Supplier Involvement in DFM

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Abstract

General Motors' efforts to improve quality have focused on prevention at every level. Quality improvement mandates have been given to design, engineering, suppliers, and manufacturing. Design for Manufacturability (DFM) is a tool used to drive product and process improvements within General Motors. Suppliers offer modularization and design integration strategies as quality improvement solutions. Recognizing the need for product & process cohesion, the DFM team has successfully enhanced our process to include suppliers.

This paper focuses on the methods and benefits of incorporating suppliers into the DFM process.

Introduction

General Motors is headquartered in Detroit, Michigan, and in 1999 celebrated ten years of DFM. In the automotive industry, a manufacturer must be able to produce its vehicles in about the same hours per vehicle as competitors. Driving improvements into the manufacturing process is the focus of General Motors DFM activities – this can be done only with process-driven product designs.

The success of initial Design for Manufacturability activities ensured continued General Motors management support. DFM is a recognized part of the vehicle development process and all new content is required to go through a DFM workshop. The DFM team conducts workshops on all new content that is installed in our assembly centers.

The Advance Product Quality Planning (APQP) compliance manual was developed and sanctioned by Chrysler, Ford and General Motors. This manual specifies that all suppliers are required to conduct DFM on their products. The purpose of the manual is to standardize supplier quality requirements for the industry.

Suppliers were not always involved in our workshops, and GM was not involved in theirs. Since suppliers are offering more modularization and design integration strategies, we must now work closer with them. It is recognized that if General Motors *or* the supplier designs and builds the module, everyone still benefits from a DFM workshop.

General Enablers

The greatest enabler to supplier involvement in DFM is to ensure the workshops are mutually beneficial to GM and the supplier. To be successful, the workshop team requires a "win-win" attitude. An outstanding product or process design is one that the team agrees is the optimum solution for all stakeholders.

Management support of DFM by both the supplier and General Motors is critical – DFM is a human resource-intensive event. Management must encourage and recognize team members for their participation in DFM. Essential team members must be allowed to participate in DFM workshops. A cross-functional team includes designers, design release engineers, manufacturing engineers and suppliers, die engineers, analysis, final assembly centers representatives and other PDT members. Managers must make sure that a follow-up is carried out to implement the workshop ideas, ensuring that feasibility studies and business cases result.

Design unity is only achieved when the manufacturing and product designs are in equilibrium; this unity can be achieved through a DFM process that maximizes teamwork. The DFM process helps build a design, manufacturing and supplier team – the focus is on communication during the workshop. The structured process helps bring a newly appointed supplier up-to-speed faster. They can meet several key individuals during the workshop and understand their requirements and constraints.

Competing suppliers should not be in the same workshop at the same time, unless they both know in advance. The *only* time they should be brought together is if they are supplying the same part or the part must attach to the vehicle in the same manner.

The workshop should end with a report showing the documentation of ideas and actions items that were developed during the workshop. This report should only be a source of information, as the ideas need further development and studies. Savings and costs still need to be developed for assembly, parts, mass, etc. All the participants and purchasing should receive a copy.

Suppliers and engineering will always learn something from a DFM workshop. Occasionally a key stakeholder will resist or delay a workshop if they feel the design is too immature or the styling is not complete. The DFM engineer must educate them on the ability to learn from a DFM workshop, no matter what phase of the design cycle. They must also be informed that the longer they delay, the harder it becomes to implement the findings of the workshop.

Vehicle Development Process Workshop Categories

Design for Manufacturability workshops can be conducted any time during the vehicle development process. The cost and ability to change the design varies with each design phase. Paper designs are the most economical and easiest to modify. Changing the design of production parts is an expensive and difficult process. The faster the design cycle, the more difficult it is to make late changes. Workshop categories can be grouped by the development process name: **Systems Level, Concept Design Direction**, **Design Refinement**, and **Production Improvements**. Their position in the design cycle is illustrated in Figure 1.

