IPC ENGINEERING WEBINAR SERIES

Using Technology to Increase Throughput and Reduce Errors in Wire Harness Production

- Presenter:
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DIT-MCO 75 YEARS OF EXCELLENCE

Background

- Traditionally, wire harness shops use automatic wire/harness testers to detect wiring faults.
- Even when such faults are detected, diagnosis to the root cause can be difficult and time consuming.

3-Typical Wiring Faults

- Mis-wires
- Open circuits
  - Complete open
  - R -> expected
- Short circuits
  - Dead shorts
  - Insulation Resistance <- expected
  - Dielectric or HiPot failures (arcs)

Background

- Failure analysis requires a highly skilled technician to decipher schematics and reported failures. Requires detailed knowledge of
  - Wire harness under test (UUT)
  - Schematics
  - Test system nomenclature & architecture
  - Wiring harness fault conditions

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:       CC  01713                                   52J-C75EB221-P
:                   01714 PASS   164.1     OHM 52J-C75EB221-R
:       CC  01701                                   52J-C75EB221-B
:                   01702 PASS   138.5     OHM 52J-C75EB221-C
:       FF  01713                                   52J-C75EB221-P
:                   01711 FAIL   138.5     OHM 52J-C75EB221-M
:                   01703 FAIL   113.0     OHM 52J-C75EB221-D
:                   01701 FAIL   113.0     OHM 52J-C75EB221-B
:                   00413 FAIL   87.40     OHM 1P-P1EB018B-C
:                   00313 FAIL   87.40     OHM 52P-P1DB076D-B
:                   00213 FAIL   61.80     OHM 52P-P1DB076A-P
:                   00113 FAIL   61.80     OHM 72P-P1BA2P1B-6
:                   00013 FAIL   36.20     OHM 72J-P1BA105-2
:       FF  01701                                   52J-C75EB221-B
:                   00413 FAIL   10.60     OHM 1P-P1EB018B-C
:                   00313 FAIL   394.6     OHM 52P-P1DB076D-B
:                   00213 FAIL   394.6     OHM 52P-P1DB076A-P
:                   00113 FAIL   369.0     OHM 72P-P1BA2P1B-6
:                   00013 FAIL   369.0     OHM 72J-P1BA105-2
:       TT  01701                                   52J-C75EB221-B
:                   01703 FAIL   317.9     OHM 52J-C75EB221-D
:                   01705 FAIL   317.9     OHM 52J-C75EB221-F
:                   01707 FAIL   317.9     OHM 52J-C75EB221-H
:                   01709 FAIL   317.9     OHM 52J-C75EB221-K
:       TT  01702         PASS   292.3     OHM 52J-C75EB221-C
:       TT  01709                                   52J-C75EB221-K
:                   01701 FAIL   292.3     OHM 52J-C75EB221-B
:                   01703 FAIL   266.7     OHM 52J-C75EB221-D
:                   01705 FAIL   266.7     OHM 52J-C75EB221-F
:                   01707 FAIL   266.7     OHM 52J-C75EB221-H
:       TT  01710         PASS   266.7     OHM 52J-C75EB221-L
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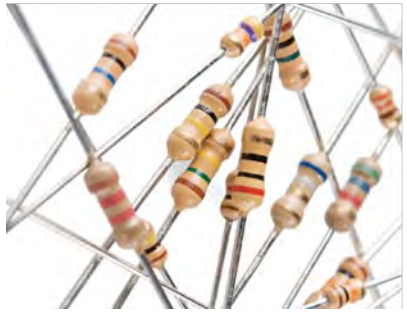
Background

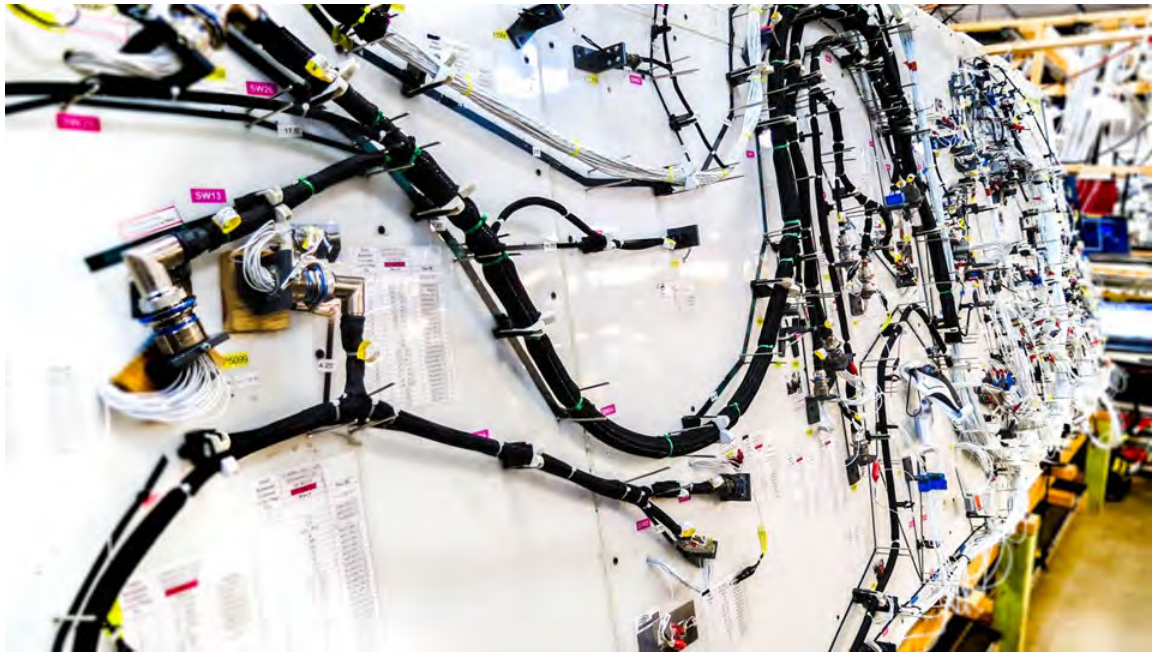
Circuit breaker

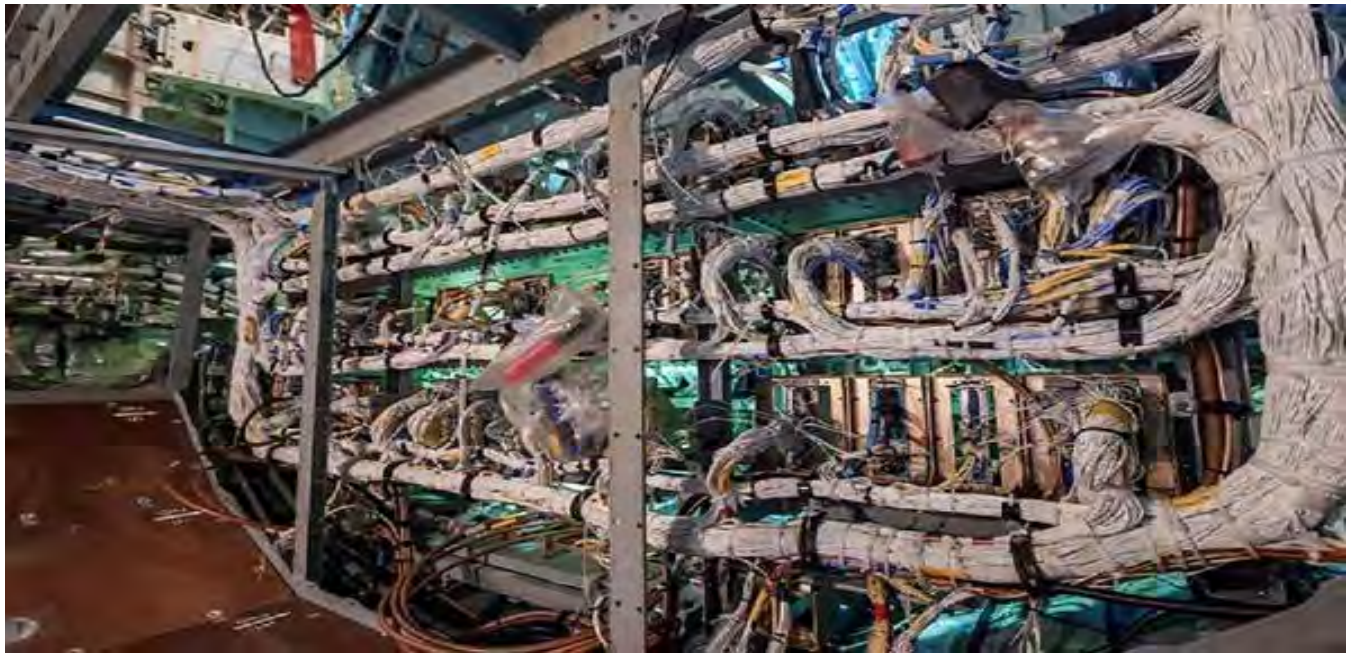
- Complexity increases with assemblies that have additional components (relays, lamps, switches, circuit breakers, resistors, diodes, etc.) and/or multiple connection points.



Background

- Additional time is required to diagnose problems with large, complex harnesses
  - On the form board
  - In the vehicle





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Summary of Challenges in the Wiring Harness Industry

- Increased use of electronics places more importance on the wiring harness
- Wiring harnesses are becoming increasingly complex
- Building wiring harnesses continues to be extremely labor-intensives with > 80% of all operations handled manually
- Fragmentation between harness design and testing leads to manual data transfer
- Many harness engineering and manufacturing processes are outdated
  - Time-consuming, error-prone and inefficient
  - Reliant on tribal knowledge
  - Problems are difficult and time consuming to rectify

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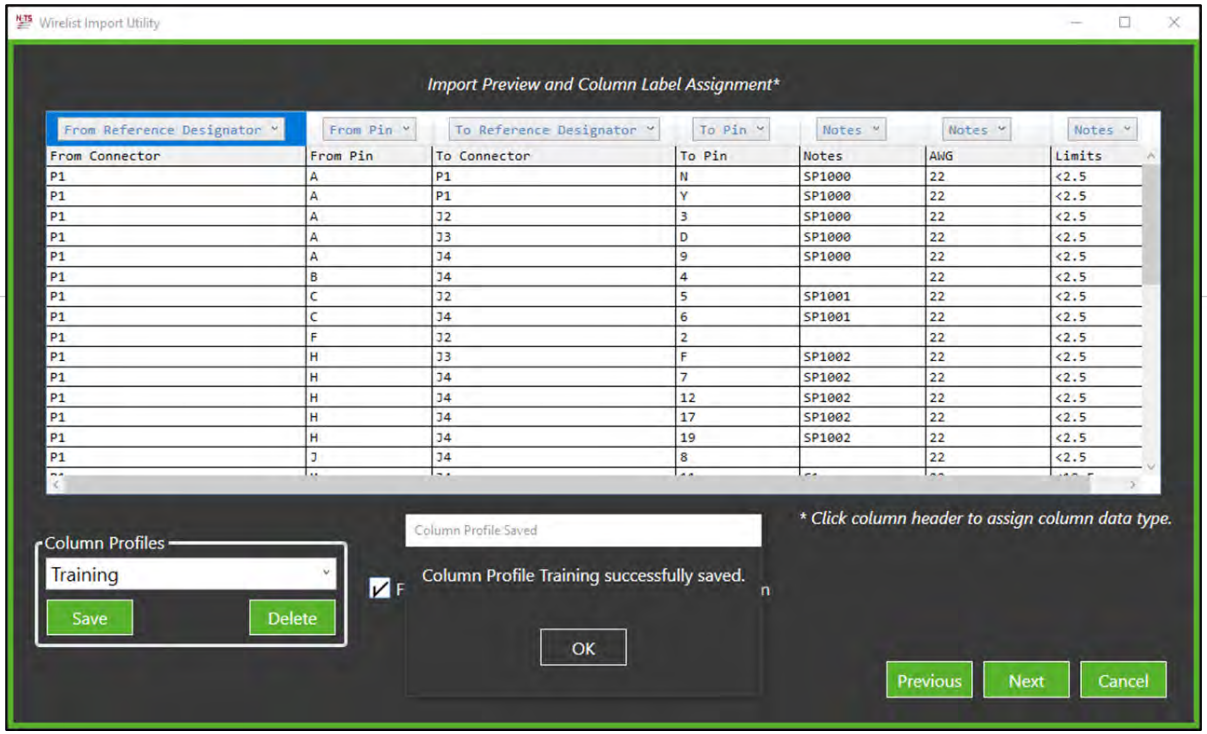
Potential Solutions

