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Flight Vehicle System Identification—Engineering Utility

THIS special section of the *Journal of Aircraft* concerns the modeling and system identification from experimental data. In the broadest sense, system identification (SysId) is the fundamental part of obtaining knowledge of any physical system that is observed, and as such has far ranging areas of applications. It would be a Byzantine task to provide a comprehensive summary of all areas; we restrict ourselves here to flight vehicles. In the past, besides the various AIAA journal publications, the former Advisory Group of Aerospace Research and Development (AGARD) effectively stimulated and fostered international scientific and technical interchange, collaboration and documentation in the field of system identification. During the last decade there has been a rapid increase in the number of applications of this methodology. Furthermore, I recall at least two incidents that led to organizing a special focus section: 1) during one of those yearly AIAA conferences, someone raised a question: "*When the aircraft is past the design and production stage, and already flying, why and where do you need system identification?*," and 2) an anonymous paper reviewer's comment: "*After perhaps 30 years of journal articles and conferences* (on SysId, Ed.), *hardly any results have been of engineering utility. Or if they are in use, the fact is not widely published.*" In light of these and other perceptions, this set of special sections attempts to provide a clear, unambiguous and consolidated picture on the status of flight vehicle system identification that would clarify not just the two above said doubts, but in a much wider sense establish this routinely applied methodology as an indispensable tool for future applications.

Accordingly, the questions to be answered in the invited papers were: What is to be the fate of the identified model? Where and what is the end use of the system identification models? Is it just for research and teaching purposes or has it been actually used in engineering applications for purposes such as simulator databases, controller design, in-flight simulators, to speedup the certification process, or for flight test envelope expansion. Since the aircraft parameter estimation methods are well established and widely published, papers were to restrict the description of estimation techniques to a minimum. A total of about 45 experts from 33 organizations in 9 countries (USA, Canada, UK, France, Germany, Italy, Australia, Russia and India) were contacted to participate in this endeavor. Roughly a third of the experts declined to contribute, mainly due to the reasons of classified and proprietary nature of the results and applications. Nevertheless, the overall response has been overwhelming as evident from the 18 papers being published in a two-part special section. They cover contributions from industry, Air Force, Army, Navy, research organizations and academia. The AIAA editorial policy makes it necessary to publish them in two parts; Part-1 appeared as July-August issue and Part-2 appearing in the current issue.

The collection of papers is exhaustive enough to provide a representative and clear picture on the various aspects of flight vehicle system identification. The nature of the papers ranges from overview to specific advanced applications. They cover techniques in both the time domain and the frequency domain; applications vary from measured data calibration to aerodynamic database generation; fixed wing aircraft, space shuttle, helicopter to unmanned aerospace vehicles. These papers summarize the general underlying concepts and methods applied and present examples of practical applications. Many of the papers help to guide the novice through the challenges of developing highly accurate models from flight data. Curiously, the applications of more recent methods based on neural network have been few.

The level of diversity of applications and ubiquity was undreamed two decades ago. From the plethora of applications reported in the various papers, it is fairly obvious to say that during the last decade there has been a rapid increase in the number of applications and the complexity of modeling. Experience and engineering judgement are critical to generate good results, involving art and science of system identification. The ability and skill to interpret the modeling discrepancies, to look beyond the obvious, and to formulate mathematical models purported to underlie the physical phenomenon mainly limits the scope of applications. Although a cook-book on the process to derive highly accurate models may be difficult, it seems reasonable to assume that certain guidelines are well established.

I would venture a guess about the likely direction of future system identification activities. Three classical topics, namely: 1) generation of flight validated high fidelity databases for simulators and other applications, 2) modeling of nonlinear aerodynamics, and 3) modeling of unstable aircraft will continue to be the prime areas of applications. Furthermore, better updating techniques will be required to accommodate using slope type, i.e., derivative, estimates on non-slope databases in a table look-up form for force and moment coefficients. The use of distributed mass models will pave way to estimation and validation of full flexible aircraft models combining flight mechanics and structural models. Real-time parameter estimation is re-emerging as yet another area of current and future research. Some theoretical aspects will focus on estimation of modeling uncertainties. Other advances will result from the actual needs, for example better air-data measurement. Although in the distant future, another thrust will be possibly on integrating the system identification and computational fluid dynamics methodologies. These may call for new modeling concepts and associated measurement and experimental techniques to enable parameter estimation. In short, we will face some most demanding and fascinating modeling problems in the future and, I am convinced, in these cases system identification will provide ultimate answers to unmasking the modeling deficiencies, reducing developmental risk and improving flight safety issues.

I would like to conclude this Guest Editorial with my appreciation of the contributors for the meticulous job in putting up their papers, focusing on the goal set for this special issue. I am sure many of them have put extra hours of work besides their already heavily loaded schedule. I really appreciate their joining this endeavor to promote the system identification methodology. All papers were peer reviewed, and I would like to acknowledge the reviewers who did an excellent job of assessing the merits and pitfalls of the papers. It has certainly helped a great deal to improve the quality of the papers. It was a pleasure to work together with Ken Holt, Associate Editor, who coordinated the review process. I would also like to acknowledge Tom Weeks, Editor-in-Chief, for approval of the proposal. Without the continued support of Ken and Tom, the job of putting together the special section would not have borne the fruits. I am sure, many AIAA staff are involved down the line, whom I would like to thank as well.

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