MIL-STD-461 and RTCA-DO-160 Preparation for Test

WHITEPAPER

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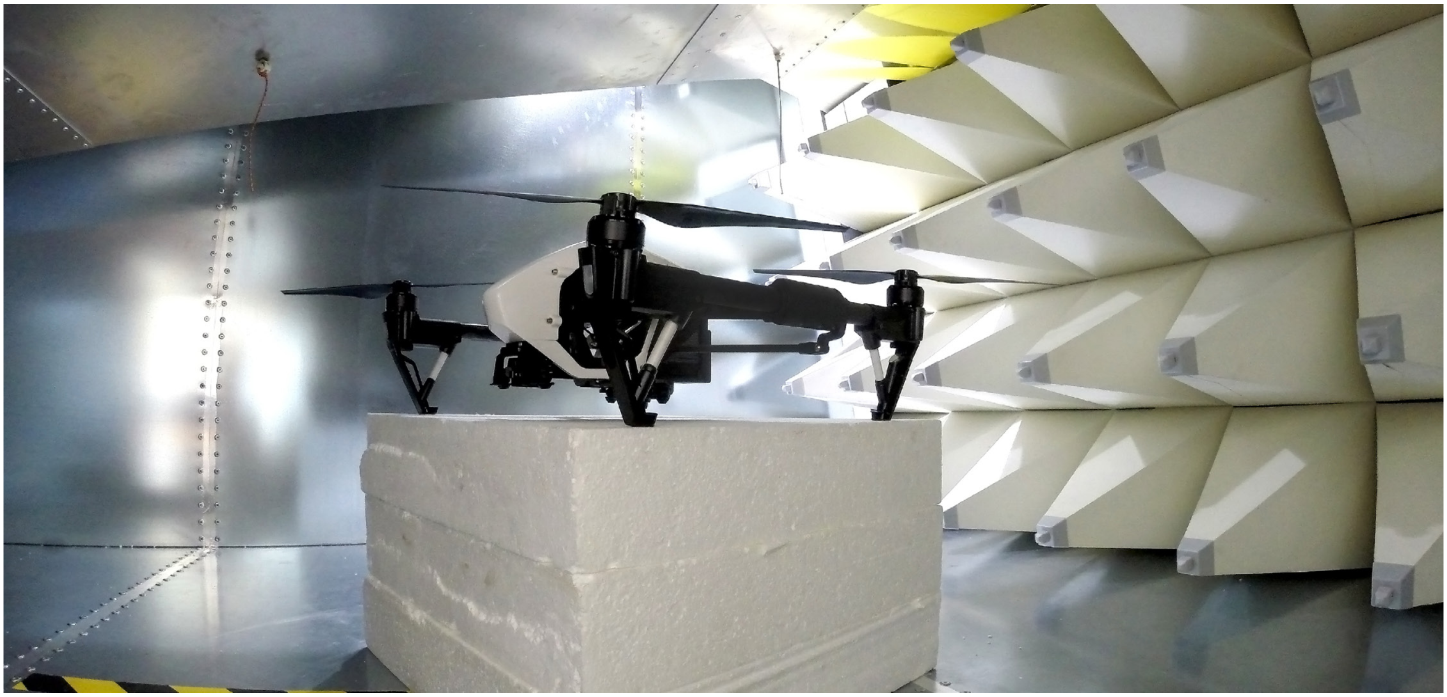


READY FOR TEST?

When Alexander Graham Bell said “Before anything else, preparation is the key to success,” he was of course not referring to Electromagnetic Compatibility (EMC) testing – but it certainly applies. The cost of EMC testing is significant, but it is far outweighed by the costs in redesigns and product delays caused by inadequate planning.

In the MIL/AERO environment, EMC compliance requirements are established by MIL-STD-461 for military applications and RTCA-DO-160 for commercial aviation. The qualification test process for both standards involve significant preparation to ensure test execution proceeds efficiently. This article poses numerous questions regarding test preparation, then provides their answers along with helpful guidance to keep tests running smoothly.

