How the 747 Got Its Hump

In the evolution of the airplane, Darwinian principles have applied unevenly

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ARGUING THAT LIFE EVOLVED WITHOUT INTELLIGENT GUIDANCE, say the people who believe in "intelligent design theory," is akin to arguing that a tornado hitting a junkyard could create a Boeing 747. So, I ask them, why does the 747 have an upstairs cabin? Because Boeing planned it that way, they answer. They are quite wrong, but the example of the 747 is useful because it points to some important general rules about how airplanes come to be the way they are.

Behind the scenes at the Farnborough airshow in England in the summer of 2000, Boeing was keen to share its opinion that Airbus' weight numbers for the A380 dual-deck jumbo, which is to enter the fleet in 2006, were optimistic. Retired 747 chief engineer Joe Sutter was there just to remind people that Boeing had studied a dual-deck airplane as long ago as 1965 and had rejected it as too heavy.

Boeing was competing for a supersonic transport contract in 1965, at about the same time the 747 was conceived, and Pan Am founder and chairman Juan Trippe believed that the big subsonic jets would end up as freighters and that the SST would replace the 747 on passenger routes. Trippe was one of Boeing's best customers and usually the first to order new models, so Boeing put the flight deck of the 747 above the passenger cabin to give the aircraft a hinged nose for a front-loading cargo door.

The first design for the cockpit enclosure was a hemispherical hump atop the fuselage. This produced too much drag, so Boeing extended the aft portion of the hump to form a teardrop. Then, in a deliberate echo of the below-deck lounge on the model 377 Stratocruiser, Boeing's 1940s flagship, Trippe and his colleagues persuaded Boeing to turn the extra space behind the cockpit into a bar and lounge.

The party days ended with the 1973 fuel crisis, when virtually every 747 operator got rid of the lounge and replaced it with more seats for paying passengers. In announcing the change, a British Airways press release noted that the upstairs area was "currently used for a first-class lunge"—the spelling was probably appropriate more often than not.

The décor in the 747 lounge is a vaguely horrible memory, but burnt-orange sectional sofas weren't the only aesthetic transgression to come out of Seattle during that era. There was the 747SP. This short-body, long-range version of the 747 was as economical as it was elegant (that is to say, not at all), but when Boeing sawed 47 feet out of the fuselage to create the SP, the engineers had to look at what would happen when the rear of the cockpit hump lined up with the front of the wing. There were no ill effects, as it turned out, so Boeing designed the new 747-300 with a longer upper deck to seat up to 70 passengers.

Today's 747 has a large upstairs cabin because Trippe thought it would be a freighter, because a round hump produced too much drag, because Pan Am bosses had fond memories of the Stratocruiser's bar (and all-night parties held by the light of the Pratt & Whitney R-4360s' flaming exhausts), and because fuel prices went through the roof. Nobody set out to design the airplane with an upper deck. It came about because it was possible and because it adapted the 747 to a changing environment. It evolved.

The history of the airplane is remindful of biological evolution. New species emerge through mutation and then survive or perish. In detail, every part of an airplane is designed deliberately and meticulously for its job. Nine times out of ten, though, the broad layout of the airplane is evolutionary.

Trace the line back and you will find an airplane that looks new and revolutionary—only to find that its own design is usually the happy combination of many strands of previously existing DNA, with results that the designers themselves never quite foresaw until the airplane was complete.

Most large commercial jet aircraft—even those designed by arch-rivals—look like members of the same family. Their engines hang on pylons, in front of and below their swept-back wings. The landing gear is in exactly the same place: hinged behind the rear wing spar and folding inward to stow behind the wing. The wings all have lift-boosting devices—flaps—across their leading and trailing edges.

All these airplanes carry the DNA of a common ancestor: the Boeing 367-80, also known as "Dash 80." That Boeing 707 prototype, in turn, emerged from a tumultuous nine-year process as the third in a sequence of significantly different airplanes, the first two being the B-47 and B-52 jet bombers.

In 1945, after Allied armies had secured German research files, Boeing aerodynamicist George Schairer unearthed a goldmine of data the Germans had compiled on swept wings. Boeing promptly junked its Model 432 straight-wing jet bomber design in favor of what would eventually become the B-47, which shared its new features—"bicycle" landing gear, swept wings, and pod-housed engines—with a Junkers design, the EF 150, that had never been built. (Unknown to Boeing, the EF 150 designers had been taken to Russia to complete their work; see "The Rise and Fall of the East German Aircraft Industry," Feb./Mar. 1996.)

