# Highly Accelerated Life Testing and Highly Accelerated Stress Screening – Next Generation Testing towards Design Validation and Reliability Assurance for Electronic systems

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***Abstract:***

*Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS) are the two accelerated test methods used in design and manufacturing phases respectively.*

*HALT/HASS screening is based on screening of the components at elevated levels used to uncover design weakness, latent defects, components selection and manufacturing defects that would not otherwise be found through conventional qualification methods. The process subjects the unit under test to progressively high stress levels, incorporating thermal dwells, rapid temperature transitions, vibrations and a combination of temperature and vibration to precipitate inherent defects. As modern active array radar employs large number of active modules, individual screening of modules by conventional method will be cumbersome and time consuming. Hence HALT/HASS is used as an effective technique to screen the module within short time frame. This paper discuss in detail about the test methodology defined for conducting accelerated test and a case study of evaluation of Quad Transmit Receive Modules (QTRMs) for one of the AESA-FCR Radar for fighter platform (LCA-Tejas) using accelerated test-HALT/HASS.*

***Key Words: HALT, HASS, POS, AESA, QTRMs, MTBF***

## I INTRODUCTION

For decades, product quality has been determined through environmental testing such as vibration tests, thermal cycling, mechanical shock, thermal shock, and more. More recently, there has been a significant trend in the marketplace to improve product quality even further with innovative approach to address Quality & Reliability requirements.

This paper will discuss an innovative approach of product validation by Highly-Accelerated Life Testing (HALT) and Highly-Accelerated Stress Screening (HASS) which are used as a supplement to traditional vibration and thermal testing to meet these new quality targets.

## THE NEED FOR INCREASED PRODUCT QUALITY

One of the most pervasive trends across a wide range of consumer, industrial, and military markets is the need for increased product quality. In consumer markets, a high rate of product failure can result in the manufacturer's loss of credibility with an attendant loss of sales, from which it can take years to recover. In industrial markets, a high failure rate can result in expensive field service calls or potentially worse significant downtime. In military markets, product failures can result in the loss of lives/mission. Although the need for quality is increasing, certain developments are making it more difficult to maintain existing quality levels. The most challenging development has been the increased use of manufacturing sub-contractors. The "manufacturer" whose name goes on a product, is likely to be relying on an outside resource - a sub-contractor -over which the manufacturer does not have direct control. This subcontractor is relying on a number of vendors, further weakening the control that the manufacturer has on product quality. If product fails, the customer will blame the manufacturer. Since the manufacturer's name is on the product, they are the ones responsible for its quality level [3].

## TRADITIONAL VIBRATION AND TEMPERATURE TESTING, AND ITS LIMITATIONS

Traditional vibration and temperature testing has played an important role in the genesis of today's reliable and sophisticated electronic and electro-mechanical products. The core philosophy of this testing method is to define a set of specifications, usually minimum or maximum temperatures and/or vibration levels, and to conduct the tests by changing only one variable at a time. Vibration testing is performed one axis at a time. If the device is still functional after being tested according to the test specs, it is considered to have "passed."

A "passing" result is a positive outcome. However, thinking about this further, it becomes clear that a "pass" result does not help identify the weakest link in the product. In other words, the traditional test cannot help the engineer/scientist make the product any more robust. Furthermore, with the "one-at-a-time" change in environmental variables, and the one-dimension vibration testing, the test specs are not similar to real-world operating environments. As a result, this kind of testing does not provide an accurate indication of how the product might perform in the field. This critical look at traditional environmental testing is not intended to be a blanket condemnation of that process. After all, this kind of testing has played a key role in the evolution of today's highly-reliable products. Instead, this examination of certain weaknesses in classical environmental testing can be helpful in understanding how new testing methods, in particular HALT and HASS testing, can lead to even greater levels of product quality and reliability[2].

## STRENGTHS OF HALT AND HASS TESTING

**Highly-Accelerated Life Testing (HALT)** exposes the product to a step-by-step cycling in environmental variables such as temperature, shock and vibration. HALT involves vibration testing in all three axes using a random mode of frequencies. Finally, HALT testing can include the simultaneous cycling of multiple environmental variables, for example, temperature cycling plus vibration testing. This multi-variable testing approach provides a closer approximation of real-world operating environments.

