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Dynamic environmental testing for space hardware

Solution brief

Siemens Digital Industries Software

Dynamic environmental testing is required for qualifying or accepting all space hardware, from the component to full-spacecraft level of assembly. The purpose of the environmental test, however, is highly dependent on the mission concepts and objectives. For standard commercial missions, the purpose is to ensure the spacecraft will properly perform its intended mission without degrading the performance of sensitive instruments. Nevertheless, for manned spacecraft or vehicles, priority could be shifted to preserving life. The type and level of required dynamic excitation to which the hardware will be subjected in service and during the tests depends on a number of factors, such as spacecraft structure and configuration. In any case, the equipment should be capable of withstanding the maximum expected launch vehicle ground and flight environments, and this is verified by running physical tests.

Simcenter™ Testlab™ software solutions provide a full suite for dynamic environmental testing of space hardware, consolidating years of expertise and end-user feedback from leading companies in the space industry.

Vibration testing

The various types of dynamic tests (acoustic, vibration, shock) have different purposes, equipment sensitivities, effective frequency ranges and risks of hardware over testing. The primary goal of vibration testing is to expose the space hardware to the low-frequency dynamic-launch environment at different levels of assembly and verify that it performs as expected after being exposed to this dynamic input.

Simcenter Testlab Sine Control is a closed-loop control solution for swept sine vibration tests. A critical concern with performing swept sine vibration tests is being able to protect the hardware from unrealistic failures, which can be a consequence of unrealistic boundary conditions that are inherent to industrial test rigs. By using a

Challenges

- Ensure space hardware integrity during qualification test
- Reduce downtime in case of malfunction
- Ensure testing productivity and processing consistency
- Control test hardware and software investment cost

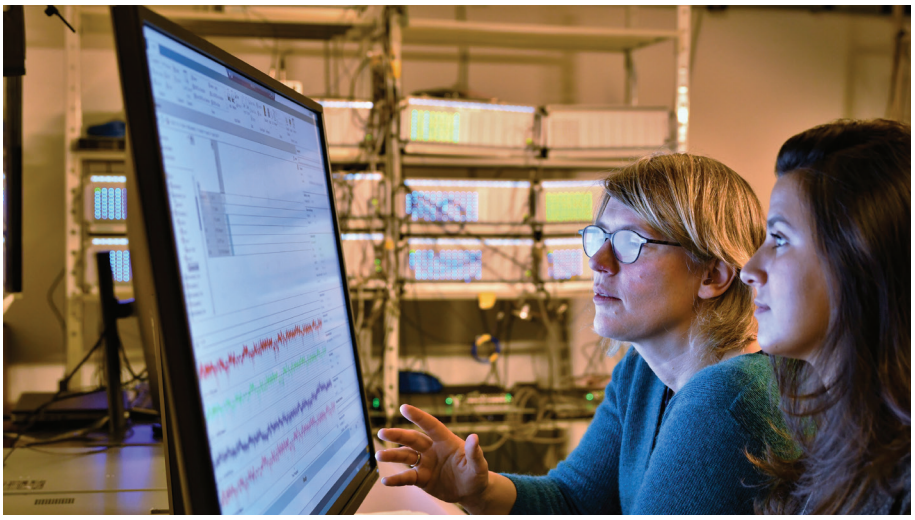
Solutions

- Single platform covering all mechanical test needs
- Embedded self-check procedure and safety diagnostics
- Reliable and scalable acquisition system
- Clear online test progress reporting

Results

- Safely conduct mission-critical qualification tests
- Efficiently interpret large data sets
- Maximize ROI
- Rapidly deliver the right answers to engineering teams

Solution focus



combination of force limiting and response limiting, the vibration test can be conducted in a safe manner. Together with Simcenter SCADAS hardware, Simcenter Testlab Sine Control provides integrated capabilities for force and moment limiting, which comprises signal conditioning and acquisition, geometrically aided channel setup, derivation of virtual channels for computation of forces and moments, limiting/notching prediction and real-time control. Simcenter Testlab Sine Control allows you to perform safe vibration tests, enabling you to realistically notch spacecraft resonances and limit (acceleration) responses in order to protect the spacecraft structure and hardware from exceeding design-strength capabilities.

