

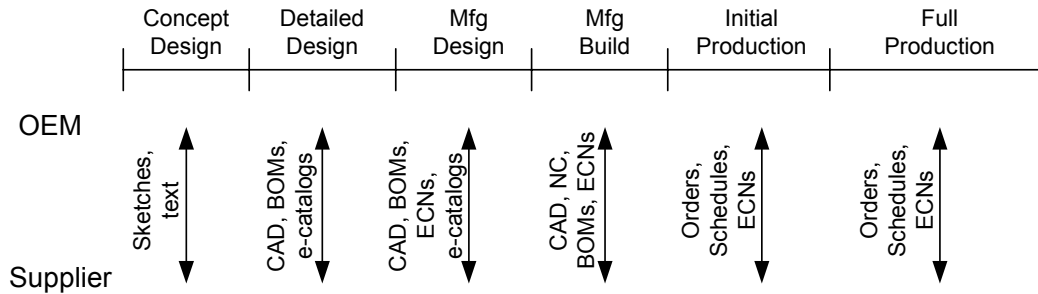
# A Review of Interoperability Issues In the Automotive Industry

A White Paper produced for NACFAM

by

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This document provides an overview of system interoperability issues in the American automotive industry. The more companies work together in the design and production of a product, the greater the level of interoperability they need in today’s manufacturing environment. Figure 1 shows the major data flows that occur in the supply network during the different phases of the product life cycle.



**Figure 1. Data exchanges across product life cycle.**

This document focuses on manufacturing-oriented interoperability during the production phase of a vehicle, a time when design is completed, vendors chosen, and contracts let.

At the production stage of the product life cycle, most of the information exchanged between an OEM and its vendors concerns ordering and schedule requests, acknowledgements of messages received, ship notices, and order tracking. To assure on-time delivery there is also information exchange with logistics functions, i.e., warehousing and shipping. Communication with logistics often means communication between the OEM and the supplier, but it could also mean communication with a third party, to whom logistics has been outsourced. Because products and component designs are never completely fixed, the production phase is also characterized by a small but continual flow of engineering change notices (ECN). Parallel to all this product oriented data is a flow of financial information which drives accounts payable and receivable, which in turn drives transactions with banks. While financial data flow does take place during the production stage of the product life cycle, it is not directly related to the production function, and is thus not included in this analysis.

The different kinds of information listed above travel to and from a number of types of software.

**Table 1 – Software and vendors related to data exchange.**

Type of data	Type of software	Transport methods and Formats	Some Major vendors
Sketches	Collaborative Design Tools, PC graphics	Shared data interfaces, fax, email	Nexprise, CoCreate, Visio, Corel (and similar)

	packages, CAD		Autodesk, SDRC, Unigraphics Solutions, Dassault Systemes, Parametric Technologies
Text	Any email package, word processors	Shared data interfaces, fax, email	Nexprise, CoCreate, Microsoft, Lotus (many others)
CAD	CAD, CAM, CAE	Data files in native, IGES, STEP, transported via email, ftp, shared file servers	Autodesk, SDRC, Unigraphics Solutions, Dassault Systemes, Parametric Technologies, MSE, Ansys, MasterCAM
e-Catalogs	e-Catalog	CD-ROM, Web access	IBM, I2, Ariba
BOM	PDM, ERP, MRP	EDI, STEP, XML	IBM, SDRC, Unigraphics Solutions, Dassault Systemes, Parametric Technologies, SAP, Baan
ECN	CAD, PDM	(See CAD & BOM above)	(See CAD & BOM above)
NC	CAD, CAM	(See CAD & BOM above)	(See CAD & BOM above)
Orders, Schedules	ERP, MRP	EDI, XML	Future 3, Harbinger/SupplyTech, Premenos, TSI

## Important Terms

Understanding interoperability among trading partners requires some background in a few key concepts.

