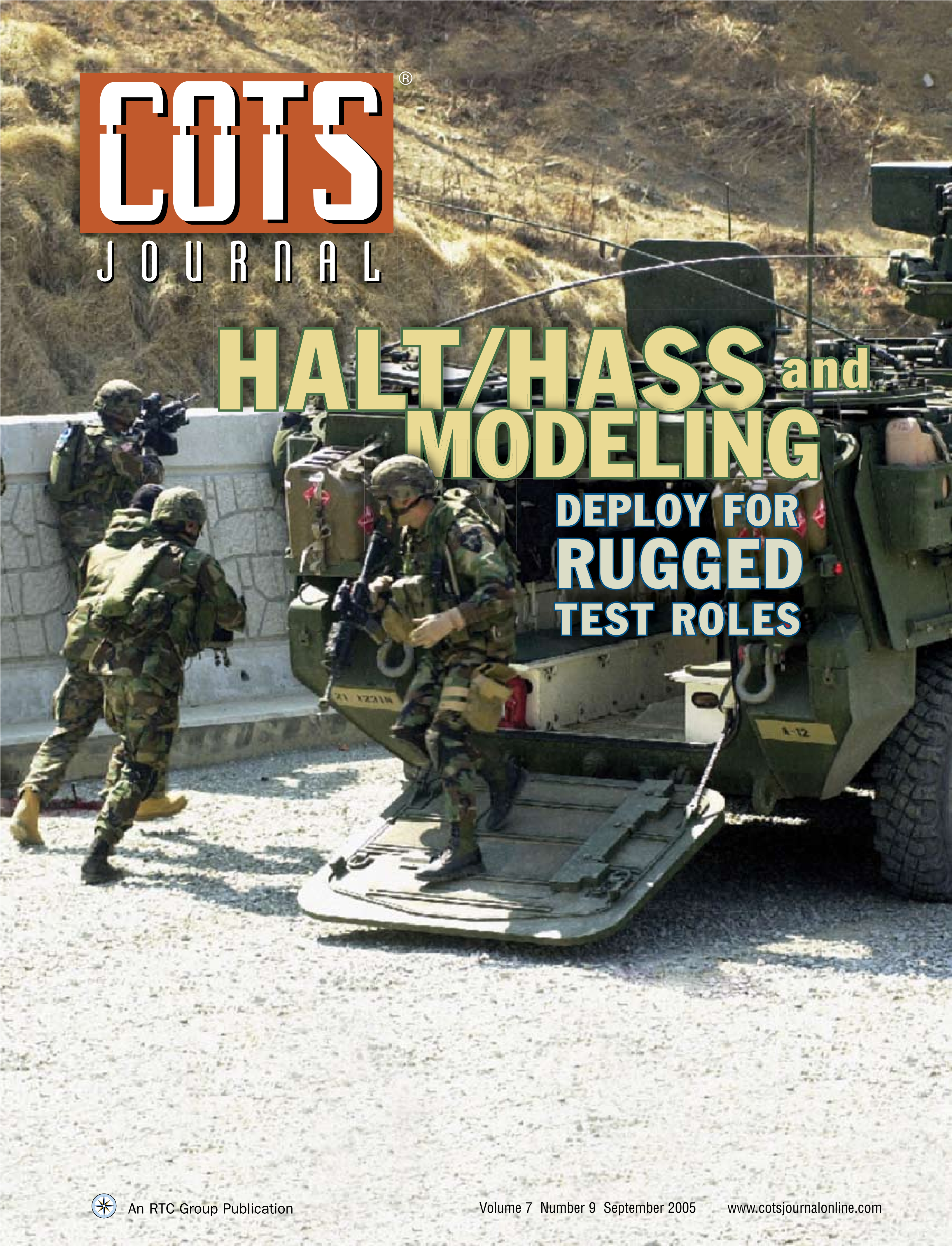

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DEPLOY FOR RUGGED TEST ROLES

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HALT and HASS Testing: Learning to Handle the Big Guns

A lack of standards for the correct implementation of the stress test techniques known as HALT and HASS has resulted in widespread confusion. When implemented correctly, HALT and HASS provide a fast, cost-effective path to greater product reliability and customer satisfaction, as well as reduced warranty costs.

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Since they were first introduced in the early 1980s, Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS) have been successfully adopted for a host of high-performance applications, such as mission-critical avionics equipment. With their promise of quickly providing valuable information about the reliability of a new or modified design, and the ability to monitor production and prevent component variations from causing latent field reliability issues, HALT and HASS techniques are ideal for designing and manufacturing with commercial-grade components.

