Actuated Wingsuit for Controlled, Self-Propelled Flight

Human flight has been an incredible driving force behind human innovation. From early epics such as the story of Icarus to Leonardo da Vinci's designs of hang gliders and helicopters, and from the Wright brothers' first planes to our first trip to the moon, human flight has accompanied and inspired us throughout much of our scientific and technological progress. The field has made spectacular advances since its inception and now permeates modern systems of everyday life, from aerial photography to air ambulances and commercial travel. For many of us, however, human flight has now become a necessity rather than a source of inspiration, evoking visions of crowded cabins with tiny windows and cramped seating rather than majestic thoughts of wind-beneath-your-wings airborne travel.

This applied research project recaptures the spirit and ambition of the man-on-the-moon-type projects that have so successfully fueled human inventiveness and innovation in the past. Simultaneously, the project tackles a perceived lack of large-scale, multidisciplinary projects that capture the public's imagination.

The Challenge: Unconstrained Human Flight

The goal of this project is to achieve unconstrained human flight by building on existing wingsuit technology (see image above) and by leveraging research in lightweight structures and propulsion systems, nonequilibrium aerodynamics, and algorithmic methods for the control of highly dynamic systems (see image on next page). The result will be an actuated wingsuit that can be actively controlled by the flyer.

As with previous endeavors in human flight, this project requires a multidisciplinary effort by researchers in mechanical and electrical engineering, materials sciences, controls, human-machine interaction, and related disciplines. Similar to the principal investigator's previous projects, the current effort allows students from semester projects and those from bachelor, master, and PhD thesis programs to become involved in the challenge. Achieving unconstrained human flight is a highly multidisciplinary challenge, requiring competencies—and offering learning opportunities—that span the entire R&D cycle, from the derivation of theoretical results to their experimental validation, practical implementation, and revision.

Existing wingsuits are purely passive designs that allow a pilot to achieve glide ratios of approximately 2.5 (2500 m of horizontal travel for every 1000 m of vertical descent); in comparison, flying squirrels achieve glide ratios of at most 2.0.

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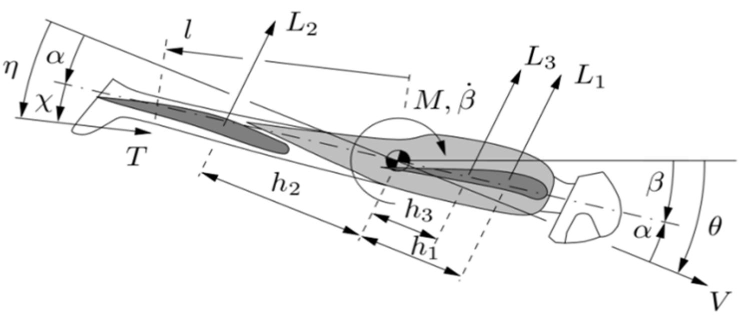
Research Project Under Way

To date, few academic studies on unconstrained human flight have been conducted; however, a recent study by our group (see citation below) highlights the potential for academic work in this field and identifies several specific areas for research contributions. Both data and algorithmic results of current investigations are freely shared for further analysis, promoting multidisciplinary research in the area. The project follows a rigorous scientific approach with results presented at major international conferences and published in high-profile journals.



$$\dot{V} = \frac{T\cos\eta - D}{m} + g\sin\theta$$

$$\dot{\theta} = \frac{1}{V}\left(g\cos\theta - \frac{L + T\sin\eta}{m}\right)$$

$$\ddot{\beta} = \frac{M}{I}$$

$$L_k = \rho V^2 c_{L_k}, \quad c_{L_k} = s_k\alpha_k + q_k$$

$$\alpha_1 = \alpha - \frac{h_1\dot{\alpha}}{V}, \quad \alpha_2 = \alpha + \frac{h_2\dot{\alpha}}{V}, \quad \alpha_3 = \alpha - \frac{h_3\dot{\alpha}}{V}$$

$$c_m := -s_1h_1 + s_2h_2 - s_3h_3$$

$$c_{md} := s_1h_1^2 + s_2h_2^2 + s_3h_3^2$$

$$M = \rho V^2\left(c_m\alpha + \frac{c_{md}}{V}\dot{\alpha} + (-h_1q_1 + h_2q_2 - h_3q_3)\right)$$

$$L = \rho V^2 c_L$$
$$D = \rho V^2 c_D = \rho V^2\left(c_p + \frac{c_L^2}{c_i}\right)$$
$$c_L = 1.17\alpha + 0.39$$

$$\begin{bmatrix} \ddot{\beta} \\ \dot{\beta} \\ \dot{V} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} a_1 & a_2 & 0 & a_3 \\ 1 & 0 & 0 & 0 \\ 0 & a_4 & a_5 & a_6 \\ 0 & a_7 & a_8 & a_9 \end{bmatrix} \begin{bmatrix} \dot{\beta} \\ \Delta\beta \\ \Delta V \\ \Delta\theta \end{bmatrix}$$

A first-principles model (physics and mathematics) of how one flies a wingsuit (from G. Robson and R. D'Andrea, Longitudinal stability analysis of a jet-powered wingsuit, Proc. AIAA Guidance, Navigation, and Control Conference, San Antonio, Texas, 2010)

Join us!

The project is headquartered in Zurich, Switzerland, which offers a unique combination of world-class research facilities at ETH Zurich, mountain geography with suitable launch sites and easy access, and an active community of skydivers and wingsuit flyers. Efforts by the project team are leveraged through a community of researchers at ETH Zurich, pilots, seasoned wingsuit flyers, and technologists whose aim is to allow humans to experience unconstrained flight.

To join this challenge, visit http://raffaello.name/dynamic-works/actuated-wingsuits
and contact info@raffaello.name.