Aircraft System Identification – Theory and Practice

Professional Development Short Course

Instructor:

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Overview

This course teaches the theory and practice of building mathematical models for aircraft based on measured data, a topic also known as Aircraft System Identification. The methods are useful for flight simulation development, aircraft stability and control flight testing, comparisons with computational fluid dynamics and wind tunnel results, flight envelope expansion, control system design and refinement, flying qualities assessment, accident investigation, and more. The course includes relevant theory and background, but focuses mainly on practical approaches and solutions. All aspects of aircraft system identification are included: experiment design, instrumentation, data handling, model formulation, model parameter estimation, model validation, and applications. The course includes instruction in the use of a MATLAB® software toolbox called *SIDPAC* (System IDentification Programs for AirCraft), which is composed of a wide variety of tools used at NASA Langley for aircraft system identification problems. The course also includes practical hands-on experience, allowing students to become familiar with the use of the *SIDPAC* software on real flight data and to interpret the results.

Who Should Attend

The course will be useful to flight test engineers, simulation engineers, control system designers, aircraft designers, applied aerodynamicists, flying qualities engineers, engineering managers, and anyone who needs to identify high fidelity mathematical models based on measured data from an experiment, or understand how it can be done efficiently and accurately.

Key Topics

Background and introduction

Mathematical models for aircraft

Modeling in the time and frequency domains

Experiment design, instrumentation, and data handling

Real-time dynamic modeling

System IDentification Programs for AirCraft (*SIDPAC*) MATLAB® software

Hands-on practical experience

Course Outline

Introduction

Aircraft dynamic models

Estimation theory and equation-error

Model structure determination

Estimated parameter error measures

Output-error

Frequency-domain methods

Experiment design and instrumentation

Data compatibility analysis and data handling

Real-time dynamic modeling

Real-world case studies

Instructor

Dr. Gene Morelli earned a doctorate in Aerospace Engineering from George Washington University, a Masters degree in Aerospace Engineering from Princeton University, and a Bachelors degree in Mechanical Engineering from Bucknell University, all with high honors. Since 1986, he has worked as a Research Engineer at NASA Langley Research Center in Hampton, Virginia. He has done research, teaching, and technical consulting in the areas of aircraft dynamic modeling, flight test data analysis, experiment design, flight simulation development, time series analysis, aircraft accident investigation, applied mathematics, and flight dynamics. Dr. Morelli has published over 100 technical papers and reports on these topics. He is co-author of the textbook entitled *Aircraft System Identification – Theory and Practice*, and is the author of the software package called *SIDPAC*, which is used at more than 90 organizations worldwide to solve aircraft system identification problems. Dr. Morelli teaches a graduate course in Aircraft System Identification at the National Institute of Aerospace in Hampton, Virginia, and a professional short course on Aircraft System Identification. He has designed experiments and identified models for many different aircraft, including the X-29, X-31, F-18 High Alpha Research Vehicle (HARV), F-16, DHC-6 Twin Otter, Navion, Eclipse 500, Tu-144LL supersonic transport, F-15B, X-43A (Hyper-X), FALCON HTV-2, MB-326M Impala, X-51A, F-16 VISTA, HL-20, and many subscale wind-tunnel models and flying models.

Frequently Asked Questions

What is the title of the course?

Aircraft System Identification – Theory and Practice

What is Aircraft System Identification?

System Identification is building a mathematical model that mimics the behavior of a physical system, based on measured data from an experiment. If the physical system happens to be an aircraft, then this activity is called Aircraft System Identification. Results from Aircraft System Identification are useful for control system design, flight envelope expansion, stability and control flight testing, flying qualities analysis, comparisons with CFD and wind tunnel results, flight simulation, aircraft accident investigations, and aircraft acceptance testing, among other uses.

How long does the course last?

The course can be tailored to 2 or 3 days, 8 hours per day. For the longer course length, the material is covered more completely and at a slower pace, with more real-world examples.

Who is the instructor?

Dr. Gene Morelli, a senior research engineer in the Dynamic Systems and Control Branch at NASA Langley Research Center in Hampton, Virginia, is the instructor for the course. His work includes over 28 years of research, teaching, and technical consulting in the areas of aircraft dynamic modeling, flight test data analysis, experiment design, flight simulation development, time series analysis, aircraft accident investigation, applied mathematics, and flight dynamics. Dr. Morelli has designed experiments and identified models for many different aircraft, including the X-29, X-31, F-18 High Alpha Research Vehicle (HARV), F-16, DHC-6 Twin Otter, Navion, Eclipse 500, Tu-144LL supersonic transport, F-15B, X-43A (Hyper-X), FALCON HTV-2, MB-326M Impala, X-51A, F-16 VISTA, HL-20, and various subscale models, both in flight testing and in wind-tunnel testing. He the author of *SIDPAC*, a software toolbox written in MATLAB® and used at more than 90 organizations worldwide to solve aircraft system identification problems. *SIDPAC* is the software package used for the practical hands-on work in the course. Dr. Morelli has taught many classes and given numerous technical lectures, and has plenty of real-life stories that illustrate “lessons learned” and “best practices”, gained over many years of practical experience.

What exactly does the course cover?

This course teaches the theory and practice of building mathematical models for aircraft based on measured data, also called aircraft system identification. The course includes relevant theory and background, but focuses mainly on practical approaches and solutions. All aspects of aircraft system identification are included — experiment design, instrumentation, data handling, formulating the model, estimating model parameters, model validation techniques, and practical uses of modeling results. Course notes and a textbook with an accompanying MATLAB® software toolbox are the materials for the course. The course roughly follows the content in the book, in approximately the same sequence. The software includes a wide variety of tools used at NASA Langley and many other institutions to solve aircraft system identification problems. The course also includes practical hands-on experience, to allow students to become familiar with the use of the software on real flight data and to properly interpret results.

Are there any computer requirements for the course?

There are no computer requirements for the course. Software associated with the textbook and the course is called System IDentification Programs for AirCraft, or *SIDPAC*. *SIDPAC* is a collection of more than 300 MATLAB® programs that perform various tasks associated with aircraft system identification. Dr. Morelli wrote and validated every program in *SIDPAC*, and has applied every one of them successfully to solve real-world problems. *SIDPAC* version 3.0 is included with the textbook for the course. Students are invited to bring their own data and modeling problems to class, and a computer with MATLAB® installed (no special MATLAB® toolboxes are required). This is very highly recommended, but not required. Real-world data sets included in *SIDPAC* are used for the practical examples in class. For those who bring a computer with MATLAB® installed, the course will include substantial hands-on learning using *SIDPAC*. However, it is also possible to attend the course without a computer and MATLAB®, and just listen and follow along as the instructor goes through the practical examples.

What materials are provided to the students?

Each student receives a copy of the hardcover AIAA textbook *Aircraft System Identification – Theory and Practice*, by V. Klein and E.A. Morelli, along with a course CD containing all class notes and exercises, the latest *SIDPAC* software with a single-user license that never expires, software for piloted simulation and 3D visualization, and an F-16 nonlinear aircraft simulation in MATLAB®. More information on the textbook and *SIDPAC* can be found at http://www.sunflyte.com/SIDBook.html.

Who do I contact concerning further questions, course scheduling, and cost?

Dr. Gene Morelli

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