Database Driven Multi Media Work Instructions

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Abstract
Work instructions are time consuming to generate for engineers, often requiring regeneration from scratch to address very minor changes. They need to be produced in varying levels of detail, with varying guidelines, for multiple stations, operators and lines. Minor component, station or process changes – down to the modification of an individual BOM component – can cause headaches when attempting to maintain consistency across multiple work instructions that are touched by the change.

The solution presented here improves efficiency and saves engineering time by making use of a database driven approach. Manufacturing details, component information, process guidelines, annotations, machine-specific data, and more can be stored in one central database. Any information stored in this single repository can then be modified quickly in one location and automatically propagate seamlessly throughout multiple work instructions. These can be instantly printed out or displayed on screens at appropriately affected stations with the simple click of a button, as opposed to regenerating from scratch, or going in and reviewing many documents to find and update with the change.

An object-oriented based approach with information stored in one central location encapsulates all of the appropriate information at the level it should be presented. This allows clearer work instructions to be provided almost instantly – the moment any change is made to the database – while also maintaining consistency across all instances of the change in question.

Introduction
Graphical work instructions used for box build and PCB assembly are typically created as static PDF files and stored on one or multiple servers. Having them ready to be used on a line usually involves copies being printed or being served locally from a resource stored on the nearest computer terminal.

Work instructions are time consuming to create and often need to be reproduced down to the smallest detail to account for the slightest of changes. Accurate reflection of up to date revisions to ensure the correct production of latest product revisions becomes a tedious chore that must constantly be addressed. Companies spend large amounts of time and engineering resource-hours to change multiple documents for the smallest changes made to product designs – often finding that incorrect versions are being used at various times or stations.

For database driven multi-media work instructions all data needed to dynamically generate work instructions should be stored in one single and central location. If this is accomplished then it follows that there are no files that need to be accounted for and maintained, inherently reducing the chance that human error is introduced while modifying work instructions. It is no longer possible to have out of date or incorrect work instructions being used at a station if they are constantly being regenerated from a central storage.

The areas necessary for a solution to be successfully implemented to address these issues are: consistency needs to be accounted for, accurate reproductions should always be generated, and updated work instructions should be rapidly generated and displayed. By using electronically based multi-media work instructions the opportunity to include more detailed visual and audial aids is provided. Video demonstrations and audio descriptions can be easily incorporated into work instructions by having files electronically served. By having work instructions be provided in such a manner there is the added benefit of operators being guided in a context appropriate and accurate manner.

The key design requirements are summarized in Table 1.

Table 1 – Key Design Requirements

Hierarchical Data Storage	Hierarchical relationships between data ensures product assemblies will be consistently and correctly structured by circuits, sub-assemblies and components.
Comprehensive	The system understands the complete manual assembly process to be implemented – from scheduling to line balancing and inspection – in order that work instructions are generated dynamically as needed.
Modularity	Database driven multi-media work instructions do not need to be implemented at every station, but should be where possible.
Dynamic Staffing Adjustments	Workload can vary significantly by shift, staffing differences, and number of stations being used implying work instructions need to be rebalanced and reconfigured on demand.
Dynamic Change Inheritance	As instruction changes are necessitated at the part or sub-assembly level, work instructions need to be dynamically updated for all product assemblies where that information is being used.
Multi-media Content	Electronic documentation allows for any kind of media to be used that a client PC or tablet can support.
Easy to Use	The system should not rely on integral database knowledge or lengthy training to be used – the usage should be abstracted to a software platform aiding engineers or operators.
Central Information Management	Assembly instructions and documentation should be managed in one central repository so that consistency is ensured.
Paperless	All documents should be generated on an as-needed basis and displayed on screen when used. An option for manual documents to be printed should exist where necessary but not the recommended goal.

Methodology

The first question is having database driven multi-media work instructions defined along with the benefits that are provided through their use. Database driven multi-media work instructions can be defined as paperless work instructions that can be generated on the fly from a single source of truth – a central repository of information – and displayed accurately and consistently whenever and wherever they are needed by being dynamically generated from the latest available information.

What is needed to accomplish this is a database-driven, modular, and dynamic software solution backed by a database that will allow for changes to be propagated to all products sharing common components.

The solution can be approached through a guided exploration of a number of relevant areas. The first, and key piece, is the storage of the relevant information about BOMs, assemblies, subassemblies, instructions and components in one central location. The ideal methodology here involves a database that is set up to hold information about all possible hierarchical levels related to work instructions. It must be implemented in such a way that it is accessible to those who need it – typically engineering staff and line operators, - sorted by indexing to provide rapid retrieval of relevant query results, and regularly backed up to safeguard and prevent loss of information.

The Database and Software Layer

The database should be accessed through an appropriately developed layer of management software that is aware of the structure of the tables and the relationships between them. This layer of software will manage a user interface to be provided allowing assembly instructions, components, and multimedia content to be manipulated logically in dynamically generated work instructions in a WYSIWYG (what-you-see-is-what-you-get) fashion. This management layer will provide abstraction away from the database structure and is the basis for all manipulation of work instructions.

A hierarchical storage mechanism provides the benefit of re-creating relevant sections of work instructions rapidly at the relevant level by re-using the necessary information to create work instructions on the fly. A request to the management software of the database can then specify subassemblies that already exist but that need to be reproduced by replacing individual components that have been updated for the latest BOM. This process does not necessitate a complete re-write of a static piece of stored information as it would in a traditional work order.

Information to be used in the system could be directly imported into the system from an on-site ERP (enterprise resource planning) system and any CAD (computer aided design) files that are already present documenting the relevant box build or PCB BOMs to be used. The documentation can be created for the box-build and PCB hand assembly.

A work instruction in this scenario has been changed from a static resource that has pre-mapped instructions to relevant components or assemblies, to a dynamically generated resource that relies on having information about relationships between components and instructions queried to generate an up to date representation of the work to be completed.

Management Software Layer
In order for the modification and creation of database driven multi-media work instructions the management software layer involved needs to provide various functionality to an end user. An editor with the ability to import ERP and CAD information should be provided so that an engineer can use the system to define work instructions at any level from the part level to the assembly level.

