

DABJ—Design and Analysis of Bolted Joints

For Aerospace Engineers

Course Overview: Just about everyone involved in developing hardware for space missions (or any other purpose, for that matter) has been affected by problems with mechanical joints. Common problems include structural failure, fatigue, unwanted and unpredicted loss of stiffness, joint slipping or loss of alignment, fastener loosening, material mismatch, incompatibility with the space environment, mis-drilled holes, time-consuming and costly assembly, and inability to disassemble when needed. The objectives of this course are to

- Build an understanding of how bolted joints behave and how they fail
- Impart effective processes, methods, and standards for design and analysis, drawing on a mix of theory, empirical data, and practical experience
- Share guidelines, rules of thumb, and valuable references
- Help you understand the analysis criteria for threaded fastening systems in a new NASA standard, which is presently in draft form

The course includes many examples and class problems. Participants should bring calculators.

Target Audience: Mechanical design engineers, structural analysts, and others interested in or involved with bolted joints

Course Developer and Instructor:

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. Since 2007, he has had a lead role on a team chartered with developing a new NASA-wide standard for use of threaded fasteners. 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 over 150 courses to more than 3000 engineers and managers in the space industry.

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

Comments from past courses:

"It was a fantastic course—one of the most useful short courses I have ever taken."

"Interaction between instructor and experienced designers (in the class) was priceless."

"(The) examples (and) stories from industry were invaluable."

"Everyone at NASA should take this course!"

"Your presentation skills are excellent, with patient attention paid to class questions."

"(This class) should be mandatory for design engineers at (our company)."

"Wonderful course."

"(What I found most useful:) strong emphasis on understanding physical principles vs. blindly applying textbook formulas."

"Great course! Lots of lessons learned. The examples made it that much better."

< What you would tell others: "Take it!" "You need to take it." "Take it. Tell everyone you know to take it." >

"Excellent instructor. Great lessons learned on failure modes shown from testing."

"A must course for structural/mechanical engineers and anyone who has ever questioned the assumptions in bolt analysis"

"The course clearly demonstrates ... the shortcomings of analytical approaches that are often favored over testing."

"Well-researched, well-designed course."

"Kudos to you for spreading knowledge!"

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Course Outline

- 1. Overview of Designing Fastened Joints**
 - Common problems with structural joints
 - A process for designing a structural joint
 - Identifying functional requirements
 - Selecting the method of attachment
 - Designing to minimize joints
 - Key definitions
 - Margin of safety
 - Establishing design standards and criteria
 - The importance of preload
- 2. Introduction to Threaded Fasteners**
 - Brief history of screw threads
 - Terminology and specification
 - Tensile-stress area
 - Are fine threads better than coarse threads?
- 3. Developing a Concept for the Joint**
 - General types of joints and fasteners
 - Configuring the joint
 - Designing a stiff joint
 - Shear clips and tension clips
 - Avoiding problems with fixed fasteners
- 4. Calculating Fastener Loads**
 - How a preloaded joint carries load
 - Temporarily ignoring preload
 - Other common assumptions and their limitations
 - An effective process for calculating bolt loads in a compact joint
 - Examples: tension, shear, moment
 - Estimating fastener loads for skins and panels
- 5. Failure Modes, Assessment Methods, and Design Guidelines**
 - An effective process for strength analysis
 - Bolt tension, shear, and interaction
 - Tension joints
 - Shear joints
 - Identifying potential failure modes
 - Riveted joints
 - Fastening composite materials
- 6. Thread Shear and Pull-out Strength**
 - How threads fail
 - Computing theoretical shear engagement areas
 - Including a knock-down factor
 - Test results
- 7. Selecting Hardware and Detailing the Design**
 - Strength compatibility
 - Common types of threaded inserts
 - Selecting compatible materials
 - Use of washers
 - Ensuring adequate thread engagement without interference
 - Simplifying assembly
 - Establishing bolt preload
 - Locking features
 - Recommendations for controlling preload
- 8. Mechanics of a Preloaded Joint**
 - Mechanics of a preloaded joint under applied tension
 - Estimating bolt stiffness and clamp stiffness
 - Understanding the loading-plane factor
 - Key conclusions regarding load sharing
 - Effects of bolt ductility
 - How temperature change affects preload
- 9. Analysis Criteria in the Draft New NASA Standard for Threaded Fastening Systems**
 - Calculating maximum and minimum preloads
 - Tensile loading: ultimate-strength analysis
 - Gapping analysis
 - Tensile loading: yield-strength analysis
 - Shear loading: joint slip analysis and ultimate-strength analysis
 - Interaction of tension, shear, and bending
 - Bolt fatigue analysis

Summary