Although the focus of this article is MIL-STD-461 and RTCA-DO-160, the preparation discussion can be applied to virtually any test program.

The following “checklist” identifies several preparation topics and gives details regarding why that topic needs to be part of your “Ready for Test” review. Many test representatives, witnesses and laboratory personnel can readily add other elements from experiences that show a lack of preparation. Hopefully, this article will help supplement your preparation list.

HAVE YOU SELECTED A TEST LABORATORY?

Selecting the test laboratory should be accomplished early in the preparation for qualification testing. In-house, independent or government laboratories require coordination to effectively conduct the test program. The test facility layout has a large influence on how the test is configured; challenges from physical constraints and test and measurement equipment to locations for the testing should weigh heavily in our preparation.

Prior to requesting test support, a basic test procedure should be assembled which provides the test requirements and a description of the Equipment Under Test (EUT). Without having this basic information, the test laboratories will have a lot of questions to determine their capability to accomplish the required tests.

Information provided when requesting a laboratory pricing proposal should include a minimum of the following:

- The physical properties (size, weight, and information on mounting hardware).
- Power parameters (voltage, current, power frequency).
- A listing of the applicable test methods.
- A listing of the support Equipment that will accompany the EUT (this should include the space and power requirement for this equipment).
- A list of the different modes of operation involved in the testing. This could be just one of various modes which are exercised at the same time or within a sequence. Duty cycle restrictions associated with the EUT need to be identified. If the test article requires a long time to complete an operation or if the duty cycle presents continuous operation, the test laboratory needs to be aware to schedule the test program properly.
- If radio transmitters or receivers are present in the test article, the details about each wireless module is needed.

The approval status for operating the transmitters at the test location should be included.

- Any restricted access or special handling (e.g., ITAR, Government classification, etc.) requirements need to be provided.

Your request for proposal should also include questions to understand the expectations as well as what is provided and what is required. Avoiding assumptions will help the test program progress with minimal delays. At a minimum, it is beneficial to request that the laboratory provide information on:

- The capability to accomplish the required test methods and levels for this type of device.
- Where the testing is going to be accomplished. (This may be apparent, but often tests are accomplished with sub-contracted laboratories that could impact your support or witnessing.)
- Accreditation body; confirm that the specified standard(s) and test methods are included in your accreditation.
- Personnel experience, certifications and credentials associated with accomplishing or overseeing the testing.
- Is a representative from the manufacturer required to be present to operate and monitor the EUT during test?
- In addition to the pricing, the expected duration of the testing.

A reply to your proposal request should be timely – a delayed reply may be indicative of how responsive the laboratory will be in accomplishing the testing and dealing with issues that may arise (such as scheduling adjustments).

IS A TEST PROCEDURE ESTABLISHED?

Test procedures are the key to successful testing, providing detailed instructions for accomplishing the complete test program. Scheduling testing by just stating MIL-STD-461 along with listing the applicable test methods (or RTCA-DO-160 applies) omits the details for selecting the appropriate frequencies, test levels and configuration for the testing. In the absence of this information, the laboratory will be asking a lot of questions to ensure that they have the capability to perform the tests. Often, additional questions which were not previously addressed (such as what emission limit applies) will surface at the onset of testing. A good test procedure provides the answers. In almost every case, the absence of a test procedure is more costly than the cost of preparing a procedure.

MIL-STD-461 identifies a Data Item Description (DID) DI-EMCS-80201C that provides an outline and describes the content to be provided in the EMI Test Procedure (EMITP). RTCA-DO-160 serves as a procedure document. It supports preparation of a separate document incorporating the required procedures which describes combining the various tests and the product specification. Although the DID provides instructions on preparing the procedure, many details necessary to the test program are not listed.

ARE ALL REQUIRED TEST METHODS CONSIDERED?