### Interoperability

For the purposes of the discussion presented here, we define “interoperability” as the flow of information from one system to another without the need for human intervention. Interoperability can exist either within or between different applications. Interoperability within applications refers to the transfer of files between applications that exercise the same functionality. A common example would be the ability of two CAD packages to read each others’ files. Interoperability between applications refers to the ability of output from one application to be read by a different kind of application. An example of this type of interoperability would be a suppliers’ order entry system accepting information from their customer’s ordering system.

### EDI

Electronic **D**ata **I**nterchange is a standards-based method for exchanging business data. In the US, the common standard is ANSI X.12. The European standard is EDIFACT. OEMs use both, depending on the supplier.<sup>1</sup> EDI is characterized by “transaction sets” which correspond to common business processes. For instance, the 866 transaction specifies parts sequencing for logistics activities. Each transaction set specifies a set of data fields and allowable contents for each field. The architecture of X.12 and the structure of transaction sets were established during the era of mainframe computing. Because EDI is intended for computer-to-computer communication, the contents of an EDI message is

<sup>1</sup> Various efforts are under way to harmonize X.12 and EDIFACT, although the progress of these efforts is hard to follow.

undecipherable to all but the most trained eye. The automated flow of EDI requires a special “translator” application on each end. While X.12 is in fact a standard, it allows a great deal of variation within each transaction set. To reduce this variation, the Automotive Industry Action Group developed an automotive subset of the standard. While this action helped, there is still a lot of variation as to how different users in the automotive industry configure their transaction sets.

### Implementation Convention

Because X.12 transaction sets are subject to so much variability, each trading partner relationship requires an “implementation convention” which specifies exactly what data elements will be present, and where they will be placed. Without this level of specificity, computer-to-computer communication, i.e., system interoperability, breaks down. All EDI relationships begin with agreement on a convention, and are maintained by a continual series of agreements about as-needed changes to those conventions. Given the buying power of OEMs relative to their suppliers, “agreement on a convention” usually means that suppliers accept the convention provided to them by their OEM customers.

### XML

The eXtensible Markup Language is a method of organizing information by using intuitively obvious tags to identify critical parts of a message.<sup>2</sup> For instance, a recipe would be announced by using a “begin recipe” tag, and an “end recipe” tag.<sup>3</sup> Between those limits, other tags would indicate the start and end of ingredients lists. Nested within the ingredients list would be tags to define each ingredient. After the ingredients would come tags to define the beginning and end of the cooking instructions. Thus the message would look like:

```
<recipe>
  <ingredient>
    <item> </item>
  </ingredient>
  <directions>
  </directions>
</recipe>
```

XML is a powerful way to present information. It announces to the user *what the message is*. (You might be expecting a purchase order, and a recipe. The tags tell you, or your computer, which has arrived.) It indicates when specific types of information begin and end. It provides detail, e.g., what specific ingredients are needed. It is both human and machine readable, and does not require specialized translation software.

### DTD

**Document Type Definitions** can be thought of as a “packing list” that XML messages carry with them so that the recipient can check actual contents against what is supposed to be there. For instance, the recipe example above may contain: <!ELEMENT recipe (recipe\_name, meal, ingredients, directions)>.<sup>4</sup> This is a table of contents which tells the user that the message should have a recipe name, meal description,

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<sup>2</sup> In addition to being a standard, XML is also the parent of several derivative standards, chief among them being: 1- UDDI (Universal Discovery and Description Language), a repository for XML based searching across industries. 2- SOAP (Simple Object Access Protocol) a standard for invoking objects across remote servers. 3- XSLT (eXtensible Stylesheet Language Transformation) for translation between XML vocabularies. Depending on circumstances, interoperability may also require one or more of these.

