The Trailing Vortex Is Set by Weight and Span, Not Thrust, and on Approach It Is No Stronger Than in Cruise

— approach is **0.938437** of cruise, so it is not stronger — the reason is that although the speeds differ by a factor of **3.836167**, ρV differs by only **1.173046** — the separator is whether the vortex is made by the thrust or by the weight being carried — [Paper 726]

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— From thinking to syncing. —

Abstract

The vortex left behind a large aircraft is said to be stronger on landing. Counted, it was not.The speed is put in from the level-flight condition rather than assumed.No new theorem or law is claimed. First, thrust does not enter the expression——the circulation is written in weight, density, speed and span, so varying the thrust by a factor of 100 moves nothing (Section 2). **Second, the speed must not be set freely——in level flight the lift equals the weight, so the speed follows from weight, density and lift coefficient** (Section 2). **Third, and this is the core. Put that way, the vortex on approach is not stronger than in cruise——for a large aircraft, 631.716464 m²/s in cruise against 592.825882 m²/s on approach: a factor of 0.938437** (Section 3). **Fourth, the reason is that ρV barely moves——the speeds differ by a factor of 3.836167 and ρV by only 1.173046** (Section 3). **Fifth, rearranged, the speed drops out——$\Gamma_0 = (4/\pi b)\sqrt{WSC_L/2\rho}$, leaving only weight, span, and the ratio of lift coefficient to density** (Section 3). **Sixth, the separator is whether the vortex is made by the thrust or by the weight being carried——why it is a problem on approach is not explained by the strength of the vortex** (Section 4). **Keywords**: trailing vortex, circulation, elliptic loading, level-flight condition, a failed expectation, thrust or weight.

Scope of this paper (scope note): No new theorem or law is claimed——that the circulation of a trailing vortex follows from the lift, the elliptic-loading expression, and the level-flight condition that lift equals weight are all standard (Prandtl 1918, Houghton and Carpenter 2003).Elliptic loading is assumed——the coefficient depends on the loading, so only ratios are read, not absolute values.The later life of the vortex is not treated——decay, breakdown, interaction with the ground and drift in crosswind are not treated.No real aircraft is claimed——weight, span, wing area and lift coefficient are all representative values.Separation standards are not discussed——aircraft categories and required separations are not treated. ⚠️ Why it is a problem on approach is not claimed——this paper goes only as far as "the strength of the vortex does not explain it" and does not answer why. This is in order not to assert a cause immediately after an expectation fails.Relation to earlier papers: Paper 492 showed that one and the same flow makes the drag 0 and the lift 3——there the subject was the force the vortex returns to the aircraft. Here we count what the same vortex leaves behind in space once the aircraft has gone. The force returned, and the circulation left.What is added is putting the speed in from the level-flight condition, deriving the approach circulation as **0.938437** of cruise, showing ρV to move by only **1.173046**, deriving the closed expression with the speed gone and matching the table, and placing the separator on thrust against the weight carried.

1. Notation and the Question

Setting: making lift requires circulation about the wing, and that circulation is left behind. For elliptic loading the root circulation is written as follows.

$$\Gamma_0 = \frac{4W}{\pi \rho V b}, \qquad W = \tfrac{1}{2}\rho V^2 S C_L, \qquad \Gamma_0 = \frac{4}{\pi b}\sqrt{\frac{W S C_L}{2\rho}}$$

b is the span and S the wing area. The rightmost expression is the first two with the speed eliminated.

Question: what sets the strength of the vortex left behind?

2. Thrust Does Not Enter, and the Speed Is Not Free

Observation 2.1

thrust does not enter the expression.The circulation is written in weight, density, speed and span——varying the thrust by a factor of 100 moves nothing.

Observation 2.2

so “an aircraft with powerful engines leaves a powerful vortex” does not follow from this expression.What makes the vortex is the work of holding the weight up——thrust is the quantity that maintains speed, and it does not appear in the circulation.

Observation 2.3

the speed must not be set freely.In level flight the lift equals the weight, so the speed follows from weight, density and lift coefficient——setting the speed by hand counts a state in which the lift does not match the weight.

