Breaking the Sound Barrier: The Aerodynamic Breakthroughs that Made It Possible

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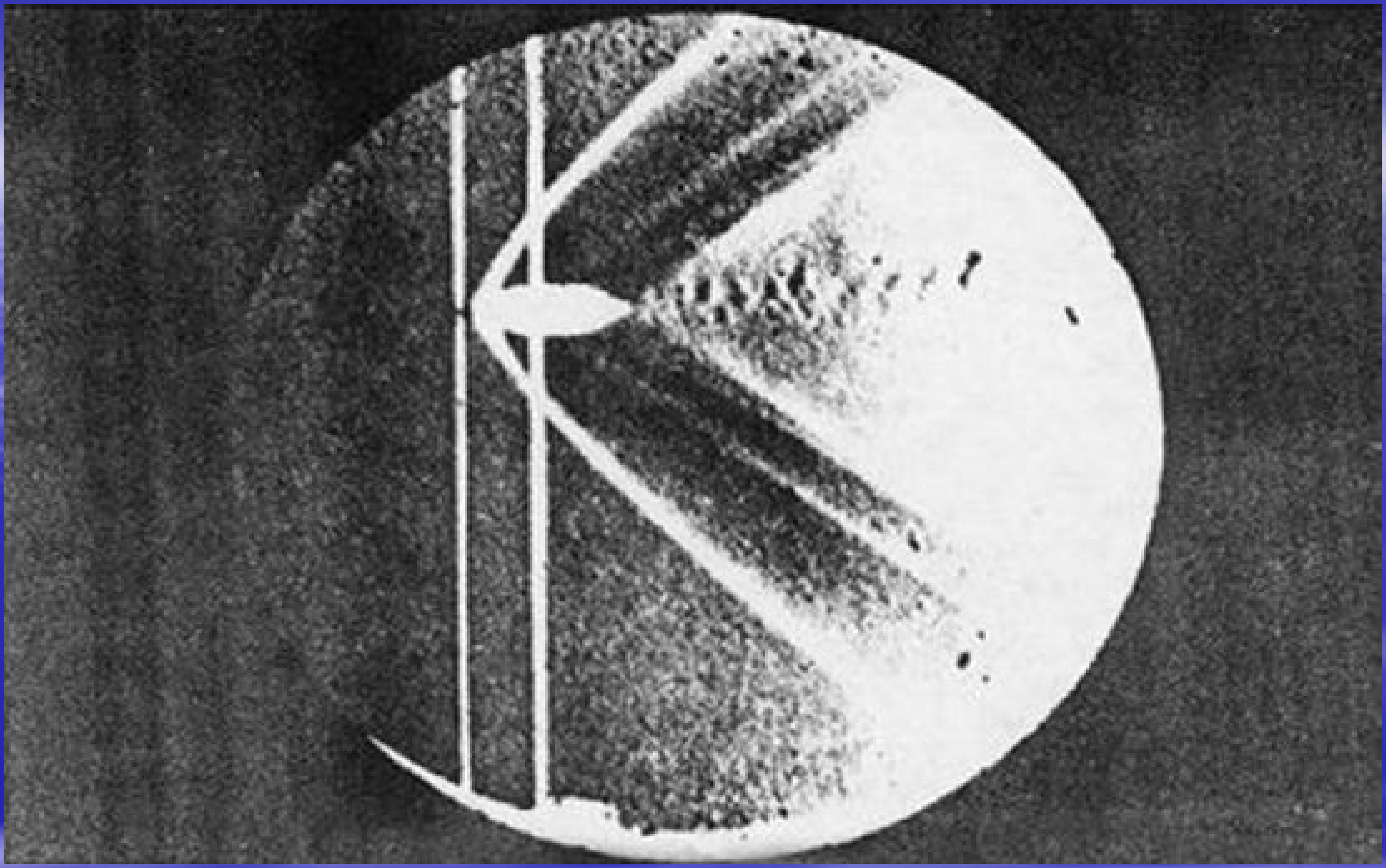
I. PREHISTORY

II. EXPLAINING THE COMPRESSIBILITY PROBLEM

III. LEARNING HOW TO DEAL WITH IT

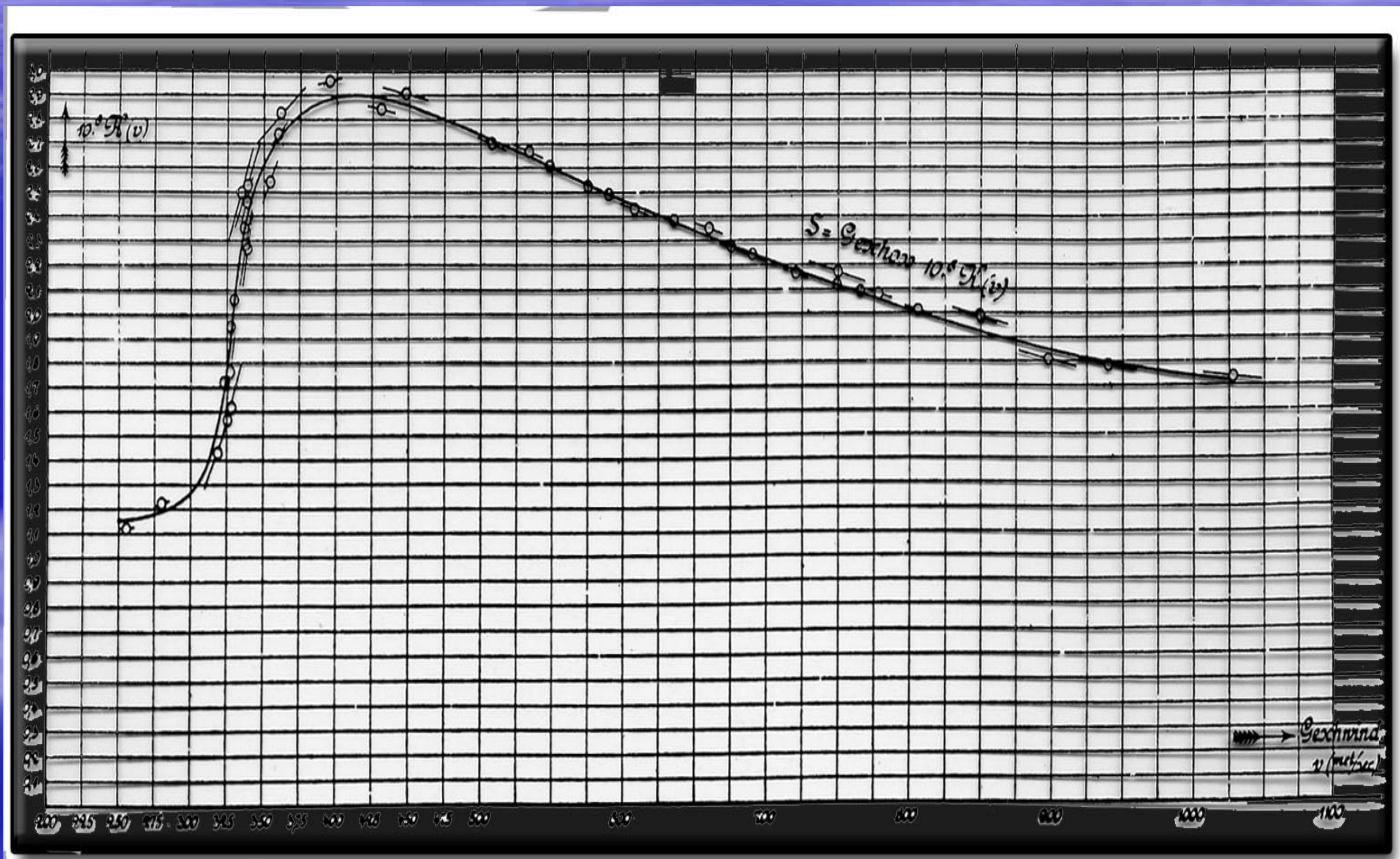
Ernst Mach, a great 19th century scientist from Austria.

