What's in a Winglet?: Inside the Epic Quest To Build a Better Airplane Wing

Winglets predate the Wright brothers, but it took nearly a century for the idea to go mainstream.

// BY ERIC TEGLER JUL 5, 2020

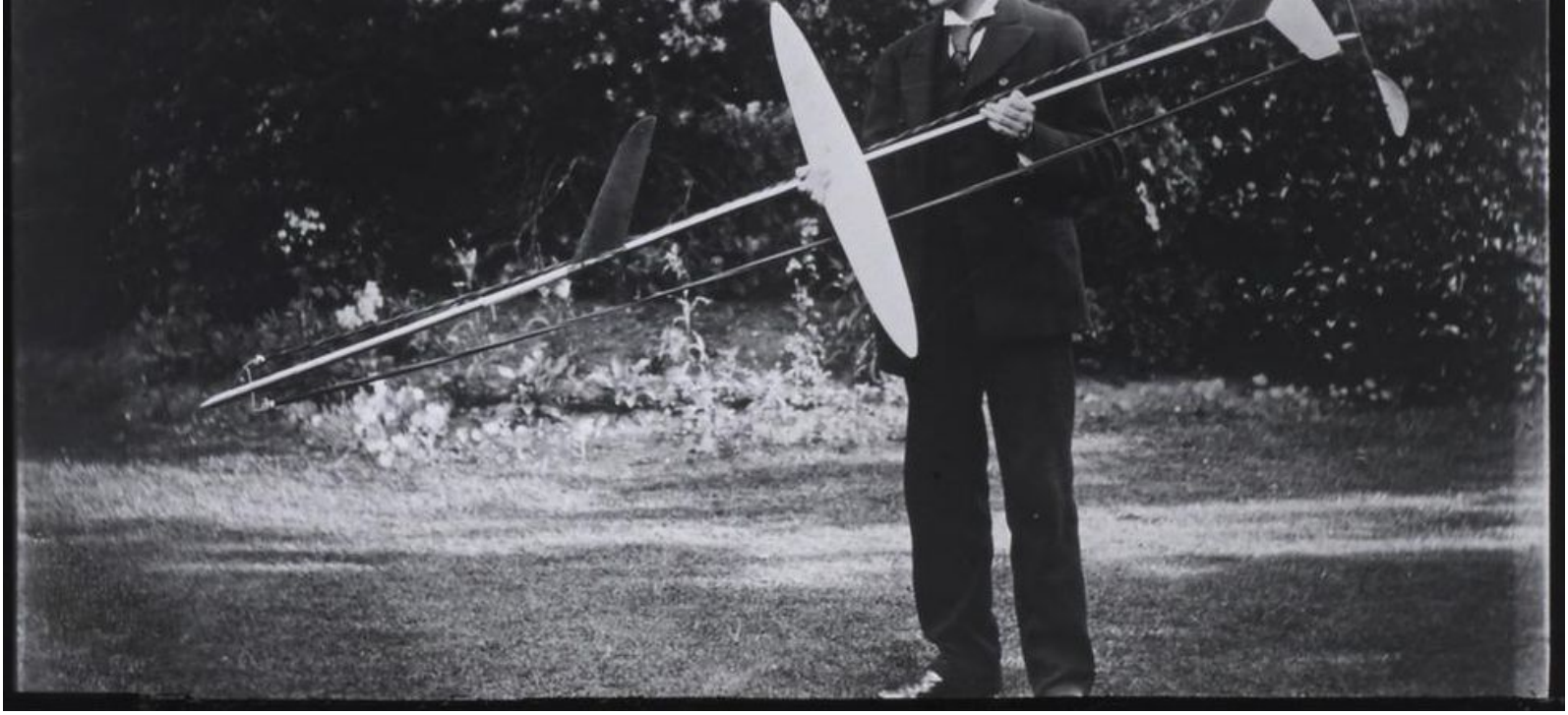
HORACIO VILLALOBOS

When Boeing's new 777X taxied out for takeoff for its first flight earlier this year, it shared the look of most modern airliners. Its long fuselage was flanked by two massive engines under its long wings—the tips, known better as "winglets," turned up in familiar fashion.

This is just the latest chapter in a 120-year-long quest to create a better airplane wing. Today, Boeing, Airbus, Embraer, Gulfstream, Bombardier, and other manufacturers produce multiple aircraft types with winglets, but as recently as the late 1990s, you rarely saw winglets on passenger aircraft.

Here's what gave rise to the little-known-but-immensely-important winglet.

