Automated Testing of Infotainment Systems

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1. Business Summary

Automotive original equipment manufacturers (OEMs) and suppliers are faced with the ever-increasing challenge to provide in-vehicle infotainment (IVI) features that are exciting to their customers. Drivers and passengers want to feel that the infotainment system is an extension of what is familiar to them. IVI systems have to provide seamless connectivity, naturally extend mobile device app features to the system, and operate intuitively and flawlessly. New technologies increase the demand of what the vehicle owner expects and suppliers comply by adding more and more features and content. This creates increasing opportunities for flaws to appear in the products. Compounding the complexity challenge is the need by suppliers to reduce development time from the traditional 3-5 year automotive cycle to the expected consumer expectation of 1-1.5 years for new features. These are in addition to the ever present requirements to meet cost, packaging, weight, power budget and reliability targets.

Testing these ever changing systems is a daunting task, with the outcome of either releasing a successful product to market or introducing a brand-tarnishing loser. This white paper outlines how Danlaw's Mx-Suite™ IVI Test Software can be used to improve IVI system testing and reduce the challenges faced by IVI systems developers.

2. Conclusion

To deliver their extended and diverse functionality portfolio Infotainment Systems are now, by many measures, the most complex system in the vehicle. In addition to delivering the traditional behaviors of a real-time embedded controller while being highly distributed and having high I/O types and I/O counts, Infotainment Systems have to support multiple bus, RF and cellular connectivity, present several MMI surfaces (multiple user displays, touch screens, audio in and out, switch interfaces, …) and process large amounts of data.

Given such systems, two main conclusions are drawn:

- Traditional automotive system test tools don't adequately address the requirements of bench testing such a system.
- With the extent and diversity of asynchronous I/O it is impossible using a manual test strategy to test any significant subset of the use cases of an Infotainment System.

Features of Mx-Suite like its library of existing interfaces, ability to add new interfaces, and support for: concurrent test execution, test pattern generation from test primitives, environment simulation, image capture and display and robotic manipulation make it stand way ahead of the traditional test tools.

Mx-Suite helps users quickly and easily develop feature by feature test cases and automate test execution. Extensive endurance, stress, and stability tests are constructed from these test primitives helping further wring out real world issues earlier in the life cycle and long before in vehicle testing begins. Mx-Suite provides integration to Application Lifecycle Management (ALM) tools for further test process automation.

3. Technical Summary

In-Vehicle Infotainment (IVI) systems in today's automobiles provide users with an increasing number of audio, video, telematics and connectivity related features. Simple concepts like a radio with an embedded compact disk (CD) player have evolved into systems that can include multiple media player interfaces, support mobile devices, connect to audio and video content providers, and provide GPS navigation with route planning and guidance. The user expects the features available with the automobile to be an extension of those provided in-home and with their personal wireless devices. Furthermore the user expects their IVI system to support vehicle connectivity for the purposes of personal communications, social networking, vehicle diagnostics, prognostics as well as safety and security.

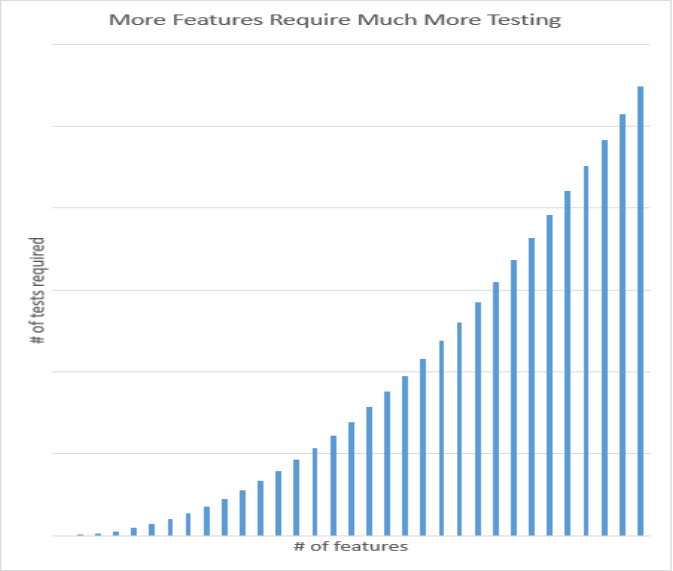
In order to support these features, the IVI system is implemented as a distributed system. The system hardware usually includes at least one high-quality video display, a variety of wireless communication access points (either in a module or as a wired mobile device), an instrument cluster, and speakers/headphones. Audio can often be configured to support the driver's listening preference as well as passengers in other zones. The system commonly relies on one or more in-vehicle networks such as controller area network (CAN), Local Area Network (LIN), Media Oriented System Transport (MOST) or Ethernet Audio Video Bridge(A/VB). These networks are used to support all facets of system interaction, such as, command and control, audio/video source transport, data and diagnostics. There may also be proprietary networks to interconnect IVI system modules to the rest of the vehicle or to each other. The complexity of testing an IVI system increases as more interfaces are added.

