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Embracing a New Paradigm: Electronic Work Instructions (EWI)

Jeffrey Rupert & Travis Loving
ScanCAD International, Inc.
Littleton, Colorado

Abstract:
While there have been quite dramatic and evident improvements in almost every facet of manufacturing over the last several decades owing to the advent and mass adoption of computer automation and networking, there is one aspect of production that remains stubbornly unaffected. Massive databases track everything from orders, to inventory, to personnel. CAD systems allow for interactive and dynamic 3D rendering and testing, digital troubleshooting, and simulation and analysis prior to mass production. Yet, with all of this computational power and all of this networking capability, one element of production has remained thoroughly and firmly planted in the past. Nearly all manufacturing or assembly procedures are created, deployed, and stored using methodologies derived from a set of assumptions that ceased to be relevant fifty years ago. This set of assumptions, referred to below as the "Paper Paradigm" has been, and continues as the dominant paradigm for manufacturing procedures to this day. It is time for a new paradigm, one that accounts for the vastly different technological landscape of this era, one that provides a simple, efficient interface, deep traceability, and dynamic response to rapidly changing economic forces.

There are of course, numerous different systems available to streamline the creation, deployment, and storage of 'paperless' work instructions but it is very important to understand that the simple absence of tactile paper, does not mean that a system has transcended the limitations of paper. Most procedures today are created using standard word processing tools, managed using file management systems and deployed using various different flavors of PDF. While the tools are slightly different than those available in decades' past, there is no fundamental revolution in process and capability. A word processor is nothing more than a simple, logical extension of a typewriter. A file management system is nothing more than a virtual version of a folder overseen by a manager, and a PDF has the effect of turning a computer screen into nothing more than a sheet of paper. Regardless of the tool used for creation, regardless of the system used to manage files, and regardless of the mechanism of deployment, nearly all manufacturing instruction systems in place today conform to the same fundamental assertions as systems in place over one hundred years ago.

1. Procedures must be deployed to operators in a paper or paper analogue format.
2. Procedures can only provide a one-way flow of information from the document to the operator.

The Paper Paradigm:

3. Procedures cannot react to changing circumstances.
4. Procedures cannot be interactive.
5. Procedure revision must be manually controlled.

This paper seeks to present an alternative. Instead of enhancing and improving on systems that became irrelevant with the invention of a database, instead of propping up an outdated, outmoded and inefficient system with incremental improvements; rewrite the paradigm. Change the underlying assertions to more accurately reflect our current technological capability. Instead of relying on evolutionary improvements, it is time for a revolution in manufacturing instructions.

It is time to embrace a new paradigm.

Introduction:

While there are quite dramatic and evident improvements in almost every facet of manufacturing over the last several decades owing to the advent and mass adoption of computer automation and networking, there is one facet of production that remains stubbornly unaffected. Massive databases track everything from orders, to inventory, to personnel. CAD systems allow for interactive and dynamic 3D rendering and testing, digital troubleshooting, and simulation and analysis prior to mass production. Yet, with all of this computational power and all of this networking capability, one element of production has remained thoroughly and firmly planted in the past. Nearly all manufacturing or assembly procedures are created, deployed, and stored using methodologies derived from a set of assumptions that ceased to be relevant fifty years ago. This set of assumptions, referred to below as the "Paper Paradigm" has been, and continues as the dominant paradigm for manufacturing procedures to this day. It is time for a new paradigm, one that accounts for the vastly different technological landscape of this era, one that provides for a simple, efficient interface, deep traceability, and dynamic response to rapidly changing economic forces.

