AEROSPACE
SHORT COURSES

Aircraft Structures Flight Testing (AERO0700)

Instructor: Bill Norton

Course Description

The course will provide the students with a foundation for understanding structures flight testing to the extent that they can plan and participate in structures flight trials of air vehicles of all kinds. One half will consist of academics, building knowledge of aircraft structures and how they behave. The second half will transition this knowledge into flight test planning and execution techniques used in gathering data to validate predictions and demonstrate flight safety. The instructor brings a wealth of structures flight test experience and has examples illuminating the course topics and providing lessons learned. The course complements those focusing more generally on aircraft structures topics such as materials, stress, loads and dynamics design, analysis and certification. It also fits nicely with other KU Aerospace Short Course flight test courses and reflects a similar approach in providing flight test fundamentals along with details of the core subject.

Who Should Attend?

This course would benefit those planning and conducting aircraft flight testing. Depending on the nature of a test program, structures will almost certainly have some bearing and so the fundamentals must be understood. Managers will understand the importance and safety implications of structures and how to build and execute a suitable flight test program. Designers and analysts will understand such tests that deliver vital data and so work more confidently with testers in formulating an effective and efficient test program. Testers will form a solid foundation for performing efficient and safe tests. Test pilots will better understand their role in collecting essential data in a safe manner. All these participants will appreciate each other's roles better.

Learning Objectives

- Understand the vital importance of structures in aircraft development and service and how this drives structures ground and flight testing.
- Develop a sound foundation of vocabulary and concepts essential for the study of aircraft structures, structural statics, and structural dynamics.
- Understand the basics of flight mechanics, the fundamentals of aerodynamic forces, and the flight environment.
- Identify the basics of structures flight testing to include test team organization, data management, test and safety planning, test integration, and data analysis.
- Describe structures data acquisition and analysis.

- Recognize likely applicable regulations and specifications bearing on structures test planning and conduct.
- Understand the theoretical fundamentals of materials, solid mechanics, structural dynamics, aeroelasticity, vibration and acoustics, and aeroservoelastic, as a foundation for application to modeling and analysis of complex aircraft structures supporting testing.
- Describe the basic steps in preparation, execution, and analysis of a loads and structural dynamics ground and flight test program while understanding the inherent limitations of the applied measurement techniques and test methodologies.
- Identify operational factors that will load aircraft structure to limits, also explaining limiting measures for flight safety and now these are verified through analysis.
- Appreciate potential failure modes and adverse interactions in order to identify these with confidence during structures ground and flight tests.
- Prepare test, test safety, and other planning documents for structures flight test programs and post-test reports.

Course Outline
Day One

- Appreciate the role of structures in aircraft design and its integration with other disciplines, and adverse consequences of inadequate structural design or testing.
- Describe the role of structures testing throughout an aircraft lifecycle.
- Describe the role of each sub-discipline within structures flight testing.
- Define the variety of airloads and other loads, static and dynamic.
- Identify the common aircraft forces, moments and reactions, and how these are modeled.
- State the primary function of basic structural elements.
- Understand the limitations on structures analysis and lab test at all levels.
- Know the basic concepts of stress and strain and how they are related.
- Understand flight mechanics, maneuver effects, and stability on the aircraft structure.
- Explain the basic differences between subsonic, transonic, and supersonic flight.
- Grasp the concept of aerodynamic modeling and airflow visualization.
- Understand the effects of aeroelasticity on stability and control.
- Understand the relationship of stress and strain, the meaning of elastic and plastic material behavior, and implications of yield and ultimate strength.
- Appreciate that different structural materials have different properties that make them suitable for different applications under different operating conditions.
- Remember the basics of corrosion and inspections.
- Understand the concept of fatigue and be familiar with an S-N diagram.
- Understand the meaning of Design Limit Load and be able to calculate Factor of Safety and Margin of Safety.

Day Two

- Given a cutaway drawing, identify the basic aircraft structural components and describe the structural functionality of each.
- Appreciate that aircraft structure is designed for specific conditions and loading cases.
- Understand the use of V-n diagrams and implications of operating at its limits.
- Know the difference between gust and buffet loads and the implications of these loads.
- Know the meaning of mass, stiffness, and damping and how these interact in determining structural resonance.
- Appreciate the complexity of structural dynamic analysis that underlies modal analysis (mode shapes and frequencies). Identify basic aircraft mode shapes.
- Define divergence, control reversal, buzz, and landing gear shimmy.
- Understand that vibration, either internally induced or transmitted via the air (acoustic), can induce material fatigue and compromise the structure.
- Know the common measurements of sound pressure.
- Appreciate potential aeroelastic effects on stability and control.
- Define flutter and aeroservoelasticity (ASE) and differentiate the instabilities.
- Understand the fundamental nature of flutter prediction and the basic outputs of frequency, damping, mode shape, plus the uncertainty that underlies such predictions.
- Recognize the fundamental requirements for damping and flutter speed margin.

