Ornithopter Report Update, 19 July 2006

Recall that in the previous report it had been stated that the flight was terminated due to a cross wind (which was NW at 3-6 knots). However, photographs from the chase vehicle following the aircraft clearly showed a bulge occurring, during the downstroke, on a portion of the left wing's upper trailing edge. This was about 2/3 of the way out from the flapping hinge. A rear-view video also showed this happening just before the bank angle divergence began. What is now obvious is that the flight loads, in conjunction with the flapping loads, caused the buckling strength of that portion of trailing-edge strip to be exceeded. The consequence, also seen in the video (now that we know what to look for), is that the shearflexing action was jammed up thus reducing the aeroelastic twist. This would have caused flow separation with resulting loss of lift and thrust. The aircraft's behaviour bears this out.

It should be noted that Jack Sanderson, the pilot, anticipated this conclusion because, based on his considerable experience with yaw-roll coupled aileron-less ultralight aircraft, he stated that the banking felt like it was due to some sort of direct roll moment and not due to cross-wind effects.

It might be asked why this didn't happen to the right wing. In October 1999 the aircraft was damaged such that the right wing had to be rebuilt from the spar up. In that case the trailing-edge strips were built more robustly and thus had a higher buckling load. The left wing had been undamaged and had given no problems up to that point, so it was not changed in the same way. However, the addition of the flight loads in addition to the flapping loads exceeded its capability. In a strange way it was fortunate that the right wing had to be rebuilt because if both trailing edges had stayed the same they would have both buckled and we would not have known how much additional strength was required to fix this.

The videos and photographs are providing a great deal of additional information. For example, the cockpit-camera video shows that once the undercarriage was off the runway, the air speed increased from 51 mph to 55 mph. It seems that the ground friction was larger than estimated, and that the

flapping thrust was performing as predicted. If the flight had been longer, Jack was planning to continuously throttle back the jet to assess the wing's capability to sustain flight. As it is, the 14 sec flight answered a lot of questions. What have been learned are:

(1) Once off the ground, the cockpit environment is very tolerable, with smooth motion in response to the flapping. Jack said that he could function indefinitely in such an environment. This is largely a consequence of the 3-panel wing design.
(2) The longitudinal trim conditions were near perfect, showing that the standard airplane criteria of neutral point and static margin likewise apply to this type of ornithopter. It was seen that the stabilator was at a nearly zero trim angle.
(3) There was no tendency for pilot-induced oscillations in response to the flapping forces. The stabilator was rock steady.
(4) The stored energy from the small flywheel/fan attached to the engine, in conjunction with the 60:1 drive reduction, allowed smooth sinusoidal flapping motion even under flight loads. That is, the upstroke and downstroke were of the same duration; the wing wasn't slowed during the downstroke.
(5) The unsteady wake from the flapping wing had a negligible effect on the stabilator's ability to provide steady non-pitching motion. This had likewise been seen for the 1/4-scale model in 1991, but it was still something that was carefully considered.
(6) The ability of an ornithopter to take off from a ground roll, without bouncing, has been demonstrated. This is largely due to using a boost from the jet engine, and this would be a valuable feature for any future ornithopter.

There is another accomplishment which, though non-technical, is perhaps of equal importance. Namely, the flight on 8 July crosses a psychological barrier regarding the feasibility of a full-scale flapping-wing aircraft. Up until now the notion of large-scale human-carrying ornithopters has seemed to be in the realm of fantasy or the hapless efforts of backyard inventors. However, the Flapper's few seconds of sustained flight brings this notion into the realm of reality. Speaking personally, even though I have envisioned this flight for decades and have seen it in numerous simulations, seeing it for real was an experience almost beyond my words to express. Until the trailing-edge buckling happened, it was smooth, steady, and looked almost… well…*normal*. Perhaps this is the greatest contribution of this project.