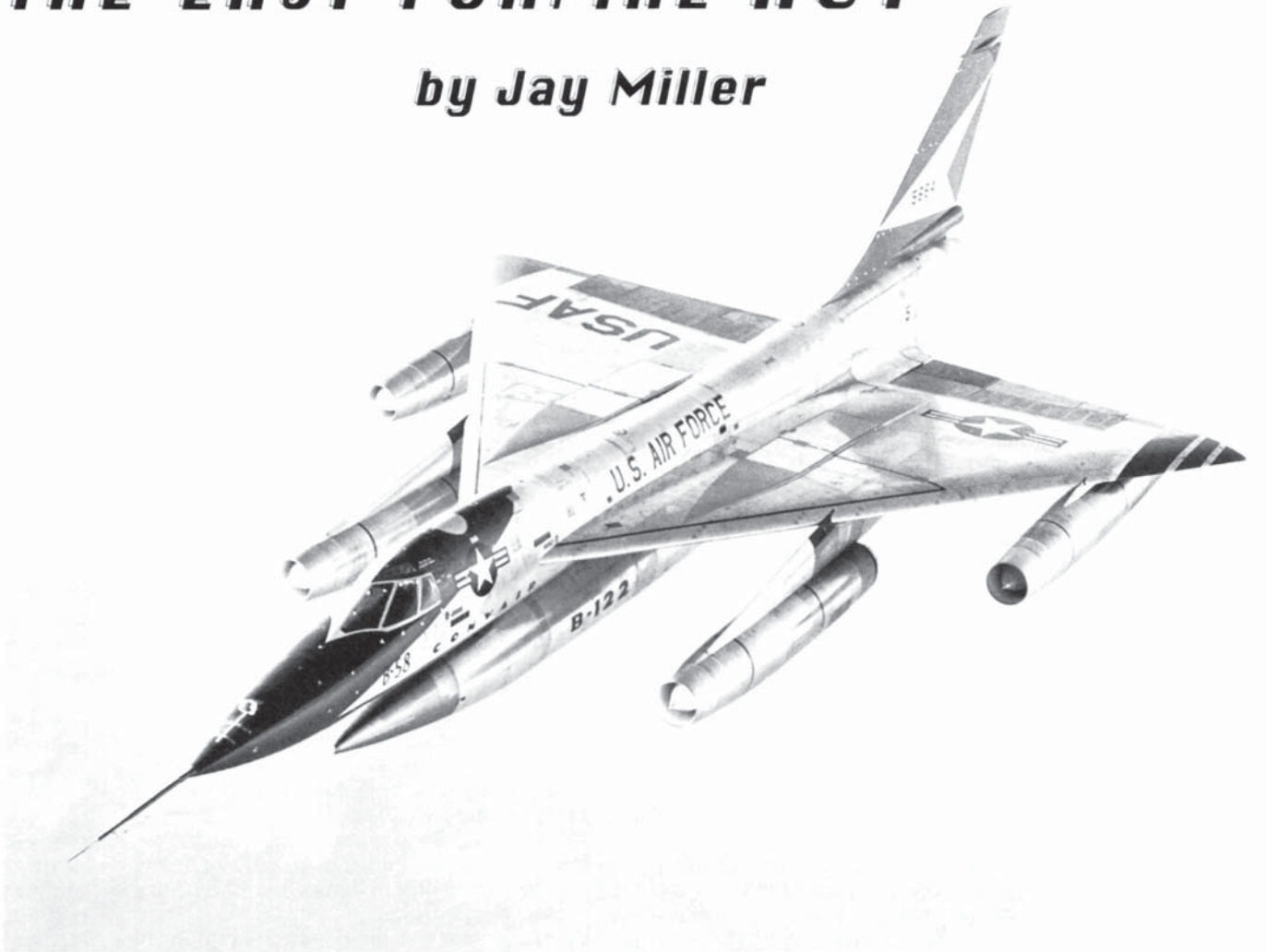


THE LAST FORMAL ACT

by Jay Miller



1: The B-58 remains one of the most aesthetically pleasing aircraft ever to serve with the U. S. Air Force. B-58A, 55-664, is seen midway through its flight test career. Discernible are the small red triangles indicating the locations of the strain gauges on the aircraft's skin. (Photo from General Dynamics)

At 5:02 p.m. on November 7, 1959, a delta wing Convair B-58A *Hustler* supersonic bomber - flying at 35,000 feet and twice the speed of sound - approached the small farming community of Duncan, Oklahoma, on a south-westerly heading. As Duncan drew near, Raymond Fitzgerald, the company test pilot at the aircraft's controls, took his feet off the *Hustler's* rudder pedals and slowly placed them solidly on the cockpit floor. Communicating via intercom with third station flight test engineer Donald Siedhof to verify that the aircraft's special data recording/transmitting equipment was functioning properly, he simultaneously checked to make sure the aircraft was trimmed and in level flight. Moments later - after acknowledging radio contact with a ground monitoring team at Convair in Ft. Worth, Texas - he purposefully reached over with his gloved left hand and tripped a switch activating a cut-off valve that controlled the fuel flow to the *Hustler's* number four engine. It was the last formal act he would ever complete.

