

## Hybrid contrails over Rangsit, Pathum Thani

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Contrails formed by the freezing of water vapor in engine exhausts behind this plane decay over two minutes in an unusual way. Outer parts of the trails sublime and thin residual trails develop undulations and loops.

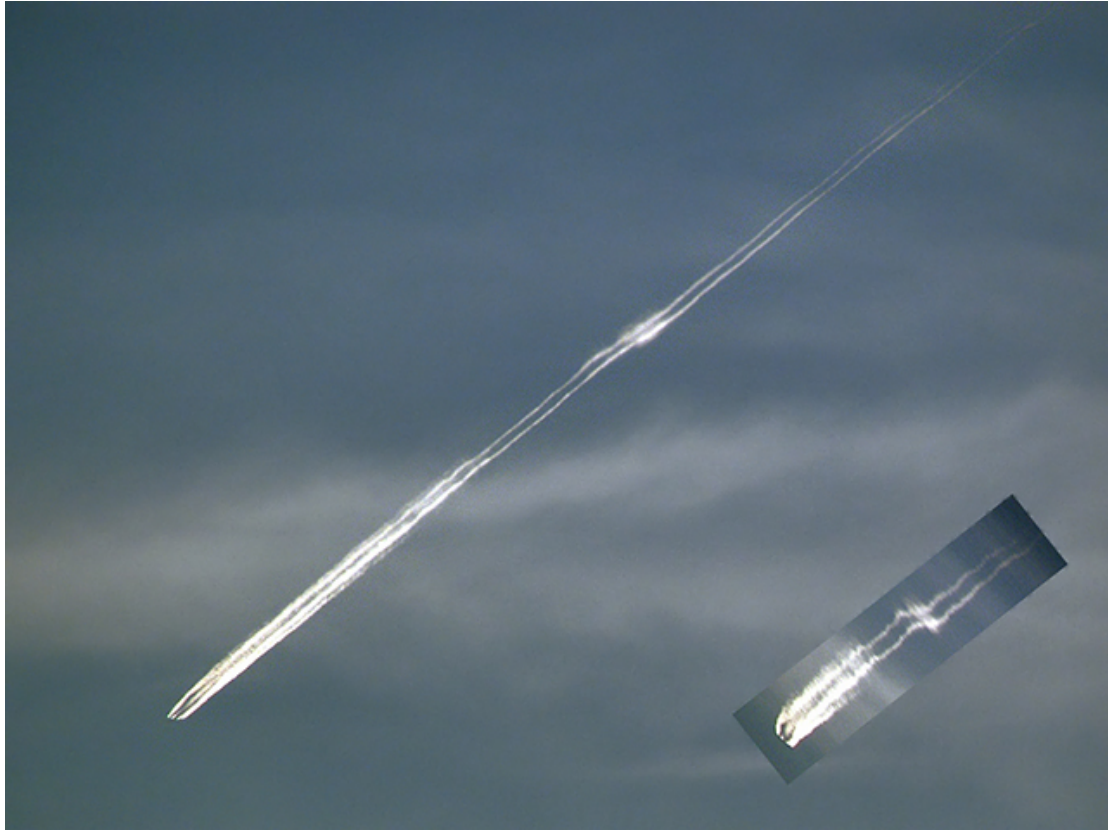


**Fig 1-** A two-engine plane leaves what look like normal engine tails. Two minutes later (inset) the trails have decayed to thin central cores with outer cloud lingering in places.

Several questions can be raised. How are the residual trails formed? Why is decay not uniform over the length of the trail? Slightly younger trails on the left are almost straight. What leads to undulations and loops that become more pronounced with age?

### **Turbulence**

A plane in flight creates two giant counter-rotating vortices formed by a downwash of air over the wings. (This downwash is partly responsible for generating the lift that keeps the plane in the air.) Turbulence persists in the wake of the plane and landings on the same approach path are kept five minutes apart. Under just the right conditions ice crystals entrained along the vortex cores sublime more slowly than outer unconfined crystals. A related effect (also rare) forms horseshoe vortex clouds by condensation along the core of a natural rotating vortex of air. That local conditions are critical can be seen by the changes along the trails in fig. 1 and in fig. 2 below.



