Easy Access To Everything - Or How the Web Can Bring It All Together

Over the years, engineering teams from numerous automation companies have created highly focused engineering tools to manage and maintain steel mill equipment, control systems and production. This paper outlines the methods and benefits of using existing web technology with a Data Center approach to create a unifying environment to deliver these applications and more, over a plant network. Old programs are given new life by linking them together in a secure space that can pass context data at runtime. Tools are integrated on the web site with other analysis and maintenance functions including production reports, model logs, knowledge bases, diagnostic reports and status dashboards.

This is accomplished by adding two new layers on top of the industry standard Manufacturing Control System model without the need to change it. Using this approach, the automation and steel industries maintain their intellectual and practical investment and avoid the huge risks associated with a model update or replacement. To state this more simply, industry can reap many benefits from new technology without re-work or risk to the dominant automation model by building on what already exists.

Manufacturing Control System

Most steel automation systems continue to be built around the Manufacturing Control System (MCS) model developed and widely adopted in the early 1970s. It has a hierarchical structure, with distinct function blocks contained in discrete levels of distributed control, as diagramed in Figure 1. Commercial computing power, database design and networking infrastructure were in their infancy when the model was first used, and it would be years before inexpensive computers on reliable networks were widely available. For these reasons, the Distributed Control System (DCS) blocks were well defined and, for the most part, well delineated within each manufacturing level. Data typically flowed from the higher levels to the lower without much propagation back up the chain. For example, a Level2 setup model would receive signals from Level1 and apply these as adaptations to mill setup tables. The data rarely moved beyond this point and, when it did, only with technical difficulty and cost. Valuable operational data often dead-ended in log files or filing cabinets, never to be seen again.

The development of MCS concepts addressed many critical shortcomings of the old batch run mechanical mill and leveraged the emerging advances in automation hardware, computing power and networking. Even though the computers and networks developed at the time by Digital Equipment Corporation (DEC) and others were proprietary, expensive and difficult to maintain, there is no question that results of their application were *'game changing'* for those steel producers that adapted and '*game over'* for those who did not.

This paper demonstrates how to use existing Web technology to build a unifying environment to manage and maintain modern steel mill equipment, control systems and production over a single plant-wide network.

As time passed, the focus of hardware suppliers started migrating from large platforms to the smaller, and cheaper, Personal Computer (PC), ideally suited for key roles in the Distributed Control System (DCS) function blocks. At the same time, operating systems and software evolved to be open and object oriented, with a new flexibility not previously thought possible. During this stage, even the monolithic DEC was forced to concede to the shifting marketplace when they repackaged their premier operating system from the proprietary VAX/VMS to OpenVMS, in an effort to stay in the game.

By the 1990's and into the 2000's, most automation suppliers continued responding to pressure from industry over issues of openness, computing power and cost. They began to embrace the burgeoning PC and TCP/IP protocol over thin wire Ethernet hardware as de facto industry standards. Today, modern systems continue the trend spurred on by ever increasing technology advances and lower costs. Problems of computing horsepower and connectivity are now marginalized to the point where the typical automation engineer assumes a starting point of the ubiquitous PC, networked with virtually unlimited TCP/IP bandwidth over thin net or fiber lines. When more power is needed, another PC or switch is added. Simple.

But what happened to the MCS model during this time? In short, very little.

The number of computers on the plant floor grew tremendously, and with it an increased reliance on high speed data processing for modeling, but the fundamental MCS levels and DCS function blocks remained untouched.

