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Improving the Deployment of Open System Technology: European Lessons From the Manufacturing Automation Protocol

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Introduction

What fate awaits the Manufacturing Automation Protocol (MAP) in Europe? Two extreme views, and many in-between, can be supported by the evidence.

The most pessimistic view is that a critical mass has not been reached, that it will never be reached, and that except in isolated cases, MAP will whither as a desirable technical solution.

The optimistic view is that MAP's inherent advantages of flexibility, insurance against technological obsolescence, and functionality, will win the day.

Which future for MAP is most likely, and what might be done to insure a desirable outcome? The answer to this question is important not only for MAP, but for any promising open system technology that may be developed in the future.

As we shall presently see, there is a tension between good technical and business reasons to adopt open systems, and equally serious barriers to such implementation. This report will present a case study of how that tension plays out in the case of MAP, and then extrapolate to the general case of open systems. To accomplish this task we will summarize findings from a variety of interviews with people close to the European MAP scene, overlay the findings with a conceptual model of open systems deployment, and attempt to show how a desirable future for MAP might be achieved.

The Importance and Challenge of Open Systems¹

Open systems are important because they enable enterprise integration (EI), a condition in which accurate and timely information flows smoothly within a company, and between the company and its suppliers, customers and partners. In the integrated enterprise, all parts of the organization work cooperatively toward the satisfaction of common goals and objectives. Systems, procedures and technologies are coordinated to minimize waste.

EI is important because to an ever increasing degree the viability of businesses and industries depends on their ability to meet rapidly changing circumstances. In the manufacturing sector this ability is becoming known as "agility", and refers to the capability to rapidly bring out new products; rapidly assimilate field experience and technological innovation; continually modify product offerings; accommodate continually changing production systems; and provide reconfigurable products which users can upgrade rather than replace.²

Given the importance of agility, why is the technology of EI so critical? Because agility requires presently unavailable options regarding *organizational process, human resources, and products and services*. EI technology can enable these options because it increases our ability to access, manipulate, analyze, and communicate information. Some examples illustrate this point.

Organizational process EI technology makes it possible to separate knowledge about an organizational activity from control over that activity. Without appropriate technology for data capture, analysis and transmission, operational control is the only practical way to closely monitor an activity. With this bond now broken, organizations have new choices about how it can organize, and about relationships among its various sub-units.

Human resources Agility increases a need for skilled personnel that is already strained because of society's increasing demand for knowledge work. EI technology can help alleviate this problem by making new forms of work practical. The technology's capacity for data access and transmission increase the value of part time, flex and remote (through telecommuting) work. Wide-spread flexible access to technical information opens up new opportunities for training and the capture of institutional memory.

¹ - This section is adopted from: Morell, J.A. (1992) "*Improving the deployment of 'integration' technologies*", presented at the annual meeting of the Technology Transfer Society, Atlanta GA, June 25.

² - Details of the agile manufacturing initiative can be found in a two volume 1991 report published by the Iacocca Institute, Lehigh University, Bethlehem PA, titled: *21st century manufacturing enterprise strategy*

Products and services EI technology can enable a company to shorten its product/service development lead time, market a greater variety of products and services, and turn a profit on smaller volume. It can also allow a company to develop new types of products or services. The ability to do this is the essence of agility, i.e. the practical ability to capitalize on opportunities as they arise.

To be useful, EI technology must allow products from multiple vendors to work smoothly together, a condition which cannot be achieved without a heavy emphasis on open standards. "Openness" is needed so that users can pick the exact mix of technology that will meet their needs; have some insurance against technological obsolescence; and have the ability to continuously improve their systems through the acquisition of third-party niche products.

Open systems, however, may not be a boon to the suppliers of information technology. While such systems have the potential to increase the overall size of a market, they also make it easier for users to switch from one supplier's products to another's. Thus vendors with established market shares cannot be blamed for hesitating in full commitment to open standards. Other problems also exist from the vendors' point of view. Even without the threat of product switching, vendors may worry that open standard products will compete with their own product lines based on proprietary standards. Another risk is developing and marketing an open system product that does not pass conformance tests. Finally, vendors may legitimately worry that open system products will tax the skills and expertise of their sales, marketing, and maintenance groups who will be asked to support new, and relatively more complex products.