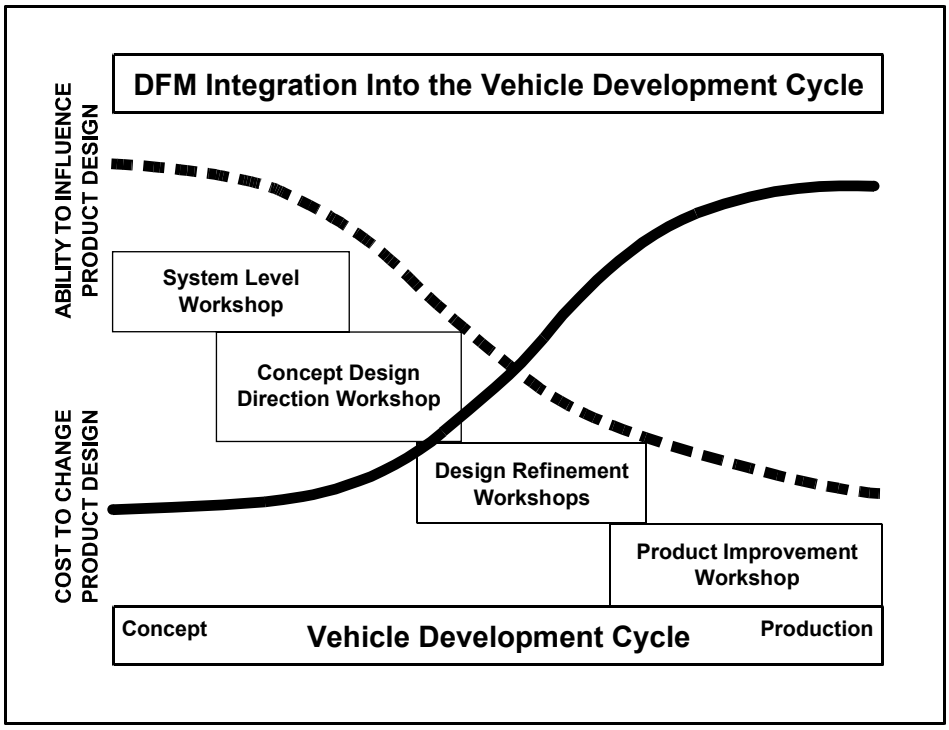

Figure 1

Systems Level Development occurs at the beginning of a vehicle program – all product and process designs will build on the vehicle architecture determined during this phase. The ability to impact future design is greatest at this point: Design criteria are being submitted, and individual system designs are not finalized. The scope of developmental DFM workshops is broad, a team will work on optimizing a complete system while individual product and process designs will improve with the system design.

Concept Design Direction is the next step in the vehicle engineering process, where individual product and process designs are in development. These designs must support the established architecture. The directional workshop scopes are focused on integrating the product and process designs to meet vehicle and manufacturing requirements. A team will work on integrating the product and process.

Design Refinement follows an initial design release and virtual or physical build with product and process confirmation having begun. The refinement workshops are focused on problem solving. Solutions must require minimal validation and developmental work.

Production Improvements begin during the vehicle launch phase, which is the most expensive time to change a design. The ability to drastically impact the design is minimal. Improvement workshops are focused on resolving a specific, complex production problem. A team will focus on immediate and short-term solutions.

System Level Workshops

When a vehicle program begins, several activities are occurring simultaneously: Technology trends must be identified, understood and evaluated for both the product and process. The vehicle's manufacturing and product requirements are in development, and the architecture of the program is maturing. These activities lead to the development of system designs for the product and the assembly center process, which are the building blocks of all associated product and processes. System level DFM workshops can help improve these designs.

The workshop scope varies with each system. They tend to be very broad and cover many sub-systems and major assemblies; however, the product and/or assembly processes are related. For example, a team may work on a vehicle's front end. This system is a composite of structural, cooling, exterior, and electrical components. These components must work together to form the front-end system in the vehicle. An example of a front-end system level design is shown in Figure 2. The team would work on improving the module and resolving what should be part of the module – this would include the lighting and determining how the front lamps and the fog lamps mount to the fascia. The team designs the grill and emblem attachments to the fascia.

