Exploiting E-Manufacturing: Interoperability of Software Systems Used by U.S. Manufacturers

February 2001

Prepared by:

National Coalition for Advanced Manufacturing (NACFAM)
2000 L St., NW, Suite 807, Washington D.C. 20036
www.nacfam.org

For additional copies contact NACFAM at: 202-429-2220

Exploiting E- Manufacturing: Interoperability of Software Systems Used by U.S. Manufacturers

February 2001

Introduction

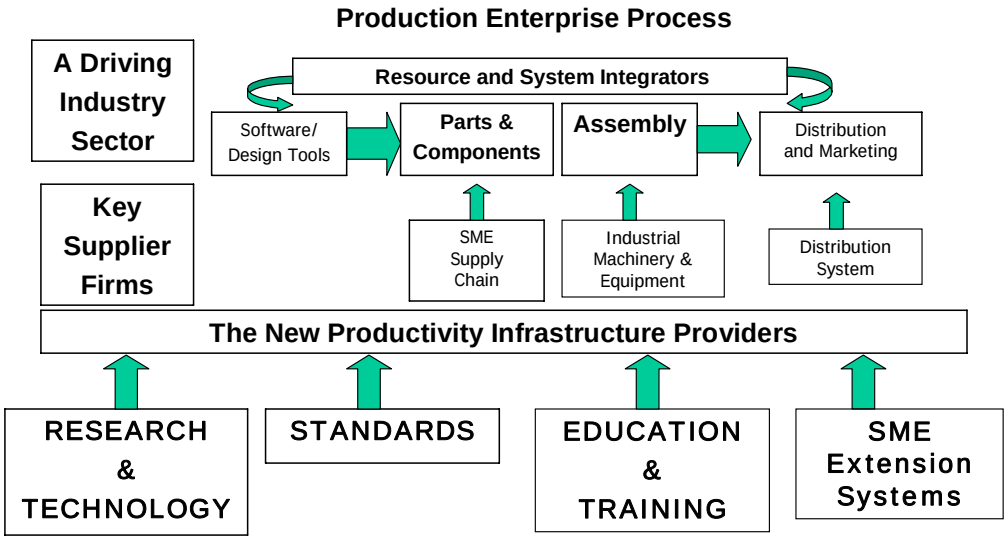
The frictionless exchange of information is the primary catalyst behind the explosive growth of the Internet, e-mail, home computer use, and other hallmarks of the "new" economy. The demand for more information, however, is not limited to the "new" economy. In fact, modern manufacturers are consuming information technology (IT) products at ever increasing rates, signaling a transformation in the way they interact with their customers and each other. This shift from mass production, where consumer preferences were aggregated, is giving way to a new era of distributed product design and engineering, networked supply chains, and consumer demand for customizable solutions. In this new era, the manufacturing enterprise is more flexible, more efficient, and more responsive to changes in customer preferences than ever before.

The key to achieving this flexibility, efficiency, and responsiveness is information. In fact, it can be simply defined as ready access to the right information by the right person at the right time. Despite the advances in information and communications technologies, the ability to achieve the levels of flexibility, efficiency, and responsiveness required to exploit the full potential of this integration of manufacturing and information technology has not been realized.

As part of its research into the sources of manufacturing's dynamic performance over the last decade, the National Coalition for Advanced Manufacturing (NACFAM) highlighted an often overlooked and misunderstood barrier to this integration, a lack of software interoperability.[1] If the goal of integrating IT and manufacturing is to be achieved, information must be able to flow seamlessly from location to location without loss or corruption of content. This will become more critical as value-creating business processes call for the exchange of increasingly complex information.

Today's software and IT systems fall short of this goal. Key parts of transmissions are lost or garbled, requiring manual re-entry of lost information or errors resulting from proceeding with incomplete or incorrect data. Incompatibilities between programs prevent users from sharing files unless they are using the same software requiring the recreation of data files in new formats if different systems are used. These examples are

Figure 1: The New Production Enterprise



Source: NACFAM, *Smart Prosperity: An Agenda for Enhancing Productivity Growth* (2000)

illustrations of the broader issue – imperfect interoperability among software systems used by manufacturers.