Despite their value, open system integration technology also poses problems for users. Many technologies provide value with a small number of users, and increase in value with the number of users. Not so with integration technology, whose value inherently depends on a large number of users in a given setting. The necessary scale of implementation for EI technology exacerbates whatever difficulties of economic justification, legacy replacement, organizational change, and training attend the introduction of any new technology.

The challenge is to understand the dynamics of open system technology development so that as many problems as possible can be minimized or avoided.

Methodology

A series of semi-structured interviews was conducted in Europe with users of MAP technology, vendors of MAP technology, and a variety of other observers who are close to MAP related events in Europe.³ In all, eleven interviews were held, three with companies with large MAP installations, and eight with a collection of equipment vendors, consultants, and system integrators. (For convenience this latter group will be referred to as "vendors" in this report.)⁴ All participants were promised confidentiality unless they specifically asked that their identities be divulged.

MAP was chosen as a case study because it is an open system which is reasonably mature, and has had conformant products on the market for a long enough time that a history of use (or non-use) can be tracked.

³ - Appendix A contains a copy of the interviews used in this project.

⁴ - One of these "interviews" was actually a briefing from an expert who did his own analysis of demand for MAP in Europe.

The Manufacturing Automation Protocol

The Manufacturing Automation Protocol was established to define a local area network for terminals, computing resources, and programmable devices within a plant or a complex. Though intended for LANs, the architecture supports wide area network interconnection.

It is comprised of twelve OSI protocols covering the seven layers of the OSI Reference Model. These layers, from bottom to top are: physical, data link, network, transport, session, presentation, and application.⁵

As the name states, MAP is intended for manufacturing. Consequently, the selection of the protocols correspond to those appropriate to the factory floor. Where this difference becomes critical is in the selection of the Physical Layer protocol and one of the Application layer protocols.

For the physical layer MAP has selected the IEEE 802.4 (ISO 8802/4) Broadband and Carrierband technology. This technology allows multiple channels over a single physical medium. One could run up to six disparate MAP networks over a single cable. But more importantly, one can simultaneously run non-MAP networks over the same MAP backbone. The broadband will support voice, video, ISDN, Ethernet, etc.

In addition to its multiservices, multiprotocol, multiLAN support, broadband cable is well-suited to the factory floor due to its low-loss characteristics and its ability to provide shielding from electrical and magnetic interference. Broadband obviates the need for later upgrades.

At the Application layer, MAP specifies six protocols: ACSE, ROSE, FTAM, Directory Services, Network Management and the Manufacturing Message Specification (MMS). MMS is a protocol very rich in services and complexity.

Though it is applicable to a wide range of factory-floor applications, MMS does not describe application-specific information. That job falls under the charter of four companion standards organizations. Companion standards contain the semantics of the factory-floor device. The devices, along with their responsible organizations are: Numerical Control Devices (EIA), Programmable Controllers (NEMA), Robot Controllers (RIA), and Process Control Systems (ISA).

In the long view of enterprise integration, MAP should be coupled with the Technical and Office Protocol (TOP). Together they address the most of the network communications problems of an CIM enterprise.

In talking about MAP use, it is important to bear in mind a critical difference between how the term is commonly used in Europe and in the United States. In the United States, "MAP" specifically includes physical and data link layers involving broadband and carrier band technology, i.e. the

⁵ Additionally, there is a "stream-lined" model called the Enhanced Performance Architecture (EPA) that operates over just three layers: Physical, Datalink, and Application. The EPA is targeted for applications that require rapid response times and are very fault tolerant.

IEEE 802.4 (ISO 8802/4) standard. Generally in Europe, the term "MAP" refers to Ethernet technology, the IEEE 802.3 standard. Up until a few months ago, Ethernet was *not* a formal part of the MAP standard. It became so at a recent meeting of the World Federation of MAP/TOP Users. and is in the process of being formally integrated into MAP.

