrics were needed to evaluate the implementation of the new functional builds themselves (i.e. were the builds productive). These metrics needed to be clearly defined and universally understood by the key stakeholders. Metrics that align the incentives of the stakeholders with the goals of the change are critical. Listed below are lessons learned and suggestions for the metrics.

- *DTS relative to target* – At the end of each build the entire vehicle is measured and compared against the target dimensional technical specifications (DTS). DTS relative target defines how the vehicle itself is doing in terms of achieving the main goals of the change, meeting the aggressive new DTS. Each build has a percentage of DTS met. If the builds progress as intended this percentage will increase for each build. Although this was implemented during the pilot program, it should have gotten more attention. This seems to be one of the high level obvious metrics for functional build.

- *New Open Issues, Ongoing Open Issues, FEDR's issued, issues closed, and days open* – For each daily build meeting, the DFFA engineer handed out a list of newly opened issues (to be assigned ownership) and on-going open issues (that had not yet been resolved). Two additions to this handout are recommended. The cover sheet should have a day by day table of the build showing new issues opened, open issues without resolution, FEDR's issued, and issues closed. This would give the team and management a very good way of determining quickly how productive the build has been in terms of discovering problems and fixing them. Table 5 below shows a simple suggested format for these metrics. In addition the detailed list of open issues should include a days open metric beside each issues. During the pilot program there were some cases in which the issue is awaiting a higher level assembly to resolve, but there were some issues that could have be resolved much quicker. This metric would force attention on issues that have remained open for long periods of time.

Table 6: Daily Functional Build Metrics

Day of Build	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	19	20	21	Total
New Open Issues																					
Unresolved Open Issues																					
FEDR's written																					
Issues Closed																					

- *FEDR definition* – It is important to clearly define a FEDR for all of the programs implementing the change. A FEDR is a resolved build issue that requires some change. The FEDR should clearly define the action plan and implementation date for resolution of the build issue.
- *Types of FEDR's* – If a FEDR is a build issue that requires a change, then these changes could be categorized into three main types:
  - FEDR's that require physical changes to parts.
  - FEDR's that require engineering documentation changes.
  - FEDR's that require changes to assembly fixtures or tools.

- *FEDR tracking* – If the FEDR's were implemented exactly as defined, it would be possible to track the completion of them relative to the promised implementation date.
- *Common System Used for Tracking Issues* – It important to have one common system for tracking and resolving build issues during the functional builds. During the pilot program there was no single system used for tracking build issues and resolutions. The initial use of the FEDR database and website was full of problems. The web interface to the database was cumbersome and difficult to search. The FEDR definition gradually changed during the early builds. The engineers who owned the issues had there own system for tracking and resolving issues. Each SMT maintained an issues resolution tracking (IRT) list of all open issues going into launch. Given the problems with the FEDR database and the familiarity with the IRT list, it was natural for the engineers to use the IRT tool, instead of the FEDR database. However this resulted in several separate lists of issues and resolutions. This was problematic in that it information was spread out in multiple different places. Sometimes these sources had overlapping and contradictory information about build issues. The build needs a centralized, easy to use database of information.
- *Critical Interface points for GA material* – in order to achieve the contract between the structures and closures SMT and the GA SMT's defining a stable vehicle body going into launch at the plant, the key interface points between the body and the GA parts must be understood. The interface points should be clearly defined going into functional build one.

In summary metrics are still very much needed to judge how builds are going at any point in the process. There are several metrics that could be used without major process changes. First FEDR's should be commonly understood and used by all teams. FEDR's should be clearly grouped into three categories, those requiring physical changes to parts, those required changes to assembly tools, and those required changes to engineering documentation. Next the DTS are good indicators of the changes to the body created by the functional build process. Once the programs enter launch in the plant DTS will show

how success the early functional build efforts have been (i.e. if the early cars in the plants take a big step backward in terms of meeting dimensional requirements then the early functional builds will likely have been of little use). During the builds the DFFA engineers should tally the daily open and closed issues to make clear to all concerned how effective the team has been at resolving build issues. Finally all the stakeholders need to use a common system for tracking the build issues. As it stands now information is badly spread out between many sources.