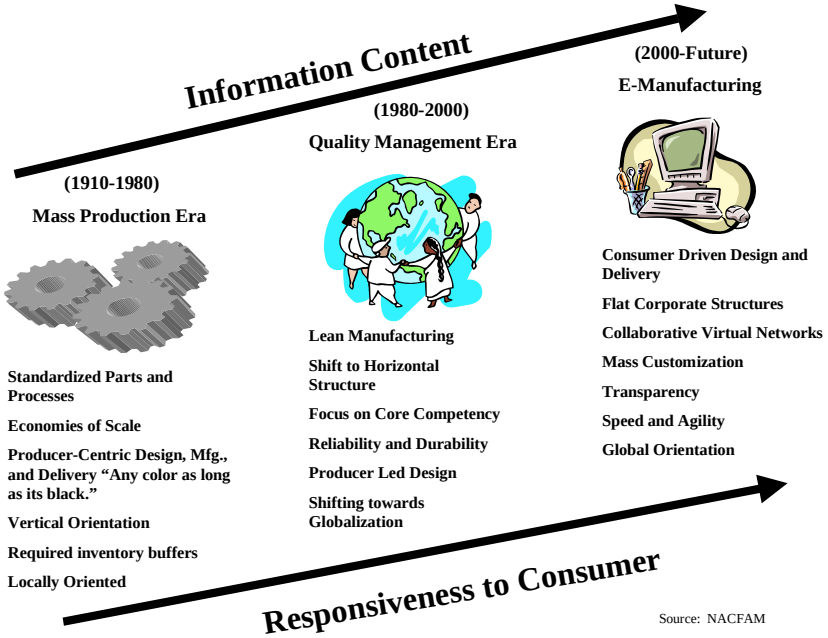
To explore this issue more clearly, NACFAM undertook a study of the automotive and aerospace manufacturing sectors to discern the implications of the interoperability challenge, the level of corporate consciousness of the problem, and to solicit views on pathways toward strategies and solutions.

Manufacturing in the 21st Century Economy

A first step toward understanding the scope of the issue and devising solutions to observable problems is to recognize that manufacturing has changed. The "new production enterprise" is more than a new assembly process – it represents a spectrum of activity all the way from research and design through distribution and marketing (see Figure 1).

For decades, the dominant manufacturing model was based on principles of mass production (see Figure 2). Standardized parts and processes made economies of scale achievable, but limited design flexibility and customization. The outsourcing and lean manufacturing movements of the 1980s and 1990s drove the emergence of a new paradigm, termed the Quality Management era on Figure 2. Manufacturing companies, particularly large original equipment manufacturers (OEMs), focused on reducing internal costs by shifting non-core functions outside of their organization.[2] Outsourcing shifts critical elements of the design and production process onto a manufacturers' supply chain. The lean

Figure 2: Evolution of Manufacturing



manufacturing movement places a premium on time and inventory reduction. Combining these two attributes of the Quality era suggests a very different business model for manufacturing – enterprise integration or e-manufacturing.