Significant challenges are presented by the IVI system software. Electronic control unit (ECU) suppliers choose from a variety of operating systems as well as software frameworks for their development. Software features work independently of each other or cooperate to provide new features. As features are developed, late arrivals can sometimes invalidate original assumptions about processing speed and memory requirements and negatively impact performance. Integration within the IVI system can many times unmask issues that were not observed or apparent in earlier product development phases. This leads to the scheduling of multiple software releases and related integration within a relatively short period of time.

Ultimately, being able to test the IVI system properly means addressing the most difficult challenges first. Looking at the technical complexities of an IVI system, it is not a surprise that the following technical areas rise to the top of a supplier's or OEM's concerns:

- Multiple user interfaces
- A relatively large number of features
- Support for mobile devices
- Interactions and communications between multiple ECUs
- Addition of features throughout the product development lifecycle
- Off-board communications

An IVI testing solution needs to take these into account. Mx-Suite™ IVI Test Software was designed with these concerns in mind. In order to understand these concerns, they are described in greater detail below.



3.1 The Challenge of Multiple User Interfaces

A vehicle may have multiple user interfaces to access features. For example there may be a human machine interface (HMI) device for input and display located on the center stack and an instrument cluster display used controlled by steering wheel switches. Furthermore there usually is an HMI to control features in the rear seating area. The system control strategies must take into account the desired command hierarchy as well as being able to resolve inconsistent or contradictory control inputs. The IVI system must anticipate and handle race conditions between the driver, passenger, and the system modules themselves in the design and implementation.

In order to test such a system tests must be designed to cover the combinations of all expected “normal” uses. The testing must also cover inconsistent and undefined input stimuli to ensure features operate reliably. The cadence, timing, and ordering of tests must be constantly changed to ensure system robustness. The test system needs to track inputs, outputs, pass/fail resolution. When exceptions/failures are encountered during testing, the test system must capture detailed data that will help the user easily determine the states of each device that participated in the test scenario. This detailed data includes logs of communications network data when the exceptions occurred.

3.2 The Challenge of Increasing Features

Today’s infotainment systems provide an increasing number of features. For example, where vehicle owners used to expect only an AM/FM tuner now expect an AM/FM-RDS/TMC/HD/SXM tuner. Where CD players were used before, now media players supporting multiple sources are used instead. As you can imagine, the number of individual test scenarios required to cover the particular device increases proportionally to the number of media types.

The increase is even greater when one considers that tests must be developed for “simultaneous” user inputs and system actions that must operate within an OEM specified hierarchy. The OEM dictates priority of all interactions with the system: Heads-up display updates, audible engine warning signals, turn signal indicators, seat belt chimes, incoming phone calls, emergency broadcast announcements, navigation announcements, video displays, and tactile/haptic feedbacks must be validated from the entire system perspective. For example, an ADAS maneuver announcement would probably have a higher priority in the front seating area than the audio output from and FM radio or MP3 player. Haptic feedback may increase in intensity, adding audio alerts if the driver does not take corrective action. Obviously tests must be designed to verify that prioritization has been correctly implemented in terms of output volumes and muting of the multiple simultaneous audio signals.

Increases in the number of features to test are exasperated by the increases in the number interfaces added into the vehicle. These include embedded 4G cellular data, Wi-Fi, and service-related interfaces such as Ethernet that are utilized during dealer or garage servicing.

Ultimately, the driver and passenger’s perception of quality is based on the OEM’s design for the infotainment system. A user’s experience is enhanced when a feature can be intuitively operated and when it “feels” to be harmonious with other features. The mix of infotainment, new apps, additional controls/displays, safety alerts, and driver information must be tested carefully to ensure the OEM’s psychometric design and intent for the driver and passengers is met.

