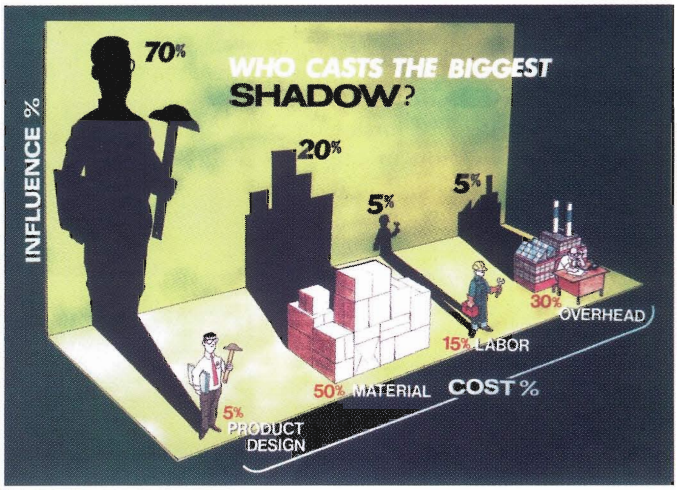
The hidden design advantage: manufacturing input

By Kami Buchholz, Detroit Editor

Design for innovation drives assembly.



Initial vehicle designs drive profit margins. "Product design, which accounts for only 5% of a product's total cost, actually dictates about 75% of the product's total accounted manufacturing cost," stresses Sandy Munro, President of Munro & Associates, Inc., a Troy, MI-based concurrent engineering consultant firm. In workshops with automakers and suppliers, Munro and staff hark a simple message: always consider the total picture. "You cannot stop the design process. Once you've passed gates, you can't go back. It's a one-way trip early on," Munro says.

Workshops by Munro & Associates challenge product engineers to assemble their own designs. Class time also is devoted to pooling the input and resources of engineering and manufacturing to improve an existing product. For instance, about six years ago a class assignment had a product design engineer, a manufacturing engineer, an hourly factory worker, and finance and purchasing representatives redesigning an 11-piece armrest bracket assembly into a one-piece entity (currently on a number of General Motors vehicles).

The 11-piece steel and aluminum armrest bracket required a stamping die, a swage tool, a riveting tool, a high-speed production press, a secondary swage, a secondary press, a palletized conveying system, and ample factory floor space. In contrast, the one-piece armrest bracket condensed manufacturing's contribution to a plastic blow molding machine. The design change also reduced costs by 76%.

"You can always fix a design at any stage, but it's impossible to make modifications later in the process without those changes resulting in huge capital expenditures and an expensive product," Munro asserts. Early involvement of suppliers is also critical. "It's very important that the supplier be involved. They know things the OEM doesn't. Supplier participation is part of the design process."

Design for assembly drives innovation, especially with a new vehicle program. At the onset of the $350 million EV1 program, 150 people — including GM engineers, manufacturing engineers, material engineers, finance representatives, and suppliers — trained and practiced over a six month-period on design for assembly dynamics. "We had progressive minded people participating, and that was further supported by good leadership," explains David Grieco, Manager EV1-5.0 Product Engineering for GM Advanced Technology Vehicles. "One of the keys to our success was combining the training with application. In the first (training) session we developed some metrics, well before there were any designs. The foundation of manufacturing technical specifications is influenced by design for assembly requirements," notes William Szkodzinski, Manager Manufacturing Engineering for GM Advanced Technology Vehicles.

Training time allowed product development teams to address assembly requirements up front. "DFA (design for assembly) flushes out a lot of issues," says Grieco. "It has to do with team consensus, and listening to the ideas of people outside the engineering group." Interlocking product engineering with manufacturing provided the framework for new technologies. (EV1 carries 23 new patents.) For instance, the 1997 EV1's patented front and rear shock towers are a single piece as opposed to a conventional multipiece construction requiring several stamping welds. Although the entire vehicle was subjected to the process, three areas where DFA had great influence on EV1 were: structure, chassis, and interior.