ENDPLATES AND EARS



Frederick William Lanchester posing with one of his gliders in 1894.

LANCHESTER INTERACTIVE ARCHIVE

The idea of turning a wingtip up (or down) dates back to the 19th century. In 1897, English engineer Frederick W. Lanchester patented the placement of end plates vertically at the tip of a wing to control wingtip vortices.

William Sommerville's biplane takes off in Coal City, Illinois. This flight is widely considered the first one to ever feature winglets.

COAL CITY PUBLIC LIBRARY DISTRICT

Generally only visible in high moisture conditions, clouds, or fog, vortices appear as twisting ribbons of air behind the wing, almost like mini tornadoes turned sideways. As air flows over the wingtip of a conventional airplane, it tends to roll upward from the high pressure area under the wing to the low-pressure area above it. At speed, airflow over the tip of the wing is also forced backward. This backward flow combines with the upward roll from under the wing to form a vortex.

They may look cool, but they're a major drag, literally. Vortices cause lift-induced drag, lowering the efficiency of the wing.

Though Lanchester recognized the problem, he never demonstrated his endplate on an aircraft. That feat would be left to Scottish engineer William Sommerville, who in 1910 patented what are considered to be the first functional winglets. Further research was done in the 1920s and 30s, but it wasn't until World War II that winglets became more common.

SAN DIEGO AIR AND SPACE MUSEUM ARCHIVE/ WIKIMEDIA COMMONS

Germany's late-War Heinkel He-162A jet fighter incorporated many advancements including winglets. Integrated by Messerschmitt/Heinkel designer, Alexander Lippisch, the 162A's winglets turned down instead of up. Their appearance gave rise to the nickname "Lippisch-Ears." This style of drooped wingtip later became associated with German aerodynamicist Sighard F. Hoerner, whose influence led them to be used on gliders and light aircraft led to a new nickname: "Hoerner tips."

But as aviation developed in the post-War era, winglets disappeared from most commercial and military aircraft—until 1973's global oil embargo.

