Flashback: Convair's F-102 and F-106 – Aren't They Really the Same Airplane?

By: Brian J. Duddy, Staff Historian

The Soviet Union exploded their first nuclear device in 1949. Following that and the Berlin Blockade, there was a major concern in the US that the Soviets were building a strategic bomber fleet to deliver nuclear weapon strikes in North America in what was termed a "nuclear Pearl Harbor." The USAF focus during those early years of the Cold War and well into the 1960s became nuclear deterrence and continental defense as opposed to fighting conventional wars. The result of that focus was the acquisition of a supersonic interceptor which became the highest priority program for Air Research and Development Command and Air Materiel Command.

During the 1950s and 60s Convair built a number of aircraft for the USAF to respond to the Soviet threat, including the B-36, the B-58 strategic bombers, the F-102 and the F-106 fighters. Externally, the F-102 *Delta Dagger* and F-106 *Delta Dart*, look quite similar. They are both single-place, single-engine, delta wing interceptor-fighters with conventional landing gear. They were both intended as single-mission aircraft to engage and defeat Soviet bombers. From a distance the main distinguishing feature is the broader, trapezoidal vertical tail of the F-106 versus the clearly triangular tail of the F-102. But a closer look, particularly at the fuselage shapes, reveals a subtle, yet significantly important difference. Performance wise, that difference in shape allowed the F-106 to be a more successful design and more effective and suitable for USAF missions. The design principle that distinguished the F-106 was the application of a theory called "Whitcomb's Area Rule", named after Richard Whitcomb, an engineer with the National Advisory Committee for Aeronautics (NACA) – the forerunner of the National Aeronautics and Space Administration (NASA.)

Left: F-102A in Air National Guard service

Right: F-106A at Tinker AFB

In September 1950, Air Materiel Command sent out a requests for proposals to the aircraft industry to build a new supersonic jet interceptor, with an eye to having an initial operational capability by 1954. Convair won the contract and planned to build on their experience with their futuristic delta-wing prototype design, the XF-92A. Their new design proposal was called the MX-1554 All Weather Interceptor.

Left and Above: Convair's elegant XF-92A delta-wing prototype. This very aircraft can be seen at the National Museum of the United States Air Force.

Early in the program, Convair and the Air Force agreed that the new aircraft, initially designated the YF-102, and eventually the F-102A, would be an "interim" design solution based around the delta wing concept, and paired with the Pratt and Whitney J57 engine. The F-102 was in fact the first USAF acquisition program managed by the new "weapons system" approach rather than just as an airframe and engine. The weapons system package for the F-102 now included a sophisticated fire control system as well. Designating the new program as a weapons system was an important change in Air Force acquisition philosophy that is still with us today. The final configuration of the design – the F-102B – was planned to employ a more advanced fire control system and a higher thrust turbojet engine. Under the new weapons system concept, to save schedule the Air Force allowed Convair to start Low Rate Initial Production (LRIP) for the F-102, even before development testing had begun. This decision was to complicate the program significantly in the following two years when the hoped-for performance of the F-102 failed to materialize.

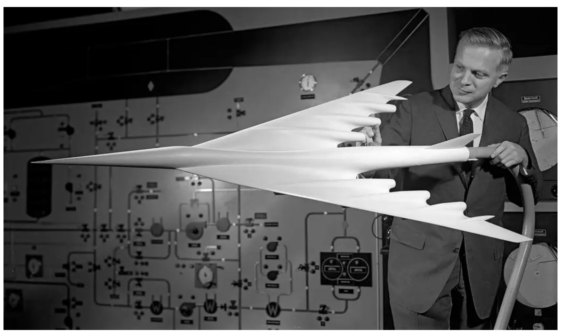
Aircraft design is a series of tradeoffs and a balance between thrust and drag, lift, and weight. The goal for powered aircraft is to maximize thrust and lift and minimize drag and weight for best performance. As an aircraft approaches the speed of sound, the drag on the air vehicle increases substantially. Unless it has enough power, the drag builds up to a point that it will eclipse the thrust available and the aircraft will have reached the "sonic wall." Until sufficiently powerful jet engines were available, the only way to break this sound barrier and achieve supersonic flight was either in a very steep dive or by using a rocket-powered aircraft. Rocket-powered craft had demonstrated the ability to go over twice the speed of sound, but they had to be carried aloft, had very limited range, and were not practical for use in normal military service.

