ELECTRONIC DOES NOT EQUAL SMART:
SERVICE DOCUMENTATION AND BRAND QUALITY

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ABSTRACT

A vehicle's electrical system is one of the top sources of problems requiring service. For years now electronic means of service documentation have been replacing static documents as a way of speeding vehicle troubleshooting. The next step on this path is to turn e-documentation into smart maintenance systems, capable of offering technicians true data insights and highly-efficient diagnostic procedures. This paper briefly summarizes the technologies underpinning the evolution in electrical system diagnosis and repair, which include schematic layout automation using prototypes and rule-based styling, instant language translation, 2D/3D view links with schematics, interactive diagnostic procedures, and dynamically-generated signal-tracing diagrams. These technologies empower after-sales service teams with state-of-the-art capabilities, which not only reduce costs but also improve brand quality in the eyes of its customers.

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INTRODUCTION

Lousy service is expensive for all parties involved, but perhaps ultimately most of all for carmakers and their brands, luxury or otherwise. Indeed the range of derogatory acronyms out there — Ford, "Fix or Repair Daily"; Jaguar, "Just Another Gearbox Under Annual Repair"; Toyota, "The One You Ought To Avoid" — suggests that no brand is immune.

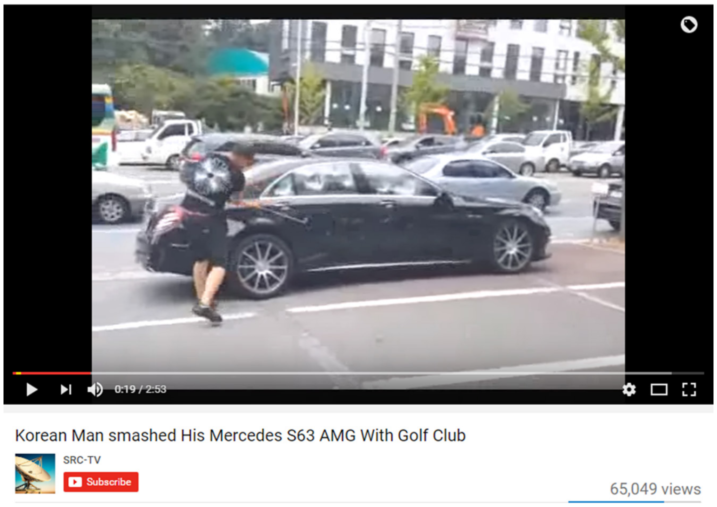

Figure 1: Je-Ha Yu vents his frustration at lousy dealer service.

This vulnerability to service frustration looms especially large in the age social media and Web forums. Case in point is Tesla, with an online community that is alive and well. It's easy to browse to lots of paeans from happy Tesla owners, including on Teslamotors.com, an independent enthusiast site. But searching also turns up a vibrant discussion thread kicked off by a July 13, 2016 post, which led with this subject line: "Anyone else extremely frustrated with getting Model S in for service?"[1] The four pages of comments that follow include no shortage of fairly harsh criticism, like this July 14 rant from a user with the handle of Mike K: "I'm growing increasingly frustrated too. I can deal with the 3 week wait times for an appointment and I can deal with the fact that my early build 2013 is going to have more problems than the average Model S but what really chaps my ass is when they give me back the car not fixed."[2] Search Twitter for #teslasucks for more blunt assessments still.

Tesla and wunderkind CEO Musk are magnets for all sort of attention but the phenomenon of frustrated car owners going the internet to vent, occasionally in dramatic fashion, is widespread. In 2015, South Korean Je-Ha Yu made news and garnered tens of thousands of YouTube views by smashing his Mercedes-Benz S63 AMG with a golf club to protest the poor service he'd received from the dealer.[3] A similar feat at the Qindao International Auto Show in 2013 — the car, a Maserati; the means of destruction, a sledgehammer — generated its own slate of headlines.[4]

The much chronicled rise of electric/electrical system content in vehicles, much of it ostensibly in an effort to deliver the features customers demand most, is somewhat paradoxically also tied to lots of customer annoyance. In-car electronics caused more problems in 2013 models than anything else, with Cadillac, Ford, Honda, and Lincoln vehicles accounting for the most complaints, in Consumer Reports 2013 survey of automotive reliability.[5].