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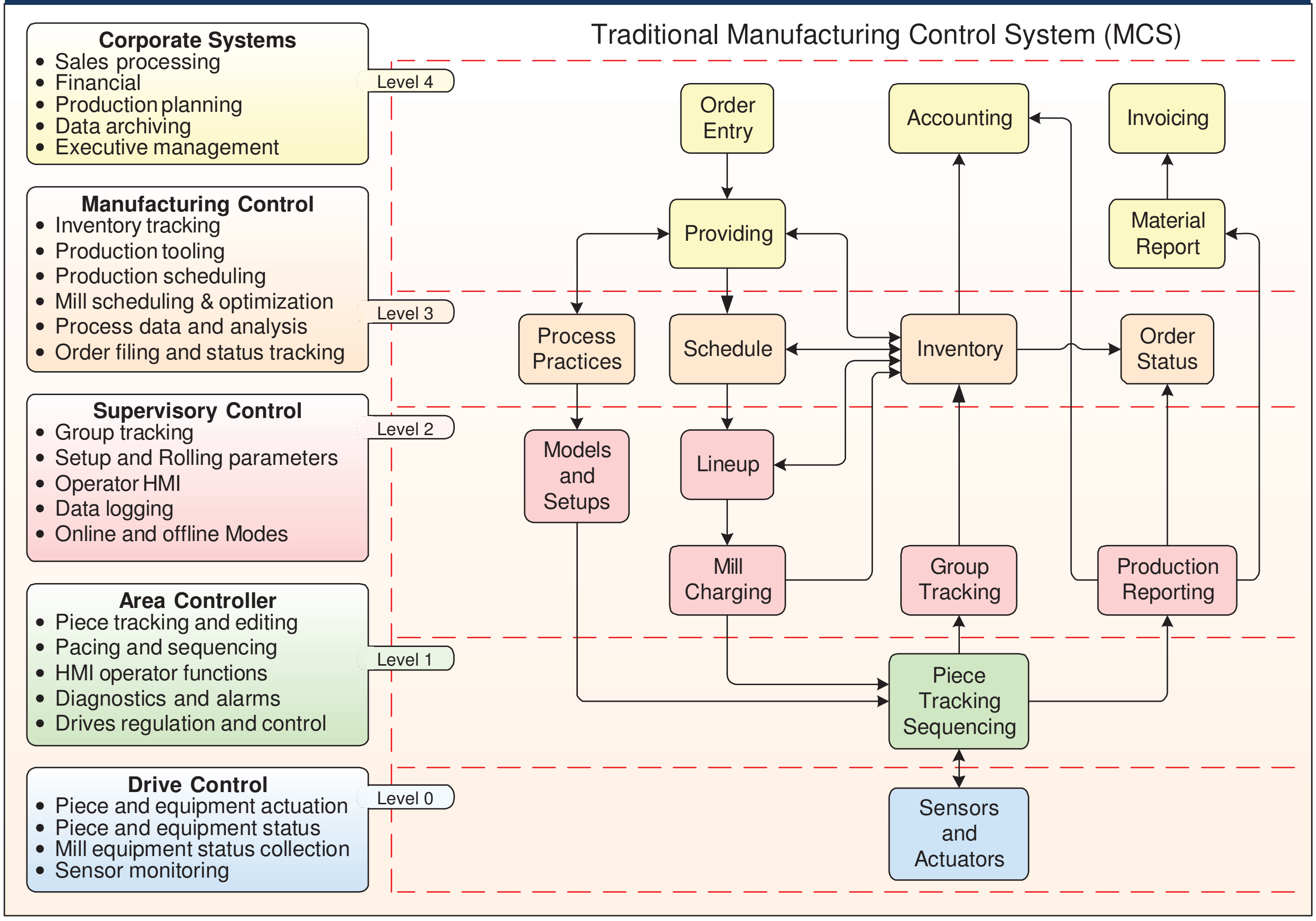
Figure 1



The Manufacturing Control System

The TCP/IP protocol, running through high speed switches and hubs, emerged from the global rush to the 'Internet Super Highway' to become 'the only game in town' but again, and for the most part, MCS and DCS did not change. To be sure, some of the lines between the manufacturing levels have blurred recently, and some DCS functions may overlap where they were once clear-cut, but the underlying philosophy prevails.

The MCS is a technology model. When dated, in terms of it's technological age, it is very old indeed and, in fact, could fairly be called the 'legacy' MCS. The robust, well thought out design that helped it prevail through several computer and network generations, now provides strong reasons to believe it will continue to be a solid foundation for automation systems.