Today, forty-three years after Fitzgerald's ill-fated reach and fifty years after the Air Force's B-58 designator was officially assigned to the Convair Model 4 project on December 10, 1952, the bi-sonic delta-winged *Hustler* remains the fastest dedicated bomber platform ever to achieve operational service

with any of the world's military air forces. Capable of cruising at twice the speed of sound (Mach 2.0) over ranges in excess of a thousand miles, it remains the performance standard by which all contemporary bombers are judged no less than thirty years after the type's final flight in 1970.

From its start in the late 1940s, Convair's B-58 engineering team, under the direction of Bob Widmer, Bill Dietz, and Harry Hillaker (who later would father the incomparable F-16), had elected to pursue design criteria that centered on two crucial performance areas...speed and altitude. Though the initial general operational requirement had loosely called for "high subsonic to supersonic speeds at high altitude," by late 1953, the Air Force had upped the ante to a Mach 2.0 aircraft that would routinely cruise at 50,000 feet or above. This was a tall order for the time. The first U.S. aircraft powered by jet engines - the 475 mph Bell XP-59 - had flown only ten years earlier.

Convair chief test pilot Beryl Erickson and company flight test engineers J. D. "Mac" McEachern, and Charlie Harrison had crewed the prototype B-58 during its historic first flight on November 11, 1956. Because of the size of the predicted flight test program and the associated volume of work, it was proposed that a sizable crew cadre be brought onboard to accommodate B-58 requirements. An initial batch of thirteen pre-pro-



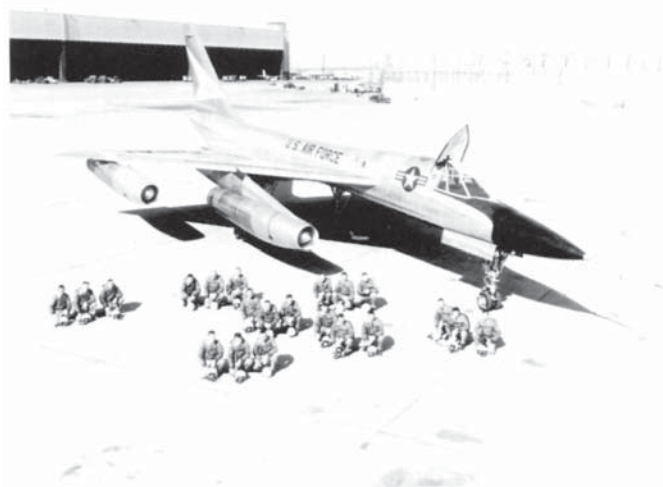
2: At one point in its flight test career, '5664 was utilized to clear the B-58's inflight refueling envelope. It is seen taking on fuel from an early, short-tail KC-135A. (Photo from General Dynamics)

duction-series aircraft was to be utilized to explore the performance envelope, confirm structural limits, and verify mission and weapon system capabilities. Each would require skilled crews to accomplish the requisite tests.

As time would tell, the thirteen test aircraft would prove inadequate for the task. By the advent of the B-58's entry into operational service, an unprecedented thirty aircraft would be allocated for flight test work due in part to the spate of losses suffered by those that had been assigned initially to the test fleet.

Of the thirty test B-58s, no less than nine eventually would be written-off in major accidents...and a tenth airframe would be purposefully destroyed to accommodate the static structural test requirement. This abysmal record was not the end product of bad design, poor engineering, or simple bad luck, but rather the fallout of an aerodynamic platform that was years ahead of the materials, powerplants, and systems around which it had been built.

Underscoring this lack of technological maturity more than any other *Hustler* accident was the loss of the fifth B-58A, AF serial number 55-664, on November 7, 1959, in the skies over



3: With part of Convair's enormous production facility visible in the background, '5664 was used as the backdrop for this dramatic photo of the first seven B-58 flight test crews. The second crew from the left included Fitzgerald (F) in the middle. (Photo from General Dynamics)

Oklahoma. A dedicated test flight, it had begun with a departure at 4:10 p.m. from the flight line of the mile-long Convair production complex co-located with the Air Force at Carswell AFB on the northwest side of Ft. Worth, Texas. Piloted by one of the company's most experienced test pilots, thirty-five-year-old Raymond Fitzgerald, '5664 taxi, takeoff, and climb to altitude had been routine and without incident.

Unlike standard B-58s that normally flew with a three-man crew, '5664 could accommodate only two. It had been heavily modified for flight test work. The second station, usually the domain of the bombardier/navigator, was instead filled with purpose-built equipment that semi-automatically monitored the aircraft's structural loads in flight. Though the second station's ejection seat had been removed, the original test instrumentation panel had been left intact. Additionally, structural beams had been installed longitudinally on either side of the second crew station from bulkhead 3.0 to 4.0 and laterally from station side to station side. These served to support '5664's bulky, dedicated data recording/telemetry system while also taking up the structural loads that normally would have been absorbed in part by the boxy bombing and navigation system package.

The third crew station, normally occupied by the defensive systems operator in an operational aircraft, was configured in '5664 to accommodate a flight test engineer whose singular duty was to monitor special test instrumentation on his main forward panel. On the ill-fated November 7 flight, twenty-five-year-old Donald Siedhof, a company flight test engineer, had been picked to monitor the third seat instrumentation.

