Whitepaper

Manufacturing Systems Integration

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1 Introduction

Modern Manufacturers experience enormous pressure to survive and grow. The global economy has introduced the threat of low cost providers in Asia and Eastern Europe; consumers demand ever more personalized products and marketers insist on increasingly agile responses to market forces. Meanwhile, investors require solid return on investments and expect plants to do more with less.

There are many different responses to these pressures, but a common reaction has been to improve efficiencies and business decision making through better automation of business processes. Companies both large, and small, have implemented integrated business systems to improve both the efficiency and effectiveness of those processes.

Some focus on their core business processes with Enterprise Resource Planning (ERP) systems like SAP, Oracle 11i or Microsoft Dynamics. Others turn to Customer Relationship Management Systems (CRM) like Siebel or Microsoft CRM to improve their sales and customer satisfaction processes. At some point, many will also investigate supply chain optimization solutions like SAP APO or I2.

No matter where these businesses start, the results often fall short of original expectations – for a variety of reasons. One common reason is due to lack of integration between these core software systems and the manufacturing environment. In many companies, manufacturing accounts for over 50% of the organization’s costs – and yet large scale business automation projects often fail to address the needs of manufacturing – focusing on the corporate or financial needs instead.

For many businesses, it is only by recognizing the importance of the manufacturing sites, along with their unique requirements, that companies can truly realize the benefits of their software investments. Optimized supply chain plans are useless when based upon out-of date inventory and production information, or when they are not visible to the shop floor. Likewise, corporate measurements of business performance require accurate and timely information from the shop floor.

This paper examines some of the benefits, objectives and challenges of improving integration between business systems (especially ERP) and manufacturing systems. The author, Chris Boothroyd, is the owner of Avatar CTS, a Phoenix based systems integration consultancy. Prior to starting Avatar CTS in 2007, the author spent over sixteen years working for Honeywell Process Solutions and this paper also draws from those experiences: helping Fortune 50 companies to integrate their business systems with Manufacturing Execution Systems (MES).

2 Why Integrate?

There are a number of generic benefits to improved systems integration. The obvious, surface level, benefits being reduced effort (of data entry) and fewer errors. While these alone can be significant, there are often even more significant benefits that result from enabling business processes that were previously impractical.

2.1 Specific Benefits

The driving forces for business to shop floor integration vary with the exact nature and operating philosophy of each company. However, the examples below are real world examples:

Increase Revenue	• The efficient flow of accurate inventory and production results to corporate (and supply chain) planning systems can enable businesses to adapt more rapidly to changing market conditions. For example: responding to opportunities for sale of unique, high value, products.
	• Improved maintenance strategies (enabled by automated collection of machine/equipment use and health) can result in better asset utilization, and ultimately increased production.
Reduced Cost	• The improved maintenance strategies referenced above will also typically result in fewer unnecessary preventative maintenance orders; reducing cost of labor and spare parts
	• Providing accurate feedback to MRP II planning tools is essential to ensure that purchase orders are placed for the right materials and the right time
	• Reduced data entry time & transcription errors. (In one example, transcription errors resulted in incorrect invoice data being entered and vendors being overpaid).
Increase Free Cash Flow	• More efficient materials planning (by feedback to MRP II) helps to lower raw materials inventories and ensure that the right products are made, this lowering finished goods inventories.
Better Decision Making	• People at different levels of the organization typically work with the system(s) that provide the most value to them, personally. So, business people tend to look to the ERP system, while plant personnel turn to shop floor systems. When these two systems are not in tune with one another, someone is looking at the wrong data, and could be making the wrong decisions.