Wind tunnels and wind tunnel models are used to investigate and test aircraft designs and facilitate these design tradeoffs. NACA controlled several wind tunnels at their Langley facility in Virginia, where Richard Whitcomb worked there in the aerodynamics section. The transonic drag problem that was present from Mach 0.9 to Mach 1.2 was plaguing aircraft manufacturers (including Convair) who had been using long-standing design principles that a bullet-shaped body produced less drag in flight than other designs. Whitcomb examined this phenomenon in detail and in early 1952 was struck with an inspiration of how to conquer it.

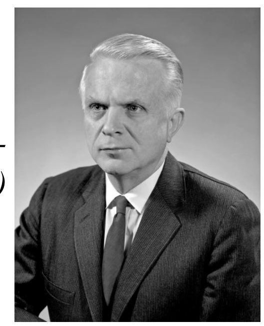
In contrast to conventional wisdom and prior designs, Whitcomb felt the key to overcoming the transonic drag buildup was to present a more consistent and less variable "frontal area" of the aircraft as it passed through the transonic region. Whitcomb calculated that the drag at transonic speed depends almost entirely on distribution of the aircraft's cross section. Working from the nose rearward to the wings, the frontal area of an aircraft is more or less constant or gradually increases. But as the wings are taken into account, the frontal area represented by the cross section increases significantly over a short distance aft.

Whitcomb felt that to present a more consistent frontal area without dramatic increases, the fuselage dimensions of supersonic aircraft needed to narrow in proportion to the wingspan increasing - in a sense, trading fuselage area for wing area. To Whitcomb, the key was cross section, not overall shape or streamlining. His discovery quickly came to be known as the "Area Rule" meaning designers should make adjustments to the fuselage dimensions as necessary to keep a relatively consistent ratio of area with the increase in wingspan. (By example, air and water are both fluids, so moving your hand sideways through water is much easier than moving it flat against your palm.)

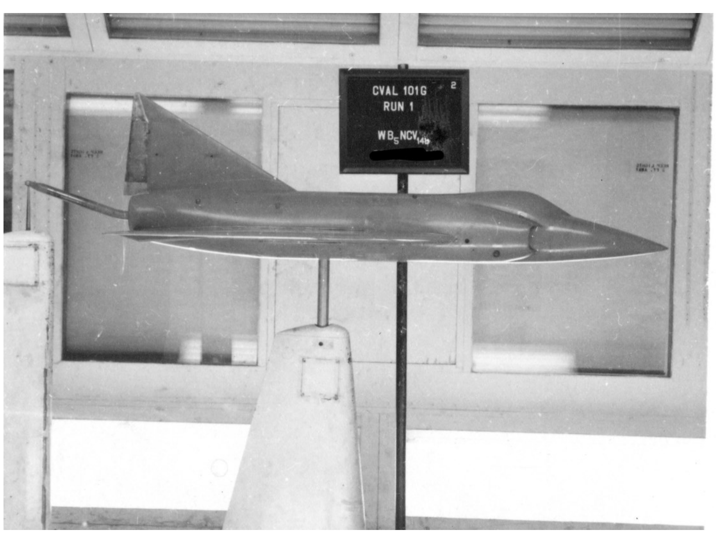
Applying his theory to NACA wind tunnel models, Whitcomb found that by indenting the body, or reducing the cross-section, reduced the drag rise with both unswept (straight) and delta wings by 60 percent near the speed of sound. This was significant because it meant that using this design would virtually eliminate the drag rise encountered by the air as it passed over both the wing and fuselage together. This discovery promised to solve a major design challenge for aircraft manufacturers.

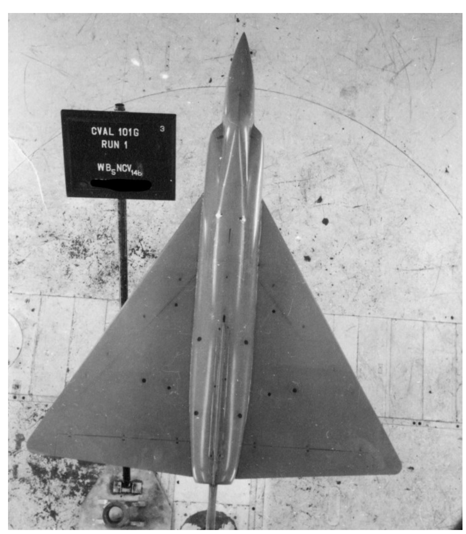


Richard Whitcomb, NACA/NASA engineer with wind tunnel model (left) (NASA Photos)