Day Three

- Understand the influences playing in ASE instabilities and differentiate structural coupling from pilot-structural coupling. Describe the potential ASE solutions.
- Appreciate how the structures team fits into the larger test program organization.
- Understand how structures testing might need to progress in an integrated envelope expansion scheme.
- Describe the elements of risk management and system safety.
- Prepare a Test Hazard Analysis worksheet for a proposed test.
- State the purpose, entrance criteria, and deliverables for test planning reviews.
- Review the fundamentals of data acquisition and onboard data systems.
- Emphasize the importance of knowing what happens to data from when it is sensed to when it is available for analysis. Discuss means of ensuring suitable data.
- Understand the basics of Pulse Code Modulation.
- Outline the limitations on data acquisition and how to deal with them.
- Review the sources for data errors, how these may be estimated and minimized, and the total error commonly accepted.

Day Four

- Understand the fundamentals of strain gage functions, installation, calibration, and limitations in measuring loads. Be able to calculate stress from gage output.
- Identify the purpose of the static and durability ground testing.
- Explain the link between the loads flight testing progression and static article testing.
- Explain the buildup approach for loads testing and how loads are monitored and tracked.

- Understand the role flight control changes can have in altering structural loads and the need for regression testing.
- Recognize factors (condition, configuration, control inputs, etc.) that can alter loads and so must be monitored in test.
- Recall the fundamental loads flight test maneuver types and their general purpose.
- Recall the potential pitfalls in loads testing and the means of mitigating them.
- Understand the basic methodology of airloads and landing gear loads testing.
- Appreciate the potential for dynamics from gusts and buffet to add to "static" loads and explain how associated testing is performed.
- Understand the general sources for error in loads measurements.

Day Five

- Describe placement of transducers for structural dynamics testing.
- Recognize the purpose and basic execution of wind tunnel structural dynamics tests.
- Understand the fundamental nature and modal results of a Ground Vibration Test.
- Understand the two types of aeroservoelastic ground tests and their expected outcome.
- Demonstrate the purpose and expected results of vibroacoustic ground tests.
- Perform basic time domain and frequency domain modal analysis.
- Recognize the fundamental purpose of flutter and aeroservoelastic testing.
- Understand the basics of flutter envelope expansion to include modal excitation/tracking and general abort procedures.
- Understand the fundamentals of ASE flight testing.
- Understand how and why notch filters are applied plus the potential adverse ASE implications.
- Distinguish flutter and ASE instabilities.
- Appreciate the grave hazards inherent in flutter and ASE flight testing.
- Define the basics of vibroacoustics testing.
- Understand the nature of landing gear shimmy and gear walk, common damping requirements, and the basics of how testing is performed.

Classroom hours / CEUs

35.00 classroom hours
3.5 CEUs

Certificate Track

Aircraft Structures
Flight Test and Aircraft Performance

Course Fees

Early registration course fee: $2,595 if you register and pay by the early registration deadline (45 days out).

Regular registration course fee: $2,795 if you register and pay after the early registration deadline.

Course Materials
Course materials, including outlines, presentation copies, and supplementary materials, will be accessible through Canvas, KU's online learning system. Instructions to access Canvas will be provided upon completed registration. Students are required to bring a computer or other electronic device with PDF-viewing capabilities with them to class each day. If you require accommodation contact us at professionalprograms@ku.edu and we will work with you on an accessible solution.

U.S. Federal Employee Discount
This course is available to U.S. federal employees at 10% off the registration fee. To receive the federal employee discount, you must enter the code **FGVT116** during the checkout process. Please note that you must validate your eligibility to receive this discount by entering your U.S. government email address (ending in .gov or .mil) when creating your online registration profile. This discount is available for both the early registration and regular registration fees.

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Instructor Bios
William J. Norton is retired from a flight test engineering career that spanned 40 years, including 20 as a US Air Force officer. He held numerous positions in many organizations on dozens of aerospace programs spanning all aircraft types. He led structures flight test teams on several programs across many years including modifications of existing designs and entirely new aircraft including the C-17, F-22 and F-35. He has penned scores of technical papers (many addressing structures flight testing), 20 books, and a multitude of magazine articles. His principal writing topics have been aircraft development and military aviation history. While a USAF officer, Bill wrote the important *Structure Flight Test Handbook*, the first book of its kind focusing on the subject. This later became a primary text at several test pilot schools and was the basis for a similar book at the National Test Pilot School (NTPS). Bill taught at NTPS, where he served on staff, and the USAF Test Pilot School, in both institutions substantially reworking and teaching the structures flight test content. Bill holds a Masters in Aeronautical Engineering and has taught courses at the college graduate level. He teaches other courses for KU. Bill is a civil pilot with numerous ratings and has had jobs as a professional pilot supporting flight test. Bill has been honored as a Fellow of the Society of Flight Test Engineers. He restored and operated a DHC-1 Chipmunk, and built and flight-tested a Rutan Long-EZ.

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