<sup>3</sup> This example is drawn from an excellent overview of XML, which can be found at: <http://hotwired.lycos.com/webmonkey/98/41/index1a.html>

<sup>4</sup> DTDs can be much more complicated than this example. For instance, they can contain a whole set of conditions, which determine what information is either required or, optional, or irrelevant.

ingredients, and directions. Because the tags for those elements are already known, it becomes an easy matter to see if all the needed elements are indeed present. For instance, an XML message might mistakenly omit the “recipe name”. The ELEMENT list allows the recipient of the message to check the actual contents of the message against the “packing list”, thus revealing that information is missing. As a result, message integrity is maintained. DTDs represent a critical set of agreements that trading partners must accept if systems are to be interoperable. This is because DTDs are the definitions and rules that trading partners need to automatically assimilate incoming information into their computer systems.

### IGES

The **I**nitial **G**raphics **E**xchange **S**pecification is an ANSI (the American National Standards Institute) Standard. It was created to support the exchange of electronic representations of drawings as were produced on what were effectively computer-aided drafting systems. Revised and expanded many times, IGES is still widely used to exchange CAD data between different CAD systems and between CAD systems and other systems, such as computer-aided engineering<sup>5</sup> and computer-aided manufacturing systems.<sup>6</sup>

### STEP

The **S**Tandard for the **E**xchange of **P**roduct model data, STEP is an ISO (international) Standard, the first parts of which were published at the beginning of 1995. STEP was intended to supplant IGES, with considerably greater capabilities and a structure designed to overcome some of IGES’s weaknesses. In particular, STEP is designed to support the exchange of an enormous variety of kinds of product data. To date, STEP has seen mixed success. The initial release of STEP provides much better support for exchanging certain kinds of data than IGES (especially solid model geometry). However, software vendors have much greater experience in implementing IGES and therefore the implementations of STEP have not always been as effective. Also, STEP’s potential for supporting non-geometric product data has yet to be realized because most of the necessary parts of STEP are still in development. Over the next few years, that will change and, if software vendors implement the new capabilities, STEP could substantially impact interoperability.

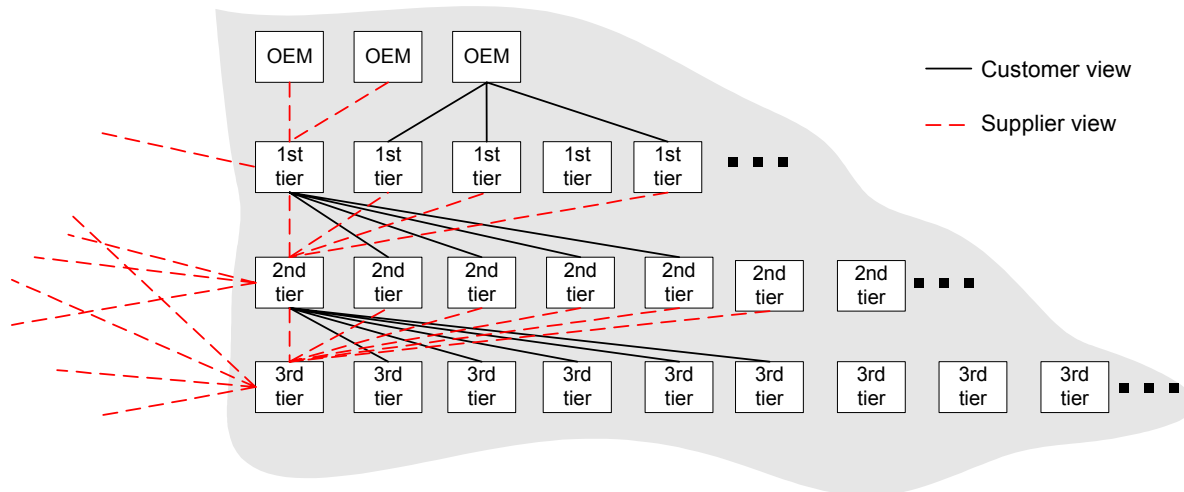
## **Structure of Automotive Supply Chains**

Much of the discussion that follows turns on important differences in the business climate above and below first tier suppliers. The situation is illustrated in Figure 2.

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<sup>5</sup> Including, for example, finite element analysis and mold flow analysis.