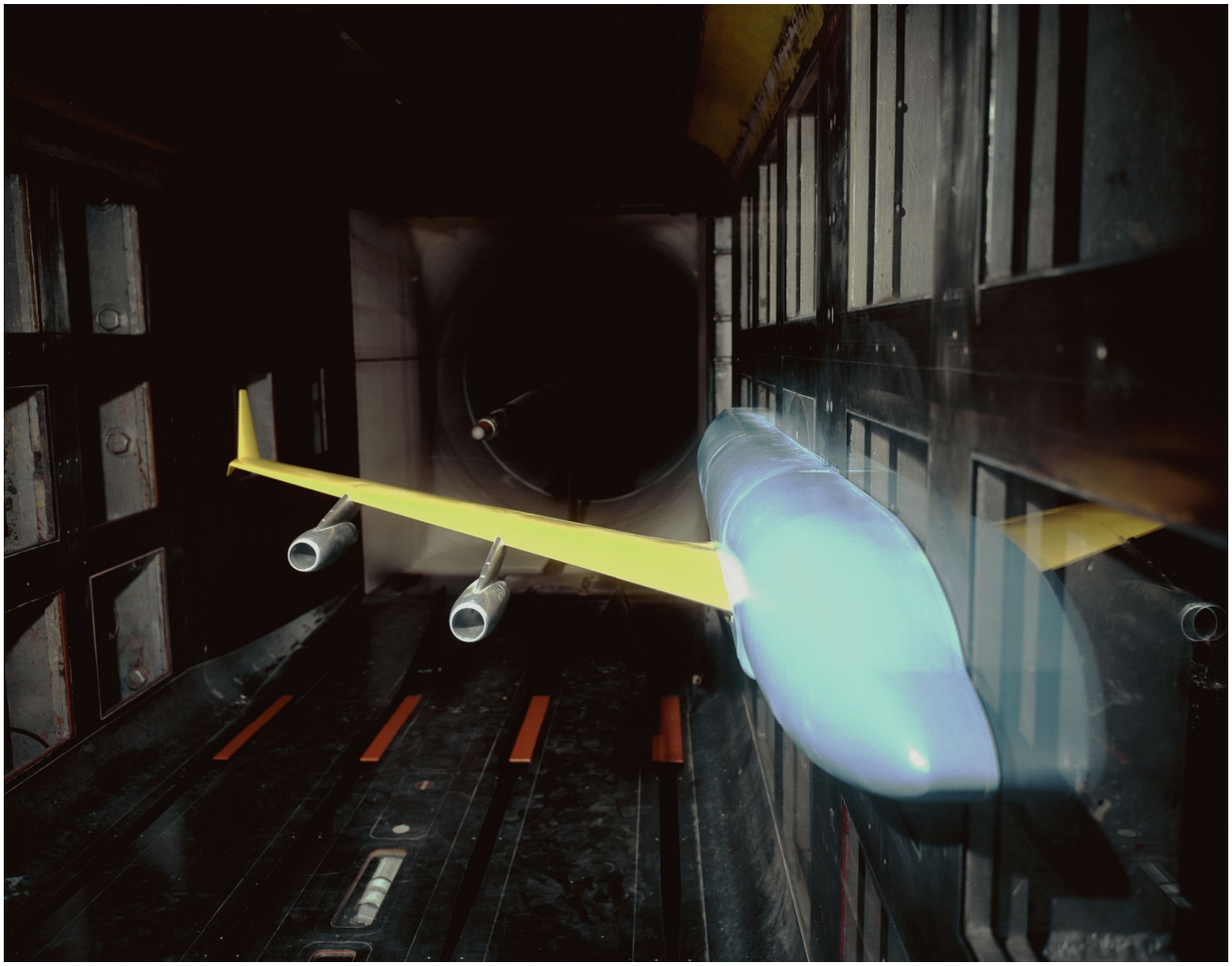
LESS DRAG = LESS FUEL

A retouched image of NASA Langley's Research Center's work on airplane vortices. Winglets are designed to cut down drag created by these vortices.

NASA

When the Organization of Arab Petroleum Exporting Countries (OPEC) drastically cut oil exports in the fall of 1973, crude oil went from $3 per barrel to almost $12 a barrel by March, 1974. Then (same as now) fuel accounted for 40 to 50 percent of operating costs of a single flight, depending on the type of airliner used. It was no surprise that airlines were hit hard.

The dramatic spike in oil prices got Richard Whitcomb, an aeronautical engineer at NASA's Langley Research Center, thinking about winglets. He had studied Lanchester's original concept and surmised that making the vertical surface of a winglet a refined airfoil would more effectively allow it to interact with the wingtip airflow vortices, reducing drag.



Winglet model being tested inside the 8-Foot Transonic Pressure Tunnel at NASA's Langley Research Center, 1970s.
NASA / LANGLEY RESEARCH CENTER

Whitcomb began a series of wind tunnel tests using a model of a DC-10, evaluating winglets at different airspeeds with different flap and aileron configurations. He found that adding them to the DC-10 model reduced overall drag by five percent compared to the model without the devices. In the mid-1970s, Boeing made its own engineering study of a 747 with winglets, which predicted a four percent reduction in aero drag.

As the NASA and Boeing studies went forward, Bill Lear's innovative Learjet Corporation actually put winglets on its prototype Learjet 28 business jet in 1977. It became the first production jet to use winglets. In flight testing, they reportedly increased range by 6.5 percent. Bizjet maker, Gulfstream, also experimented with winglets in the late 1970s, installing them on the Gulfstream III in 1980.

The collective research inspired a test program for an airliner-sized aircraft at the NASA Dryden Flight Research Center in 1979-80. The U.S. Air Force furnished a KC-135 aerial refueling tanker (similar to a Boeing 707) for testing and Boeing built prototype winglets measuring nine feet high and six feet across at the base.

NASA's KC-135 featuring Richard Whitcomb's winglet design during a test flight on July 24, 1979. These tests showed that winglets provided a 7 percent improvement in range over the standard KC-135.

NASA

The winglet-equipped KC-135 first flew on July 24, 1979. Another 47 test flights followed, evaluating it against the stock KC-135 configuration. The results were close to what Whitcomb had forecast in his wind tunnel studies, only better. Drag decreased by 6.5 percent according to NASA with a corresponding reduction in fuel consumption.

