

## *MAE Seminar Series*

# **Dynamics and Control of a Minimally Actuated Biomimetic Vehicle**

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### **Abstract**

An aerodynamic model of a minimally-actuated flapping-wing micro air vehicle is derived from blade element theory. The proposed vehicle is similar to the Harvard RoboFly that accomplished the first takeoff of an insect scale flapping wing aircraft, except that it is equipped with independently actuated wings, and the vehicle center of gravity can be manipulated for control purposes. Using a blade element-based approach, both instantaneous and cycle-averaged forces and moments are computed for a specific type of wing beat motion that enables nearly decoupled, multi-degree-of-freedom control of the aircraft. The wing positions are controlled using oscillators whose frequencies change once per wing-beat cycle. A new technique is introduced, called Split-Cycle Constant-Period Frequency Modulation, that has a number of desirable properties, such as maintaining energy efficiency by operating the wing-actuator systems near resonance, as well as providing a high level of control input decoupling for vehicles without active angle-of-attack control. The wing angle-of-attack variation in this vehicle is passive by design, and is a function of the instantaneous angular velocity of the wing in the stroke plane and the geometry of a hinge limiting device. A control-oriented dynamic model of the vehicle is derived for the purpose of developing a cycle-averaged control law. The cycle-averaged control law is tested in a simulation of the vehicle that accounts for instantaneous variations in the forces and moments as the wings move through their wing beat cycles. Simulation results indicate that controlled six degree-of-freedom motion of the fuselage can be achieved by appropriately shaping waveforms that drive two actuators that control the instantaneous position of the wings in the stroke-plane, and a third actuator that provides limited control over the vehicle center of gravity location.

### **Speaker Biography**

David B. Doman is a Senior Aerospace Engineer with the Air Vehicles Directorate of the Air Force Research Laboratory at Wright Patterson AFB in Dayton, OH. He received his Ph.D. in Aerospace Engineering from Virginia Polytechnic Institute and State University in 1998. He completed the Aerospace Vehicles Test Course at the USAF Test Pilot School in 2005. He is currently the Technical Area Lead for the Micro Air Vehicle Dynamics and Control Group in the Control Science Center of Excellence at AFRL. He has published over 120 refereed conference papers, journal articles and technical reports and holds two U.S. patents. He was the co-recipient of the 2003 Gen. Benjamin D. Foulois Award as well as the 2000 Dr. Courtland D. Perkins award for his technical contributions at the Air Vehicles Directorate of AFRL. He was recently presented with the 2008 Silver Medal of the Royal Aeronautical Society for his work in the area of hypersonic vehicle dynamics and control. He is an Associate Fellow of the AIAA, a Senior Member of the IEEE, and an Associate Editor for the Journal of Guidance, Control and Dynamics.

**110 Knox Hall**  
**Thursday, April 2nd, 2009**  
**3:30 pm – 4:30 pm**

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