2.2 Typical Integration Scenarios

Just as the priorities and potential benefits vary from industry to industry and business to business, so do the specific integration scenarios that delivery those benefits. Discrete manufacturers deal in individual parts and care little for recipes, but for a batch chemical company, recipe management is critical. For an oil refiner, equipment capacities and constraints dictate production, where in other industries the notion of production capacity is much more flexible. Again, the following are examples of real world integration scenarios, but are by no means exhaustive:

• Communicate plan / schedule to operations	The best plan in the world is useless unless it is followed, yet the output of advanced planning and scheduling activities is often not clear to shop floor personnel. Either they continue follow an out-of date version of the plan, or (and this actually happens) they have their own idea about how the plant/mill should be operated. By transferring the plan/schedule into a system and format with which the production personnel feel comfortable and will refer to, and by ensuring that updates are quickly made available, businesses can help to ensure that the plan is followed. In some cases, of course, cultural and even organizational changes may also be required to ensure the effectiveness of such a technical solution.
• Link actual production with planned production	Enables accurate tracking of inventory consumed, production values, scrap and/or rework. Allows planners to examine basis of their planning models and recognize that, sometimes, the model needs to be adjusted.
• Synchronize inventories	Where either raw material, intermediate or finished goods inventory can be physically measured and tracked, that physical measurement is liable to be far more accurate than the "booked inventory" in the business system. On a regular basis, inventory snapshots (or material movements) can be posted to the business system from shop floor systems, helping to improve the efficiency of production planning, purchasing and supply chain operations.

• Raise work order requests	Where the health/condition of shop floor machinery/equipment can be monitored through on-board instrumentation (or implied by other data), there is an opportunity to go beyond the "use based" maintenance strategy described above. Rather, if impending breakdown can be implied, then an alert can be sent to the CMMS system, automatically triggering an unplanned work order. In a related scenario, production personnel are often in a position to recognize that equipment maintenance is required, but have not access/training in use of the CMMS system. By providing them with a simple on-line tool (ideally integrated with their existing shop floor system) to report such incidents, again unplanned work orders can be generated and the potential breakdown/failure avoided.
• Maintenance planning based on equipment use	In machine/equipment intensive environments, maintenance is often carried out on a calendar basis. So, for example, the impeller on a pump is replaced every 30 days. This preventative maintenance approach helps to prevent breakdowns (and loss of production), but also guarantees that a maintenance technician will use up 1 impeller a month, and work on that pump for (say) two hours – even if the pump was only used for 10 hours during the month. Where shop floor systems allow the usage (and condition) of machinery to be monitored, the maintenance strategy can be changed. Instead of replacing the impeller every 30 days, the maintenance plan can call for the impeller to be after 700 hours of operation. Now only worn out impellers will be replaced. However, in a facility which has (say) 1500 such pumps, the process of manually entering the usage data into the Computerized Maintenance Management System (CMMS) would be prohibitive. Thus integration of shop floor devices with the CMMS enables a business process that would otherwise be impractical.
• Communicate maintenance plan to operations	No matter what the maintenance strategy, equipment maintenance often means downtime (or reduced capacity). Operations (production) personnel tend to focus on their jobs and the systems that support them, yet they need to know about impending interruptions. By transferring relevant portions of the maintenance plan from the CMMS to the operational systems, production personnel have visibility to planned maintenance activities.

• Manage master formulas/recipes	In batch chemical plants, the production recipe dictates how products are made. In certain markets (e.g. retail) there is a strong imperative to frequently update/alter the product formulation. Research departments dream up new recipes and these recipes need to be communicated to the production site(s). However, the research department does not know (or care) how the individual activities in the recipe are automated, nor on which equipment. So the production site(s) need to be able to receive a new recipe and map it onto existing production cells and control strategies. With some plants manufacturing hundreds of different products, and formula changes occurring daily, automation of this recipe transfer step can be essential.

The underlying objective of all these scenarios was to optimize existing business processes and/or enable new processes through automated interoperability.

3 Challenges to Successful Integration

There are five principal challenges to successful integration projects:

- Scope
- Process “Blind Spots”
- Cultural Issues and Terminology
- Model Disconnects
- Technology

3.1 What is the scope?

Surprising though it might seem, many integration projects start before the business really understands what problem (or problems) they are trying to solve by integrating. This is especially true in large corporations where, for example, improved integration is a corporate I.T. strategy, and the project in question is simply the “next cab off the rank”.

