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LEFTOVERS / VAPOR TRAILS

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"Leftovers" investigates the cultural significance of detritus.

In early October 1918, a young American army captain named Ward Wells found himself bivouacking with his unit in a patch of forest a little northwest of Verdun, just as a tremendous bombardment up ahead shattered the bright autumn morning. He described what he saw in a from-the-trench letter to his brother back in Iowa:

Our attention was first drawn to the sky by the sudden appearance of several strange and startling clouds—long, graceful, looping ribbons of white. These were tapering to a point at one end, and at the other, where they dissolved into nothingness, 60 degrees across the sky, were about as broad as the width of a finger held arm's distance from the eye.

He and his fellow doughboys had never seen anything quite like it, and they scrutinized the celestial calligraphy with squinting faces:

On close observation we noticed some distance ahead of each cloud point the tiny speck of a chasse plane. Apparently the churning of the air was all that was needed to upset the delicately balanced meteorological conditions and precipitate this strange cloud formation.

It was an astute interpretation of an as-yet untheorized bit of aerodynamics and atmospheric chemistry. Young Captain Wells, who had some scientific training, closed his letter with a poetic flourish:

I had seen ships leave their tracks in the clouds, similar to those of little sea animals in the wet sands at the shore, but never before had I seen a plane writing in white upon the blue slate of the sky.[1]

This was not, of course, "skywriting"—at least not in the conventional sense of an airplane making smoke intentionally for the purpose of inscribing messages in the air. Such skywriting did not yet really exist in its conventional form, and anyway the aces dueling for position over the battlefield had no time for playful tracery. What Ward Wells and his comrades witnessed on that otherwise cloudless morning was in fact one of the very earliest documented occurrences of a meteorological phenomenon now familiar to all of us—what have come to be called *contrails*, the streak-like white wisps that (sometimes) lace the sky where planes have passed.[2]

I turn my head right now and look out the window, and there are two of them overhead: one a loose and tufted relic, only distinguishable from the cirrus ribs with which it lies on account of a slight skew; the other presently streaming in fresh billows from a silver jet raking the cerulean vault.

What are contrails? Why do they form? To whom do they matter?

Bracketing a powerful strain of paranoia-spectrum analysis that has vexed these questions in the last decade (to which I will return), the physics of contrail formation is helpfully disclosed in the etymology of the term itself, a portmanteau contraction of *condensation* and *trail*. Contrails are visible ribbons of water vapor suspended in the atmosphere, which is to say, they really are clouds—linear, anthropogenic clouds. They happen under two quite different scenarios.

Let's do the less important (and less common) one first. Most powered flight works by creating (via a precisely shaped wing or propeller slicing through the air) local regions of low pressure. Depending on just how low that pressure gets, and how fast it gets low (and some other factors that have to do with the mechanics of vortices), you can actually get a substantial sudden drop in temperature in these low-pressure regions. This is not totally unrelated to the phenomenon that causes your canister of compressed gas to get very cold when you vent its contents. If these low-pressure zones get cold enough in relation to the humidity of the air in question, you hit the "dew point"—that sweet spot of pressure and temperature at which a gaseous substance (in this case H_2O in its gaseous state in the atmosphere) becomes a liquid (in this case liquid H_2O, suspended in droplets in the air), i.e, *condensation*.[3] A stream of that finely particulate condensation flowing out behind the wing or propeller tip will be a whitish streak of contrail. It's even possible that the temperature drops so low that the tiny water drops *freeze*, which actually looks about the same, as far as the contrail is concerned—if perhaps a little whiter and often slightly more durable as the indicative mist hangs in the empty air.

Contrails of this first type (sometimes called "visible wing-tip vortices" or "aerodynamic contrails") tend to be short-lived, and mostly appear during high-strain and/or high-speed maneuvers. Fighter jets generate them as they bank hard or climb fast. But passenger planes can produce them too, generally speaking only at takeoff and landing, and only if the weather conditions are just right.

Usually when people talk about contrails, however, they are talking about the other kind—like the high, straight, persistent ones outside my window right now. These are the product of the same basic "event" (the airborne condensation/freezing of gaseous water) but the key water in question in this second type of contrail is not water just "there" in the air as the plane passes. It is, rather,

the water that results from the combustion of fossil fuels—water, that is, in the exhaust of the plane's engines.