- Mach was actually the first person in history to develop a method for visualizing the flow passing over an object at supersonic speeds. He was also the first to understand the fundamental principles that govern supersonic flow and their impact on aerodynamics.



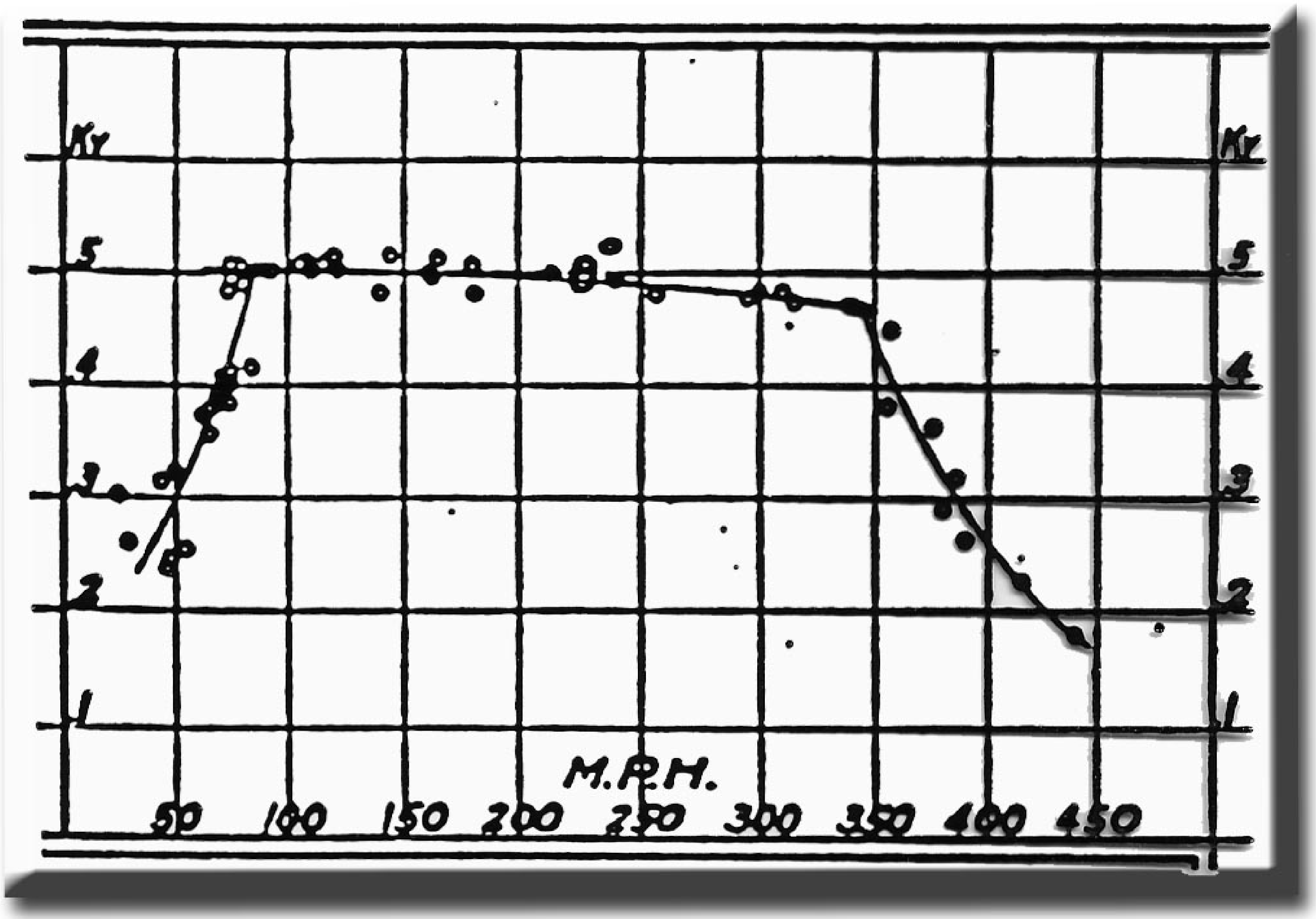
Photograph of a bullet in supersonic flight, published by Ernst Mach in 1887

BALLISTIC MEASUREMENTS OF DRAG COEEFICIENT 1910



- FRANK CALDWELL AND ELISHA FALES
- McC00K FIELD, DAYTON, OHIO
- 1918 – WIND TUNNEL TESTS: 25-465
- AIRFOILS: 8% TO 20% THICKNESS

