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Editorial

Active Flexible Wing Program

THE development of structural design optimization procedures in the 1960s and 1970s, and the continual enhancements of these tools in the 1980s and 1990s into highly integrated, multidisciplinary optimization methodologies, has resulted in innovative options for improving the capabilities of the next generation of flight vehicles. It is expected that these vehicles will be highly flexible, have very low structural-weight-to-take-off-weight ratios, be capable of performing a multitude of mission scenarios at very extreme and hostile flight conditions, and incorporate digital flight control systems that perform complex flight-control functions and manipulate aerodynamic loads and aeroelastic response.

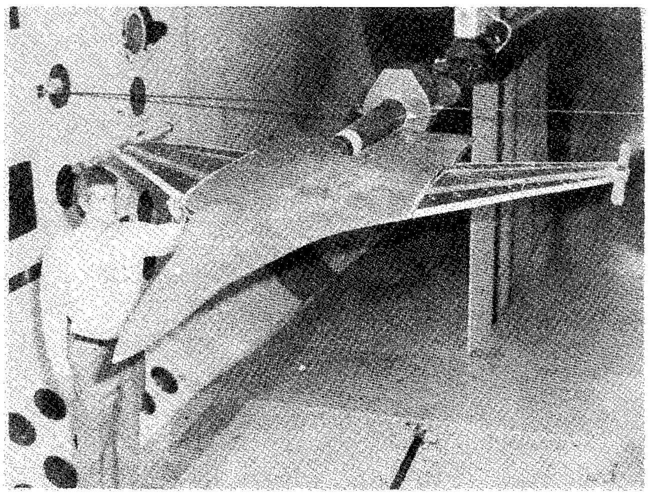
Presently, specialists developing the design methodology are working towards the integration of technical disciplines that include vehicle performance, propulsion, structures, aerodynamics, and flight controls. Within the structures discipline structural dynamics, aeroelasticity, and aeroservoelasticity are now beginning to play major roles in the vehicle conceptual and preliminary design process. Aeroservoelasticity is, in itself, a multidisciplinary technology that deals with the interactions of an aircraft's active control systems, its flexible structure, and the steady and unsteady aerodynamic forces resulting from rigid-body and flexible motions.

During the 1970s aeroservoelastic interactions were of great concern to the aircraft designer because of their adverse effects on vehicle stability and performance. Examples of adverse aeroservoelastic interactions included the YF-16 and the F-18, which exhibited instabilities in flight. The YF-18 and the X-29 were predicted to be unstable, resulting in flight-control-system modifications prior to first flight.

There has been much progress made in the last few years that demonstrated the usefulness of active controls technology for favorably modifying the aeroelastic response characteristics of flight vehicles. Today, aeroservoelastic analysis and design methodologies are emerging that offer a viable design option to exploit the aircraft's aeroelastic characteristics for meeting the minimum weight, optimized performance, and multimission requirements being imposed on future designs. It is apparent that the future will demand high-gain control systems and flexible structures, two ingredients requiring significant interdisciplinary communication, not only to avoid adverse aeroservoelastic interactions, but also to make maximum use of this promising technology.

To demonstrate the benefits available through the use of active controls, Rockwell International Corporation in cooperation from the Air Force Wright Aeronautical Laboratories (presently Wright Laboratories) and the NASA Langley Research Center (LaRC) initiated a research program in 1985 to develop and demonstrate a concept Rockwell named the Active Flexible Wing Concept. The concept exploited wing flexibility and active leading- and trailing-edge control surfaces, up to and beyond reversal, to provide high-performance roll rates without the use of all-movable horizontal tails. The goal of the research program was to validate a multidisciplinary technology that integrates active controls with a highly flexible, advanced aerodynamic wing design to produce enhanced aerodynamic performance and control. Rockwell designed and built an actively controlled, aeroelastically scaled, full-span wind-tunnel model of an advanced tailless fighter. The wind-tunnel tests, performed in 1986 and 1987 in NASAs Transonic Dynamics Tunnel (TDT), were highly successful, thus providing a proof of concept.

At the completion of this initial research program, the NASA LaRC and the Rockwell International Corporation agreed to perform additional cooperative studies to develop and test enabling technologies for the Active Flexible Wing Concept. The objectives of this follow-on program were to design and analyze digital, multi-input/multiple-output, multifunction active control concepts; develop near real-time simulation techniques; perform ground and wind-tunnel experiments; and validate current aerodynamic, aeroelastic, and control system analysis and design methodologies. Active control concepts considered during the program included active flutter suppression and rolling maneuver load alleviation. The goal of the active flutter suppression system design was to use multiple surfaces and sensors to prevent two modes of flutter simultaneously. For the rolling maneuver load alleviation design, the goal was to reduce wing loads at multiple points on the wing while undergoing high performance rolling maneuvers. In addition, the rolling maneuver load alleviation and the flutter suppression systems were designed to be compatible such that they could be tested simultaneously, even at conditions above the passive flutter speed of the wind-tunnel model.



The Rockwell AFW wind-tunnel model is shown in the figure with wingtip ballast stores added to lower the model flutter speed into the operational capabilities of the TDT. The model was sting-mounted utilizing an internal ball-bearing arrangement and a roll degree-of-freedom brake that allowed the model to either roll about the sting axis between ± 145 deg, or to be held fixed. In addition, an actuator located at the model c.g., was available for remotely positioning the angle of attack from approximately -1.5 to $+13.5$ deg. The model had two leading-edge and two trailing-edge control surfaces on each wing panel driven by rotary-vane, electrohydraulic actuators powered by an onboard hydraulic system. The model was instrumented with a variety of sensors that included accelerometers, strain gauges, rotary variable differential transducers, and a roll rate gyro. Two wind-tunnel tests were completed between 1989 and 1991.

The objective of this special issue of the AIAA *Journal of Aircraft* is to summarize the details, findings, and conclusions resulting from, primarily, the 1991 wind-tunnel test. Nine papers and two engineering notes are included in this issue. These 11 contributions highlight the activities associated with resolving modeling issues, developing a digital controller, performing near real-time simulations, designing active flutter suppression and rolling maneuver load alleviation systems, and performing the wind-tunnel test experiments. This edition of the *Journal* includes all the pertinent facts related to an AFW program. However, each article was written with the intent of minimizing overlapping details, and therefore, care must be taken when reviewing individual articles, as they may appear to be incomplete.

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