Abstract Submitted for the DFD15 Meeting of The American Physical Society

Analytic State Space Model for an Unsteady Finite-Span Wing JACOB IZRAELEVITZ, MIT, QIANG ZHU, UC San Diego, MICHAEL TRI-ANTAFYLLOU, MIT — Real-time control of unsteady flows, such as force control in flapping wings, requires simple wake models that easily translate into robust control designs. We analytically derive a state-space model for the unsteady trailing vortex system behind a finite aspect-ratio flapping wing. Contrary to prior models, the downwash and lift distributions over the span can be arbitrary, including tip effects. The wake vorticity is assumed to be a fully unsteady distribution, with the exception of quasi-steady (no rollup) geometry. Each discretization along the span has one to four states to represent the local unsteady wake-induced downwash, lift, and circulation. The model supports independently time-varying velocity, heave, and twist along the span. We validate this state-space model through comparison with existing analytic solutions for elliptic wings and an unsteady inviscid panel method.

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Date submitted: 01 Aug 2015

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