In some cases, the project team simply takes on far too much, attempting to find each and every touch point between the systems and planning to address them all. The net result can be a project that can never be delivered within the planned budget and schedule constraints.

3.2 Process Blind Spots

The implementation of large scale systems like Enterprise Resource Planning (ERP) or Customer Relationship Management (CRM) often begins by mapping out the company’s business processes. Each high level process is broken down into small processes and, ultimately, into activities. Then the activities are mapped onto capabilities of the software system and, eventually, automated. Where a process cannot be automated by the system in question, the most common solution is to mark that as interface to an external system. The process map stops at that point.

However, business processes don’t just stop because the ERP (or other) system doesn’t have the functionality to automate the entire process. No, they continue on in other more-specialized environments: such as Manufacturing Execution Systems (MES), specialized software packages, robots etc. The team mapping out the processes can become so focused on their project that they develop blind spots and ignore the rest of the process.

Not only can this lead to inefficiencies in the practical execution of the processes, but in some cases can impact other processes. For example:

> Suppose a process map shows that the final step of a process is for the ERP system to print a report. On further analysis we might find that someone types data from that report into another application. We have essentially introduced a manual step into the process which may become a bottle neck and/or a source of error.

This poor understanding of the end-to-end processes can have secondary, unpredictable results. In one real life example:

> A process called for shipment records to be finalized on the fourth day of the month (for the previous month). This process was mapped out almost entirely in the ERP system, with an interface to download the results to a production system. Another process called for the production facility to finalize its inventory postings by the end of the third day. This process was managed almost entirely outside of the ERP system and appeared on the process map as an interface.

Had the processes been fully mapped out, the team would have found that the shipment record data was an essential input to the inventory calculation process. So the demand for the production site to close inventory on day three when they were dependent upon a process that did not close until day four was impossible to meet.

Even though the process maps showed the necessary interfaces, they did not show the *interdependency* of the two processes. This problem was not detected until the entire system went live and the company attempted to close the first month's books.

3.3 Cultural Issues and Terminology

In large manufacturing organizations, the world of the corporate offices is very different from that of the manufacturing sites. The problems faced and conquered on a daily basis by production personnel are very different from those addressed by corporate strategists. Safety and production continuity are the watchwords of the shop floor, where things can change in the blink of an eye.

Even though the manufacturing sites use standard Information Technology offerings in their administrative offices and to manage many of their daily tasks, there are also highly specialized technologies applied in most production facilities. Whether they are conveyers, packing machines or process control systems; these technologies require a very different set of skills to operate and maintain than the more run of the mill I.T. personnel have to offer. As such, the production sites often develop dedicated groups who are responsible for this specialized equipment. A line is effectively drawn between corporate I.T. and plant specialists and turf wars are commonplace.

Over time, the vocabulary used by corporate decision makers; I.T. personnel; plant supervisors and plant technologists becomes highly specialized and jargonized – presenting significant barriers to effective communication. Worse, some words and phrases will be used by several groups but will have subtly different interpretations, which can result in one side misinterpreting the others. For example:

> The term "real time" when used by corporate I.T. personnel generally means that information is presented to users as and when they request it and is updated within a few minutes of new data being available. To a chemical plant control room operator, though, "real time" means what is happening now: what is the current temperature and pressure in a reactor; what is the current level in a tank? Telling him that the tank has overflowed ten minutes after it happened just isn't good enough. Yet, if you were to hold a requirements meeting with both groups represented the term could be discussed happily by both groups, with *neither group realizing that they each mean something entirely different*.

This combination of cultural barriers and conflicting lexicons can undermine project progress; presenting artificial barriers to accurate requirements analysis and potentially resulting in lack of "buy in" to the project from one faction, or another.

3.4 Model Disconnects

Every software system has some model of the real world: a CRM system will model a company's customers and their organizations and (perhaps) the company's products and services; a production planning system will model the workstations/equipment; operations and materials; etc. The level of detail in the model will generally be based upon the needs of that system. For example, an inventory tracking system needs to know the capacity of a hopper or drum (and perhaps its dimensions) but a CMMS system will need to know about all of the spare parts (covers; hinges; nuts and bolts) required to maintain that hopper. Similarly, a supply chain management system will need to know how much inventory a plant has by product but not in which hopper/hoppers the inventory is stored.