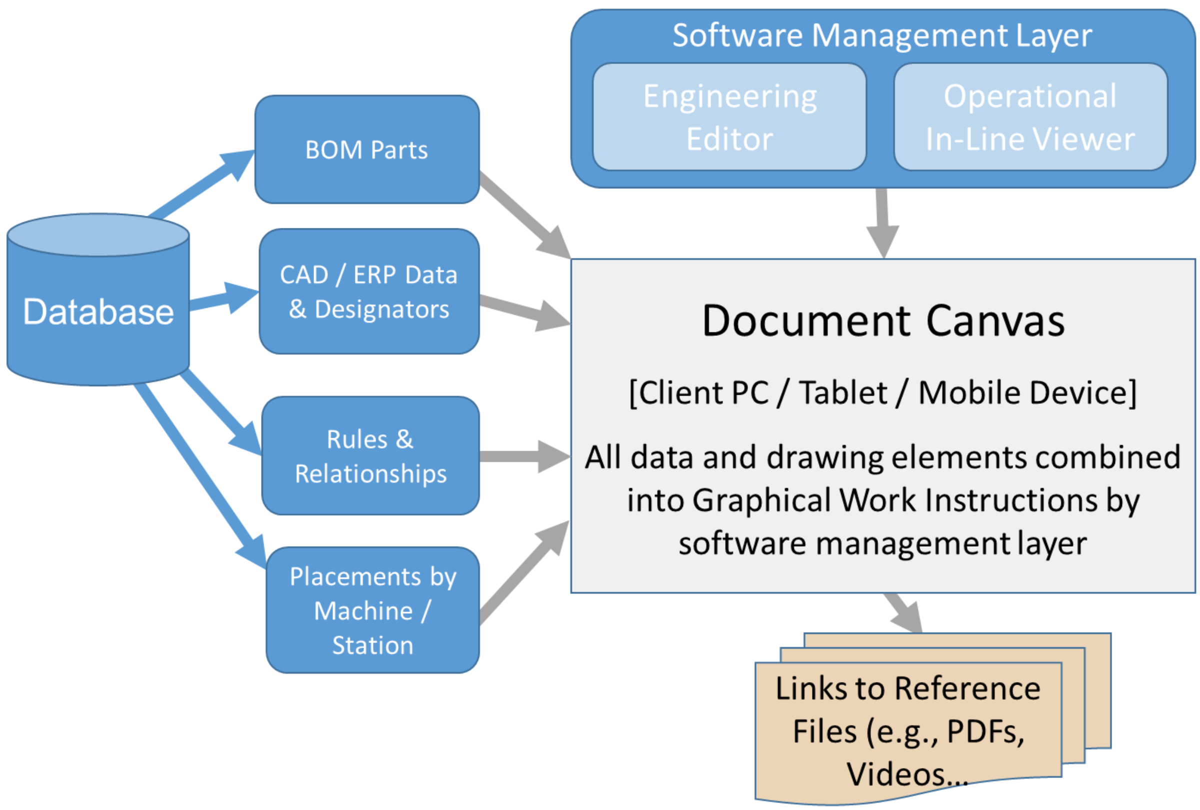

Figure 1 – Software Management Layer Organizational Chart

Such an editor would need to be made up of standard drawing and text-based tools to allow work instructions to be annotated. The relevant data necessary for drawing on work instructions to be recreated should be stored as part of the data in the central database. The ability should be presented for associating information to specific parts – for example to annotate quality control instructions to be followed while inspecting a manually inserted part at a specific station on the line.

Additionally, as shown in Figure 1, in order for viewing on the line to be facilitated there should be a separated version of the editor that only allows database driven multi-media work instructions to be viewed in context. Operators on the line are the consumers of the work instructions that are dynamically generated by this system.

The management software layer should abstract all communication and modification being done to the database away from the user so that the end user of any database driven multi-media work instructions need not know there is a database involved at all. The user will have a document canvas to create and/or view work instructions with all relevant information pulled from the database transparently.

Dynamically Generated Resources

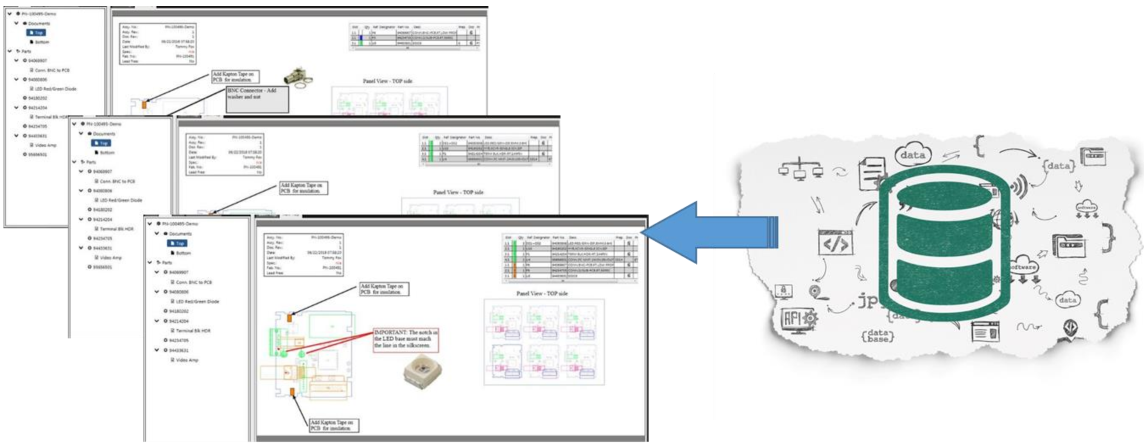

Figure 2 – Dynamic Work Instruction Generation

The implication that can be taken from this is that the database to be implemented must not just store information about the static resources used as part of a work instruction – components, BOMs, assemblies and so on – it must also house information stored about the relationships between these pieces of the hierarchy, in addition to instructions about how they are to be used.

The concept of a static resource that can be retrieved no longer exists in this scenario – except at the hierarchical level from the user's perspective. An operator can still have a work instruction that has been requested for a specific station, that references a specific assembly, and has specific instructions on how components should be added to said assembly – but all of the information necessary to have this information displayed will be generated on the fly. This work instruction is dynamically generated from the central database using predefined rules about the relationships between each piece of information as demonstrated in Figure 2.

In this fashion, changing a specific resistor that needs to be checked for quality control during a station inspection does not necessitate the creation of a whole new work instruction from scratch to document which component should be present and where. The work instruction will be created by a single query to the database management software specifying the relevant work instruction which will then be generated dynamically from the database using whichever resistor is specified in the appropriated location in the hierarchy of tables. It does not matter for the work instruction generated whether the information about the resistor was entered 2 months ago, or updated 15 seconds ago – in either scenario the work instruction is created by the relationships between the necessary components and instructions.

This is an example of the implementation of dynamic 'where-used' inheritance. As work instruction changes are implemented anywhere in the system – whether at the part level, sub-assembly level, instruction level or elsewhere – any work instructions that make use of this information are dynamically updated when they are displayed. All product assemblies that use that information are completely consistent with product changes and constantly up-to-date when viewed, with the convenience of being properly maintained at the lowest level in the BOM hierarchy with just one minor update to a database.

The implication of being able to change a single piece of information and have that propagate through all relevant work instructions is that the storage of change history becomes a critical piece of the information stored in the database. Having the ability for historical work instructions to be stored and regenerated based on original specifications becomes a much quicker and easier process when information about changes made is also stored in the database. Having the database queried for changes from the management software layer allows dynamic reproduction of the state of a specific work instruction at any point in its history. It is in this way that version control of work instructions is built into the solution itself.

Database Driven Multi-Media Work Instructions

Work instructions are dynamically generated every time an operator opens a job. All information attached to an assembly, or components in the assembly is retrieved from the database and displayed as work instructions. In most cases, a large part of the work instructions for a new assembly will be available as soon as the assembly is defined as all prior defined components with work instructions are incorporated. The engineer only needs to define assembly specific instructions and those for any new parts.

Figure 2 shows an example of a work instruction as it could be viewed in an editing or viewing environment. Components highlighted in orange show pre-completed work to be inspected at a station and components highlighted in green show work to be implemented at that station. Any relevant information can easily be included as part of the work order – in this case a holistic view of the panel from the top, along with a list of components and identifiers, adds clarity to work to be completed at the station. Finally, the work itself to be done is labelled clearly through the use of graphics and text.

Now that this information is stored in the central database as a collection of components, relationships, rules, machines and assemblies it can be easily modified for any future changes across one or many lines. It can also quickly and easily have supplementary information added – for example if a high scrap percentage is being caused at one particular station, engineering personnel have the option to add demonstration video directly into the work order to help clarify what should be done.

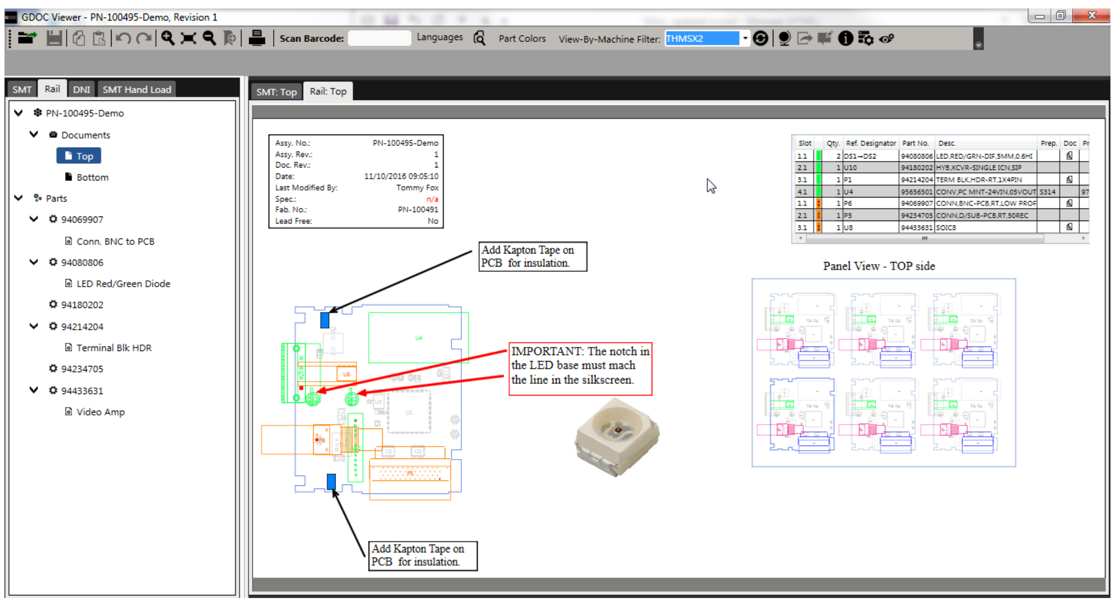

Figure 3 – Sample Database Driven Multi-Media Work Instruction

Accrued Benefits

Hand assembly can vary significantly by shift at each station on a line due to staffing changes between shifts causing major problems with traditional static documentation. With multi-media work instructions being dynamically generated as they are needed it becomes possible to quickly adjust to the number of stations available while ensuring that the work instructions for each station are rebalanced on the fly.