Unlike conventional testing, the goal of HALT testing is to simulate product failure. When the product fails, the weakest link is identified, so engineers know exactly what needs to be done to improve product quality. After a product has failed, the weak component(s) are upgraded or reinforced. The revised product is then subjected to another round of HALT testing, with the range of temperature, vibration, or shock further increased, so the product fails again. This identifies the next weakest link. Iterations are continued till multiple failures occur simultaneously; the product can be made quite robust. With this informed approach, only the weak spots are identified for improvement. This type of testing provides so much information about the construction and performance of a product, that it can be quite helpful for newer engineers assigned to a product with which they are not completely familiar.

HALT testing must be performed during the design phase of a product to make sure the basic design is reliable. But it is important to note that the units being tested are likely to be Engineering prototypes and also we have to ensure that HALT testing should also be performed on actual production units after completion on proto, to ensure that the transition from engineering design to production design has not resulted in a loss of product quality or robustness. Some engineers may consider this approach as scientifically reasonable, but financially unrealistic. However most common apprehension about HALT is the high cost, but because of this new approach it has been found that the cost of HALT testing is much less than the cost of field failures, service calls or loss of credibility or loss of business due to poor product quality.

**Highly-Accelerated Stress Screening (HASS)** is an abbreviated form of HASS testing. HASS testing is an on-going screening test, performed on regular production units. Here, the idea is not to damage the product, but rather to verify that actual production units continue to operate properly when subjected to the cycling of environmental variables used during the HASS test.

The limits used in HASS testing are based on a skilled interpretation of the HALT testing parameters. The importance of HASS testing can be appreciated when one considers today's typical manufacturing scenario. Circuit boards are purchased from a vendor who uses materials purchased from other vendors. Components and sub-assemblies are obtained from manufacturers all over the world. Often, the final assembly of the product is performed by a subcontractor.

This means that the quality of the final product is a function of the quality (or lack thereof) of all the components, materials, and processes which are a part of that final product. These components, materials, and processes can and do change over time, there by affecting the quality and reliability of the final product. The best way to ensure that production units continue to meet reliability objectives is through HASS testing[1].

# II. Case Study of HALT/HASS testing on QTRMs of AESA-FCR for LCA Tejas Platform

This section brings HALT tests carried out on X Band QTRMs during initial development phase followed by HASS test. The HALT/ HASS tests bring out the design deficiencies leading to its improvement which may be required to be incorporated into the design prior to qualification testing. In HALT, every stimulus of potential value is used under accelerated test condition to find the weak links in the design and fabrication process of a product.

HASS screening of the modules after HALT and Proof of Screening (POS) is conducted from First Article Inspection (FAI) batch. HASS screening uses the highest possible stresses; well beyond the operation level, to attain the time compression in the screening process. HASS applies many stresses simultaneously resulting in exposure of flaw precipitation/Manufacturing defects. A drastic reduction in time of screening equipment and man power will be achieved if correct screening of HASS is carried [1].

## SCOPE

The paper covers HALT/HASS test methods carried out for X Band QTRMs proposed along with its screening procedure in detail, challenges faced and improvement in design by proper FRACAS implementation during failures at the time of HALT/HASS test.

## ITEM DESCRIPTION

The Transmit/Receive Modules (T/R Modules) are the basic building blocks for active phased arrays. In Transmit (TX) mode the T/R Modules receive the RF signal, amplify it and transmit the amplified signal to antenna elements. In receive (Rx) mode each T/R Module receives a signal from antenna element and provides low noise amplification of the signal. Four numbers of T/R Modules is housed in a single package called as the Quad-TRM or QTRM. The QTRM may be called QTRM-X (in X -Band) and integrated with 1:4 ways RF power combiners. Figure 1.0 shows functional block diagram of the QTRM

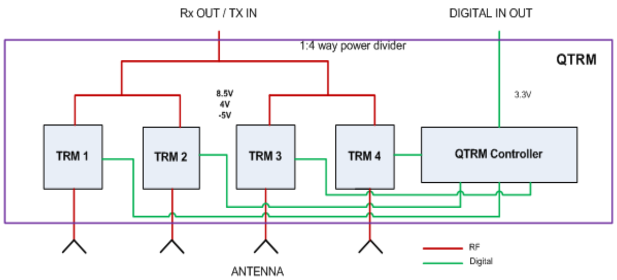


**Figure 1 : QTRM-X Functional Blocks.**

## PURPOSE

The purpose of the HALT testing is to expose design deficiencies in the design prior to qualification testing. The purpose of the design verification testing is to make sure that the design meets the requirements of technical specifications.