This seems like an obvious detail, but if overlooked, recovery can be painful. During development, the requirements can be amended to accommodate additional applications for multi-service, various aircraft or simply to support open sales. If discovered during the test report approval phase, a redo can be expensive and delay the approval process. This is especially difficult if the redo results in identifying non-compliance issues.

HAVE YOU DEFINED THE RESPONSIBILITIES?

Most laboratories have general guidance that requires the customer to provide the Equipment Under Test (EUT) and all support items to establish and monitor operation of the EUT. The laboratory will normally provide the test instrumentation to capture and measure emissions and to generate and apply interference signals. However, a general guide may not be detailed enough to avoid getting the test underway.

Power for the EUT may be assumed, however special power needs should be coordinated with the laboratory. For example, has the availability of DC, 50 Hz or 400 Hz power with the necessary ampacity been confirmed? If special power considerations apply, has the responsibility to make the connections and filter (if necessary) been defined?

Wireless devices are incorporated into many EUTs, and with that, the need to operate the transmitters with support equipment and to protect the measurement equipment from overloads is needed. If the transmitter is not approved, has a Special Temporary Authorization been granted or controls established with the laboratory to prevent unauthorized transmissions and the risk of FCC fines?

The incorporation of wireless devices often brings the need for tunable equipment testing where each tuning band is subject to many of the individual test methods. The test procedure should address this need and identify how many different tests apply. A simple radio operating with VHF-AM, UHF-AM and UHF-FM capability will require testing with EUT operating at three frequencies per tuning band for three or more of the test methods. Make sure that the laboratory is fully aware of this need and that the time for testing has been allotted.

Is the equipment available to prevent measurement system overloads (such as notch filters that attenuate the required transmission frequency without attenuating the unintentional emissions from the EUT)? Even if these filters are part of the measuring system, the laboratory may not have items with the ratings appropriate for your device readily available.

WHAT IS GOING INTO THE TEST?

The test procedure introduction should contain a description of the EUT, however details of the build level may not have been available. When the EUT is prepared for test, an expanded description should be prepared with the details of the actual test item. Each of the sub-assemblies are listed with revision identification to document how the actual test item is constructed. This configuration management tool supports the ongoing compliance need to identify changes during the item life cycle. Take pictures (inside and out) to supplement the description and provide the information for inclusion in the test report.

ARE THE PROPER BONDING AND GROUNDING PROVISIONS IN PLACE?

Both MIL-STD-461G and RTCA-DO-160G provide guidance on the bonding and grounding provisions for the test configuration. Contrary to commonly used practices, the resistance from the EUT surface to the facility ground plane is not less than 2.5 milliohms. Both standards specify that only provisions included in the design or installation instructions be used to connect the EUT to the chassis.

The less than 2.5 milliohm resistance requirement is associated with bonding of the ground plane to the shielded enclosure, the bonding of the Line Impedance Stabilization Networks (LISN) to the ground plane and the junction resistance of individual faying surfaces.

Normally the measurements of the grounding provisions for the EUT are accomplished without cables being attached to obtain the worst-case values. When cables are incorporated, the associated grounded connections and cable shields are placed in parallel with the grounding provisions resulting in a lower resistance.

Incidental ground connections should be avoided when establishing the grounding. For example, a rack mounted equipment may be placed in a rack arrangement for testing with a designated ground wire connection between the equipment chassis and the rack. In addition, the mounting may make a contact between the equipment mounting tabs and the rack. This additional contact lowers the resistance.

If the real installation uses a rack with a non-conductive mounting surface, then the lower resistance is not supported for the “as installed” configuration. If the installation uses a conductive surface rack mount, then the measurement with the contact would be correct.

Additionally, the materials selected for the grounding may influence the resistance. A ground strap making an electrical connection around a shock mount may use a metal that tolerates vibration and corrosive effects but has a higher resistance than the test configuration strap. The standard calls for matching the installation material. RTCA-DO-160 specifies the use of a 30 cm wire of the representative type if the length is not defined in the installation. The representative type is normally the same size wire as the power lead.