AIRFOIL LIFT COEFFIENT VERSUS VELOCITY – DATA OF CALDWELL AND FALES -- 1918



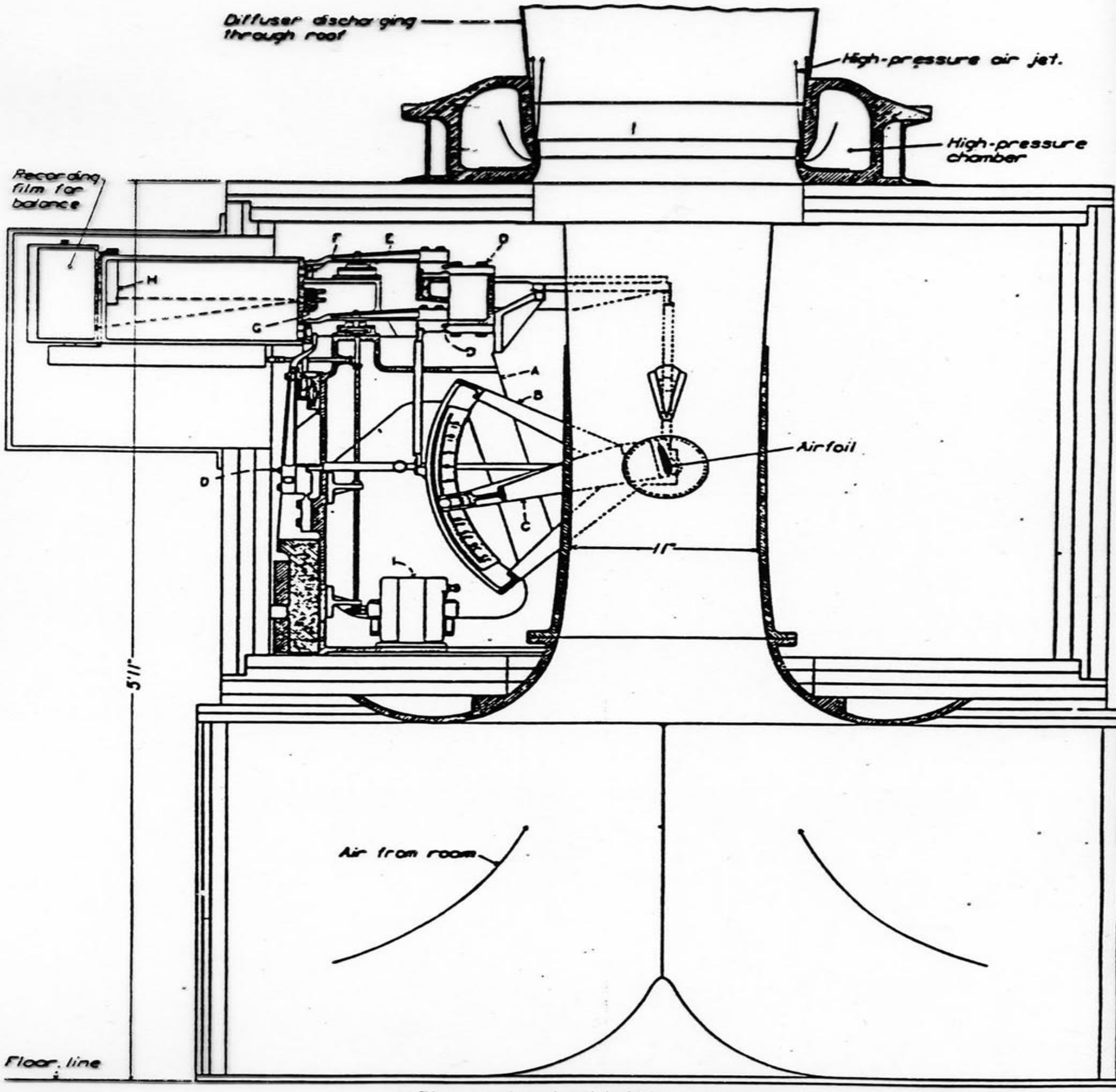
- LYMAN J. BRIGGS AND HIGH L. DYRDEN
- NATIONAL BUREAU OF STANDARDS, 1924
- COMPRESSIBILITY EFFECTS
- AS THE AIRFLOW INCREASES BEYOND A CERTAIN “CRITICAL SPEED”:
  1. LIFT DECREASED DRAMATICALLY
  2. DRAG INCREASED DRAMATICALLY
  3. CENTER-OF-PRESSURE SHIFTS REARWARD
  4. THE “CRITICAL SPEED” AT WHICH THESE OCCUR DECREASES AS THE ANGLE OF ATTACK IS INCREASED AND THE AIRFOIL THICKNESS IS INCREASED

