Success Stories in Control

Nonlinear Dynamic Inversion Control

NASA plays an important role in advancing the state of the art in flight control systems. In the case of Nonlinear Dynamic Inversion (NDI) NASA supported initial implementation of the theory in an aircraft and demonstration in a space vehicle. Dr. Dale Enns of Honeywell Aerospace Advanced Technology performed this work in cooperation with NASA and under NASA contract. Honeywell and Lockheed Martin were subsequently contracted by AFRL to create "Design Guidelines for Multivariable Control Theory". This foundational work directly contributed to the advancement of the technology and the credibility of the control law as a design option. As a result Honeywell collaborated with Lockheed Martin to produce a Nonlinear Dynamic Inversion controller for the X-35 and subsequently Lockheed Martin did the same for the production Lockheed Martin F-35 vehicle.

The theory behind NDI is to use a systematic generalized approach to controlling a vehicle. Using general aircraft nonlinear equations of motion and onboard aerodynamic, mass properties, and engine models specific to the vehicle, a relationship between control effectors and desired aircraft motion can be formulated. Using this formulation a control combination is used that provides a predictable response to commanded motion. Control loops around this formulation shape the response as desired and provide robustness to modeling errors. Once the control law is designed it can be used on a similar class of vehicle with only an update to the vehicle specific onboard models.

In the mid1980s NDI was a new theoretical control approach. A proposal was made to the High Alpha (angle of attack) Test Program (HATP) that an NDI control approach would be a good solution for the highly nonlinear, uncertain post-stall environment. A Honeywell NDI design was selected for competition as a controller for the F-18 High Angle of Attach Research Vehicle (HARV).

At that time a significant challenge to overcome was to implement the fairly complex NDI control laws into the very limited computer resources available. This was eventually accomplished and in the process some interesting multi-channel interactions with the NDI controller were identified. The NDI design was implemented in a full hardware in the loop piloted simulation. Although never flown on the F-18 HARV, significant maturation of the design concept occurred due to the HATP effort.

In the late 1990s NASA developed an X-38 Crew Rescue Vehicle program. The program consisted of a series of developmental vehicles that would lead to a production vehicle that would serve as the Space Station lifeboat. The NDI controller was proposed as a good solution for this program since it would provide a generic control approach. As the vehicle developed, the outer mold line would change. The NDI control approach allowed for control updates by simply updating the onboard aerodynamic model.

The foundational work sponsored by NASA under the HATP program and AFRL's sponsorship of the design guideline led to collaboration between Honeywell and Lockheed Martin and implementation of NDI on the X-35 prototype and eventually the production F-35 vehicle. The NDI controller has provided consistent predictable control through the transition from conventional aircraft flight mode to hover. The research and development that NASA accomplished has contributed to a flight control advancement that is now implemented on the latest state-of-the-art production vehicle.

References and Resources

John T. Bosworth john.bosworth@nasa.gov

Honeywell and Lockheed Martin, "Multivariable Control Design Guidelines", Final Report, WL-TR-96-3099, Wright Patterson AFB, OH, 1995.


United States

Dryden Flight Research Center EC91 495-15 Photographed 1991
F-18 NASA photo