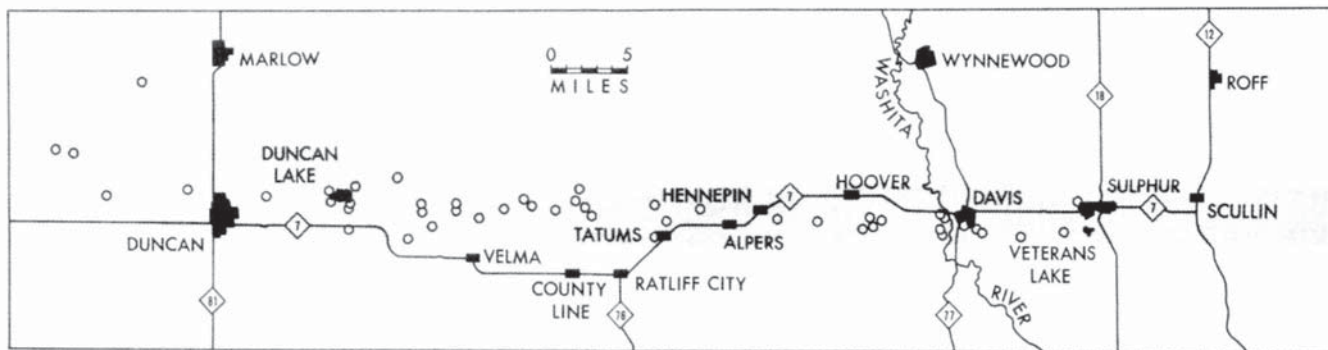
Other modifications unique to '5664 included numerous skin panels with pressure sensors, strain gauges, and accelerometers attached, and special sensors for ascertaining and documenting ranges of control surface (i.e., rudder and elevon) displacement. The pressure sensor ports were visible on the aircraft's skin as small, red-outlined triangles. These were strategically positioned on the left-half of the fuselage, both sides of the vertical fin and rudder, both surfaces of the left wing and elevon, select areas of both surfaces of the right wing and elevon, the number 1 engine nacelle, and the number 2 engine nacelle and pylon.

According to retired Convair engineer Tom Freeman, "During an actual flight, data obtained from these sensors was relayed via wire to the recording and telemetry package in the second crew station. From there it was radioed to a ground receiving station located in Convair's flight test department in the company's flight test hangar. Data then was relayed via cable to the Convair engineering department on the north side of the company office complex where it was picked up and stored in an analog computer. During this upload process it was monitored by a structural loads test team."

The empirical data this system generated helped ascertain - in near real time - whether the aircraft was meeting its structural integrity requirements. Later, detailed analysis of this data permitted handling and performance projections concerning unexplored parts of the aircraft's flight envelope.

A separate, dedicated switch in the pilot's cockpit had been installed in '5664 to actuate a fuel shut-off valve regulating fuel flow to the number 4 engine. Though this had been done to eliminate the need for the pilot to change hands during flight (which he would have been required to do if the normal fuel valve shut-off switch had been used), it also underscored the engineering staff's desire to have the engine failure simulation mode be as realistic as possible.

In fact, actual inflight engine failures often were the result of mechanical problems that led to near instantaneous thrust

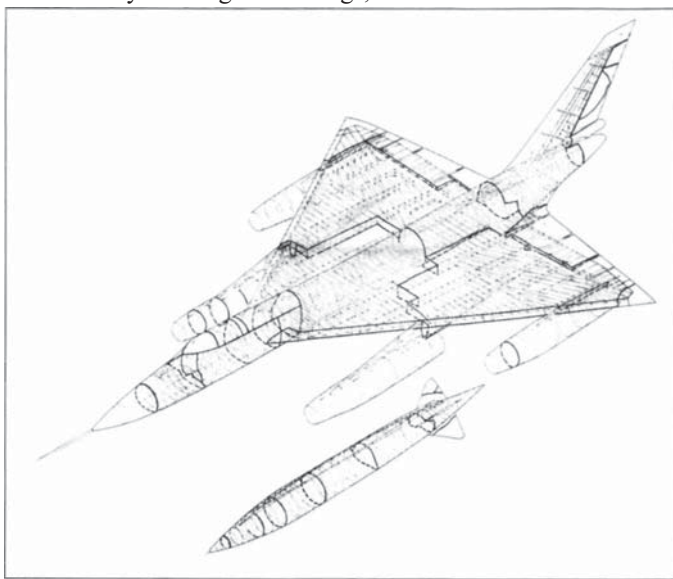


4: The debris footprint over Duncan, Oklahoma, following the loss of '5664 on November 7, 1959. Small circles indicate landing spots of larger debris chunks. Footprint was some 75 miles long. (Photo from General Dynamics)

decay. Simply withholding fuel from the engine could not replicate such conditions; in merely denying fuel, engine spool-down times were usually lengthy. Thrust continued to be generated for two to three seconds - or longer - because residual fuel left in the fuel line between the cutoff point and the engine fuel injection nozzles continued to provide sufficient volume for combustion. Convair's engineering team, knowing this, concluded that the latent effects of fuel flow cut-off and relatively slow engine spool-down times would have to be acceptable variables.

One of the Air Force requirements that had concerned Convair's engineering staff during the course of the B-58's design development program was the need to certify the aircraft's structural integrity in the event of an outboard engine failure at Mach 2.0 and medium altitude. Following an engineering team meeting on October 20, a series of flights exploring the adverse effects of asymmetric power had been undertaken by Fitzgerald in '5664 during the weeks leading up to the ill-fated November 7 mission. According to Erickson, though the flights were deemed successful, "they were not flown with the aircraft in a most severe condition (i.e., furthest aft center of gravity and highest dynamic load)."

