Is the Current Dominant Aircraft Design Configuration Optimal?

VSoE Research Innovation Fund: Final Report

G.R. Spedding
Aerospace and Mechanical Engineering
University of Southern California
Los Angeles,
CA 90089-1453

(213)740 4132
geoff@usc.edu

Abstract

It can be argued from theoretical grounds that current aircraft designs are not optimal. A new design has been proposed for novel and different ways of performing both control and variation in wing geometry. There are potentially large consequences, both for mainstream passenger planes, and also for the emerging class of small-scale flying machines, where significant challenges in aerodynamic control mechanisms prevail. A meeting of experts from two continents occurred at USC to rigorously examine competing concepts for next-generation aircraft. A series of new measurements on the proposed configuration demonstrated, for the first time, that the theoretical concept was sound. The results have been incorporated into an updated AFOSR brief, and funding decisions are pending. One publication and two conference papers have thus far been produced. There has been Popular Press interest in the second conference paper.

Background
The aircraft industry has settled on a general Dominant Configuration for heavier-than-air transport that one can show cannot be optimal for drag reduction, and hence cannot be the best solution to minimizing fuel costs. The argument for this notion takes full account of the desired payload mass density and grain size that is typical for current use (passengers, their baggage, and cargo containers of a given size). The purpose of this project was to make the first practical test of a new configuration that has been proposed by a colleague working somewhat in isolation in South Africa.

Original Goals
1. Test a new hypothesis about optimal aircraft design for minimum drag
2. Introduce RJ Huyssen to local leading aerospace industry leaders
3. Transfer technology to USC wind tunnel operation.
4. Act as seed for larger-scale investigations and funding

Outcomes
The project was successful in all goals. RJ Huyssen came to USC for one month from April 17th 2010 to mid-May 2010. The experimental work was complex and took longer, with a slightly different configuration than originally envisioned. RJH extended his stay and we were able to cover his costs for one extra week. During that time of almost 24-hour work cycles, an entire data set was covered for the variable configuration model.

The Basic Result
Wind tunnel tests were conducted for three configurations: (1) an isolated wing; (2) the same wing with payload-carrying fuselage; (3) wing + body + tail, where the tail is designed to control and modify the circulation distribution on the body. The main idea is that, unlike present-day aircraft, the body can now act as a lifting device, with the consequence that the overall circulation (lift) distribution of this practical configuration can be tuned to resemble that of the ideal wing in isolation. The measure of this was the distribution of the vertical velocity induced by the wings/body combination. This downwash distribution can be shown to be directly related to the aerodynamic efficiency. Figs 1-4 show the basic result.

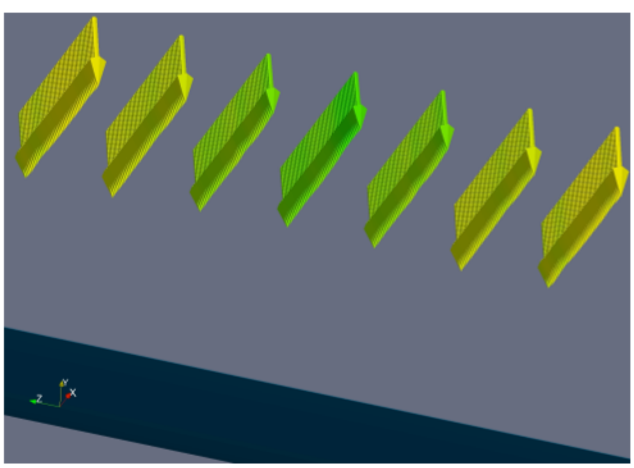

Fig. 1: The ideal downwash distribution is a uniform vertical velocity, which is constant across the span. Experimental data from the wind tunnel experiment demonstrates that such a result is indeed measured. The velocity vectors in one single plane from the 3D volume of data are colored by magnitude. The view is from an observation point behind and below the wing.