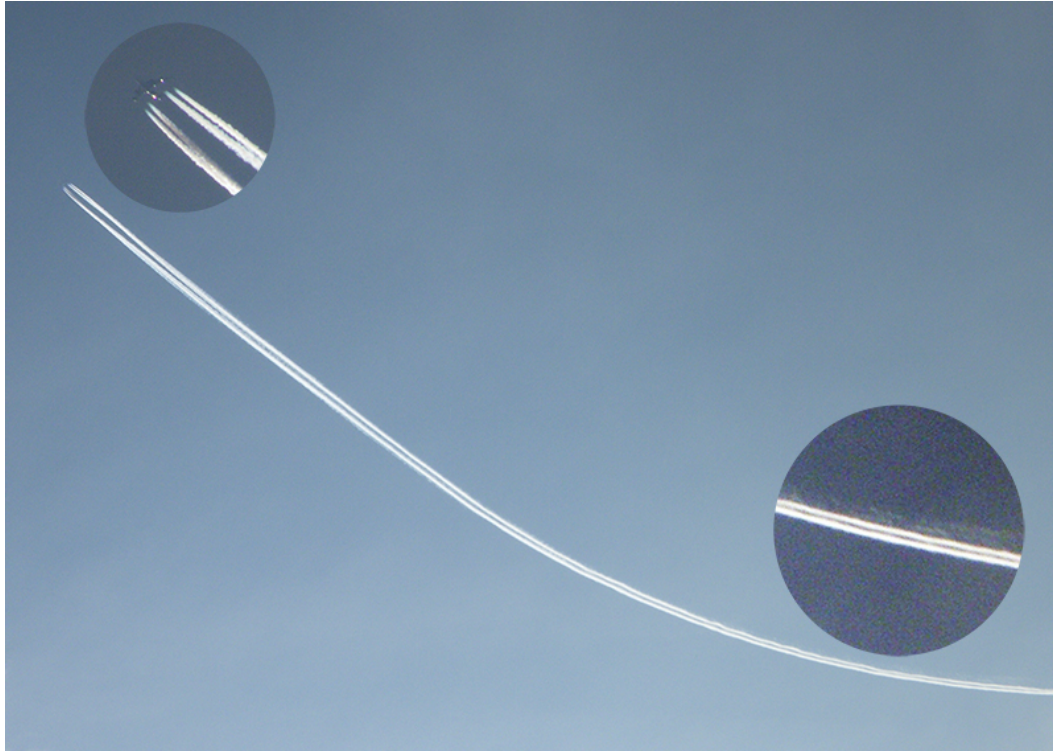
**Fig 2** – four engine trails are reduced to two vortex trails in this distant view, taken on another occasion in Rangsit, Pathum Thani. The vortex trails sublime before Crow instability breaks them into loops.

The inset (figure 2) with reduced scale, shows outer engine trails disappearing and the inner trails doing the same a little slower, but leaving two short-lived vortex trails. The vortex trails do not persist long enough for the Crow instability to develop undulations and break them up into loops and bows.

### **Details**

The life of a vortex tail depends critically on humidity. When engine trails form in very dry air at around  $-40^{\circ}\text{C}$  they persist for a few seconds before sublimation returns the ice to water vapor and the trail is visible for only 10-20 plane lengths. At the other extreme, in very humid air, trails may stretch from horizon to horizon and extend over hours to form wide complex bands of cirrocumulus cloud. Hybrid trails (figures 1 and 2) may form if the humidity is such that ice sublimates over a minute or so but at the lower temperature along the low-pressure core of a vortex the trail persists for longer. On rare occasions when critical conditions are met over a wide area a hybrid trail may age to produce a long series of undulations, loops and bows.

The images below, taken two minutes apart, show what may happen under ideal conditions. They were taken in Rangsit, Pathum Thani in mid-afternoon on December 20<sup>th</sup>, 2010: on the only occasion that the writer has seen this phenomenon.



**Fig 3** – four engine trails (inset) become two.

The development of undulations and loops is shown in the image below.



**Fig 4** – bows and loops along the trail above two minutes later.

See [https://www.flickr.com/photos/jacobs\\_ian/35809760905/in/dateposted-public/](https://www.flickr.com/photos/jacobs_ian/35809760905/in/dateposted-public/) for images. See <http://contrailscience.com/hybrid-contrails-a-new-classification/> for additional images from other sources and a forum discussion.