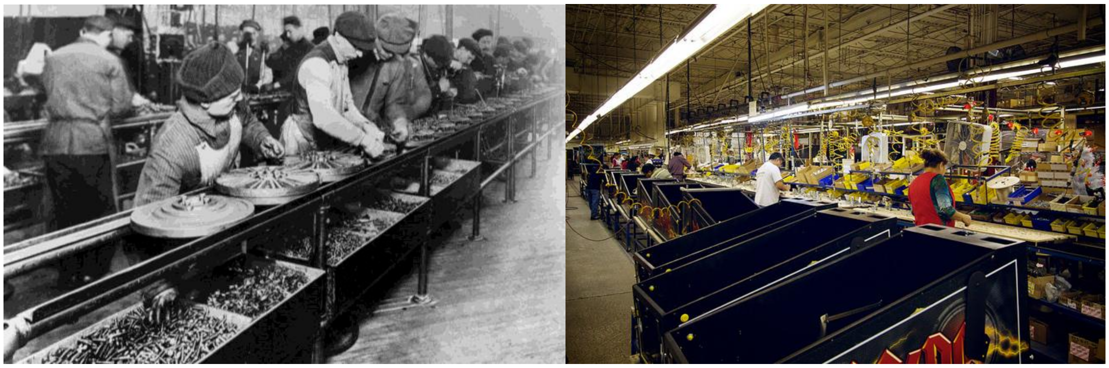

Figure 1 – Manufacturing 100 Years Ago vs. Now   Photo by Marcin Wichary

In the majority of manufacturing facilities today, work instructions are created using standard office tools such as word processors, spreadsheets or presentation software and then deployed to operators on the floor as a paper document or perhaps as a paper analogue, such as a PDF file or image file that is then displayed on a screen. In other facilities, perhaps these PDF or image files are created by an MRP/ERP system or by CAD software, but the fact remains that these files, even if displayed on a monitor or even displayed on a tablet, are still virtually no different than a piece of paper. Even if these files are supported by sophisticated database systems that manage the files and determine when and where the PDF file should be displayed, the fact remains that nearly all production today is supported by paper or a computer screen acting like a piece of paper. Virtually identical to production of 100+ years ago.

The paper paradigm has been the dominant mechanism for managing production for decades, and since its initial inception, there have been nothing but minor, incremental improvements regardless of the tremendous technological revolution that has taken place over the course of the last few decades. Paper work instruction deployment initially started with handwritten instructions, then printing presses, typewriters and mimeograph machines... and has since evolved to incorporate the development of computers in the late 20th century using word processing and spreadsheet software as a replacement for manual work instruction generation. Since the advent and expansion of sophisticated networking, it has further evolved to incorporate networking and shared file storage technology to simplify storage. These incremental developments have helped simplify the creation and storage of paper work instructions to some extent, but they have failed to understand and leverage the full promise of our new technological capability. The basic challenges of building quality products with a changing workforce remain unsolved since the majority of operations in place, at their core, still maintain the following fundamental assertions of the Paper Paradigm:

- Procedures must be deployed to operators in a paper or paper analogue format.
- Procedures can only provide a one-way flow of information from the document to the operator.
- Procedures cannot react to changing circumstances.
- Procedures cannot be interactive.
- Procedure revision must be manually controlled.

The overt reliance on this paradigm and reluctance to adapt or to create a new one has led to the creation of many systems built solely to support outdated methodologies including document control systems, database systems designed to display PDF and Graphic work instructions, separate systems to track different elements of the process, etc. This gets even more difficult while trying to use the paper paradigm and also maintain ISO, AS or other certifications.

The new Electronic Work Instruction (EWI) paradigm is not an extension of this old, outmoded paper paradigm, it is a revolution incorporating a brand new way of supporting manufacturing and assembly processes. EWI is an entirely new paradigm, with entirely new assumptions based on the vast computing and networking capabilities available in the 21st century.

The new EWI Paradigm:

1. Procedures are an extension of the work that is being done. They are living, evolving elements that become a virtual representation of the procedure being completed.
2. Procedures support a two-way flow of information. Information is captured for complete traceability
3. Procedures are dynamic. They filter and display relevant information in a relevant language to the operator and dynamically change when necessary based on the needs of the operator. Procedures should react to changing circumstances.
4. Procedures are interactive and engaging.
5. Procedure maintenance and versioning can be automated so Process Engineers can focus on their processes and not maintaining them.

