

**Fast and Flexible Design and Manufacturing Systems  
for Automotive and Sheet Metal Parts**

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## Fast and Flexible Design and Manufacturing Systems for Automotive and Sheet Metal Parts

### Overview

Our project continues to work on case-based research on the interface of design, manufacturing, and supply chain issues in the automotive industry, with close interaction with our companion project in the aerospace industry. Major milestones this period were the completion of three six-month internships in the auto industry (two at GM, one at Ford), plus ongoing work on projects initiated through our sites at Ford (Explorer in Kentucky, Electronics in Pennsylvania), and GM (Saginaw).

Integrating all of this work is the notion of Technology Supply Chains, the concurrent pursuit of design and development of automotive products (or subsystems), manufacturing processes, and supply chains. Each of the project updates described below fits into this framework. The individual sub-projects below are categorized by which one (or more) of these three areas are addressed.

#### From Brian Kelly, MIT:

##### *Product & Process development in an Automotive Supplier*

Brian completed his six-months of field work at Cadillac and the Die Management Group at General Motors in December. He developed a model of the die development process which he then converted into a (field-tested) "board game" that illustrates the key drivers of die development cycle time to the various constituencies on the corporation. Underlying the model and game are queueing and financial analyses. Brian's Masters thesis on this project will be completed in May 1996.

#### From Paul Gutwald, MIT:

##### *Concurrent Product & Supply Chain Development*

Paul completed his six-months of field work at General Motors in December. He developed a decision model to support the simultaneous car development processes in the car platform teams with the supply chain development processes in the Worldwide purchasing organization. Paul's Masters thesis on this project will be completed in Summer 1996.

From Joe Kowalski, MIT

*Factory Metrics Development to fit new (Ford 2000)  
product development strategy and Ford Production System*

Joe completed his six-months of field work at Ford in December. He developed an analysis of factory metrics needs in the face of the Ford 2000 program as well as an assessment of the metrics strategy in place for that program. Joe's Masters thesis on this project will be completed in May 1996.

From Narendra Soman, MIT:

*Product and Process Development*

The goal of my thesis is to "develop a structured method for designing locator schemes." I focused on the front end of the 1995 Ford Explorer. As a case study, I studied a 2D model of the front end with simplified part geometries for the fender inner and the fender outer. The simplified assembly sequence had two PCFR cycles. I analyzed the behavior of this assembly its PCFR cycles to derive the best possible locator schemes for the fender inner and the fender outer. This locator scheme minimizes the sensitivity of assembly dimensions to errors in manufactured parts, error in fixtures and error in welding gun positions. Based on the study, I have derived rules for such an analysis.

From Marty Anderson, MIT:

*Product & Process in an Automotive Supplier*

1. Consolidating the results from Saginaw and other sites to produce document on "transactions analysis" and related issues of: information architecture, cost measures, requirements capture and communication. We are awaiting last pieces of data from the site (the exact configuration of factory floor data bases). This stream is designed to yield a "how to" oriented final report later this year, in accordance with contract schedule.
2. Following, in real time, the advances in network communication software and methods that will enhance the "transactions analysis" methods piloted above. Most specifically, new forms of "internet like" networks can allow the kind of cross-web communication we hypothesized early in this program. I am following both the industry literature, and several field innovators as a way of keeping track of this fast-moving technology.

From Mary Meixell, Lehigh:

*Integrating Production Decisions with Sourcing and Supply Chain Management*

This research addresses the supply chain management issues specific to production planning applications in an agile manufacturing environment. Previous research on this problem uses extended inventory theory or enhanced MRP models to determine the appropriate safety stock or safety time strategy for an inherently stochastic manufacturing environment. Our approach models supply chain and production planning decisions in an integrated fashion such that the information gathered along the supply chain can be used to improve the quality and robustness of production planning decisions, and vice versa. Both the design and operation of a supply network are addressed by viewing the supply chain management problem with both intra-chain and inter-chain perspectives. Mathematical programming and decision analysis models provide the analytical backbone for this research and formulate the supply chain problem. A solution methodology is based on a heuristic method that separates the stochastic production planning problem into solvable pieces through the use of a statistical influence diagram.

From Doo Hwan Kim, Lehigh:

*Process Development*

B-spline free form surface was designed and generated through Unigraphics Design and Manufacturing module. In order to evaluate the free form surface more accurately, new method was developed using constant curvature contour lines of maximum curvature. Each magnitude of contour length and level rank of curvature were adopted as two variables of new weight function to determine number of measurement points. Accordingly, the weight effects can be changed by emphasizing on a variable due to the given specification. Various ways of determining measurement points can be created through new method.

Based on the developed method, physical free form surface model which was machined on CNC machine was measured on Coordinate Measuring Machine. Output measured data were compared with the designed true data. As a statistics tool for comparative error analysis, root mean square method was employed. All new methods were analyzed and compared with existing conventional methods. Currently, data of each method are being collected and analyzed.