- BRIGGS AND DRYDEN, NBS, 1926
- PRESSURE DISTRIBUTIONS INDICATED FLOW SEPARATION
- OIL FLOW EXPERIMENTS CONFIRMED IT

John Stack -- 1906-1972
American Aeronautical Engineer

- Played an important role to achieve manned supersonic flight

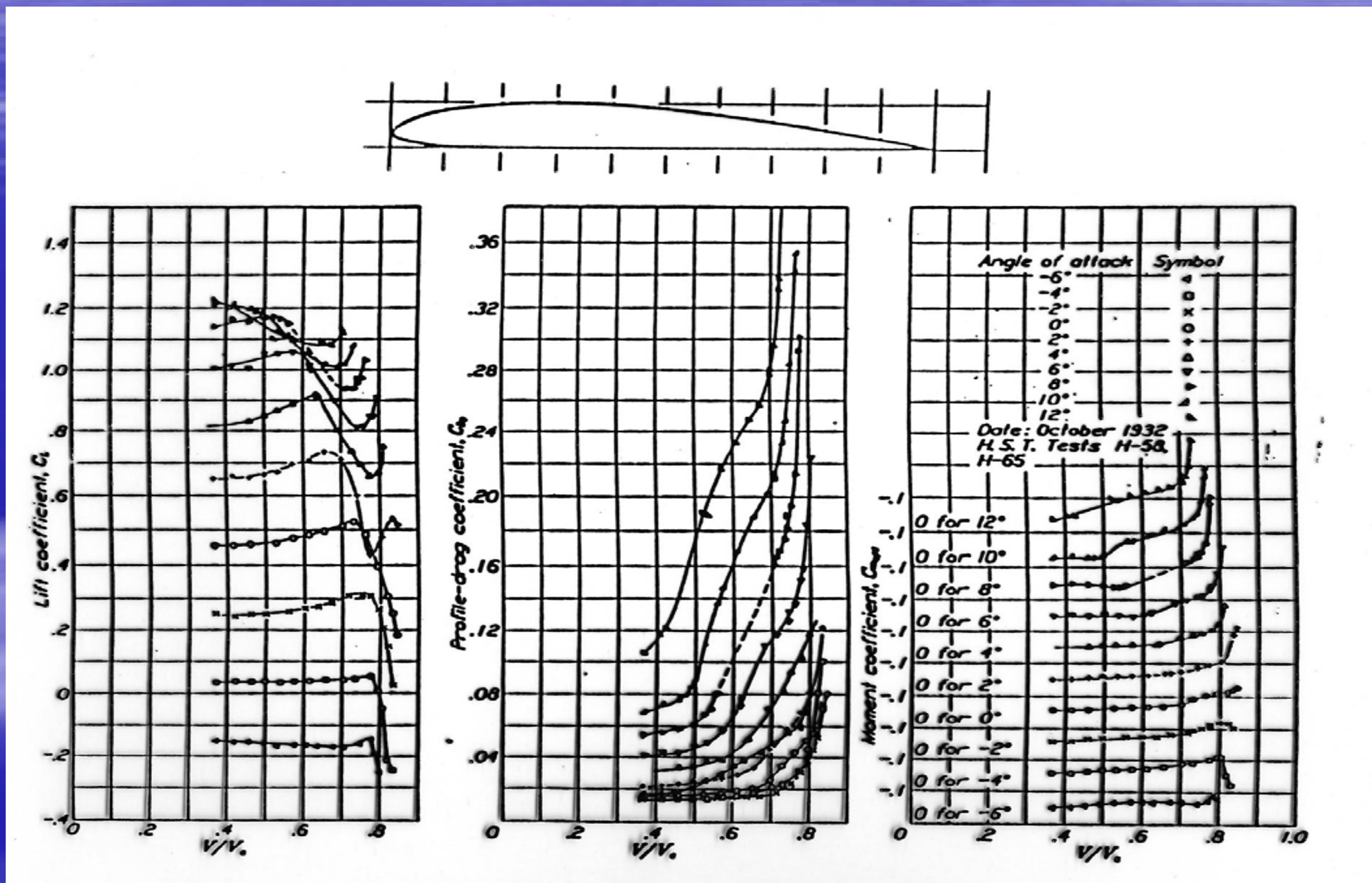
NACA HIGH-SPEED WIND TUNNEL



—Diagrammatic section of the high-speed wind tunnel.

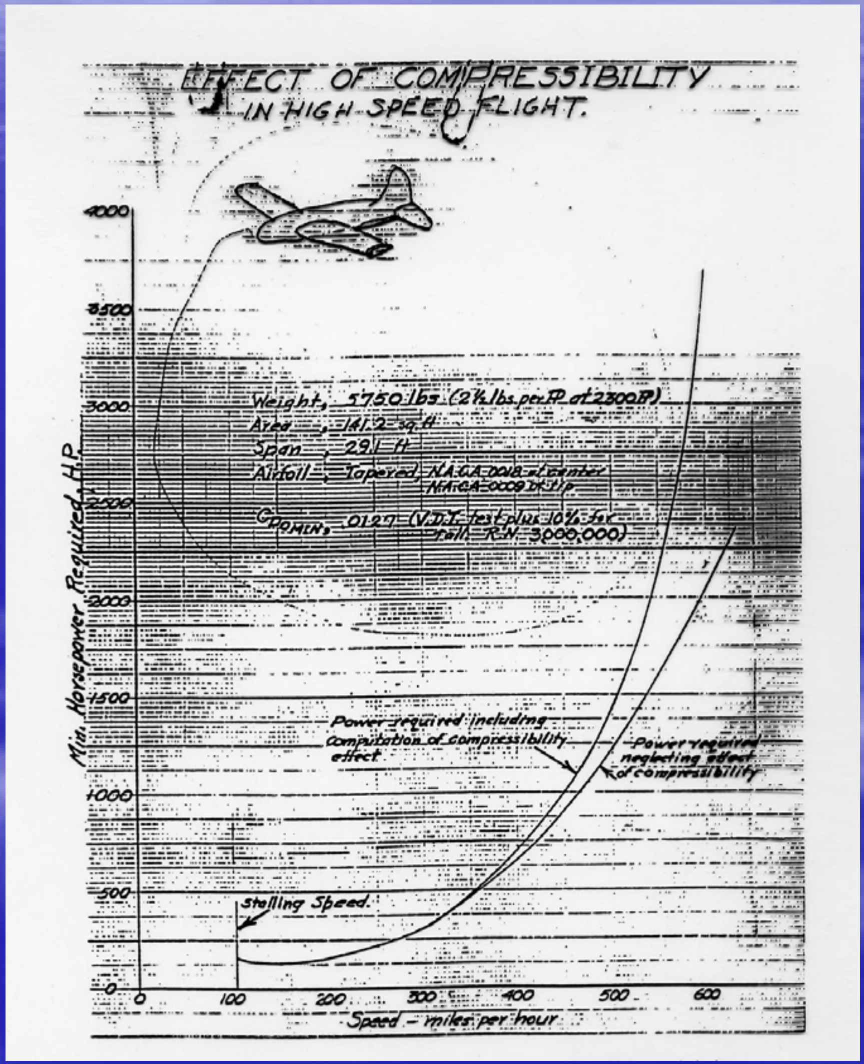
A, balance frame
B, cradle
C, rotatable yoke for changing angle of attack
D, springs
E, dashpot
F, lens and mirror container
G, N.A.C.A. pressure cell
H, source light
I, film drive motor