Of course technology is transforming the work of dealers' service departments, including when it comes to service documentation. (Mostly) gone are the days of weighty and space-consuming paper manuals, which bring with them their own reams of problems and inefficiencies, often stemming from the fact that the relentless increase in electronic content in vehicles is optional in this age of consumer choice. As a result, the documentation supplied to the dealer must cover all possible configurations and the technician referring to a manual must discern how the wiring diagrams describing all possible configurations relate to the actual car being worked on. With paper, the fault-finding process requires the technician to flip continuously between different sections of the manual, which is time-consuming and error prone. Finally, as the book-production process is very onerous, updates and corrections to erroneous content are infrequent.

The good news is that nearly everywhere, paper has been replaced with electronic documentation as there has been a steady improvement in off-board diagnostic tools [6]. Instead of plying through reams of paper, technicians can consult the documentation on a computer and find the parts, service information, and wiring diagrams they need. Electronic documentation is much easier to use and update than paper documentation, but in most cases it is still not interactive, particularly compared to many other Web or app-based services that nearly everyone is used to. The e-documentation is rarely vehicle-specific and instead can be little more than an electronic transcription of the antecedent paper documentation. The technician must still determine which variation of the vehicle is being serviced. As a result, errors are still made.

This paper presents a look at something much more useful to the technician and to the manufacturer: Automated Smart Documentation. Smart documentation is a highly integrated, indexed and hyperlinked environment to view and interact with various parts of the electrical system in an automated way. These can include part numbers, diagnostic codes, wiring diagrams, diagnostic procedures, and the VIN number of the vehicle being serviced. It can also incorporate modern approaches to fault model-based diagnostic techniques [7].

My goal is to explore the concept of automated smart documentation from preparation, to production, to the eventual use by technicians in service centers.

BEYOND THE SERVICE DEPARTMENT

Electrical technical product documentation is most often associated with the dealers' service departments, but actually it is used throughout design and manufacturing stages. During the electrical design process, documentation is produced and utilized during design reviews and to provide access to mobile workers or workers at other sites. During manufacturing, documentation allows electrical faults to be diagnosed and corrected quickly, and accurately. Earlier, the value in the service department was made quite clear. Finally, contract manufacturers, such as harness makers, require accurate documentation to produce their subassemblies.

The electrical documentation package itself covers a large breadth of topics, well beyond the traditional wiring diagram. The ideal package is a fully integrated confluence of:

- Wiring diagrams
- Location views in both 2D and 3D
- Diagnostic procedures
- Diagnostic code definitions
- Service procedures
- VIN, vehicle identification numbers

The key point in smart documentation is that these resources are brought together in an integrated package, using automation. This ensures that a technician can link from fault code to diagnostics to wiring diagram to connector face view to location diagram to service procedure, quickly, accurately, and specifically for the vehicle being serviced.

Procedurally, creating a documentation package today is not much different than when it was all done on paper. It may be assembled, electronically, on a DVD or a website, but the technical publications team still operates much the same way, often redrawing wiring diagrams in vector graphics packages, restyling, hot-spotting, writing procedures, and integrating the entire package for distribution.

The list on the next page is a selection of the most common tasks associated with producing releasable documentation – which in most organizations are still done manually:

- Import wiring diagrams
- Redraw wiring diagrams
- Re-style diagrams
- Create wire lists
- Create hotspot diagrams
- Translate contents
- Create cavity charts
- Create connector face-views
- Create location views
- Create diagnostic documents
- Link everything
- Generate output

DIVIDE AND CONQUER: SEPARATING TASKS

The set of tasks highlighted above can actually be divided into two separate areas: data preparation and documentation synthesis. By dividing up the full set into two categories, each can be performed separately in a streamlined flow for production of technical documentation. In the following sections we will discuss each process and where automation can be employed in each.

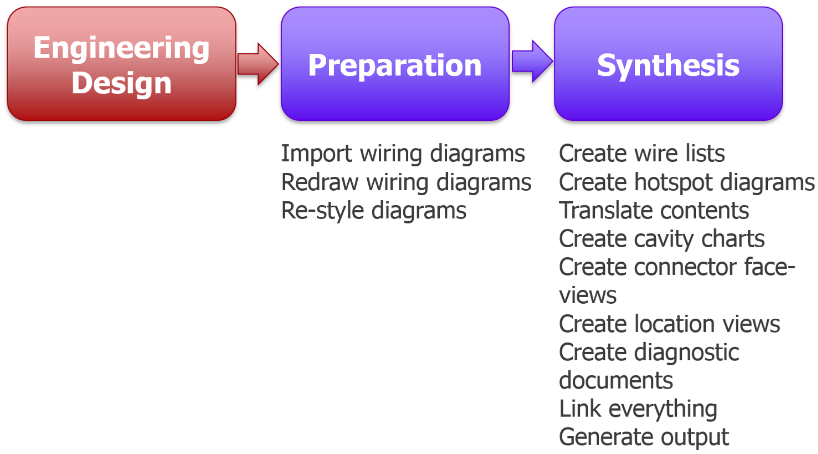

Figure 2: Dividing the process of service documentation production into two areas allows technical authors to conquer the task efficiently by focusing on design content specification; this frees them from the repetitive/programmable tasks of data mining, packaging and linking, which are carried out by a synthesis engine.