Regardless, some of these flights had nibbled at the edges of instability. Among other things, there had been hints that the



5: B-58 (w/MB-1 pod) internal structure drawing. Dark lines indicate most significant points of separation when '5664 disintegrated. (Photo from General Dynamics)

aircraft's vertical tail lacked sufficient stiffness. These small excursions were not ignored, but the consensus among both engineers and the flight test staff after they were evaluated was that they were definable anomalies that did not represent a danger to the aircraft or its crew. Erickson later would note that, "as a result, a certain level of confidence was achieved; Fitzgerald and I agreed that it was time to move ahead to a Mach 2.0 test."

The November 7 flight had been designed to ascertain structural integrity of the B-58 to "60% of limit tail load due to power failure of [the] number 4 (right hand outboard) engine." It had also been proposed that, once this flight had been successfully completed, two follow-on flights would be undertaken that would increase the test's severity. Loads to 80% and then 100% of the calculated structural limit were to be verified as safe.

Concurrent to these tests, a B-58 airframe was being statically stress tested to destruction at the structural test facility at Wright-Patterson AFB, Ohio. Convair projected this specimen would survive limit loads of 150% of the maximum specified for the aircraft in flight.

A failure at any point in this structural testing process would lead to a major redesign of the failed parts and almost certainly a repeat, from scratch, of the structural test program. Convair had no desire to assimilate the costs of a second structural test series and thus placed considerable emphasis on successfully completing both the flight and static portions of the Air Force requirement.

Design limit load on the B-58's vertical tail had been calculated to be 45,000 pounds. During static tests of the vertical tail and aft fuselage, shear failures had occurred in the fuselage side panels from bulkhead number 15 to bulkhead number 19 at approximately 98% of the design ultimate load of 67,500 pounds. These tests, coupled with the flight test work that had been on-going, helped convince Convair and the Air Force that the structure was safe enough to approve the November 7 flight.

B-58A, 55-664, officially a YB/RB-58A, had been completed on November 14, 1957, and had made its first flight on November 30. Assigned by Convair to serve as the airloads data test aircraft, it had also been used to help establish the B-58's inflight refueling envelope, and from June 27, 1958, through March 17, 1959, its operational mission profiles. By the time of the ill-fated flight, '5664 had accumulated 58 hours and 55 minutes in the air including 6 hours and 25 minutes of flight at supersonic speeds. It had flown a total of 41 times.

Sudden and unexpected yaw oscillations induced by engine failures were not new to the B-58. Such failures of one or more of the aircraft's four General Electric J79 turbojets had been



6: Empennage and vertical tail of '5664 as it was found in a field outside Duncan, Oklahoma. Telemetry antenna for the data relay system was located inside the area covered by the black dielectric panel with the circular pattern on it. Triangles mark points where strain gauges were located. (Photo from General Dynamics)

experienced with some regularity during previous flights at supersonic speeds. Though unpleasant experiences for the crews, the excursions had been controllable and had not caused any serious damage to any of the aircraft involved. Noteworthy was the fact that the number 7 B-58A, 55-666, had experienced a vertical tail load of over twenty tons during a test flight when it lost afterburner on its number 1 engine at a speed of Mach 1.96. The significance was that this tail load was determined later to be some 30% higher than that experienced initially - and catastrophically - by '5664 on November 7.

According to Erickson, Fitzgerald had been selected to conduct the November 7 test "because he had requested and been granted permission to fly the earlier flights that had explored asymmetric thrust scenarios." These flights had moved the bar higher in increments of a tenth of a Mach number each. Eventually, an asymmetric flight at Mach 1.60 was flown without difficulty and no adverse effects on the airframe were detected during the post-flight examination.



7: The hydraulic actuator assembly for the rudder was completely destroyed when the rudder separated from '5664's vertical fin at nearly twice the speed of sound. (Photo from General Dynamics)



8: '5664's aft center fuselage section with right wing panel partially attached. Severity of damage underscored how completely the airplane was destroyed as a result of the enormous aerodynamic loads imposed at 2.0 Mach. (Photo from General Dynamics)

By this time, Fitzgerald, Erickson, and - most influentially - the engineering department, were beginning to feel confident the B-58 could handle an outboard engine failure at Mach 2.0 with a far-aft center of gravity (e.g.). After considerable deliberation it was decided to skip the remaining tenth-of-a-Mach increments and go for the brass ring. Fitzgerald, who by now could lay claim to having flown the B-58 in an asymmetric thrust configuration more than any other pilot, was cleared to fly the critical mission.