Specific instructions are stored in association to the parts that are referenced as opposed to in a specific static work instruction. This provides rapid modification of work instructions for individual stations regardless of how much information is being added or removed, and allows the ability to have the workload present at each station dynamically rebalanced to focus on efficiency.

Any type of media can be presented in work instructions that are stored in this manner. Work instructions can be viewed on tablet computers, desktop terminals, or whatever electronic setup is present meaning that movies, pictures, PDFs, commercial word processing documents and any other electronic file type can be displayed as part of the instruction. Quality control, manual insertion, and every other operation to be performed can be demonstrated in a live fashion so that appropriate action remains consistent between operators, shifts and products.

A paperless solution is provided when work instructions are generated dynamically from a central location. Instructions cannot be lost on the line and previous revisions will not be accidentally used. If necessary, paper copies can be printed from the screen as with any other electronic document losing only interactive content and demonstration.

Dynamic Scheduling

In this solution, the complete process of manual assembly from scheduling to line balancing, from creating specific work instructions to ensuring the integrity of the information being provided to each operator on a line is comprehensively detailed in one central and cohesive location.

Implementation of such a system in a live factory setting can be accomplished in stages as existing work orders are reproduced in the system with the bonus that as each instruction is reproduced, all subsequent instructions related to the same products or lines will have some, if not all, of the relevant information already stored in the system.

With the assumption that the software management layer has provided optimization algorithms, it becomes straight forward to schedule and balance manual assembly lines. This work is included without direct intervention from users - work load is able to be automatically balanced across stations on each assembly line and graphical work instructions to match the line optimizations are dynamically generated in real time based on the current status of the database. As each shift's needs have to be accommodated in terms of staff available, expertise and more relevant work instructions are ready in real time at each station detailing the work to be completed.

Conclusions

Electronic documentation, beyond simple and static PDF documents, being adopted leads to a myriad of benefits. There is no limit to the number of files or supplementary data and information that can be included in work instructions provided in this manner allowing for more accurate instruction and reproduction of the necessary steps at each station.

Added benefits to this style of documentation include cost avoidance, risk reduction and risk mitigation through the consistency afforded. Direct scrap reduction can be measured as a result of having database driven multi-media work instructions implemented throughout a factory floor. ISO standards for process tracking, ensuring assembly consistency, process, and inspection (e.g. ISO-13485 for medical equipment) are helped tremendously using dynamic data base driven multi-media work instructions.

Database Driven Multi Media Work Instructions

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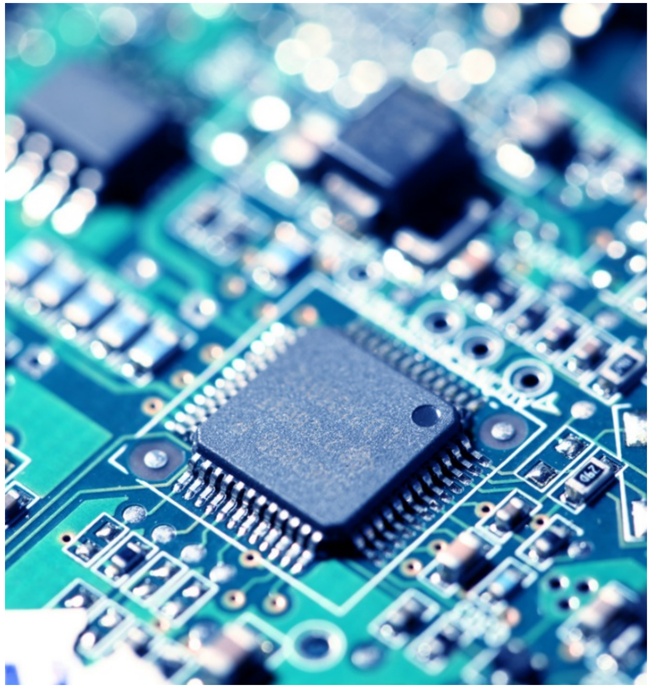
Introduction