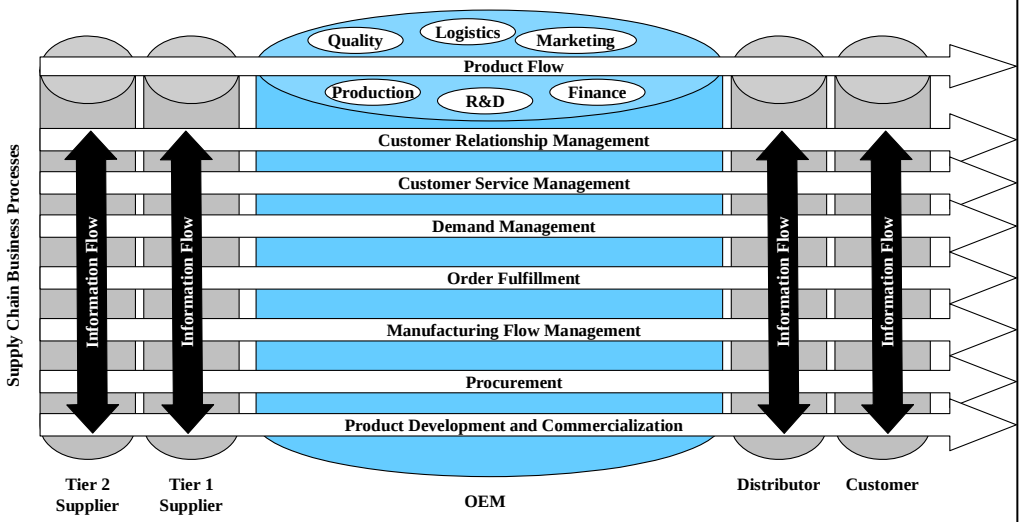
In the e-manufacturing era, companies will be able to exchange information of all types with their suppliers at the speed of light. Design cycle times and inter-company costs of manufacturing complex products will implode. Information on design flaws will be instantly transmitted from repair shops to manufacturers and their supply chains.

In conjunction with the shift to an enterprise model, pressures for reduced design time, increased production speed, and enhanced customization continue unabated. The automotive industry is working toward a 12-month goal for design of a new vehicle program, down from 30-months presently. Aerospace has set similar goals for itself and other industrial sectors have followed suit. All face consumer pressures for greater customization without sacrificing functionality and performance.

This transformation of the enterprise coincides with the increasing content of information contained in products and processes. The new production enterprise is information-rich.

The ability to exchange information and automate manufacturing processes are two of the building blocks of the virtual manufacturing companies of the near future. Company after company has realized that huge savings are to be found from knowing exactly where each widget is in the manufacturing process. These benefits are not limited to the private sector. The nation has benefited greatly from the productivity gains derived from IT investments of U.S. manufacturers.[3]

Figure 3
Information Exchanges in Manufacturing



Adapted from NRC, Surviving Supply Chain Integration (2000)

However, more and more companies are faced with customers with ever-greater quality requirements and ever-tighter delivery requirements. This demands speed, flexibility, and responsiveness on the part of manufacturers. Without automation and sophisticated controls customer needs can not be met. It also demands greater collaboration and cooperation not only within a company but across company boundaries as well. Like the information economy, the new production enterprise is a network that shares experience, knowledge, and capabilities. It is critical in this new environment for a manufacturing company to be able to efficiently tap these knowledge and information networks.

The Information Backbone

When the manufacturing enterprise is viewed in terms of its functional components, the significance of the information flows and their integration into business processes becomes clearer. Three types of information exchange are evident within a single organization:

- Information is exchanged within a specific function;
- Information is exchanged between functions to address issues raised by specific business processes;
- Information is exchanged between business processes.

Figure 3 offers a simplistic, but useful depiction, of the interconnections between business processes, functional activities, and the need to share information across a supply chain.

Virtually all manufacturing companies share a set of common functions, such as R&D, production, quality control, logistics, and so forth. Within each function, systems must be in place so information can be shared and exchanged. These common functions are connected virtually by business processes that are related to product flow. Customer relationships, demand management, and product development, for example, are cross-cutting activities that link the functional of the production enterprise. Consequently, each function must be able to communicate with other functions sufficiently to make appropriate decisions.

These exchanges range from product development or design issues all the way through customer relationship management. These information types are obviously different, but each is related to the others. For example, the unique attributes of a particular product will have an impact on the schedule of the production process, the type of materials that have to be ordered, when they have to arrive at the production facility, and the scheduling of the actual assembly or production process.

Information exchange processes are complex enough within a single enterprise, but become more so when suppliers, distributors, and customers are added.[4] A manufacturing OEM will routinely share product designs and order schedules with their suppliers and expect similar information in return. Increased demand for customized products means that consumer preferences in design of a product have to be communicated to the operational elements to make the appropriate changes in design, schedules, orders, and production. Systems must be in place to reconcile the final product against the design and the changes to ensure that the delivered product meets specifications, is operable, and is safe.