6.2 Process, Material Acquisition, Resources

This section contains lessons learned and recommendations focused on the process design, the required resources and the overall design of the process.

- *Material receiving and availability* - At gate reviews before events material availability is a major topic. However the existing process for receiving material in the PPO shop, the organization of received material, and internal company systems for tracking material are problematic. Information on material was often inaccurate and difficult to come by. Considerable time was spent by the change agent tracking material during the course of the project. This is not an overly complex process and has lots of room for improvement. The DFFA group must have an understanding of what they have before the build is scheduled to start and owners must be present to deal with any missing parts or data. Given the number of new programs that will be implementing functional build, it probably makes sense to have a separate dock just for this material. Received material must be checked in against a bill of material and then immediately put in bins designated for that sub assembly of that program (as opposed to all over the table and floor of one section of the building).
- *Build length and timing* – The goal of four week functional builds was not met. When the builds run long that often does not leave time in between builds to allow the suppliers to make changes to dies and ship new parts for the next build. This endangers the underlying goal of quick iterative builds. Either the builds

need to be completed as intended or the number of builds and time between them must be re-evaluated.

- *Manpower and resource availability* – Build schedules during the early implementation were based on assumptions of available labor. Rarely were these assumptions met. The functional builds seek to assemble and measure twice as many parts as the old functional evaluation in less than half the time. This will not be free. Additional cost will be incurred for the labor and material. If the organization deems this change as valuable in its current form, then it should commit the resources to the effort. Without the resources implementation will probably fail to meet most of the goals.
- *Root causing time and resources* – It was discovered that the original template for the builds did not incorporate adequate time for root causing of build issues. Part of this could be attributable to the decision making process and incentives. However some of it is just a underestimating of the original plan. In order to accommodate these activities, additional labor and resources must be available during the builds for unplanned root causing activities (i.e. the original estimates for labor required were not sufficient). These root causing activities include additional measurements, side builds or studies, and plant investigations.
- *Dimensional results package for body shop tune in* – During a meeting involving body shop execution and dimension management it was decided that the program dimension manager and launch dimensional manager should create a package to be handed off at the completion of FB2 (or soon after – takes time to create). This package should include a summary of all measurements taken on the functional builds. It will then break these down into a smaller subset of critical measurements by sub-assembly. The critical points will include a set that are off-nominal and are acceptable from a functional perspective. These points will be used throughout body shop tune-in and production. It will allow containment and understanding of "goodness" early bodies to the FB bodies built.
- *Wrap Up meetings* – The purpose of a wrap up meeting is two-fold: 1) Brief summary of event and measurable metrics for Exec Review, 2) Public Contract between issue owners and the team to close FEDR's as promised. The data for

these meetings should be easily available from the common database and interface used by the whole team (as opposed to the current system).

- *DES files and routines* – DES files are the measurement points used by the FARO arms and CMM machines to measure and compare the physical assemblies to the design intent of the CAD data. These were a bottleneck for DFFA group during the pilot functional build. These files contained all the points to be measured during the build. However it was impossible to predict how the physical assembly would go together before the build so often additional measurement points were added during the build. The process should have a formal step between functional builds in which the DES files and measurement points are updated based on results of the previous build. There should be similarities between vehicle programs and lessons learned should be incorporated into future programs.
- *Final complete measurement yielded many new build issues* – Many of the build issues surfaced as a result of the final measurement of the vehicle at the end of the build. These were complex issues that required time to diagnose and resolve. The wrap up meeting is scheduled to be given within a week of the completion of the build. All effort should be made to close issues if possible, but it should also be understood that given the timing of the final measurement and the meeting, that some of these items will still be open at the meeting.
- *Measurement tools used (FARO versus CMM)* – Measuring assemblies using the FARO arms takes considerably more time than measuring the same points using the CMM room. However the assembly must be moved to the CMM room to be measured and time on the CMM must be scheduled. It is possible that with operator experience the FARO arms could be used a lot more efficiently. If the FARO arm does not improve as a tool for measuring the vehicles, some of the sub assembly measurements should be done in the CMM room. This should be part of the build plan for each program. The build fixtures used may limit the use of the CMM. If PPO weld tools are used to assemble the parts it may be impossible to measure many of the assemblies in the CMM room.
- *FEDR Tracking meetings* – If one system is to be used to document all changes, then there should be some process in place to track these changes through to

completion. On the pilot program, the DFFA build engineers held several weekly status or update meetings between FB1 and FB2 on the progress of action plans for FB1 FEDR's. These meetings should be formalized this as part of the process.