Peter the Process Engineer

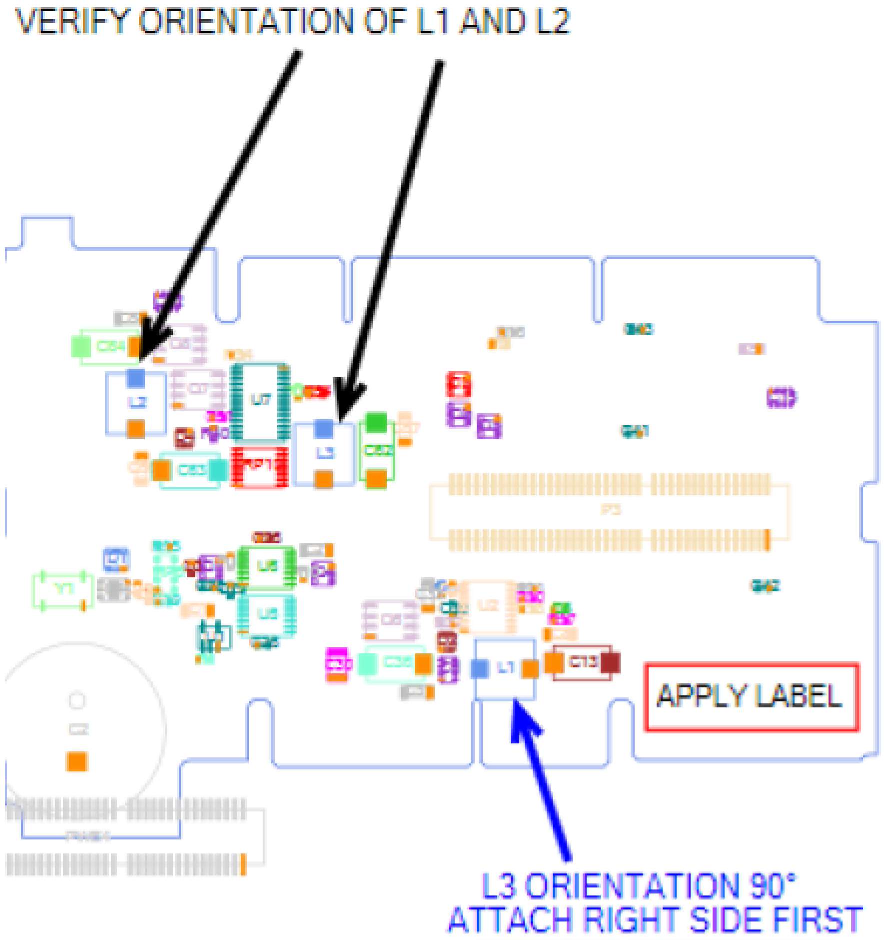


Oliver the Operator

TECHNOLOGY'S TURNING POINT

TURN ELECTRONICS MANUFACTURING INSPIRATION INTO INNOVATION

Work Instructions



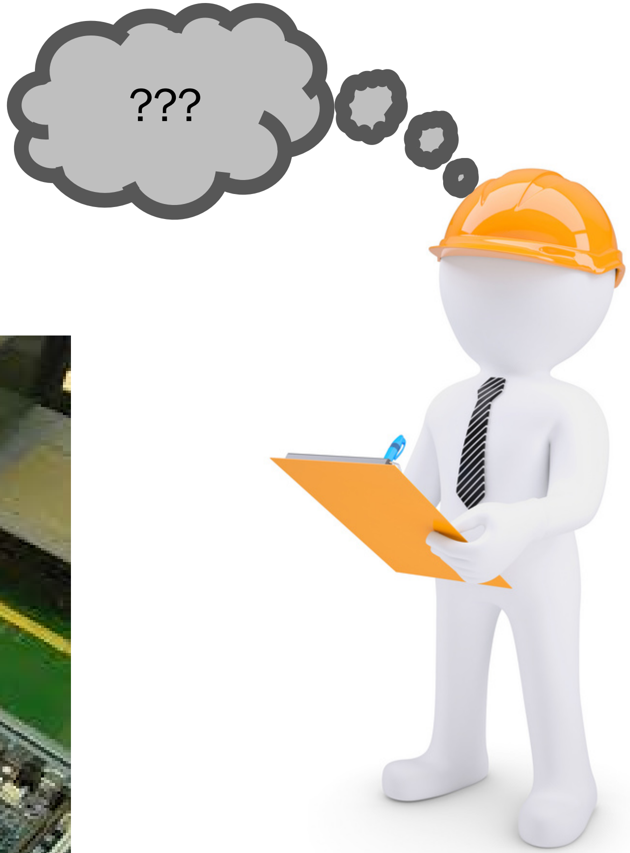
Color	PartNo	Desig	Docs	Desc
	94332601	D3		DIO,PWR-FAST,DUAL-70V,
	94354401	R3		RES,MF-1.00K 1/10W,1%,8
	94355053	C51		CAP,CER-470PF,50VDC,5%
	94362301	Q1-Q4		XSTR,FET-N,100V,.2A,SOT
	94379759	R1		RESISTOR
	94379811	R38		RES,MF-1.27K,.063W,1%,6
	94379833	R15, R19		RES,MF-2.15K
	94379930	R10, R12, R16, R21		RESISTOR
	94379965	R20		RES,MF-46.4K,0.1W,1%,06
	94384337	C19, C38		CAP,CER-50VDC,100PF,10
	94384353	C5		CAP,CER-50VDC,470PF,10
	94384361	C3, C25		CAP,S,C-50VDC,1000PF,10
	94384377	C10, C61		CAP,S,C-50VDC,4700PF,10
	94384496	C26, C28, C39, C41-C43		CAP,S,C-16VDC,.1UF,10%
	94386036	C54		CAP,S,C-X,0805,16V,.22U
	94394001	R13, R34		RES,MF-10.0,.063W,1%,06
	94394058	R32		RES,MF-39.2,.063W,1%,06
	94394065	R40		46.4 1% 63MW 060
	[illegible]	RP5		[illegible]