EWI's are not an evolution of Paper, but a revolution in the manufacturing process. There are only a few companies that have taken this step to EWI's, but the vast majority of manufacturing facilities globally are still stuck in the paper paradigm. This paper will explore the many advantages of moving to EWI's to help keep your business competitive in today's rapidly changing global marketplace.

Ewi's Are More Than Just an Extension of Paper:

Paper work instructions or paper analogue work instructions are limited to the types of media that can be displayed on paper. For example, with paper, you can display lists of text based instructions, photographs, tables of data, etc. These types of instructions can be effective for a trained, experienced operator who has gone through the procedures before, but it is difficult if not impossible create a paper document that works for both inexperienced and expert operators. If enough detail is put into the process for the inexperienced operator, it will surely slow down the advanced operator who does not need that level of granularity. And finally, how well will this procedure work for the non-English speaking operators when the instruction is written in English? These are some of the challenges that have existed for engineers and technical writers that have been creating work instructions in the paper paradigm.

With the new EWI paradigm, it is possible to take new operators right off the street and have them successfully building products right from the start simply by following the procedures in the EWI. These procedures are no longer limited to paper type displays. For example, steps in the EWI can include a variety of media such as videos. The new operator can view an actual video of the step and can pause, replay when necessary to see exactly what to do. There can also be photos…. but unlike paper, the photos can be zoomed in when necessary to see details that may not be apparent in the original display. There can be many photos, taken from many angles. The limitations of physical space on paper have been eliminated.

EWI's can also display and even edit supporting documents such as CAD files, Word or Excel documents and many more. Virtually any type of file that can be opened on a PC can be opened within an EWI. So, if an operator needs to view or modify a CAD file, this can be done in the EWI and they have all the capability that is available in the CAD viewer such as zooming in, rotating, exploding, etc. Try doing this with a paper work instruction!

Figure 2 – EWI in Action

BOM/BOT information is also available in the EWI along with descriptions of the parts, photos, etc. This information can be kept up to date by interfacing with the ERP/MRP system to ensure that the very latest BOM/BOT data is being used. If a change is made to the ERP/MRP system, it can automatically flow to the EWI software.

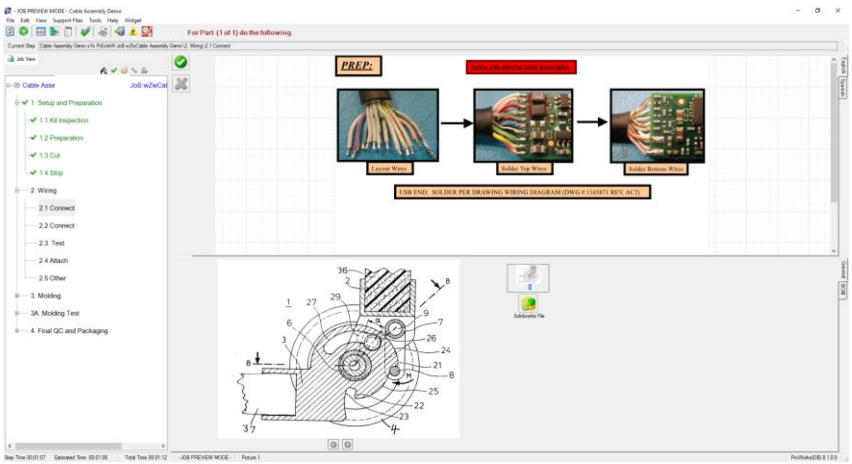

Figure 3 – EWI Information Portal

All of this capability opens up new opportunities not available with the paper paradigm. There is a company that builds expensive, complex electrical tester systems that made the transition from paper work instructions to EWI's several years ago in part as preparation for transitioning a portion of the manufacturing from North America to Asia. There were numerus benefits that were realized by this transition to EWI, but we will just mention a couple of these benefits for now.