The existing process was not completely defined by the start of the pilot program. The pilot program provided many valuable lessons on what to do differently in the future. One of the major things needed in future builds will be more labor. Furthermore the process and incentives for root causing and decision making will require additional resources if the intended timing of the builds are to be met. A better process and system for receiving material will help the teams before the start of builds making sure that required parts delivered in time. The experience of the early builds should be used to improve the selection of points to be measured and the selected system used for taking these measurements (CMM vs. FARO arm). Finally the vehicle program teams and DFFA engineers should all understand the purpose and agendas for the wrap up meetings. The proposed new metrics for the process, along with a single common system for tracking them should make the wrap up meetings much easier to organize and run.

6.3 Involvement, Incentives, Training

Several of the problems with the early implementation of the change can be traced back to stakeholder involvement, incentives, and training. This section contains recommendations to resolve many of these issues.

- *Body shop execution team* - During the pilot programs the body shop execution team was not very involved in the functional builds. The body shop execution team installs and tunes in the body shop. If the goal of the functional build process is to achieve a stable body after functional build two, then the body shop execution team must be part of the team.
- *Vehicle Program Team* – Given the hierarchical nature of the company culture, it is very important for the leaders of the vehicle program team (the program engineering manager and the program launch manager) to understand and buy

into the functional build process. Without leadership buy-in the vehicle development and launch teams are likely to resist the change. This makes a huge difference in success of the implementation.

- *Training of vehicle program teams* – Prior to the start of the first functional build the vehicle program team leadership should train the team in the process and goals of the functional builds. This will only happen if the leadership buys into the change initiative.
- *Training consistency* - During the early implementations there was a problem with consistency between the vehicle teams. Some of the teams interpreted aspects of the build differently. For example several of the early teams used FEDR's completely differently. Training of the stakeholders early on with a consistent definition and process will help institutionalize this change effort.
- *Skilled tradesmen involvement* - The skilled tradesmen who actually build the car are not treated as part of the team. They are excluded from the daily build meetings and are almost never asked for advice or information. This is completely contrary to the global manufacturing system principles of people involvement and teamwork. The knowledge gained from actually putting together the parts is invaluable. The hands on knowledge of this group could be tremendously valuable and should be included.
- *Skilled tradesmen incentives* - The incentives of the skilled tradesmen do not line up with the needs of the functional build. There is no incentive for them to finish the build on time. The longer the build takes, the more pressure there is to use overtime labor. Overtime labor means more pay for the skilled tradesmen. It would make more sense to somehow change the compensation of those involved to be based on timely completion of the build at given quality levels, rather than hourly overtime. Changing this compensation may be completely unrealistic due to union rules and the relationship between management and the UAW. However with the existing compensation structure it is very unlikely that a build will be completed on time.
- *Consistent team throughout the process* – The team responsible for the functional builds should remain intact and consistent until the vehicle is launched. Between

the first and second functional builds on the pilot program more than three quarters of the engineers for the body and closures SMT were replaced. New engineers on program have spent lots of time and energy revisiting prior decisions and resolving old problems. Much learning and experience about both the vehicle issues and the new process was lost when the engineers were replaced. Much learned in FB1 and consequently lost because the team changed.

