ABSTRACT

The Inclined Wind Tunnel: A new tool for flight.
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INTRODUCTION:
Fatal crashes in wingsuit flying are increasing and a major risk factor is flight path miscalculations. It would be desirable if wingsuit flight training could be undertaken in a safe environment enabling detailed evaluations. A candidate technology for creating such an environment is the wind tunnel. The use of horizontal wind tunnels to simulate flight of anchored wing profiles has played a central role in the development of aircraft. Another type of wind tunnel is the vertical, in which gas flows directly opposite to the direction of gravitational acceleration, creating a force equilibrium at which untethered objects float on the pillar of ascending air; among applications are rotameters and skydiving simulators. Neither horizontal nor vertical wind tunnels can accommodate actual flight. A third type of wind tunnel is the inclined tunnel, with airflows directed obliquely upward, allowing sustained gliding flight. Using small wind tunnels that are tiltable as a whole, the flight of small animals has been studied. Further biology research is frustrated by physical dimensions and achievable flows, but variable inclination wind tunnels of greater capacity are difficult to construct, since weight and size of recirculating wind tunnel systems limit what is feasible to tilt in its entirety. We hypothesized that by attaching an adjustable inclination segment to a fixed recirculating wind tunnel system, capacity limitations can be mitigated since the rest of the recirculating system may be designed for maximum performance, regardless of dimensions or weight. Thus, it would seem theoretically possible to construct a variable inclination wind tunnel in which wingsuit flying is possible. However, since the wingsuit airfoil profile and flight characteristics including glide ratio is incessantly and sometimes rapidly altered while in flight by pilot body position, it could not be determined by reasoning only if it is actually possible to fly, untethered, a wingsuit in an inclined wind tunnel. The aim of the project was to (1) test the technology of an adjustable inclination wind tunnel segment, and to (2) examine if it is possible for a human to learn to fly a wingsuit in it.

METHODS:
A large prototype adjustable inclination segment was designed and attached to a horizontal recirculating wind tunnel system, the LT1 wind tunnel at the former Swedish National Aeronautical Research Institute (Flygtekniska Försöksanstalten, FFA). A systematic test protocol, progressing from tethered to hypothetical untethered free flight, was created, to examine varying inclinations and airspeeds with several different types of glide ratio enhancing garments, including commonly used types of wingsuits, as well as a number of other types of heavier-than-air aerodynes and ski flying (Nordic ski jumping).

RESULTS:
The adjustable inclination segment produced variable inclination airflows of good quality. A total of >500 test flights, duration circa 1-9 minutes, were performed. The authors, who had never flown wingsuits themselves before, were able to learn untethered free wingsuit flying at self-perceived ease. All tested types of commercially available wingsuits were flyable. Experienced wingsuit flyers reported no difference in subjective perception of flight, and several commented approvingly on a high level of precision being trainable, including touching physical objects while in flight. Several of the Fédération Aéronautique Internationale (FAI) wingsuit competition aerobatic manoeuvres were performed without negative events. Elite athletes in Nordic ski jumping found training conditions desirable.

DISCUSSION:
The use of inclined wind tunnels is no longer restricted to the study of small bird species, but may be applied to new types of flight research and training in sports such as wingsuit and ski flying. For these purposes, a large-scale (4.5 x 3.0 x 10 m) commercial inclined wind tunnel has been opened.

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