## HALT Test Objective

- ❖To determine upper and lower operating, Screening and destructive limits of the product
- ❖To find and fix weak component and product design, mounting practices and manufacturing process problems that can restrict the production ESS environment[5]

## HALT Test Facility

The facility required for HALT/HASS Testing and analysis shall consist of the following:

a. HALT/HASS Chamber shown in figure 2.0 below
b. Temperature Range: -100°C to 200ºC
c. 6 Axis vibration specification range from 0 to $50g_{rms}$
d. Type- T Thermocouples
e. Product Clamping test fixtures
f. 10mV/G miniature single axis accelerometers

**Figure 2: HALT/HASS Test Facility**

## HALT Test Procedure - Cold Step Process

Step-1: Adjust the test chamber conditioned air ducting to allow rapid stability of product temperature.

Step-2: Place QTRMs inside HALT chamber, paste a thermocouple on the enclosure and record the temperature data. Cover the sensor with high temperature tape to isolate them from direct conditioned airflow

Step-3: Carry out Performance check after each stepped stress process for X QTRM for the duration of the test defined. The product has to monitor closely for failure modes like mechanical joint loosening, deviation in performance etc.,

Step-4: Decrease the temperature from ambient to 0°C at a ramp rate of 40ºC /min or high and dwell it for 20 Minutes carry out PC and check whether any Failures/deviation at this condition.

Step-5: If no failures occur, continue to decrease the temperature level according to predetermined levels as per HALT procedure with 20 minutes dwells as define in step 4 at each step stress test, until a lower design limits is obtained and carry out PC at each temperature stress levels.

Step-6: When the Lower Destructive Limit (LDL) is determined proceed to high temperature step test.

Step-7: Whenever an anomaly or failure is detected, perform the corrective action (FRACAS) and continue the test until design limits are reached.

## HALT Test Procedure - Hot Temperature Step Process

Step-1: Upon completion of the low temperature steps, raise the test chamber temperature to 30°C at a ramp rate of 40°C/min or higher. When the product's internal temperatures reach the target temperature, dwell for 20 minutes and carry PC.

Step- 2: If no failures occur, continue to increase the temperature level according to the pre-determined levels as per HALT test procedure with 20 minute dwells as defined in step 1 at each step, until a upper design limits are achieved with a PC at each temperature stress during the last five minute of dwell period.

Step-3: When the Upper Storage Limit (USL), Upper Operating Limit (UOL) and Upper Design Limit are found proceed the testing for HALT Vibration stress test.

Step 4: Whenever an anomaly or failure is detected, perform the FRACAS and continue the test.

## HALT Test Procedure - Vibration Step Process

Step-1: Fabricate a vibration text fixture to hold the product securely on the vibration table.

Step 2: Mount the system feedback accelerometers on the Table surface or on the fixture at locations that afford protection from damage during product handling.

Step 3: Attach an auxiliary accelerometer to the product to measure its vibration responses.

Step 4: Carryout the visual inspection and PC for the duration of the test. The product should be monitored closely during testing for failure modes not normally detected by its self-diagnostics, e.g., mechanical parts loosening, electronic parts breakage, degradation in PC, etc.

Step-5: Begin vibration at 10 Grms performed over a frequency bandwidth from 10Hz to 10 KHz on the product at a ramp rate of 10Grms/min or high and dwell it for 10 minutes at each step stress with a PC.

Step- 6: Step the stress (increase the Grms level on the product) as per vibration test profile of HALT test procedure and dwell for 10 minutes at each Grms level with a PC.

Step 7: Perform a continuous visual inspection and PC test to verify any failures during the test at each level of vibration step stress.

Step 8: When the UOL is determined or if no failures have occurred up to the maximum vibration capability of the system, proceed to the simultaneous Temperature and Vibration Test.

Step 9: Whenever an anomaly or failure is detected, perform the FRACAS and continue the test.

**HALT Test Procedure - Combined Temperature and Vibration Test**

On completion of Temperature: Cold, Hot and Vibration tests, proceed to the following Combined Temperature and Vibration test on X-QTRM

Step-1: Place the product response thermocouple inside the product or any other location specified to determine the temperature response time. In addition, place other thermocouples, if available, in places inside the product that will provide meaningful temperature response data. Cover all thermocouples with high temperature tape to isolate them from direct conditioned airflow.

Step 2: Attach the auxiliary accelerometer(s) on the product to measure the vibration response of the product.

Step 3: Set the test chamber temperature set point to the temperature LOL at a ramp rate of 40°C/min or high. When the product's internal temperatures reach dwell for 15 minutes with PC, similarly repeat the same procedure for upper operating temperature limits.