Much thought and study had gone into every possible failure mode that could occur as a consequence of an outboard engine failure at Mach 2.0. Even long-shot items like concurrent loss of a same-side inboard engine due to airflow distortion (caused by yaw angle and the blanking effect of the fuselage) were given consideration. As no B-58 had suffered an inboard engine spool-down after an outboard engine had lost thrust, it was concluded that this possibility was extremely



9: Workhorse of the parts location and retrieval team was a single Sikorsky H-37. Its heavy lift capabilities allowed it to haul the biggest chunks of 5664, such as this engine nacelle component (note engine already on flatbed), to the truck and trailer units tasked with transporting everything back to Ft. Worth. (Photo from General Dynamics)

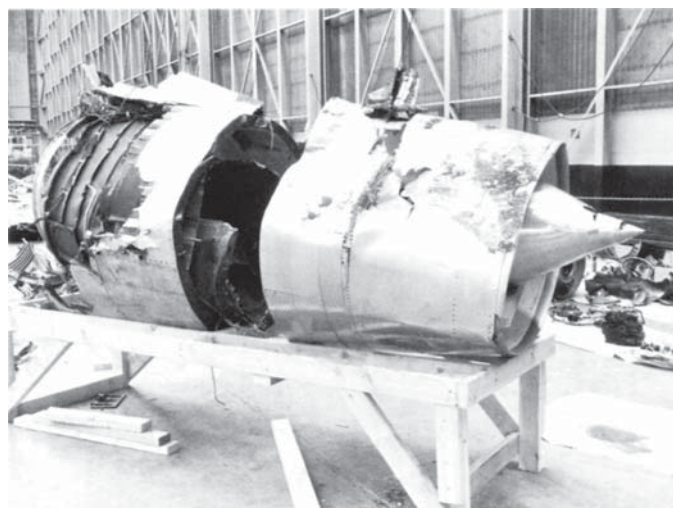


10: Remains of '5664 were transported by truck from Oklahoma back to Convair's Ft. Worth plant for partial reassembly in an attempt to ascertain the cause of the accident. In the foreground is the tail of the aircraft's MB-1 pod. (Photo from General Dynamics)

remote. Additionally, none of the other predictable scenarios seemed to indicate there was anything particularly unsafe about the proposed flight.

As an additional requirement, Fitzgerald had been asked by the engineering department to conduct the asymmetric test with the aircraft's yaw damper system inoperative. Additionally, he was asked to avoid manually responding with rudder to the yaw that was expected to occur following engine spool-down. Level flight was to be maintained using only the control stick...and the aircraft's massive elevons (working in aileron mode; elevons are dual-purpose control surfaces that serve as both elevators for pitch control and ailerons for roll control).

In response to the no-rudder-input request, Fitzgerald had commented to the engineering staff that, "It's against my piloting instincts not to use rudder during a yaw oscillation. In view of this I'll keep my feet on the cockpit floor to ensure compliance." Fitzgerald also recommended that a subsonic flight be conducted in order for him to get a feel for how the aircraft might handle under the required "feet on the floor" conditions.



11: The forward section of the number 3 engine nacelle. Damage to this suspect part did not yield any clues indicating whether it had played a prominent role in the loss of '5664. (Photo from General Dynamics)

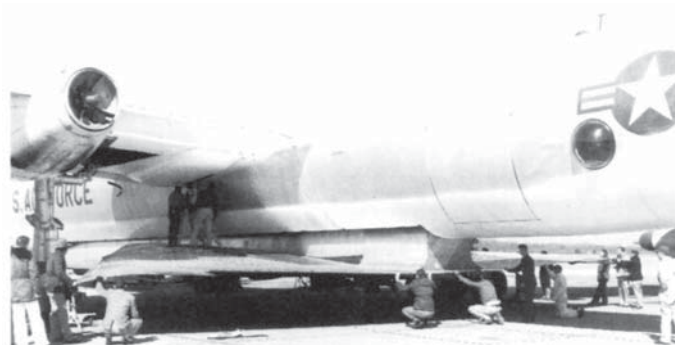
This flight was in fact undertaken without any difficulty. Post-flight examination of the aircraft indicated no adverse effects on the engines, accessories, or fuel system.

The Flight...

The November 7 flight route following departure from Carswell AFB had eventually brought Fitzgerald and Siedhof into a medium altitude high-speed flight corridor where the test was to be conducted. Heading southwest after routing north out of Texas and then turning back toward Ft. Worth, they penetrated the south central part of Oklahoma and ascended to an altitude of 35,000 feet. At that point, they began their acceleration profile out to Mach 2.0.

This speed, at the assigned altitude, placed '5664 in what was referred to as the "max Q" part of its flight envelope. This meant that it was operating in its highest dynamic environment wherein air pressures and associated structural loads were at their respective peaks. This was, in fact, the most difficult environment for the aircraft to fly in...and it was also the environment in which failures would be most pronounced, and thus most unforgiving.

Once the aircraft stabilized, Fitzgerald and Siedhof started their countdown to the test. At 5:02 p.m., Fitzgerald radioed



12: Arrival of B-58A airframe "number 4A" at Wright-Patterson AFB, Ohio, following its trip from Texas in the modified bomb bay of Convair B-36F, 49-2677, on March 12, 1957. (Photo from Wright Air Development Center)

the flight test department at Convair and stated, "My feet are off the rudder pedals and on the floor. I'm tripping the fuel switch..."

He was never heard from again.

With the virtually instantaneous loss of thrust suffered by the number 4 engine, the resulting asymmetric drag immediately skewed the aircraft to an angle of 3.2 degrees to the right of the direction of flight. As residual jet fuel flowed into its combustion chamber, the number 4 engine momentarily came back to life. For just a second, '5664 stabilized, but at the very point where it should have begun to recover, a second yaw oscillation pushed the angle of divergence even further to the right...to an untenable 12 degrees off center. Now, without any kind of corrective rudder action, and a vertical tail that - because it was bending in an ever more severe arch toward the right side of the aircraft - had limited ability to provide a correcting force, all remaining directional control was lost.