From Erkan Baykan, Lehigh:

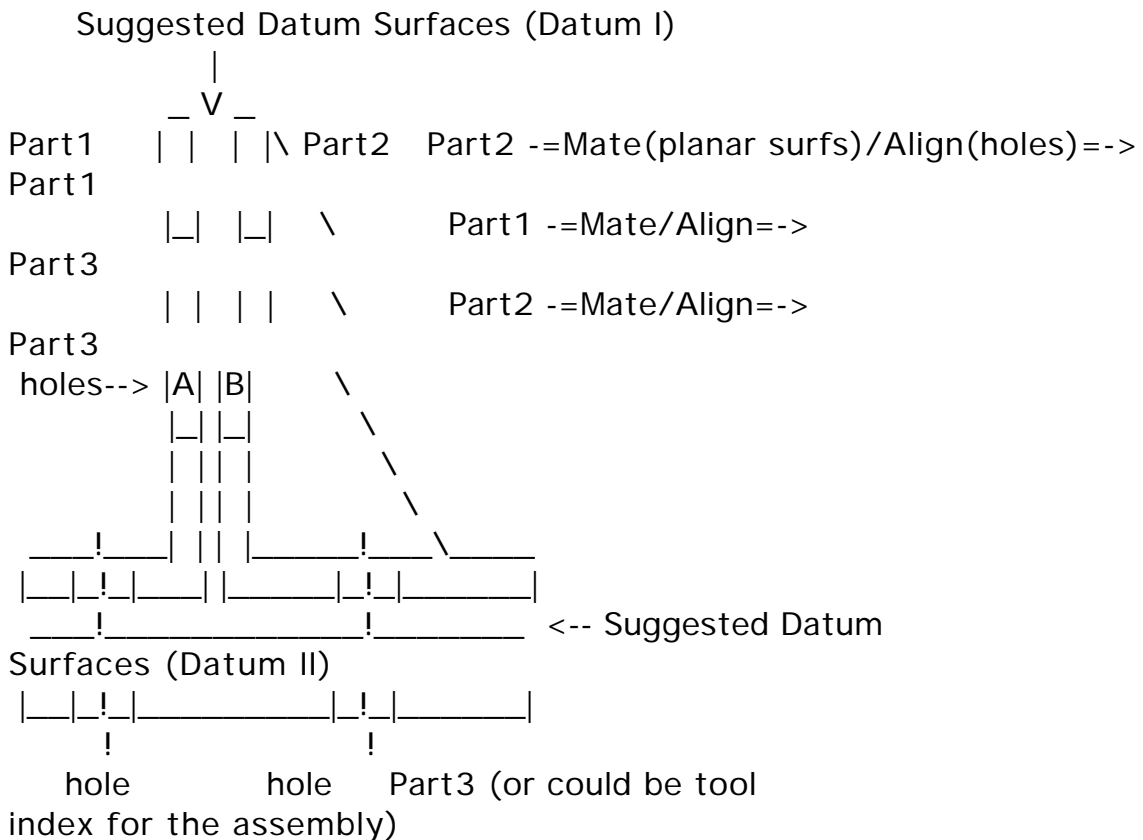
1. *Assembly and Tolerance Modeling, Process Development*
2. *Relations between TA and DSM, Product & Process Dev.*

I. ASSEMBLY and TOLERANCE MODELING:

Constructing constraint assembly via mating relations has a profound effect on variation control procedures such as datum selection and tolerance distribution. Top-down datum selection process:

In a constraint assembly, careful analysis of mating conditions at an assembly or a subassembly level may yield datums which would be referred at part level. This way of identification of datums will ensure coordination of datums with the assembly requirements so that assembly-parts can fit and function properly. For example;

Figure 1: Three part assembly



In figure 1, Datum II is vital for alignment of holes A and B. From a CAD's point of view, these datum surfaces could be identified by searching the mating graph with a certain rule such as 'if any two or more parts have a "mate" relation to a common part, then the mating features involved in this mating condition could be selected as datums'.

(Currently, I am working on development of this type of rules and implementation of datum selection system with Unigraphics solid modeler. I finished the implementation of mating graph generation from a Unigraphics' assembly model [including sub-assemblies], and of its graphical representation.)

#### Tolerance Chain generation process:

Once datums are identified, the part's dimensions to which tolerances might be assigned will be identified by considering the datums as well as the selected critical assembly clearances. Here, analysis of mating conditions at part level is required.

Mating conditions are attached to part's features (surfaces, axes, etc) They are called mating features and can be a part of any kind of form feature. Mating conditions are used for retrieving the corresponding mating features.

A pair of mating features forms a dimension or an angle if the pair's surface-normal or axis vectors satisfies the certain relational rules such as 'if two planar surfaces are parallel to each other, they form a dimension which is a shortest distance from one surface to another. If perpendicular, not.' etc. (Currently, I am working on the development of these rules).

Later, effects of the identified dimensions on the selected assembly clearance (sum dimension) is checked and mapped as a chain link to form tolerance chain.

## II. RELATIONS between TA and DSM

Representation of transactions in TA is a merely graph structure with a hierarchy of certain time span. In technical terms, it is a combination of a directed graph and a tree structure.

Each transaction forms a graph node, and each relation among transactions creates a graph arc. Time span of transactions determines its position in the hierarchy.

From a graph-theory point of view, DSM is a 2D relational-matrix representation of the transaction graph. Thus, conversation between them is possible.

With this in mind, I implemented a simple working prototype to show conversion between TA and DSM. The user constructs the transaction graph interactively, then the software generates the corresponding DSM from the graph.

From Steve Roth, Lehigh:

*Transaction analysis along the product realization process*

My concentration on the fast and flexible project at Ford Motor Company's North Penn Electronics Facility (npef) has been in conducting a transaction analysis along the product realization process of the electronic engine controller (eec) line, manufactured for Ford and other customers. There were several objectives: 1) to perform a transactions analysis to gather data and to assess the performance of the transaction analysis technique; 2) to use the results of the transaction analysis to create a design structure matrix of the eec product realization process; 3) to assess the migratability and scalability of the dsm management tool; 4) to comment on two issues raised by npef management regarding their ability to evaluate new product requests for manufacturability and to evaluate their speed of response to requests for quotation.