A Model for Understanding Open System Deployment⁶

The deployment of an open system technology can be viewed as a set of complex interactions between vendors and users. Improving that deployment requires understanding the leverage points in those interactions, and how the vendors, users, and third parties might act on those leverage points. The model we propose is shown in figure 1.

Insert Figure 1 about here.

The process depicted in the model begins with vendor decisions as to whether a technology should be developed or marketed. Included in this decision are factors such as the characteristics of the technology in question, market structure, costs, and strategic positioning of one's product line.

These vendor deliberations determine whether a product will be made available. Once available, the product can be characterized by a number of important variables. These include price, functionality, modularity, compatibility with other products, and ease of use.

That unique product then interacts with two multi-faceted elements that determine whether a technology will be accepted by end-users. The first element is end-users' ability to use a product. Determinants of that ability include variables such as the users' technical sophistication, technology infrastructure, planning capacity, human resources, and management capabilities.

The second multi-faceted element of acceptance is the users' need for the technology in question. Determinants of need include factors such as competitive environment, production requirements, and the organizations relations with its customers.

Finally, "ability to employ technology", and "need" combine to explain two aspects of technology acceptance - implementation and use. The distinction between implementation and use is important because much purchased technology is unused or under-used.

Also included in our model are numerous feedback loops. As examples, user experience with an existing product may affect vendor decisions about new products; changing user needs may affect vendor decisions about pricing or functionality; and widespread use within an organization can change both the organization's further need for the technology, and its ability to exploit that technology.

⁶ - This section is adapted from: Morell J.A., Tornatzky, L.G., and Behm, J. (1990) *CASE implementation: Dynamics through the technology life cycle*, presented at the CASE Adoption Workshop, Software Engineering Institute, Carnegie Mellon University, Pittsburgh PA, Nov. 13.

Findings

Value of MAP

MAP's advantages for end-users are considerable and well recognized. Table 1 summarizes the advantages noted by respondents.⁷ (Recall that there was a total of eight vendors and three users in the sample.)

{PRIVATE }Table 1: Stated advantages of MAP			
advantage	vendors	users	total
ease of integrating new equipment	3	2	5
vendor independence, ability to use a variety of equipment	5	0	5
easier applications development	3	0	3

Demand for MAP

Given the advantages laid out above, is MAP technology being actively sought? Not particularly. Not a single respondent made an unambiguous statement that there is a real demand in Europe for MAP. On the other hand, people expressed considerable optimism that such demand would develop.

Vendors are getting clear messages from the automobile industry that MAP is a requirement of selling automation equipment to that industry. Major automobile industry implementations of MAP - as opposed to test installations - however, are few. Outside the automobile sector there are three or four large installations, some testing going on, but not much real demand. Paraphrases of responses illustrate these points.

vendor #1: A few big companies require MAP, such as the auto industry in Europe and British Steel. But I'm not hearing demand from other companies. There is scattered interest, but that is about it. In the last 18 months or so interest has gotten stronger.

vendor #2 MMS will develop in the long term. But how fast? At present there are prototype products and more and more products. I have been to demonstrations at trade shows, and have been impressed with the number of new products on the market. Also, the .3 change will accelerate the use of MMS.

vendor #3 Demand in Germany is very low outside of the automobile industry, chemicals don't

⁷ - These data come from content analysis of a direct question on the advantages of open systems, as well as from related comments embedded in other questions. Unless otherwise noted, all data reported come from an analysis of this type.

care. I don't see any demand being conveyed through our technology groups, who know customer needs. I talk to end-users at seminars and meetings, and don't see any demand from there either.

But I do believe demand will increase from its present low state. Particularly in the UK, implementations and demonstrations will fuel interest.

Our new automation device is really good and it has MAP profiles as well as proprietary functionality. Customers will be drawn to the product, and thence to MAP.

vendor #4: Outside of one large customer, there is no interest in MAP in Europe, but I think the Japanese will really exploit it. One problem is that MAP was over-promoted in the 86-87 time frame.

vendor #5: A lot of interest in MMS over Ethernet, but not much actually going on. We have about 12 customers with at least one PLC that is doing something, pilots, testing, stuff like that. But there is not much factory floor MMS, people are buying single machines for testing. Two automobile companies and one chemical company are exceptions for us.