<sup>6</sup> For example, systems that generate the code that drives numerically controlled machine tools.



**Figure 2. Automotive industry structure differences above and below first tier.**

- There are only a few OEMs, and first tier suppliers will often do business with a few of them.
- Because of the OEM's interest in outsourcing complex components, the number of first tier suppliers is small.
- First tier suppliers do relatively little business outside of the automotive sector.<sup>7</sup>
- As one moves to lower tiers, the total number of potential suppliers increases.
- Lower tier suppliers nearly always have a larger customer base than first tiers, often an order of magnitude or more larger.
- Also as one moves down the chain, automotive suppliers tend to also sell to other industrial sectors, thus decreasing their dependence on automotive business.

The real supply chain network in the automotive industry is far more complicated, and has many more exceptions, than the simple picture shown here. But the illustration correctly depicts a fundamental difference in business climate above and below the first tier. First tier suppliers do almost all their business within the automotive sector, and within that sector, with only a few different companies. Because of the small number of customers involved, achieving interoperability is relatively simple. Below the first tier, each member of the chain may deal with a large number of trading partners who reside both inside and outside of the automotive industry. Thus dependence on automotive business decreases while the complexity of information flow increases.

## Business Data

Two general types of data flow exist. The first is information that flows directly between a customer and a supplier. The second is the case where third-party logistics companies are brought into the data flow.

## Interoperability in Customer <-> Supplier Communication

The genesis of data flow is either a conscious decision by the OEM to manufacture product, or an automated decision based on inventory levels. In the latter case, the OEM's internal systems check

<sup>7</sup> Many first tier suppliers are actually divisions of larger companies. The view presented here, however, does represent the business reality of the divisions within those companies that sell to the automotive industry.

production schedules against inventory, and automatically generate the necessary messages to suppliers.<sup>8</sup> This communication in turn, begins a “conversation” which might comprise any combination of messages about availability, pricing, order content, schedules, order status, and acknowledgements of messages.

From the point of view of understanding interoperability, two different scenarios are important. In the first, the OEM and the supplier exchange high volumes of information. In the second case the volume information exchange is low.

In *both* cases the OEMs use systems that send and receive messages via EDI. For three reasons, we believe that reliance on EDI will continue for the foreseeable future. First, OEM’s have large legacy systems that are integrated into EDI applications. Switching costs would be very high. Second, the OEM’s IT personnel have long experience with optimizing EDI systems. This human capital is valuable. Third, for high volume communication, EDI requires less bandwidth than XML.

If a supplier is exchanging high volumes of data with its customer, interoperability problems are likely to be relatively small. This is because at high volumes, it becomes cost efficient to implement EDI systems that are integrated into functions such as order entry and shipping. The problem emerges when low volumes are involved on the supplier end. In this case, EDI is not cost efficient, and some means must be found to translate the OEM’s EDI transaction into English. One solution is for the OEM to make the translation and send the information via email or fax. A second solution is for the OEM to direct the transaction to a service which does such translations. A third possibility is for the supplier to purchase a low-end EDI system which can receive messages and output them in plain text. Under all these conditions, the information on the supplier end becomes non-machine readable, and interoperability disappears.

Another option is developing which within a few years *may* improve interoperability in low volume situations. This would be a scenario in which EDI and XML formatted messages are translated into one another. This would allow OEM’s to send and receive information in EDI format, and suppliers to send and receive messages in XML format.

The above discussion focuses on 1:1 relationships, i.e., between one OEM and one of its suppliers. There are industry wide dynamics at play which affect the aggregate impact of these 1:1 transactions. One factor is how much power the customer has vis a vis the supplier. When the power differential is high, the customer can force interoperability. This will happen when high volumes of information are used to drive tight delivery schedules. In such a case the customer has no choice but to install systems that can feed incoming data into order entry systems, and export shipping data as automated advance ship notices. The second important factor is the spread of suppliers’ business across industrial sectors. For instance, companies who sell exclusively to the automotive industry would adapt AIAG guidelines as their EDI standard.<sup>9</sup> But companies that sold to multiple sectors would incur the cost of supporting multiple data exchange standards.