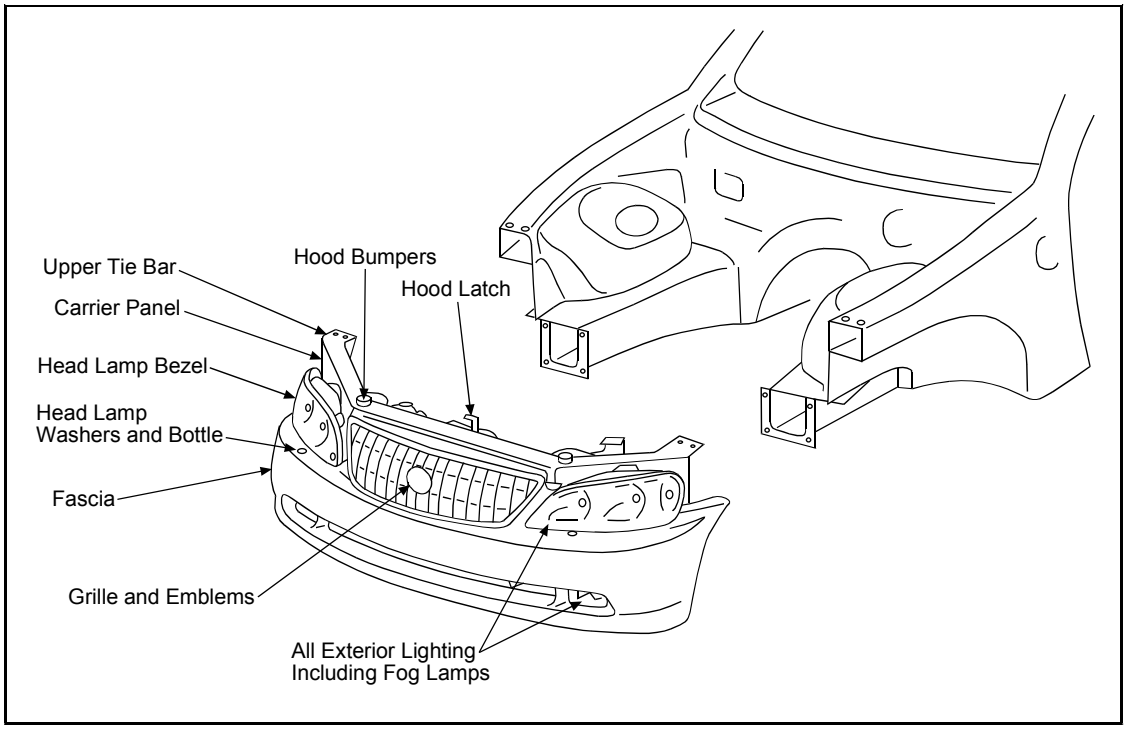

Figure 2: Example of Front End Build

Generally, several suppliers are involved in a vehicle system. These suppliers are simultaneously working on their system designs. Improving supplier's system designs is outside the scope of General Motors DFM workshops, yet they need to be comprehended and included in the overall system design. To accomplish this, a representative from all identified suppliers should be a part of the workshop. If they have not been identified, they can be brought in as advisors to provide information that is essential to the workshop's success, and as such, they can participate in the complete workshop or only at a designated time.

A goal of System Level workshops is simplification. The team goal is to minimize the vehicle construction requirements, which occurs by combining functions and parts. The team must work to eliminate the difficult and non-value added operations. The objective is not met by making one product or process better at the expense of another; the team must also determine the level of commonality and modularity in the system. This requirement must be determined before design concepts can begin. The team objective is simplifying the manufacturing process.