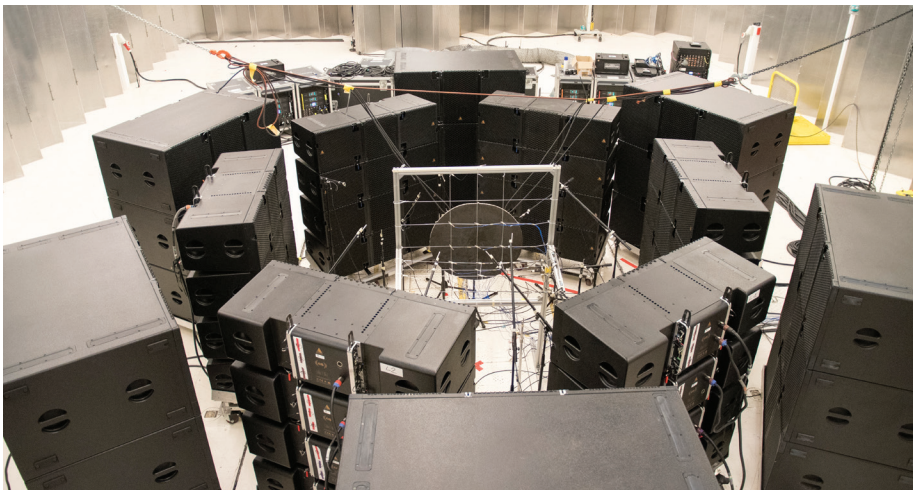
Simcenter Testlab Random Control provides all necessary features to define and control a random vibration excitation that matches a predefined power spectral density profile. Although random testing is commonly performed for subsystem and component levels of assembly, some space end users also prefer random vibration input for system-level qualification tests. Using a highly reliable and safe test enables you to cover mechanically transmitted energy due to vibro-acoustic excitation in the mid-frequency range. Among several safety features, Simcenter Testlab Random Control offers response limiting (spectral and root mean square) and sigma limiting. The reliability of sigma limiting is critical to estimate peak responses in random control tests. Therefore, the implementation of a phase optimization algorithm with no amplitude distortion and out-of-band noise, which is available in Simcenter Testlab Random Control, provides added value compared with traditional sigma clipping algorithms.

Simcenter Testlab Shock Control is a time-domain control package to operate shakers and replicate shocks with short excitation pulses. Spacecraft can be exposed to various types of shock during its development and mission. Shock qualification consists of assessing the capability of the system, subsystems or components to withstand and eventually operate in an induced shock environment. Simcenter Testlab Shock Control can use a previously measured pulse as a reference waveform for control, a classical waveform such as a half sine pulse, or the result of a synthesis exercise. This software solution offers a unique shock response spectrum (SRS) limiting algorithm for optimal test-specimen protection, and online SRS calculation with a wide range of post-test data analysis capabilities. It also enables point-by-point abort checking with user-defined tolerances. For complete safety during the closed-loop control shock test, the end user can define a maximum update ratio for the amplitude of the signal driving the shaker. Moreover, the voltage waveform of the updated signal can be displayed before each pulse is streamed to the shaker.

Closed-loop solutions have set trends for industry safety features since the first systems were installed over 20 years ago when a smooth ramp down of the voltage was used to reduce jolts in the amp-shaker system. Parameters have been added to the software to create a highly flexible and safe vibration control system.