One way to look at these interoperability issues is to imagine a continuum. One end is a use-context that represents a limited and controlled set of business relationships. There is only one industry, suppliers are captive to their OEM customers, and those customers have the bargaining power to dictate information

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<sup>8</sup> Strictly speaking, the triggering event may come from the customer or, if a vendor managed inventory system is in place, from the supplier. But notwithstanding what company or computer generates the message, from a logical point of view, what we have is a request directed by an OEM to its supplier.

<sup>9</sup> There is plenty of standards variation in the automotive industry, and suppliers often have to deal with multiple “flavors” of an agreed upon protocol. Still, the variation is much less than what would be the case when entirely different industries are involved.

exchange policies. These conditions foster interoperability, and it is precisely these conditions that describe the relationship between OEMs and their first tier suppliers. At the other end of the continuum, suppliers spread their sales across many companies in several industrial sectors. Here, nobody can dictate terms. This heterogeneous business environment describes the situation below the first tier in the automotive industry, and indeed, in a very large percentage of all American industry.

To effect interoperability under these conditions, the *cost/benefit* ratio for interoperability must be lowered to a point where individual companies can make a business case for implementing whatever changes would be required to achieve system interoperability with their trading partners. XML represents such a solution. In terms of cost, XML does not require large investments in new hardware, software, or human capital.

The benefits are considerable. First, the same XML message that might feed data into an order entry system is also, by its nature, human readable, thus making it efficient to go back and forth between automated processing and human processing. Second, XML can be a meaningful mode of communication without first establishing an implementation convention.

We do not mean to imply that the costs of interoperability are trivial when XML is involved. Individual companies will still have transition costs when adapting their internal systems from manual to automated data entry. There are also costs for industry as a whole. While XML is powerful and flexible, interoperability still requires very well defined and commonly excepted definitions for a large amount of detailed information. One solution is for industry groups to develop and accept a common set of definitions. Several industries are now involved in this arduous and time consuming process. The second solution is for third parties to act as translators, thus allowing the transmission of XML based data to unfamiliar trading partners. This approach too, is rapidly expanding. Undoubtedly the best practical solution will turn out to be a combination of these two approaches.

Complicating the cost benefit calculation for XML is the likelihood of network externalities, i.e., the phenomenon where the value of a technology to any one user increases with the total number of users who possess the technology. (Telephones and email are good examples.) Recall the focus of this analysis, i.e., interoperability between OEMs and their first-tier suppliers during the production phase of automobile production. Given present conditions for this setting, EDI is the favored mode of effecting interoperability. However, both the effects of externalities and changing business conditions, on the economics of interoperability are difficult to predict.

### **Interoperability With Third-Party Logistics Companies<sup>10</sup>**

It is common in the automotive industry for warehousing and shipping to be handled by third parties who specialize in logistics. One reason for this trend is cost. It is often more cost effective to outsource services to specialists. A second reason is that third party logistics firms can provide value-added services that cannot exist with direct shipping between suppliers and customers. One common service is “cross docking”. In this case a logistics firm picks up parts from multiple suppliers and reorganizes the loads so that the right mix of parts goes to the OEM. One advantage of this technique is cost reduction resulting from more fully loaded trucks. Another advantage is that the right mix of parts arrives, at the right time, at the OEM’s loading docks. Taking cross docking one step further, logistics companies also provide “sequencing” services. Here, different parts are arranged so that a particular combination of components can move together, from a truck into the assembly process. This frees the OEM from the effort of reorganizing parts that come off a truck as those parts move through vehicle assembly.

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<sup>10</sup> Thanks to Dik van Meerten for assistance in developing the ideas presented in this section.

While the inclusion of third parties and value added services complicates data flow, the basic issues of interoperability mirror that of direct communication between supplier and customer. Logistics companies working between first tier suppliers and OEMs have sophisticated systems that are compatible with the standards being used by their customers. EDI communication is used to coordinate all the necessary activity.

