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## THE VALIDATION OF A GENERALIZED AERODYNAMIC MODEL FOR A MULTI-BODY BIO-INSPIRED WING

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### ABSTRACT

Bio-inspiration has introduced new and innovative flow control methods in gust alleviation, maneuverability and stability improvement for morphing aircraft wings. The bio-inspired wing model under consideration imitates the techniques used by birds to manipulate localized air flow through the installation of feather-like panels across the airfoil's upper and lower surface, replacing the traditional wing's surface and trailing edge flap. Each flap is designed to rotate into both the airfoil profile and inbound air flow, using a single degree of freedom about their individual hinge points located at 20%, 40%, 60% and 80% of the chord. This wing morphing technique offers flap configurations typically unattainable by traditional aircraft and enables some advantageous maneuvers, including reduced turning radii and aero-braking. Due to the number of potential configurations, a generalized adaptive panel method (APM) has been developed to model the pressure distribution using a series of constant-strength doublets along the airfoil surface. To accommodate for the wake regions generated by the unconventional wing profiles, viscous Computational Fluid Dynamics (CFD) simulations are performed to characterize these regions and identify their outer boundaries. The wake profile geometries are integrated into the APM, and are used to accurately model the aerodynamic influence of the wake. To calculate the drag generated by each configuration, Thwaites' laminar and Head's turbulent boundary layer methods are implemented to enable identification of flow transition and separation along the airfoil surface. The integration of these aerodynamic techniques allows the flight characteristics, including the pressure, friction, lift, drag, and moment coefficients, of each morphing airfoil configuration to be calculated. The computed aerodynamic coefficients are validated using experimental data from a 4'x1'x1' test section in a low speed suction wind tunnel operating over a Reynolds Number range of 150,000-450,000.

### INTRODUCTION

As the aerospace industry has advanced, the introduction of wing morphing has offered enhancements to flight performance by manipulating the wing's geometry [1]. The use of flaps, slats and slots were developed to offer improved lift-to-drag ratios and to allow the aircraft to fly at slower speeds during the approach and landing sequence. In the last fifty years, a multitude of new aircraft has been developed for the US Armed Forces, each designed with specific mission objectives that may include low-altitude reconnaissance flights, close-quarters combat, long-range missions and cargo transport [2]. However, if these aircraft were required to perform an objective outside their design specifications, their ability to fulfill the required maneuverability, stability and endurance would be insufficient and potentially compromise the mission. Consequently, the introduction of morphing aircraft that can manipulate their structural and wing geometry offers the ability to perform an array of mission objectives with a single aircraft while performing maneuvers not possible by traditional aircraft [3].

During the last decade a considerable focus has been given to avian flight and its applications to Unmanned Aerial Vehicles (UAVs), as birds have the ability to adapt their wing profiles to attain desired flight characteristics while gliding, hunting, perching, and carrying a payload, each requiring its own specific wing geometry for optimal performance. Initial developments in wing morphing were inspired by the wing cross-section deformation performed by birds, including variation of wing span, sweep and twist. However, with each additional degree of freedom available in the wing, the aerodynamic model and onboard flight controller grows in complexity while improving the flight capabilities of the aircraft. Recently, an array of new and innovative morphing wing techniques has been recently developed from the inspiration of the evolutionary adaptations of avian flight. Bilgen et al. varied the shape and position of the camber line, thereby enabling profile deformation and trailing edge deflection to be achieved with an airfoil with no flaps [4].

 