Some potential customers (all automobile companies in Germany) say that if you want to sell controllers to us, you must have MMS. This reinforces my sense that interest in MAP in Europe is much stronger than in the US.

vendor #6 In terms of demand for MAP, I see a lot of user pressure on vendors for it, but more talk than action, except for auto, EDF, and a few others.

vendor #7 The technical value of MMS is not well understood by users. At present there are only a limited number of experimental applications. I see slow growth in the next three years, with fewer than 10 large implementations in Europe in 1993.

vendor #8 MMS in France - big customers have pilots with good results, but only a few companies are moving to full implementation - EDF and Renault. MMS has 87 services. Customers want them all, but don't know why. They only need 10-20. Customers don't know their needs.

user #1 There are no other big installations in France that I know of. I asked a BMW plant in Germany if they plan to use MMS. They are only looking.

Explaining the State of Demand

The present low level of MAP use can be explained by three interlocking factors - cost, scale of implementation, and time horizon - of which cost is the single most important. This perspective emerges clearly from respondents' comments, paraphrased below.

vendor #1 People talk about long term planning, but in reality they buy what is cheaper at the moment. Savings come from life cycle costs. MMS/MAP makes sense for big and big medium companies. But there is a problem for smaller companies for two reasons: 1- cost, and 2- scaling, in

a small context, not being open is not such a big deal.

vendor #2 In the long term, a company found that 50% of the cost was in networking construction. An open system can bring down these large SI networking problems. These savings only show up in large scale implementation, not pilots.

vendor #3 As a developer, I know that MAP boards are too expensive. We can bring costs down by implementing one platform and porting it to others, thus reducing development cost.

vendor #4 It's too expensive in terms of initial cost. We try to promote it over a 5 year time frame, but people are not looking at it that way. They do have an extended life cycle view, but proprietary systems are 30% cheaper and that counts for a lot.

vendor #5 Users usually look at something more than up front cost. The customer's attitude is: "For an open solution, we will pay X more". The engineering staff makes a careful cost analysis of the options, and then they make an intuitive judgement about whether it is worth it.

vendor #6 The cost of PC boards will come down because those costs will parallel the price behavior of computers. We see this in his own business, where we can quote volume discounts. But the cost of MAP boards for PLCs will not come down because PLCs themselves will not to see a big drop in price, and the board prices will follow that dynamic.

One way to bring cost down is by action during the design process real costs are not so much in boards, but in embedded software. So by reuse of OSI software for telecommunications in PLCs and robots for instance, costs could be lowered. But to do this the device maker has to think in these terms, from the beginning consider integrating an MMS environment into the device. This involves fundamental design decisions, of which OSI is only a part.

vendor #7 Why is MAP more expensive: 1- cables; 2- vendors have to buy or develop additional software; 3- hardware is more complex. 4- engineering workforce - we may need 10 full time equivalent engineers on MAP, while a proprietary system would take 1 or 2.

vendor #8 Siemens has a dominant position, and they were slow to commit to MAP. They now have MAP products, but it took too long. They had a public plan to come out with MAP products slowly, and they did exactly what they said they would. But in the meantime they were pushing their proprietary systems, and MAP is still more expensive.

vendor #9 The value of MMS is not well understood by users, and it is expensive, badly integrated and supported. Success will require: 1-Ethernet; 2- Unix environment; 3- access point < \$10,000, and 4- support.

user #1 We made a corporate decision a few years ago was that each time they retooled a factory, we would install MAP. But we expected costs to come down, which they have not, so we are now questioning that policy.

user #2 We are committed to MAP, but the time line varies. We are waiting in old plants that are not well laid out, because the cabling costs are high. With regard to networks, the choice of

Ethernet was easy. For a PC an Ethernet card is 800DM, for broadband with card, modem, etc, its 4,000DM.

PLC boards are expensive, around 6,000DM. Others are waiting to see if it pays us. We think we will save money on the software development side, but other companies are not so convinced.

