Instar Engineering and Consulting, Inc.

USV—Understanding Structural Verification
for Space-mission Hardware

Course Overview: This three-day course, aimed primarily at systems engineers and managers, provides a rigorous yet understandable look at what it takes to ensure space hardware is structurally ready for flight and able to meet mission objectives. Emphasis is on concepts, processes, and what to look for rather than on equations. The objectives are to improve your understanding of

- structural requirements and flight environments
- how structures and materials behave and how they fail
- how to establish (or recognize) sound plans, criteria, and processes for ensuring payloads can safely withstand launch and other flight environments
- and how to assess risk when problems arise

Target Audience: Nonstructural engineers, systems engineers, and managers involved in ensuring that launch vehicles and their payloads are structurally ready to fly. Note: This course is a condensed combination of two other Instar courses: SMS (Space-Mission Structures: From Concept to Launch) and STDI (Structural Test Design and Interpretation). We recommend that structurally inclined engineers having in-depth roles in structural design, dynamics, stress analysis, or testing take the SMS and STDI courses instead of USV.

Course Materials: Course book and a copy of the instructors' book, *Spacecraft Structures and Mechanisms: From Concept to Launch*

Instructors:

Tom Sarafin is president and chief engineer for Instar Engineering. He has worked full time in the space industry since 1979. He worked over 13 years at Martin Marietta Astronautics, where he contributed to and led activities in structural analysis, design, and test, mostly for large spacecraft. Since founding Instar in 1993, he's consulted for NASA, DigitalGlobe, Lockheed Martin, AeroAstro, and other organizations. He's helped the U. S. Air Force Academy design, develop, and verify a series of small satellites and has been an advisor to DARPA. 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's taught over 150 courses to more than 3000 engineers and managers in the space industry.

Poti Doukas is vice president and a senior consultant at Instar Engineering. He worked at Lockheed Martin Space Systems Company (formerly Martin Marietta Astronautics) from 1978 to 2006. He served as Engineering Manager for the Phoenix Mars Lander program, Mechanical Engineering Lead for the Genesis mission, Structures and Mechanisms Subsystem Lead for the Stardust program, and Structural Analysis Lead for the Mars Global Surveyor. Since joining Instar Engineering in 2006, he has consulted for Lockheed Martin, the U. S. Air Force Academy, AeroAstro, Design Net Engineering, and NASA. He's a contributing author to *Space Mission Analysis and Design* and to *Spacecraft Structures and Mechanisms: From Concept to Launch*.

Course Length: Three full days or five 5-hour days

Comments from past participants:

"Excellent examples were provided throughout the course on best practices."

"I liked how the course put structural verification in context in each phase of (spacecraft development)."

"I think this content should be mandatory for spacecraft development team members regardless of discipline."

"The final example on risk analysis was excellent, especially for managers!"

"Excellent course. Perfect in breadth and depth. Well presented, well organized."

"Instructor was excellent—great examples!" "Super job!"

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Outline

Introduction

1. **Overview of Structural Requirements and Verification**
   Structural functions and requirements, effects of the space environment, categories of structures, how launch affects things structurally, understanding verification, available standards
2. **Review of Statics and Dynamics**
   Load and displacement, static equilibrium, the equation of motion, modes of vibration
3. **Flight Environments and How Structures Respond**
   Quasi-static loads, transient loads, coupled loads analysis, sinusoidal and random vibration, acoustics, pyrotechnic shock
4. **Mechanics of Materials**
   Stress and strain, understanding material variation, benefits of ductility, thermoelastic effects, mechanics of composite materials, corrosion, standardization
5. **Introduction to Finite Element Analysis**
   Understanding FEA and stiffness matrices, limitations of FEA, quality assurance for FEA
6. **Verification Planning**
   The building-blocks approach to verification, verification methods and logic, protoflight vs. qualification testing, product inspection, types of tests, verification processes for small flight structures and for large flight structures
7. **Stress Analysis**
   What it means to assess structural integrity, the process for verifying structural integrity, the margin of safety, verifying structural integrity is never based on analysis alone, an effective process for strength analysis, common modes of failure, case histories, fatigue analysis, fracture control
8. **Improving the Loads-cycle Process**
   The traditional loads-cycle process and coupled loads analysis (CLA); improving the process by (a) managing math models, (b) integrating stress analysis with loads analysis, (c) variational CLA to assess sensitivity; potentially eliminating the need for payload-specific CLA for small payloads
9. **Designing an Effective Test**
   Designing a test, configuration and boundary conditions, a key difference between qualification tests and acceptance or proof tests, success criteria and effective instrumentation, preparing to interpret test data
10. **Static Loads Testing**
    Objectives, configuration, load application, designing a static loads test, centrifuge testing
11. **Testing on an Electrodynamic Shaker**
    Test configuration, sine-sweep testing, sine-burst testing, random vibration testing, avoiding over-test with notching and force limiting
12. **Modal Survey Testing and Model Correlation**
    Objectives and target modes, key considerations, checking the test data, correlating the math model
13. **Final Verification and Risk Assessment**
    Overview of final verification, addressing late problems, using estimated reliability to assess risk, example: negative margin of safety, making the launch decision

Summary