JOHN STACK'S AIRFOIL DATA -- 1934

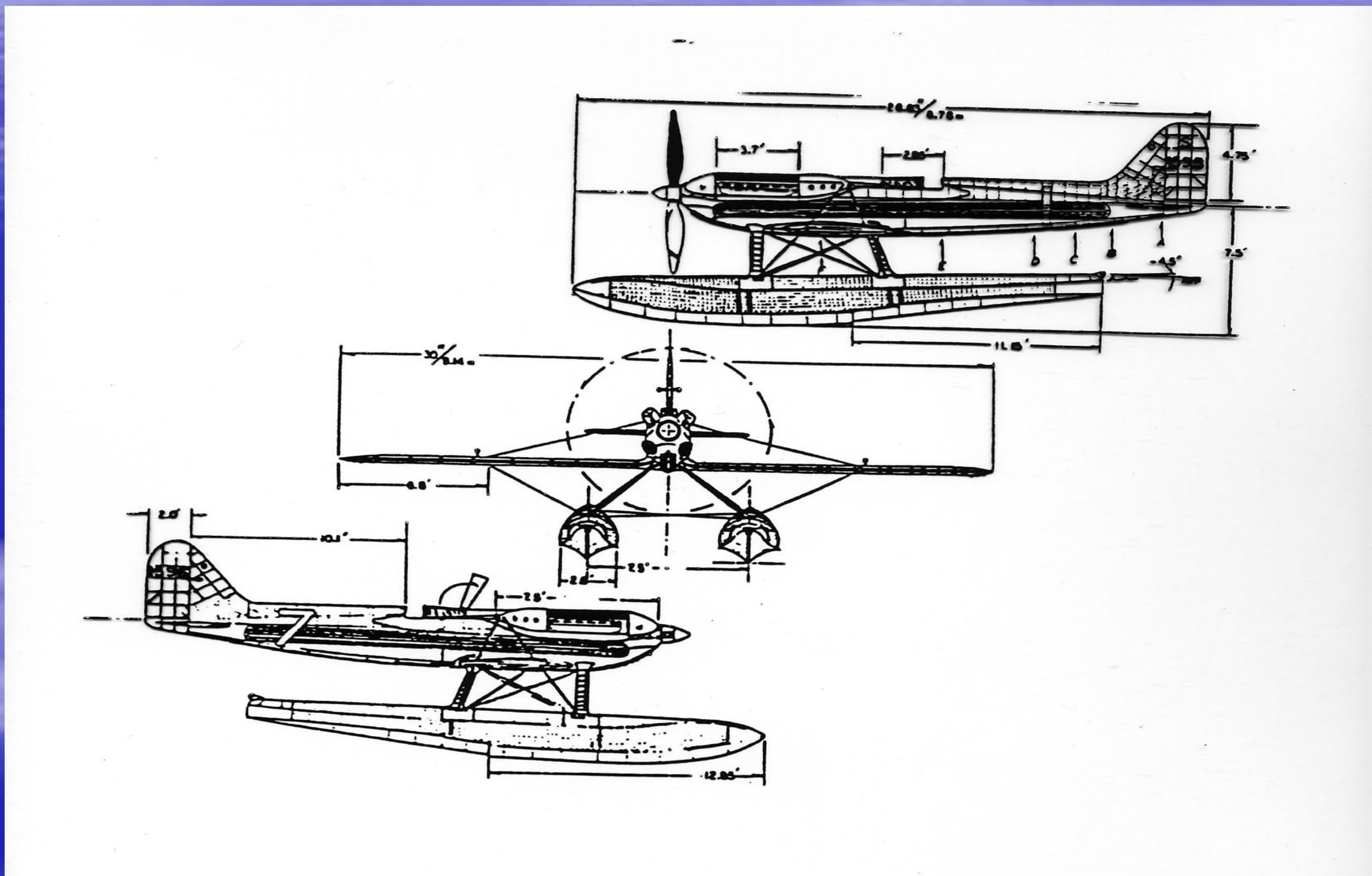


High-Speed Research Airplane

Stack's hand-drawn graph of the power required for a high-speed airplane illustrating the effects of compressibility (1933). (From John Stack Files)



SUPERMARINE S6-B



EASTMAN JACOBS

- Wind Tunnel Work In The 30's Established The Shape Of Airfoils
- 1939, Eastman Jacobs at NACA at Langley designed and tested the first laminar flow aerofoil. These shapes had very low drag and the section shown below achieved a lift to drag ratio of about 300.

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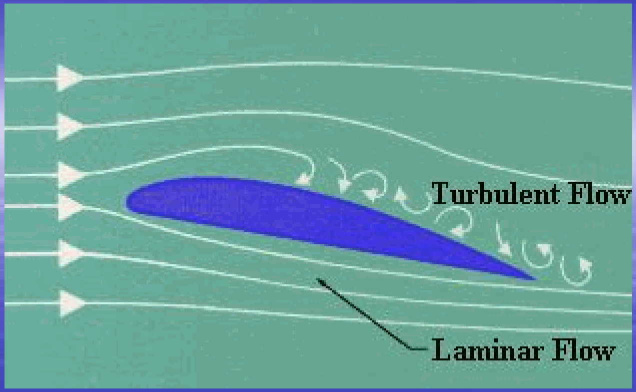
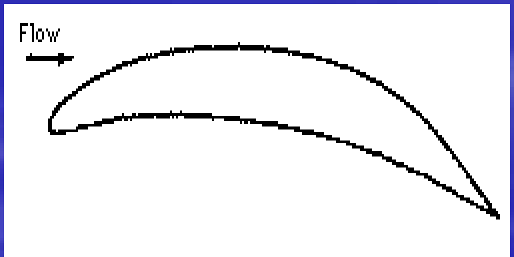
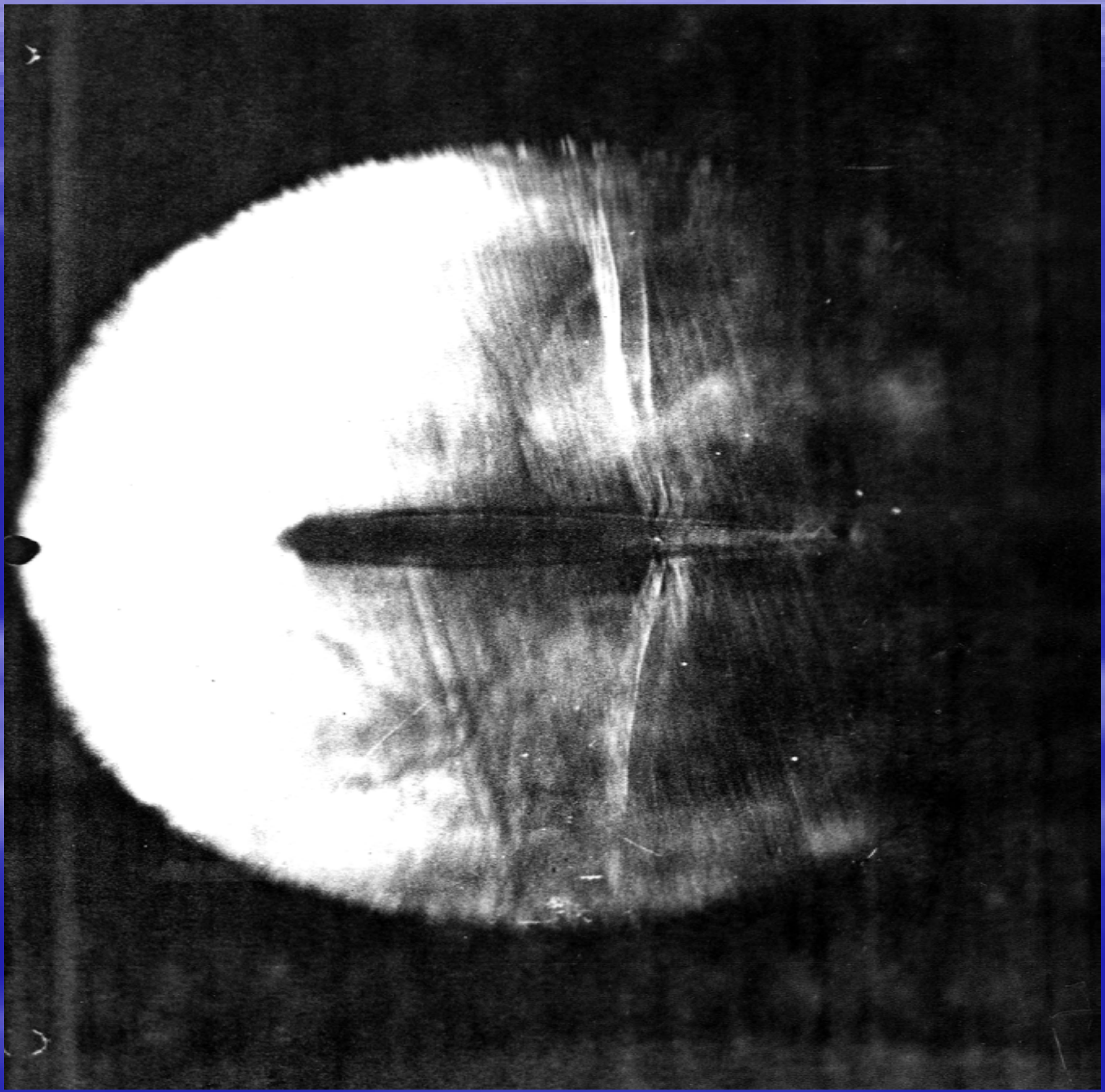