The workshop team will focus on combining functions and parts to minimize the manufacturing process. The first step in the DFM process is to bring all team members, including suppliers, up to the same level of understanding. They must understand, document, *and* evaluate the system's overall function. Identification of the functional and non-functional parts occurs next. The vehicle's architecture is evaluated: What are the physical relationships? What is the physical and geometrical compatibility of the parts? Can they go together? Can they package close to each other? What is required? What parts can be eliminated? What parts can be fastened together? What parts can be combined? These questions and answers will drive solutions that will combine and maximize functions and parts within the complete system. This also helps set the styling criteria, cut lines, gaps and flushness. All team members must agree to these solutions, and work to make them happen. The GM engineers and the supplier's engineers will have to agree to revise the designs to benefit the vehicle and not the system.

Identification of the difficult operations and non-value-added operations is essential. The team will work on eliminating these parts and operations. They must look at all operations in the process. They must ask: What are we doing at the supplier's location? Where is it easiest to perform these operations? What is the proper line height? Where is the ideal line height location? How can we reduce overall costs? What are the cost drivers at the suppliers? What are the cost drivers at the GM assembly centers? The issues identified by the team become the groundwork for brainstorming. Team members will work on improving the product and process by eliminating or improving those non-desirable operations. If the entire team understands and agrees to the basic concerns, issue resolution can occur.

The level of commonality must be determined at the beginning of the program. The team must standardize components and processes with other vehicles, since investment, piece cost, and timing savings will occur by *not* customizing parts. Suppliers are a great source of what other manufacturers are doing and if that design will work on this program. They can also share what needs to happen to make this part work on the vehicle.

The modularity requirements must be designed into the system. The team must determine the level of modularity. It is not necessary to know who is going to build the module. A flexible module design can be built at the supplier's location or the final assembly centers' location.

The product must be simplified in order to "simplify" the manufacturing process. The production process is developed simultaneously with product development. The workshop team should attempt to minimize the interactions between the various parts within the system to improve flexibility in the assembly sequence. Questions asked by the team include: What design modifications will simplify the equipment and tooling requirements? What minimizes the retooling requirements? How can reliability of the manufacturing process be improved? The team attempts to simplify the manufacturing process for the final assembly center as well as the supplier's assembly center.

The program team will attempt to identify and evolve new technologies and concepts early in the vehicle development process. A System Level workshop will help speed the developmental cycle and will bring all the stakeholders together to identify and understand the new requirements and the current limitations. The team simultaneously develops the technology, the product design, and the manufacturing process. An output of the workshop is the beginning of the Statement of Requirements for source selection.

To evaluate the available technologies, suppliers are invited to come in at predetermined times to review their engineering proposals. The team can then evaluate the pros and cons of each proposal and help to decide which supplier is the most capable. Team members will develop ideas to improve the system, which will help the supplier further develop its proposal to eliminate the concerns identified by the workshop. This simultaneous process will help drive innovation in a timely manner.

The purpose of these system level workshops is to assist in establishing the foundations of all product and process designs by identifying and implementing new technologies and concepts. The workshop team will work on optimizing a complete system, which is done through the structured DFM methodology utilizing cross-functional teams. A DFM workshop is an inexpensive design tool that can have a great impact during development.

Concept Design Direction Workshops

The product and process design details must be developed to support the established architecture. Design elegance can only occur with teamwork, detailed analysis and balanced design solutions. The DFM process helps the program team achieve this objective.

The DFM process can begin with the earliest available ideas to determine the concept design direction. Detailed manufacturability analysis will be applied to proposed designs. The DFM engineer focuses on getting process-driven product designs implemented. Expertise on the DFM process is provided to the product development team, or PDT. To drive the process, the DFM engineer must become an active participant in the PDT – they work with the team to determine the timeframe and scope of the workshop. After the workshop, the DFM engineer will help drive the ideas into a design solution through internal tracking.

The concept design direction workshop brings a cross-functional team together to focus on balanced design solutions utilizing a structured methodology. The team will focus on integrating product and process designs to meet defined vehicle and manufacturing requirements. Since several activities are being done simultaneously to reduce the time in the product development cycles, *all* activities need to share information and may not be aware of conflicting requirements. The workshop process has all team members share their information and understand the other's requirements and concerns. This drives the team to agree to and clarify the design specifications. If suppliers are involved in the workshops, the solutions will also be balanced for the suppliers. Once a common understanding is achieved, they can begin to work on design solutions that will achieve a balance of all the objectives and requirements.