3.3 The Challenge of Mobile Device Support

Support for more kinds of mobile devices are appearing in vehicles. Bluetooth streaming for hands-free cellular calls or USB memory sticks containing a user’s audio collection has evolved into a larger demand for cellular voice, text, information, and streaming video support for the vehicle. User features can include contact list transfer, text messaging, email, voice calls, navigation support, traffic status, vehicle diagnostics and prognostics.

Additional complexity is introduced by mirroring technologies such as Android for Auto and Apple Car Play. These allow the “projection” (usually by means of a USB connection) of the mobile devices’ user interfaces onto the vehicle display. This allows the user to select features that are supported by the mobile devices and its wireless access. Tests must verify the head unit’s HMI, as well as the mobile devices’ projection of its HMI on the head unit, work properly.

Lastly, availability of software updates for the mobile devices are independent of infotainment system schedule. When mobile devices software is updated, the infotainment system must be tested again with the new mobile devices software.

3.4 The Challenge of Increasing ECUs and their Interactions

Today’s infotainment systems use in-vehicle networks to communicate between ECUs. The communications consist of not only command and control (e.g. increment volume, select entertainment source …) but also audio and video streams. The command and control strategy may include a sequence of interactions between several (e.g. more than two) ECUs within the system. Because of this, exceptions may occur due to incorrect command sequence execution or timing.

Whenever command/control/streams are communicated between ECUs over a vehicle network, there is a chance that non-deterministic transfer rates can artificially create delays or race conditions in transferring data. These can result in performance delays which impact the user’s perception of performance or quality.

An IVI system tester must be able to determine whether or not a sequence of network messages complies with the OEM specifications. The tester must have access to the vehicle networks in order to monitor interfaces and inject stimuli. In addition, the tester must also have the ability to analyze the sequence of command and control events and log network traffic in order to analyze system performance. Detailed logs for off-line analysis could also be required.

3.5 The Challenge of Navigation Testing

In-vehicle GPS navigation is becoming more complex as mobile device apps create market pressure for more and more features. What used to be a “wow” feature is now expected to work without failure every time it is used. OEMs have to ensure that GPS navigation features always work, regardless of how the vehicle passengers are using the infotainment system. Locating the vehicle in the wrong area or the map (or wrong map), choppy screen updates, and wrong audio instructions are not tolerated by GPS users.

An IVI system tester must be able to simulate good routes, problem routes, and out of service areas so that the mapping functions, audio overlays, and continuity of the display can be tested. The IVI system tester should also be able to import actual navigation routes to simulate issues found in the field.

3.6 The Challenge of Off-board Communications

Infotainment systems are relying more and more on off-board wireless communications links such as 4G cellular and Wi-Fi service. The 4G device may either be embedded within the vehicle or be provided by a mobile device. Testing the infotainment system requires wireless links to be active during testing to ensure full system test coverage. Wired links, such as Ethernet are found within a service bay environment, must also be tested. Infotainment system testers must simulate the service bay environment for setting calibrations and reading/clearing diagnostics.

4. An Ideal Solution Meeting These Challenges

What is the right solution? Different kinds of testing during phases of development cycle identify the weakness of the system. Component level functional testing is performed during the early development phase of the component. Later, during development and integration, focused testing of interfaces and communication between various components is performed. Performance benchmarks for the features are also tested. In order to address these testing needs, the following are required:

- Automated testing to quickly generate engineering evidences and test reports
- Connectivity with automotive protocols such as CAN, LIN, MOST, Ethernet A/VB, Android Debug Bridge (ADB)
- Ability to trigger multiple stimuli and verify multiple outputs
- Time-synchronous command/control/monitoring across test equipment and IVI components
- Integrate with application life cycle tools to support supplier/OEM development processes

Danlaw's Mx-Suite™ IVI Test Software helps you to do all the above seamlessly. Here is a brief overview of types of system testing performed during infotainment system, followed by a description of Mx-Suite capabilities.

5. Types of System Testing for Infotainment System

Various types of Infotainment system testing is performed to find defects early in the development cycle. Below is a brief overview of what they are and how Mx-Suite can help perform those tests.

5.1 Functional Testing

The primary focus of functional testing is to test a given feature with from the user's perspective. Testing usually starts early in the development cycle during feature development and continues through product integration. Functional tests assure the interactions between infotainment modules support a feature correctly. Ideally, the test-team develops the test cases at the same time developers implement the features.