Jacobs Designed & Tested Laminar Flow Airfoil

SHOCK WAVES ON AIRFOIL FIRST PHOTOGRAPH, 1934



THEODORE THEODORSEN

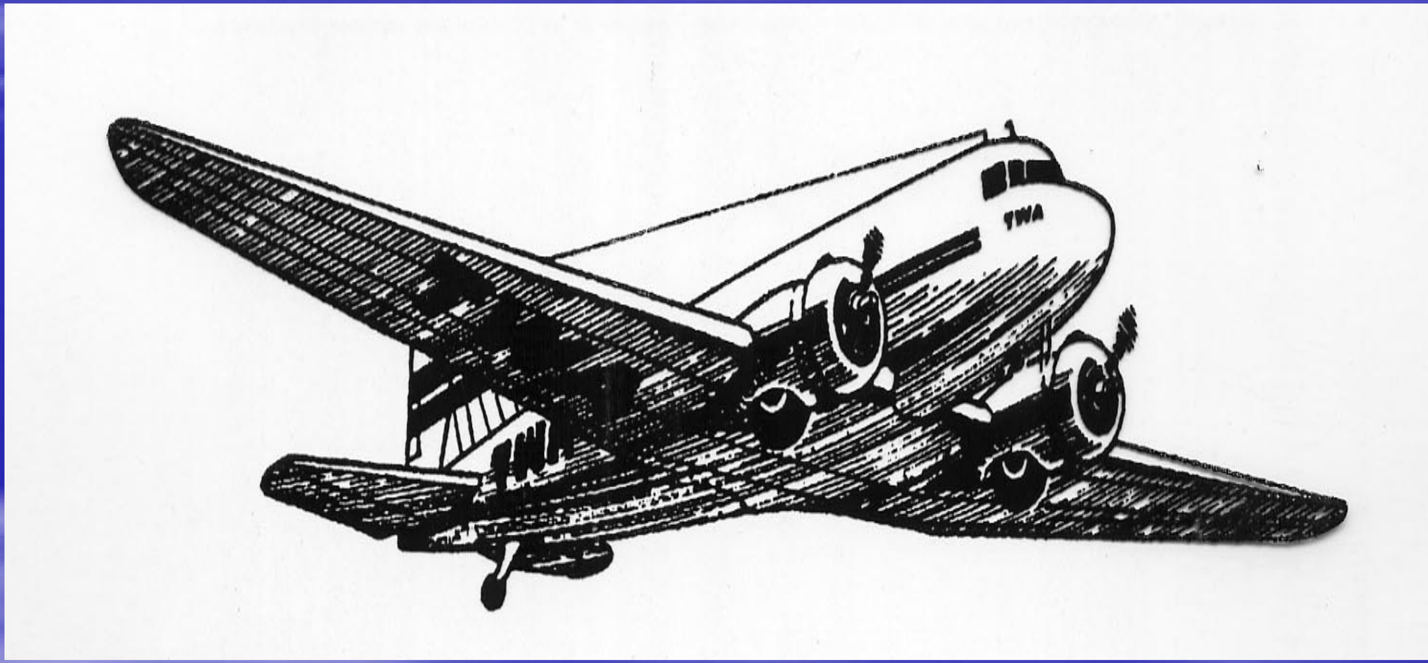
- General Theory of Aerodynamic Instability and Mechanism Flutter
- Aerodynamic forces on oscillating airfoil

DC-3

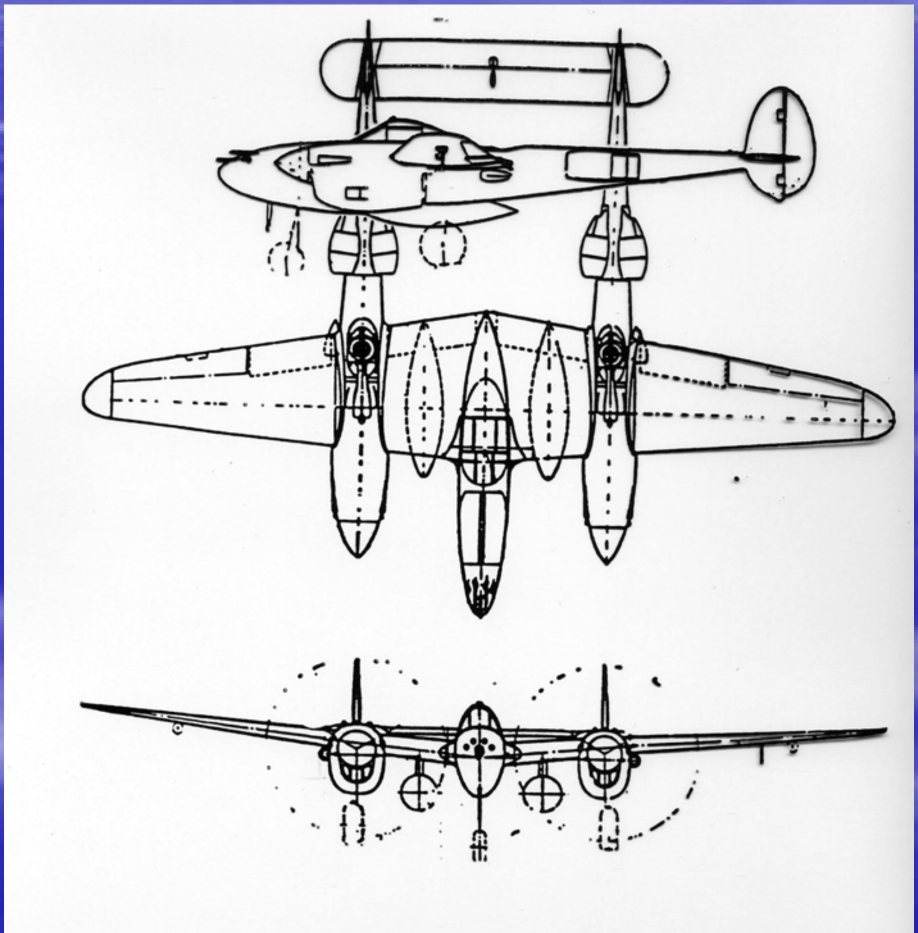
- **Manufacturer:**Douglas
- **First Flight:**December 17, 1935
- **Wingspan:**95 feet
- **Length:**64 feet 5.5 inches
- **Height:**16 feet, 3.6 inches
- **Weight:**30,000 pounds
- **Top Speed:**216 mph
- **Cruising Speed:**192 mph
- **Flight Altitude:**20,800 feet