The review and evaluation of current conditions occurs first, then the team will work on reviewing and evaluating proposals. The suppliers are responsible for reviewing and evaluating their manufacturability analysis – this iterative process will prevent late design changes.

Detailed analysis is varied and depends on the specific commodity. Analysis must include all steps in the manufacturing process, at the supplier's location and at the final assembly center. All the analysis is focused on driving solutions that mature the product and process designs. Some common design analysis includes:

- Determining the minimum number of parts required.
- Simplifying parts that are over-designed.
- Reducing the number of fasteners.
- Analyzing the best fastening technique.
- Determining the best fastener size and torque.
- Identifying what assembly motions can be eliminated.
- Eliminating the assembly fixture.
- Improving the product and process fixture interface.
- Analyzing the assembly sequence and assembly direction.
- Evolving product and process flexibility.
- Improving operator ergonomics.
- Understanding the shipping and packaging requirements.

General Motors has increased its drive to improve quality, and the overall quality of the vehicle cannot improve without individual product design improvement. DFM is viewed as a tool to help drive quality improvements – the fewer parts the better the quality. If the product is easy to manufacture, quality should improve. If the overall process is simplified, the reliability improves. The workshop team identifies the quality issues and drivers. The changes required to improve quality are brainstormed during the workshop. With more supplier modularization, the product and process must be simplified to improve overall quality. Workshops can be focused on improving the module and the module's assembly process. As an example, Figure 3 shows the earlier module in more detail. How do the pieces fit together? What is the assembly order? Solutions to these questions are determined in a workshop setting.