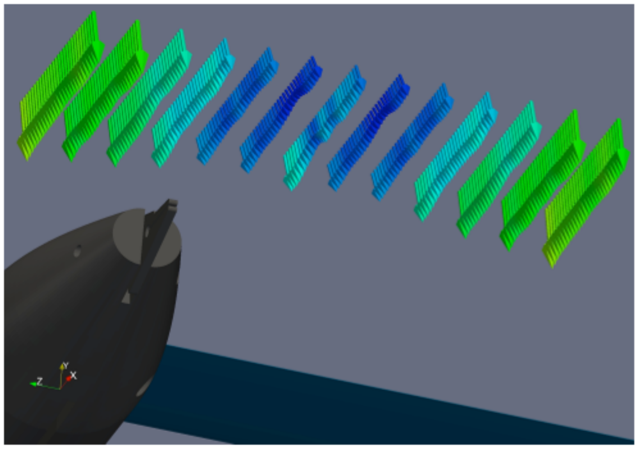

Fig. 2: The presence of a body reduces the vertical downwash velocity magnitude in a significant area of the wake extending in both spanwise and streamwise directions. No particular care is taken in making this body shape a very-well streamlined one. Rather, we pose a big disturbance problem.

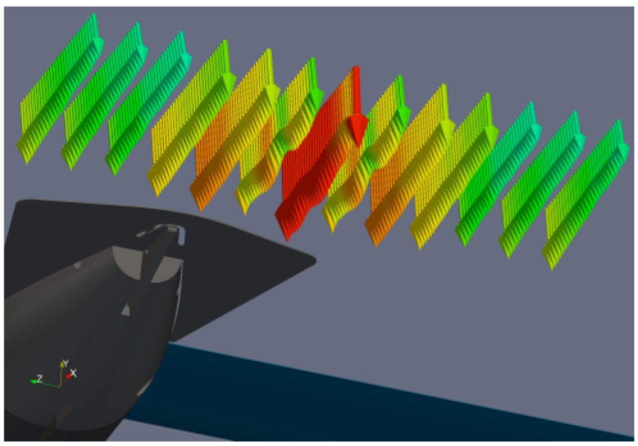

Fig. 3: The addition of a circulation-control tail completely changes the downwash distribution in the wake of the model. The changes imply a higher lift and reduced drag. The downwash magnitude has increased at the centerline, and further deflection of the tail can lead to further lift increases, but with a cost in increased drag.

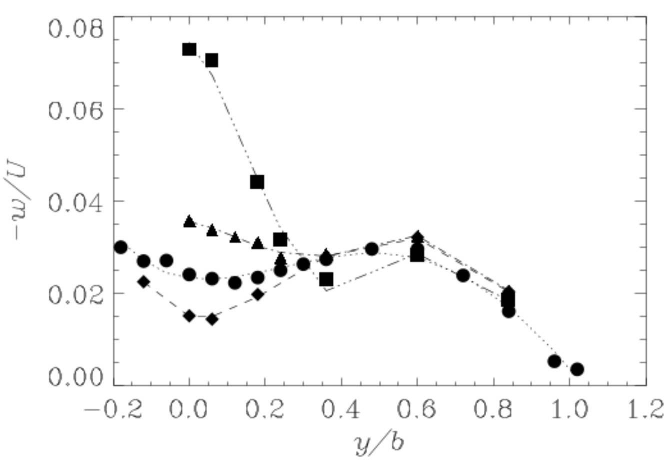

Fig. 4: The spanwise (y/b) variation of normalised downwash velocity w/U shows the wing alone in filled circles, the wing+body in diamonds, and wing/body/tail configuration in small deflection (triangles) and large deflection (squares). The triangle distribution has the least kinetic energy loss per unit downward momentum flux. The highest lift configuration has an integrated magnitude of about 30% higher than wing alone.

Summary and future directions

1. The original premise behind the wing/body/tail configuration was confirmed. Very large deviations from optimal wing circulation distributions can be corrected by a suitable tail geometry. The function of the tail is not the same as in normal aircraft configurations. The main result is described in a paper in preparation for the Journal of Aircraft.

2. Consultations with Mark Page (Swift Engineering) and Blaine Rawdon (Boeing) held in a conference room in OHE were stimulating, encouraging and positive. The USC AeroDesign Team was also briefed. Both collaborations continue.
3. The technology transfer has been completed. Experimental work is continuing in the USC wind tunnel, where the model and fittings now reside. It will form the basis of a new PhD project here.
4. The work has provided original and novel information for proposals to AFOSR. One such proposal is under consideration at present, but funding decisions have not yet been made in that program. The work has been reported at an invitation-only meeting in Cambridge, England in September and will be the subject of a contributed talk at the forthcoming Division of Fluid Dynamics Meeting of the American Physical Society in November. This talk has been abstracted by the APS Press Department, with a 2-page press release, constructed mostly by the PI.

It seems quite clear that the project will run to larger scale, and is in fact only now beginning. We thank the Research Innovation Fund for their support.