- **Range:**1,495 miles
- **Engines:**Two 1,200-horsepower Wright Cyclone radial engines
- **PassengerAccommodations:**3 crew and 14 sleeper passengers, or 21 to 28 day

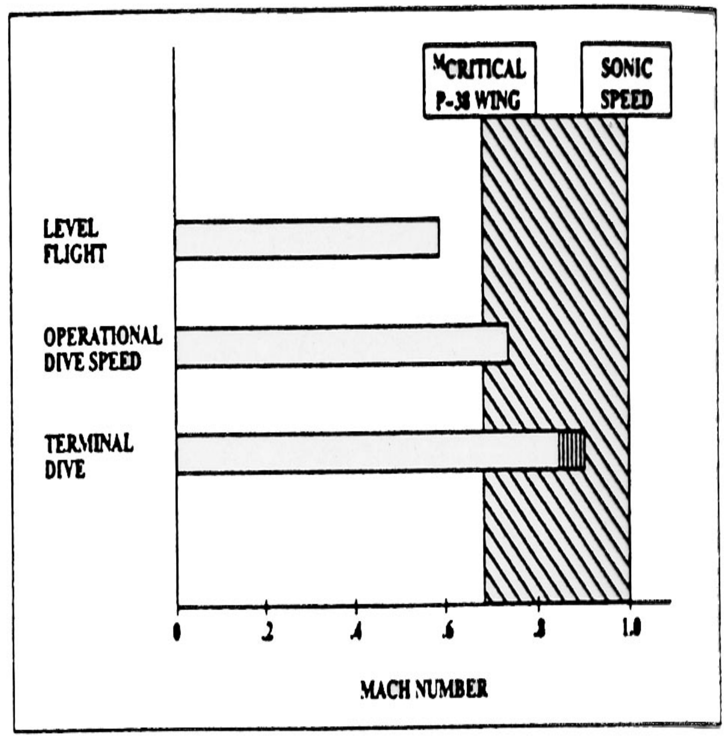
DOUGLAS DC-3 1935



LOCKHEED P-38

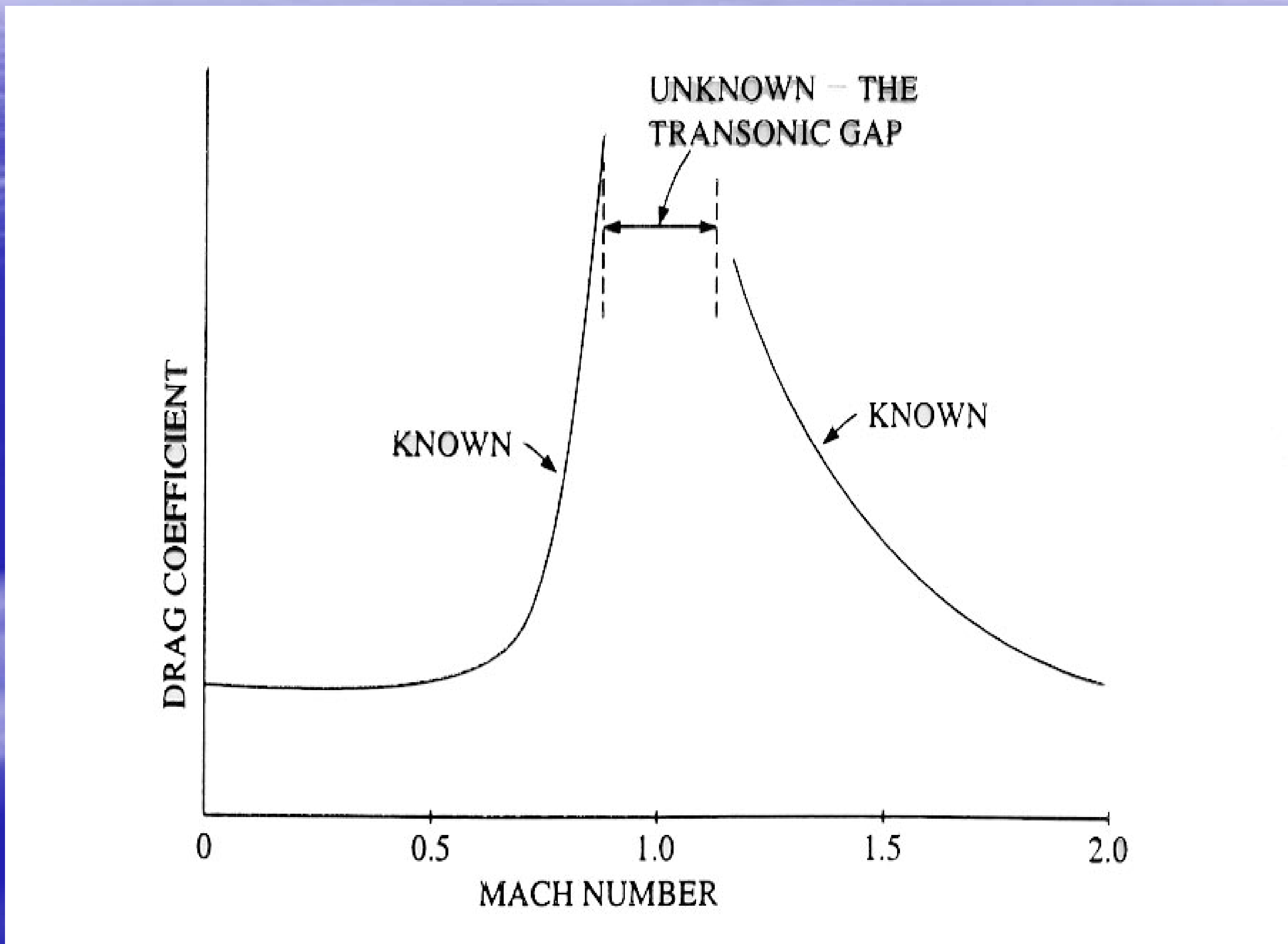


BAR CHART SHOWING THE MAGNITUDE OF HOW MUCH THE P-38 PENETRATED THE COMPRESSIBILITY REGIME



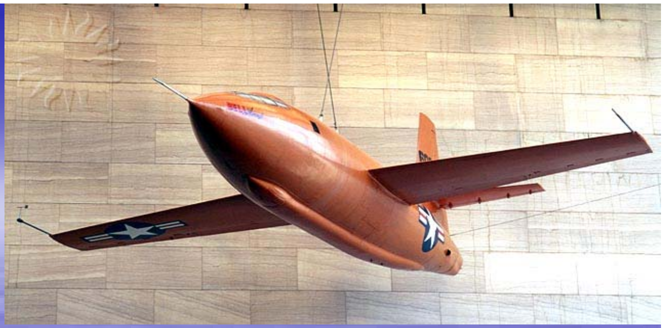
(From R. L. Foss, “From Propellers to Jets in Fighter Aircraft Design,” in Diamond Jubilee of Power Flight: The Evolution of Aircraft Design, ed., by Jay Pinson, AIAA, New York, 1978, pp. 51-64