Limitations and Drawbacks

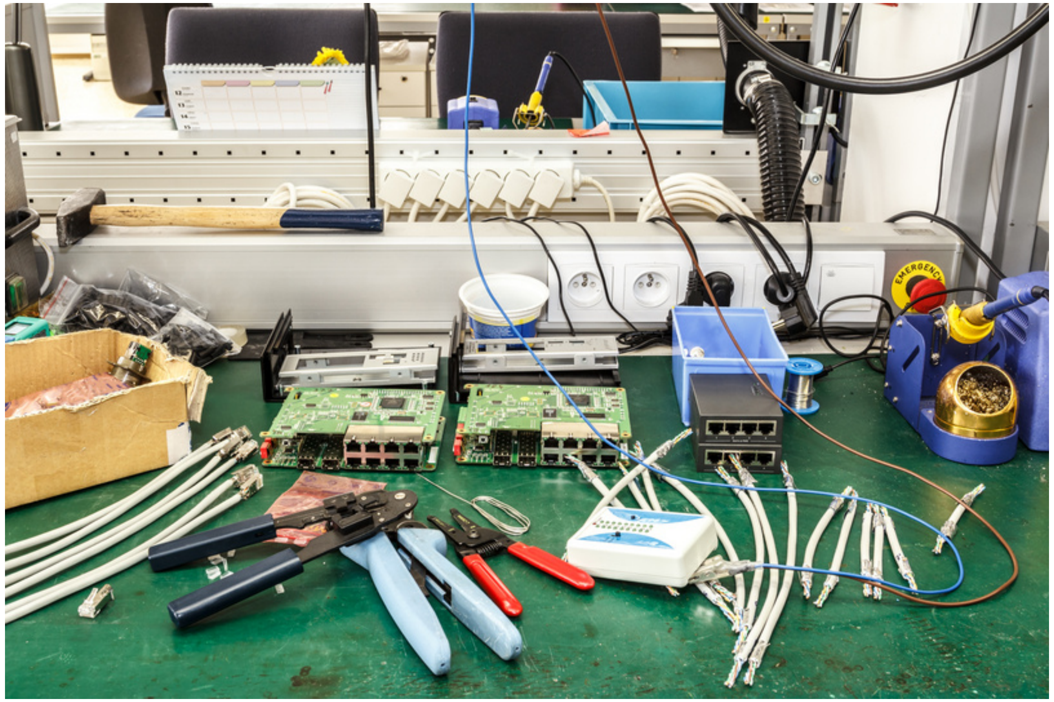
Limitations and Drawbacks

SMT Line / Pre-Oven Insertion Inspection

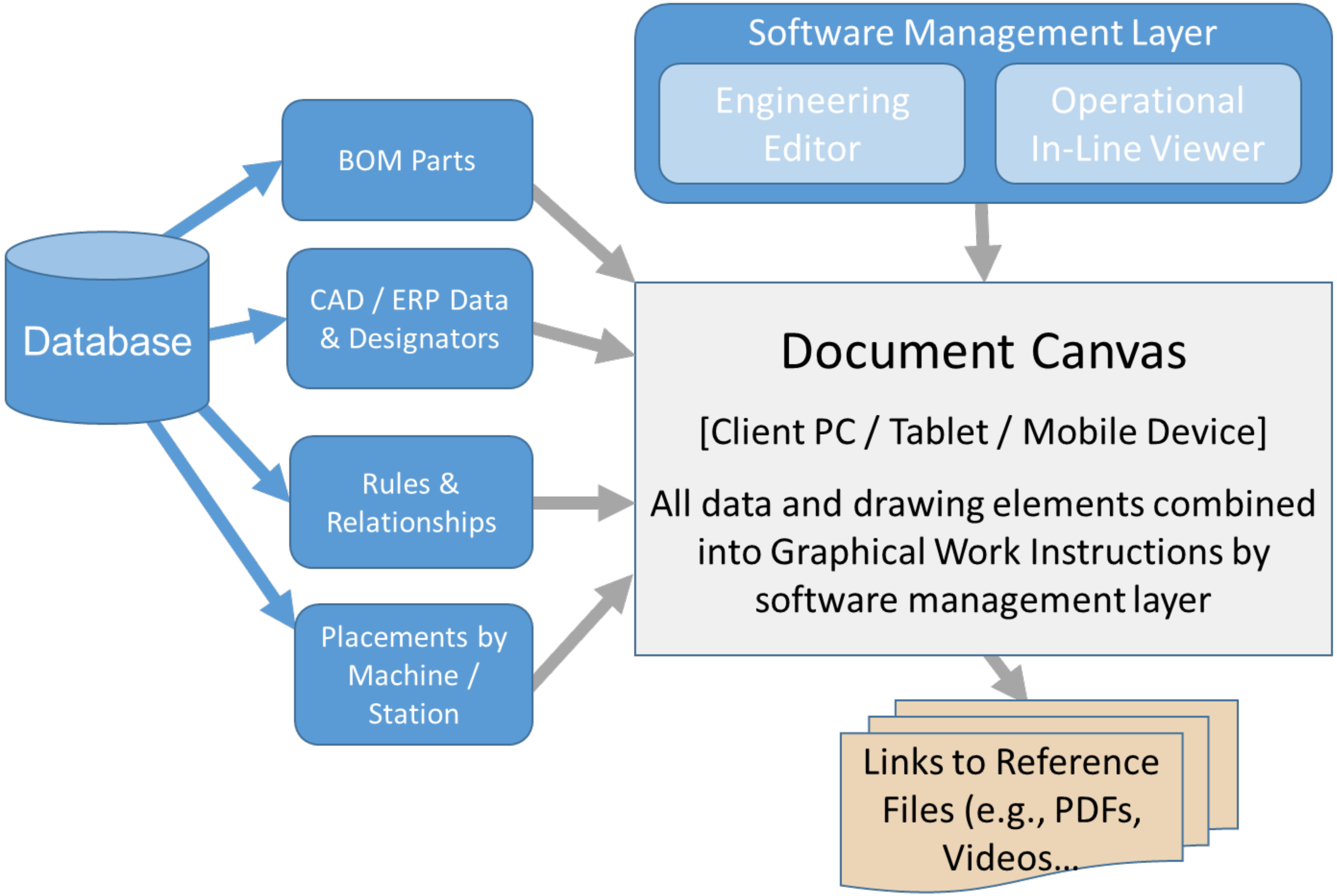
Slide-line Hand Insertion



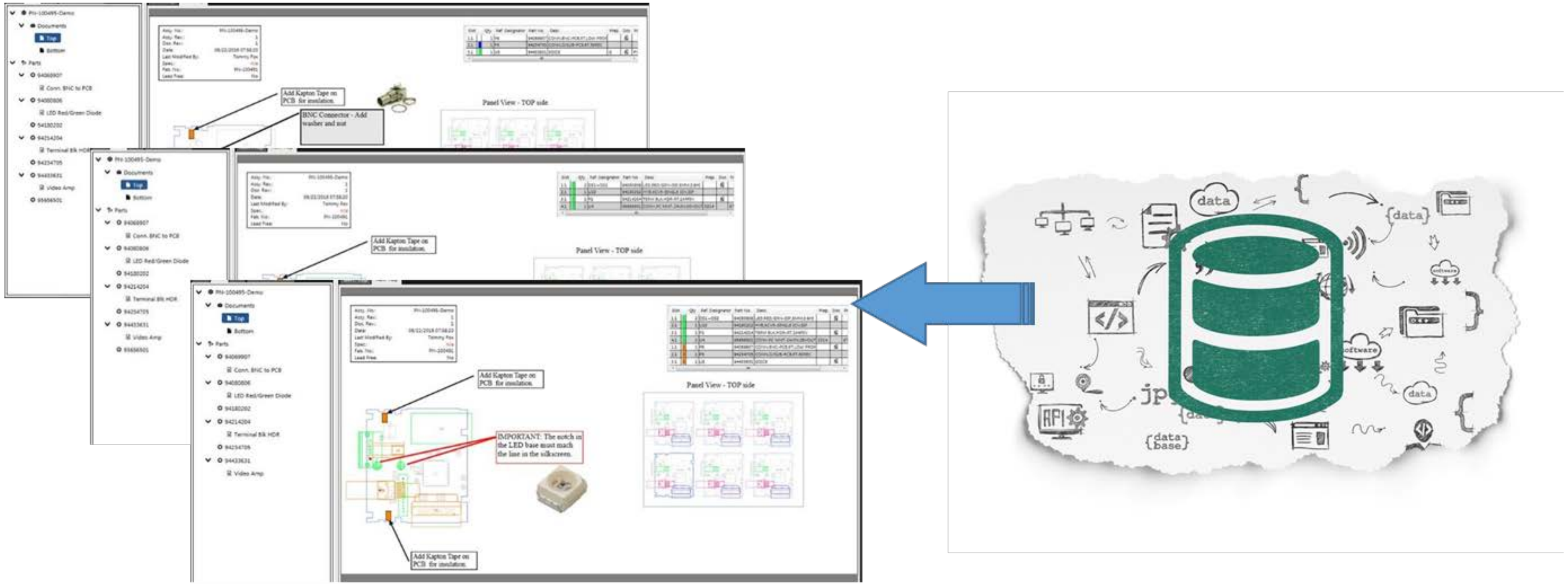
Work Instructions In Use



Database Driven Multi Media Work Instructions


Software Management Layer
Engineering Editor
Operational In-Line Viewer
BOM Parts
Database
CAD / ERP Data & Designators
Rules & Relationships
Placements by Machine / Station
Document Canvas
[Client PC / Tablet / Mobile Device]
All data and drawing elements combined into Graphical Work Instructions by software management layer
Links to Reference Files (e.g., PDFs, Videos...

Database Driven Multi Media Work Instructions



Dynamic Staffing Changes

Dynamic Staffing Changes

Dynamic Staffing Changes

Necessities for Database Driven Multi Media Work Instructions

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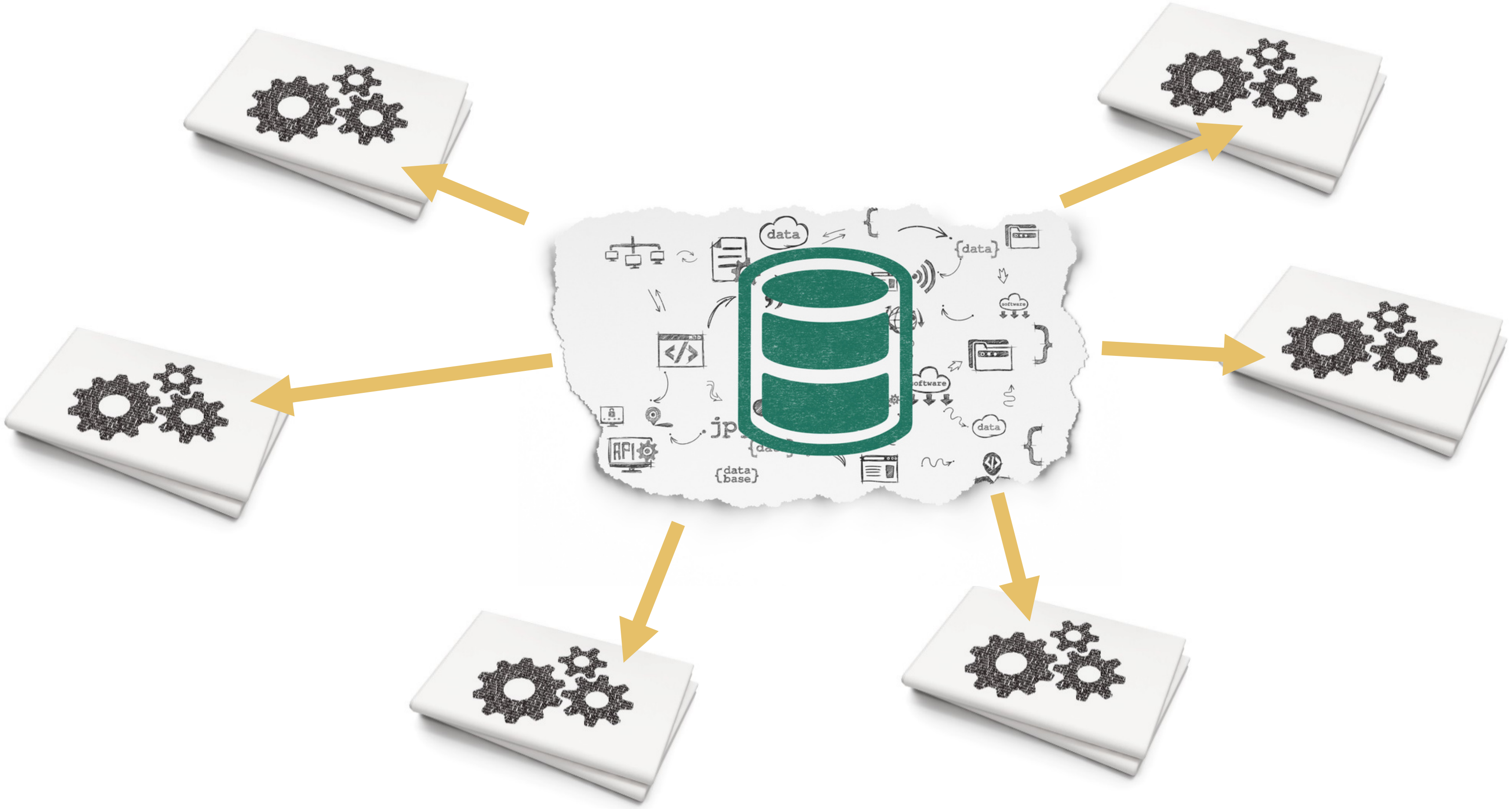
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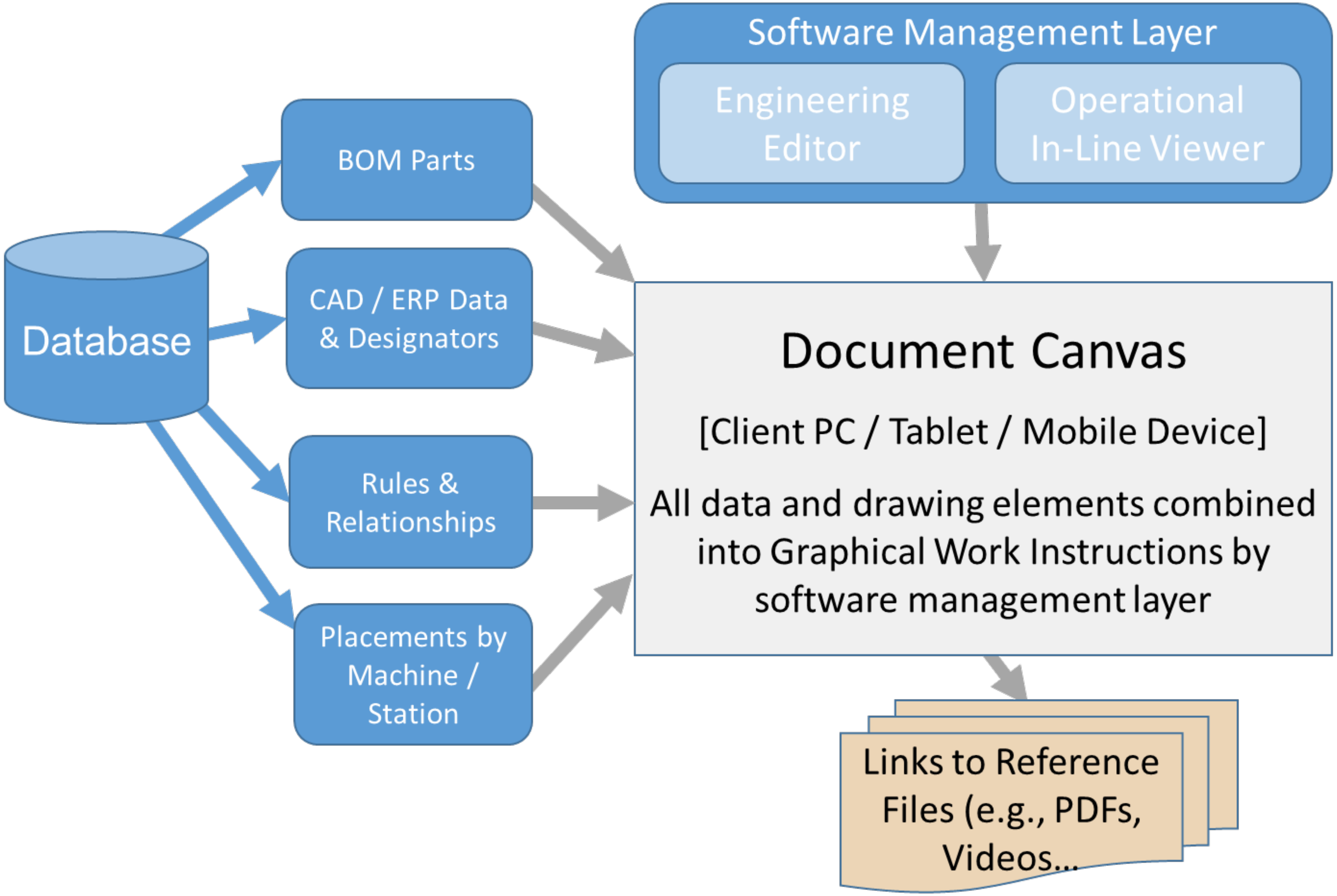
API


