VTSS—Vibration Testing of Small Satellites

with optional Notching and Force Limiting Workshop (NFLW)

Course Overview: This course provides a tutorial, practical guidance, examples, and recommendations for engineering a test of a small satellite on an electrodynamic shaker. Addressed are sine burst testing, random vibration testing, and low-level diagnostic sine sweeps. Notching, response limiting, and force limiting are addressed in detail, with examples. The course is primarily aimed at satellites in the 50 – 500 lb (23 – 230 kg) range, but it also applies to CubeSats. Most of the guidance applies to larger satellites as well if they will be tested on a shaker and to spacecraft components.

The objectives of this course are to improve your understanding of how to …

- establish an effective vibration test program
- identify and clearly state test objectives
- design (or recognize) a test that satisfies the objectives while minimizing risk of an over test
- establish pass/fail criteria and interpret test data
- write effective test plans and test reports
- and, last but not least, design your SmallSat to withstand the vibration test!

Target Audience: All engineers and managers involved in ensuring small spacecraft can withstand launch environments

Course Length: Two full days for basic VTSS course; three days when combined with NFLW

Course Developer and Teacher:

Tom Sarafin is President of Instar Engineering and Consulting, Inc. He has worked in the space industry since 1979 as a structural engineer, a mechanical systems engineer, a project manager, and a consultant. Since founding Instar in 1993, he's consulted for NASA, DARPA, the DOD Space Test Program, Lockheed Martin, DigitalGlobe (Maxar), Sierra Nevada Corp (Sierra Space), and many other organizations. He was a key member of the team that developed NASA-STD-5020, "Requirements for Threaded Fastening Systems in Spaceflight Hardware" (March 2012). He is the editor and principal author of *Spacecraft Structures and Mechanisms: From Concept to Launch* and is a contributing author to *Space Mission Analysis and Design*. Since 1995, he has taught well over 300 courses to more than 6000 engineers and managers in the aerospace industry. He teaches the following courses: Space Mission Structures, from Concept to Launch (SMS), Design and Analysis of Bolted Joints (DABJ), Structural Design and Analysis for Aerospace Engineers (SDA), Structural Test Design and Interpretation (STDI), Vibration Testing of Small Satellites (VTSS), Notching and Force Limiting Workshop (NFLW), and Ten Principles for Successful Space Programs (TenP).

Testimonials:

"Anyone involved with the mechanical structure of a spacecraft or test engineering of ensuring a spacecraft survives launch should take this course – very well taught!"

"The course was very interactive and tailored to the class' needs. I enjoyed this class very much."

"This course is incredibly useful to understand the types of vibration tests used for spacecraft design and the proper use of these tests. This course should prepare you to design tests for successful missions, not just to follow requirements."

"Whether you're a novice engineer with little to no experience in vibration testing of a more experienced engineer with vibration testing history, you'll walk away from this class feeling you've learned a lot."

"A must have for anyone involved in vibration testing. You have a great ability to take complicated concepts and make them completely understandable."

VTSS—Vibration Testing of Small Satellites

Course Outline

Introduction

1. **Overview of Vibration Testing**
   - Electrodynamic shakers
   - Vibration test objectives
   - Review of mechanics; transmissibility
   - Common types of vibration tests
   - Limitations of testing on a shaker
   - Pass/fail and success criteria
   - Dry running the test
   - Taking responsibility for verification
2. **Configuration, Fixtures, and Instrumentation**
   - Test article configuration
   - Design of test fixtures and mass simulators
   - Providing a flight-like interface
   - Instrumentation and use of accelerometers
   - Strategies for determining base force and moment
3. **Low-level Sine-Sweep Testing**
   - Objectives and test parameters
   - Examples of response data
   - Deriving damping from test data
   - Criteria for pre- and post-test comparisons
   - Common reasons for differences between pre- and post-test data
   - Limitations of detecting yielding with sine sweep tests
4. **Sine Burst Testing**
   - Introduction and objectives
   - Applicable standards
   - Limitations of sine burst test effectiveness
   - Recommended success criteria
   - Designing a sine burst test
   - Establishing the test axes and deriving the target accelerations
   - Selecting the sine burst frequency
   - Accounting for dynamic amplification
   - Potential problems and recommendations
5. **Random Vibration Testing**
   - Introduction and objectives
   - Acceleration (or power) spectral density: understanding g^2/Hz
   - Root-mean-square acceleration
   - Peak load for random vibration
   - Decibels
   - How test environments are derived
   - Government standards
   - Use and limitations of GEVS environments
   - Standard test-control tolerances
   - Data resolution
   - Interpreting test data
6. **Notching and Force Limiting**
   - Introduction to notching and its justification
   - The dynamic absorber effect
   - Three methods of notching related to base force
   - STEP-4 case history: how notching without technical rationale led to mission failure
   - Using force gages to measure base force & moment
   - Force limiting with the Semi-Empirical Method, examples, modification during test
   - Response limiting to simulate force limiting
   - Manual notching to simulate force limiting
   - Other technical rationale for notching
   - Appendix: Example presented at 2023 SCLV
7. **Designing a SmallSat to Pass the Vibration Test**
   - General strategies
   - Making load paths direct
   - Separating modal frequencies
   - Panels used to mount components and mounting strategies
   - Understanding how the primary structure carries loads
   - Bolted joints
   - Avoiding component failure
   - Using appropriate design loads
8. **Case Study: FalconSat-2**
   - Introduction
   - Key structural requirements
   - Approach to structural design and verification
   - Simplifying the design loads
   - Testing the engineering model (EM)
   - Deriving design loads from EM test results
   - Designing the flight structure
   - Qualification and acceptance testing
   - Launch … and FalconSat-2 today
   - Conclusions

Appendix: Test Documentation and Reviews

Summary

Combine this course with the 1-day computer workshop, Notching and Force Limiting Workshop (NFLW), using tools and examples that we provide!

Download a PDF file containing all the course materials at no charge, along with PDF files for Tom's other courses, at https://instarengineering.com/resources.html.