During the early stages of product development, the requirements often change and require engineering work by both the development and test teams. One practice that is very useful, especially while other features are in development, is to select a sub-set of automated test cases, called "sanity" test cases, that will insure that features operate correctly. Even if there are changes to the requirements for features, these set of "sanity" test cases will catch issues early and the effort to update the test cases themselves will be manageable.

5.2 Mx-Suite for Functional Testing

Mx-Suite presents test cases as reactive systems in its GUI. Detailed test cases and test results are presented as timing charts with accompanying tabular data. Test results are marked up by Mx-Suite to help reviewers focus on root symptoms of problems.

Connectivity from the test cases to the implementation under test is provided using built in interfaces to most test and measurement devices used for functional testing. This helps the user to quickly and efficiently configure and build interfaces by "dragging and dropping" the interface icons (called Mx-Suite Transforms) into the test framework and connecting to the test cases themselves. The Mx-Suite Transform library support over 150 component interfaces and new ones are being added by Danlaw each month. Since Mx-Suite is an open platform, new custom-built transforms can be created very quickly and easily by a software engineer.

5.3 Performance Testing

The primary focus of audio performance testing is to deeply test the audio characteristics of the implementation early, before the feature is “locked down”. Special equipment is used to perform this testing. Audio performance (also called audio quality testing) usually consist of (but is not limited to)

- Volume, balance, fade
- Volume per feature (main, loudness, GPS-NAV, ADAS warning, park assistance, hands-free, MTS, beep, …)
- Base, treble, and tone
- Equalization
- Vehicle speed compensation
- Multi-tone beeps and chime
- DTMF tone testing
- Distortion (THD) and noise (SINAD)
- Digital or analog audio format test

Audio quality testing should be performed for a range of different user calibrations. The IVI tester should be able to compare actual performance with previously obtained benchmarks or test data to ensure that performance expectation are met.

5.4 Mx-Suite and Performance Testing

Mx-Suite has built in Transform interfaces (drag and drop) to specialized equipment like Audio Precision test & measurement equipment for audio and the ECHO1 devices for Ethernet A/VB specific test cases. New Mx-suite Transform interfaces can be quickly built for other devices once the instrumentation software application program interface (API) is identified. In Mx-Suite test cases are written and triggered for execution by specialty instrumentation. The major advantage of using Mx-Suite is to have a common interface for developing test cases and creating a system conditions during feature performance testing.

5.5 Stability Testing

The primary focus of stability testing is to test the overall system with all of the possible use-cases it might be subjected to throughout its lifetime. Automation greatly assists in performing this type of testing. Critical issues that have high impact on brand recognition is usually the initial focus of stability testing (some of the key focus areas to look for during this testing are blank screens, pops, timings, etc.). Stability tests are automated regression tests that execute 24x7, and simultaneously subject the infotainment system to user interactions and vehicle network bus interactions. Stability tests also attempt to cover all system states through combinations of tests. The network is often forced into heavy loading conditions with messages for creating high loads and varying combinations of test cases.

5.6 Mx-Suite and Stability Testing

Mx-Suite adds high value for performing the Stability testing by

- Executing stability tests 24x7
- Loading the system with vehicle network messages
- Performing synchronized control of external smart devices (like phones etc.)
- Automatically forcing the system through all state-transitioning (Eulerian path)

5.7 Power Mode Testing

Unique to automotive infotainment products is the ability to perform well during power disturbances. The primary focus of power mode testing is to test how the product reacts to these varying power conditions (i.e., during starter-cranking, low power, etc.) in a controlled environment. Power mode testing is usually performed on a component-by-component basis first, and then executed at the system level by combining it with stability testing.

5.8 Mx-Suite and Power Mode Testing

Mx-Suite has built in interfaces to various kinds of power supplies. If there is no need of fast slew rates then use programmable power supplies like GW Instek, BK Power supply, etc., Mx-Suite interface transforms are already available. If fast slew rates with high accuracies are required, then use Danlaw's Low Voltage Tester (LVT) power supply hardware along with the Mx-Suite built in transform.

Typical Power mode testing includes, but is not limited to

- Varying the voltage around operating voltages and testing the behavior
- Measuring start-up, sleep times, and sleep currents
- Placing the system in various power mode states while running stability tests
- Varying the voltage in background while running functional tests
- Running crank profiles and test how system reacts to various power cycles.