- Integration of wire harness design data with manufacturing & testing processes
- Augment insertion of wires into connectors to eliminate cross-wire errors
- Use harness design data to create adapter cable designs
- Auto generate testing programs to completely test the integrity of the wiring harness
- Advanced system architecture to allow complete testing of all wiring networks in lieu of individual wires.
- Advanced trouble shooting tools during harness testing

Wirelist Import

- Minimizes test programming errors
- Wirelist import function
  - Required – from/to connectors & pins to be tested
  - Include non-adapted points – splices, internal connectors
  - Components – part number, reference designators & electrical characteristics
  - Wire ID
  - Connector part numbers
  - Signal names
- More data = better testing



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PinMate - Operator Assisted Guided Insertion

- **Features**
  - No adapter cables required
  - Large connector library
  - Lightweight, flexible
  - Quick set-up
  - Easy to use software
- **Benefits**
  - Helps eliminate mis-wires
  - Improves throughput
  - Saves time & money – up to 40%-time reduction
  - Reduces eye strain & fatigue

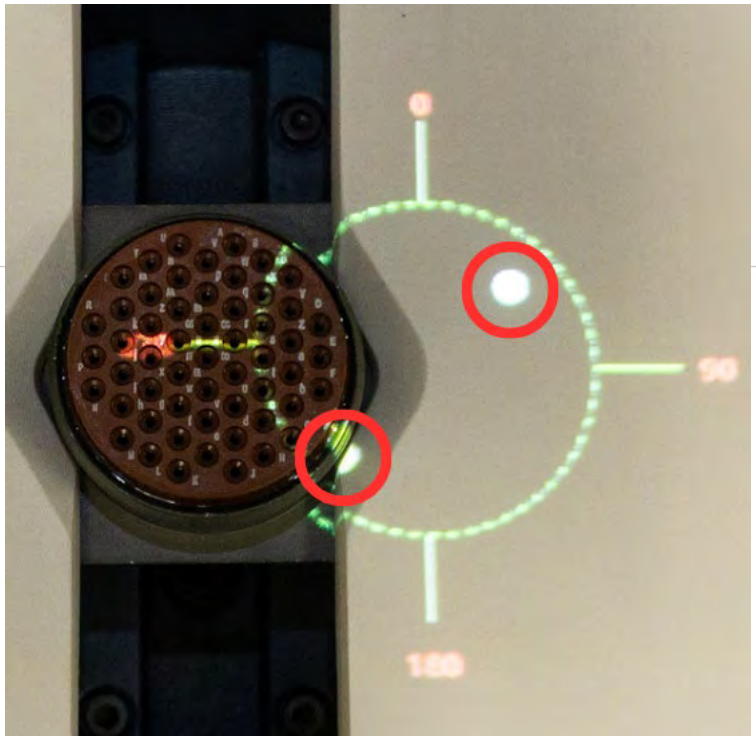
PinMate technology was patented by Boeing and developed into a commercially viable product by DIT-MCO.

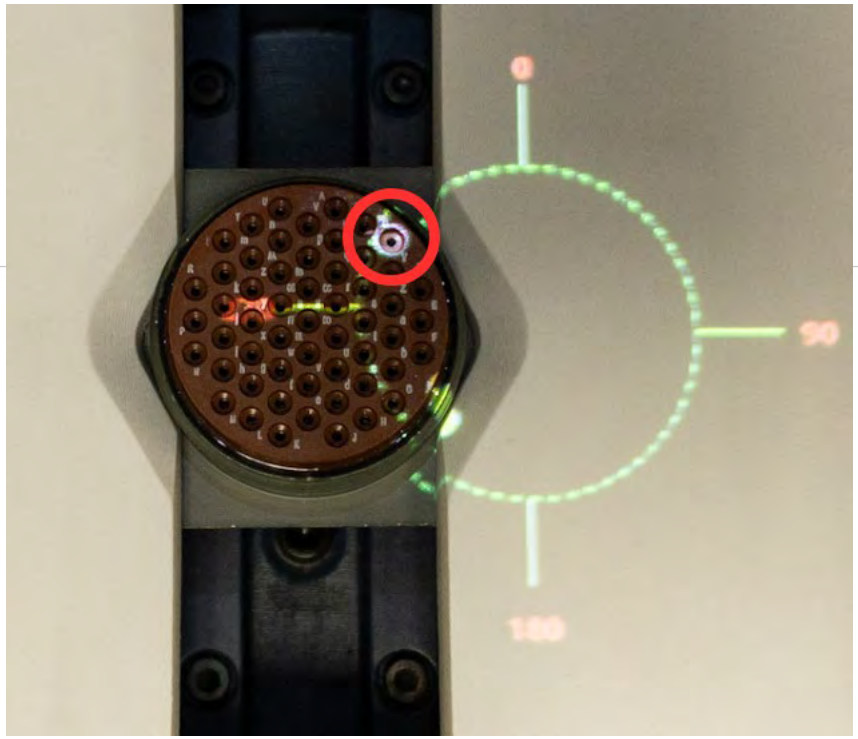
Mis-wire errors driven to near ZERO in use for over 2 years in Boeing in-house wiring shops.

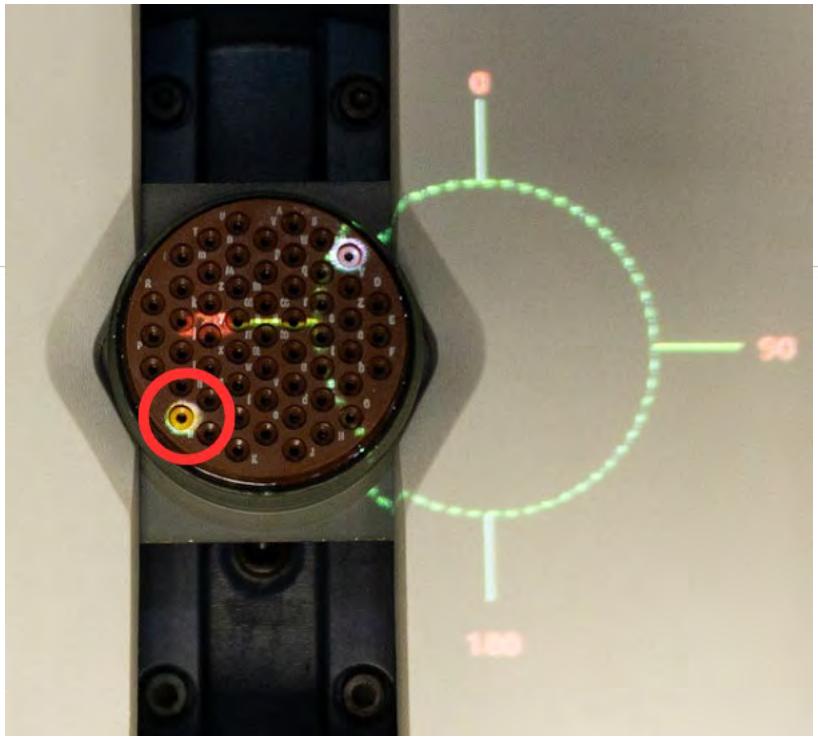
PinMate

- Easy to Use
  - Call up load program
  - Load connector into holder
  - Align connector
  - Insert spare pins/seal plugs (if used)
  - Enter wire IDs and follow prompts