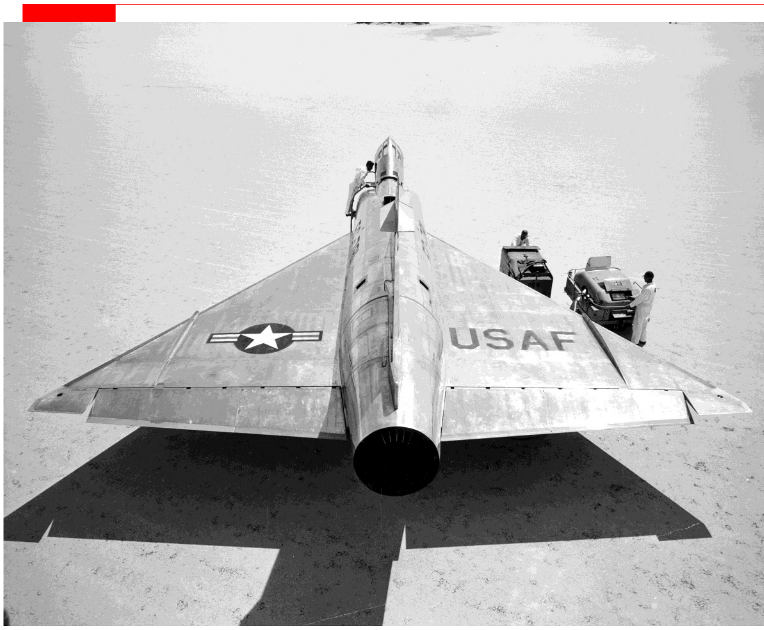


At the same time Whitcomb was exploring the potential of the Area Rule theory, Convair was in the midst of the detailed design of their F-102. In 1952, Convair's early tests of the F-102 model in the NACA wind tunnel forecast that the drag on the straight fuselage might be too high for it to surpass the transonic region. In their proposal to the USAF, Convair had promised an aircraft capable of speeds up to Mach 1.8, depending on the engine selected. Their current design was clearly unable to meet that, so the Convair team asked the NACA specialists if they had any suggestions, and the application of Whitcomb's new theory was brought forward. Fate presented both NACA and Convair the chance to make the Area Rule a practical reality.





Left: F-102 initial design wind tunnel model.



Above (L and R): The early F-102 with the straight fuselage before the Area Rule redesign.

In parallel with the rest of the F-102 development, Convair worked with Whitcomb and NACA to understand what design changes might be required to the F-102 fuselage to allow it to increase its transonic and supersonic performance. This collaborative work was unfortunately too late for the design to be changed before the first full-scale F-102 prototypes were fabricated and shown to the Air Force, but the new innovation had promise. From 1953, when the first unmodified F-102s were tested, they confirmed the disappointing performance forecast by the NACA wind tunnel testing. (The higher-than-estimated engine and avionics weight also contributed to the unspectacular performance.) It would not come close to reaching Mach 1.8, in fact, the aircraft could barely go supersonic, and then only in a dive. Application of the Area Rule seemed to be the only way out of the dilemma.

The USAF was also aware of development in the Area Rule theory and Air Force leadership desperately wanted to deploy a supersonic interceptor to counter the Soviet bomber threat. Convair pressed ahead with the LRIP of the subsonic F-102 also because implementing design changes during production would be a waste of money if the Area Rule gamble did not pay off with increased performance. The earlier decision to permit LRIP before the performance of the design could be verified was starting to haunt the Air Force. Since the original goal of the program was to have an initial interceptor capability deployed by 1954, Air Materiel Command did allow the F-102 production to proceed in order to get some kind of capability on the ramp quickly. But the F-102 program office also informed Convair that if they did not make a serious attempt to incorporate the Area Rule into the F-102, the USAF would cancel the remainder of F-102 contract.

With this additional incentive, Convair was quickly convinced of the virtues of Whitcomb's Area Rule and eventually production of the F-102 was halted to incorporate what now promised to be a superior design approach. Convair reshaped the fuselage to keep the cross-sectional area of the aircraft as constant as possible and remove any dramatic changes in frontal area between the wings and the fuselage. The resulting configuration changes to the cross section were significant. It took on what became known as the distinctive "Coke bottle" or "wasp waist" shaped fuselage – those of us old enough know what the means - wide at both ends and narrow at the middle. Wind tunnel tests confirmed that this F-102 redesign according to Area Rule principles would meet the USAF supersonic requirement.