When the installation parameters are unknown, using the MIL-STD-464C guidance can help us arrive at a target value for the DC resistance of the bonding:

- 10-milliohms from equipment enclosure to the system structure
- 15-milliohms from cable shields to the equipment enclosure
- 2.5-milliohms across individual faying interfaces within the equipment

This guidance would place a requirement of 25-milliohms between a cable shield and the system structure. This could be significant for rack mounted enclosures if the rack provisions are not carefully considered. The bonding also has an impact on the performance of filter connectors, filter inserts or transient suppressors that rely on connection to the equipment ground point or chassis. The bonding resistance is placed in series with the reactive component of the filter component that decreases the effectiveness of the filter.

For safety purposes, if hazardous voltages are present, MIL-HDBK-2036 reminds us to achieve 100-milliohms or less to avoid shock hazards presented by fault conditions.

As part of your preparation, you will need the proper ground provisions and adequate knowledge of the installation requirements to duplicate the installation in the test configuration.

DO YOU HAVE THE INTERFACE CABLES?

Cables and the arrangement of those cables tend to be the primary cause of test variances even with the details for the test configuration documented thoroughly in the standards. Many years ago, a lot of effort was expended trying to make the cables disappear as part of the test configuration. They served as radiating/receiving antennae, and their positioning contributed to the parasitic effects such as distributed capacitance and mutual inductance which allowed cable crosstalk. Test configurations would place cables inside shielded boxes which abutted the EUT interface to demonstrate (through test) that the EUT complied with the requirements and passed the responsibility of field EMC issues to the installation team for resolution.

A few years back, the standards addressed these concerns by requiring that the cables which were suitable for the installation be used during test. This included guidance on the cable layout to arrive at a standardized test program. It soon became apparent that EMC control measures related to cable management which resulted in the test configuration driving changes into the installation that were unrealistic. Now the standards require that installation practices be incorporated into the test configuration with limitations driven by the test facility constraints.

Generally, cables are arranged based on guidance provided in the standard with the cable length as used in the installation with length restrictions for long cables. The cable arrangement places the cable 10 cm from the ground plane front (front is the side facing the measurement system antenna) on top of a 5 cm non-conductive spacer above the ground plane. A length of cable (at least 1-meter for RTCA-DO-160 and at least 2-meters for MIL-STD-461) is aligned along the ground plane front (10 cm behind the front edge) with excess cable placed in a zig-zag pattern at the rear of the ground plane.

Do not arrange the excess cable on a spool – this is like fabricating an inductor and it degrades the test configuration. The cable end is terminated into the appropriate load or stimulus equipment that may be located on the ground plane or routed outside the shielded enclosure to the support equipment. At the shielded enclosure boundary, connections penetrating the enclosure will most likely need some isolation to limit the support equipment and the outside environment exposure to the test conditions.

For RTCA-DO-160, the cable length used for test is 3.3-meters unless a specified length is called out for installation. If cable length exceeds 15-meters, then up to 15-meters is the maximum required length for the test configuration. MIl-STD-461 calls for the length as used in the installation with at least 10-meters for long cables.

It should be noted that the standard provides generic guidance on the test configuration that may be applied for a variety of installations. For equipment that has limited applications or are always installed the same way, a test configuration that mimics the actual installation should be considered.

DO YOU HAVE THE PROPER POWER CABLES?

Power cables for the test configuration merit a separate discussion because the test configuration power arrangement is a bit more complex than the outward appearance. RTCA-DO-160 prescribes a 1-meter power cable length to the LISN following the same layout guidance. MIL-STD-461 specifies a maximum 2.5-meter power cable length to the LISN. Based on the wording, it appears that a 1-meter cable would meet both standards, but that theory falls apart when MIL-STD-461 specifies placing 2-meters of the power cable along the front of the ground plane.