Sometimes this difference in model granularity can present a barrier to integration. For example:

> Let's say that a company's ERP system tracks shipments of finished goods from the manufacturing site by recording the marketing part numbers delivered to customers. The same physical product could be sold to many different customers in different configurations and for different prices. However, the manufacturing site doesn't usually care how the product was sold – they just need to know the total of the total number of physical products shipped. The shipment records use marketing model numbers, but the production site wants to know physical part numbers. Before the shipment records can be used by the production site, we need to translate marketing model numbers into their physical equivalents.

Even where the model granularity is the same in two given systems, there are still naming issues to deal with. For example:

> A manufacturing company with production sites in, say, Mexico and Arizona may choose to name all products and raw materials with a standard material code (say a 10 digit number). However, suppose that the Manufacturing Execution Systems (MES) at each site were implemented by local contractors who chose English and Spanish names for the materials. Before messages can be exchanged between the sites MES and the ERP system, the names must be translated from English/Spanish into their 10 digit equivalent.

3.5 Integration Technology

The last challenge to successful integration is that of the technology used to implement the solution. Oddly enough, many project teams jump straight to this question and spend much more of their time and attention on technology than on addressing the other, very real, challenges to success.

While not surprising, this emphasis on solving the technology problem is unnecessary. Certainly, there have been integration projects that ran into technical difficulties, but in general the technology issues have merely exacerbated underlying scope, process, cultural or model issues.

4 Strategies for Success

4.1 Coping with the Scope Issue

4.1.1 Look to Others

In the early stages of scope definition, there may be a period where the team really has no idea what the project is trying to accomplish. (This happens more often than you might imagine). In times like these the examples of other businesses (or even other industries) can be helpful in mapping out the objectives.

A discussion with the supplier of one, or more, of the systems in question can lead them to share examples of successful projects that they have implemented. Ask the supplier *why* the business did what they did, as well as *how* they did it.

In addition, locating relevant standards for message exchange that have been developed by industry trade associations (e.g. CIDEX, ISA S95) can help to identify important integration scenarios and, ultimately, map out the overall project scope.

4.1.2 Focus on Business Benefit

Believe it or not, some project leaders and consultants forget this rather obvious truth: just because information *can* be passed automatically from one system to another does not mean that it *should*. The project team and its leaders need to begin with an examination of business value:

- What benefits will be delivered to the business by integrating the two systems?
- What kinds of integration scenarios will support those business benefits?
- How much value will any given scenario deliver?
- Are other scenarios dependent upon this scenario?

The next question that needs to be addressed is one of cost:

- What is the cost of automating a given integration scenario?
- What are the risks (to the business or to the project) associated with automating that scenario?
- Do the benefits outweigh the cost and risks?

4.2 Better Business Process Mapping

Ideally, all of the systems to be integrated would be implemented in parallel with separate, but coordinated, project teams. These teams would map out the processes of the entire business and make realistic and informed decisions about where the various process activities should be automated. The process maps would always be end-to-end, ignoring artificial system boundaries.

If that ideal situation is not possible, then the business processes involved in the integration should certainly be re-mapped from end-to-end. The owners of all affected systems should also be forewarned that changes may be required in their system implementations in order to ensure smooth operation of the integrated solution. Finally, the team should examine all of the affected business processes, looking for primary and secondary interactions between the processes.

4.3 Breaking Through Culture and Terminology Barriers

Solving cultural barriers can be a significant hurdle, but being aware that such barriers exist is an important first step. Armed with that knowledge, the team leader can ensure that all stake holders are represented in the project team and can also secure executive sponsorship for the project (from a level that crosses all/most of the departments involved).

Again, awareness of potential terminology issues can allow such issues to be identified more quickly. Ask each stakeholder to discuss the project from their perspective and to take the time to explain important terms and concepts. If necessary, a team lexicon (a "Rosetta Stone") can be prepared.