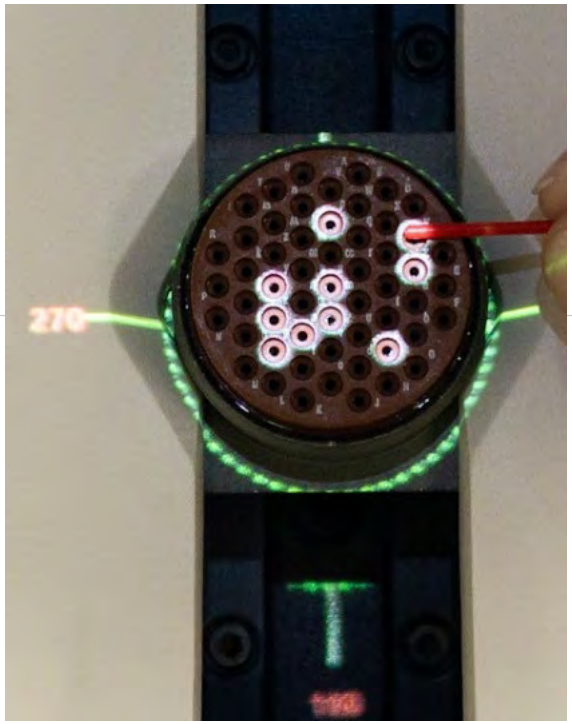
Align Connector Location

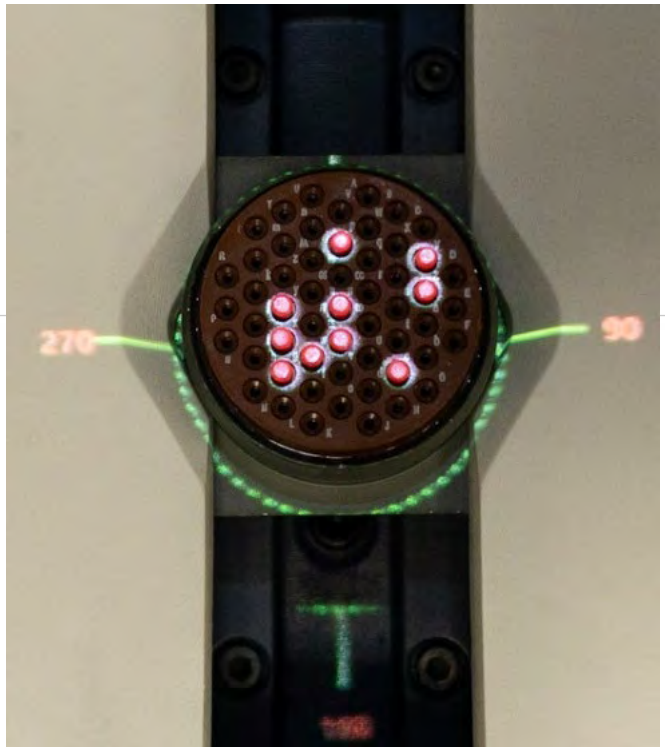




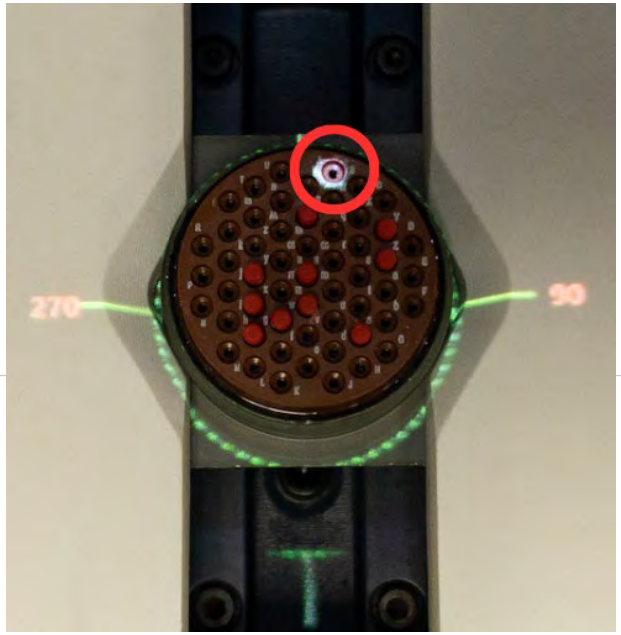


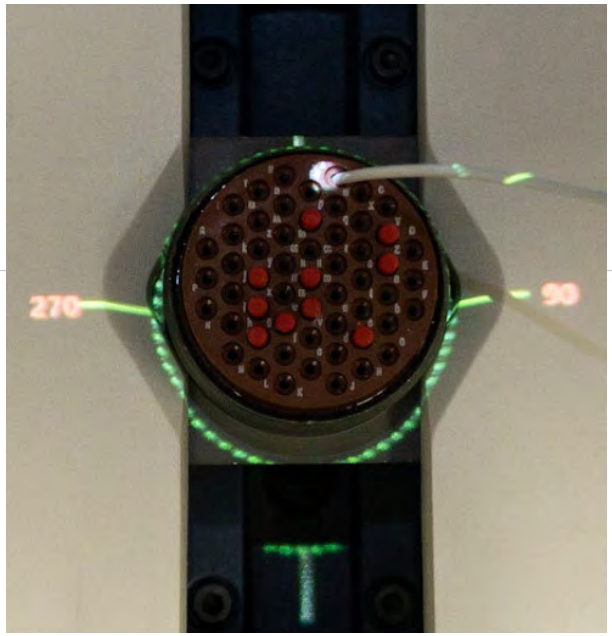
Seal Plug Installation

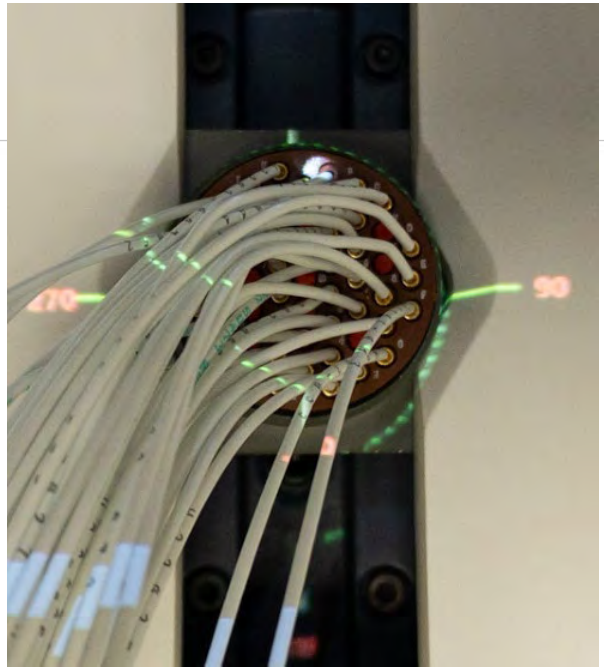




First End Wire Installation







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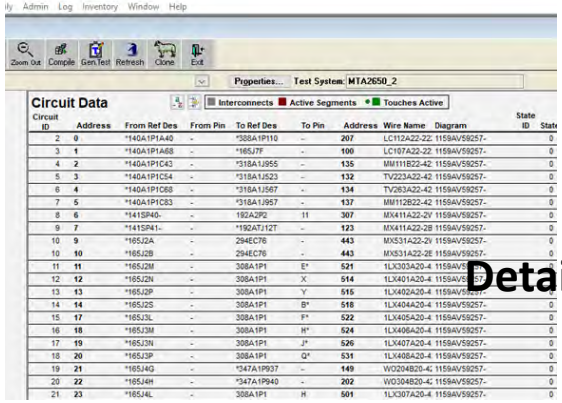
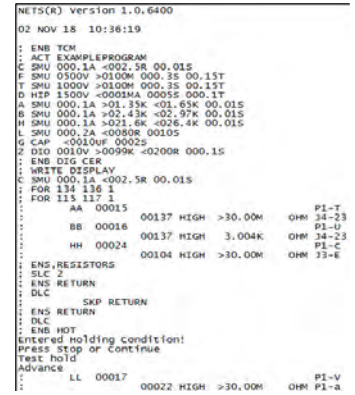
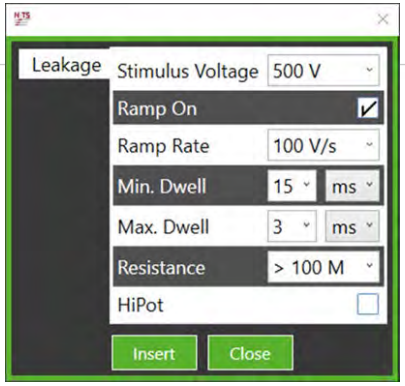
Advanced Tools to Streamline Time to Test





Detailed Wirelist



Test Parameters

Parts List

Test System Architecture

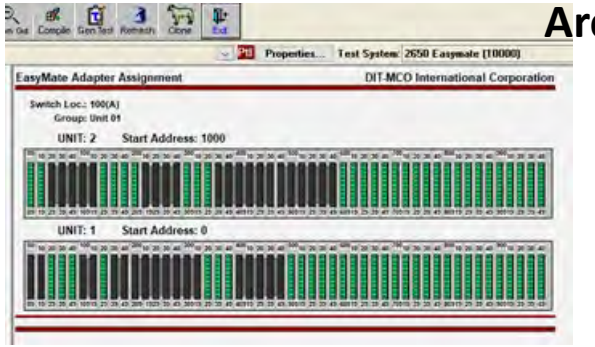
Advanced Test Generation Tool

Comprehensive Test Program

Adapter Cable Design

Bill of Materials

Hook-up Instructions



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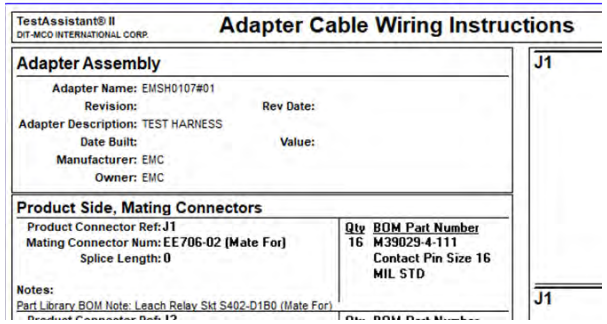
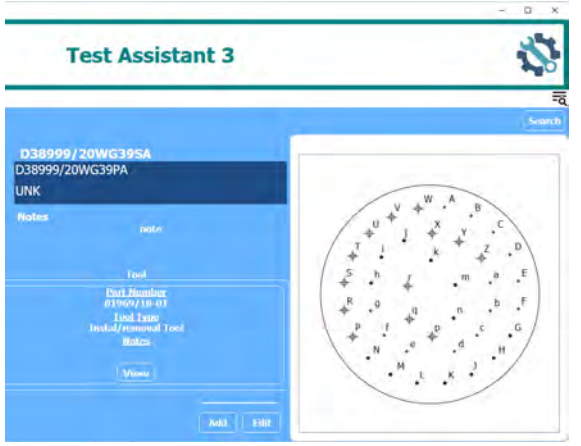
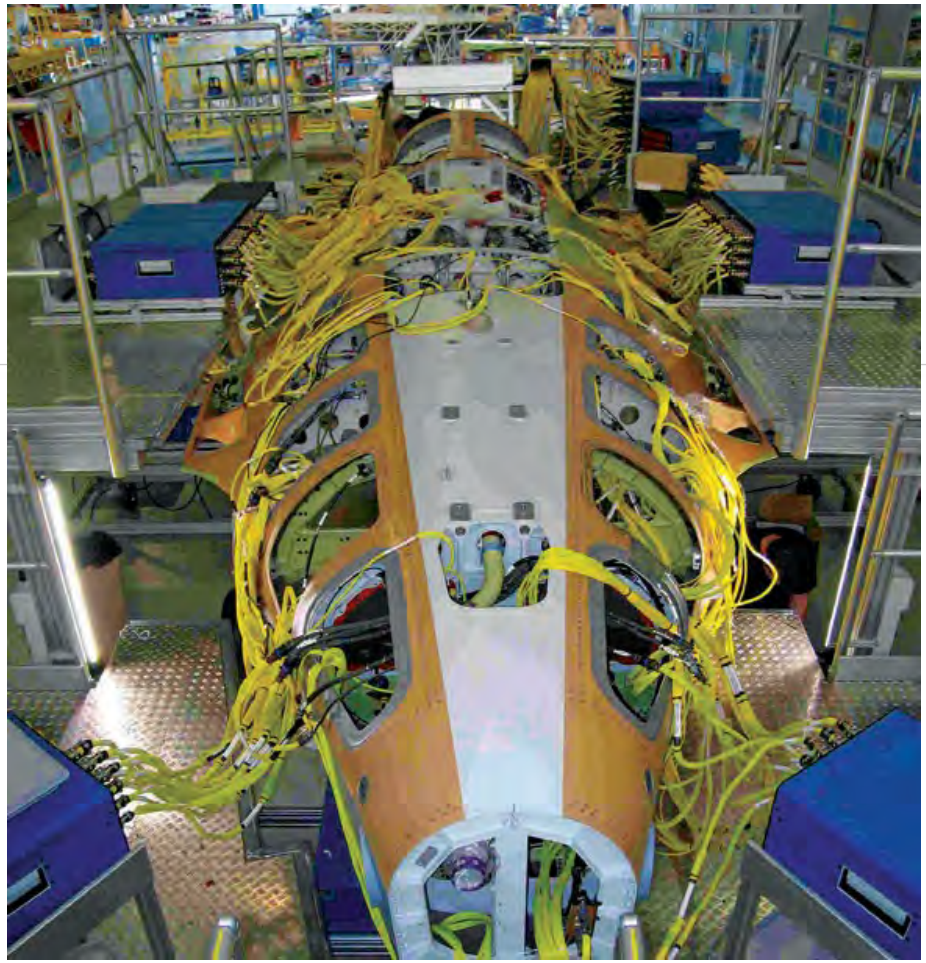