By now, the vertical tail aerodynamic loads, later estimated to be in excess of forty tons, had exceeded their maximum sustainable limits. The skins and longerons between fuselage stations 13.0 and 15.0 began to buckle...and then fracture. As they failed, the entire vertical tail began a rapid separation from the aircraft's core components. Consequently, all signals between the second station transmitter system and aft transmitter anten-



13: Moving B-58A airframe "number 4A" into the structural test facility on the Wright side of Wright-Patterson AFB, Ohio. Note the abbreviated landing gear for moving the aircraft on the ground. (Photo from Wright Air Development Center)

na ceased...as the wiring between them separated.

At this point, the entire tail assembly blew away from the forward two-thirds of the aircraft. Moments later, the eleven intermediate hinges failed that attached the rudder to the vertical fin. When the top and bottom hinge brackets gave way, the rudder separated completely. Per engineering predictions, the rudder deflection angle had stabilized at 12 degrees to the right following engine spool-down.

In the meantime the remaining components, including the forward fuselage and crew, had yawed to an angle of 30 degrees to the line of flight. The entire assembly was still supersonic at this point, though slowing rapidly. Structural and aerodynamic loads were enormous. The fuselage now began to break in two at about bulkhead 10. Concurrent to this, a transverse break occurred in both wings, going to the aft inboard corner of each main gear well. In a matter of seconds, the main wing panels broke downward and aft and separated from the forward fuselage section containing Fitzgerald and Siedhof. The right wing departed with the aft center fuselage section still attached, and the left wing flew off on its own. The engines, three of which were still functioning, now separated from their attachments and continued forward along separate parabolic paths.

As the fuselage began to break-up, the ventrally-mounted MB-1 fuel/bomb pod rolled to the right of its attachment points, separated, and began to break into several major pieces. A small fire broke out in the empty forward bay normally occu-

ried by a W39Y1 nuclear weapon.

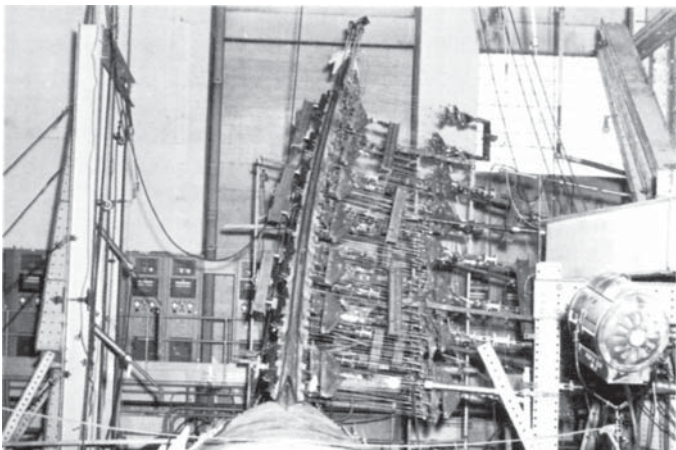
By the time the cockpit area broke up between station 256 and bulkhead 5.0, Fitzgerald was totally incapacitated. The g forces were well in excess of human tolerance and the structural failures taking place in the forward fuselage section almost certainly would have prevented a successful ejection sequence even if one had been attempted. Siedhof, in the aft station, was in a similar situation. Neither man would survive '5664's subsequently agonizing, horrendous plunge to earth.

On the ground, prompted by a series of readily discernible explosions, a significant number of Duncan residents peered skyward as the disintegrating B-58's fuel and vapor trails began to intersect and gyrate across the deep blue of the cloudless late-fall sky. In the setting sun it looked to be a fireworks display gone awry. Pieces of the once stunningly beautiful supersonic bomber - at first appearing minute as a result of their great distance from observers - grew noticeably larger as they fell. Many Duncan locals watched in stunned silence as wing panels, landing gear, control surfaces, fuselage sections, and engines rained down on the trees and cultivated fields that surrounded their town. Some pieces containing combustibles such as fuel or oil were seen to burst into flames and emit long trails of smoke as they descended in sometimes bizarre, zig-zag patterns. On the outskirts of town, farmers and ranchers watched in stunned disbelief as many of the larger pieces landed heavily in their fields and pastures.

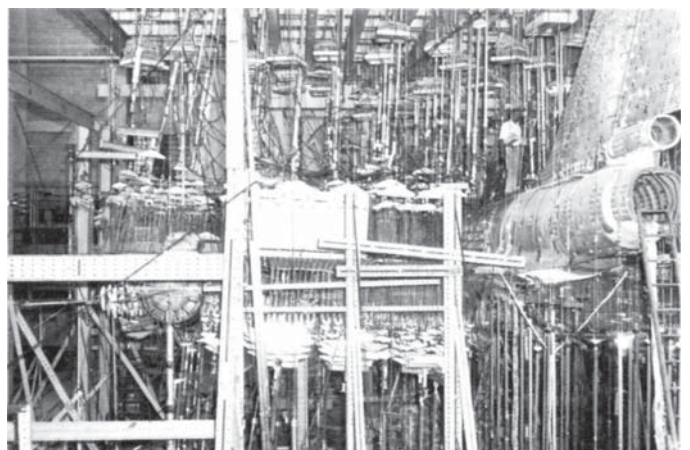
In all, it was later estimated that some 2,000 people witnessed '5664's final seconds in the sky. Local newspaper accounts recorded that the accident was visible as far away as Ft. Worth. In at least one instance, an amateur still photographer caught much of the destruction on film. Later, many of these eye-witness accounts would be reviewed for clues as to why '5664 had destroyed itself over Duncan.