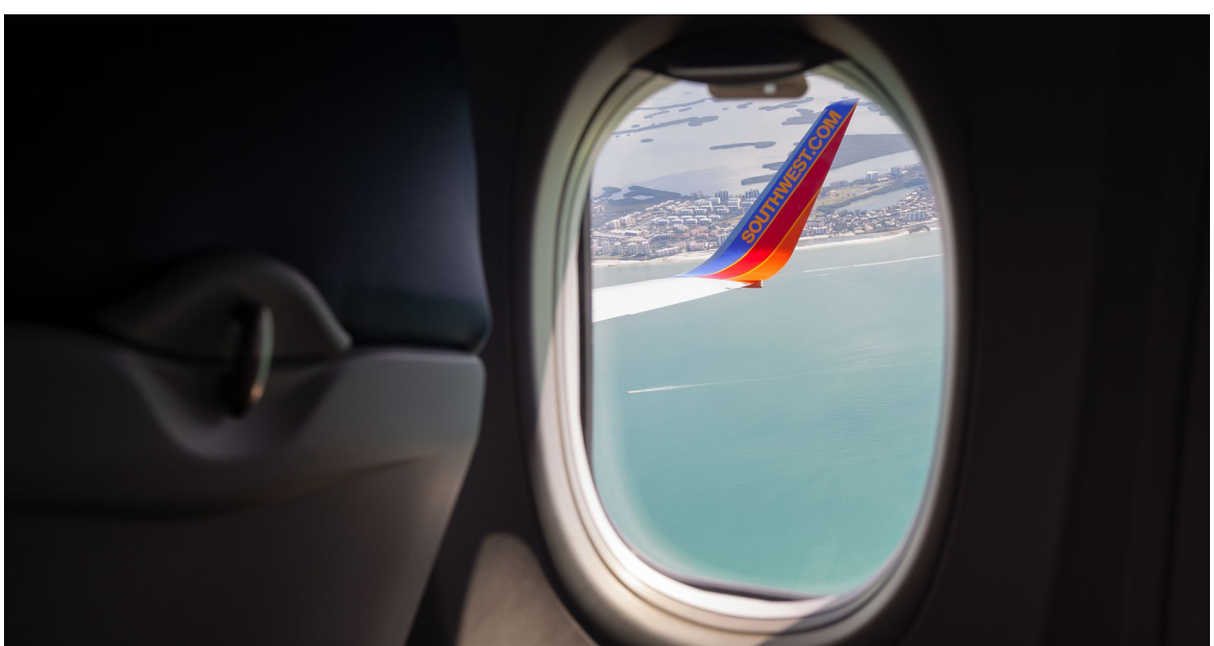
CERTIFIED BADASS

Why the 747 Is Such a Badass Plane

Despite the added fuel benefits, it still took awhile for the aviation industry to catch on. In the mid 1980s, Boeing was looking to revamp flagging sales of its 747 Jumbo Jet by increasing range and lowering operating costs. The 747-400 was the first commercial airliner ever to feature winglets. According to Boeing, winglets increased the 747-400's range by 3.5 percent over its 747-300 predecessor.

While it seemed that winglets had *finally* arrived (McDonnell Douglas' MD-11 debuted them in 1990), a small Seattle aviation company would be the one to really accelerate winglets as a standard feature in modern aviation.

BLENDED WINGLETS



Example of a blended winglet on a Southwest Airlines airliner.
SOUTHWEST AIRLINES

As Boeing cranked out its 747-400, Joe Clark was well into a career that included Learjet sales, establishing a regional airline, and selling ex-military training aircraft to American companies and individuals. One day his business partner, Dennis Washington, called. He'd admired the winglets on Gulfstream's GIII and asked Clark if he could add a pair to his own Gulfstream GII.

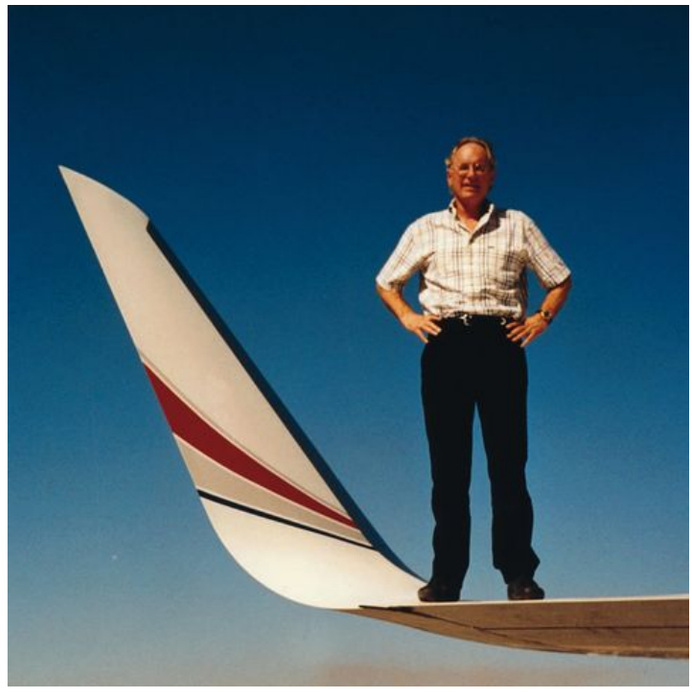
"He really just wanted to modernize his airplane and make it look better," Clark told *Popular Mechanics*. Instead of simply installing the standard GIII winglets, Clark gathered together a team of retired Boeing and Lockheed engineers and came up with a new concept–the blended winglet.