- *MFD involvement and relationship* – Traditionally the relationship between the metal fabrication division (MFD) and the product design engineering community has been somewhat rocky. The goals and incentives of the two groups are somewhat opposed. MFD seeks to get a stable part design and deliver the tooling and dies on schedule. Design changes make their job very challenging. Design engineers want to produce the best product possible and often want to make changes to part designs. However if the functional build is to be success, MFD must be a valued key stakeholder. MFD controls the changes to most, if not all, of the major metal body panels. These are large complex dies that require lots of time and resources to change. Much more can be achieved if the relationship with MFD is a positive and constructive one.
- *Incentives for decision making* – It was very common during the early builds to commit to having a solution, part, or data by given date and then not meet this commitment. The incentive structure present seemed to favor indecision rather than making a risky decision. Punishing missed commitments is probably not the best way to overcome this problem. If management wants to achieve a quick decision making process then they must devote more resources to the root causing and actively support and value the ability to make quick accurate decisions.

Many of the problems with the initial functional builds are attributable to involvement, or lack thereof, of many key stakeholders. Often the reasoning behind this lack of involvement is based on poorly aligned incentives. Recall the commitment chart in section 5.2. The major problems with stakeholder involvement were with the labor who put together the assemblies, with people from the plant (especially those who installed and tuned in the body shop production lines), with maintaining a consistent team throughout the process, and with the incentives for team members to make decisions. The skilled tradesmen that put together the functional builds were not involved with the functional build teams or team decisions. Furthermore there was a very bad misalignment between the compensation incentives of the skilled tradesmen and the stated timing of the builds. If the company hopes to complete the builds in the stated time, the compensation of the people who put them together must reflect that. If the builds hope to make an impact during the vehicle launch at the plant, people who work on and control this launch at the plant should be intimately involved with the functional builds. In addition one stable team should be created starting before the first functional build and be maintained until the car is well into production. Replacement of key team members in the middle of the process creates a loss of technical and process learning. Finally if the change initiative seeks to accomplish quick iterative builds, then the decision making process must support this. The current process supports a more risk-averse stance from the team members.

6.4 Change Leadership and Vision

Leadership and vision will play a key role in the implementation of this change initiative. Leaders will be required to push institutionalize this change effort. Leaders will need to present a common vision and understand of the change. Below is a list of the lessons learned and recommendations concerning leadership and the vision of the change initiative?

- *Build issue focused rather than part focused* – The teams must develop a focus on assemblies and build issues rather than a focus on fixing parts. This is a major mindset shift. The current material submission requirements put an emphasis on parts rather than assemblies. Although parts are critical to the process, the team must focus on assembly build issues rather than submission problems with parts. Other major goal is to discover build issues, assign and accept ownership, create an action plan to resolve, and see it through to resolution (quickly).
- *Shift of resolution ownership* - One key aspect of the craftsmanship initiative is a philosophical change to the ownership of build issues to the design engineers. The

build events are now engineering events and the engineers are responsible for its success. In the old FE process product engineering did not have this role. MFD and the FE build engineers diagnose and proposed resolutions for issues.

- *Importance of presence of vehicle program team leadership during builds* – There was a strong correlation between the attendance of the vehicle team leadership (PEM or PLM) and that of the team members at the functional build daily meetings. Furthermore when the leadership was present the meetings were a lot more productive and efficient. Many more issues were resolved with the leadership present. In order to insure leadership presence at the events, the original schedule of the builds must be met. Otherwise the builds drag on for too long and the leadership can not devote the necessary time.
- *Develop launch team mentality* – The functional builds are essentially attempts to move the launch of a new vehicle further upstream in the vehicle development process. In order to formalize this change the launch of the vehicle should be formally defined in the vehicle development process as starting at the beginning of functional build one. By functional build one the launch team should be in place and consistent for the remainder of the build.
- *Formalize the role of the change agent* – The new functional builds require considerable effort and support to pull of. The change agents supported a lot of this work in the pilot and early programs. The vehicle program teams need someone on the team to assume this role. This could possibly fall under the role of the PPI group or a completely new position. These new team members should have common training and understanding of the process, and be able to institutionalize the new process.
- *Shift of process ownership* – The functional build process must be considerable a launch event. The vehicle program team (or launch team) should own these events. In the past the FE group or MFD were the primary event owners.