As linkages with suppliers become more critical, the need to exchange information without fear of lost data or mistakes increases. Many manufacturers have turned to advanced software systems to manage these complex needs. Despite the high level of functionality in this software, the seamless exchange of data often remains an elusive goal. Manual re-entry remains commonplace, even at the largest corporations, and human error and other mistakes are prevalent, adding time, cost, and risk to product development and production.

The growth of enterprise integration will only compound this issue. Over the next two to five years, enterprise integration will occur at increasing rates in manufacturing supply chains. Investments in information technology drive this transformation. In the 1990s, manufacturing companies invested hundreds of billions in new systems and software. In 1996 alone, an estimated $47 billion was spent by manufacturers on IT, including desktop computers, robotics, and software for design, enterprise resource planning, and productivity. In 1997, U.S. manufacturers purchased more than $6 billion in software services.[5]

Integration costs drive these estimates even higher. Installing a new computer system or piece of software costs more than the product itself. For example, the cost of software integration has been estimated to be between $1-5 for every $1 of software purchased. Modern manufacturing processes have strong IT components, meaning the costs of

integrating process technology investments will rise precipitously.

Yet, there are limits to the extent to which customers and suppliers can exchange design, engineering, and manufacturing data. The systems are complicated and data is formatted and maintained in thousands of different ways. Outsourcing, cooperation, collaboration, and investments in new IT systems only compound this problem by inserting new users with distinct or unique systems into an already complex environment.

The Interoperability Problem

The IT intensity of modern information-based manufacturing and engineering systems and manufacturing equipment ironically complicates their ability to exploit the full benefit of these investments.

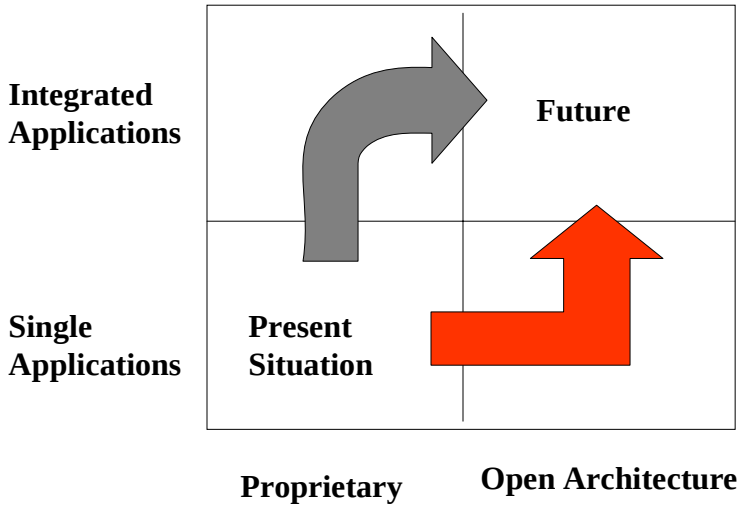
The problem is twofold. The first is the corruption or loss of data between nominally compatible or incompatible software systems. The second is the high cost of integrating software and hardware components into manufacturing equipment and enterprises. The ultimate goal is complete interoperability, which is the seamless high-fidelity exchange of data between different systems, without any loss or corruption.

The costs of interoperability are staggering. An internal study from a major automobile manufacturer recently revealed that a lack of interoperability is costing them between $200 million and $400 million per vehicle program. According to a recent study of product data exchange in the automotive sector, the inability to efficiently exchange product data through the automotive supply chain alone conservatively costs the industry $1 billion per year.[6] Similar estimates are available in the aerospace sector. In both industries, officials clearly believe the real costs of interoperability are much higher.[7]

Additionally, these costs are particularly pernicious because they frequently are borne by those least prepared to deal with them: small- and medium-sized manufacturers (SMEs). There are more than 300,000 in the U.S. alone and they hold the key to the efficient operation of the new manufacturing enterprise. America's largest companies have outsourced critical design, production, and resource requirements to them. To take advantage of this new opportunity, SMEs made huge investments in IT and software so they could work more closely with their larger partners. If these companies work for more than one large OEM, they often have to maintain redundant and costly software packages in order to communicate with their customers. In this way, the large manufacturing companies have pushed costs onto SMEs by encouraging their suppliers to "standardize" around their preferred software systems.