While canted winglets, like the ones on NASA's KC-135, attach to the wingtip at a sharp angle approaching 90 degrees. A blended winglet attaches to the wing with a smooth curve instead of a sharp angle, reducing interference drag at the wing/winglet junction. Shaping and sizing the winglet properly is crucial to getting a vortex away from the flat, planar part of the wing Clark says. His newly formed Aviation Partners Incorporated (API) evaluated different shapes for Washington's GII wing, finally building prototypes.

In 1993, Clark's team flew the GII with its blended winglets. The bizjet had 7.2 percent less drag with its new appendages. The improvement spurred an aftermarket business building blended winglets for the Gulfstream II, eventually equipping over 80 percent of those produced.

Ironically, most business jet customers aren't really motivated by the fuel efficiency gains Clark says. "They do it for the looks. The perception is that when you put winglets on, you get what looks like a whole new airplane."

API's blended winglets are on over 1,000 business jets today, including the Hawker 800 and Dassault Falcon. As API's success grew, it made an agreement with Boeing to install winglets on its 737-derived Boeing Business Jet (BBJ) in 1996. The BBJ caught the attention of airlines who, like bizjet owners, dug the look of blended winglets.



Joe Clark standing on the wing of a Gulfstream II, featuring the new blended winglet.
AVIATION PARTNERS

Winglets: A Visual Guide

Blended Winglet

Canted Winglet

Sharklet

Spiroid Winglet

Split-Scimitar Winglet

"When the airlines came to me they said 'We know they don't work'. I said, let me do a study. We did it and I told them they'd get between five and seven percent better fuel efficiency. 'Impossible,' they said. I said, I'll build a set of prototype [blended winglets] and fly them at my expense if you give me an airplane."

Clark got one of the first Boeing 737-800s, owned by Air Berlin, flight tested with blended winglets and achieved the fuel efficiency gains he promised.

“They were so impressed with the winglets, they installed them on their first 60 [737-800] airplanes," Clark says.

In 1999, API formed a joint venture with Boeing (Aviation Partners Boeing) to sell aftermarket winglets for its 737NG airliners. The company subsequently developed blended winglet programs for the Boeing 737 classic, 757, and 767-300ER. API has installed 20,000 winglets on 10,000 airplanes (900 bizjets, 9,100 airliners), saving an estimated 10.4 billion gallons of fuel.

THE FUTURE OF WINGLETS

JASON REDMOND / GETTY IMAGES

One of the advantages of winglets is that they effectively increase wingspan without increasing the horizontal length of the wing. That’s an issue for the 777X which, as the largest twin-engined widebody ever made, has a wingspan of over 235 feet–23 feet more than the older 777-300 variant.

The longer wing means the 777X cannot fit into the gate and ramp areas commonly used by the 747-400 and 777-300ER. To address the problem, Boeing integrated 24-foot folding wing tip sections, called "raked wingtips."

On the ground, they’re folded up, looking like canted winglets. But before takeoff, the flight crew folds them down, regaining the full wingspan. The tips fold up again on landing as soon as the 777X’s ground speed slows below 50 knots.

An animation of the Boeing 777x raked wingtips in action.

Raked wingtips (also on the 787) have a higher degree of sweep than the rest of the wing. They're said to interrupt wingtip vortices and decrease drag much like winglets. Boeing and NASA assert that raked wingtips have been shown to reduce drag by as much as 5.5 percent, as opposed to improvements of 3.5 to 4.5 percent from conventional winglets.

Joe Clark disagrees.

"My office is right off the main runway at Boeing Field and I watched 777X land, watched those wingtips fold-up and I thought, what an insane idea!," Clark told *Popular Mechanics*. "If you put winglets on the 777, you'd have the same or better performance for the wingspan and you wouldn't have to worry about the gate space. Now they have to fold [the tips]. It's nuts."

Popular Mechanics reached out to Boeing, but the company said its engineers were unavailable, but NASA Langley's Rich Wahls, Strategic Technical Advisor for its Advanced Air Vehicles Program, says "there are design trade-offs for both. You can make a winglet or a raked tip work. It really depends on the [specific] wing and airplane."