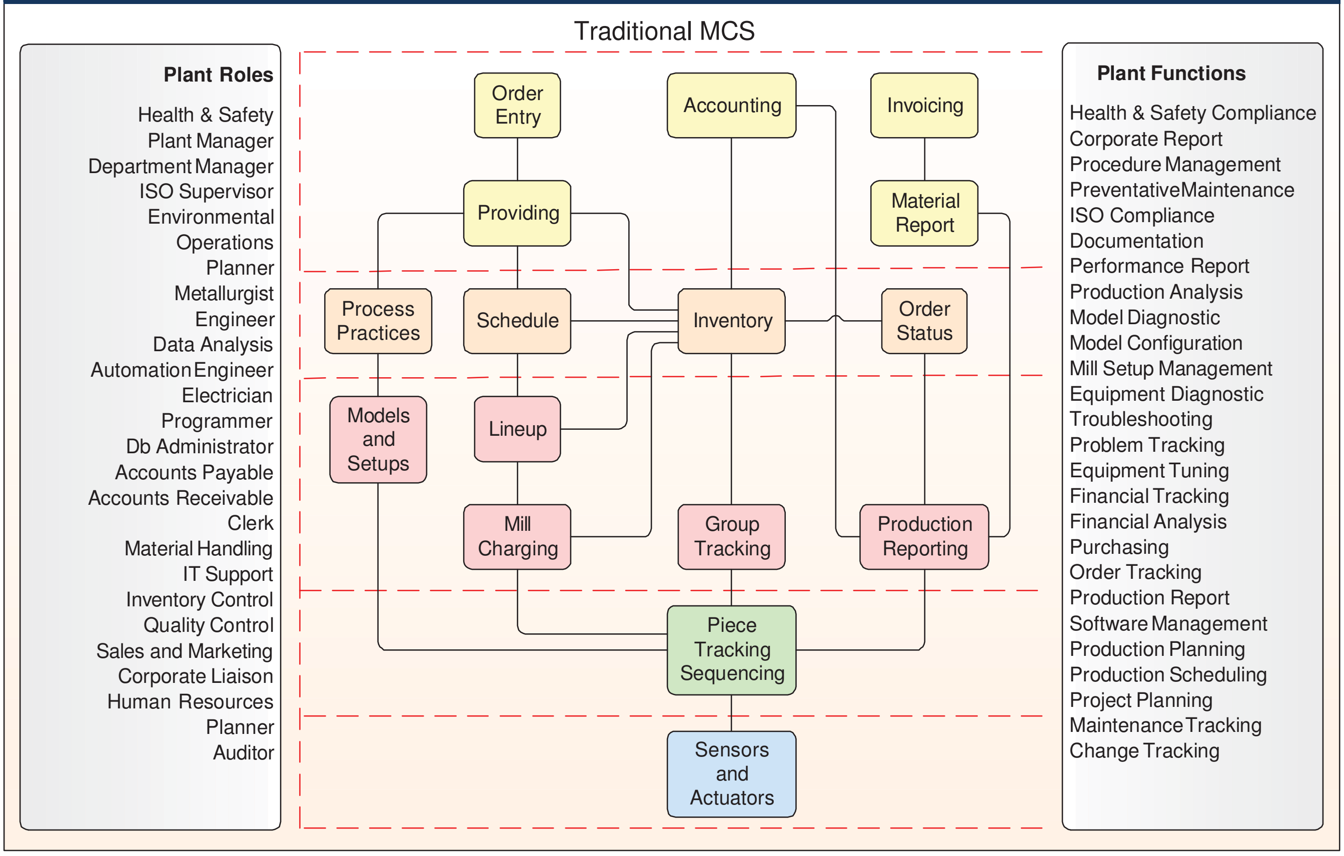
Traditional Manufacturing Support

Building a new steel mill, or expanding an existing facility, is a very large and complex undertaking that is engineered through the combined efforts of highly skilled teams with specialized knowledge and tools. Upgrade projects are smaller in scope and similar in nature, but have the additional complexities and constraints imposed by integrating the new with existing equipment, and by working around the ongoing mill production schedules. It is common practice to engage multiple suppliers and integrators on a project and have individual teams focus on a single, or a few DCS functions.

As a result of this distributed engineering, each vendor typically supplies their own array of task specific tools for low level configuration, diagnostics and troubleshooting. After commissioning, these tools are left behind for the customer who will frequently identify them collectively as the 'engineering tool box'. Because intimate knowledge of process hardware and software is required to use them properly, it becomes imperative that the customer maintain a number of employees with the required skills. This role often falls within the electricians domain because of their unique central relationship with the mill systems. This ongoing maintenance cost is not welcome, but it is viewed as essential to running the facility. With the passage of time and the inevitable addition of more tools, the box evolves to become the 'legacy engineering tool box'.

This, however, is only one contributing factor in the success or failure of the enterprise. Once commissioning ends, the plant is signed over to 'plant operations' with dozens of traditional plant roles to fill. Each role relates, and often overlaps, with the plant functions listed in Figure 2. For most of these tasks, the MCS serves as a vital data source providing essential information. This situation holds true even when there was little, or no, focus on future operational needs during the design and automation deployment. The MCS now has the role of the all important data source for everyone.

Figure 2



Typical plant roles and functions

As production increases and plant roles mature, the pressure to provide better and more complete data gathering, reporting and analysis increases. Usually at this stage, the company takes advantage of employee ingenuity and problem solving skills to create 'home grown' solutions that enhance the capabilities of the 'engineering tool box'. For example, in a typical steel mill, the HMI system is often the only well understood environment with the ability to easily cross DCS function and MCS level boundaries. Because of this, it is sometimes commandeered for diagnostic and analytical functions that fall outside the intended scope of real time operator displays.

