Close Formation Flight for Automated Aerial Refueling

Unmanned Aerial Vehicles are in high demand today and will continue to be in the future. Key to increasing their use is development of automated aerial refueling to keep them in the sky and in the fight. The Advanced Navigation Technology Center at AFIT successfully developed and tested an automated refueling design paving the way for automated aerial refueling in the near future.

Short term applications center around unmanned combat aerial vehicles, but the technology could also be used for drag reduction and fuel savings on manned aircraft ferry operations. Close formation flight applicable to automated aerial refueling was recently demonstrated by Capt Steve Ross for his thesis research. Capt Ross was a recent (Mar 06) graduate from the Joint AFIT-USAF Test Pilot School program, and received the Master of Science Degree in Aeronautical Engineering. His thesis was selected as the 2006 Commandant’s Award winner. The Commandant’s Award is presented to the graduating student, or team of students, who produces the most exceptional master’s thesis.

Capt Ross’ research involved the design, implementation, and test of a formation hold autopilot capable of precisely holding the position and attitude of a trailing aircraft relative to a lead (tanker) aircraft. The autopilot was a fully coupled (lateral and longitudinal modes) non-linear design, a necessary design feature due to the multiple coordinate rotations and lack of small angle approximations. A new reference frame tied to the tanker body was developed to decompose error measurements into the components necessary to generate proper steering commands. The controller was installed on a Calspan owned Learjet LJ-25 with a Variable Stability System capable of driving the control surfaces and the throttle with external inputs. Both the lead and wing aircraft were equipped with a carrier phase differential Global Positioning System (GPS) system, also designed as an AFIT thesis project by Capt Chris Spinelli (GEE-05M). The lead aircraft was also equipped with a small Micro-Electrical Mechanical System Inertial Measurement Unit (MEMS IMU) for attitude measurements. A commercial data link system was installed on both aircraft to transmit the relative position and attitude parameters of the lead aircraft (a C-12 simulating a tanker) to the trail aircraft (the Learjet, simulating a receiver).

Validation of the autopilot design was completed using modeling, simulation, and flight test. Scenarios for test included representative aerial refueling profiles, to include straight level flight, movement between contact, pre-contact, and observation positions, and ingress and egress from 15 and 30 degree banked turns. Established error thresholds were tightest for the contact position and were based on actual tanker boom limits. As is often the case, numerous practical problems had to be solved for flight test, to include data drop outs on the differential GPS system and failed channels in the MEMS IMU. Capt Ross was able to work through these problems by rapidly developing and implementing various filters to compensate for missing or corrupted data.

Capt Ross flight tested his controller in October 2005 for the Test Management Project portion of Test Pilot School. The system performed quite well and demonstrated the capability to refuel off of a KC-135 or KC-10 aircraft during straight and level flight, or when established in turns up to 30 degrees of bank. All position changes were performed safely and efficiently, and safety or stability was never in question.

Capt Ross’ research resulted in a first ever demonstration of closed-loop position and attitude hold for aerial refueling, to include maneuvering flight. His work conclusively demonstrated the feasibility of refueling unmanned air vehicles and a critical technology for the Air Force to fully integrate unmanned systems into combat air operations. His research was sponsored by the USAF Test Pilot School and the Air Vehicles Directorate of Air Force Research Laboratory. Dr. Dave Jacques, from the Department of Aeronautics and Astronautics, and Dr. Meir Pachter, from the Department of Electrical and Computer Engineering, served as thesis advisors for Capt Ross’ project.