When you "burn" a hydrocarbon (methane, butane, gasoline, jet fuel, etc.), what you are doing is ripping up some bonds between atoms of hydrogen and carbon by means of a rapid chemical reaction (i.e., *combustion*) with molecules of oxygen. The main products of this violent recombination, besides a lot of energy, are carbon dioxide and water. So airplane engines, like basically all engines (whether jet or internal combustion), release a lot of gaseous water into the atmosphere. If you do that at thirty-five thousand feet or so, where it is, say, minus sixty-five degrees Fahrenheit, that water vapor is very likely to condense and instantly turn into ice crystals—leaving a wake of white cirrus trailing behind your engines. These are the contrails of the high sky—the cold darts and long tracks that tail the metal birds.[4]

The history of contrails is difficult to separate from the history of aviation. As Ward Wells's letter makes clear, streamer clouds trailing airplanes were a novelty in 1918—novel enough that his correspondence eventually found its way to publication in *Scientific American* the following year, as evidence for a hitherto unseen phenomenon, a phenomenon in need of an explanation. While heavier-than-air aviation was by then already more than a decade old, it took the exigencies of war (together with the derring-do of stunt pilots) to push the early flying machines to the extremes of force and altitude that generate vapor trails. For instance, another of the earliest published accounts of the phenomenon accompanied a breathless report on Major Rudolph W. Schroeder's near-fatal attempt on the world altitude record in September of 1919. Running out of oxygen around thirty-six thousand feet, Schroder apparently lost consciousness, and dropped some thirty-three thousand feet in less than three minutes, as the ice in his goggles froze over his eyelids:

For a brief time residents of Dayton [Ohio] were sure a comet had appeared in the sky. They had mistaken the trail of vapor escaping from the machine as it sped downward for a "stranger in the heavens."

The exhaust gas from the airplane, freezing in the frigid temperature, caused a cloud-like formation, resembling the tail of a comet, to hang below the clouds. Inasmuch as the airplane was not visible, speculation varied as to what it was. Some witnesses were inclined to the belief that a strange body was coming with a message from Mars. Professor William Beck, the astronomer at St. Mary's College, making observations through a telescope, discerned the airplane.[5]

Schroeder lived (though he did not recover his sight for some time), and his vapor trail streaked the upper limits of powered flight in those years.

More high-altitude flights in the decades ahead made the phenomenon less exotic, but it would take the rise of reliable jet aviation in the period immediately following World War II to make the avionic vapor trail sufficiently commonplace as to demand a new word. The term *contrail* was coined in the mid-1940s. By that time, long, thin, pointer-clouds pricking out high-flying bombers (and their fighter escorts) had become all too familiar to civilians and military personnel alike across much of Europe and the Pacific, causing considerable concern to those engaged in the sneak-attack game of strategic air warfare.[6]

And it was in this context that a US Air Force–trained meteorologist named Herbert Appleman set to work on the problem, with an eye toward developing a quantitative model for the conditions under which exhaust contrails could be expected to occur. The result, published in 1953, can be thought of as a rule-of-thumb guide for high-flying pilots trying to avoid divulging their daytime location.[7] If you plotted the relevant variables (altitude, humidity, temperature), you ought to be able to find a flight path that kept you out of vapor-trail zones. The Appleman chart and its descendants duly became standard tools in contrail avoidance, but they were never foolproof—there being enough wonky factors in the weather and the behavior of air around fast-moving bodies to make for plenty of undesirable contrail surprises.[8] The problem was sufficiently serious (there being no obvious way to eliminate engine exhaust) that a pinnacle technology of secret Cold War surveillance, the U2 spy plane, was forced to rely on an ultra-low-tech hack to minimize contrail disasters: a little rearview mirror on the side of the plane. If the pilot saw a contrail behind his craft, he was supposed to change altitude in a hurry. Down on the ground, sky-watching civilian Cold Warriors, like members of Britain's Aircraft Recognition Society, read up on how to identify specific airplanes by their contrails, and later sentinels scoped out other details of celestial tracking: "distrails," for instance ("negative" contrails—clear streaks made through cloudy skies by the passage of aircraft), and contrail *shadows* (sometimes visible on the underside of light clouds), which could disclose the passage of a high-flying airplane above the cloud ceiling.[9]