Where power leads are part of an overall cable bundle, RTCA-DO-160 calls for separating the power leads from the bundle where the bundle the test area. MIL-STD-461 indicates separation of power leads at the EUT connector and routing them outside the overall bundle. Mil-STD-461 discusses an exception to remove power leads from the bundle if power is derived from a source the includes filtering to the mains. For example, if the EUT receives USB power, the USB source would normally provide a level of filtering between the mains power and the USB interface to the equipment. In cases like this, separation of the power leads from the bundle would not be applicable. A test that calls for testing of power leads would default to bundles testing only.

Where power leads are not specified to be part of a bundle, the leads are separated from the interface bundle and treated as a separate interface for testing even if the power shares the same interface connector.

Additionally, if the power return wire uses a local ground in the installation, then connecting the return to the ground plane without a LISN is specified. If unknown, then a LISN in each lead would be appropriate.

The cable discussion points out the cables are an integral part of the preparation. Be sure that the cables meet the layout needs and that cables are included to make connection inside and outside the enclosure. Make sure that the cable lengths will also reach the enclosure interface panels with connections for isolation as described in the test procedure.

ARE APPLICABLE ELECTRICAL AND MECHANICAL LOADS AVAILABLE?

Providing terminations for the various electrical interfaces is usually included in the support equipment identification and configuration of the test item. Having passive load circuits or loop-back wiring in place of an active piece of equipment is generally preferred for the test configuration. Dummy loads attached to antenna ports instead of including the associated antenna are used throughout the test community.

Often, the requirement to include appropriate mechanical loads as required by the standard is forgotten or inappropriate loads are substituted. It is not correct for a pump designed to move fluids to be operated pumping air during the testing; the load does not conform to the installation effects. It is feasible to incorporate substitute loads that will produce the appropriate loading, however the means to attain the mechanical loads must be considered and included in the preparation.

DO YOU HAVE THE SUPPORT EQUIPMENT AND ISOLATION?

Support equipment are normally the numerous items that make the EUT operate and the monitoring equipment to assess the performance of the EUT during test. We should also include software in the aggregate of support equipment, especially if the software is tailored to provide continuous or multiple modes of operation. The support equipment can produce emissions or demonstrate susceptibility during test that appears to be a EUT non-compliance and it may be difficult to determine that the issue is directly attributed to the support devices.

Emission testing provides methods to accomplish a test configuration ambient evaluation that is required to be below the applicable limit with all support equipment operating and the EUT off. Simulated loads are used to substitute for the EUT during the ambient testing. Normally, the support equipment with active circuits are not designed to meet the stringent emission requirements. Therefore, additional control measures may be required. This also applies to the support equipment immunity where susceptibility testing causes support equipment interference.

An additional concern is the coupling of the environment into and out of the shielded enclosure. Conductors penetrating the enclosure boundary tend to carry ambient signals such as radio, TV and general communications and these signals radiate from the conductor. This causes the test chamber to show high level emissions preventing detection of EUT emissions and high-level ambient conditions. The same conduction path allows susceptibility test signals to be radiated into the environment, violating FCC regulations.

The planning process should have addressed support equipment risks with a detailed plan to provide isolation or control. During the preparation process, the control measures that have been defined need confirmation of availably for use during test.

WHAT ARE THE NECESSARY PRECAUTIONS?

Most of the time we rely on the test laboratory to observe test precautions regarding accessory equipment, excess equipment (clutter), overloads, RF hazards, shock hazards, spectrum restrictions and other concerns that could affect the measurements or violate regulatory rules should be documented in the procedure.

Spectrum restrictions need to be addressed if radio transmitters are present. In the absence of clear approvals to operate the transmitters, the laboratory will need to assume that the transmitter operation is restricted.

Are special precautions applicable to your EUT or the test configuration? The laboratory needs to be made aware of risk areas that may not be obvious. For example, the equipment may use materials with a low flash point (fuels, inks, lubricants, etc.) and methods to mitigate electrostatic charges must be incorporated to prevent ignition risks.