Software Management Layer
Engineering Editor
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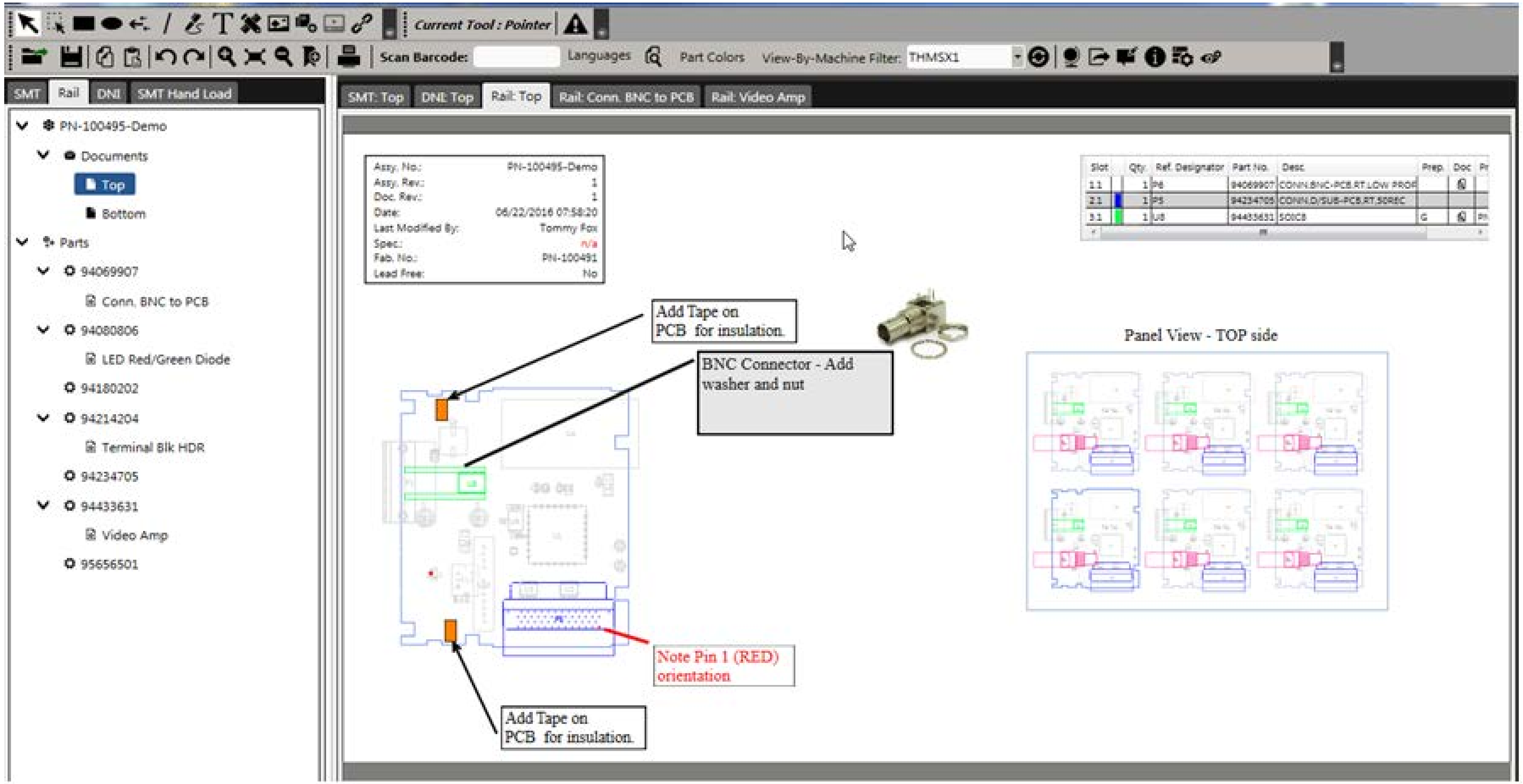
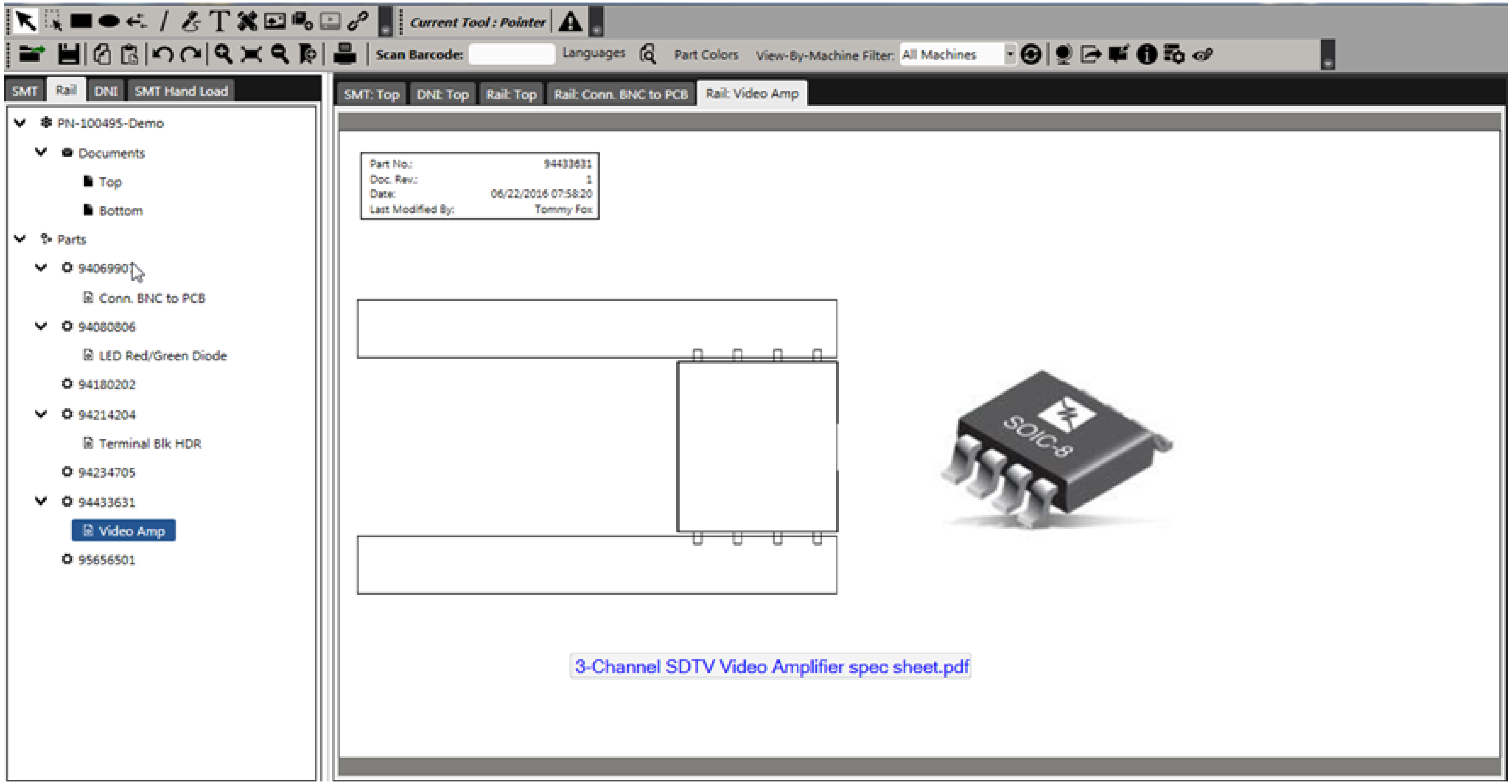
Placements by Machine / Station
Document Canvas
[Client PC / Tablet / Mobile Device]
All data and drawing elements combined into Graphical Work Instructions by software management layer
Links to Reference Files (e.g., PDFs, Videos…