The 17th century French author, Francois del la Rochefoucauld wrote, 'the only thing constant in life is change'. This observation applies more than ever in a modern steel mill and to 21st century life in general. Nothing stays constant, ever! As a mill evolves, the employees are often left with a vast array of legacy tools to master with final success dependent on extensive 'tribal knowledge'. This becomes a key, and often undocumented, piece of the training process as skills and know-how continue to pass from one generation of employees to the next. Figure 3 illustrates the many typical legacy tools required to maintain a running mill.

To keep production, quality and new development moving forward, the 'legacy engineering tool box' must be mastered even though the original developers may no longer be available and the initial intent is obscured by time and tradition. Often today's quick invention of a 'clever' solution creates big problems down the road, when systems change, and the tools are no longer well understood. For example, many computers in existing mills are littered with Microsoft Access applications that no longer work because some underlying structure, or data point, has changed. All too often they are not deleted for lack of understanding and fear, thereby clouding the maintenance environment.

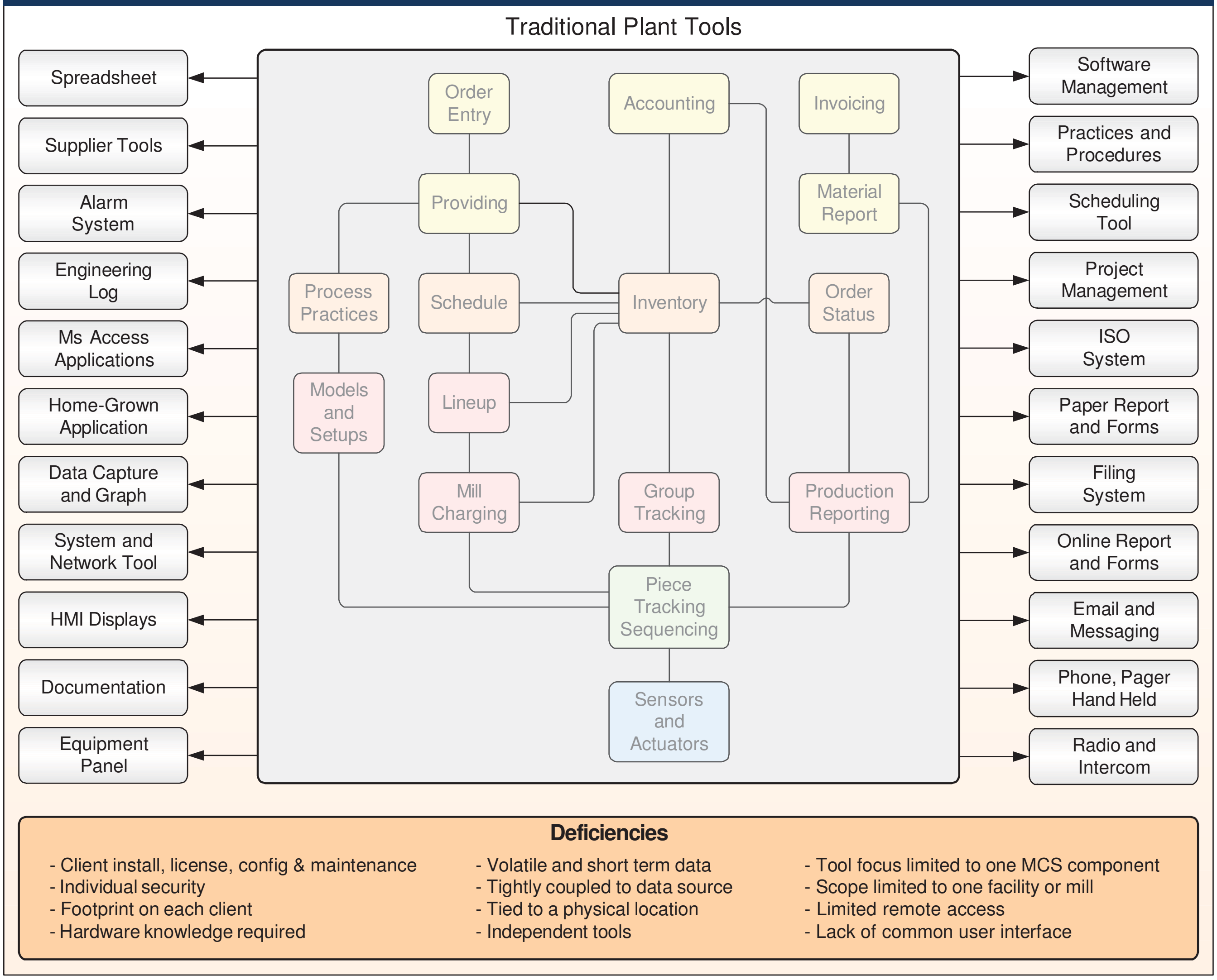
Letting mill maintenance software evolve without an engineered plan inevitably results in huge production inefficiencies and ongoing maintenance costs. The most glaring deficiencies associated with the 'legacy engineering tool box' approach are listed in Figure 3 and most of these are clearly identified by steel producers, as serious problems impacting their ability to compete.