HAS THE PASS/FAIL CRITERIA BEEN ESTABLISHED?

This may appear obvious because the applicable test limits are specified so pass/fail is simply a measurement and comparison to the limit process. Frequently, indicators of susceptibility are not identified or adequately defined. The susceptibility monitoring needs to be objective and measurable, so the acceptability of the results is easily determined. Monitoring for illumination of an alarm light with a requirement that the light remains off seems to be an easy indicator to use.

However, if an alarm condition existed and the indicator circuit was susceptible the inability to detect the alarm condition would be an unacceptable condition. Would the operational software to exercise the equipment need to generate an alarm and the criteria for acceptance changed to require that an alarm be detected at specific intervals?

Another subtle example may be that a temperature-controlled fan is activated when a certain temperature is reached. So, normally the fan would be off at room ambient conditions. If the temperature measurement system is susceptible the actual temperature could cause the fan to run continuously or never start. One condition could be acceptable and the other unacceptable, but in either case the EUT is susceptible to failing to operate at the required performance. In this example, we need to make sure that the risks are known, and monitoring is established.

Preparation needs to provide the means to assess compliance and that the necessary hardware and software to support operation and monitoring is present and functioning.

IS THERE AN ESCAPE PLAN?

It's unfortunate but not uncommon that unexpected events occur during testing; they are not always an indication of a test failure.

For example, maybe an over-limit emission is detected, but can no longer be detected during the investigation. A retest is performed, and the emission returns, then disappears once again while observing the signal. While investigating the EUT operation to determine what circuits operate intermittently, the emission returns, so the EUT is powered off. The signal amplitude decreases but does not disappear.

After a long investigation, it is discovered that an ambient signal is present related to another test in the laboratory which provides a carrier for an EUT emission, so the measurements show the modulated carrier elevates the emission level.

Another scenario: during susceptibility testing the EUT stops operating and repairs find a circuit failure. The failure analysis does not reveal the relationship of the failure to the test being accomplished. What steps are needed to continue the testing? Just repair and repeat? Repair and repeat 3-times? Repeat other tests to see if the failure was attributable to cumulative effects?

Because irregularities and unforeseen issues can always crop up, we need to have a documented approach to proceeding with the evaluation project. Consider potential events, such as:

- What happens if a failure occurs related to the testing?
- What happens if a failure occurs but cannot be duplicated?
- What happens if support equipment induces a failure?
- What happens if the EUT fails because of an operator error?
- What happens of the EUT goes Tango Uniform (toes up)?

The above and other issues may occur, so it's important to have a recovery plan. Identify the person that will make decisions or approve any paths applicable to the project. Not having a plan will normally cause delays with each occurrence.