DATA PREPARATION

The engineering data is a rich resource to use as a starting point to the data preparation stage. Moreover, it is a resource which is available much sooner than the service documentation phase, and that richness and availability can and should be leveraged.

The engineering data is copied to form the starting point for service documentation. The native format is then changed to repartition the electrical system content into different designs and functions that would make more sense to the technician when viewed at service time. Then diagrams are repaginated so that they fit into different borders and paper sizes for a printed version of the documentation. Finally some clean up and additional edits are done to update the names of components to their service equivalent, add any text or graphics that would aid the technician when looking at the wiring diagrams.

As engineering data matures, so does the service documentation counterpart. Updates are made to previously prepared data, making sure that the effort invested previously is not wasted. This is achievable by incrementally adding and changing system connectivity on top of the present service wiring diagrams which are used as "prototypes". The use of prototyping ensures that the partitioning, pagination and layout settings in its current form does not get wiped or redone, but is rather added upon as and when new connectivity is made available from the engineering side.

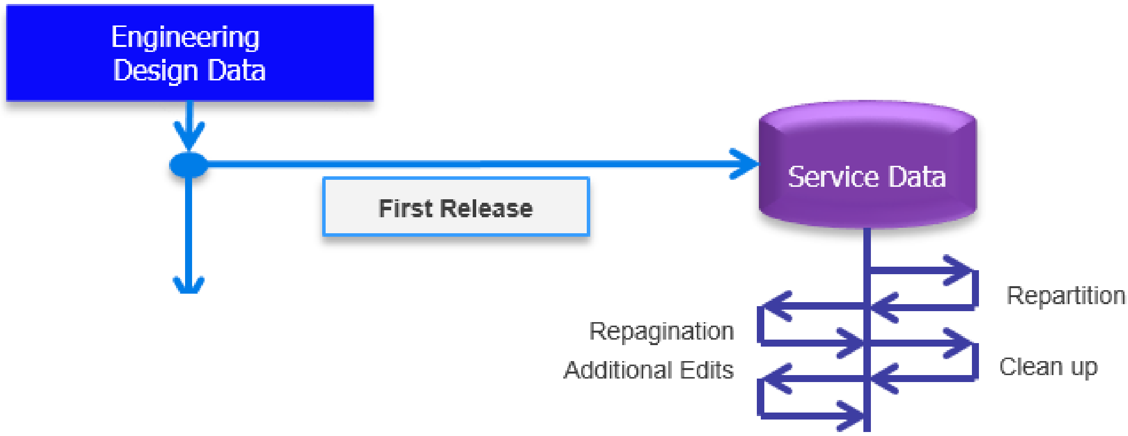

Figure 3: Engineering wiring diagrams are reused as a starting point for service diagrams in which a copy is taken and processed through repartitioning, repagination, clean-up, and service-specific edits.

Finally the use of "Styling" technology allows for a rule-based formatting of the text and graphics of every aspect of the diagram. This would ensure company formatting rules are respected, and that the process of implementing them is as streamlined and as quick as possible. Formatting can range from a simple rule such as setting the wire graphics so that the color follows the definition in library, to a more intricate rule that traces a component's connections and displays a special symbol if one of them is of specific significance.

