

SMS—Space Mission Structures

From Concept to Launch

Course Overview: This course presents the structure for a space or launch vehicle as a system. Originally based on the instructors' book, *Spacecraft Structures and Mechanisms: From Concept to Launch*, this course has evolved and been improved continuously since 1995.

If you are an engineer involved in any aspect of spacecraft or launch-vehicle structures, regardless of your level of experience, you will benefit from this course. Subjects include functions, requirements, environments, mechanics, loads analysis, stress analysis, fracture mechanics, finite-element modeling, configuration, producibility, verification planning, quality assurance, testing, and risk assessment. The objectives are to give the big picture of space-mission structures and improve your understanding of

- structural functions, requirements, and environments
- how structures behave and how they fail
- how to develop structures that are cost-effective and dependable for space missions

Despite its breadth, the course goes into great depth in key areas, with emphasis on the things that are commonly misunderstood and the types of things that go wrong in the development of flight hardware. The instructor shares numerous case histories and experiences to drive the main points home. Calculators are required to work class problems.

Target Audience: Structural design engineers, stress and dynamics analysts, systems engineers, and others interested in the topic

Course Materials: Course book and a copy of the instructors' 850-page 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: Four or five full days (5-day version includes extra topics and allows more time for class problems and discussion)

Comments from past participants:

- “Many really good examples.” “Excellent presentation—a reminder of how much fun engineering can be.”
“An excellent course. It gave me a lot to think about.” “Good stuff, and a very clear presentation.”
“Very valuable. Relates classroom knowledge to actual experiences in the space industry.”
“Great course!”—Retired Chief Engineer who previously helped develop the Saturn family of launch vehicles

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Course Outline

Introduction

1. Introduction to Space Mission Structures

- Structural functions and requirements
- Effects of the space environment
- How launch affects things structurally
- Dispelling some myths
- Typical structural design criteria
- Understanding verification
- Relating verification to requirements

2. Review of Statics and Dynamics

- Static equilibrium
- Dynamic equilibrium
- The equation of motion
- Transmissibility
- Modes of vibration

3. Launch Environments and How Structures Respond

- Breaking down the launch environment
- Quasi-static loads
- Transient loads and coupled loads analysis
- Acoustics and random vibration
- Pyrotechnic shock

4. Mechanics of Materials

- Stress and strain
- Accounting for material variation
- Interaction of stresses and failure theories
- Bending and torsion
- Thermal effects
- Introduction to composite materials
- Recognizing and avoiding weak spots in structures
- Standardizing materials

5. Assessing Structural Integrity: Strength Analysis

- What it means to assess structural integrity
- Standard test options and factors of safety
- Dependence on test
- An effective process for strength analysis
- Common pitfalls and case histories
- Failure modes for bolted joints
- Buckling
- Structural design criteria

6. Structural Life Analysis

- Fatigue
- Fracture mechanics
- Fracture control

7. Overview of Finite Element Analysis

- Idealizing structures
- Introduction to FEA
- Effective use of FEA
- Quality assurance for FEA

8. Preliminary Design

- A process for preliminary design

- Configuring a spacecraft
- Types of structures and forms of construction
- Materials and methods of attachment
- Using analysis to design efficient structures
- Estimating weight and managing weight growth

9. Avoiding Problems with Loads and Vibration*

- Introduction to passive loads control
- Controlling the forcing function
- Deciding where to place components
- Adding passive damping and vibration isolation

10. Improving the Loads-Cycle Process*

- Overview of loads cycles and ideas for improvement
- Managing the math models
- Integrating stress analysis with loads analysis
- Potentially eliminating the need for mission-specific coupled loads analysis
- Sensitivity analysis for large payloads

11. Designing for Producibility

- Cost contributors
- Minimizing parts
- Designing an adaptable structure
- Designing for the fabrication process
- Dimensioning and tolerancing
- Designing for assembly and vehicle integration

12. Verification and Quality Assurance

- Whose job is this?
- Attending to details
- Controlling the configuration
- Proactive verification
- Verification methods and logic
- Approaches to product inspection
- Designing an effective test
- Documenting and presenting verification

13. A Case Study: The FalconSAT-2 Small Satellite

- Overview of the FalconSAT program
- Approach to structural design and verification
- Testing the engineering model
- Designing the flight structure
- Testing the qual model and the flight model
- Launch of FalconSAT-2

14. Final Verification and Risk Assessment

- Overview of final verification
- Addressing late-arising loads problems
- Using estimated reliability to assess risk (example: negative margin of safety)
- Making the launch decision

Summary

* Included in 5-day version only