1. When production was moved to Asia, the training of the new operators was done strictly by EWI's. The new operators could sit in front of the workstation and step through the EWI and successfully build the product without any other assistance. These complex products were built to the same level of quality and in the same amount of time as they were being built by the experienced operators in North America previously. This could be done because of the detailed instructions, embedded videos, photos and supporting documents in the EWI's. Of course to be effective, the instructions also needed to be displayed in the native language of the Asian workers. EWI's can be set up so that they are displayed in the preferred language of the operator. An operator need only log in and their system and EWI's will dynamically adjust to their home language. The same EWI can be available in many languages and changed as needed.

2. For this same company, a certain tester model phased out of production and was replaced with a newer model. Years later, a customer with this older model was expanding their capability and wanted to purchase this tester that was no longer being built. The manufacturer no longer had any operators that had ever built, or even seen this machine! Fortunately, there were EWI's available to build this older tester. New workers were used to build a complex tester that they had never seen and it was built to the same quality level and in the same amount of time as it was built when it was in standard production years before.

Ewi's Provide Two Way Communication:

Paper work instructions or paper analogue work instructions provide a one-way flow of information. Instructions are provided for operators on the manufacturing floor to help assist them with assembling a product. However, they do not allow for communication to come back from the floor to the engineers and managers who need this information to make process improvements, product enhancements, and business decisions. Furthermore, they do not allow for the detailed traceability needed for regulatory compliance and oversight.

EWI's can provide an interactive real time communication tool for the manufacturing floor. Now information from the floor can seamlessly flow back to the people in the offices at other locations who need this information to make decisions and help improve manufacturing processes. For example, with EWI's there can be a mechanism in place for operators to provide feedback to the EWI author when there is a confusing step in a procedure. This is can now be quickly documented and assigned to the EWI author to make a change to the step so that it is more understandable. Quality issues can arise when a step is not clear and subject to interpretation so this capability can help with product quality.

With EWI's, email or text can be sent automatically to predefined people upon certain trigger events. When a step fails, an email can be sent to an engineer or technician to come to the floor and see the issue. This can minimize line downtime and help solve problems in a more efficient manner. Email notifications can also be triggered upon the passage of a certain step. For example, an email can be sent to the Shipping and Receiving Department when a certain step passes to let them know that the assembly is almost complete which gives them advance notice to get their processes started. The same communication can be utilized across company boundaries, including subcontractors & suppliers, providing advance notice of events of interest. The technology is all about improving the overall process.

Another great feature that can be implemented with EWI is interactive troubleshooting support. Now software can help get an operator back on track when there is a problem on the floor. With traditional paper based work instructions, an operator needs to find a more experienced operator or engineer when there is a problem they cannot figure out. Companies running several shifts may not have these experienced operators available at all times so production is impacted. With EWI's, the knowledge can be built into the software. When there is a failure, the software can automatically go into a troubleshooting mode that provides a list of potential problems with solutions to these problems. Even more powerful is the fact that this troubleshooting database can be expanded upon by experienced operators and technicians. These systems can be set up to be self-learning… when a new problem is resolved, the system can ask for details of the fix, thereby passing valuable information back to engineering for inclusion in future troubleshooting iterations. Most facilities have experienced people who know how to get around certain problems that occur, but this "tribal knowledge" is not documented anywhere. Now this information can be captured by the software so others can benefit from it and there is no danger of losing this information when experienced personnel retire or leave the company. In the new paradigm, EWI learn from problems in such a way as to neutralize them in the future.