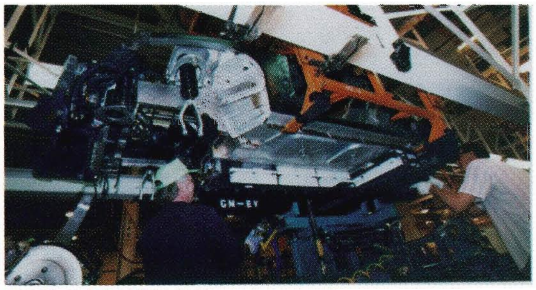
EV1's structural elements are joined by 2000 spot welds, 40% fewer than a typical steel structure. About one quarter of the electric car's all-aluminum structure is made of folded parts (including the central tunnel and rear cross member). Single and multi-cell extrusions comprise another quarter of the parts, while the remaining structural components are castings. The entire structure, secured by spot welds, rivets, and aerospace adhesive bonding, has a mass of 131 kg. Conventional stampings were used for half of the vehicle's total part count. Because manufacturing aspects spurred part consolidation and reduction, EV1's space frame exemplifies simplicity. Consider, for example, the integration of 24 separate sheet metal pieces into four castings, which attach chassis springs and shock absorbers to the space frame. In total, EV1 uses 165 formed parts.

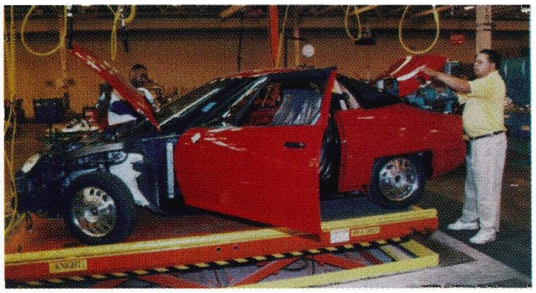
The multitude of one-piece snap-on parts, extrusions, and foldings that make EV1 an engineering benchmark are possible because design engineers looked at manufacturing considerations from day one. "The principles of DFA can be used from the concept phase up. Others may say, 'You have to have the designs in place.' But you really don't," Szkodzinski says. EV1 also realized plant floor benefits as the design of tooling was driven by manufacturability. "If we didn't design for assembling the EV1, then the plant layout would be radically different — probably twice as large and more complicated," asserts Grieco. The Lansing (MI) Craft Centre assembly area for EV1 covers 10,200 m^2. Layout of the assembly processes — paper to production — took eight months as opposed to the typical industry time frame of three to four years. "The plant has a modular design. There is no assembly line. There are no conveyors, except in the paint oven area, involved in the 45 minute job cycle," Szkodzinski says. EV1 is the first production vehicle to be made using epoxy draw dies, and those dies were up and running in 20 weeks, compared to the typical 45 to 48 weeks for metal dies.

Another General Motors example of data-driven engineering unfolded during planning sessions for the design of five new minivan brands (Chevrolet Venture, Pontiac Trans Sport, Oldsmobile Silhouette, Opel Sintra, and Vauxhall Sintra). The 1997 minivans cover two wheelbases, four engine families, two sliding doors, left or right hand drives, and automatic or manual transmissions — all from a single platform at a single assembly plant in Doraville, GA. "It's the complexity that drove a very early manufacturing presence," says Rick Heithaus, Program Manufacturing Manager.

The process began with engineering and manufacturing representatives coming together in an area peppered with paper drawings of engineering releases. As the design process unfolded, the wall became a paper replica of the Doraville assembly plant. "When you're not looking at what's going on around a part, you could miss critical things. If an engineer doesn't understand how a part will be built and assembled, the outcome can result in ergonomic and/or quality problems," explains Chuck Kingsley, Total Vehicle Integration Engineer. With engineering drawing releases being viewed early in the process by purchasing, quality, production, and material departments as well as plant workers, the time-to-production table shrank.

"Engineers watched operators assemble cardboard mock-ups to see how practical or impractical the process was. This was especially important in the trim area because the process can be analyzed before a mold is cut," explains Heithaus. Give-and-take design exercises netted various simplified assembly methods. For instance, instead of multiple door plug harnesses, a single door plug serves a dual role. "Door plugs come equipped with a high penetration option — such as power windows. The electrical lead comes to (an operator) taped back. It can be brought forward for insertion when the option content demands it, but remains taped back for low running options — such as manual windows," says Heithaus.