Pyroshock

Simcenter Testlab Transient Capture is a dedicated solution for the acquisition of transients, resulting from pyroshock explosions, drop tests or shaker-controlled tests. A pyroshock is a violent event characterized by its short duration (a few milliseconds) and a high magnitude with extreme acceleration levels. In the space industry, pyrotechnic devices such as explosive bolts are routinely used; for instance, in the release mechanisms employed for stage separation or payload release. The resulting pyroshock event may cause damage to the payload's electronics and compromise the functionality of mechanical parts, such as bearings, gears and worm wheels. Simcenter Testlab Transient Capture covers data acquisition needs for self-induced and externally induced shock tests, enabling triggered and continuous acquisition modes and an integrated digital scope function for full pretest instrumentation checkout. Because of the criticality of this type of test, its short duration (milliseconds) and high-frequency content, at least to 10 kilohertz (kHz), the acquisition system must be reliable enough to not miss the event. It must sample high enough frequencies (200kHz is best practice) and it must process data quickly to provide engineers all relevant information. Shock response spectrum must be available in



all instances to enable engineers to perform the relevant engineering analysis. This type of data measurement and analysis can be done with the Simcenter Testlab data analysis software and the Simcenter SCADAS acquisition system.

Acoustic testing

At the system level of assembly, most spacecraft are required to be acoustically tested. However, acoustic test at lower levels is typically reserved for large, low-surface-density components and subsystems, such as solar arrays, antennas and reflectors. Acoustic loads can cause paint flaking, debonding and cracking of built-up structures, and electronic failures in equipment mounted on honeycomb panels. State-of-the art testing methods to replicate such loads make use of reverberant acoustic fields.

Simcenter Testlab Acoustic Control is a closed-loop control solution for the operation of reverberant rooms. It implements a robust proportional-integral control algorithm based on parameters that can be measured with standard microphones during setup (and are adapted to the room acoustic properties). The automatic control ensures spatial uniformity of sound pressure level in one-third or full octave bands within tight tolerances and an extra check on overall sound pressure level responses. Simcenter Testlab Acoustic Control integrates three layers of safety checks to avoid over testing: at individual microphones, overall sound pressure levels and structural responses of the test specimen since the user can define power spectral density abort profiles for the vibration acquisition channels. This solution has been designed to provide lab engineers and technicians with a comfortable system to carry out the delicate job of qualifying the satellite for acoustic loading. Dedicated features, such as the definition of the reference profile in an Excel spreadsheet editable table format, a checkbox to select which microphone should be included in the loop for measurement or setting any abort parameters on both acoustic or vibration channels, enable smoother workflows for the users. The control system can work using multiple signals to feed the different types of power amplifiers of the acoustic sources. Simply setting the bandwidth of each signal and the desired crest factor value ensures safe development of the environmental test. In a standard application of Simcenter Testlab Acoustic Control, the user leaves the task of defining and updating the amplitude of the drive signal to the closed-loop controller. This is the Simcenter Testlab Automatic Control mode. However, several reasons may motivate the test engineer to take manual control before stepping into the next level of a test schedule. For example, the test engineer could be interested in manually slowly raising the level. In addition, he/she may want to reduce the excitation at a certain band; for instance, if unexpected structural responses are being monitored. Such manual control can be done with the mouse directly on the sliders, or with the keyboard arrow keys to have even finer control of the voltage level sent to the power amplifiers of the acoustic sources.

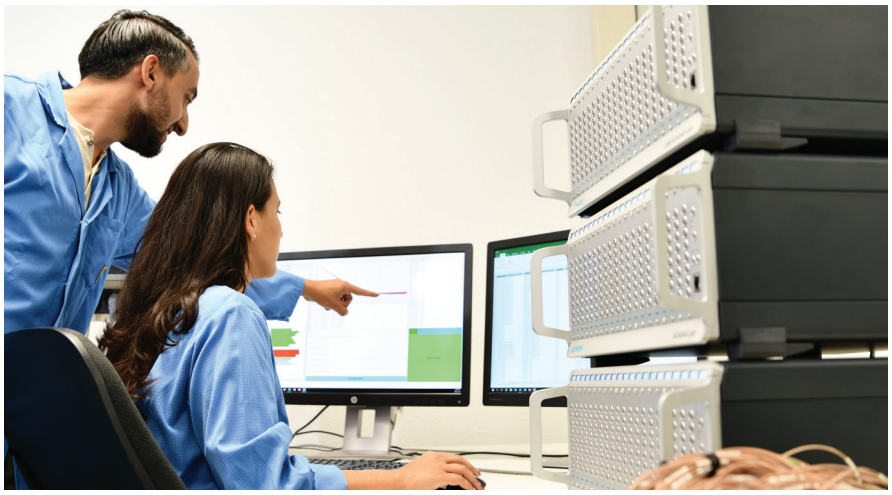
Simcenter Testlab Multiple-Input Multiple-Output (MIMO) Random Control for direct field acoustic tests is a narrow-band closed-loop control solution to replicate the acoustic loads with loudspeakers in (acoustically) ordinary rooms – a technique called direct field acoustic noise (DFAN). Since this technology does not require a dedicated facility, tests can be conducted at the