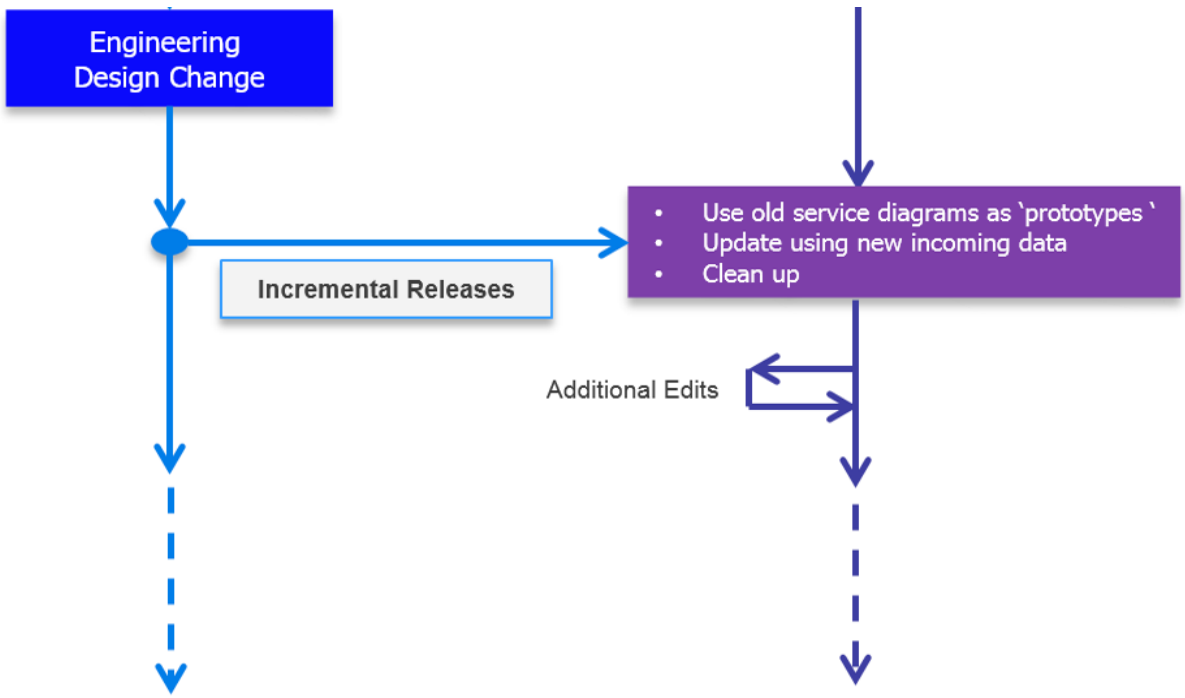

Figure 4: Service and engineering design changes go hand in hand; as the designs mature on the engineering side, incremental changes are made to service diagrams where the use of prototypes saves time and effort and ensures there's little to clean-up after the changes are made.

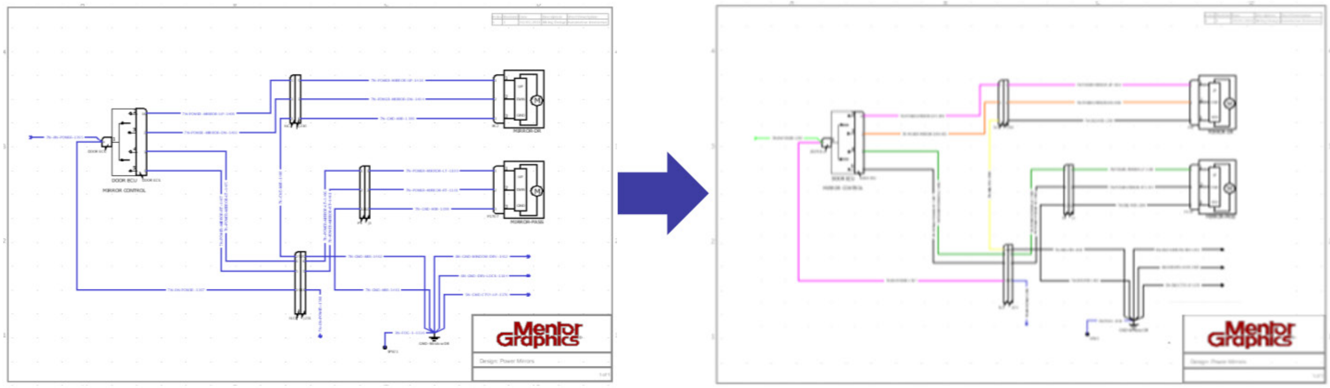

Figure 5: Styling technology separates design content from style which enables a more efficient flow where the formatting of text and graphics is automated through rules and standards.

With this iterative process, service data preparation is:

- Started as early in the cycle as possible
- Implemented as automatically and as quickly as possible
- Finished as accurately as possible

INTEGRATED DOCUMENTATION SYNTHESIS

In order to aid the technician in rapidly finding the source of electrical problems, service documentation needs to be highly integrated and interactive. I posit that this can be achieved using a process called documentation synthesis. This process starts by using the highly valuable intellectual property that has been authored by the engineering department during the Design phase, and further embellished/reworked by the service department in the Preparation phase. A synthesis engine can be employed to iterate all of the electrical design data and automatically create the fully interactive and integrated documentation.