CREATE A SOLUTIONS KIT

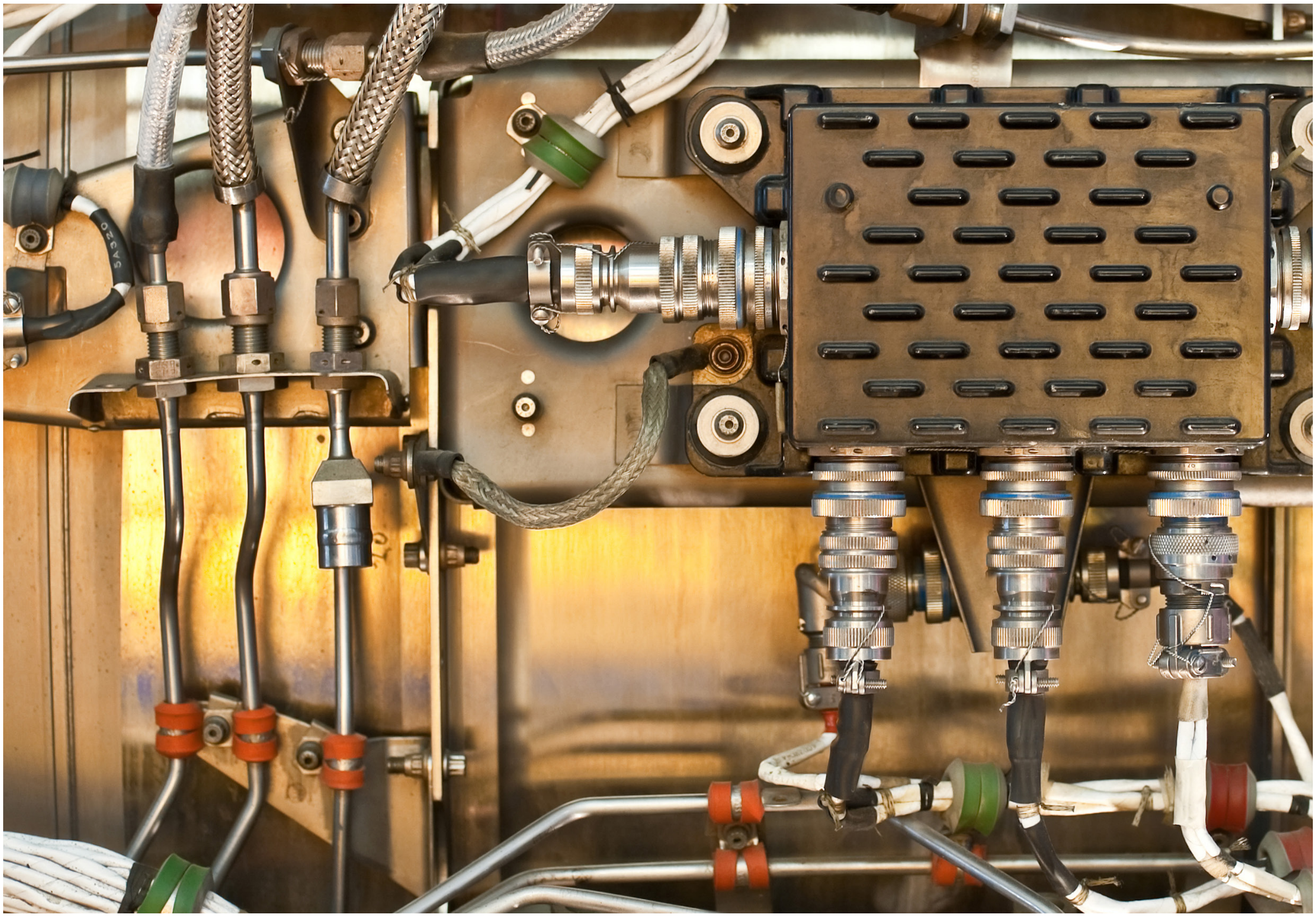
Although you believe that the design team has produced a product that will comply with the requirements, risk elements may be present in the design. These risks are expected to accept trade-offs associated with constraints and the cost escalation from an over-design. Of course, the unexpected issue may be identified during test.

As part of the test preparation, assemble a kit of parts that could be implemented to mitigate an issue or at least help identify the source of the problem. Common passive components (resistors, capacitors, inductors), ferrites, filters, shielding materials, fingerstock, copper tape and the like that are readily available can be a vital asset. Components that can be installed quickly without the delays of having a buyer seek a source, place orders and have drop shipped to the laboratory can avoid major delays in solving problems.

For example, EESeal® EMI Filter Inserts are an easy retrofit that require no special tools or training to install. They can be added to a connector in just 30 seconds and instantly provide permanent, rugged mitigation against RF emissions and transients, including ESD.

By including a light-weight, hassle-free component like the EESeal® in your testing toolkit, you arm yourself with a solution that can not only fix unexpected problems as soon as they occur, but can be implemented permanently without a need to return to the design phase or accrue additional costs.

Quell makes it easy to assemble these items in your solutions kit. Free samples of the EESeal® that are designed & built to your specific application can be provided in 24 hours!



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