In addition to issues of cost and implementation, the information presented above provides three important insights about the cost of open system technology. First, one cannot assume that the cost behavior for such technology will parallel the traditional dramatic reduction in the cost of computing power. Second, product cost must be considered at the time when open system standards are being developed. Finally, careful attention to "reuse" in the product phase may ameliorate high costs that were built in during standards development.⁸

Explaining Implementation

If barriers to implementation are as high as they are portrayed in the previous section, why are decisions ever made to implement MAP? An answer comes from inspection of how implementation decisions were made in three companies who are committed to large MAP installations. In each case, the reasons cited for choosing MAP reflect the commonly stated value of the technology that *everyone* states. Overlaid on these reasons, however, is a centralized decision making structure that highly valued those advantages. Consider the scenarios outlined below, synthesized from much discussion with respondents on how they came to implement MAP technology.

User #1 We take a 20 year life cycle view, and have a long history of recognizing our need for open systems, based not only on belief but on needs studies we have done. Our problems involve a heterogeneous environment and the need to inter-connect networks. This belief was shared by very high level decision makers, including a person who reports to the head of the company. This high level information system planning group made the decision for the entire corporation.

User #2 We had a clear need to upgrade, our old system consisted of pair to pair communication. In discussions with our systems integrator, we realized that MMS does away with lots of detail, thus making programming easier. The choice of Ethernet over Broadband was easy. We looked at the number of PCs and PLCs we had, and realized how big the cost differential was. The actual decision was made centrally, by my group. Centralized planning was critical because there are not enough people in plants to do the work themselves.

User #3 We have quite a few plants. A corporate decision was made a few years ago that each time we retooled a factory, we would put in MAP. The choice was a strategic headquarters decision, based on a study by the central group in charge of shop floor computer environments for the company. The study team included people from the plants. The study pointed to idea that an open solution would be best.

"Support from the top" is an oft-stated condition for organizational change, and that principle

⁸ - Thanks to Laurent Steffan of Marben for some of the ideas put forward in this paragraph.

certainly seems to be working here.⁹ In all three cases the implementation decision came at a corporate level, from a perspective that rose above the immediate networking needs of any particular site. Usually though, "support from the top" means high level sanction for action taken by lower level personnel. In this case, it means both support and action by higher level authorities. Why might this be so?

We believe the answer can be found in the principles of ----, one of which states that a problem should be solved by the personnel who are closest to the problem. The need for factory networking has two components. One component is the short term need to connect machines and get a factory up and running. The second component is a longer term, more strategic problem. The company needs to insure itself against technological obsolescence, position itself to capitalize on new business opportunities, and insure long term overall corporate efficiency. That second component is *not* the immediate concern of plant level managers or engineers. Rather, it is precisely the concern of centralized corporate planners.

Vendor Position on MAP Product Development

If MAP implementation is limited and barriers are high, why do vendors go to the trouble and expense of making, selling, and supporting the technology? One reason is that the automobile industry is demanding MAP as a condition of being a supplier of automation equipment. Never mind that the industry has only partially acted on its stated convictions, the stated demand of such powerful customers cannot be ignored. A second reason seems to be that MAP really is a superior technical solution. We think many suppliers believe that such a solution *must* eventually become popular. Finally, vendors must hedge against a future in which MAP is the commonly accepted architecture for manufacturing networking.

We have encountered much speculation about how market dynamics may affect the interplay of proprietary and open systems in vendors' product strategies. Responses from the three automation equipment vendors in our sample indicate that this issue is salient but not critical. Questions about it elicited brief well considered responses, but little passion. Paraphrases of those responses appear below.

vendor #1 From the beginning, we saw MAP as the basis of our high-end communications product. Other companies however, may feel a tension, a vulnerability to opening up systems and keeping them proprietary. I believe that company X has used pricing and the timing of product introduction as a way of having a presence in the open system world, but still protecting their proprietary line.

vendor #2 There is a conflict related to markets where companies have a big market share with proprietary systems. Companies worry about losing market share in those areas. But we see offering open systems as a way of getting into a market where we want to expand.