**Proof of Screening (POS)**

This process demonstrate that the chosen HASS screen profile does not take out much life out of the equipment and sufficient life is left in them to survive the normal lifetime of field use. Also it shows that the chosen HASS screen is effective in finding out the latent defects in the product.

After completion of the HALT tests as per approved test plan, the POS shall be carried out on new set of QTRMs as defined in the following steps: -

Step 1: Perform a POS on new set of QTRMs with combined temperature and Vibration limits as per the HASS screening profile and record the results, results of Proof of Screening test. Verify that there is no hard failure during the test.

Step 2: No of Cycles for POS should be minimum 10-15 defect free HASS cycles, after POS the unit will be yellow banded and all production deliverable modules will undergo HASS on fresh units

**Challenges faced during HALT Test:**

**Observations in detail noticed**:

After completion of vibration step stress test, failure was noticed during visual check on QTRM enclosure, it was noticed that top lid cover of QTRM housing opens along with the mounting bracket of the fixture after the HALT Vibration.

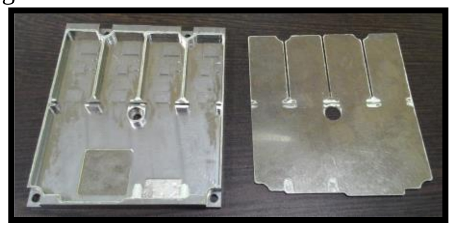

**Figure 3: Mechanical Housing of QTRM Top cover lid opens after HALT Vibration step stress Test**

**List of observation noticed**

- The QTRM enclosure from BEL for doing passive HALT is recoated and increased coating thickness up to 22 micron electro less Nickel coated on 10 microns coated surface
- Cross brackets on the lid cover not provided
- Detail bonding and curing process was not followed

**Recommendations**:

A) **Corrective actions**:

- Do the complete inspection of the mechanical enclosure before HALT test, like leak test, Non Destructive Test (NDT) and pull test on mechanical enclosure to heck the bond strength
- Correct mixing ratio of hardener and strainer of adhesive bonding material to be followed by fully atomizing the process and soak it properly based on the recommendation from data sheet

B) **Preventive actions**:

- Measurement of Electro less Nickel conformal coating thickness of the enclosure used.
- Provide Cross brackets to have more surface bonding area, this helps in increase of bonding / joint strength
- Used recommended coating thickness on the QTRM enclosure
- Follow the correct bonding process
- Use proper fixture to conduct HALT test simulating actual mounting configuration

## III. Inference and Conclusion

HALT was successfully conducted for the first time in LRDE-DRDO with the approval from CEMILAC for the test procedure and results obtained during the test. This new approach of screening has replaced conventional qualification with next generation test - HALT/HASS.

HALT was conducted during design stage to identify product operating, screening and destructive limits. The test provides a stringent environment to force design and process maturity by stressing the product at much faster rate By [6]:

- Quickly discover design & process flaws.

- Evaluate & improve design margins.
- Reduce development time & cost.
- Eliminate design & process problems before release to manufacturing.
- Demonstrate product reliability [5]

HASS is a process used for screening the modules during manufacturing/production phase. HASS allow discovery of process changes and prevent products with latent defects from getting into the field By:

- Quickly detect shifts in manufacturing processes.
- Reduce production time and cost.
- Increase out-of-box quality & in-service reliability.
- Reduce infant mortality rate at product introduction.

Therefore HALT/HASS test is used to widen the product operating, screening and destructive limits by addressing the failures during each step stress test during initial design phase itself, thus making the product rugged and highly reliable [6].

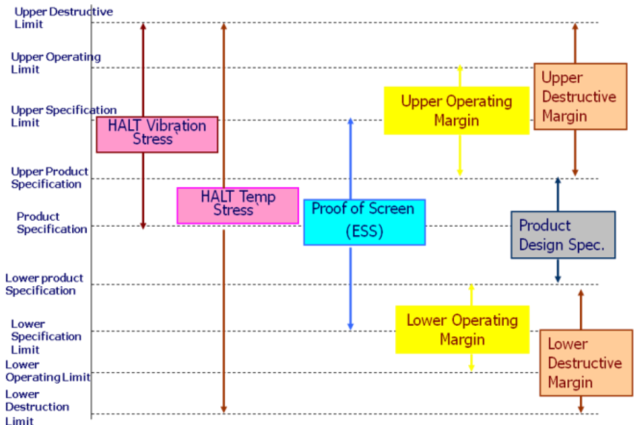


**Figure 4: HALT Identifies Product Operating, Screening and Destructive limits**

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