The troubleshooting information is all captured in the EWI, so now it is known exactly what errors are occurring and how often. No more work arounds occurring that engineers do not even know about. For problems that are occurring frequently, corrective actions can be assigned and implemented. There are some companies using EWI's that have monthly meetings based upon these Corrective Action reports to address quality issues and greatly improve product quality and throughput.

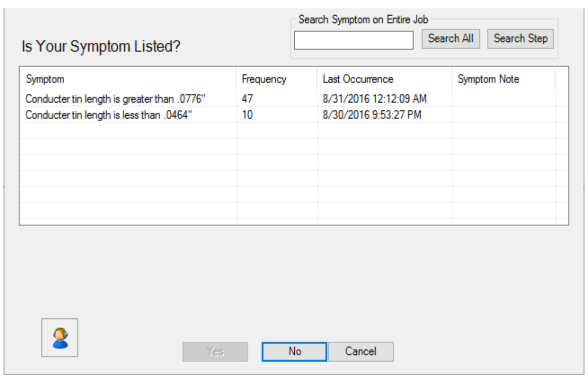

Figure 4 – Corrective Action

EWI's can also capture information or data from the floor in a way that cannot be done with paper based work instructions. Many facilities using paper will have a traveler or paper worksheet that goes along with the assembly and it may have a place for operators to write in a value from a manual measurement or data from a piece of equipment. There may also be a tolerance on this worksheet that the measurement has to fall within to pass. Many times this data is then just stored in a file folder or it could be checked off on by a QA person and then stored. Sometimes the data may even be later manually entered into a spreadsheet for further processing or traceability. This procedure contains the extra step of manual data entry which takes extra time, causes a delay in the availability of the data and introduces the possibility of data entry error.

With EWI's, this process is much more streamlined and much less prone to data entry error. There can be a step in the instruction with a field where data is entered. This data can be automatically checked by the system to make sure it falls within tolerance. If it is out of tolerance, a troubleshooting mode can be automatically initiated. It is even possible to interface the measurement equipment directly to the EWI so no data entry is required. Now there is no possibility for error and the data goes right into the database for reporting or further processing.

Figure 5 – Measurement Data Captured by EWI

An industrial air conditioner manufacturer implemented EWI's because of a specific yet persistent problem where operators were repeatedly installing the wrong motor. This mistake was typically not discovered until after the units were installed in their final location, typically on the roof of a building, ensuring that a simple oversight became a very expensive and visible blunder. With the full implementation of EWI's, the manufacturer was able to simultaneously simplify the procedure and validate each installed component in real time using a barcode scanner. This serious problem was never experienced again.

In addition to the obvious EWI capability of automatically validating a data input, it can also accommodate the requirement for a human inspector. If there is a requirement for QA approval, certain steps can be configured so that the operator needs to review the step and have a QA person enter a password or scan their badge before the operator can continue on. This QA approval is also captured in the database for traceability… including date and time stamps.

Ewi's Are Dynamic:

Manufacturing processes in most facilities is a dynamic operation. Products with a variety of configurations and options need to be assembled by operators with a variety of skill levels that communicate in a variety of languages. It is a major challenge to assemble these products in this environment to a high level of quality, especially with a static, paper work instruction.

First let's discuss building a product with a variety of options. One example to illustrate this challenge that many people are familiar with is a PC. The same make and model PC may come with many different permutations including various options for RAM, Hard Drive, DVD Drive, Graphics Card, USB ports, etc. One very large work instruction with all possible configurations could be generated, but the operator will have to jump to different steps between different sections and this can easily cause issues. Furthermore, what if a more powerful graphics card necessitates a more powerful power supply? How does that get reflected in this methodology? The other possibility is to create a different work instruction document for each different configuration. This method is very difficult for the work instruction author to manage since there are common sections that all have to be changed when there is an update. As the amount of options increase, this method becomes nearly impossible as the number of permutations approaches hundreds or even thousands of different products.