Both test methods use direct inject, high flow rate liquid nitrogen cooling, tens of kilowatts of heating and powerful, multi-axis broad-spectrum vibration. Although these aggressive test methods are very different from standard life testing, design verification testing (DVT) and end-of-production testing, there are no published industry standards that define these

Figure 1

The Repetitive Shock (RS) systems used for HALT stress testing are equipped with multiple pneumatic actuators that randomly strike the bottom of a semi-rigid table. These systems can stimulate a product with a much wider range of frequencies than those used in DVT, and in all three axes and rotations simultaneously. This stimulation will rapidly drive a poor solder joint or weak mechanical connection to failure.

powerful test methods. Since they deploy extreme stresses designed to rapidly precipitate flaws and force them to failure, misapplications or misinterpretations of these tests can easily result in damaged products, wasted money and frustrated engineers.

HALT is used as part of the new product design process and is typically performed on pilot or pre-production units. During HALT testing, the product is subjected to increasing stresses until weak points in the design emerge. Failure modes are identified and analyzed, and the product design is modified based on the results of that analysis. A typical HALT test will take three to five days. HASS, on the other hand, is a production screen, and typically tests 100% of production units. HASS uses similar stresses to those used in HALT, but at lower levels based on the limits identified in HALT. HALT must be completed before HASS can be implemented, and HALT is the most widely used of the two tests.

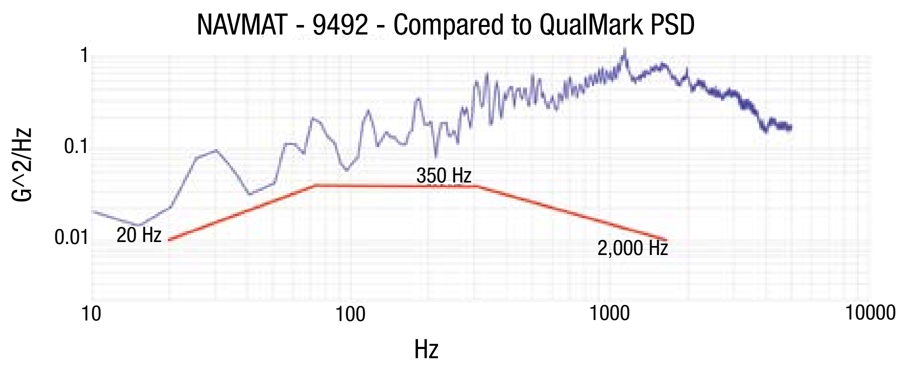

Figure 2

The spectral content of the signal in RS systems is determined by the table's construction, and is usually very different from the vibration profiles run on the Electro-Dynamic (ED) shakers used in DVT testing. The graph compares the PSD (Power Spectral Density) plot from an RS HALT system (blue) to the ESS profile defined in the Navy's NAVMAT profile P-9492 (red). An ED shaker provides little energy above the 2 kHz limit of this profile, while an RS shaker clearly exceeds that.

HALT and DVT

Although HALT may appear similar to DVT, it has different goals, uses different stresses and provides different results. The goal of DVT is to demonstrate whether a product will function in its intended environment and meet its specifications. The purpose of HALT, however, is to subject the product to environmental overstress, effectively forcing failure modes to emerge by accelerating mechanical fatigue. HALT quickly identifies a particular product's set of failure modes by applying the same environmental stresses that occur in the field, but at much higher levels. DVT and life testing can sometimes identify those failures, but this rarely occurs because the required time and number of units in test would be extreme.

One of the most significant characteristics of HALT is that it is not a pass/fail test. There are no pre-established limits. The test concludes when product destruct limits have been reached or the engineers determine that no more useful information can be gained. A final HALT test report includes detailed data on the product's operating margin, destruct margin and design flaws, along with what the new margins will be if each of the design flaws is eliminated.

When HALT is used, it is performed before DVT, so failure modes are exposed quickly and inexpensively before DVT begins. At that point, they can be analyzed and corrected without the pressure of a looming release date. If this is not done, many products will exhibit multiple failures during DVT. This can initiate costly and time-consuming redesign/retest cycles. But as a product nears its scheduled release date, the pressure to pass DVT can be intense. Too often, dealing with these critical failures may be postponed until after product launch, resulting in even greater losses and customer dissatisfaction.

The HALT Test Method

The stresses used in HALT are applied beginning with the least destructive and ending with the most destructive. A test sequence starts with cold step stressing and proceeds to hot step, rapid thermal ramps and vibration. It ends with a combined environment of vibration and rapid thermal ramps, dwelling at both temperature extremes. Other stresses include input voltage variations, loading, clock frequency variations and mechanical loading, if appropriate. Combining stresses will often reveal failure modes that individual stresses cannot.

Each time a failure occurs it is carefully documented and, if possible, a quick work-around is identified. Testing concludes when multiple failures occur simultaneously or fundamental design or technology limits have been reached for individual and combined stresses.