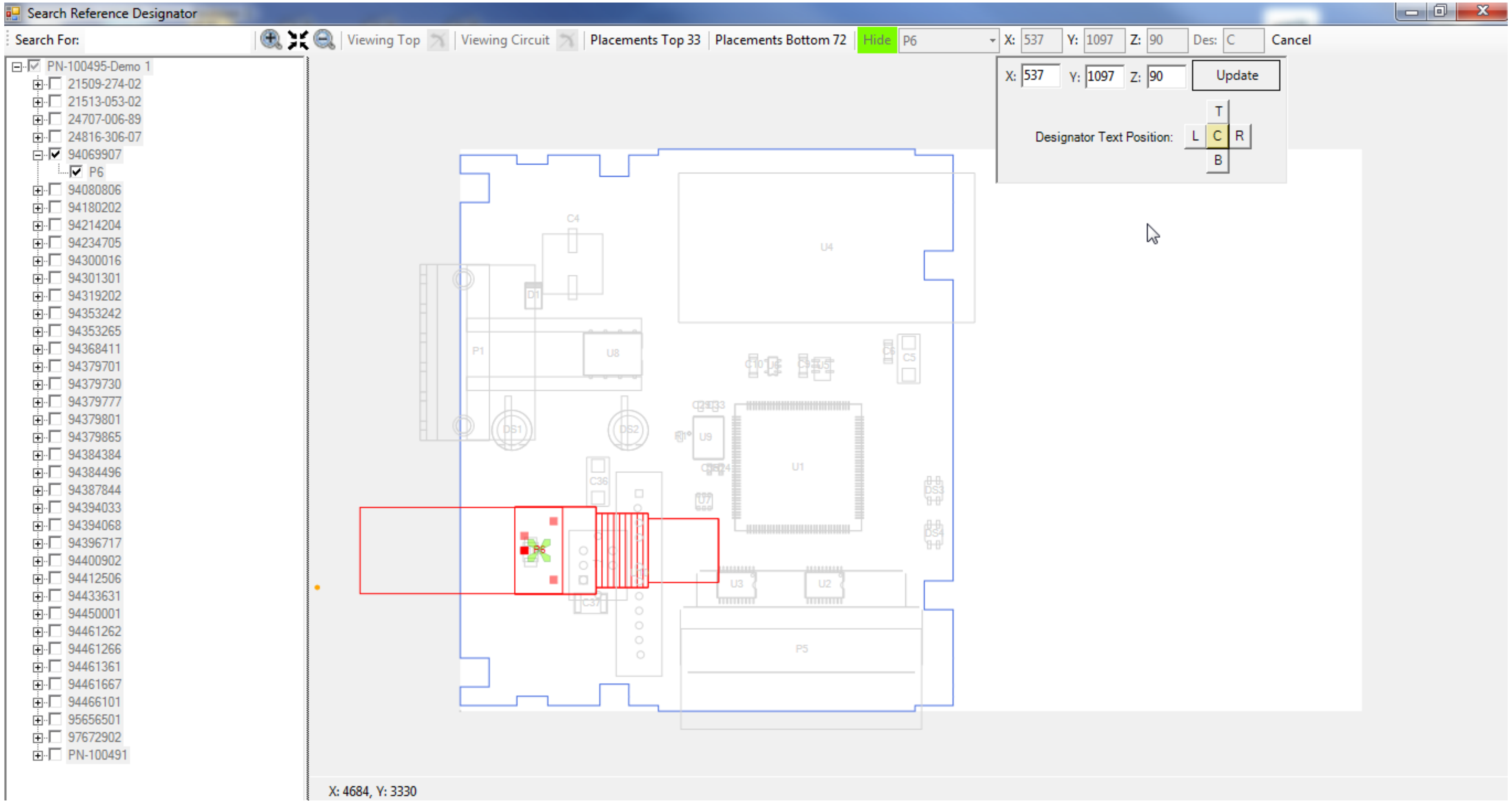
Required Solution Functionality - By Station



Required Solution Functionality – Edit Parts



Required Solution Functionality – Edit Parts



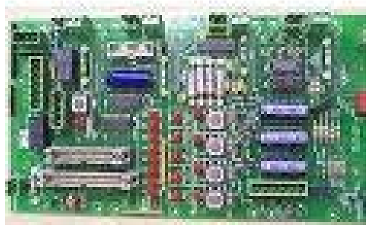
Dynamic Change Inheritance

Work Order level

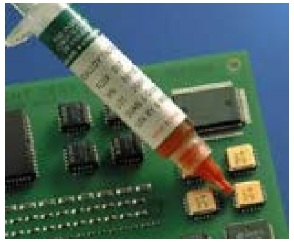
Work order # 22458

Note: xxxxx....