Logistics below the first tier level, however, usually do not justify EDI-based communication. While some second tier companies are EDI-capable, most are not. Fewer and fewer EDI-capable companies appear below the second tier level.<sup>11</sup> As with direct supplier to customer communication, system interoperability in this domain will require the development of XML-based communication standards.

Apart from the question of who is managing logistics, there is also the question of system interoperability for order tracking. As of now, almost all EDI activity in the automotive industry travels either directly between trading partners, or via the intermediary of a Value Added Network. Very little traffic flows via the Internet. While a switch to the Internet is appealing, the movement is retarded by the problem of reliable order tracking. The parties involved need to know if goods have been shipped, and whether or not they have been received. Functionality for tracking and delivery acknowledgments is proven with direct or VAN-based communication, but is *not* well developed in the Internet domain. The functionality and standards needed to provide this assurance is currently under development.

## **Emerging E-business Trends: Implications for Interoperability**

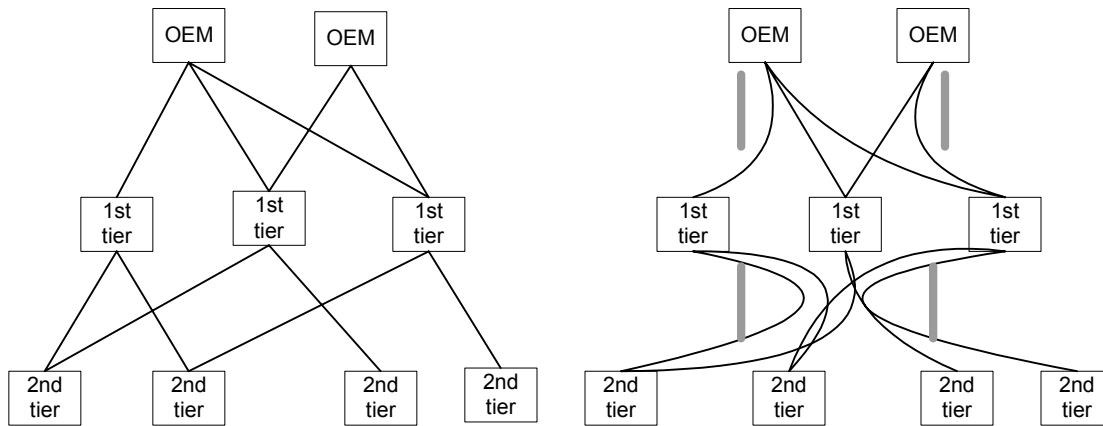
Two developments in e-business may have consequences for interoperability. The first is electronic catalogues (e-catalogues). This development is important because the move from paper to bytes can change how business is done. Customers can check prices and availability from a larger pool of potential suppliers. Because publishing lags are eliminated, information on price and availability will be current. A greater variety of complex information can be accessed. For instance, companies are now including AutoCAD files as a part of their catalogues, thus allowing customers to easily incorporate a part into a design. As with EDI and XML, the impact of e-catalogues differs from the first tier up and the first tier down. Above the first tier, contracts tend to be long term. It is uncommon for an OEM, in the middle of a production run, to shop for a new supplier. In any case, the industry's emphasis on buying complex components limits the number of potential first tier suppliers available to an OEM. As a result, the impact of digitizing catalogues is small. (Recall that the emphasis here is the production phase of the lifecycle.)

Below the first tier, however, contracts are likely to be shorter term, and any potential customer will have a relatively wide choice of suppliers. As a result, e-catalogues may very well affect who gets automotive business, and on what terms. However, the power of e-catalogues can only be realized if customers can query a wide variety of catalogues. Complicating the problem is the best value for a buyer may come from outside of its traditional industrial buying base. As a result, either standards, or trustworthy translation systems, are needed to allow catalogue searching across a very wide range of companies and industrial sectors. In essence, to capitalize on the potential of e-catalogues, a high level of interoperability is needed for e-catalogues and e-catalogue searching systems.