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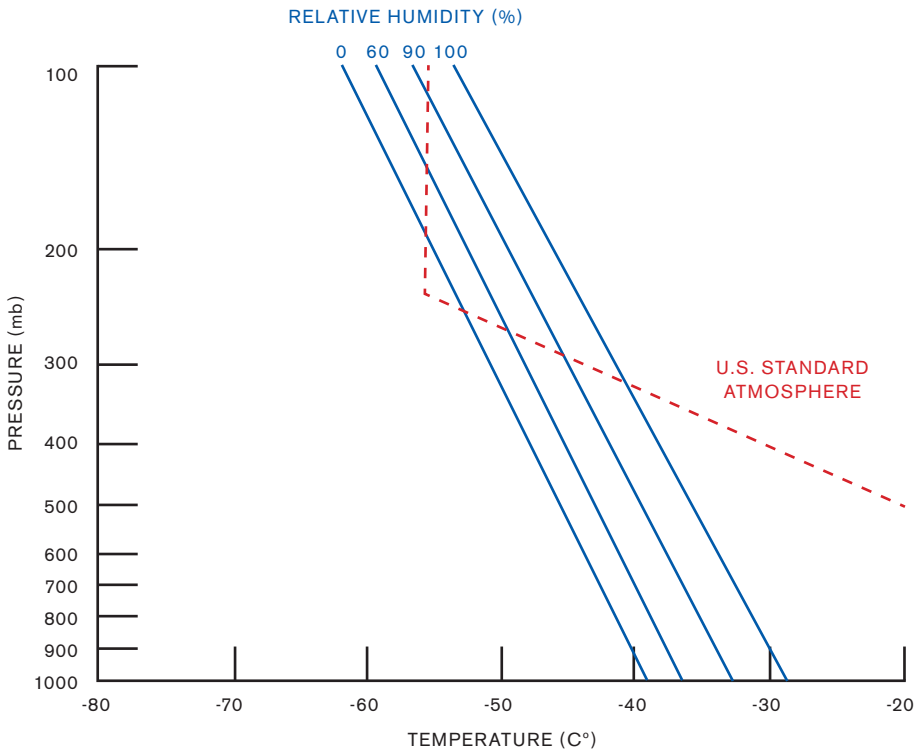
This 1950s nexus of military-industrial paranoia, anthropogenic cloud monitoring, and civilian sky gazers has proven strangely durable—if also unsettlingly plastic. For about a decade now, a vast conspiracy-theory subculture out there in the interwebs has promoted, with stupefying energy and commitment, the notion that some, many, or even all visible contrails are in fact properly



understood as *chemtrails*: miasmatic evidence of a sweeping government plot to deploy aerosol spraying across the country (and perhaps the world). Many argue that this has something to do with climate change geo-engineering, but others allege large-scale human experimentation, genetic manipulation of populations, and possible military objectives. It is a passionate community, if somewhat shadowy, and at times genuinely enraged. For all that, its partisans have had some success in forcing their issue to the edges of respectable investigative reporting and non-fringe documentary filmmaking.

I could be wrong, of course, but I spent some time with the available material, and it seems that there is nothing to it at all. Contrails are contrails. They have been around for a long time. They are not new, and the things that are streaming out of the airplanes outside my window are contrails. There is a lot of good evidence for all this. While from time to time people do spray stuff from airplanes, and while this has surely been, on a number of notable occasions, a very bad idea, commercial airlines are not being deployed in a secret, large-scale plot to defeat our enemies, willfully transform the earth and its inhabitants, or poison us by nefarious means. While contrails themselves, it turns out, may indeed be slightly altering the weather (because they actually slightly add to the earth's total cloud cover), this has absolutely nothing to so with so-called chemtrails, which, in a basic sense, do not exist.[10]

When I first turned to the topic of contrails, I was motivated by what seemed to me the poetry (and poignancy) of these ephemeral indications of human movements through the upper atmosphere. If on earth, we leave expressive threads of footprints, and in the water we open the self-closing sea-wound of a wake, then the air-equivalent of these marks of passage would be the contrail, a kind of comet tail to our celestial ambitions. I thought I would sift some forgotten sources in an effort to recover the records of the early encounters with the phenomenon, in the hopes of finding a freshness of perspective on a sky effect that has long since become a commonplace—but that I suspected would once have been met with surprise, and even wonder.

But the surprise, in the end, was entirely my own: there is, in fact, really no such thing as a "forgotten source" bearing on contrails. As a direct result of more than a decade of hot Internet conflict between

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Above: Herbert Appleman's nomogram, 1953. Temperature and pressure measurements falling in the region to the left of the 0 percent humidity line could be assumed to constitute contrail-forming conditions, according to the Appleman model, while the region to the right of the 100 percent line could be assumed to be contrail-free. For the intervening zone, contrails would be assumed to form behind a passing jet at a given pressure (altitude) if the temperature fell to the left of the relevant line indicating the observed ambient relative humidity.

chemtrail advocates and their equally impassioned opponents/debunkers, *essentially every single historical instance of the observation of a vapor trail in the sky* has not only been tugged up from the archives of oblivion, it has also likely been subject to layers of critical scrutiny and trenchant commentary. We basically have crucible-tested knowledge of the full universe of contrail appearances of any and all imaginable forms across the twentieth century. Thousands and thousands of photographs of contrails dating back to the interwar period have been posted to websites dedicated to this purpose in the belief that the long and well-documented existence of contrails refutes the conspiracists' arguments concerning the ostensibly nefarious innovation of chemtrailing.[11] You can quickly find, for instance, that a shockingly anachronistic contrail streaks the backdrop sky thirty-four seconds after the title credits in John Ford's elegiac 1964 western, *Cheyenne Autumn*—set in 1878. Interested in the history of contrails being seen as meteors or even UFOs? There are extensive and well-documented online discussions of both matters.