The smart documentation tool mines the text in various resources to locate all pertinent information, regardless of format. Once it has all the data, it is able to search its database on engineering data and to match the unstructured data with the electrical design data. Where matches are made, the hyperlinks between illustrations and wiring diagrams can be made. The tool imports fault codes, and then analyzes the design to create relationships to the object that a particular fault code indicates. Symptoms are linked to the likely causes of the problem along with diagnostics steps to confirm whether a component is at fault.

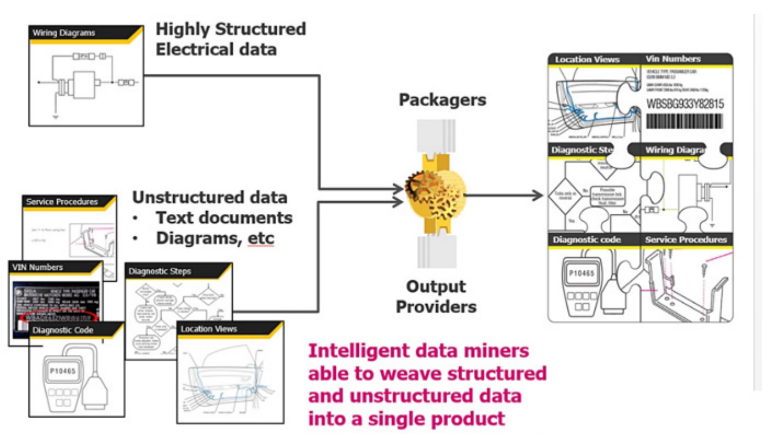

Figure 6: The valuable unstructured data is mined and weaved into the final, single package of documentation.

When the source data is updated, the documentation synthesis tool can once again use the updated data to re-establish relationships and create new links. The synthesis engine can create an integrated documentation package for a variety of common devices and in a variety of formats.

USING SMART DOCUMENTATION

While the paper thus far has explained the theory and mechanisms that allow the automation of smart documentation, actual examples can be more useful in demonstrating the full capabilities.

Mentor Graphics Capital Publisher will be used for example purposes. Figure 7 demonstrates how the system has collected the structured data from the documentation system and weaved it together with the unstructured data that was mined. The result is an easy-to-use technique to rapidly and accurately locate faults. Every view is now associated with the parts that are present on that unique vehicle, and they are linked to wiring diagrams, location views, and troubleshooting aids. In the example, the circuit under scrutiny has been isolated for the technician, and only the parts that have this connector are shown.

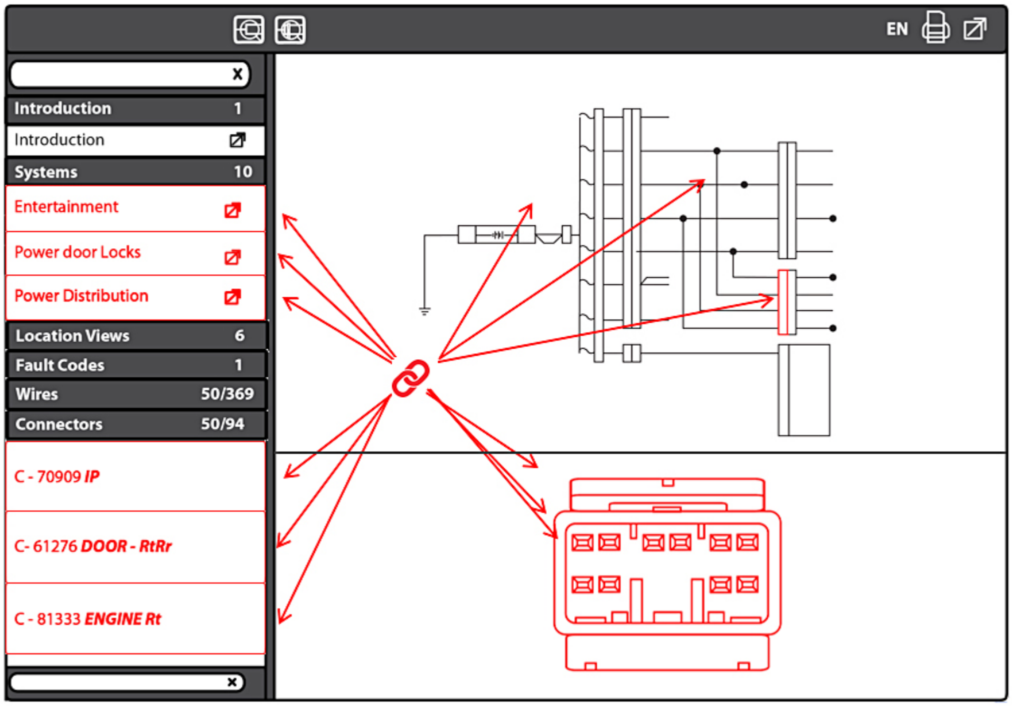

Figure 7: Through mining and processing all documentation data and resources, a highly usable output is presented to users.