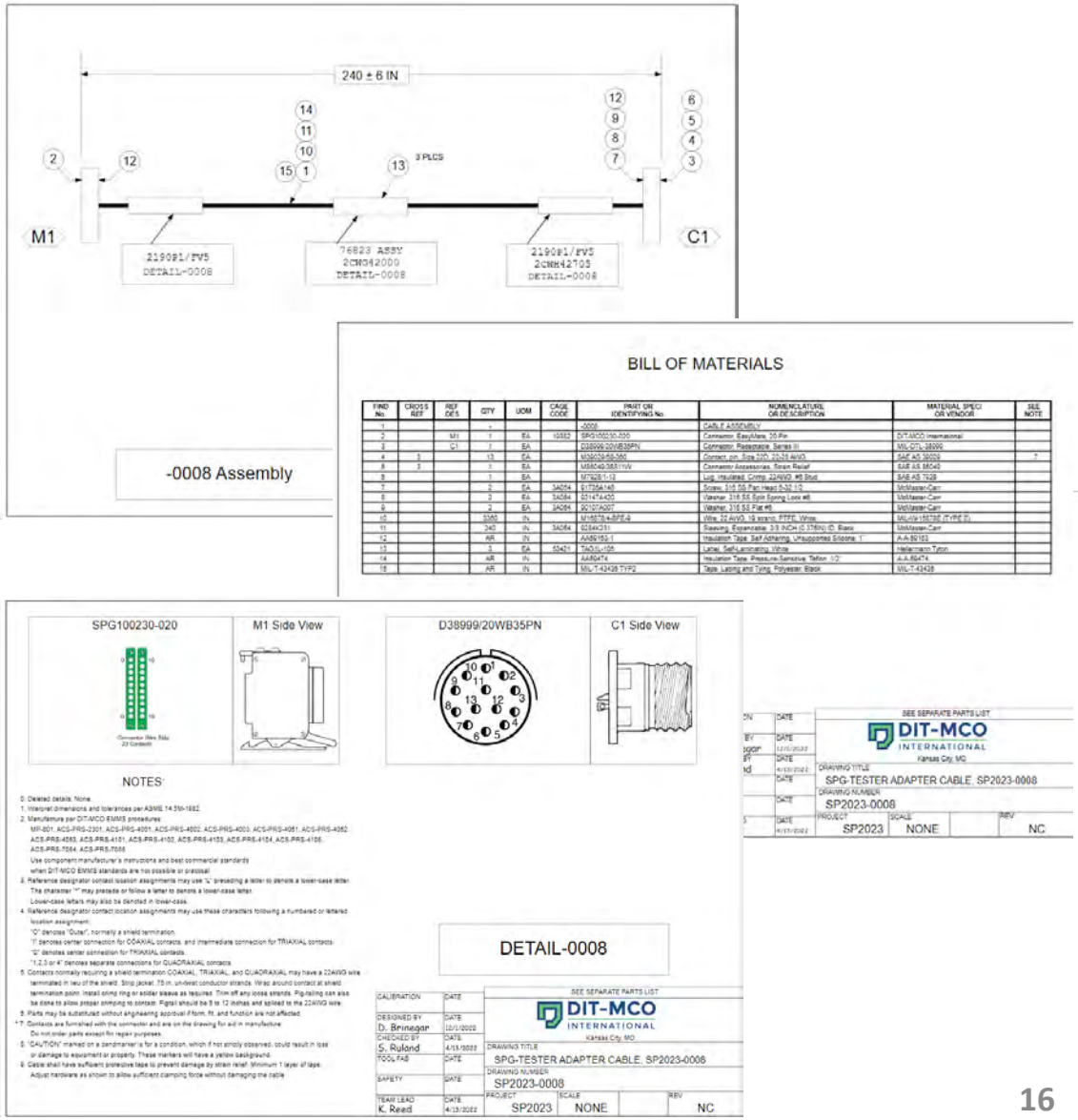
Adapter Cable Design Challenge

- No time allotted in project plan
- Identifying UUT mating connectors
- Matching UUT points to test system architecture (50 – 128 points / test connector)
- Physical location of UUT connectors
- Requires detailed knowledge of test system architecture
- Connecting adapter cables in a large system
- Time consuming and challenging process



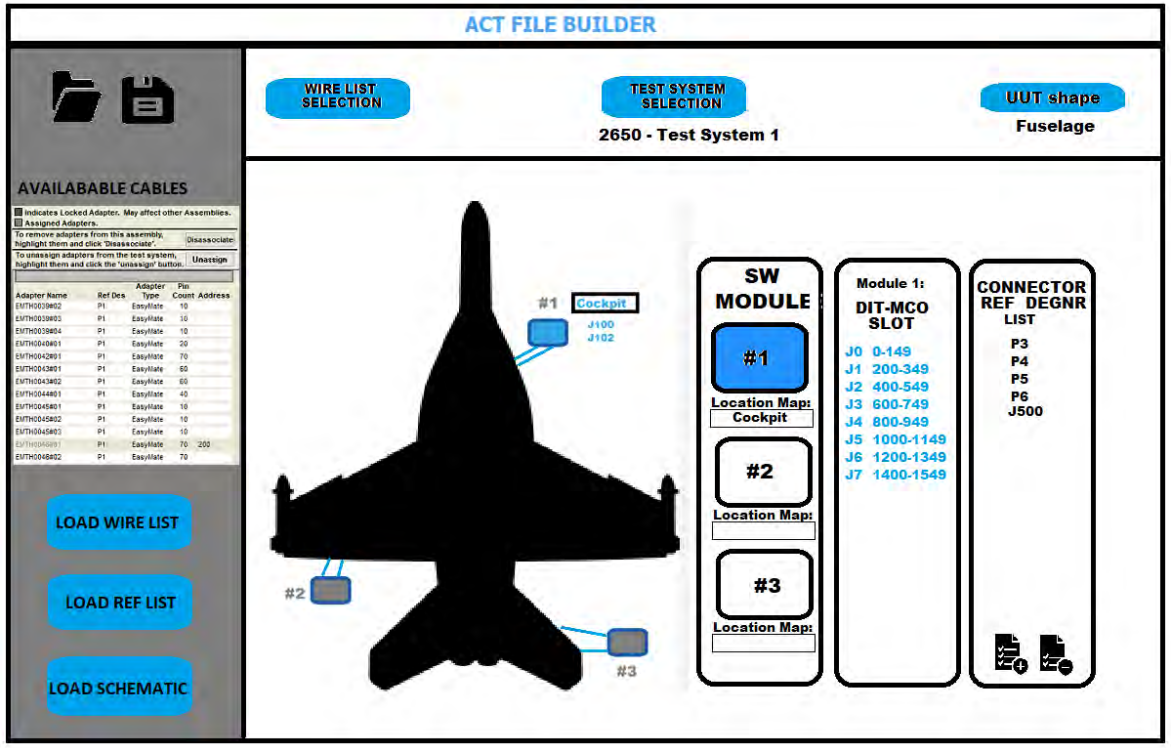
Adapter Cable Design Solution

- **Automation!**
- Inputs
  - Wiring list including detailed connector information
  - Location of connectors relative to Test System
- Auto generate
  - Complete adapter cable design
  - UUT point/wire mapping to Test System architecture to streamline test program creation
  - Random hookup
  - EasyMate connectors
  - Cost reduction



Advantages of Advanced Test Generation

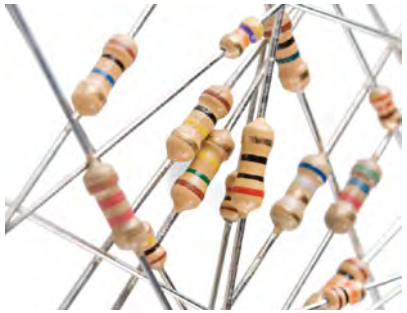
- Reduce programming time
  - Auto generates test program
  - Easy to use drop-and-drag editing tools
- Improve reliability of test program
  - All points will be tested with correct set of parameters
  - Test parameters will not exceed electrical limits of any components installed in the UUT
- Test program development process is database driven
    - Revision history and
    - Certification test process



Component Testing

- Typical components
  - Relays
  - Switches / Circuit Breakers
  - Indicators/LEDs
  - Passive components

- Be aware of electrical specifications of in-harness components to avoid damage during bulk resistivity or other high voltage, high current harness testing



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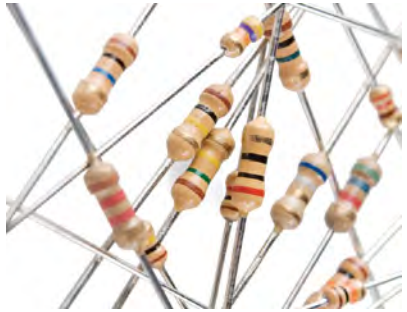
Component Testing

- Switches & Circuit Breakers
  - Test all positions for proper operation
  - Requires operator feedback to change switch positions & confirm proper results
- Indicators/LEDs
  - Understand electrical limits
  - Requires operator feedback to confirm proper results
- Passive components
  - Test components to specified limits



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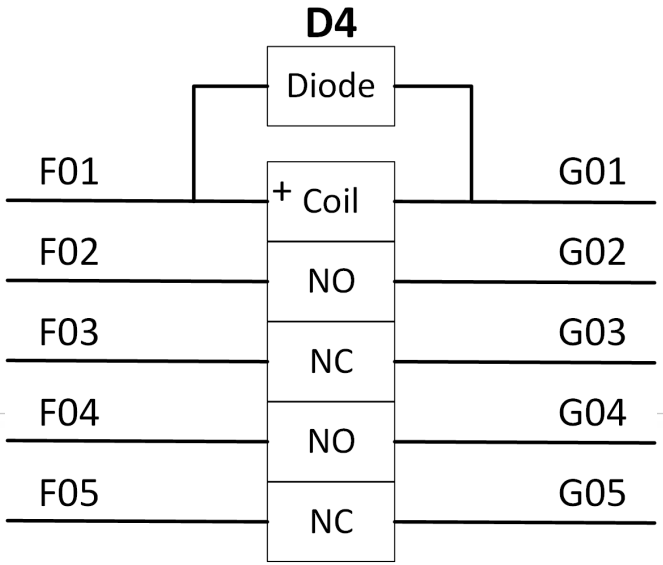
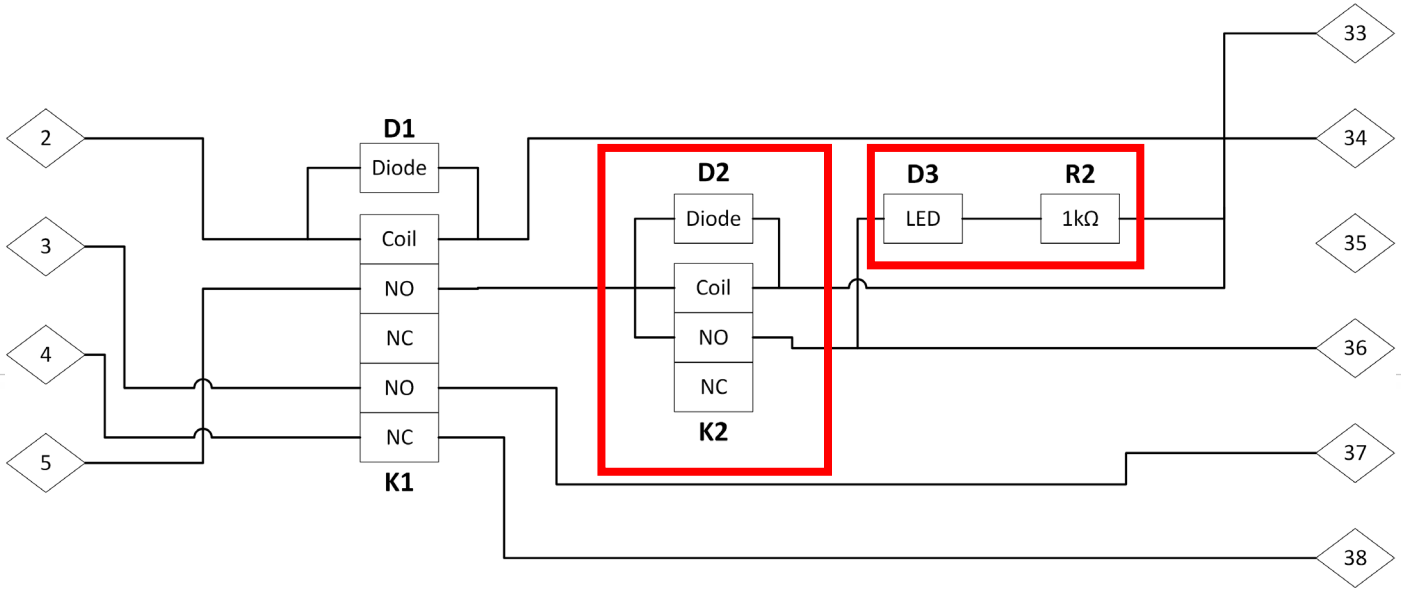
Component Testing - Relays