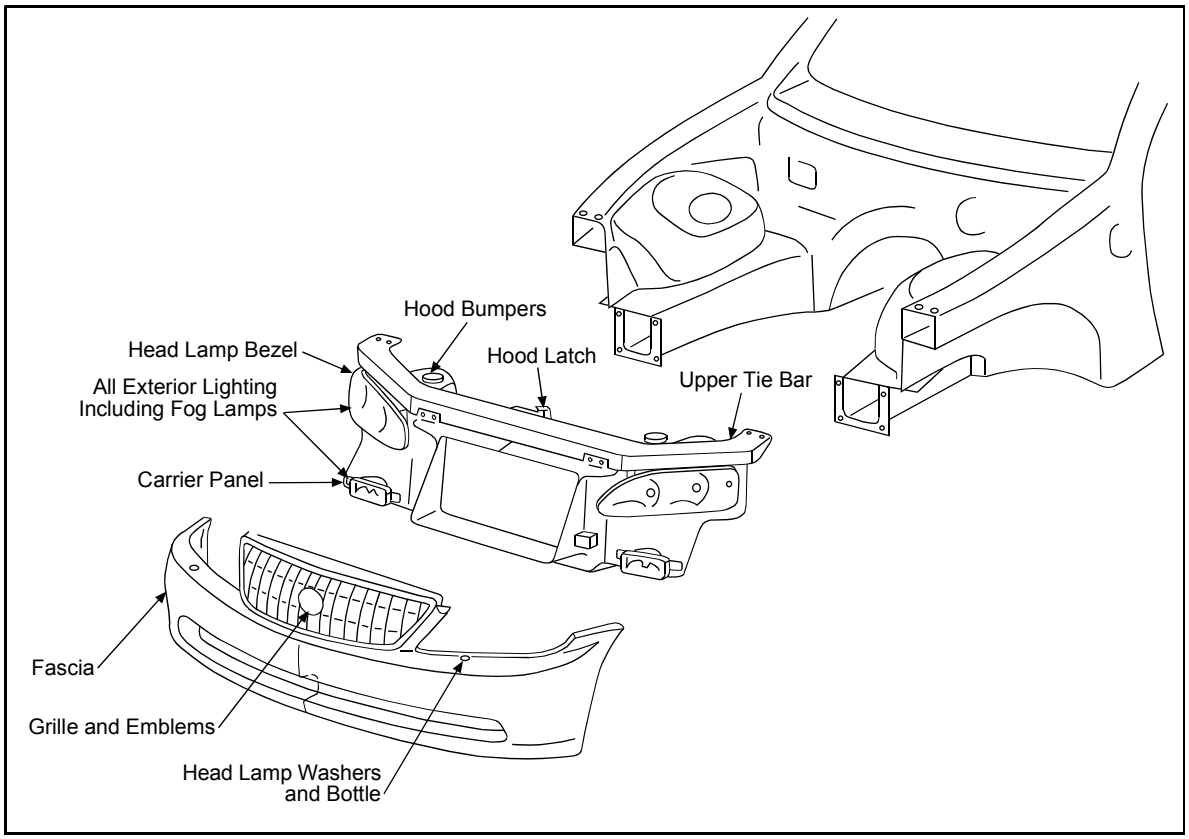

Figure 3: Front-end Module

The importance and benefits of DFM during this design phase cannot be stressed enough. This is the time to innovate and evolve the design. Investment costs have not been incurred. The DFM process creates ideas to help arrive at the best design solution.

New car programs are feverishly working on satisfying anticipated customers needs, meeting schedules, and requirements. DFM is not apparent to the purchaser, but it impacts his / her satisfaction through quality and serviceability. DFM saves time by utilizing preliminary data to drive decisions. Many of the manufacturing costs are predetermined once the conceptual design is finished. To avoid increased manufacturing costs, the manufacturing process must be determined while the design is being developed. The DFM activity increases communication and improves the simultaneous engineering process.

Design Refinement

Design Refinement occurs after initial design release and before production begins. Final design release has occurred for some parts, while tool design and build may have begun for others. Start of production is close at hand. Final details are being put on the product design and the manufacturing process. To ensure success in production, GM conducts virtual and physical

builds. Manufacturability issues are discovered during these build events. The design refinement workshops are focused on creating ideas to resolve issues that surfaced during the build events.

Evolving the design with proven problem-solving techniques is required at this phase in the program. Solutions must require minimal validation and developmental work. A complete rethink of the design would result in failure to deliver a validated design for production due to the short time cycle. A DFM workshop will focus on revising or adding a feature on the part to improve buildability. Other workshop objectives will improve the assembly sequence or refining the fastening technique to meet the assembly process.

Advancements in technology have enabled us to simulate the assembly process with math data. Simulations evaluate and implement DFM ideas before tool construction begins. Build issues are discovered during virtual builds. This visual information encourages the workshop team to optimize the design. It helps team members to change difficult operations, access problems, and blind operations. GM and suppliers use a common computer design system to achieve these simulations.

The next level of build analysis occurs with mock-up parts. The mock-ups may be made of cardboard or cobbled current design parts. This analysis level enables the workshop team to further visualize the final product and process. Engineers and assemblers have something tangible for physical evaluation. Several issues and ideas result from this activity. The assembly motions can be simplified. The tooling fixtures can be simplified. Features may need to be revised to improve buildability. Integrated suppliers are often responsible for these mocked up parts. Bringing these mock-ups into a workshop allows them an initial review, while there is still time to fix the concerns prior to production.