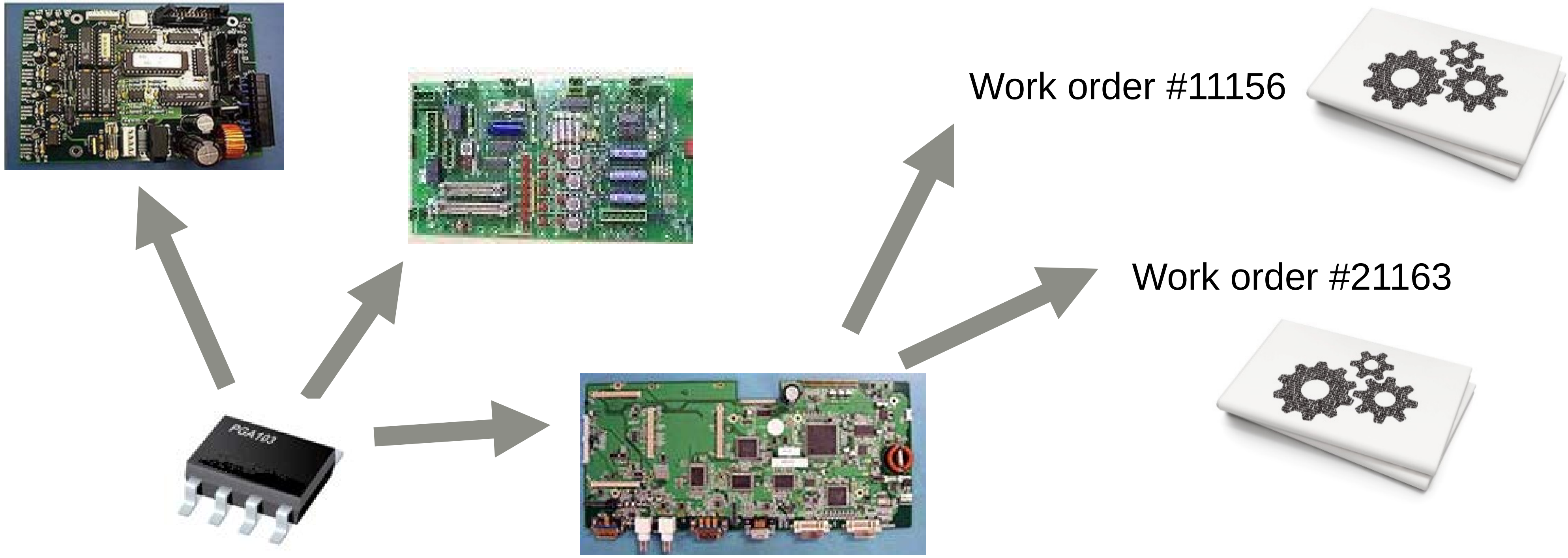
Assembly or revision level

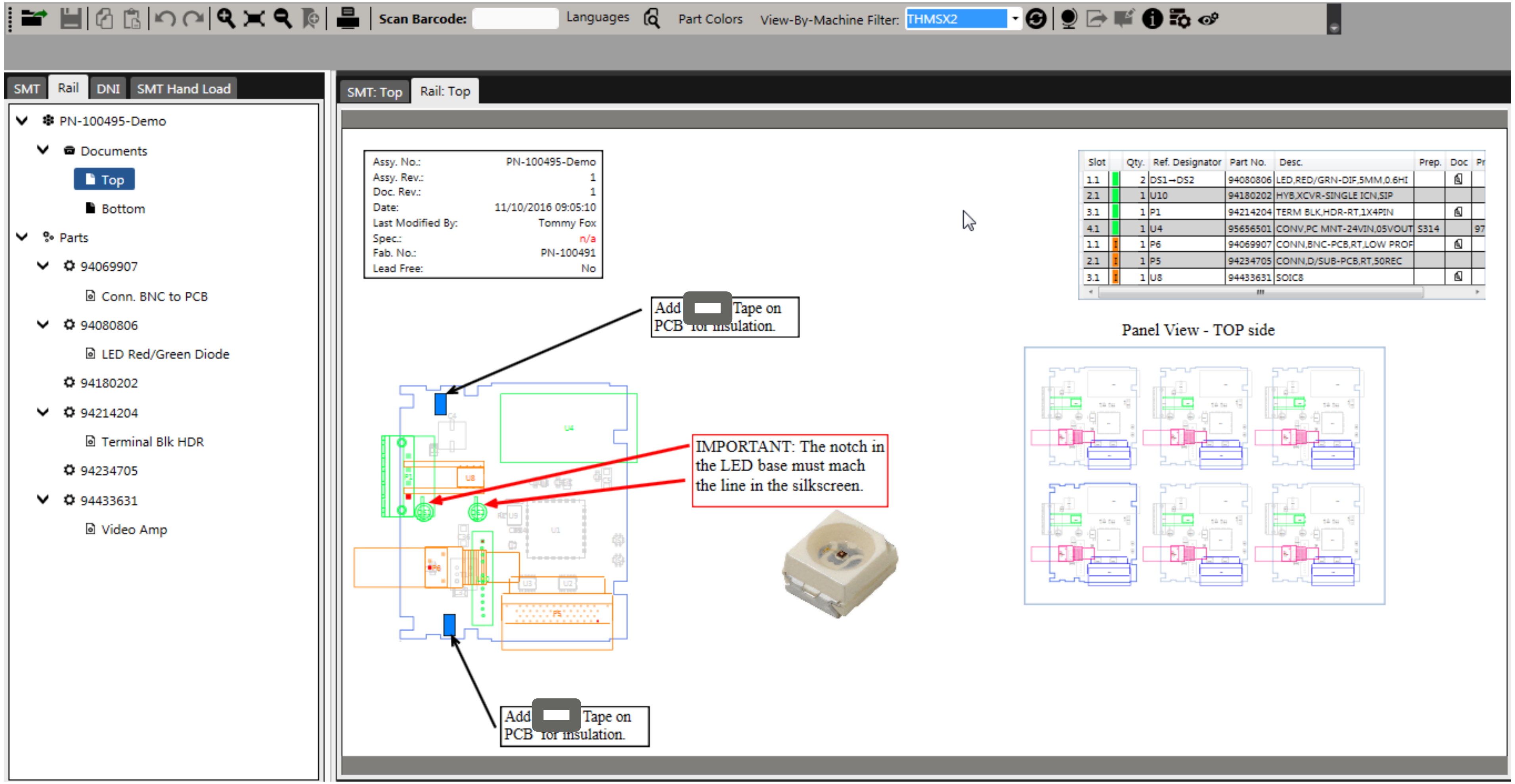


Part level



Dynamic Change Inheritance




Scan Barcode:
Languages
Part Colors
View-By-Machine Filter: THMSX2
SMT
Rail
DNI
SMT Hand Load
PN-100495-Demo
Documents
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Bottom
Parts
94069907
Conn. BNC to PCB
94080806
LED Red/Green Diode
94180202
94214204
Terminal Blk HDR
94234705
94433631
Video Amp
SMT: Top
Rail: Top
Assy. No.: PN-100495-Demo
Assy. Rev.: 1
Doc. Rev.: 1
Date: 11/10/2016 09:05:10
Last Modified By: Tommy Fox
Spec.: n/a
Fab. No.: PN-100491
Lead Free: No
Slot | Qty. | Ref. Designator | Part No. | Desc. | Prep. | Doc
1.1 | 2 | DS1→DS2 | 94080806 | LED,RED/GRN-DIF,5MM,0.6HI
2.1 | 1 | U10 | 94180202 | HYB,XCVR-SINGLE ICN,SIP
3.1 | 1 | P1 | 94214204 | TERM BLK,HDR-RT,1X4PIN
4.1 | 1 | U4 | 95656501 | CONV,PC MNT-24VIN,05VOUT | S314
1.1 | 1 | P6 | 94069907 | CONN,BNC-PCB,RT,LOW PROF
2.1 | 1 | P5 | 94234705 | CONN,D/SUB-PCB,RT,50REC
3.1 | 1 | U8 | 94433631 | SOIC8
Add [redacted] Tape on
PCB [redacted] insulation.
IMPORTANT: The notch in the LED base must mach the line in the silkscreen.
Panel View - TOP side
Add [redacted] Tape on
PCB [redacted] insulation.

Conclusions & Benefits

- Multi-media Content
- Central Information Management
- Paperless
- Easy to Use

Conclusions & Benefits

- Hierarchical Data Storage
- Comprehensive
- Modularity
- Dynamic Staffing Adjustments
- Dynamic Change Inheritance

Questions?

Database Driven Multi Media Work Instructions

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