spacecraft or component designer's integration facility. This reduces the handling risk during transportation, as well as a potential risk to overrun the program cost and schedule. A dedicated graphic user interface (GUI) enables a smooth definition of the acoustical test specifications and tolerances in one-third or full octave bands. Furthermore, innovative pretest analysis assists the user in defining the optimal narrow-band control parameters so optimal on-line MIMO control ensures a safe, time- and energy-efficient workflow for the environmental acoustic test. The narrow-band operation enables line-by-line abort checking for each control or measurement channel. Background noise measurements serve as a basis for an open-loop threshold check. Responses and notching predictions for control and measurement acoustic and vibration channels are also supported, as well as overload predictions for the multiple signals driving the loudspeakers and singular values analysis for system conditioning checks.

General features and integration with Simcenter data acquisition product family

All Simcenter Testlab solutions for dynamic environmental testing fully support NASA, European Space Administration (ESA) and international spacecraft testing standards and are American National Standards Institute (ANSI) compliant for the octave-filtering acquisition process. General safety features allow user-defined smooth shutdown time using a double exponential curve (0.01 to 20 seconds) for every environmental test conducted with Simcenter Testlab. Moreover, it is possible to define actuators' profiles with maximum physical capabilities to protect the user's facility. This provides a lot of flexibility for Simcenter Testlab solutions, ensuring smooth adaptability to any kind and brand of actuator.

For traceability and reporting purposes, Simcenter Testlab offers throughput recording for all controlled/measured channels and extensive data documentation capabilities. The intuitive data management utility allows you to



retrieve, view, plot and delete data using a Windows like browse tree with folders and search view. Post-test results are stored in a log file and archived settings file to keep track of test events and schedules, generate reports and recall previous test configurations.

Simcenter Testlab solutions for dynamic environmental testing easily and seamlessly integrate with Simcenter SCADAS hardware. The scope of a mechanical qualification test is to acquire and analyze the vibration response on the test item. In other words, the signals from hundreds of sensors (accelerometers, strain gauges, force sensors, etc.) attached to the satellite need to be measured, recorded, processed and stored. Having equipped some of the biggest vibration test facilities on five continents, Siemens Digital Industries Software has collected a wealth of experience in hardware and software configuration to provide the most flexible and robust lab layout management. The acquisition cards to measure charge, Integrated Electronics Piezo-Electric (IEPE), strain and pressure sensors can be optimally distributed over several acquisition units. These can work as a standalone or clustered to provide a measurement system of several hundred channels with an architecture that provides safe risk mitigation against any possible data loss. Simcenter software is available to manage multiple acquisition stations centrally so the systems can be started/stopped simultaneously, and all the data collected in a central repository. At the same time, the software gives lab engineers and customers a live view on critical data processed in frequency (narrow band and/or octave) for immediate engineering feedback on vibration and acoustic response. The combination of the Simcenter SCADAS hardware and Simcenter Testlab software has been used to acquire data on hundreds of satellites over the past decades. This impressive track record gives the lab engineers and managers the necessary confidence and peace of mind to use Simcenter solutions for their most critical tests on multimillion-dollar objects.

With the addition of solutions for reverberant chamber control and direct field acoustic testing to the vibe, pyro to the vibe, pyro and data acquisition systems, Siemens Digital Industries Software's Simcenter Testlab has closed the loop on providing all the necessary tools to complete a full mechanical qualification or acceptance test campaign for all space hardware.

Siemens Digital Industries Software
siemens.com/software

Americas +1 314 264 8499
Europe +44 (0) 1276 413200
Asia-Pacific +852 2230 3333

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