With EWI's, these issues can be solved quickly and easily. The base procedure and all optional elements can be programmed ahead of time. When the order is generated, the EWI's can be automatically reconfigured on the fly to reflect only the relevant steps. All other irrelevant steps can be hidden. The operator need not even be aware of other options, they simple proceed through the EWI, step by step seeing only what is needed for the configuration of PC being assembled. It is also very easy for the author to manage since there is just one work instruction. One work instruction that has a wide variety of options. It is even possible for an ERP/MRP system to automatically drive the creation and configuration of the EWIs based on the order configuration.

Another challenge with creating work instructions is adjusting the amount of detail to put in the instruction. For novice users, there needs to be enough detail for them to successfully complete their assembly task. However, with this large amount of detail, the expert user will more than likely be slowed down.

EWI's solve this issue by dynamically configuring themselves to account for the skill level of the operator. Operators can be designated as either novice or expert. Information only steps can be added to the work instruction with details needed for the novice. An example of an informational only step is how to remove a cover from an assembly…where the bolts are located, what tool is needed to remove the bolts, how to properly and safely use this tool, where to put the bolts when they are removed, etc. The novice user needs this information, but the expert user has done this procedure many times so reading through this information will only slow them down.

If the job is released to the floor to a novice, the informational only steps are displayed. If the job is released to the floor to an expert, the informational only steps are automatically waived (although the expert can go back and review them if necessary.) This capability allows novice users to complete complex tasks and yet does not slow down the expert user.

In today's global economy, many companies have facilities spread throughout the world. Many times different subassemblies are built in one country with other subassemblies built in another country and perhaps final assembly yet somewhere else. It is also not uncommon to see operators speaking different languages even within the same manufacturing facility. In a single USA facility there can be operators speaking English, Spanish, Vietnamese and other languages. Creating paper work instructions for operators speaking different languages can be a big challenge.

There is an American automobile manufacture that was using paper work instructions written in English that failed an audit when the person performing the audit found out that operators on the production line using the work instructions only spoke and read Spanish. Operators may be able to look at the photos and have a basic understanding of what is going on in the work instruction, but obviously details will be lost and quality can suffer if they cannot read the work instruction. Even if they are experienced and have memorized the procedures, what happens when a new revision with changes is released to the floor?

EWI's can support multiple languages simultaneously avoiding this problem entirely. Each user can select their own preferred language and the system will adapt each EWI to display only the relevant language. English, Spanish, and Vietnamese speakers can all access the same EWI and see only their relevant language. Now, all operators can follow the work instruction in their native language so they truly understand all the details in every step. There is no more guessing. The process is enhanced.

Procedures Are Interactive:
EWI's are interactive and engaging. No more reading through paper documents which can lead to boredom and fatigue after many hours. With EWI's, operators are constantly engaged through an interactive and modern interface. Operators must pass steps confirming they have performed an operation, they must input measurements and scan components; they have constant positive feedback as they complete procedures and interactive support in the event of a failure. Images can be viewed and manipulated, and 3D CAD drawings can be navigated and exploded. Active, engaged, and interested operators are far more successful, than bored operators performing tasks from memory. Worse yet, boredom can lead to missed steps or even intentional short cuts. Regardless of the complexity of the task at hand, the operator becomes an integral component of a larger system and not just an automaton performing redundant tasks. The new paradigm engages operators as part of integrated, interactive environment.

Figure 6 – EWI on a Tablet

Furthermore, every single interaction with the software is tracked and recorded, whether it is with the raw EWI procedures (from an engineering standpoint) or a procedure being executed. Did a process engineer log in and change a step? Recorded. Did an operator scan the barcode of a component? Validated and recorded. Everything is always, automatically time-stamped and recorded allowing for the dramatic simplification and automation of everything from versioning, approval, quality control, ISO/AS compliance, management oversight, and continual process improvement based off of granular, real time data feedback from production. The operator does not even need to be aware all of this data is being captured. They are just following instructions and entering information when necessary and the EWI is doing the rest behind the scene.