Considerable effort has been put forth by many people to date in this change effort. Much more will be required if the change is to become a useful part of the launch process. Leadership will have to share a common vision of the change. Leaders must convey the idea that the functional builds now begin the launch of the vehicle. They must instill the idea that the vehicle program owns the functional builds and are responsible for their success. The focus of the builds must be on build issues rather than simply parts meeting specifications. The role of the change agent will need to be formalized as part of this launch team. Leaders will need to not only understand this vision but be able to instill it in the team. In order to accomplish this they could use some of the methods outlined in the leadership lesson examples in section 5.4. The ability to not only have credibility as a company insider, but be able to see and attack problems from an outsider's point of view (unencumbered by the biases of a long time company insider) will make the change process much easier for leaders. In addition this change must not just be forced or pushed upon the teams implementing it. The leaders must create scenarios in which the team understands how this change will help them and then actually wants to implement the change (rather than just being told the will do it).

6.5 Conclusion and Areas of Further Investigation

So far the initial functional builds have been only moderately successful. By fixing some of the major flaws the process can be a lot more successful. First the incentives and involvement of the people putting the build together must be fixed. The builds should mark the beginning of the vehicle launch. One consistent stable team should be put together to see this launch through to the end. This team must include people who can accomplish the tune in at the plant (i.e. plant personnel and execution folks). This team must understand and accept ownership and responsibility for the builds. A single team will also need a single system for tracking and resolving issues. The timing of the builds is critical to achieving quick iterative builds and maintaining team focus. Without more labor this will just not be possible. During the functional builds all stakeholders must understand the metrics upon which the builds and the vehicle are being evaluated. These recommendations provide a basis for improving future functional builds. There are many areas that require further investigation.

This change initiative involves so many stakeholders and affects such an important core process for the auto manufacturer that there are many areas left to be explored and improved. Suggestions for future research are listed below:

- *Design methodology and its relationship to functional build* – What is the process used by the auto manufacturer to design the nominal assemblies? Does the company use a top down methodology in which high level product requirements are used to define assembly and parts interfaces? Or does the company pursue a more traditional bottom up assembly in which parts are designed and then fit together to create higher and higher level assemblies.[11] Part of the craftsmanship initiative is the improvement of ICD's, or interface control documents. ICD's are an attempt to document key interfaces between mating parts that will affect the functionality of the end product. How are ICD's being employed and will they be successful?
- *Skilled tradesmen involvement and incentives* – Getting these key stakeholders more committed and involved will be extremely challenging. Furthermore, attempts to change UAW compensation to more closely align with the goals of the change initiative will be even more difficult. However changes have been made in many of the plants and could be used as benchmarks for improving the effectiveness and involvement of these key stakeholders.
- *Other options for the build locations* – Other options for possible build locations and resources could be examined. Obviously there are many problems with the PPO resources, systems, and the UAW labor. It may make sense for one of the supplier partners to undertake these builds. Would this be realistic or possible? If so would it make improve the outcome of the builds?
- *PPAP* – The production part approval process dictates when suppliers complete their dies, how parts are approved, and when the suppliers get paid. Many of the details of this process do not align with the goals of the functional builds. PPAP is deeply rooted within the auto manufacturer. A study could examine what problems PPAP creates and propose alternatives.

[11] Design and Assembly Text, Chapter 2, Daniel E Whitney, 2003.

- *Measurement plans and DES files* – During the early functional builds measurement and root causing of problems was a major bottleneck to the process. What steps can be taken to improve the measurement of the assemblies. Can the lessons learned from each of the functional builds be used to improve the accuracy of the DES files? How would the company institutionalize what are the appropriate areas and points to measure based on build experience and engineering knowledge?

Appendix A: Acronym Definitions

BTP – build to print
EFF – exterior fitting fixture
FE – functional evaluation
FEDR – functional evaluation disposition report
FB – functional build
GA – general assembly
ICD – interface control document
ICF – interior cubing fixture
MVB-NS – manufacturing validation non-saleable
PEM – program engineering manager
PLM – program launch manager
SMT – system management team