6. Mx-Suite and Integration with Application Lifecycle Management (ALM)

Adhering to a product development process is very important during IVI system development. Mx-Suite has several built in adapters which will interface with ALM tools available in the market. The traceability, in-context collaboration and test design can be done in the ALM tool but the actual test case development and test execution is performed by the Mx-Suite. The devision of labor is conceptually simple: The ALM tool triggers the Mx-Suite adapter when a test needs to be performed. Mx-Suite executes the test cases and provides the test cases, test results, and test reports back to the ALM tool for archiving.

7. Mx-Suite IVI Test Software

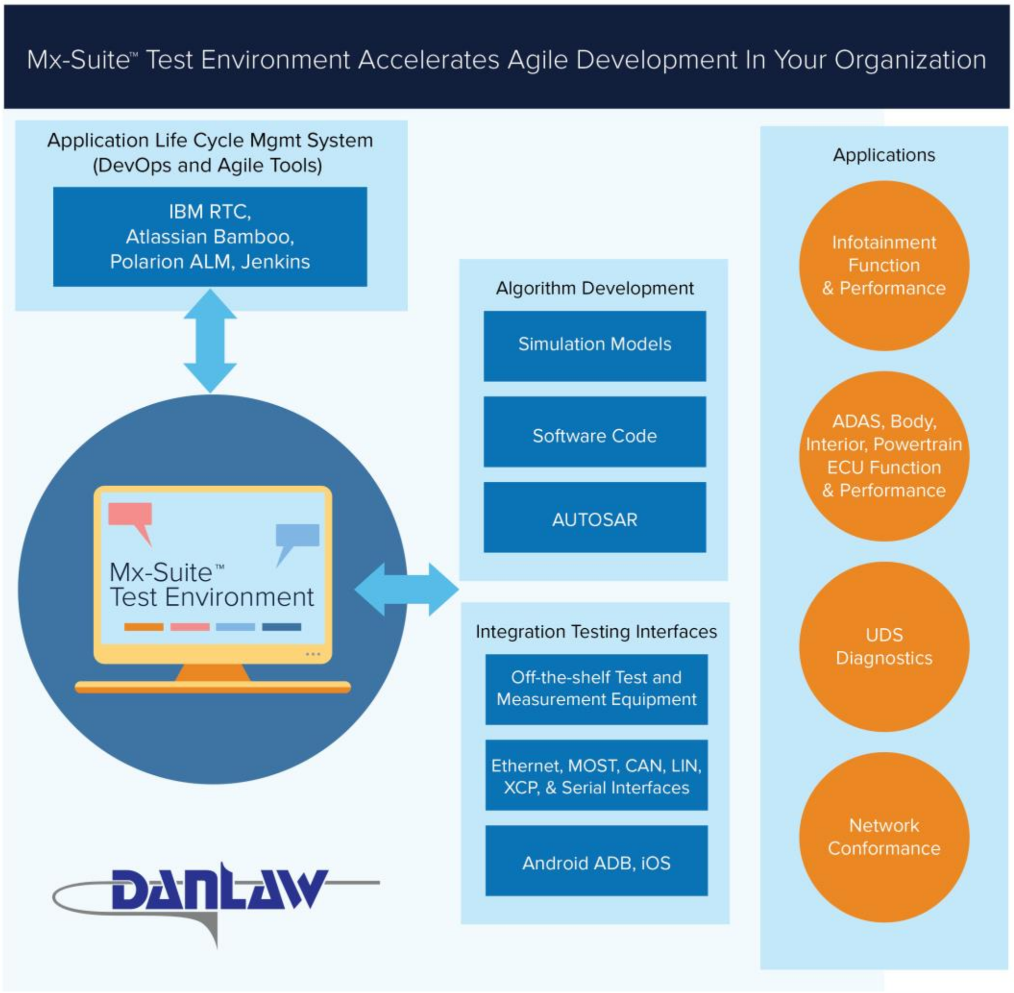
Mx-Suite with its rich set of built-in interfaces for infotainment system protocols helps users to develop test cases quickly. With its intuitive graphical user interface, users can easily develop test cases without the need for learning any new software programming languages. Mx-Suite can also command and control test & measurement equipment, external devices, and the head unit to perform many combinations of tests. Mx-Suite allows users to explore stimulus-response behaviors over many inputs and outputs as they design their tests. Mx-Suite can run regression tests 24x7. Mx-Suite generates the executive summary and detailed reports in pdf format which can be archived and shared across the organization.