But these deficiencies are only the negative half of the equation. The positive side includes the countless productive benefits realized through engineering a comprehensive, long term, data storage and delivery system, and for this, web technology is a perfect fit.

Web Site and Data Center

Web server technology, coupled with data center techniques, can significantly improve business efficiencies at many different levels by delivering timely, relevant data to the client browser as actionable information. In short, this is a system of easy access to everything using the power of the web to tie it all together.

Figure 3



The legacy engineering toolbox

Some of the recent technology and infrastructure advances that can be leveraged for this purpose include:

- fast and reliable PC hardware and software
- dependable, secure, high speed, high capacity networks and servers
- massive, inexpensive, fast and reliable data storage
- advances in database engine and storage design
- advanced database stored procedure scripting
- mature web technology

However, recognizing these expanded capabilities raises a real question. What is the best way to leverage the advances but still retain investment in the MCS model? That is to say, how do we apply these technologies to create an information system that does not jeopardize mill operation through extensive MCS model and performance changes? The answer lies in a two part design combining a data gathering and transforming back-end, with a web presentation front-end.

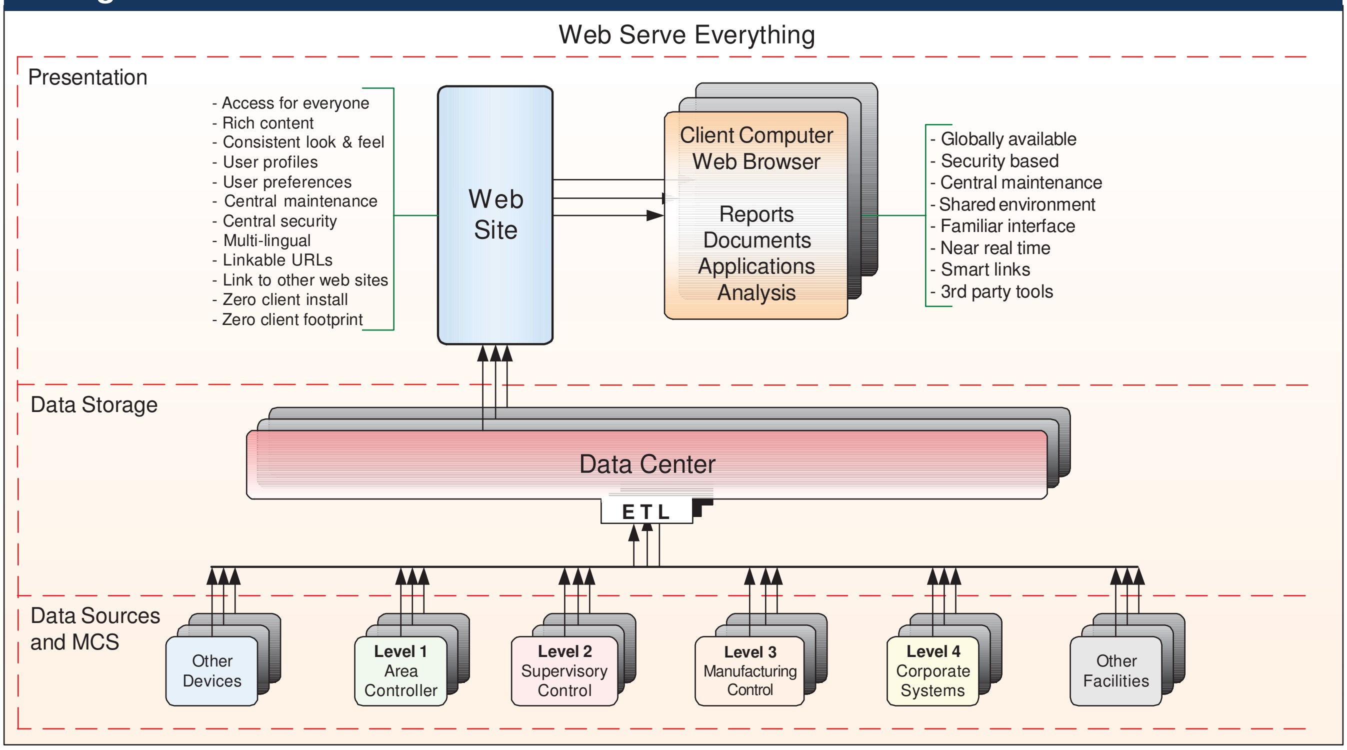
Figure 4 compresses the full MCS, and more, across the bottom of the diagram into a Data Sources and MCS layer. For the purpose of this discussion, this shift in perspective relegates the model to the role of data supplier and positions it, like a foundation, as a system resource for the new Data Storage layer. The storage layer design and it's properties are detailed later. First, examine the features and benefits of implementing a web based Presentation layer.