The potential benefits from HALT are significant. A single failure mode, caught before it becomes an issue that requires field rework, can save millions of dollars and help maintain a company's reputation and likelihood of getting future contracts. In addition, using HALT helps DVT go smoothly, so products are more likely to be released on time.

HALT may be considered successful when DVT and product launch proceed without last-minute design changes caused by late detection of failures. Success is further characterized by a lack of field issues in the weeks and months following launch. But a successful HALT also requires other conditions. The development team must accept ownership of the process from the beginning. HALT must be applied as early as practical in the design process, and failure analysis must be fast and accurate. It is imperative that failures are not overlooked or explained

Figure 3

The stresses used in HALT and HASS require unique test equipment for implementation. The QualMark Typhoon 3.0, for example, is a typical HALT chamber. Since HALT and HASS are most effective when stresses are combined, this chamber can provide both thermal and vibration stresses.

away, and the product development team must apply solid judgment when deciding which failure modes to eliminate.

The vibration stress used in HALT can be another source of confusion, since it deploys a type of shaker system different from that used in DVT. The Electro-Dynamic (ED) shakers deployed in DVT can be carefully controlled to provide exactly the stimulus needed for an analysis of the product's vibration response. They provide this stimulation in only one axis at a time. In HALT, rapid fatigue, not analysis, is the goal, and Repetitive Shock (RS) systems are used. These systems (Figure 1) can stimulate a product with a much wider range of frequencies, in all three axes and the rotations about these axes simultaneously. This stimulation will rapidly drive a poor solder joint or weak mechanical connection to failure.

In RS shaker systems, the signal's spectral content is determined by the table construction, and is usually very different from the vibration profiles run on an ED shaker. For example, an ED shaker provides little energy above the 2 kHz limit of the Navy's NAVMAT profile P-9492, while an RS shaker clearly exceeds that level (Figure 2). ED shakers are thus effective at characterizing a product's resonant modes, while HALT is more effective at precipitating failure modes, particularly on PCBs where higher frequencies are required.

HASS Production Screening

Once a product has been ruggedized with HALT, the question of production testing arises. Manufacturing variations and vendor changes can mean disaster, whether in a high-dollar, low-volume product, or one to be used in critical applications where failure can be very expensive or dangerous. Companies often use long burn-in tests to reduce these risks, only to discover that burn-in failures are rare, yet warranty issues are still a problem.

This is where the HASS production screen comes in. It applies stresses similar to those used in HALT, but at substantially reduced levels, based on the limits identified in HALT for each of the applied stresses. HASS provides continuous verification that additional failure modes, resulting from manufacturing or component variations, have not crept into the product.

Unlike HALT, HASS is a pass/fail test. A HASS screen consists of a "precipitation" phase that may exceed operating limits. This is followed by a detection phase in which the stresses are reduced to within operating limits and the product is monitored for failures. The test usually requires from 30 minutes to two hours, and in many cases eliminates the need for 24 or 48 hours of largely ineffective burn-in. The potential lot-to-lot variations that have been introduced with commercial-grade components mean the risk of a component change, which could introduce a new field failure mode that would be undetected by functional testing or a few days of burn-in. HASS applies combined stresses to precipitate these failure modes and then detect them via a change in the operating margins or a hard failure.

Many engineers have expressed the concern that HASS can damage products and may actually cause field failures. However, proper implementation of the HASS Proof of Screen provides a clear understanding of screen effectiveness and ensures that there is no effect on product life or performance. Proof of Screen includes repetitive application of the HASS stress profile to a small population of production samples. HASS is only implemented after it has been proven that all "good" samples can withstand from 20 to 50 repeated HASS cycles without damage or wear.

HALT and HASS Test Chambers

The stresses used in HALT and HASS require unique test equipment (Figure 3). Since HALT and HASS are most effective when stresses are combined, test chambers are capable of providing both thermal and vibration stresses. Direct inject liquid nitrogen cooling and high-speed fans allow product temperature change rates of up to 60°C per minute, with air temperature change rates far exceeding that.

HALT and HASS chambers are expensive, but the cost is minimal compared to what many companies pay in direct costs and lost business if failures occur in the field. Furthermore, most companies approach HALT and HASS carefully, in stages. The first stage might consist of using HALT on a single new product and conducting the tests in an established commercial test lab. As more products follow and confidence increases, it may become cost-effective to purchase a chamber. After additional time and solid experience with HALT, many companies are making the move to HASS.

When designing with commercial-grade components, there is always a valid concern about potential degradation of product life and performance. With adequate training, the right equipment and a clear commitment from the organization, the powerful tools of HALT and HASS can very effectively reduce those risks.

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