The issue at hand is more than just cost savings for industry. The nation loses significant opportunities if the goals of flexibility, efficiency, and responsiveness are not attained. New products and services that would enhance quality of life may not be produced. Productivity gains are lost, with a related loss of increased standards of living. Market opportunities are ceded to foreign competition. Employment gains, wage growth, and new business start-ups are all placed in jeopardy.

Figure 4
Alternative Solution Pathways



Source: NACFAM

Developing a Framework for Action

The issue has not gone unrecognized. Indeed, many have spent countless hours working toward solutions. The market, sensing an opportunity for profit, is fast developing products to fill the void. What is under appreciated and, hence, where the danger lies, is the lack of systematic evaluation of the implications of the different pathways toward the future.

Figure 4 offers a very simplistic view of the broad choices that face the nation in this area. The present situation is characterized by single software applications that frequently do not interoperate with other pieces of software. Integrated applications or suites are emerging daily. These suites offer the most simple solution to data exchange problems – the suite is interoperable between its own components. Unfortunately, this is hardly a solution. One would still encounter problems sharing information with those who do not use the same integrated package that you use.

In contrast, a system resting on a more open architecture would facilitate exchanges between single or integrated applications because they would share a "base" on which product differentiation could thrive. The Internet, with its TCP/IP protocol, is a prime example of the possibilities of such a model.

Much has been said and written about the power of XML (extensible Markup Language) to serve as a solution to the interoperability problem. Indeed, XML is a powerful tool and one that clearly facilities the exchange of information, but even XML requires agreement on a "base" of information to operate effectively.[8] The "base" refers to agreement on sets of well-defined and commonly-accepted definitions.

Recommendations

Leadership is needed to drive solutions. There is little question that the interoperability problem is a significant one. It consumes tremendous resources that could be more productively deployed elsewhere. It inhibits the achievement of broad corporate and national goals. It jeopardizes quality and safety of manufactured products by allowing error to persist in the design and production process.

While there is agreement on the nature of the problem, there is little consensus on what should be done to solve it. The lack of consensus arises from misperception of goals and incentives among the various stakeholders working on solutions. Dialogue and leadership can bridge that gap.

The responsibility to provide leadership is shared by all concerned stakeholders – industry, software companies, system integrators, and even the federal government.

NACFAM's survey of two leading manufacturing sectors leaves little doubt that industry is the pivotal player. As consumers of software systems, the leaders of the manufacturing community must come to appreciate the significance and scope of the interoperability problem as an unnecessary cost to their companies and as a barrier to achieving their corporate objectives. This realization will encourage change in market behavior and affect the character of products.

Manufacturing companies acting alone will not solve this problem. Software companies and system integrators are equally important for they must ultimately design interoperable software and systems. These companies both lead and follow the market. They lead in the sense that their innovative product ideas can revolutionize organizations and operations. But, they also react to pressures from the marketplace and important customers.

If realization, understanding, and market demand are sufficient to generate market solutions, then the problem is easily solved. Unfortunately, the nature of the interoperability problem is more complex because it requires agreement on certain common principles and features before truly interoperable solutions can emerge. This, in turn, requires a mechanism to convene the right decision makers to produce the necessary agreement.

To date, this role has been filled by industry-oriented organizations, such as the Automotive Industry Action Group (AIAG), or standards-developing consortia, such as PDES, Inc. Despite their efforts, these groups simply have not had the resources or support to broker solutions fast enough to suit the demands of industry, who themselves are subjected to market conditions and international pressures that change at an ever quickening pace, nor comprehensive enough to put robust solutions in place for all U.S. industry.