GENERIC VARIATION OF AIRPLANE DRAG COEFFICIENT VERSUS MACH NUMBER OF SUBSONIC, TRANSONIC, & SUPERSONIC SPEEDS



BELL X-1

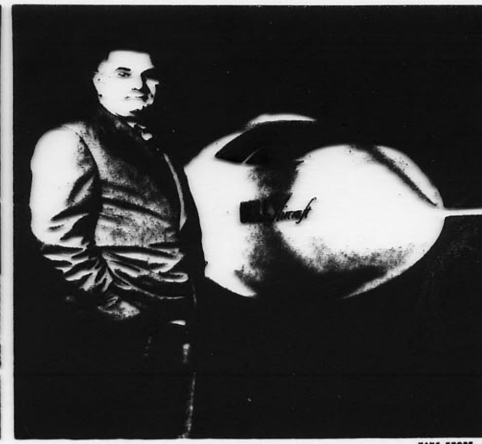
Bell X-1



- First of the rocket-powered research aircraft, the X-1 (originally designated the XS-1)
- Bullet-shaped airplane that was built by the Bell Aircraft Company for the US Air Force and the National Advisory Committee for Aeronautics (NACA)
- X-1 mission was to investigate the transonic speed range (speeds from just below to just above the speed of sound) and, if possible, to break the "sound barrier"
- The **Bell X-1** was the first aircraft to exceed the speed of sound. It was the first of the so called X-planes
- X-Planes were a series of aircraft designated for testing of new technologies and usually kept highly secret

- In the 1947 special case, combat aviator Chuck Yeager flew manufacturer Lawrence Bell's new X-1 airplane faster than the speed of sound. Yeager thereby not only pierced the so-called sound barrier, but helped operate a transonic research tool conceived mainly by veteran NACA high-speed researcher and manager John Stack

EDWARD BURKS



HANS KNOPF

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SCIENTIST: John Stack, for the past 20 years a government research scientist with the National Advisory Committee for Aeronautics, is the first of the three men who share the award of the Collier Trophy for the achievement of human supersonic flight. It was because of Stack's awareness of the absolute necessity for ever superior aircraft, and his intensive study of problems of supersonic flight that a workable program for the construction of a research plane came into being.

MANUFACTURER: Lawrence D. Bell, president of Bell Aircraft Corporation, was awarded the contract by the Air Force to design and build the plane evolved from Stack's scientific presentation of supersonic flight. Bell has a reputation for taking on the unusual, the unconventional and what some called the impossible. The ship he designed and built was the Bell X-1 which, before delivery, was tested in 21 flights at a speed slightly less than that of sound.

PILOT: Captain Charles E. Yeager, USAF, was chosen from the nation's finest test-pilot talent as the man to fly the plane pioneered by Stack and built by Bell. Deemed "a natural airman, if there is such a thing," on October 14, 1947, Yeager became the first man to fly faster than the speed of sound. It is for the combined achievement of these three men in their successful penetration of the transonic barrier that the Collier Trophy for 1947 has been awarded.

The Collier Trophy

For Flight Beyond the Speed of Sound

By FREDERICK R. NEELY

For bringing about the achievement of human supersonic flight, John Stack, Lawrence D. Bell and Captain Charles E. Yeager, USAF, win America's highest aviation award

AMERICA'S highest aeronautical honor, the 37-year-old Collier Trophy, was presented by President Truman at the White House Friday, December 17th, to the three men adjudged most responsible for the attainment of human supersonic flight. The trophy is awarded annually by a committee selected by the National Aeronautic Association for "the greatest achievement in aviation in America, the value of which has been demonstrated by actual use during the preceding year." It will be shared equally for the ensuing year by:

John Stack, career government research scientist of the National Advisory Committee for Aeronautics "for pioneering research to determine the physical laws affecting supersonic flight and for his conception of transonic research airplanes."

Lawrence D. Bell, president of Bell Aircraft Corporation, "for the design and construction of the special research airplane X-1."

Captain Charles E. Yeager, U.S. Air Force, "who, with that airplane, on October 14, 1947, first achieved human flight faster than sound."

To those three men goes the honor of playing the major roles in an achievement which the Collier Trophy committee termed "the greatest since the first successful flight of the original Wright Brothers' airplane."

All three have been outstanding in their contributions to the vitally important science of supersonic flight—flight that is faster than sound, the speed of which at sea level, with a temperature of 59 degrees and in still air, is 761 miles an hour. However, at altitudes ranging between 40,000 and 100,000 feet, the speed of sound is reached at only 663 miles an hour. This is due to the fact that at such high altitudes the temperature is almost constantly 67 degrees below zero and sound travels more slowly in cold air. At just what altitude Capt. Yeager flew is as much of a secret as the actual supersonic speed he attained.

The problem that confronted Stack, Bell and Yeager was not so much that of flying faster than sound as it was successful flying at speeds between 600 and 900 miles an hour—the transonic range.

Aeronautical scientists were in grave doubt as to just what took place when conventional aircraft entered the transonic range in high-speed dives. They knew that both plane and pilot were kicked around unmercifully for seconds that seemed like centuries and that both were completely out of control. Badly and naturally frightened, the pilots were unable to bring back detailed scientific reports on the phenomenon, and they were usually unwilling to repeat their flights.

Wind tunnel tests with small-scale models revealed that the flow of air over a plane in the transonic range was partly subsonic and partly supersonic. Because of this, the conventional planes (usually fighter types) took on an extremely inconsistent and erratic behavior. But the tunnel findings were not conclusive and since supersonic tunnels large enough to mount a full-scale airplane are prohibitive in cost the scientists concluded they needed a special research airplane equipped with instruments capable of measuring and automatically recording all of the forces acting upon an airplane in transonic flight.

This was where John Stack came in. It was natural that he should have conducted the research phase for he had been working on the fundamental problems of high-speed flight in the wind tunnels and laboratories of the NACA at Langley Field, Virginia, since 1929, shortly after he had joined the government's great aeronautical research es-

JOHN STACK AND HIS SECOND COLLIER TROPHY, 1953