For the historian, it is an incredible thing: crowd-sourced, paranoia-driven, globally aggregated research of a sort heretofore entirely beyond the dreams of the most dogged student of the dusty shelves. The resulting archive of contrails may be the best-documented collection of sources on anything that I have ever encountered.

I have, of course, written this piece out of that archive, and as I now push away from the desk, I am struck, looking out the window, by the strange weather and the weird vortices that sometimes cause the passage of time, winging by, to leave dense trails of visible condensation hanging before the eye.

Dichten = Condensare.

1 These extracts from Wells's communication survive because his brother conveyed the observations to *Scientific American*, which published them on 7 June 1919 (vol. 120, no. 23, pp. 600–601).

2 For an impressively detailed account of the early sightings and their interpretations, see Donald R. Baucom, "Wakes of War: Contrails and the Rise of Air Power, 1918–1945—Part I: Early Sightings and Preliminary Explanations, 1918–1938," *Air Power History*, vol. 54, no. 2 (Summer 2007).

3 It should be said that a significant factor in this process, as in any process of atmospheric condensation (rain, snow, fog), is the availability of "condensation nuclei," e.g., little particles of dust, etc., that facilitate the transition of gaseous water to its liquid form. In the case of exhaust contrails, particles of various exhaust products provide these nuclei in abundance.

4 As it happens (this is nuance, but worth getting right), with big, persistent contrails the majority of the visible water you are seeing actually *is* atmospheric water—it is atmospheric water the condensation of which has been catalyzed by the initial condensation of the water of combustion streaming out of the airplane engines.

5 "Major Schroeder in New Altitude Flight," *Aircraft Journal*, vol. 6, no. 12 (20 March 1920), p. 14. This account of the formation of the contrail is surprisingly precise, given the many theories that circulated around these apparitions in the early years. As it happens, a brief scientific account of the phenomenon did appear in 1920, authored by the great German polar researcher and geophysicist Alfred Wegener, but it was not abstracted in the English-language literature until 1921: Alfred Wegener, "Frostübersättigung und Cirren," *Meteorologische Zeitschrift*, vol. 37 (1920).

6 A valuable index of the general understanding of vapor trails among English-language aviators and aviation professionals at the outbreak of the war is afforded by *Flight* magazine's pair of publications in 1940: "Visible Vortices?" (18 July 1940) and "Visible Vortices" (5 September 1940). The former served as a call for correspondence from those who had seen vapor trails and "who have any additional facts to add or any alternative explanations to give." The latter summarized the results of the query.

7 Herbert Appleman, "The Formation of Exhaust Condensation Trails by Jet Aircraft," *Bulletin of the American Meteorological Society*, vol. 34, no. 1 (January 1953). For a sense of similar (non-classified) work through the war, consider A. M. Descamps, "Les traînées blanches d'avions," *Ciel et Terre*, vol. 61, nos. 7–8 (July–August 1945).

8 For a detailed treatment, see Frank G. Noppel, "Contrail and Cirrus Cloud Avoidance Technologies" (PhD thesis, Cranfield University, 2007).

9 "Identification by Contrails," *Flight*, vol. 70, no. 2480 (3 August 1956). See also "Contrails and the GOC [Ground Observer Corps]," *The Aircraft Flash* (published by the US Air Defense Command), vol. 2 (1953).

10 The idea that aviation-induced clouds might have a measurable effect on weather patterns appears to have been first mooted in 1970 by the American geophysicist Wallace B. Murcray in his "On the Possibility of Weather Modification by Aircraft Contrails," *Monthly Weather Review*, vol. 98, no. 10 (October 1970). He ends his meditation on the question with a solid invocation of Dr. Strangelove-esque anxiety: "In conclusion, it should be stated that if contrails are affecting the weather it is not necessarily for the worse, although if there is any considerable change it is sure to make someone unhappy. The Russians might well be pleased with an ice-free Arctic Ocean; but if it leads to major glaciation in central Canada, it is unlikely that the Canadians and Americans would regard it as favorable." For a useful recent review essay on the question, see Ulrich Schumann, "Formation, Properties and Climatic Effects of Contrails," *Comptes Rendus Physique*, vol. 6, nos. 4–5 (May–June 2005). Perhaps the most striking recent work in this area has been that of Rob MacKenzie, now at the University of Birmingham. He and his colleagues used historical records of World War II bombing raids, which produced dense contrail cover, to assess local climate variation. See A. C. Ryan, A. R. MacKenzie, S. Watkins, and R. Timmis: "World War II Contrails: A Case of Aviation-Induced Cloudiness," *International Journal of Climatology*, vol. 32, no. 11 (September 2012).

11 See, for example, <contrailscience.com/about>.