The Strategic Air Command learned to live with the B-47's deficiencies and vile habits because the Stratojet was faster than most Soviet fighters. Too fast to land safely, B-47s trailed two braking parachutes. Underpowered, the bombers were fitted with booster rockets for takeoff. Short on range, Stratojets were refueled in flight by a fleet of hundreds of SAC tankers.

Boeing corrected many of the B-47's problems by improving the wing and engines in its next heavy bomber design, which could have fit the intelligent design theory had it led to a commercial jet or transport. But its conceptual design phase encompassed a weekend marked by an atmosphere of crisis in a hotel room in Dayton, Ohio: the B-47 follow-on was in trouble.

In October 1948, three senior Boeing engineers had a bad-news Friday meeting at Wright-Patterson Air Force Base in Dayton. Weary of problems with the engine installation on Boeing's new heavy bomber, the Air Force made it clear that the project was all but dead.

But two other Boeing engineers were also in Dayton and working on a study for an improved B-47-size medium bomber with a better wing design and better engines. Over the weekend, the Boeing team projected that airplane's characteristics into a larger, eight-engine design. George Schairer bought balsa wood and tools at a hobby shop, and by Monday, the Boeing team had a model to accompany its presentation. The project won a reprieve, and Schairer posed for a publicity photograph with the model in his hands. It is quite recognizably a B-52.

Boeing's first idea for a jet transport incorporated the swept wings and podded engines of its bomber predecessors, but it also shared a high wing. With the wing on top of the fuselage, the only place for the landing gear was in the belly, arranged like a skateboard's wheels—ahead of and behind the airplane's center of gravity. The tricycle gear on an airliner places the main gear close to the center of gravity, with just enough weight forward to ensure that the airplane stands lightly poised on its nosewheel. On takeoff, every airliner pivots (or "rotates") on its main gear, noses up, and climbs away at an angle.

But because of the tandem bicycle landing gear arrangement on Boeing's bombers, they can't rotate to climb any more than your car could. To take off, the bombers' wing has to be in a flying attitude to generate lift on the ground, and that's how they're built: with the wing at a positive angle of attack. They both land and take off with their fuselage—and landing gear—in a level attitude, levitating more than climbing, settling more than descending. On rollout after landing, the wings generate lift and the wheel brakes don't work very well, so they need braking parachutes. This would not do for a transport. The 367-80, therefore, had a low wing to which was affixed the main wheels of a tricycle gear, which folded inward into the fuselage. So in the end, the bombers contributed only swept wings and pod engines.

Nobody knew at the time that the 367-80 layout would eventually dominate designs for all airliners. Boeing's second all-new commercial jet, the 727, had three engines clustered in the aft fuselage and a T-shaped tail. It was a hot seller in the 1960s, as was the rear-engine Douglas DC-9. Great Britain and France produced rear-engine jets, including Britain's 707-size Vickers VC-10 and France's early Sud Caravelle. The 707 looked positively dated.

And yet today, the last of the paltry 54 VC-10s, converted into military tankers, roar and snort their way around the world. The last 727 rolled off the production line in 1984, replaced by the underwing-engine 757. Europe adopted the Boeing-style shape for the Airbus A300—and for the first time had an airplane that the world wanted to buy. Today, the Boeing 717—the re-badged tail end of the DC-9 line—is the last rear-engine, 100-plus-seat jet in production.

Underwing-engine airplanes evolved and became dominant because they were more efficient. An airplane's wing is like a beam with the mass of the fuselage at its center; engines hanging at mid-span on the wing counteract some of the bending loads on the beam, so the wing can be built lighter. With the weight of the engines at the back, an airplane balances nicely with a shorter aft fuselage, so the horizontal stabilizer has less leverage to balance the airplane and must be bigger and heavier. British reports bragged that the VC-10's all-moving tail was bigger than the wing of a Hunter fighter—but it weighed a ton.

Iguanas and Komodo dragons survive after allosaurs die out. Almost all business jets and most regional jets still have aft engines and high tails. In 1959, McDonnell actually did try to adapt the 707 shape to a small airplane; the result was the model 220 prototype, a competitor for an Air Force contract for a utility transport and trainer. It looks like it might be a 707's awkward chick, a creature that has some growing to do before it can fly. The model 220 shows that 707-style underwing engines don't adapt well to small sizes. You can scale down an airplane but not the air; the gap between the engine nacelle and the wing cannot shrink in proportion to the airplane. While the forward cabin door is high off the ground, the engines' ground clearance is reduced and the inboard engine is in line with the bottom of the steps, perfectly positioned to eat the impatient CEO who won't wait for the engines to shut down.

