

## **LEGACY IN SAFETY: NASA CONTRIBUTIONS TO KNOWLEDGE IN AIRCRAFT DITCHING**

The dramatic ditching of US Airways Flight 1549 in the Hudson River on January 15, 2009, without fatalities to 150 passengers and five crew members was an outstanding demonstration of professional airmanship by the pilot and copilot. Although ditching a commercial transport is one of the rarest events in aviation, a successful outcome is dependent on an in-depth knowledge of the proper procedures and critical parameters to be maintained prior to the water impact. Land-based aircraft are not designed for routine entry into the water, and inadequate piloting procedures can easily result in catastrophic results.

In view of the widespread interest generated by this incident, it is appropriate to briefly review the roles that the National Advisory Committee for Aeronautics (NACA) and the National Aeronautics and Space Administration (NASA) have played through the years in the development of aircraft design methods and ditching procedures. Contributions of the efforts of these government agencies in this area have served as a foundation of knowledge for current and future military and civil aircraft.

In the 1920s, the Langley Memorial Laboratory of the NACA in Hampton, Virginia, began research efforts in the field of hydrodynamics directed toward improving the takeoff and landing performance of seaplanes and flying boats which were rapidly emerging as a primary means of transportation. A towing tank capable of moving models at speeds of up to 80 mph through water was built having a width of 24 feet, a length of 2,900 feet, housing a long channel a 12-foot depth of water. A decade of research on flying boat performance was initiated in 1931 directed at seaplane problems such as takeoff, landing, porpoising, skipping, and water spray control. The workload at the towing tank increased dramatically and a second towing tank known as Tank No. 2 was added to the Langley test capability.

During World War II, a major operational problem arose for the nation's military aircraft and the focus of research in Langley's towing tanks was redirected. The problem of ditching, defined as the forced landing of a land-based airplane at sea, had become a critical issue for aircraft in the European and Pacific theaters. Damaged and fuel-starved aircraft were being routinely forced to ditch at sea, and many designs lacked adequate structural design and optimized procedures for surviving the impact of the landing. In addition to structural failure and excessive (often fatal) loads transmitted to the aircrews, some aircraft rapidly nosed over into a deep dive, completely submersing the crew and preventing escape.

In 1943 the Army and Navy requested that Langley undertake a major study of ditching with a view to providing procedural recommendations to operational military units as well as to provide designers of new military aircraft with valuable data. The resulting research effort at Langley was extremely broad, including: structural tests to determine the structural load limits of actual aircraft such as the Boeing B-17 Flying Fortress, the Consolidated B-24 Liberator, and the Martin B-26 Marauder; measurement of the stresses imposed on structures during landings in calm and rough seas; and observations of aircraft behavior during ditching as replicated by free-

flight models in Tow Tank 2. Virtually every U.S. bomber and fighter configuration was evaluated in simulated ditching tests to determine the most desirable airplane attitude and configuration for ditching. Major questions required answers, such as whether to deflect wing trailing-edge flaps or extend the landing gear, whether bomb-bay doors should be opened to partially absorb the impact, and whether one wing tip should be allowed to hit the water first to slew the airplane around to absorb energy.

The B-24 bomber, in particular, had exhibited appalling ditching behavior in operational service. When ditched, the airplane suffered massive structural failure and a diving tendency with a poor record for survivability of the crew. Extensive testing of a B-24 model in the towing tank faithfully replicated the undesirable ditching characteristics and permitted the evaluation of many modifications to improve the aircraft as well as recommendations for ditching procedures of operational aircraft. In addition to studies conducted in the Langley laboratories, the NACA provided instrumentation for two experimental ditching tests by the Army Air Forces in Virginia and Florida. The test in Virginia was conducted by the Army Air Forces in the James River near Newport News in 1944 and was followed by additional B-24 model tests in the Langley towing tank for comparison of accelerations during the ditching impact. Excellent agreement was obtained between the model and full-scale results, providing additional confidence in the Langley testing procedure. Tests in a structures research laboratory at Langley showed that the bomb-bay doors of the B-24 had only one-fifth as much strength as the rest of the bottom structure, and door failure was known to be a major factor in the unacceptable ditching characteristics of the airplane. Working with the Army Air Forces, Langley designed and evaluated stiffening ribs that were distributed to the operational squadrons in 1944 for implementation prior to ditching. The ribs could be rapidly installed by the crew in a few minutes during preparations for the landing.

After the war, the introduction of civil propeller-driven transports required an assessment of ditching characteristics for safety and regulatory perspectives. The Civil Aeronautics Administration (predecessor of today's Federal Aviation Administration) requested Langley to conduct model tests of the Douglas DC-4 and DC-6 transports in the Langley tow tank and with an outdoor catapult that launched models into simulated ditchings in the nearby Back River. After years of progress in the testing technique during the war, the transport models were upgraded to include scaled structural components and skins to assess damage after the impact. Results and recommendations of these early studies of commercial transports in 1949 have generally held true for most subsequent transport configurations. The most important findings were that the most favorable ditching results occurred by contacting the water at a nose-high attitude with the wing landing flaps full down.

The introduction of trans-oceanic jet transports with unconventional features such as podded wing-mounted engines brought new questions regarding ditching behavior, and in 1955 the CAA requested that Langley conduct tow-tank tests of the Boeing 707 configuration. The objectives of the tests were to observe the behavior of the model during ditching and to determine the safest procedure for emergency water landing. As was the case for the earlier transports, it was concluded that the transport should be ditched at a nose-high attitude (about 12° nose up) with the landing flaps down. Based on the model results, peak decelerations along and normal to the fuselage axis were each predicted to be about 5g, and some of the engine nacelles of the four-engine airplane would probably be torn away.

Additional ditching tests of transport-type aircraft have been conducted in subsequent years. For a number of years, airplane configurations and sizes were not too different from the Boeing 707, and adequate predictions could be made of ditching characteristics. However, the massive Lockheed C-5 military transport was much larger and heavier than any aircraft design previously tested for ditching behavior at Langley. Therefore, ditching tests of a model the C-5 were conducted in 1969 for the Air Force with results indicating, once again, that a nose-up (about 7°) landing attitude with flaps down would be most favorable for ditching. Langley's researchers were especially challenged in this study for recommendations regarding the landing gear position for ditching. The large number of main landing-gear wheels on the airplane (24) and variable gear positions led to extensive testing and specific recommendations for the C-5.

Langley's research programs on hydrodynamics and aircraft ditching ended in the late 1960s, but its contributions to the operational safety of the nation's civil and military aircraft programs are legendary.

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