THE PROBLEM OF CONFIGURATION COMPLEXITY

Configuration complexity has long been a headache for technicians and other document users. Technicians are commonly provided with 150% electrical documentation that describes all possible configurations of a vehicle. This electronic configuration complexity continues to grow at an unceasing pace. Each wiring diagram is dense with content – much of which is not relevant for the actual vehicle configuration that the technician is working on. Sorting the wiring diagram for the car being serviced and finding the problem is another opportunity for error. Smart documentation creates a unique presentation to the user by including only the systems, interconnections, and wiring that is present on the vehicle of interest.

In figure 8, the entire set of audio options is shown as the technician attempts to locate a problem with the In-Vehicle-Infotainment System (steering wheel audio controls).

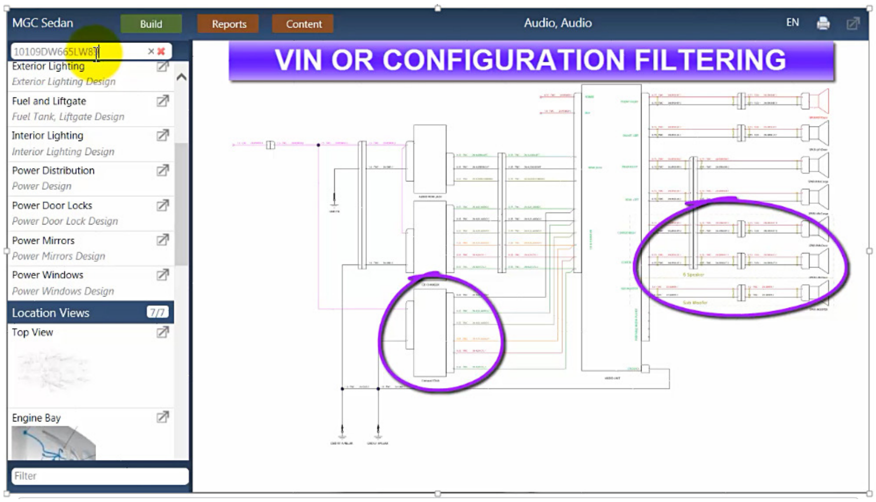

Figure 8: The entire set of options is shown for the IVI system before the VIN is entered.

In figure 9, after the VIN has been entered, the system can look up a database to find which options are supported on that vehicle. The wiring data is all tagged with option expressions and the system can then filter for the configuration. Then only the items that are present are displayed; all other information is removed from this and all subsequent views. Now the technician not only has an uncluttered, non-distracting view, but the view is error free as well.

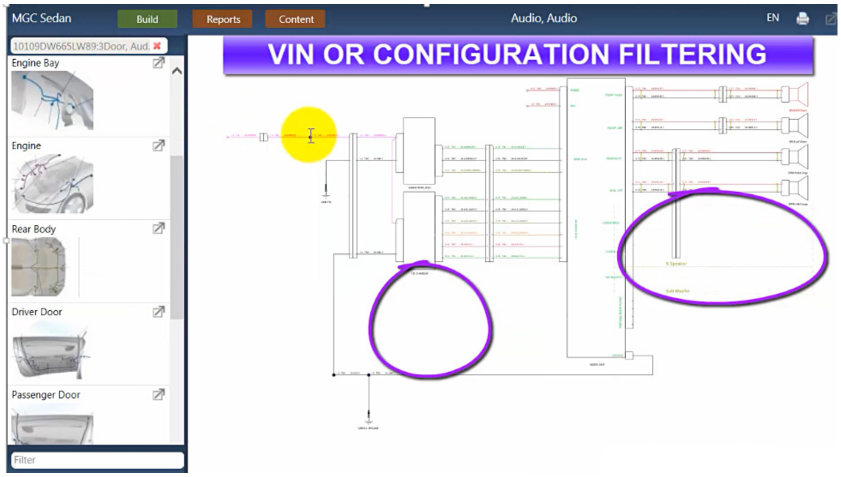

Figure 9: Once the VIN is entered, all optional components not present in that unique vehicle are removed from view, presenting a clear, non-confusing document.