7.1 MX-Suite Overview

Danlaw's Mx-Suite™ IVI Test Software provides the test-authoring interface, the test execution environment, a co-simulation environment for mixed virtual/real ECU testing, and the pass/fail decision criteria for the Infotainment system.

Mx-Suite™ provides the graphical user interface for test case editing; test schedule assignment; configuration of connection interfaces; customization of Mx-Suite™ connector transforms; and test results reporting. The data for these artifacts are available in files, which can be archived by a version control system for configuration management purposes.

Signal inputs and outputs to the test cases are configured in generic "engineering units" (such as SI units or English Engineering Units) to ensure test case portability. Connectivity to test entities (modules, virtual nodes) configured using Mx-Suite's transform editor, which defines the mapping from engineering units to actual interfaces used. The Mx-Suite™ has an architectural design-in to allow use with any continuous integration software package, and supports popular ones, such as IBM Rational Quality Manager (RQM), Jenkins, and CruiseControl.



Mx-Suite™ Test Environment Accelerates Agile Development In Your Organization
Application Life Cycle Mgmt System (DevOps and Agile Tools)
IBM RTC, Atlassian Bamboo, Polarion ALM, Jenkins
Mx-Suite™ Test Environment
Algorithm Development
Simulation Models
Software Code
AUTOSAR
Integration Testing Interfaces
Off-the-shelf Test and Measurement Equipment
Ethernet, MOST, CAN, LIN, XCP, & Serial Interfaces
Android ADB, iOS
Applications
Infotainment Function & Performance
ADAS, Body, Interior, Powertrain ECU Function & Performance
UDS Diagnostics
Network Conformance
DANLAW

7.2 Mx-VDev - User Interface

Mx-VDev is the user interface to Mx-Suite™, and it provides three main ways to interact with the test bench: definition and execution of test cases, definition of test case harness to items under test, and test reporting. Other main functionalities include the following:

- Provide the users an efficient way to create and edit test cases.
- Users are provided sample test cases as a model to help define new test cases
- Online help is immediately available to guide users during the process of using Mx-Suite™
- Define mapping and transformations of each event to the values needed by the underlying components to do the work.

7.3 Mx-Transit – External Interface

Mx-Transit configures the interfaces to the external hardware and software components. Access from the Mx-Suite test cases to the hardware and software is provided by the drag and drop Mx-Suite Transforms. There are nearly 150 built transforms readily available within Mx-Suite, which can be easily configured and used right away. Building a new interface is very easy through provided COM APIs. Below are some of the automotive IVI interfaces that are readily available within Mx-Suite

- Intrepid NeoVI (LIN/CAN)
- MOCCA (MOST)
- Programmable Power Supply
- National Instruments data acquisition (DAQ) card
- Web Camera or High speed camera
- USB Switch
- RF Relays (Antenna Switching)
- National Instruments (NI) Vision software
- Android Debug Bridge (ADB)
- iOS App connector
- Audio Precision APx585
- Vector CANCaseXL (LIN/CAN/MOST)
- Vector CANCaseXL (Ethernet A/VB)
- ECHO NIC-1 Card (Ethernet A/VB End Point)
- Microsoft speech library
- Microsoft COM

7.4 Benefits

Mx-Suite™ IVI Test Software is an infotainment system tester that runs on a PC workstation. It allows test personnel to create test cases without writing scripts, and creates easily understood test reports that can “drill down” to stimulus/response behavior details. It is a comprehensive test tool that offers:

- Time savings through naturally understood graphical test cases & results
- Reduced costs through automation and reusable test cases over your product life cycle
- Assured quality through documented quality evidence of conformance with OEM requirements and standards
- Rigor to your development process by ensuring measurable pass-fail criteria are defined for requirements
- Test-access to the infotainment system through all the available interfaces (human-machine, electronic, or network)

8. Company Profile

Danlaw's 500+ engineering professionals have been providing automotive embedded electronics solutions to OEM's and their Tier-1 supply base for over three decades. Danlaw has facilities in the USA, India and China. Its specialty areas include embedded systems development and testing for Embedded Control Units (ECUs), vehicle network communications, infotainment, and telematics. Its customers include Automotive OEMs, automotive electronics suppliers, fleet and automotive insurance companies worldwide.

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