- In normal conditions
  - Continuity across NC (F03-G03, F05-G05)
  - Open across NO (F02-G02, F04-G04)
  - Coil resistance is 742Ω-906Ω (F01-G01)
  - Diode test on D4 (G01-F01)
- If all above pass, proceed to test Relay energized
  - Apply appropriate voltage to coil (+ F01, Ground G01)
  - Open across NC (F03-G03, F05-G05)
  - Continuity across NO (F02-G02, F04-G04)
- De-energize relay, retest Normal condition
  - Remove voltage from coil (F01)
  - Continuity across NC (F03-G03, F05-G05)
  - Open across NO (F02-G02, F04-G04)
  - Coil resistance is 742Ω-906 Ω (F01-G01)



Relay
DPDT
Contacts: 250VAC
Coil: 824Ω +/- 10%
Coil voltage: 40-48 Vac, 400Hz

Relay Ladder Testing



- Understand relay logic required to properly test down stream components
- In above example, K2 will not actuate unless K1 is actuated, and the proper voltage is used on Address 5
- D3 and R2 cannot be tested without K2 being energized

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Energization of Harness Components

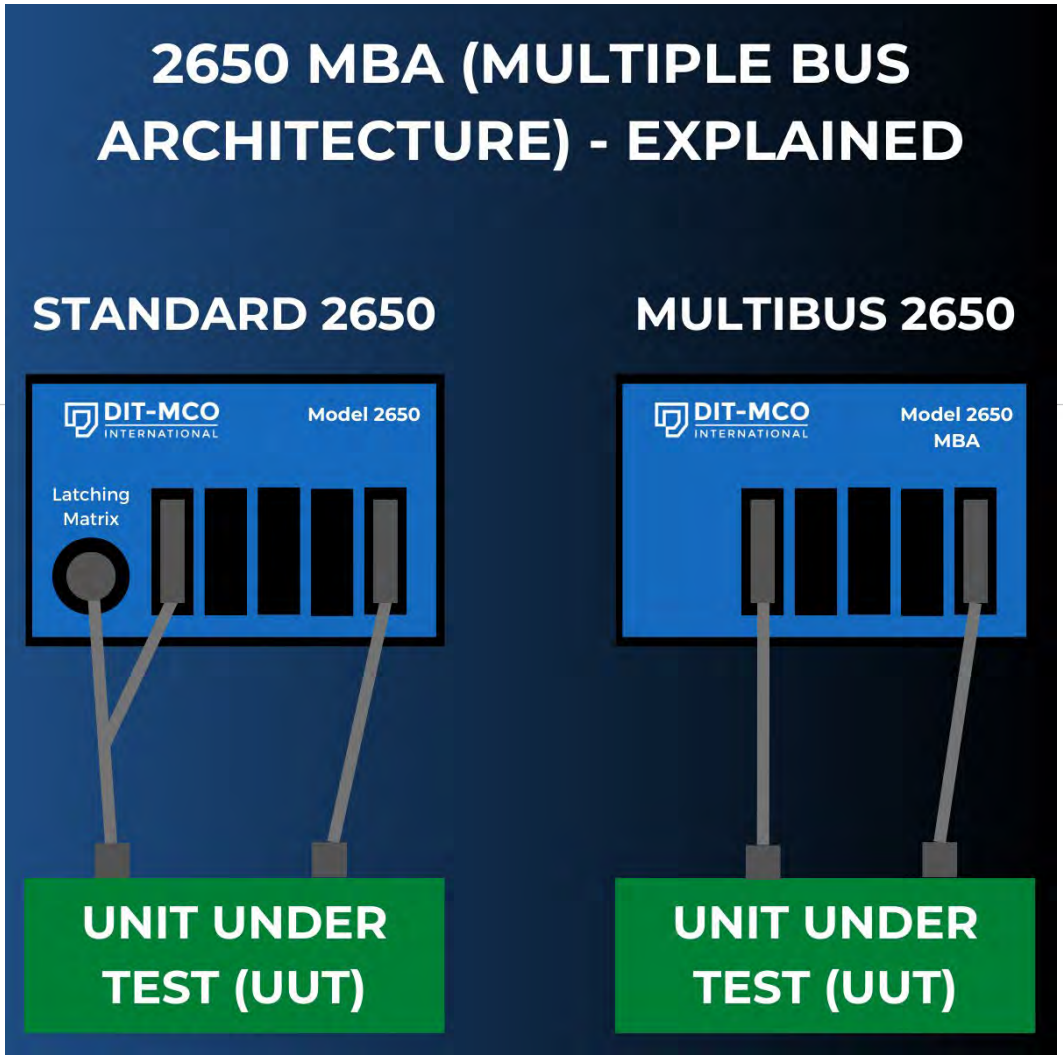
External Energization

- Allows external power source to be applied to test point outside the test analyzer system
- Can accommodate broad range of external sources
- Requires special adapter cables
- Difficult to change as product design is modified
- Need to carefully program use of external sources to prevent unintentional damage to UUT or test system

Multi-Bus Architecture

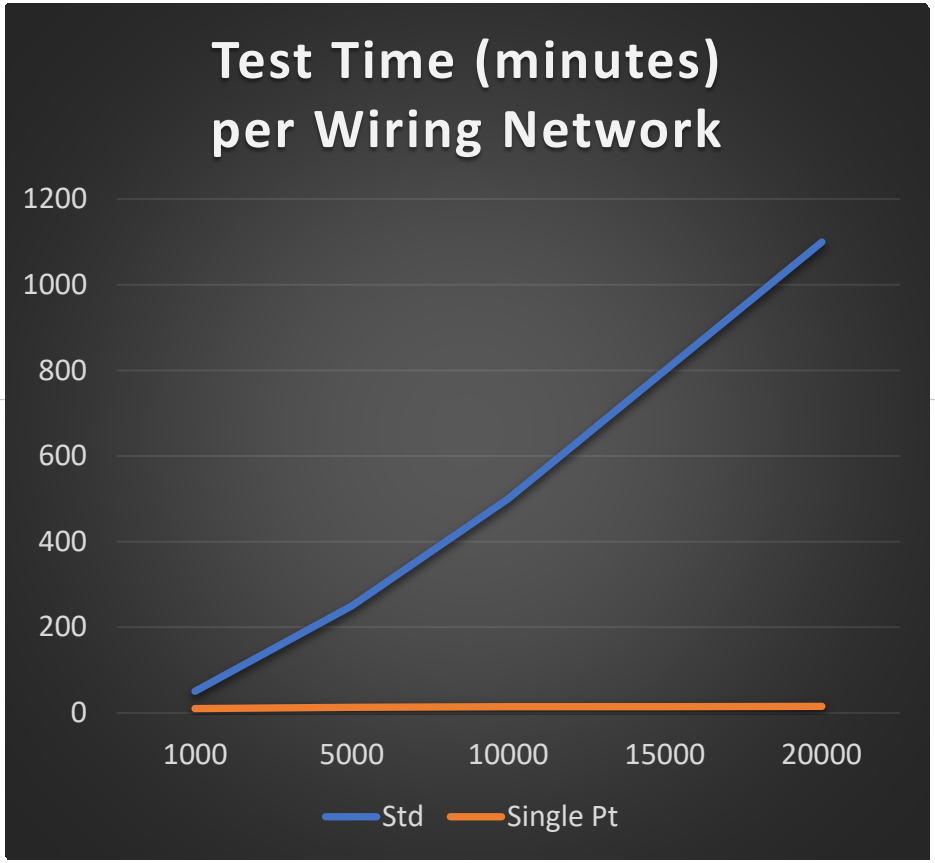
- Multi Bus Architecture is a technology that allows any test point to also be a power source for relay activation.
- MBA simplifies the tester interface and test program generation.
- Simplifies adapter cables
- It accommodates product design changes without changing the test interface to the product.
- It eliminates the need to design an interface prior to generating a test program.
- Lower cost of ownership

Energization of Harness Components



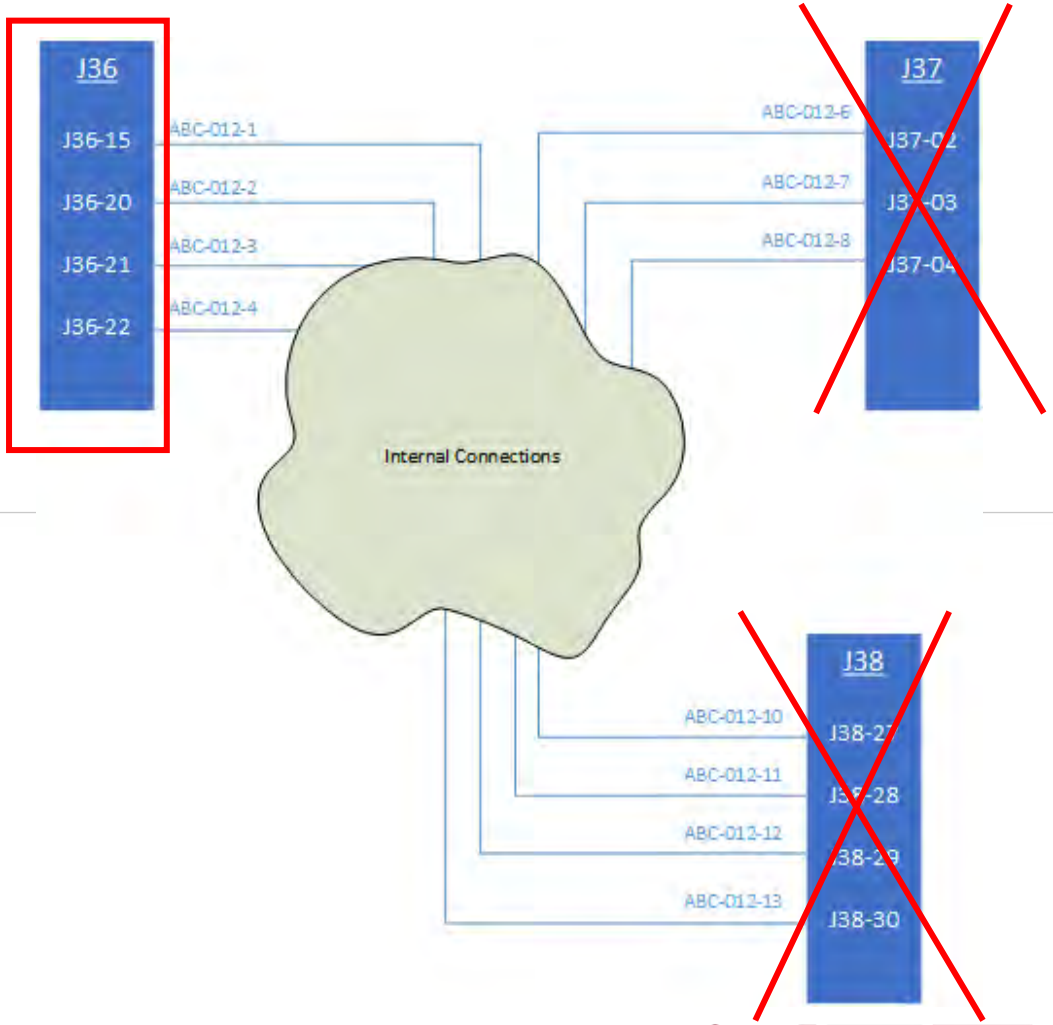
Wiring Network based Testing Benefits

- Faster insulation resistivity testing
  - Can test multiple networks simultaneously vs. testing a single point in a wiring network.
    - Insulation resistivity of wiring harness with 128 wiring networks can be tested in 7 test cycles vs. 127 test cycles with no errors.
    - Error identification takes ~50% of the cycles as conventional testing methods
- Can detect parallel insulation resistivity associated with near fault conditions across multiple wiring networks.
- Different networks can be tested at different voltage – isolating sensitive networks or networks with components