The Presentation Layer

A well engineered web presentation layer offers a wide range of improvements including the following:

Efficiency ⅄ Open access to plant data is provided through the familiar, easy to use web browser with no installation or training required. It guarantees that all users see the same information, in the same way, and at the same time. The web makes it simple to share data links through the email system.

Figure 4



The Presentation Layer

Web-delivered 'legacy engineering tool box' applications are enhanced by sharing a common look and feel that helps unify the user experience.

The global nature of the web system naturally reduces the adverse effects of artificial job boundaries between employees and between departments. It provides a focal point for the facility with the potential to evolve into a web portal, becoming 'the' source for all manner of company information beyond plant production.

Workflow ⅄ Web site techniques can be provided for users to save and share data by downloading results directly to their computers. For example, table data could be saved in a csv file for later spreadsheet analysis or for forwarding to others.

Extensive use of hyperlinks imbedded into web content increases efficiency and productivity. Smart links take this concept one step further by passing context information between web pages and applications. For example, a product ID or time range could setup an application to point in the right direction on startup.

Environment ⅄ Modern web programming languages and environments are well developed with many excellent open source products available for free. Online documentation, help, forums and code samples provide a rich support environment. Because web technologies are 'hot topics' in schools and software houses, there is an abundance of skilled web programmers readily available to fill contractor or employee positions in the steel industry.