⁹ - An important weakness of this analysis is the lack of a "non-MAP" control group. We originally planned to find sites which considered and rejected MAP. The comparison would have been useful, but we were not able to identify appropriate respondents.

vendor #3 We also have a proprietary communications system, and are worried that MAP's speed performance problems may give our proprietary systems a bad reputation. In all likelihood though, experience will solve the performance problems. A secondary problem is that standards will allow others to eat into our market. Still, we had no choice because of pressure from the auto industry.

The Standard Setting Process Counts

Throughout the interviews, respondents made it clear that MAP product adoption is affected by the process which generated the standard. One obvious example is the matter of product cost - MAP conformance requires expensive hardware. This issue was either not considered during the standard setting process, or considered and discounted. History has shown us the enormity of this error.

Another problem involved the stability of the standard. Both the conversion to version three and the present efforts to move from a "draft international standard to an "international standard" introduced uncertainty that affected both the standard and the technology in which the standard is embedded.

Finally, MAP was associated with a good deal of publicity in the trade press, and several respondents commented that this publicity served only to set unrealistic expectations.

Discussion

It is clear from the above data that the course of MAP has not worked out as many had hoped. While there has unquestionably been a good deal of success, MAP is far from the accepted way of networking factories. Given these findings and the model of user/vendor interaction cited above, how might we better understand the deployment of an open system technology such as MAP?

The most dramatic finding is that organized interactions among users and vendors can actually produce not only new products, but a radically new set of technological options based on open systems. The fact is that MAP is an accepted standard, that MAP-conformant products are being produced, and that a considerable number of test installations and a few large scale implementations do exist. In spite of whatever mistakes the developers and partisans of MAP may have committed, they obviously did many things right.

Whatever mistakes were made show up most clearly in the second level of the model - "availability of products". Pricing is clearly the major problem. MAP product pricing has not followed the behavior of pricing for computing power, and at the moment shows no sign of doing so. Lesser problems relate to functionality (primarily speed) and the long delay in accepting Ethernet into the standard.

These problems place a special burden on the link between "availability of products" and "user ability to employ the technology". That link may be especially problematic if the speculation of two respondents is correct, that users often do not appreciate the full benefits of MAP. Under these circumstances there is a special burden on vendors' marketing staff to understand the value of the technology they are selling, to communicate that information to potential users, and to assist with problems of implementation. In this regard it is worth noting that one vendor complained that his company's marketing staff was not up to the task of explaining the new and more complex MAP technology to potential users.

There seems to be a serious problem in the link between the top and bottom of the model - supplier decisions and technology acceptance. A few comments interspersed in the interviews indicate that users' statements about their desire for MAP technology is greater than their willingness to actually buy it. Some users who profess to want MAP technology are only willing to acquire limited quantities for test purposes. We have no hard data as to why this may be so, but we suspect it is because those who articulate strategic intent to vendors do not have full control over actual decisions to purchase equipment. This internal inconsistency then results in skewed feedback to vendors, who then rely on untrustworthy information to commit to product development.

Vendors clearly recognize that "vendor independence" is one of the main attractions for users of open system technology. They also realize that no matter how concerned they may be about furthering that independence, they may have no choice but to do so. The data clearly show that customer demand and the need to stay competitive virtually force one to market open systems. This decision has major consequences for the second level of the model - "product availability".

One possibility is for a vendor to assume that his customers will begin to "mix and match", and in

reaction, to try to compete by offering lower prices. This would be a mistake for several reasons. First, the ability to switch vendors does not mean that customers will do so. Trusted vendor - user relationships are valued, and in any case, users are likely to value functionality and maintenance over the lowest possible price. Further, there is a general trend in manufacturing to limit the number of one's suppliers, not to increase them.

If not price, what? It seems that the move to open systems will put a greater burden than ever on vendors to compete as they traditionally have - on the basis of product functionality, customer service, and maintenance. Customer service, however, is precisely the weakness that some vendors complain about when asked about their difficulties in offering open system products.