External consultants – especially those who understand both the manufacturing and the corporate environment – can become the mediators between departments and so can help to accelerate the development of a set of shared objectives and that all stake holders have a common understanding of those objectives.

4.4 Resolving Model Disconnect

As has been discussed, the software applications typically build their model of the physical world based upon the level of granularity needed by that system. The needs of other systems are not considered.

Integration projects are simplified greatly if the models have a one-to-one mapping between them. For example:

> If there is a raw material called WATER in one system, there is also a material (and only one) for water in another system. The second example does not have to be called WATER (it could be called AGUA, for example) but having one, and only one, instance of water in the second system simplifies things tremendously.

If one-to-one mapping cannot be achieved, then many-to-one mapping is the next goal. Here, many items in the source of a message are represented by a single item in the destination. For example:

> An inventory tracking system may have storage locations of RL1S1, RL1S2 and RL1S5 all of which hold a product called DVD-RW. If the Supply Chain Management (SCM) system tracks inventory of that product, it will not care where in the warehouse the product is stored, so it may have an inventory location called WAREHOUSE. As long as we send inventory related messages from the warehouse management system to the SCM system, we can map RL1S1 to WAREHOUSE; RL1S2 to WAREHOUSE and RL1S5 to WAREHOUSE and the SCM system will understand all of these messages.
>
> However, what happens if we try to send a message from the SCM system to the warehouse? To which warehouse location should the message be directed? If it needs to go to all of them, how do we split the quantities in the message across these three locations? This is a one-to-many problem.

It is very rare for one-to-many mappings to be successfully handled by an automated interface. In most cases, the external model will need to be modified to allow the business objectives of the integration scenario to be achieved.

NOTE: Identifying and resolving model mapping issues can be a huge bottleneck to the project (especially where very large models are involved). The model owners themselves can be a barrier to resolution – often they do not even accept that a problem exists and may have little incentive to make changes. As ever, early awareness of the problem combined with clear communication and executive support are the best weapons to use.

4.5 Choosing the Right Technology

Today there is a wide availability of robust, easy-to-use integration middleware products, which provide a re-useable infrastructure for message delivery; message routing and message translation. Products such as SAP NetWeaver; IBM Websphere or Microsoft BizTalk Server provide such services; support business process mapping and automation; provide a wealth of adapters for common software systems; and can even simplify secure transmission of messages across the internet.

The recent popularity of XML and Web Services, as well as the advent of Service Oriented Architectures also lowers the technical barriers to integration – by ensuring a common format for message delivery and interpretation. However, the notion that Web Services or XML deliver integration is false.

A well composed Web Service exposes the capabilities of a software system in such a way that they can easily be understood (at a business level) and can easily be consumed by a variety of other software applications. However, the content of an XML message conforms to some pre-defined schema. Unless two systems understand and expect the same schema as one-another, then using XML does not preclude the need to translate a message from one schema to another.

A number of standards initiatives are underway to help define common XML schema that can be shared by many different software packages, out of the box. Standards bodies like OAGIS & CIDEX have already published hundreds of such schema and, in the long run, these standardized schemas should dramatically reduce the barriers to system integration projects.

In the meantime, the combination of the aforementioned middleware solutions with XML and Web Services has become the most common approach for larger integration projects. The Web Services provide a common way to access system services and process messages; while the middleware takes care of coordinating message flow and performing schema translations.

For smaller projects, custom code often fills the need for coordinating processes and message translation – although such code can become unwieldy if the system complexity increases significantly over the life cycle of the solution.

5 Conclusion

Huge benefits can be delivered through effective integration of software systems and applications and the biggest benefits can come from enabling new and innovative business processes. The challenges to effective integration come more from people and organization than they do from technology, and good project management, accurate scope definition, cross functional team work and committed executive sponsorship are the foundations of successful projects. Technological challenges do exist, but technology has advanced to the point where technology can be more of an asset than a barrier.

The bottom line is that you can reduce costs; make better (and more effective) decisions and even grow your business by eliminating the artificial barriers between systems.