A close-up of Airbus's "sharklet" on its A330neo.
AIRBUS

Since the blended winglet, API has developed a split-scimitar winglet, now seen on over 700 737NGs, notably Southwest and United Airlines. The company has also been working on spiroid winglets, which look like a loop of rigid ribbon at each wing tip, and a new "super winglet" is also in the works.

Today almost all airliner manufacturers build winglets. Airbus' winglet design, called the "Sharklet," can be found on the A330neo. These winglets attach to the wing with a smooth curve rather than a sharp angle, lowering interference drag where the wing and winglet pair together. In fact, the drag-reducing design is so similar to API/Boeing's blended winglets that it spawned a years-long patent dispute. Eventually, Airbus paid an undisclosed sum to the American-based companies.

Nearly 120 years after Frederick W. Lanchester's original patent, winglets are evidence that early aviation pioneers knew more about aerodynamics than we give them credit. This century-old concept has finally become a permanent part of modern aviation engineering—and it'll likely fly well into a second century.

In memory of Joe Clark, aviation pioneer, who sadly passed away while writing this article.

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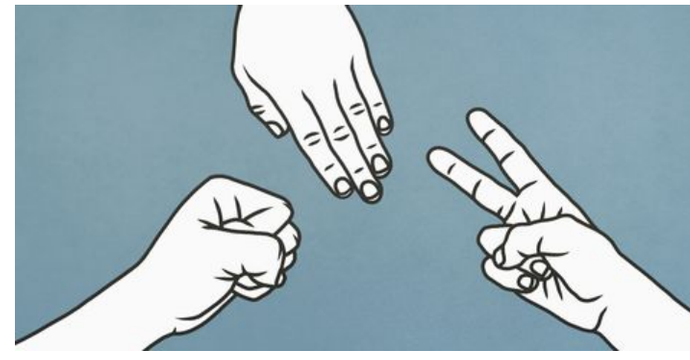

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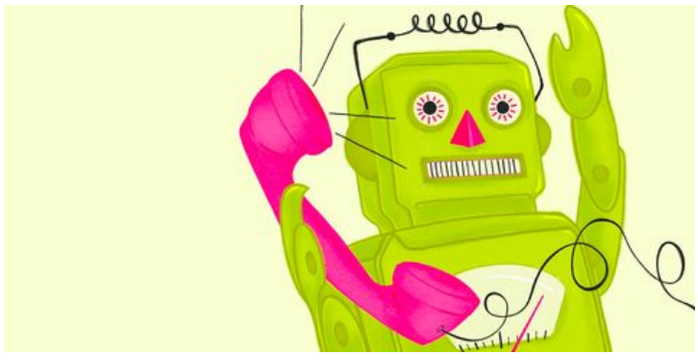

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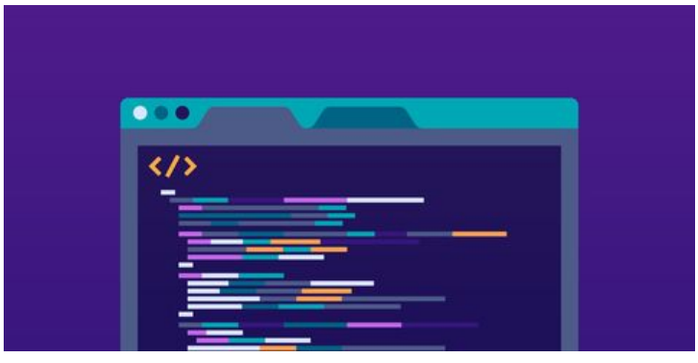

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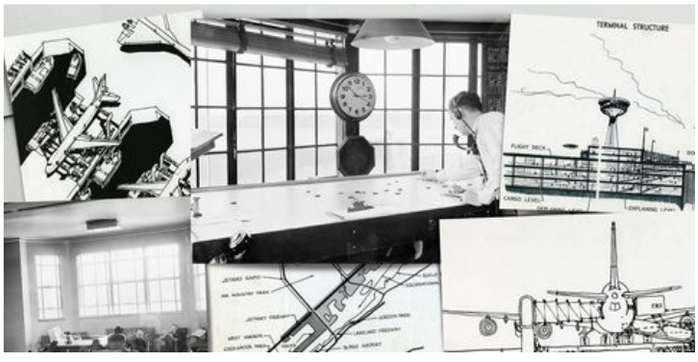

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