The view outlined above is one of a system in stress - because of some special characteristics of MAP technology, interactions among various elements of the "vendor/supplier" model are not working well. We believe that one approach to solving these problems is to encourage more concerted action by third parties. Our reason for this recommendation is that there are useful tactics that cannot be done (or at least not done well) without the action of trade associations, consortia, and other similar entities. Three examples will serve to illustrate this point.¹⁰

Example #1: The Standard Development Process A standard is valuable only if particular conditions apply. The standard must: 1- represent the needs of potential users; 2- allow the development of products that are technically sound and cost effective for vendor development; 3- be developed in a manner that is synchronized with vendors' product development activities; and 4- be unambiguous and supported by conformance tests and tools for conformance testing.

In addition, standards must be developed within a fairly narrow span along the technology development life cycle. Standard development must begin only *after* it is clear that a particular technology is the solution of choice to a problem, and *before* any single vendor locks the market into its proprietary solution.¹¹

Thus for a standard to be useful a lot of work has to be done within a relatively short period of time. Third party assistance is critical if the deadlines are to be met. Consider. 1- Consortia and trade groups are needed for developing consensus on when the time is ripe for a new standard, and what characteristics the standard must have to satisfy the user and vendor communities. 2- Government agencies and private consortia can provide credible neutral locations for discussing controversial issues. 3- Consortia can provide legal protection for meetings that might otherwise violate anti-trust provisions. 4- Government and consortial funding has fueled the development of conformance tests and tools. 5- To the extent that standards have implications for foreign trade protection, the role of government is indispensable.

Example #2: Market Development: Despite strong support from the automobile industry, MAP in

¹⁰ - These examples are adapted from our presentation to the Technology Transfer Society, cited earlier.

¹¹ - An in-depth analysis of standards and technology development is available in an unpublished white paper available from the Industrial Technology Institute: Morell, J.A. (1990) *Standards, the standards process and technology acceptance: An exploration of relationships*

Europe remains far from a generally accepted solution for factory networking. If an industry of that size and buying power cannot generate the necessary critical mass, cross-sector action may be required. It is hard to imagine such cross sector activity being effective without some kind of consortial or government action. Over and above the general problem of needing to coordinate a complex activity, a third party forum is needed to rationalize complex differences in technical needs, and facilitate meaningful discussions between potential users and the vendors who will have to produce saleable products.

Example #3: Supporting Implementation: Several problems arise because of the large scale implementation that is required before mature, proven integration technologies will be cost effective in any given setting. Beyond the obvious obstacle of cost, other serious difficulties can be identified. One major problem is that difficult organizational change may be needed to support technology that is useful only if alterations are made in how work is done across the organization. As an example, technology which allows concurrent engineering is valuable only if a variety of groups change their normal ways of relating to each other. A related problem is that a desire for integration requires a shift in commitment from local to global optimization. At present those with responsibilities for discrete parts of an organization will strive to optimize only that part of the organization for which they are responsible.

Third party assistance can help with these problems. One dimension of implementation assistance is to lower the cost of deploying integration technology. As an example, third parties may be useful in tracking technological developments, disseminating information from demonstration programs, developing implementation guidelines, or working out business case models. Individual companies may not be able to gain access to the sensitive data needed to develop this information, or afford to do the work on their own. Once developed however, the information would be useful in numerous settings.

Third party action of the type described above is needed because standards have only a narrow window of opportunity in which to succeed. If standard conformant technology does not achieve a critical mass in time, two factors may make the standard obsolete. First, new technological developments may make the standard obsolete. Either technology will solve problems in lieu of a standard, or highly desirable new functionality may not be accommodated by the standard. In either case the standard will not succeed. Only if a standard reaches a critical mass will those new developments be specifically planned with conformance to the standard in mind.

A related question is what it means for standard conformant technology to reach a "critical mass". One obvious possibility is that markets get large enough that costs begin to come down, thus setting up an ongoing cycle of growth and cost reduction. In the case of MAP, however, we have seen that this possibility may be limited. Thus other dimensions of "critical mass" must be defined and pursued. We propose two elements of critical mass which should be furthered for MAP technology - encouraging a profusion of third party niche products which add tremendous value to MAP architectures; and expanding the base of expertise for exploiting MAP. Together, these activities may make MAP the dominant accepted way of networking factories.