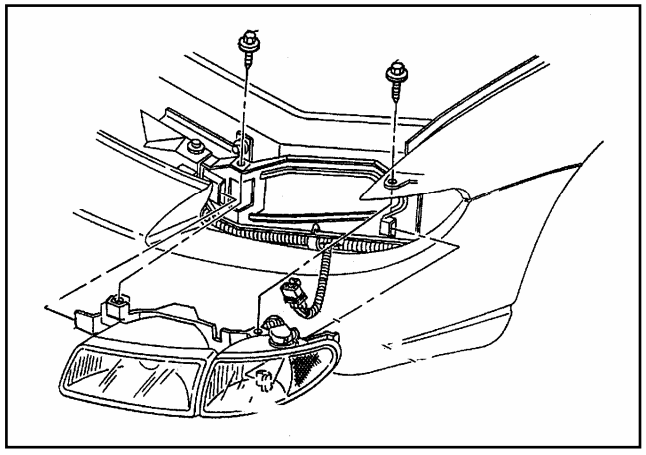

Figure 4: Old Intrigue Headlamp Mounting Design (2) Fasteners

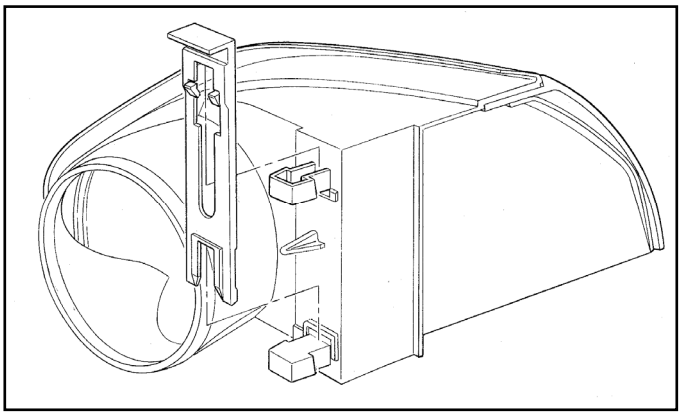

Figure 5: New Intrigue Headlamp Mounting Design – Clip Installed

During a recent design refinement DFM, a team worked to make the headlamp installation and removal using *no* hand tools. This occurred by using an attachment design that holds the lamp to the body with a clip (Figures 4 and 5).

Production Workshops

Production improvements begin during the vehicle launch phase. Workshops in this time frame are focused on creating ideas around specific issues and features. The DFM group is asked to bring this issue into a workshop environment. A key enabler for success is that only through communication and teamwork can these issues be resolved.

A current assembly issue might be complex or impact several stakeholders. The owners may not be able to find an agreeable solution. The ideas and final solution are based on what is appropriate for this time frame. It may not be the ideal solution, but can be implemented. The team creates ideas that may be can be implemented immediately and others can be implemented later.

A workshop will occur to add a new feature to an existing vehicle. Major design revisions to production components are prevented at this time frame due to cost considerations. A program will want to add a new technology option.

Suppliers Workshops

Suppliers are required to conduct DFM workshops. This is spelled out in the Advance Product Quality Planning (APQP) process. The details of how to conduct DFM are left to the supplier. A tremendous amount of DFM activities are occurring. If a supplier is conducting its own workshops, we ask that they fill out this standard form.

The purpose of this form is to make sure that DFM is in process. It keeps us informed of all the DFM activity that is going on in the program. By having a standardize form, we can provide a common level of information to the program.

There are some additional benefits to this form. It is a communication tool, providing a source of contact within the General Motors team and a contact into the supplier's DFM team. This communication tool will enhance General Motor's knowledge and execution of DFM. New industry trends can be identified. We can learn more about DFM from our suppliers. Sharing information on what DFM techniques work well. Hopefully, by opening the lines of communication they can also learn from General Motors.

Conclusions

Design for Manufacturability (DFM) is used to drive improvements through simplification. Including suppliers in our DFM process helps this occur at all levels of vehicle design and build. Suppliers must be able to build and design a quality component. By including suppliers,

improvements will also occur in quality, operator ergonomics and product development time. Suppliers can help identify new technology and the proper requirements. Involving the supplier early will prevent late design changes thus reducing costs.

Design unity is only achieved when the manufacturing and product designs are in equilibrium. This unity can be achieved through a DFM process that maximizes cross-functional teamwork. This must include our suppliers, and assembly plants. Product and process design concerns can be identified and resolved utilizing a complete team. The best ideas and solution are based on what is appropriate at that time. Having a cross-functional team will allow more agreement in determining the appropriate design because the team understands the product and manufacturing requirements at source and assembly.

Workshops need to create a “win/win” environment. Success can only be achieved by follow up and driving business case support for the workshop ideas into the program. The DFM process must start early to obtain the advantage. A good solution aggressively executed today is better than a perfect solution next week.