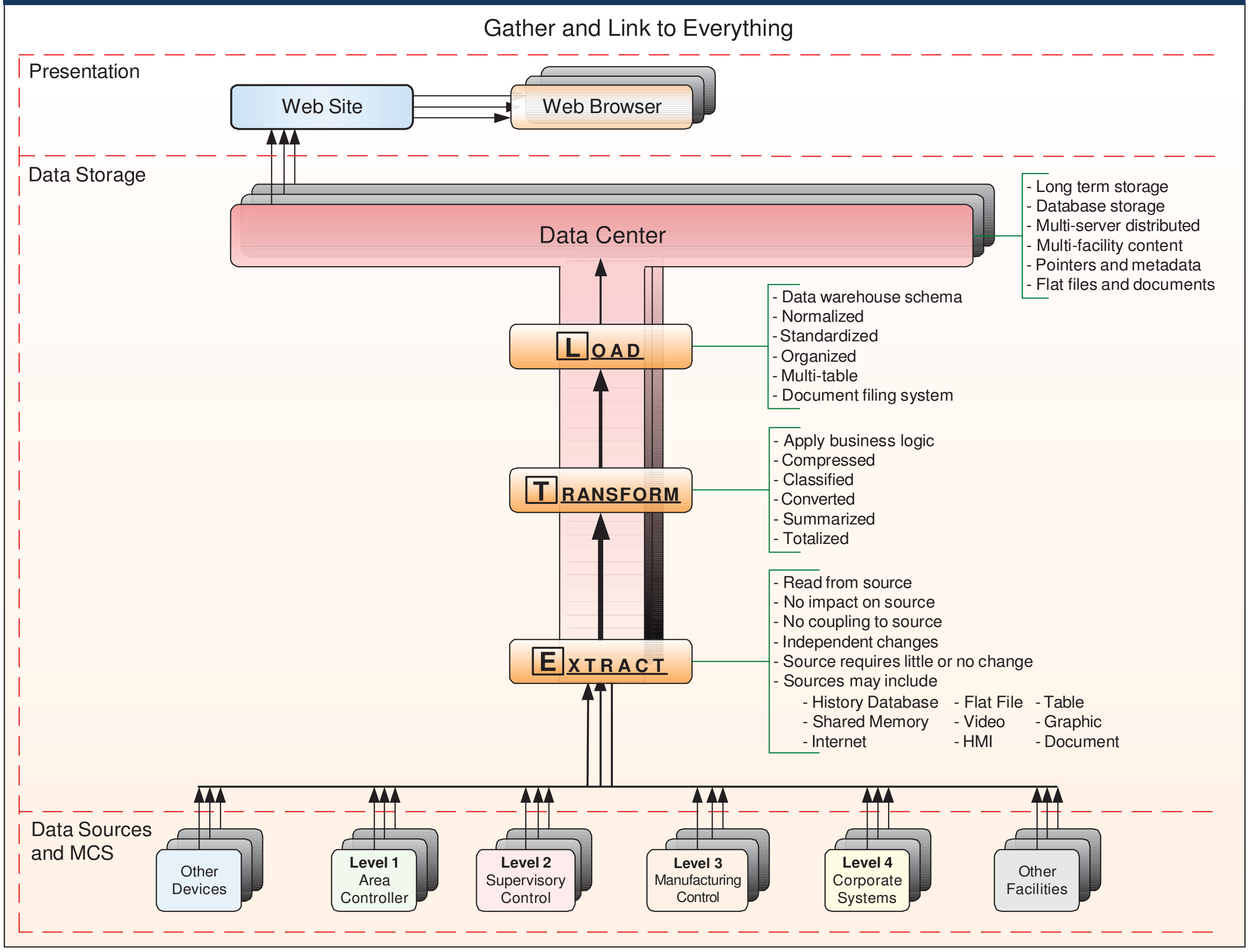
The web can be used to deliver rich content on demand in the form of tables, graphics and video and this ability can be extended beyond desktop computers to include mobile and hand held devices. With this model, plant data is accessible anytime, anywhere, on any device and in the most relevant format possible. Links to other plant content such as 'ISO' or 'Health & Safety' sites are easily provided as are the links to external facilities within the enterprise, provided the appropriate security filters are used.

Maintenance ⅄ Program maintenance is performed on a central server with backup, test and development environments easily configured and maintained. When new or upgraded web content is published online it is immediately available to all users without the need to distribute or upgrade software to the client. For added code security, third party source management software such as Source Safe can be layered in if desired.

Security ⅄ A user security system can be built into the web site to track and control access to sensitive data and applications. Hooks to an existing or 3rd party system can be used if desired. Users gain access to restricted content through a single, site wide, sign-on. This is only enforced for secure areas with the rest of the site always openly available to everyone. The web server can maintain user profiles and preferences, beyond security, and use these to enhance the user experience and increase efficiency.

Training ⅄ The learning curve for training new hires, or existing employees, is reduced by providing online documents, procedures, best practices and other content. These resources are available for self-directed learning at all times with security measures restricting access to sensitive documents as needed.

Figure 5



The Data Storage Layer

Dashboards ⅄ Dashboards are a special class of web application designed to distribute sharply focused, high level, status and summary information in near real time. They can provide time critical, situational data, that is vital to ensure the very best minute-by-minute operational decisions.

Translations ⅄ A mechanism for language translations can instantly convert web controls, tips and content to any language a facility requires. The impact of this can be significant in today's international market environment but may be of special importance to steel producers with facilities in multiple countries.

In addition to these advantages, the web site acts to minimize or eliminate the deficiencies listed for the 'legacy engineering tool box' approach in Figure 3. Of course, none of this matters if the web front-end does not have valid MCS data to draw upon in the storage back-end. The role of gathering, transforming and storage, collectively called the Data Center, forms the second part of the solution.

Data Storage Layer

The all important Data Storage layer occupies an area between the Data Sources and the Presentation layers just described. This layer, shown expanded in Figure 5, stores the various types of electronic data collected from the MCS and other resources using a database industry concept called Extract, Transform and Load or ETL for short.

The advantages of using ETL are explained below, but by far the most compelling reason for the steel industry to embrace these methods rests in the fact that the investment in the MCS model remains unchanged. A few simple engineering considerations are needed to implement the technology in a green field site, while often only a small number of minor modifications are needed to apply them over an existing MCS. In the latter case, the web and data storage layers are implemented gradually and in parallel with the 'legacy engineering tool box' as the new functions are completed thus, exposure to risk is reduced.