Troops from Ft. Sill, Oklahoma, and Sheppard AFB, Texas, civil defense police, highway patrolmen, sheriff's deputies, and others in an official capacity were called out within hours of the accident to control spectators and protect the wreckage from pilfering. Newspaper accounts at the time estimated that "several thousand" people rushed to the main impact sites shortly after the last pieces hit the ground. In at least a few instances there were attempts by some of the more unscrupulous to walk off with B-58 souvenirs.

Army equipment and personnel from the Ft. Sill, Oklahoma, Army Depot were brought in to assist in the discovery and recovery process. One Sikorsky H-37 and two Bell H-13 helicopters also were provided. The former, capable of heavy lift-



14: Structural testing of "number 4A's" vertical tail at 90% of design ultimate load. This test was conducted less than a month after the crash of '5664. (Photo from Wright Air Development Center)



15: A stunning view of the extremes to which structural testing takes an airframe, "number 4 A" is seen at 50% of design ultimate load during the course of a general structural test. (Wright Air Development Center)



16: Nose of '5664 with strain gauge locations marked by triangles. Color scheme was primarily red and white.

ing, was quickly put to work retrieving '5664's larger parts and moving them to flatbed trailers for transport by truck back to Convair.

Pieces of '5664 were scattered over a roughly 25 square mile area. The debris trail itself, close to 75 miles long, would be many days in being defined. When it came apart the B-58 was moving so fast and flying so high, ballistic paths of its thousands of parts varied enormously depending on weight, drag, relative velocity, and even local wind speed and direction. It would be months before the last of the pieces was retrieved for analysis.

The day after the crash, Siedhof, still strapped to his ejection seat, was found on the Roy Wilkins farm about 11 miles southwest of Lawton. He lay on his side not far from the main portion of the wreckage. A day later and about a mile from Siedhof, Fitzgerald was located on the Bufford Arnold farm. Enmeshed in a crushed section of the forward fuselage, he, too, was still strapped to his ejection seat.

Three magnetic tape data recorders that had been onboard '5664 at the time of its demise. These quickly became a central focus of the accident investigation process. Two of these recorders and their intact tape were found shortly after the crash, but a third was not recovered until several days later. Mysteriously, its tape complement had disappeared...apparently as a result of the aircraft's disintegration. Much to the accident team's frustration, it soon became apparent the missing tape contained the data most critical to the investigation.

After initial attempts by military and government personnel to find the tape failed, Convair moved ahead with a plan of its own. A reward of \$10 per linear foot was offered to anyone who could find the tape or any piece of it.

Each recorder had a tape capacity of about 3,000 feet. Approximately 7,500 feet were found shortly after the crash. but 1,500 feet remained unaccounted for. About 330 feet of the latter were thought to contain flight test data, and of that, about 46 inches was thought to contain the information that was key to determining what had destroyed '5664.

The basic tape, containing data from some twenty-five sources in the aircraft, was a reddish brown plastic strip 1.5 inches wide and a thousandth of an inch thick. Its recovery became such a critical issue, a month after the accident 2,000 Convair employees were given paid time-off to make the first of several trips to Duncan in order to participate in a massive ground search.

No less than fifty-eight chartered buses were required to accommodate this enormous volunteer effort. Following arrival at the crash site, the buses were spaced apart at 320 foot intervals. When the searchers were off-loaded and lined up, they formed a human chain three miles long. This eventually resulted in coverage of virtually every square inch of the 25 square miles thought to be the most likely area in which the tape would have landed. It was all to no avail. Only a few small pieces ever were found...and the critical evidence that lay in the rest of the tape was never brought to light.

The official accident board that convened shortly after the



17: Right outboard engine nacelle. This was the engine that was purposefully failed for the ill-fated November 9th flight.

crash was headed by Col. Robert Harriger, chief of the investigation and field operations division of the Directorate of Flight and Missile Safety Research at Norton AFB, California. Convair investigators included Rex Collingsworth, Bill Funk, W. W. Westcott, Oscar Thompson, J. L. Wood, Tino Sierra, G. O. Warila, Jim Hicks, and Don Martin. These men were tasked with assimilating the huge mass of accumulated data and determining an accident cause. Their final report would strongly influence any corrective measures Convair would be required to take in order to make the B-58 a safe airplane for Air Force crews to fly.

Recovered parts of '5664 were moved into Convair's enormous flight test hangar at their Ft. Worth facility and slowly reassembled in an attempt to ascertain the chain of events that had led to its disintegration. At the same time, data on what there was of the recovered magnetic tape was reviewed and a time history of the aircraft's destruction was recreated.

As the analysis progressed, it became apparent that the cause of the accident was not a simple issue of structural failure. Though this was the penultimate event leading up to the aircraft's virtually instantaneous and complete destruction, the seminal event lay elsewhere and the investigating team knew it.

Eventually, and somewhat ambiguously, the accident board summarized their findings by noting there was a "design deficiency in that the directional restoring moments on the aircraft were not adequate for the test conditions." This provided little consolation to those who sought a more definitive statement, but it did suffice to justify several major changes in the B-58's design.