Left: Side by side comparison of the F-102 and F-106 (L) showing the modified design.

Right: The F-106A in service. (NASA)

In less than four months, Convair pressed on to build a new prototype based on that Area Rule redesign and called it the F-102A. It flew for the first time in December 1954 and easily broke the sound barrier not only in level flight, but in its initial climb. The F-102A confirmed conclusively that Whitcomb's Area Rule was the true breakthrough it had shown in the wind tunnel experiments. Convair and the Air Force were both relieved and encouraged by the results of the redesign. It meant the supersonic interceptor program could continue on track, but there was still more work to do.

Convair evolved the F-102A design further into the F-102B, extending the fuselage, modifying the intakes, and upgrading the engine to a more powerful version of the Pratt J75. By 1954, the Air Force was so pleased with the F-102B concept it proceeded with the remainder of the program and finally redesignated the aircraft as the F-106 in June 1956. This step clearly signaled that the F-102 and the new F-106 were distinctly different aircraft. Convair later took advantage of the Area Rule concept and applied it to their new B-58 delta-wing bomber.

Right: Convair's "Deltas."

From top: F-102, F-106 and B-58

The basic F-102s did soldier on in Air Force service, but never achieved their initial promise as "The Ultimate Interceptor." That laurel instead went to the F-106, which was a significantly different aircraft. In December 1959, a standard F-106A production aircraft broke the world absolute speed record with a flight at 1526 mph, a feat not possible without the discovery of the Area Rule.

The F-102A did not become operational until April 1956. The F-106 entered service in 1959 and matured into an effective Mach 2 interceptor. The F-106 stayed in Air Force and Air National Guard air defense service until the late 1980s, well beyond its initial proposed service life. In fact, the B-1B Aircraft Production Acceptance Flight Test Program used the last active USAF service F-106's as safety chase aircraft. The final USAF F-106 was flown to Davis-Monthan Air Force Base, Arizona, on July 6, 1990.

Above: The F-106s starts their second life as Chase Planes for the B-1B program and Logo. Note Air Force Systems Command shield on the tip of the vertical tail.

The Area Rule-influenced designs of the B-58 (Top) and the T-38 (Above) showing the narrow fuselages.

Rocket-powered aircraft had demonstrated that supersonic flight was possible, but the Area Rule demonstrated that supersonic flight was now practical for jet-powered production aircraft. Significantly, other manufacturer's aircraft designs of that decade, including Grumman's F11F Tiger and Northrop's T-38/F-5 series, also incorporated an Area Ruled fuselage. The use of wind tunnels to perfect the Area Rule also clearly showed the value of what we later came to know as "Modeling and Simulation."

So, with such a powerful design principle at hand, why don't aircraft look like that now? The "Coke bottle" fuselage has essentially disappeared in modern aircraft– why? As noted, powered flight is always a balance between thrust and drag. In the early days of jet powered fight, particularly with the turbojet, the engines did not produce sufficient thrust to overcome the drag in the transonic region. That problem has long been conquered. Today's turbofan engines are much more powerful and efficient and no longer struggle to push the aircraft through transonic drag region. Richard Whitcomb's Area Rule was developed at just the right time - allowing the aerodynamics to balance the available power and optimizing the design necessary to achieve sustained supersonic flight. His work allowed the powerplant design to "catch up" to the air vehicle in better harmony. In a side note, the F-102/F-106 series aircraft is notable for one more leading-edge design feature: They were the first aircraft to be equipped with a computer—the Hughes MA-1 electronic guidance and fire control system. At the center of the MA-1 system was the Hughes Digitair, the first airborne digital computer with 2K of words of core memory. Mission data from aircraft systems was recorded to onboard drum storage, which could hold 13,000 words. All intercept data was stored on the drum, as was target information and radio and navigation data. For all these reasons, the F-102/F-106 series were truly groundbreaking aircraft in Air Force history.

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4225 Logistics Ave., RM S133 • Wright-Patterson AFB 45433-5006 • DSN: 713-1797 • Comm: (937) 713-1797

For general inquiries, archives, and/or research questions, contact: R. Ray Ortensie

For heritage and exhibit questions, contact: Jack Waid

HQAFMC.HO@us.af.mil