The second important development is the rise of industry portals. These are becoming commonplace in many industries, and efforts to develop portals which can serve the automotive industry are well under way. (Covisint is the most noteworthy example.) From the point of view of interoperability during the production phase of the lifecycle, portals are interesting because of their potential to consolidate data

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<sup>11</sup> This statement is generally true until one reaches the very bottom of a supply chains. There, raw materials producers are found, some of whom are very large companies with sophisticate IS capabilities.



**Figure 3. Supply Chain With And Without a Unified Portal**

flow, and thereby, perhaps change demand for interoperable systems. The situation is illustrated in Figure 3.

Without a unified portal, communication between trading partners is negotiated by the trading partners. Whether EDI, XML, or a proprietary format, each trading partner pair decides on its own how to communicate. True they will probably use an industry standard, but no matter how good the standard, variation will always creep in to each individual decision. And each company involved has to make that decision with each of its trading partners. With a portal, however, the situation changes. Now each company makes an information format decision *with only one entity*, the portal. The greater the number of tiers at which the portal operates, the greater the degree of data uniformity within the industry. The greater the uniformity, the lower the cost of interoperability. We do not know if automotive industry portals will succeed, or to what degree. We know however, that the cost of interoperability is inversely related to the success of a uniform portal. We believe that lower costs for interoperability may change business practices, but we cannot foretell how. In any event, the success of portals, and their impact on interoperability, should be watched carefully.

## Engineering Changes

An inevitable part of production is dealing with engineering changes (EC's). These are the formal product changes that are instituted in response to some officially recognized need for a change in the product. An EC may be initiated due to a request from the end user, the manufacturing floor, marketing, or any other interested party. The common element is that each EC must be at least approved by the engineering staff overseeing the product. Then the EC must be approved by others and distributed to all affected parties, which, depending on the affected product, will include such groups as customers, suppliers, tooling design and manufacture, the manufacturing floor, inspection (quality control), and so on.

Interoperability is an issue for EC's because they now nearly always include electronic data, especially CAD (computer-aided design) data defining the geometry of the part. Other controlling data may also be provided electronically, such as effectivity dates, approvals, and existing completed parts disposition. EC's are relatively rare compared to the business data described above. They are usually generated at unpredictable intervals, though the rate is normally much higher in the time surrounding a product's early production. The data they contain also tends to be much more complex and unstructured than business data. Hence exchange methods are substantially different from the EDI or XML approaches. Standards

such as IGES and STEP have been created to support this kind of data exchange. The issues associated with these types of data are covered in detail in an AIAG/ERIM report to NIST.<sup>12</sup>

## Standards Groups

Table 2 lists the types of major interoperability standards, examples, and responsible organizations.

**Table 2 – Standards groups and their responsibilities.**

<b>Data types</b>	<b>Examples of Standards</b>	<b>Responsible orgs</b>
Product data, e.g. CAD, PDM, CAE	STEP, IGES	US Product Data Organization (US Pro), ISO
Business data, e.g. orders, ship notices, payment notices	EDI, XML	ANSI X12, EDIFACT, UN, RosettaNet, OASIS, OMG

## Summary

A fundamental question regarding interoperability is “How big an issue is it?” The answer is that interoperability is a very large issue and growing larger all the time as more and more of the business and activities involved in getting a product to market is conducted electronically. Email, a very simple interchange application, works very consistently, but only if people are careful about using the special capabilities of their email software. Nearly all other electronic data exchange is more complex and therefore more subject to problems. Those who underestimate the cost or effort involved in assuring interoperability, whether company, industry, or government, are sure to regret it.

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<sup>12</sup> *Automotive Supply Chain Collaboration: The Need for Broad Systems Interoperability.* Results from an industry workshop sponsored by the Automotive Industry Action Group for the National Institute of Standards and Technology. Prepared for AIAG by ERIM, August, 2000.