PERFORMING DIAGNOSTICS INTERACTIVELY

Diagnostic procedures enable the technician to debug vehicle problems in structured way by following a flow chart of events where different conditions are tested on the vehicle and, depending on inspection or measurement results, are moved to one branch of the flow or another. The problem with these procedures is that they're often static and involve a lot of manual work, not only in transitioning between different paths/steps, but also in going back to wiring diagrams and doing an eye-match for component or wire names.

In this implementation of diagnostic procedures, interactive hyperlinks are used as the means of transitioning between steps. They are also used to enable pinpoint access to the component or wire in question. The example below shows this in action where a diagnostic procedure instructs the technician to measure the supply voltage to the power distribution box and move to Step 3 if it is greater than a threshold of 9.4 volts (necessary for proper operation). In that example, the quick access to the location view of the PDB helps the technician to locate it in the vehicle and make his measurements quickly

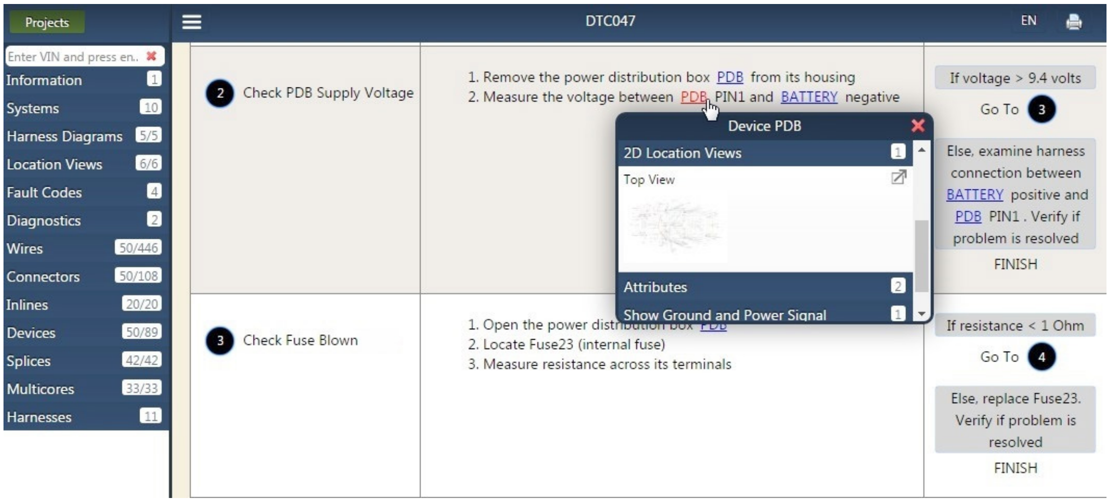

Figure 10: An interactive diagnostic procedure focuses the technician's attention on carrying out the current task in an efficient way.

Using these interactive diagnostic procedures, the technician employs more of his thinking and time into the actual inspection of the system, and less into data mining of the different resources.

IDENTIFYING ROOT CAUSES THROUGH SIGNAL TRACING

For troubleshooting, smart documentation allows the technician not only to use VIN-specific diagrams, but also to focus directly on the problem, eliminating all other circuitry from the view. For example, if a controller is not operating correctly, a wiring diagram can be dynamically created using solely this component and the technician can explore the relevant connections to this component dynamically using a technology called 'click and sprout'. This innovation allows a technician to zoom in on the problem in just a few seconds. Similar troubleshooting with current documentation could take hours.

The figures on the next page illustrate how troubleshooting might take place. Figure 11 illustrates how the technician can locate a particular connector from the wiring diagram, display the face-view, and then expand the connector diagram to show the individual signals. In this case, the technician has determined that there is no power present at the steering wheel control interface (ASWC). Zooming in on the connector as shown in figure 12, the technician can click on the power pin.

Now, only the power pin connections will be filtered and the only thing presented to the technician will be the circuit from the connector back to the connection with 12v power in the ignition. Figure 13 shows the result: a very simplified diagram that makes troubleshooting much easier and much faster.

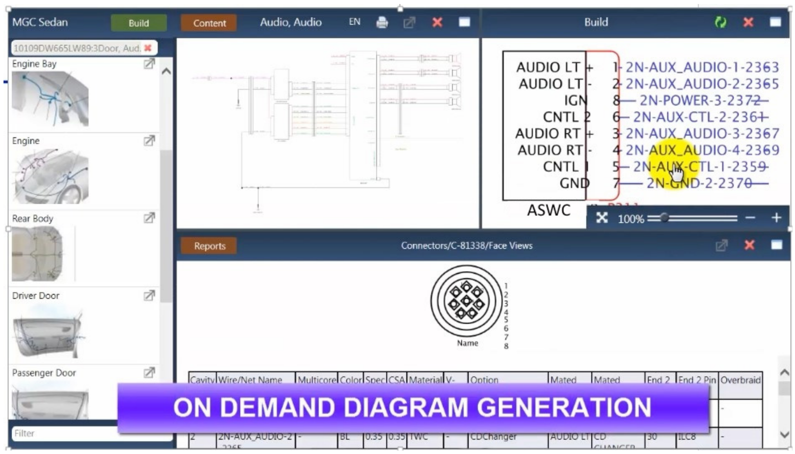

Figure 11: Focusing on the problem allows the view presented to the technician to eliminate all but the specific problem that is being troubleshot.