The federal government offers a different kind of leadership. It leads as a convener, a consensus-builder, an objective facilitator, and an arbitrator. Government cannot and should not force the development of specific solutions. To be effective, solutions must first have the trust and acceptance of the industrial and software communities. Through concerted action and dedicated effort,

Figure 5
Roles and Responsibilities

Industry & Related Associations	Software Companies & System Integrators	Federal Government
• Develop frameworks for assessing and analyzing interoperability issues affecting individual firms and industry sectors • Devise strategies for increasing the comprehension of this issue among corporate decision makers • Develop common frameworks on interoperability needs • Work to communicate those needs to the software/system integration community • Participate in stakeholder meetings	• Participate in stakeholder strategy and vision development sessions • Incorporate standards into software products and services	• Convene stakeholders to develop strategies and implement a unified vision • Work with industry to develop and maintain industry-specific frameworks and roadmaps • Represent U.S. interests internationally • Provide technical assistance in development of open interoperability standards and protocols • Develop methods for measuring the ability of products and services to comply with emerging standards. Assist in the development of tool-kits for small- and medium-sized companies • Promote widespread adoption of standards once agreement is reached • Provide tax incentives to accelerate the depreciation of legacy systems • Alter procurement rules to encourage use of software using interoperable standards

government can accelerate the pace of change and encourage the deployment of solutions.

Figure 5 summarizes the roles and responsibilities for manufacturers, software companies and system integrators, and the government that emerged out of NACFAM's conversations with representatives of those communities.[9] These roles are suggestive. Each requires additional analysis and evaluation before definitive conclusions can be drawn. Nevertheless, they are the suggestions of an informed community and deserve serious consideration.

The theme running throughout the roles is one of communication and understanding. Solutions will only emerge after stakeholders agree to work together to identify more clearly where consensus is necessary and to demarcate roles and responsibilities.

Government can facilitate this conversation. They are the only party that can effectively leverage an informed national dialogue, crossing industry and geographic boundaries. Lacking a preference for one solution pathway over another, they are also a neutral convener.

Consequently, this survey supports efforts by the federal government to convene meetings at the national and industry-specific levels to address this issue. Industry should attend, participate, and build on the outcomes of those gatherings as should software companies and systems integrators. When agreements are reached, the private sector should aggressively move to implement and adopt the results.

Related to this is a call for industry to support efforts already underway in their sectors to develop common frameworks on interoperability needs. Not all manufacturing sectors have advanced such efforts, but those that have should exploit the work that has already been done.[10] These discussions will begin developing the common set of assumptions, definitions, and agreements that are necessary for solutions to emerge. Government can aid these efforts by serving as a convener, technical advisor, and instrument to build on the work of other industrial sectors.

Participants from both industries agreed that the international aspects of this issue demand an active participatory role for the federal government. Standards developments overseas have enormous impact on the U.S. economy domestically as well as the operations of U.S. multinationals. In order to represent the interests of the United States effectively overseas, government must engage the industrial and software communities to understand and appreciate their needs and concerns. This learning process is intimately linked to the need for dialogue and discussion.

Numerous roles were advanced to facilitate the technical work needed to support solution development. Some representatives of the automotive and aerospace industries, as well as software companies, embraced the idea that the government could develop methods (or tool-kits) to assess the extent of interoperability problems at small- and medium-sized companies.[11] Others suggested the government could help develop and validate methods for use by others in evaluating the claims of software packages.

Some participants called for more aggressive steps by both government and industry to encourage the deployment of new software systems with interoperable capabilities. Representatives from the aerospace industry mentioned the influence of government's procurement power on their industry.[12] Government requirements for the submission of designs and specifications on a military aircraft, for example, oftentimes discourage the deployment of advanced software systems. Similarly, in both the automotive and aerospace sectors, meeting regulatory requirements frequently involves the transmission of large volumes of data to the government in specified formats, these formats serve as a disincentive to the migration to new systems.[13] Changes in procurement rules, regulations, or tax policy to speed the purchase and deployment of advanced software systems would have significant influence on corporate decision-making, some suggested.

