



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 instructor's 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 development, environments, structural 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 has worked full time in the space industry since 1979, with 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 Space Imaging, DigitalGlobe, AeroAstro, and other companies. He's helped the United States 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* (all three editions). Since 1995, he's taught well over 100 courses to more than 2500 engineers and managers in the space industry.

Poti Doukas 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. He's a contributing author to *Space Mission Analysis and Design* (1st and 2nd editions) and to *Spacecraft Structures and Mechanisms: From Concept to Launch*. He joined Instar Engineering in July 2006.

Course Format: Four or five full days

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, categories of structures, how launch affects things structurally, understanding verification, distinguishing between requirements and verification

2. Review of Statics and Dynamics

Static equilibrium, the equation of motion, modes of vibration

3. Launch Environments and How Structures Respond

Quasi-static loads, transient loads, coupled loads analysis, sinusoidal vibration, random vibration, acoustics, pyrotechnic shock

4. Mechanics of Materials

Stress and strain, understanding material variation, interaction of stresses and failure theories, bending and torsion, deflections and strain energy, thermoelastic effects, mechanics of composite materials, recognizing and avoiding weak spots in structures

5. Assessing Structural Integrity: Strength Analysis

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 pitfalls, recognizing potential failure modes, bolted joints, buckling

6. Structural Life Analysis

Fatigue, fracture mechanics, fracture control

7. Overview of Finite Element Analysis

Idealizing structures, introduction to FEA, limitations, strategies, quality assurance

8. Preliminary Design

A process for preliminary design, example of configuring a spacecraft, types of structures, materials, methods of attachment, preliminary sizing, using analysis to design efficient structures

9. Avoiding Problems with Loads and Vibration

Introduction to passive loads control, adding passive damping, isolating frequencies, isolating the spacecraft from the launch vehicle

10. Integrating the Loads-Cycle Process

Overview of loads cycles, output transformation matrices, integrating stress analysis with loads analysis

11. Designing for Producibility

Guidelines for producibility, minimizing parts, designing an adaptable structure, designing to simplify fabrication, dimensioning and tolerancing, designing for assembly and vehicle integration

12. Verification and Quality Assurance

The building-blocks approach to verification, verification methods and logic, approaches to product inspection, protoflight vs. qualification testing, types of structural tests and when they apply, designing an effective test

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

Overview, approach to structural design and verification, simplifying the design loads, testing the engineering model, deriving design loads from test results, designing the flight structure, testing the qualification model, testing the flight model, process changes for FalconSAT-3, conclusions

14. Final Verification and Risk Assessment

Overview of final verification, addressing late problems, using estimated reliability to assess risks (example: negative margin of safety), making the launch decision

Summary