Since all this information is in a database, it is quite straightforward to generate a variety of charts and reports to help engineers and managers gain a better understanding of their manufacturing operation. This information can be used to keep customers informed as well as to improve processes. Real time charts can also be displayed based upon this data and since the data is in an electronic database, it can be accessed globally. So, for example, a manger in the USA can open a chart showing the percent completion of all open jobs for a factory in Asia. They can tell which jobs are on schedule, which jobs are completed and which jobs are behind schedule all with the click of a mouse.

Easily Maintained:

Procedures in factories are continually changing as processes are improved, parts in the assembly process are changed, new equipment is used in the assembly process, etc. When these changes occur, the work instruction needs to be updated and approved before they can be released to the floor. Once a work instruction has been in use for a period of time, more than likely it has gone through several of these revisions. With paper instructions, there can be many challenges to this maintenance and also the challenge of tracking these instructions…. what changes were made with each revision and which products were made with which revision?

There is a certain Fortune 100 company in the USA that has rooms full of rows and rows of binders with paper work instructions. When any of these binders are opened, the paper documents inside are filled with redlines, stamps, etc. from all the changes that have been made over the years. Imagine the challenge of maintaining these rooms of binders!

With EWI's, all the work instruction maintenance can be handled within the software to streamline the authoring/approval process and provide complete traceability. The signoff procedure can be handled electronically. First an author makes changes to a work instruction and then an approver or approvers are notified that changes have been made. The approvers can go through the work instruction and see exactly what changes have been made and either approve all the changes or approve/disapprove on a step by step basis. If a step is disapproved, they can provide comments to the author on why a step was disapproved and/or provide suggestions for changes. The author can then make the necessary changes and it goes back to the approved. All this is done electronically, so the process is very easy and seamless. Once the work instruction is fully approved, it gets released to the floor. There can even be provisions made on how to handle work in progress. Should WIP be finished with the old EWI or should the new EWI come into play.

EWI's ensure that all operators are always using the latest revision of the work instruction. When a job goes to the floor, the latest revision work instruction is always used. It is not possible to accidentally use an old revision like it is with paper. No more exposure to potential audit failure because an operator had an old instruction in their workspace.

With EWI's it is also very easy to determine exactly what revision of work instruction was used to build a particular product, even if the product was built years ago. If a product comes back to the factory for analysis after failure in the field, it is easy to pull up the exact work instruction that was used to build this product along with all the associated manufacturing & test data. This can be a tremendous help with failure analysis. It is simple and easy to review which operators assembled the product, which components were used, what measurements were taken etc. The usefulness of EWI goes far beyond the original manufacturing process and can be of value to an organization for the full life of the product.

Conclusion:

In order to stay competitive in today's evolving global marketplace, manufacturing operations must recognize and embrace the vast revolution that is the new EWI paradigm. It is not good enough to state that manufacturing operations are paperless, when in fact PDF work instructions are just paper documents being displayed on a monitor. Using word processor or spreadsheet programs or even ERP/MRP or CAD software to create a PDF is not EWI, it is simply reducing a monitor, computer, and network to the functionality of a piece of paper.

The EWI Paradigm is not simply an incremental improvement on the old paper paradigm. It is not just the mashing together of a multitude of disparate systems to achieve minute improvements in document control, file storage, or deployment. It is a deep and fundamental revolution, rewriting all of the foundational assumptions of manufacturing procedures. The five pillars of the EWI Paradigm are the foundation of the next era of manufacturing.

1. Procedures are an extension of the work that is being done. They are living, evolving elements that become a virtual representation of the procedure being completed.
2. Procedures support a two-way flow of information. Information is captured for complete traceability
3. Procedures are dynamic. They filter and display relevant information in a relevant language to the operator and dynamically change when necessary based on the needs of the operator. Procedures should react to changing circumstances.
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