GM's EV1 assembly.

The 1997 model year build combinations equal 5600, compared to 312,000 build combinations for previous models — and that drastic drop includes the addition of four divisions, three powertrains, and right hand drive. "The real gains we've achieved in productivity are the result of manufacturing's early involvement in this program. The practice of involving manufacturing at the beginning of a program is not new. But what's unique is how well the team used this opportunity to allow engineering to understand and experience manufacturing at the process level," Heithaus says. By involving manufacturing early, product engineers were able to evaluate part and tooling designs while considering the aspects of assembly line motion and line height.

Door plug assembly at GM's Doraville plant.

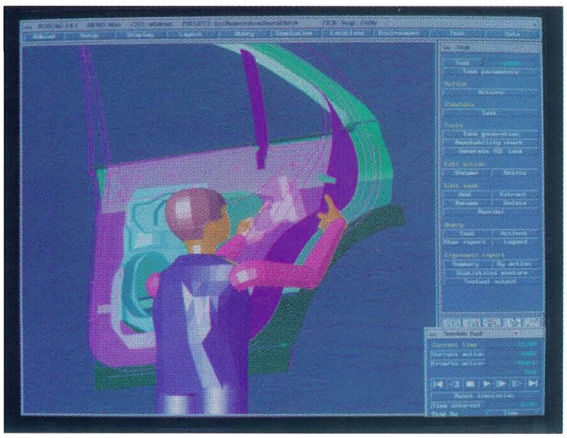
"The key is the timing, so engineering can see early on what needs to be refined," Kingsley says. Lessons learned by using a paper factory have been incorporated into a best practices lean manufacturing guidebook for other GM plants. Although computer software programs play a valuable role in the design process, GM's "paper wall" is considered invaluable. "From an engineering standpoint, it's always visible. If it's in a computer, many times you only bring it up when you're in that section. You have to see what's going on with both sides, and 'the wall' provides the opportunity to see the entire sequence of how parts are put on a vehicle," Kingsley says. Concurs Heithaus: "As programs get to faster and faster timetables, you don't have time to argue whose point is valid. With this ('the wall'), there's an understanding of engineering and manufacturing and what they do. The whole process is enhanced because both sides are meeting together, and both sides see what is actually going on."

Ford Motor Company's integrated computer-aided design, engineering, manufacturing and product information management system — known as C3P — gives the automaker the distinction of being the first auto manufacturer to use computer simulations for designing its final vehicle assembly processes globally. The digital vehicle buck and the digital factory are two elements of C3P that link engineering and manufacturing. "Manufacturing can communicate clearly and efficiently early in the program to reflect any manufacturing constraints without compromising designs," says Mark Phillips, Manufacturing Systems Supervisor, Paint and Final Assembly Engineering.

"Assembly techniques now can be developed at the same time components are designed — both on the computer simultaneously — reducing reliance on expensive prototypes early in the product development process to assess manufacturing feasibility. If you make a design change later in the product development or tooling cycle, you put your timing at risk and you pay premium costs," says Bruce Hettle, Large/Luxury Car Vehicle Center Manager, Ford Global Final Assembly Engineervidual training sessions with designers/engineers on digital buck methods. The digital buck/web-based site provides users a tool for evaluating system-to-system interfaces. "From a computer workstation, an engineer can graphically pull together — in a full vehicle environment — system interfaces before doing a physical prototype. The digital buck allows us to see aspects like interference/clearance, packaging and assembly in real time," explains Ray Byrnes, Digital Buck Methods Vehicle CAE/CAD/PIM Integration Advanced Vehicle Technology.

Because the computer simulations reduce the number of needed physical prototypes, Ford projects savings of more than $200 million annually. Digital buck and digital factory concepts are expected to reduce by 20% manufacturing-driven design changes during a new vehicle launch. "In the past, product design engineers would design a component, a prototype part would be made, and then manufacturing engineers and hourly product specialists would work to make the assembly process feasible. Making engineering changes for ease of assembly was an expensive prospect. Now engineering changes can be made sooner, quicker, with the input of manufacturing who has to build the vehicle without relying entirely on expensive prototypes," explains Phillips.