In fact, the catastrophe had started with the onset of the second yaw oscillation following the loss of thrust in the number 4 engine and the first divergence out to 3.2 degrees. The second oscillation was attributed to the failure of the number 4 engine to completely lose thrust following fuel cut-off. What later was viewed as a "thrust bloom," had caused the aircraft to semi-stabilize momentarily. However when the number 4 engine's thrust finally decayed to zero, the yaw divergence angle continued to increase unchecked.

As noted earlier, Fitzgerald had been asked to use only the control stick to stabilize the aircraft. Thus, when the number 4 engine was shut down and the aircraft yawed, corrective stick action immediately followed. Unpredicted, however, was the effect the elevons (now functioning as ailerons) were having on the adverse yawing moment. When Fitzgerald moved the stick - as any good pilot would have - he unknowingly increased the effective drag on the right side of the aircraft. This, when coupled with an extreme aft e.g., and rudder input (caused by the afore-mentioned aerodynamically induced 15 degree deflection) compounded in its affect by an overly flexible vertical tail, dictated that the aircraft was aerodynamically doomed to continue its yaw divergence far beyond safe limits. At 12 degrees the extreme aft end of the fuselage supporting the vertical tail began to fail, and at 30 degrees the entire aircraft disintegrated. Fitzgerald and Siedhof never had a chance.



18/19: Two views of '5664's vertical tail. Strain gauge locations are readily discernible as each is marked with a colored triangle. Triangle pattern was mirrored on both sides of the fin and rudder.

Other theories as to the accidents cause eventually surfaced, but none ever were given much credibility by investigators. Among these were:

(1) Increased drag on the right side of the aircraft due to the unexpected parallel loss of the number 3 engine. The latter was attributed to "blanking" of the number 3 engine's intake airflow by the fuselage as a result of the yaw angle to the line of flight.

(2) Loss of thrust in the number 3 engine caused by the ingestion of the right nose landing gear door at the onset of the initial yaw divergence.

(3) Nearly a month after the accident, a partially burned weather balloon, found in an Oklahoma farm field, was taken to Ft. Worth for study by Convair. The balloon and part of its radio transmitter were found some seven miles north and one mile west of Duncan. The balloon was partially burned and part of its transmitter was missing. There was some suspicion that the balloon had been ingested by '5664's number 3 engine, but there was never any physical evidence found on the aircraft to give this theory any credibility.

The B-58 fleet, which by late 1959 consisted of about twenty completed aircraft, was temporarily grounded following '5664's crash. As the accident investigation began to unfold, it was presumed the *Hustler* could not be flown safely at Mach 2.0 in a high-q (maximum dynamic pressure) far aft e.g. condition. Performance restrictions were levied and a plan for a fleet-wide modification program was quickly developed.

When coupled with four other fatal B-58 accidents that had occurred during the preceding twelve months, the November 7 accident came close to becoming the final blow leading up to a decision to cancel the entire *Hustler* contract. Critics of the aircraft showed no mercy in condemning it, and the Air Force found itself in a difficult political conundrum.

Following '5664's loss, the B-58 fleet was limited to Mach 1.60 for many months. Even after this restriction was lifted and the program moved back on track, rare was the occasion when a B-58 was flown at Mach 2.0. The loss of '5664 had destroyed what little remained in the way of confidence in the B-58's structural integrity. It would take many demonstration flights (often flown by Beryl Erickson) and the simple passage of time to partially heal what would be considered by some to have been the program's most self-destructive event ever. In the end, the B-58 never fully recovered, and after only 116 aircraft were completed, production was brought to a close. By 1970, the type had been pulled from Little Rock (Arkansas) and Bunker Hill (Indiana) Air Force Bases and retired from the active Air

Force inventory.

While the *Hustler* was still in service, two major changes to all B-58s were integrated as a result of '5664's loss. The first was a fix to the flight control system resulting in reduced activity gain of the aileron control input in response to yaw heading. Small trim surfaces, mounted inboard of the elevons on all early B-58s, were deactivated as well. On later aircraft, these surfaces were replaced by fixed trailing edge fairings.

The second change was a physical strengthening of the vertical fin and associated fuselage structure just forward of the tail. New aircraft were built with these modifications integral to the flight control system and structure, respectfully.

A second B-58 was eventually pulled from the production line and modified to the new standard. Just short of a month after '5664 and its crew evaporated in the skies over Oklahoma, Beryl Erickson climbed into this modified aircraft, taxied to the end of the main Carswell AFB runway, and headed skyward to complete the test that Fitzgerald and Siedhof had died attempting. Once at altitude and speed, Erickson shut down the right outboard engine. The airplane yawed, quickly stabilized, and moments later, recovered without incident. No ancillary problems were encountered. Within a week of the test the B-58 was officially cleared for Mach 2.0 flight in a high-q, far aft e.g. condition.

Much was learned from the loss of '5664. Among the industry-wide changes that resulted were: vertical fin aspect ratios (chord width to length) were reduced and, consequently, vertical fin stiffness requirements were given considerably higher priority; and where appropriate, rudder and aileron authority to offset thrust asymmetry was given considerably more emphasis.

The first aircraft to benefit from these new criteria was the General Dynamics) F-111. Its short, stubby vertical tail remains a testimony to the fact that, in the end, Fitzgerald and Siedhof did not die in vain. They can rest in peace comforted by the fact their sacrifice resulted in one less unknown confronting the many pilots who followed in their pioneering footsteps.

They are not forgotten. •

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