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The Poststall Nonlinear Dynamics and Control of an F-18 A Preliminary Investigation

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One cost effective way of keeping pace with the need to improve the operational effectiveness of today's high speed fighter aircraft is to make it possible to maneuver these vehicles without regard to the angle of attack they are flown at. Extending the operational envelope of the craft in this manner would provide the pilot of tomorrow with a repertoire of tactics that could measurably affect the combat effectiveness of these man/machine systems.

Providing an aircraft with increased levels of agility at poststall conditions is no small task. Maneuvers conducted at high angles of attack (HAOA) include unignoreable nonlinearities in the dynamics of both the aircraft, and it's control surfaces. In addition, the pilot flying the craft at HAOA is required to provide heightened levels of mental and physical effort in order to achieve control objectives. The problem is exacerbated by the fact that the correct response to phenomenon encountered during flight at HAOA (e.g. limit cycles and bifurcations) is in general counter intuitive and can produce pilot induced oscillations, which in the extreme, may result in the loss of the craft.

The successful HAOA operation of fighter aircraft will necessarily require the introduction of a new onboard control methodology that address the nonlinearity of the system when flown at the stall/poststall limits of the craft's flight envelope. As a precursor to this task, this ASEE researcher has endeavored this summer to familiarize himself with the dynamics of one specific aircraft, the F-18, when it is flown at HAOA. This was accomplished by conducting a number of real time flight sorties using the NASA-Langley Research Center's F-18 simulator, which was operated with a pilot in the loop.

Figure 1 below is offered as an example of the marginal stability of the F-18 when operated at HAOA. That figure depicts the angle of attack versus time, where the pilot was instructed to trim the plant at 45 degree AOA, and hold his heading. The plant response to a gradual lateral stick input is indicated in Fig. 1, where it is clear that the lateral dynamics of the plant,

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including side slip and roll rate become unstable. While not shown, the pilot's attempt to correct for this disturbing oscillation results, in general, in a departure of the system.

In addition to developing a first hand familarity with the aircraft's dynamic characteristic at HAOA, work was also performed to identify the input/output operational footprint of the F-18's control surfaces. Fig. 2, for example, depicts the nonlinear relationship between side force produced versus aileron position. This investigator proposes to employ the nonlinear models of the plant identified this summer in a subsequent research effort to provide a command following, near optimal feedback controller that will make it possible to fly the F-18 effectively at poststall angles of attack. The controller design used there will rely on a new technique proposed by this investigator, (Ref.1) that provides for the automatic generation of online optimal control solutions for nonlinear dynamical systems.

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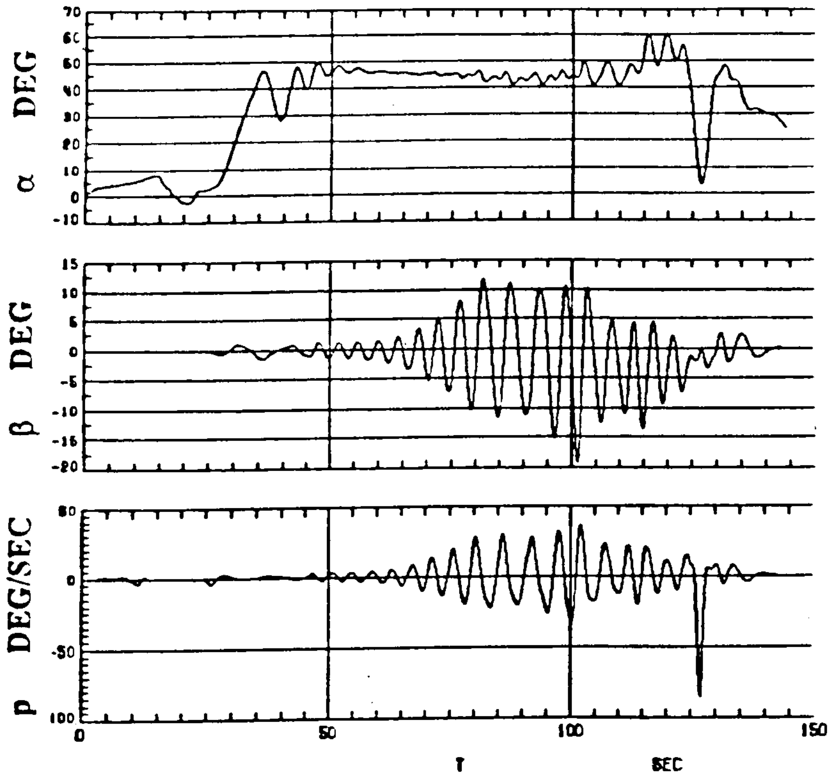
1. Patten, William N., Near Optimal Feedback Control for Non-linear Aerodynamic Systems with an Application to the High-Angle-of-Attack Wing Rock Problem, AIAA Guidance, Navigation and Control Conference, August 15-17, 1988 / Minneapolis, Minnesota, #88-4052.



Fiqure 1 Angle of Attack (α), Side Slip Angle (β), and Body Axis Roll Rate vs Time for the F-18a flown at 20,000 feet

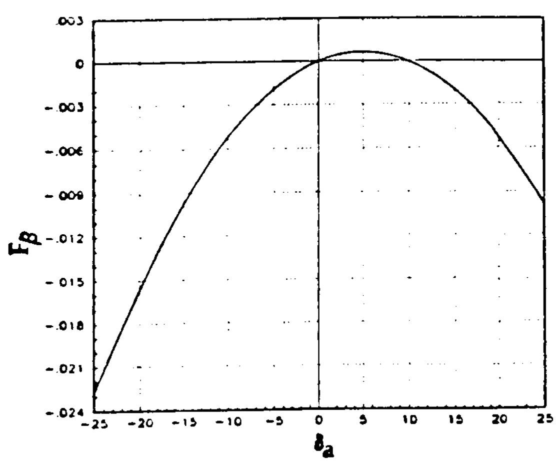


Figure 2 Side Force vs Aileron Angle.