Data Extraction

The very term *extraction* implies a pulling or dragging of an object. An extractor initiates a movement action on some passive entity whereby its location is changed. This description applies to a mill model, except that in many cases, data is not removed from the source. It is simply copied. In an MCS implementation the function blocks usually maintain data ownership and are therefore able to edit or delete as a normal part of their operation. Decoupling the extraction process from the data source is important. Extraction software must never be contained or linked directly into mission critical code.

Extractors typically run independently as scheduled tasks with the work intervals dictated by data source characteristics. The nature of slowly evolving or grouped data implies a longer term batch approach as, for example, shift summary data collected once at the end of a work scheduled time period. Faster data creation demands a more frequent extract cycle with near real time speeds used when appropriate. For example, very fast update times are needed for reporting network or computer status on a maintenance dashboard. It is important to state that, in all cases, it is imperative that database triggers not be used to activate extractors. This coupling would put the MCS data creator process at risk if serious logic or coding errors occur.

Extractors can be developed to work with any form of digital data including, but not limited to, database records, shared memory, flat files, graphics, scanned images, video and audio. They must distinguish new data from old and take the proper action on updated or intentionally deleted data. They must also possess the ability to recover safely from extended periods offline. Since they are independent of the MCS source code and data, extractors can be programmed using any language or platform appropriate to the task. A typical installation deploys numerous, varied and independent extractors to cover all data gathering needs. Once an extraction completes, the transformation phase begins.

Data Transformation

Business logic describes a set of rules and algorithms for a specific manufacturing facility and company. Business logic encodes the basic definitions the company uses to change raw MCS signals into useful information. Data transformation is the application of business logic to alter the representation, organization and, in some instances, the very meaning of the data. Typical functions include conversion, compression, summing, averaging, sampling, classifying, timing, annotating, logging, sorting and organizing.

To be sure, not all extracted data is transformed but, as a general rule, this is the absolute best time and place for it to occur. Applying rules at this stage reduces data coupling and re-work later. It simplifies the presentation layer and reduces data fetch and computing time. The effects can be especially noticeable when analyzing large data sets. It also serves, as a best practice, to organize and maintain the business rules in one place. Transforms should happen immediately after an extraction and, in fact, the two functions are usually programmed in a single piece of code. The data is now ready for storage.

Data Loading

The act of storing data is called ‘Loading’. The transformed data is written into a long term digital storage system called a Data Center. This is a storage model describing a multi-sourced, highly organized approach to store, analyze, search and retrieve data and media. To be most effective, it must be comprehensive. For this reason, it is rarely just a single database or file system on a single server. The Data Center may encompass a variety of storage formats including relational tables, data warehouse records, flat files, directory hierarchies, pointers to other sources, or any other digital media type. It could exist on a single computer or be distributed on many. The key attributes for effective data storage are organization and structure working together to support extremely efficient bulk data storing, searching and fetching.

To frame these Data Center concepts in database terms, the schema is organized in a long, flat, two dimension, horizontal structure with few, if any, sub-tables. Use of foreign keys is purposefully restricted. The data tables, because they are flat, are easily extended and indexed. Contrary to transactional database design tenets, it is acceptable and actually preferable, to leave the database denormalized by storing computed values and duplicated data. This ‘wasteful’ storage and flat organization increases the data throughput, vital when working with extreme volumes of data collected over long time periods. As practical examples, this might result in storing the average temperature as well as the samples, or duplicating a piece ID in multiple places.

The devil is in the details, but the goal remains simple. Organize the data, collected over a long time, to support efficient analysis and rapid retrieval. With careful planning, solid engineering principles and current technology, it is indeed possible to create ‘the ultimate’ data store that will span the lifetime of a facility.

Conclusion

A company, and it’s employees, will have the tools needed to reach their full potential, by implement a comprehensive web based Data Center system to distribute plant data and applications. In addition to the obvious benefits, some are difficult to quantify and esoteric in nature, but they must surely be included in any dialogue on the subject. The following aspects of business culture and personal development are impacted by the successful application of this technology.

- improved efficiency and morale
- less re-work and wasted time
- steady automation and product improvements
- more responsive to customer needs with increased adaptability
- better maintenance, planning and forecasting
- production improvements through modeling and analysis
- increased innovation and product development
- support for the skills to seize new opportunities

Direct experience, with this extension to the MCS model, has proven time and time again that the rewards, both financial and in human terms, are well worth the effort and investment. Today, the cyclical business of steel production is once again faced with a new technological challenge where the companies actively perusing this ‘game changing’ model will surely discover that they have what it takes to keep them ‘in the game’.

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