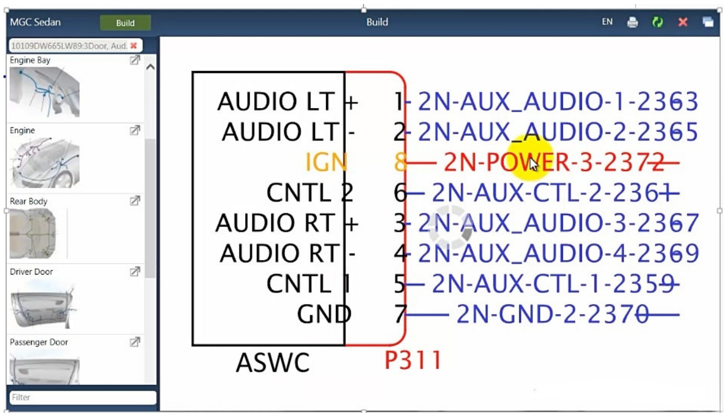

Figure 12: The problem can be isolated by clicking on the power pin.

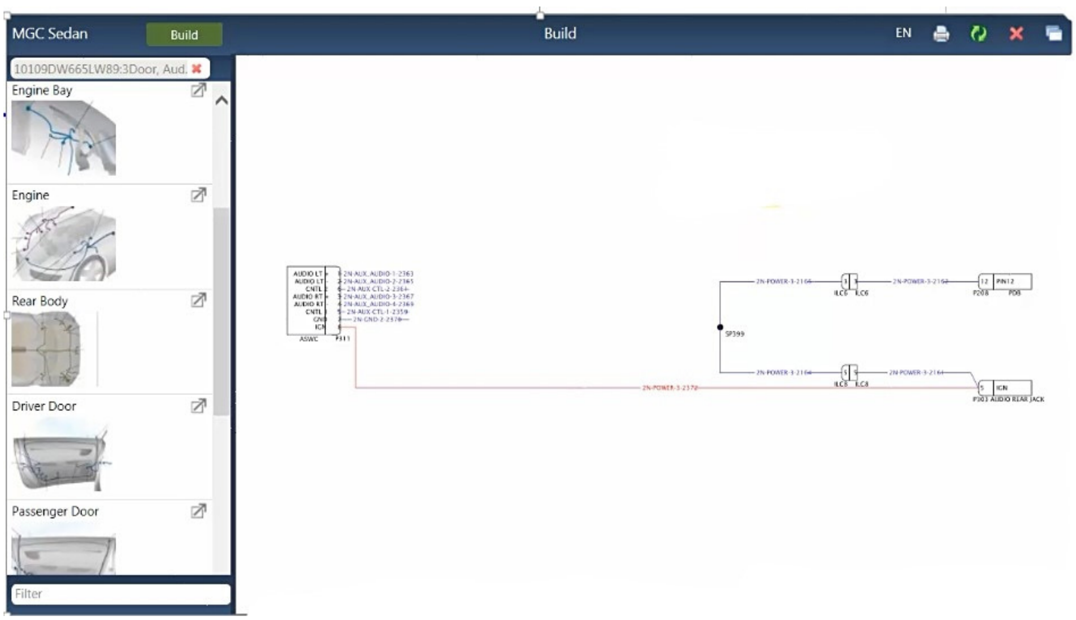

Figure 13: Isolating down to the power circuit and nothing else, it is easy to find the fault.

SUMMARY

Smart documentation is poised to significantly improve the production and usage of automotive documentation. As shown in the examples with Mentor Graphics Capital, preparation of electrical schematics can be streamlined while data from all sources are assembled and cataloged. Unstructured data is mined and relationships determined. The final package incorporates all these data sources and relationships in an east-to-use single document package.

This level of intelligence in documentation can drastically speed up the process of locating faults as well as guide the technician through rectifying that fault. Errors are cut just as drastically. And while the technician will certainly appreciate the benefits of smart documentation, the benefits to the dealerships and the entire brand go far beyond.

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