Military transport airplanes all look like Grandpa: the Lockheed C-130. It has a high-mounted wing, a stumpy-legged main landing gear in pods on the lower corner of the fuselage, and an upswept tail that incorporates a ramp door. The ramp can be lowered to the ground so that vehicles can drive in, it can be extended straight out to roll cargo pallets onto or off a truck, or it can be opened in flight to drop loads out the back by parachute.

For a brief period between World War II and the Korean War, it appeared that a very different configuration would reign, with a central pod fuselage and twin booms supporting the engines and tail—see the Fairchild C-82 Packet and C-119 Flying Boxcar in the United States and the Nord Noratlas and Armstrong Whitworth Argosy "Whistling Wheelbarrow" in Europe. But that species was doomed.

The C-130 did not spring from a clean sheet of paper. It owes a lot to some little-remembered airplanes that link it to the transport gliders of World War II and, via a forgotten experiment, to the Douglas DC-3 and its military derivative, the C-47. In 1943 and 1944, the U.S. Army Air Forces wanted to replace its C-47s with four-engine Douglas C-54 transports. This entailed replacing its transport gliders, as the steel-tube-and-fabric airplanes could not survive in tow at the C-54's 250-mph cruising speed. As an experiment, USAAF engineers at Wright Field in Ohio stripped the engines from a war-weary C-47.

Not only could the modified airplane be towed faster, but it had a low stall speed and a good glide ratio, both of which promised to make glider landings much less dangerous.
So the Army ordered two new high-speed gliders from the Chase Aircraft Company. The XCG-18 and the bigger XCG-20 shared three features: a high wing, a short, body-mounted landing gear, and a high tail. There was no ramp, but the tail was designed to stay clear of the ground when the glider landed. The XCG-18 flew in December 1947, but the USAAF had become the U.S. Air Force, and the U.S. Air Force liked supersonic fighters and jet bombers, not poky trash-hauling gliders. Chase fitted it with two engines, producing the C-122, a handful of which were built for the Air Force. Like a dinosaur with feathers, the C-122 was a link between gliders and airplanes: It still had a towing hook and could hitch a ride from another airplane to extend its range. The bigger XCG-20 acquired engines—as the C-123—before it was built.

One of Germany's largest wartime transports was the Junkers Ju 290, adapted from the Ju 90 airliner. The Ju 90 had a tail-wheel landing gear, with a nose-high ground attitude and sloping floor that made it hard to load cargo. Junkers engineers installed a powered ramp under the tail, which raised the airplane into a horizontal attitude as it opened. After the war, the USAAF tested a captured Ju 290 (nicknamed "Alles Kaput"), and the ramp subsequently appeared on the C-123.

Fairchild, which acquired Chase, built more than 300 C-123s. The C-123 still looks enough like a C-130 to double for the Lockheed airplane when a movie script calls for a military transport and the Air Force won't cooperate. C-123 credits include Con Air, Outbreak, and most Vietnam war movies in which the bad guys are Americans.

The fossil record of the creatures leading to the C-130 is hard to find because it includes a few obscure aircraft. Tracing the lineage can be more difficult if the missing link was never built.

In March 2001, Boeing unveiled the concept for an airplane called the Sonic Cruiser. A canard (tail-first) design with a compound-sweep wing and engines carried on a “back porch” extension of the wing, it looked different from any airplane Boeing had ever built. The missing link, hiding in a NASA presentation in an obscure corner of the Internet, was a Boeing supersonic transport design that—except for a pointy nose and different engines—was clearly the Sonic Cruiser. It didn’t look like anything else out of Boeing, but the aft-set, compound-swept wings and the engine location made the aircraft look very much like a series of supersonic designs from the 1990s by Sukhoi, a Russian aircraft company with which Boeing has partnered to develop a regional jet airliner. Late in 2002, Boeing cancelled the Sonic Cruiser—but don’t be surprised if this resilient gene strand pops up somewhere else before too long.

The coelacanth is a creature that was so well adapted to its marine reef environment that it did not need to evolve despite more than 300 million years of existence. In St. Augustine, Florida, Northrop Grumman still builds the E-2C Hawkeye for the U.S. Navy and export customers. The long-wing, twin-engine airplane, with a radar dish sitting on its back like a friendly UFO, no fewer than four vertical tails, and its Grumman folding wing, which looks double-jointed but isn’t, is entirely suited to the task of carrying a radar off a carrier. The production line started moving in 1960 and shows no signs of stopping soon.