Conclusion

The interoperability challenge will not be overcome quickly, but significant progress can be made if the public and private sector work together toward common solutions.

NACFAM's survey of corporate attitudes in the automotive and aerospace sectors reveals fundamental agreement on several basic points, including:

- Interoperability is recognized as a problem by involved decision-makers in the private sector, but there is a low appreciation for its impact by high-level decision-makers;
- The costs of imperfect interoperability are woefully understated by present estimates;
- Failing to devise solutions will disrupt the achievement of broad corporate and national objectives; and
- Industry-led solutions are needed, but government is essential to facilitating the dialogue that will produce those solutions. This involves substantial effort and commitment by government to bring stakeholders together and provide necessary technical expertise.

The broad conclusion is quite clear – The government can be a leader, but it cannot mandate solutions. The process suggested in NACFAM's Smart Prosperity and reinforced by meetings with leaders from the automotive and aerospace sectors is one of stakeholder involvement and consensus-building. The public sector can guide and facilitate, but the private sector must participate and, ultimately, commit to solutions.

Endnotes

[1] National Coalition for Advanced Manufacturing. (2000). Smart Prosperity: An Agenda for Enhancing Productivity Growth. (Washington, D.C.: NACFAM).

[2] National Research Council. (2000). Surviving Supply Chain Integration: Strategies for Small Manufacturers. (Washington, D.C.: National Academy Press).

[3] See National Science Board (2000), Science and Engineering Indicators 2000 (Arlington, VA: National Science Foundation), Chapter 9, for an overview of IT's impact on productivity and economic growth. Wessel, David (2001), "The Magic Elixir of Productivity," *Wall Street Journal* (February 15, pg. 1), offers a concise explanation of the importance of productivity growth.

[4] Participants in NACFAM's aerospace industry focus group commented that internal interoperability issues are potentially a more significant problem than external relationships. See National Coalition for Advanced Manufacturing (2001), Perspectives on Software Interoperability: Results of a Focus Group Discussion with the Aerospace Industry – January 2001, (Washington, D.C.: NACFAM).

[5] Figures from NACFAM (2000), "Interoperability" in NACFAM Technical Concept Papers for the Basic Manufacturing S&T Initiative, (Washington, D.C.: NACFAM).

[6] Research Technology Institute. (1999). Interoperability Cost Analysis of the U.S. Automotive Supply Chain. (Gaithersburg, MD: NIST Planning Report 99-1).

[7] NACFAM. (2000, 2001). Perspectives on Software Interoperability: Results of a Focus Group Discussion with the Automotive Industry & Aerospace Industry (Washington, D.C.: NACFAM).

[8] Morell, Jonathon, and Thomas Phelps. (2000). Interoperability Issues: A White Paper. (Washington, D.C.: NACFAM).

[9] NACFAM (2001). Interoperability of Software Systems Used by U.S. Manufacturers: A Survey of Corporate Attitudes – Preliminary Findings. (Washington, D.C.: NACFAM). Summarizes the methods used and broad findings of the study.

[10] For example, at the Automotive Industry Focus Group meeting, a representative of AIAG spoke eloquently about that organization's deep involvement in leveraging dialogue and solution development. See National Coalition for Advanced Manufacturing (2000), Perspectives on Software Interoperability: Results of a Focus Group Discussion with the Automotive Industry – December 2000, (Washington, D.C.: NACFAM).

[11] NACFAM. (2000, 2001). Perspectives on Software Interoperability: Results of a Focus Group Discussion with the Automotive Industry & Aerospace Industry (Washington, D.C.: NACFAM).

[12] National Coalition for Advanced Manufacturing (2001), Perspectives on Software Interoperability: Results of a Focus Group Discussion with the Aerospace Industry – January 2001, (Washington, D.C.: NACFAM).

[13] NACFAM. (2000, 2001). Perspectives on Software Interoperability: Results of a Focus Group Discussion with the Automotive Industry & Aerospace Industry (Washington, D.C.: NACFAM).