Traditional Fault Reporting

- Test system has access to From/To information only
- Given wiring network with 11 total connections over three different connectors
  - J36-15, J36-20, J36-21, J36-22, J37-2, J37-3, J37-4, J38-27, J38-28, J38-29, J38-30
- Continuity tests identifies & reports 28 individual faults.
  - 1 - J36-15 to J37-2 fault
  - 2 – J36-15 to J37-3 fault
  - ….
  - 27 – J36-22 to J36-29
  - 28 – J36-22 to J38-30 fault
- Technician would have little information to use to diagnose actual problem



Use Schematics as a Troubleshooting Tool

- System has access to complete wiring information
- Given wiring network with 11 total connections over three different connectors
  - J36-15, J36-20, J36-21, J36-22, J37-2, J37-3, J37-4, J38-27, J38-28, J38-29, J38-30
- Continuity tests identifies 28 individual faults
  - 1 - J36-15 to J37-2 fault
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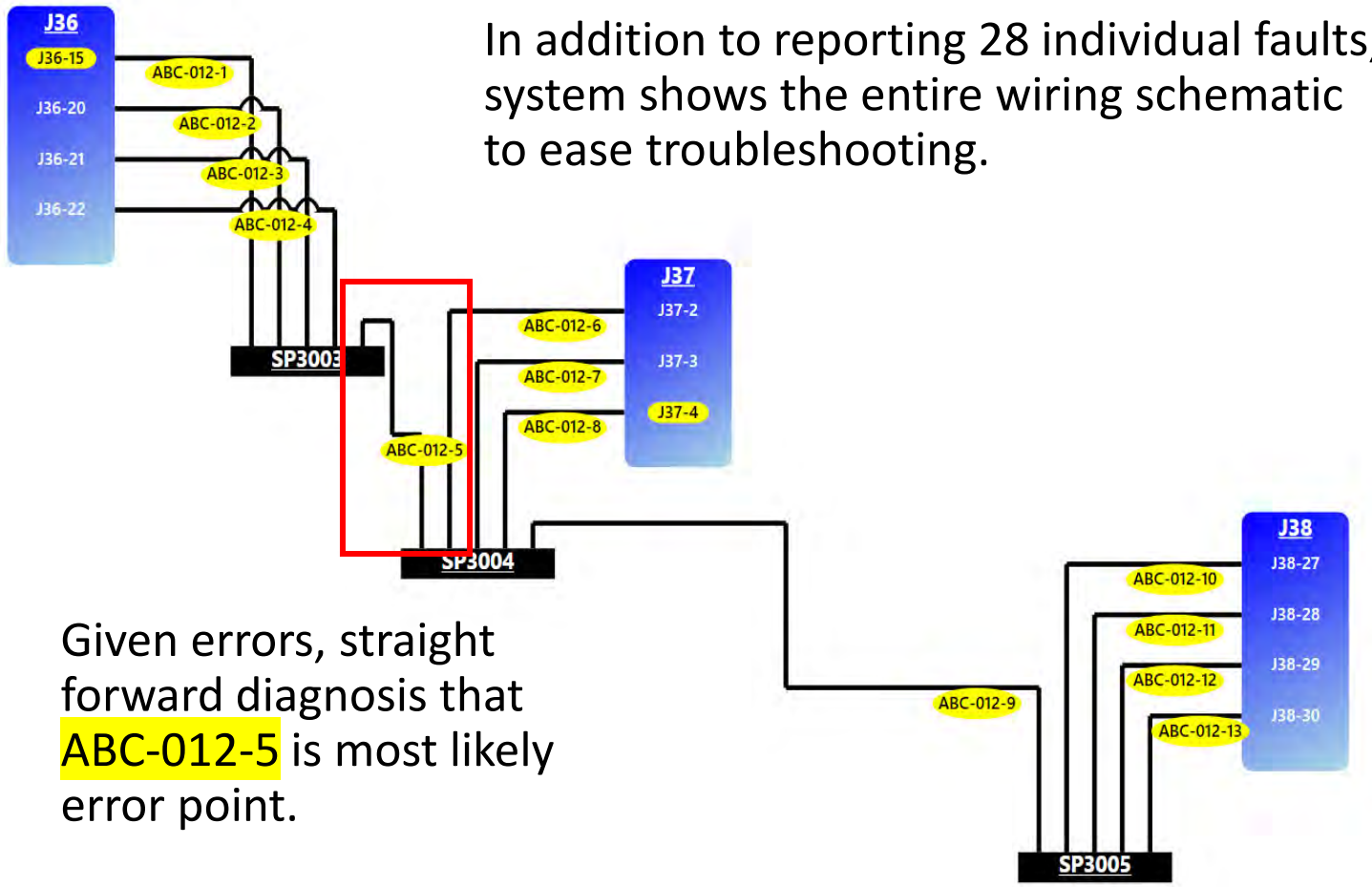
  - 28 – J36-22 to J38-30 fault



In addition to reporting 28 individual faults, system shows the entire wiring schematic to ease troubleshooting.

Given errors, straight forward diagnosis that ABC-012-5 is most likely error point.

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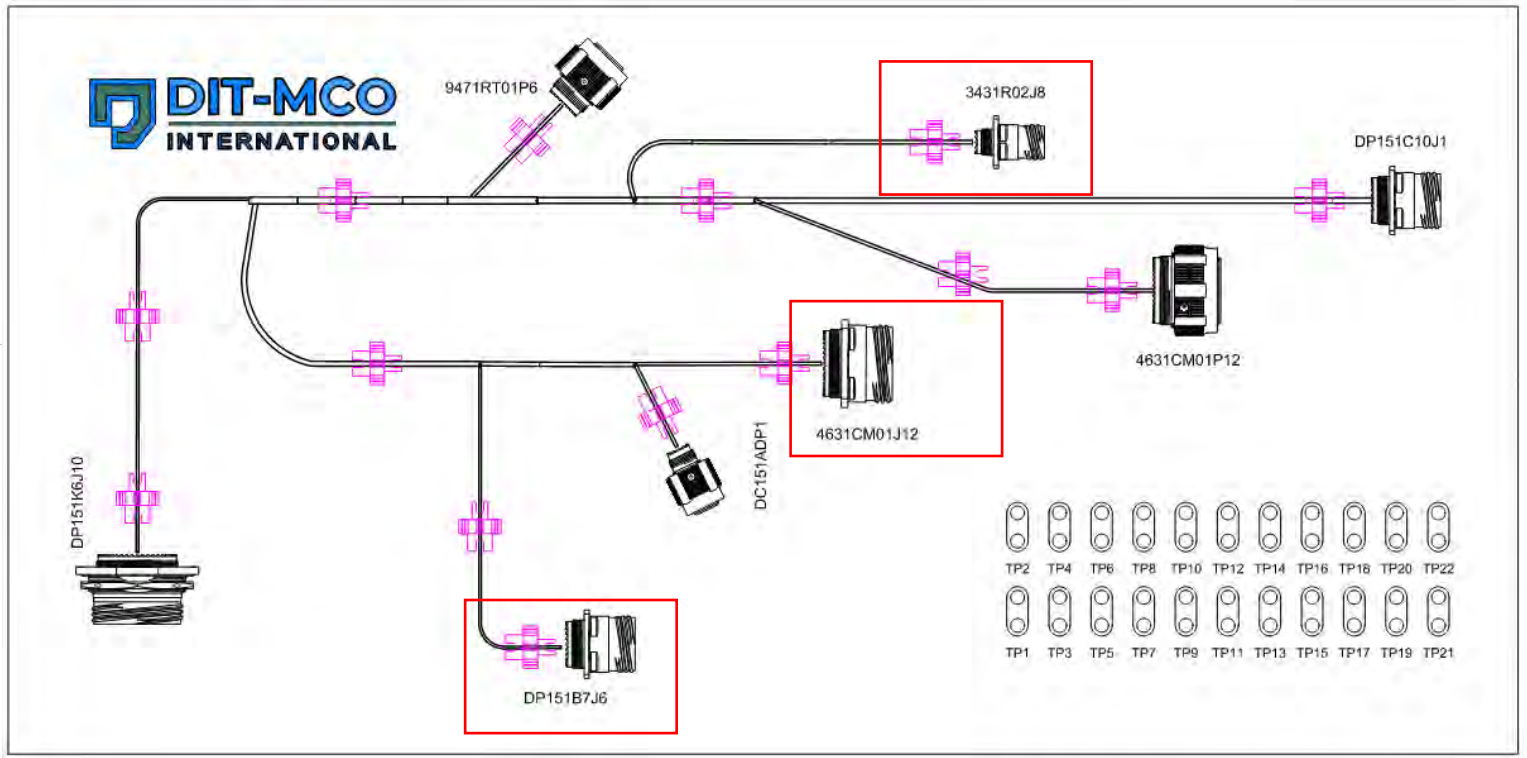
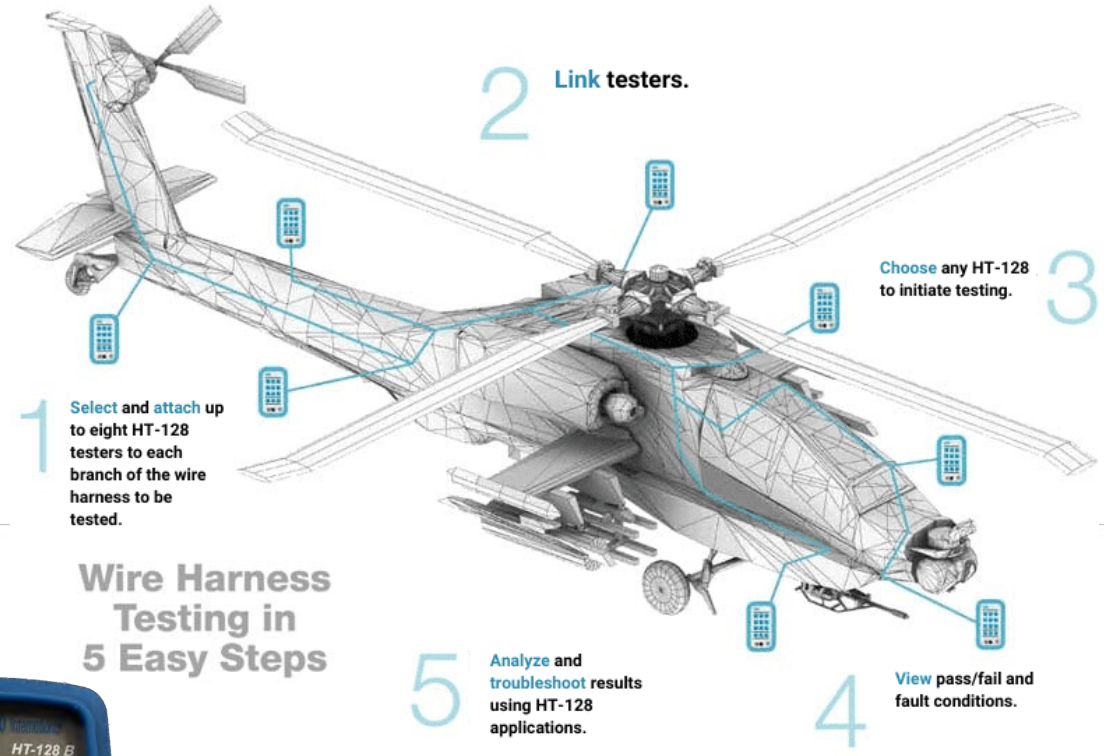
Connector Testing as a Trouble Shooting Aid