In the computer-simulated factory, assembly lines workers — of varying sizes — complete their tasks. In one example, when engineers had a computer-generated worker assemble a newly designed door system, the simulation proved that two-thirds of the population would not be able to complete the task. "We showed that a small person couldn't efficiently install the design concept, and all involved saw that we needed design changes. We made those changes early enough that there were no added costs to change the design, but there would have been significant costs if that change was made later in the process. In this example, we realized the need for a design change before the first physical prototype," notes Hettle.



Ford Motor Co.'s virtual factory.

Full service suppliers to Ford will be trained on the digital buck. "It's important to get them the right training because software will very quickly provide you the wrong solutions if it's not used properly," says Richard Riff, Manager CAD/CAM/CAE & PIM Project Office Advanced Vehicle Technology. Computer simulations now eliminate clay models from the conceptual/styling stage and the physical prototypes formerly needed in the engineering design stage, necessitating physical prototypes for the final/confirmation stage. Reducing the number of physical prototypes has helped compress the development time (from program approval to production) from 36 months to 24 months. The digital buck and digital factory are being utilized to develop critical manufacturing processes for all Ford cars and trucks, model year 2000 and beyond.

The operator (left) explains to the engineer the problems he experiences on the assembly line of the product.

Chrysler Corporation spent less than $625 million to develop (including manufacturing costs) three new aluminum V6 engines. The industry's first paperless-designed engines (2.7-L, 3.2-L, and 3.5-L) shaved 26 weeks off the development time. (Project approval to launch was 24 months.) And by utilizing input from manufacturing, CATIA-based software for predictive modeling and rapid prototyping, Chrysler considered thousands of computer-generated design iterations. "The interface of engineering and manufacturing allowed us to get all the bugs out of the process in the very beginning. The manufacturing process, the casting process, the machining process was optimized before the tooling was all built, bought, and paid for. So we bought it once, and we bought it right. We didn't have to go back and keep changing things, which costs money," explains Burke Brown, Executive Engineer of Large Car Platform Powertrain Engineering.

More than 1000 intake manifold iterations were done on computer before a prototype was built. (NOTE: Previous engine programs viewed three or four design iterations.) Computer files of the intake manifold's design were also sent to the supplier of the plastic composite part. "The files gave them access to the process. Suppliers are part of our extended enterprise, and access to that information allows them to develop a process so that they could manufacture this thing and take cost out," Brown says. In another example, the measurement process being used in the plant to manufacture the cylinder head is stored in a computer file. "It's already set up in the computer in the beginning of the design process as part of our simultaneous engineering. Prior to building our first prototypes, we reorganized our working structure to analyze and design these engines simultaneously as opposed to analyzing at 70% of design completion as in the past," Brown says.

"Downstream design changes on actual parts have been dramatically reduced. Now for a manufacturing guy that's a dream come true. It eliminates the old 'design it, build it, test it, break it…design it, build it, test it, break it' cycle that we used to have in this industry for years," says Bruce Coventry, manager of Engine Manufacturing Engineering. Production of engines begins in Kenosha, WI, and Trenton, MI, in August. The engines will power the 1998 Dodge Intrepid, Chrysler Concorde, Chrysler LHS, and Eagle Vision.

The best design strategy — as exemplified by automakers' evolving practices — involves utilizing manufacturing input. "Take the extra effort to do it right the first time and win the battle for market share by designing for annihilation in the design room, not on the manufacturing floor," Munro advises.

Munro & Associates, Inc
Phone: 248-362-5110
Fax: 248-362-5117
www.munroassoc.com

Munro
&
Associates, Inc.

CHANGE AGENTS FOR MANUFACTURING COMPETITIVENESS

900 Wilshire Drive, Suite 301
Troy, Michigan 48084
Phone: 248-362-5110 • Fax: 248-362-5117
www.munroassoc.com