Lockheed Martin’s U-2 is a serial coelacanth. The Central Intelligence Agency, which sponsored the original design in 1954, planned to build 30 airplanes and fly them until Soviet surface-to-air missiles improved to the point where the aircraft could be shot down. The CIA thought this would happen about 1960, and it did, but the agency continued fielding the U-2 because of its ability to carry heavy loads to high altitudes. The production line was restarted once in 1967 and again in the early 1980s, and every few years Lockheed Martin floats a proposal to start it yet again.

Some designers and organizations have a stronger record of creating enduring mutations than others. Europe’s Airbus has prospered by steadily evolving and refining the Boeing-type commercial airliner—and a very good job they have done of it. But the Fort Worth division of General Dynamics—now part of Lockheed Martin—went through a four-decade cycle in which none of its major airplane projects bore any resemblance to its predecessor—or, for that matter, to anything else.

The lumbering, 10-engine B-36 bomber, bristling with retracting gun turrets like a Star Wars cruiser, was followed by the compact, fast, and dangerous B-58 Hustler and the swing-wing F-111—all unique designs. When GD chief designer Harry Hillaker and his team went after an Air Force lightweight-fighter contract in 1970, the world was skeptical. Fort Worth had never produced anything that weighed less than a fully loaded semi-trailer.

Doubts increased when Fort Worth rolled out a fighter shrink-wrapped around one massive engine, with blended wings and an under-body air inlet, an airplane that would not fly straight without computers. Bill Gunston, doyen of British aerospace journalists, observed that some air forces harbored a “cavalry officer mentality…that just wanted a flashy horse that would go faster.” The GD fighter, Gunston wrote, “was like selling the cavalry officer a super horse with six legs.” Four thousand F-16s later, one has to conclude that Hillaker and his team knew more about fighters than they had been given credit for.

Lockheed’s Skunk Works is another organization with a reputation for breaking with tradition. In addition to the U-2 and the Mach 3 SR-71 Blackbird, the Skunk Works was responsible for the first stealth attack fighter: The F-117, without a single curve in its exterior surface, had to be unique, because it was the first airplane designed with reference to two equally important physical environments: the air and the electromagnetic spectrum.

Robert Silverstein, who was a Northrop Grumman executive in the early stages of the B-2 project, has compared the strange world of black projects to Australia: an isolated area where unique species can evolve without being gobbled up by bigger, more established predators. Now, the F-117’s DNA is showing up all over the place. Look at the F-22 Raptor stealth fighter, particularly in front view, and then flip it upside down: There is the F-117’s profile, softened only by a few rounded edges and gentle curves. And the new F-35 Joint Strike Fighter is the F-22’s cousin.

Maybe it’s the climate. Maybe it’s radiation leaks. Either way, a lot of strange mutations have sprung up in the Mojave Desert. The place shelters not only the black world’s equivalent of Edwards Air Force Base—the secret Groom Lake, Nevada facility—but also the town of Mojave, home of Burt Rutan’s Scaled Composites company. If most airplanes evolve by natural means, then Rutan is aviation’s Dr. Frankenstein, fashioning strange asymmetric creatures (Boomerang) and others with so many arms and legs you lose count (Proteus, ATTT).

Sometimes you know it’s all going to end in tears. Take the example of Raytheon, which thought of itself in the early 1980s as a Route 128 Massachusetts technology company. Hoping to revitalize its fuddy-duddy Beech unit in Wichita, Kansas, Raytheon bought Scaled Composites. “It was like asking Ed ‘Big Daddy’ Roth”—the king of the California hot-rod customizers—“to design the next Cadillac,” Mike Potts, a former Beech executive, observed later. Rutan enlarged his two-place canard VariEze homebuilt into the turboprop-powered Starship. Beech built it and unveiled a full-scale mockup at the National Business Aircraft Association convention in Dallas in 1983. Every Beech dealer was prevailed upon to accept one airplane.

Some said the market wasn’t ready for such a radical departure. Others said the market wasn’t ready for anything. Whatever the case, the Starship production line closed after 53 airplanes had been built.

The risks and rewards of radical change can be huge, but sometimes you end up with something better kept chained in the dungeon—and that is why evolution rules, in aviation as well as in nature.