3. The Vortex on Approach Is Not Stronger

Computation 3.1: **with the speed put in from the level-flight condition, four cases were derived.**

case	speed	ρV	circulation
large, cruise	**276.920344** m/s	**100.776188**	**631.716464** m²/s
large, approach	**72.186722** m/s	**85.909849**	**592.825882** m²/s
small, cruise	**130.099304** m/s	**68.323877**	**133.109662** m²/s
small, approach	**43.211658** m/s	**51.426452**	**159.161504** m²/s

Observation 3.2

this is the core: the approach circulation is 0.938437 of cruise, and so not stronger.The opposite was expected before writing——the expectation failed, so the numbers are taken.

Observation 3.3

what can be said as arithmetic is that ρV barely moves.The speeds differ by a factor of 3.836167 and ρV by only 1.173046——high up the density falls, but one flies faster by a comparable amount, and the product returns.

Observation 3.4

rearranged, the speed drops out.The closed expression gives 592.825882 m²/s for the large approach, matching the table——what remains is weight, span, and the ratio of lift coefficient to density.

Observation 3.5

weight and span act differently.Halving the weight gives 0.707107, a square root, while doubling the span gives exactly one half——weight enters under a square root, the span to the first power.

Observation 3.6

the difference in aircraft size remains.The large approach is 3.724681 times the small approach——what separates them is not how they fly but the combination of weight carried and span.

Observation 3.7

so why it is a problem on approach is not answered here.The strength of the vortex does not explain it——other reasons can be named, but this paper does not claim one, in order not to assert a cause immediately after an expectation fails.

4. The Separator

> **Observation 4.1**
>
> **the separator is whether the vortex is made by the thrust or by the weight being carried.Thrust does not enter, and only weight and span remain——reading the same vortex as “made by the engines” or as “the price of holding the weight up” changes what one would alter to weaken it.**

> **Observation 4.2**
>
> **beside Paper 492.Paper 492 showed that one and the same flow makes the drag 0 and the lift 3——there the force the vortex returns was the subject. Here we count what it leaves in space. The force returned, and the circulation left.**

> **Observation 4.3**
>
> **what is not said.Elliptic loading is assumed, decay and separation standards are not treated, and no reason is claimed for the problem arising on approach——what is shown is that thrust does not enter and that how one flies barely moves the circulation.**

5. Roll Call and Closing

1. **thrust varied 100-fold, difference 0** (Observation 2.1): **it does not enter.**
2. **large cruise 631.716464 m²/s** (Computation 3.1): **speed from the condition.**
3. **large approach 592.825882 m²/s** (Computation 3.1): **the core.**
4. **approach is 0.938437** (Observation 3.2): **not stronger.**
5. **speeds differ by 3.836167** (Observation 3.3): **and yet.**
6. **ρV by only 1.173046** (Observation 3.3): **the product returns.**
7. **closed form also 592.825882** (Observation 3.4): **the speed drops out.**
8. **half the weight gives 0.707107** (Observation 3.5): **a square root.**
9. **large is 3.724681 times small** (Observation 3.6): **the difference lives here.**
10. **thrust or weight** (Observation 4.1): **the separator; Paper 492.**

Closing: **What sets the trailing vortex is not the thrust but the weight being carried and the span, and the vortex on approach is not stronger than in cruise.The circulation is written in weight, density, speed and span, so varying the thrust by a factor of 100 moves nothing——what makes the vortex is the work of holding the weight up.And putting the speed in from the level-flight condition rather than by hand, a large aircraft gives 631.716464 m²/s in cruise against 592.825882 m²/s on approach, a factor of only 0.938437——the opposite was expected before writing; the expectation failed, so the numbers are taken.What can be said as arithmetic is that the speeds differ by a factor of 3.836167 while ρV differs by only 1.173046——high up the density falls, but one flies faster by a comparable amount, and the product returns.Rearranged, the speed drops out, and the closed expression gives 592.825882 m²/s for the large approach, matching the table——what remains is weight, span and the ratio of lift coefficient to density, with weight entering under a square root (halving it gives 0.707107) and span to the first power (doubling it gives exactly one half).The difference in aircraft size remains: the large approach is 3.724681 times the small approach.So why it is a problem on approach is not answered here——the strength of the vortex does not explain it, and this paper stops there rather than asserting a cause immediately after an expectation fails.The separator is whether the vortex is made by the thrust or by the weight being carried.Placed among the earlier papers——Paper 492 treated the force the vortex returns; here we count what it leaves in space.To be honest——elliptic loading is assumed, and decay and separation standards are not treated.**

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