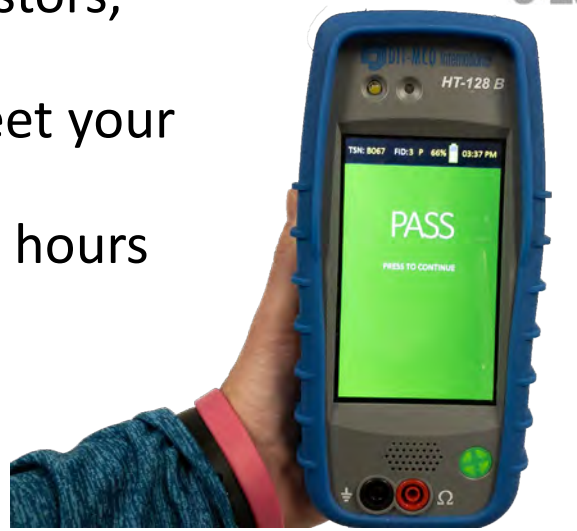
- Run test program
- Issue identified with 3431R02J8
- Operator stops test
- Run all tests associated with this connector
- After issue is resolved, resume full testing
- Simplify description – focus on benefits not process



Intelligent Handheld Troubleshooting

- USEFUL for post test troubleshooting
- ECO – just test changes
- Test installed cables without shorting plugs or long loop-back adapter cables
- More than continuity – Test for opens, shorts, crossed wires and high resistance connections
- Verify passive components (resistors, diodes)
- Cost effective and flexible to meet your needs
- Save time and money. Eliminate hours wasted on hand-beeping and troubleshooting
- Document test results





Plain Language Error Reporting with Likely Root Cause

- Traditional systems use cryptic fault descriptors

```
FF P3-7 P5-C SHORT <30.0K OHM
```

- Fault reporting does not identify root cause of the failure
- Troubleshooting is difficult
  - Need to understand system architecture
  - Need to understand cryptic error messages
  - Need to understand multi-page schematics
  - Need to understand likely failure modes

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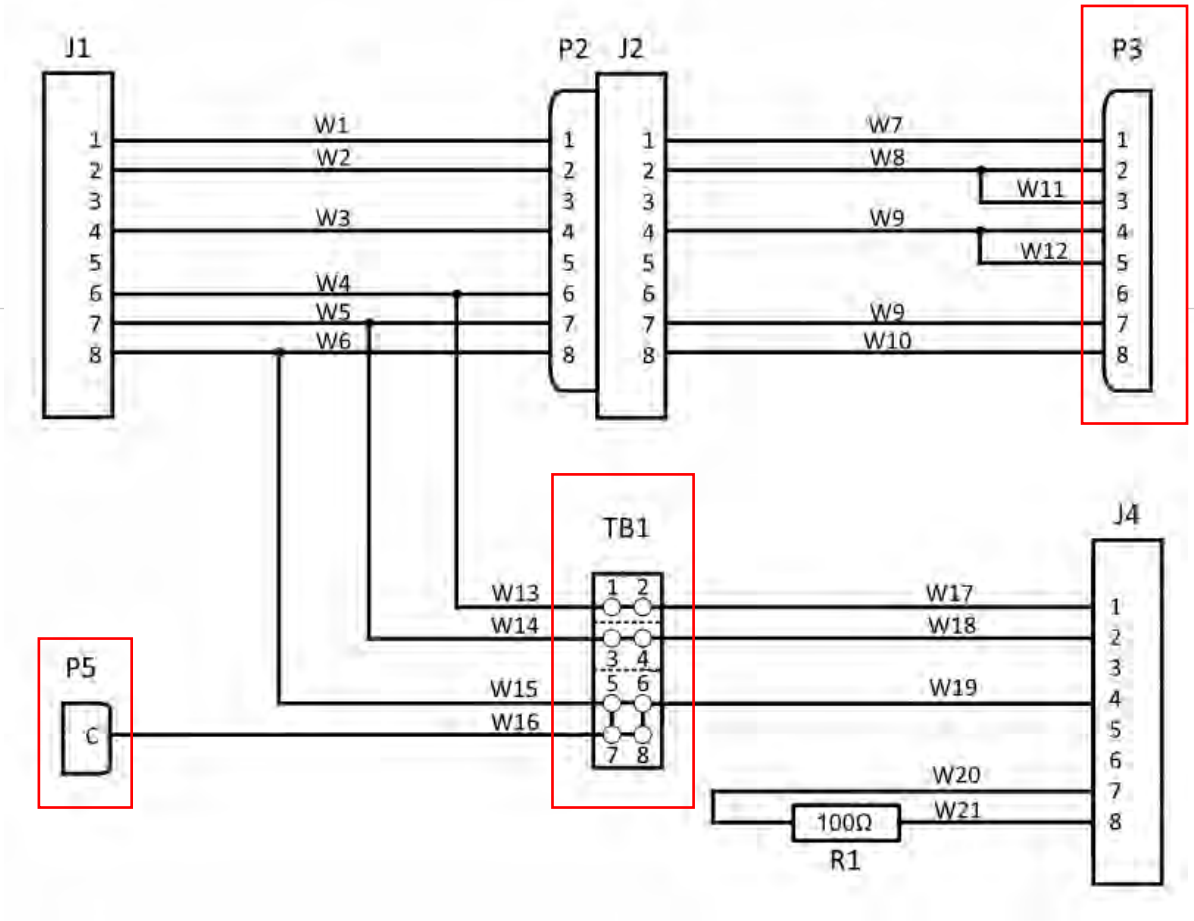
Proposed Solutions - Patent Pending

- DIT-MCO proposes to utilize machine learning and natural language output to provide less skilled technicians with easy-to-understand fault diagnosis.
- System quickly develops a list of possible root causes for each failure.
- Rank the possible root causes by order of likelihood.
- Utilizes cable construction, component types, connector layout, and a number of other parameters, to determine most likely point of failure.
- Translate difficult to decipher test results into full sentences.
- Available in multiple languages with proper syntax.
- Patent Pending

Example of a Short Circuit

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FF P3-7 P5-C SHORT <30.0K OHM
```

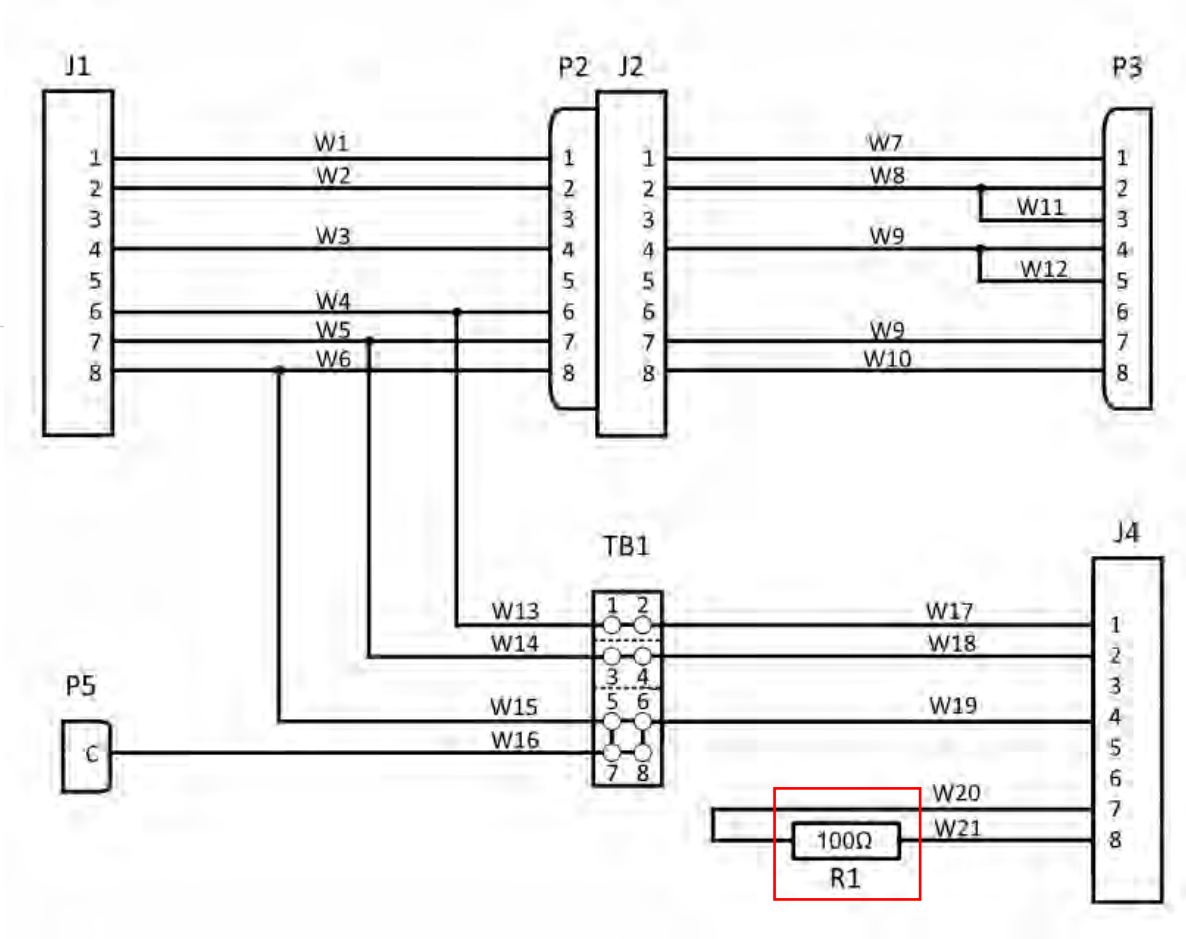
The proposed solution offers more detailed information such as:

```
Short circuit found between wires
W9 and W16, is most likely found
at TB1
```

A more detailed report might say:

```
Short circuit found between wire
W9 and W16, is most likely found
at TB1. If not found there,
inspect wire W5 and W6 between
J1-7 and P2-7 and J1-8 and P2-8
or wire W9 and W10 between J2-7
and P3-7 and J2-8 and P3-8
```

Example of a Component Failure



CC P4-7 P4-8 LOW 51.2 OHM

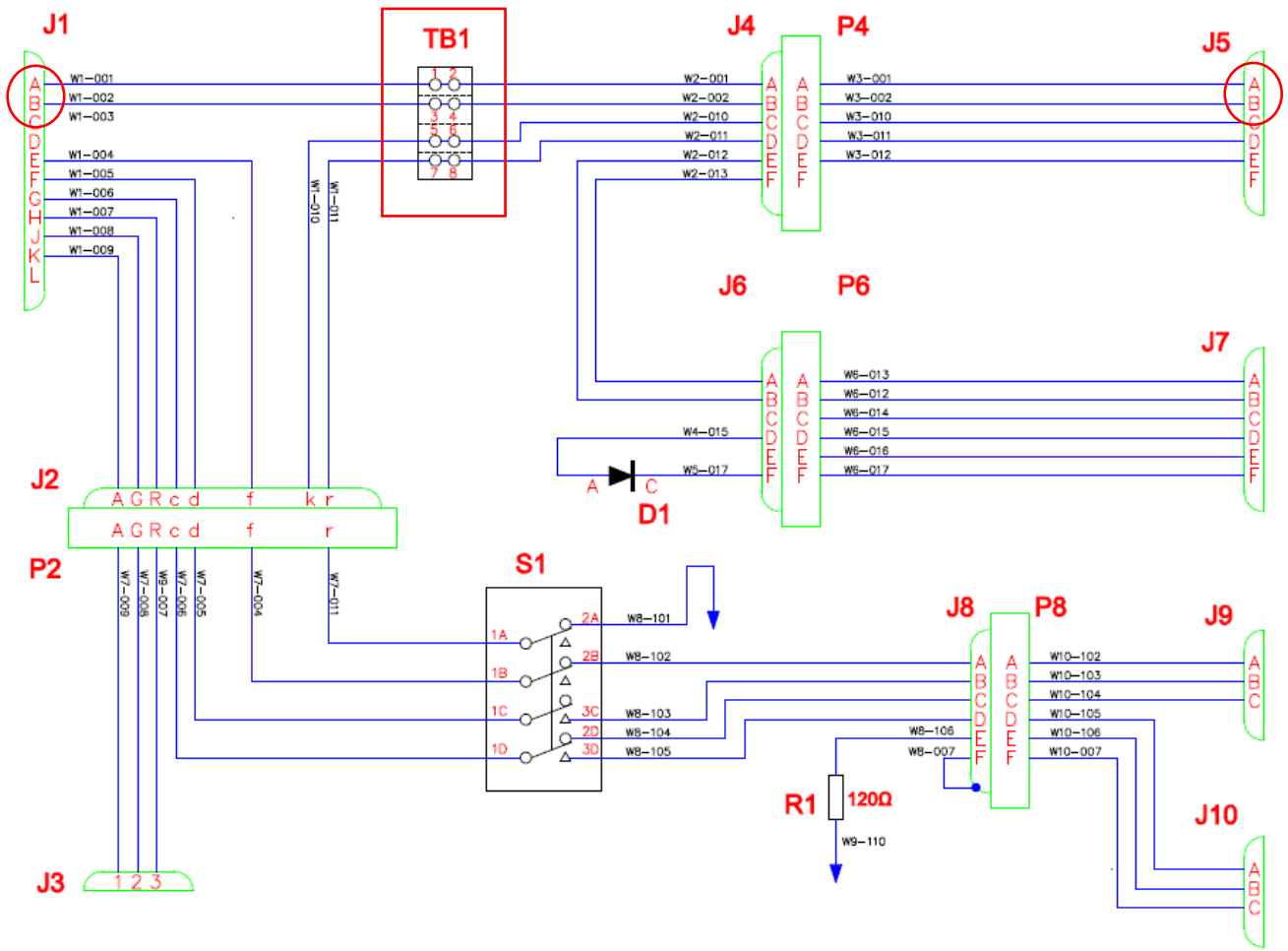
This reported error tells the technician that resistance is low but does not tell the technician there is a resistor in the circuit that has failed.

The proposal output would read:

Resistance failure between J4-7 and J4-8 most likely due to component R1. Value should be 100 ohms ±10% but is reported as 51.2 ohms

This gives the technician enough information to conclude that the resistor R1 needs to be replaced.

Isolating Probable Causes



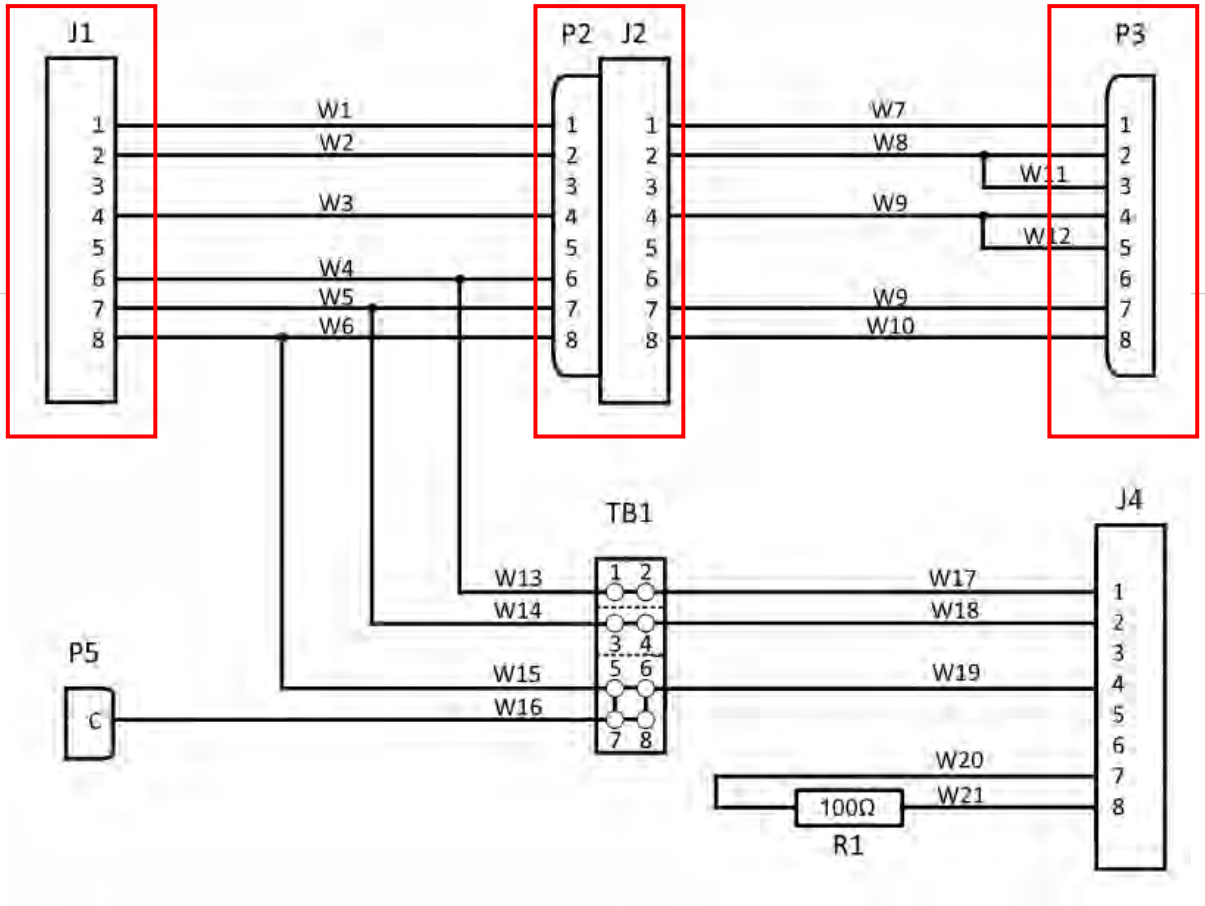

```
CC J1-A   J5-A OPEN >30.0M OHM
XT J1-A   J5-B WIRED <0.100 OHM
XT J1-B   J5-A WIRED <0.100 OHM
```

The above indicates a miswire, however, there are a few places in the schematic that a miswire can occur.

Proposed solution will provide a user-friendly output:

```
Continuity failure between J1-A
and J5-A is most likely pins 1
and 3, or 2 and 4 reversed in
terminal block TB1
```

Isolating Probable Causes

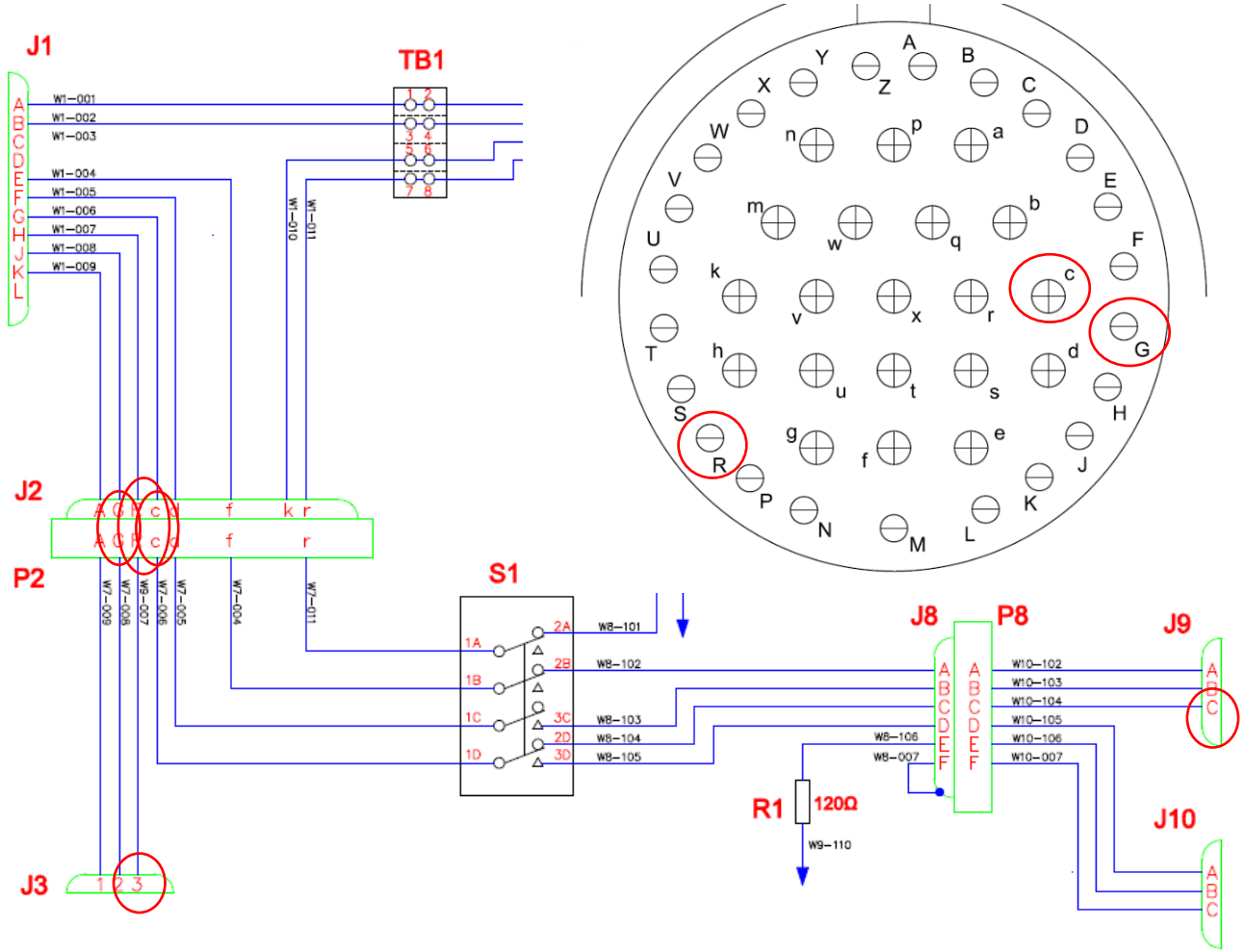


Additionally, the report can be configured to look at networks that share the same interface connections. For example, J1 and P3 both have connections to J4 through J2 and P2. The software can be configured to test through the contacts of a shared connector and use that information to help narrow down the root cause.

The output might read:

```
Continuity failure between J1
and P3 but not J1 and J4, nor P3
and P3, are most likely due to
connectors P2 and J2
disconnected in the UUT
```

Example of Component Topology



CC J3-3 J9-C SHORT 0.100 OHM

There may be an instance where a short occurs between two wires that are physically distant from each other. Using machine learning the contact arrangement of connectors shared by the wires can be examined. In this case the contacts ‘R’ and ‘c’ in J2/P2 are adjacent on the schematic but not physically.

However, contact ‘G’ and ‘c’ are adjacent in J1.

The proposed solution might read:

Short circuit between J3-3 and J9-C is most likely found at J2/P2 adjacent contacts G and c.

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Conclusions – Best practices in Wiring Harness Testing

- **INTEGRATE** all wire harness design data with manufacturing & testing processes
- **AUGMENT** guided pinning of connectors helps eliminate wiring errors
- **CREATE** adapter cable designs using wire harness data and automation design tools
- **GENERATE** automatic test programs to completely test the integrity of the complex wiring harnesses and integrated components
- **REDUCE** test times and improve reliability by using **wiring network** centric system architectures and testing algorithms.
- **TEST** wiring harnesses as they are constructed to minimize trouble shooting complex wiring harnesses only after manufacturing is complete
- **DISPLAY** informative, plain language error messaging with probable root cause and drastically reduce troubleshooting and error correction

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Questions?

Thank you!