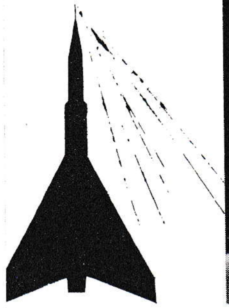
how to fly at MACH 2

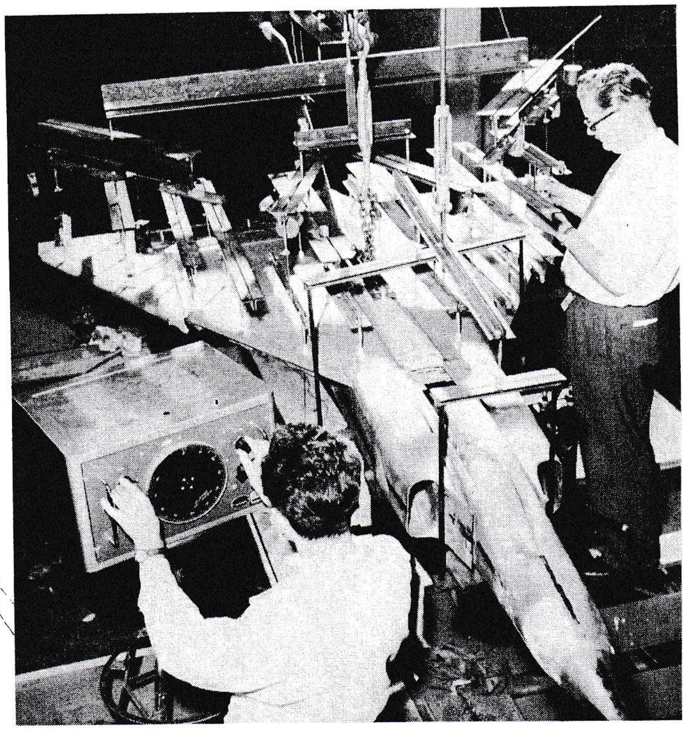
by Neil A. Macdougall

The Arrow uses twice as much power as the Queen Mary — almost enough to lift the big plane vertically off the ground.

IMPERIAL OIL WAYS

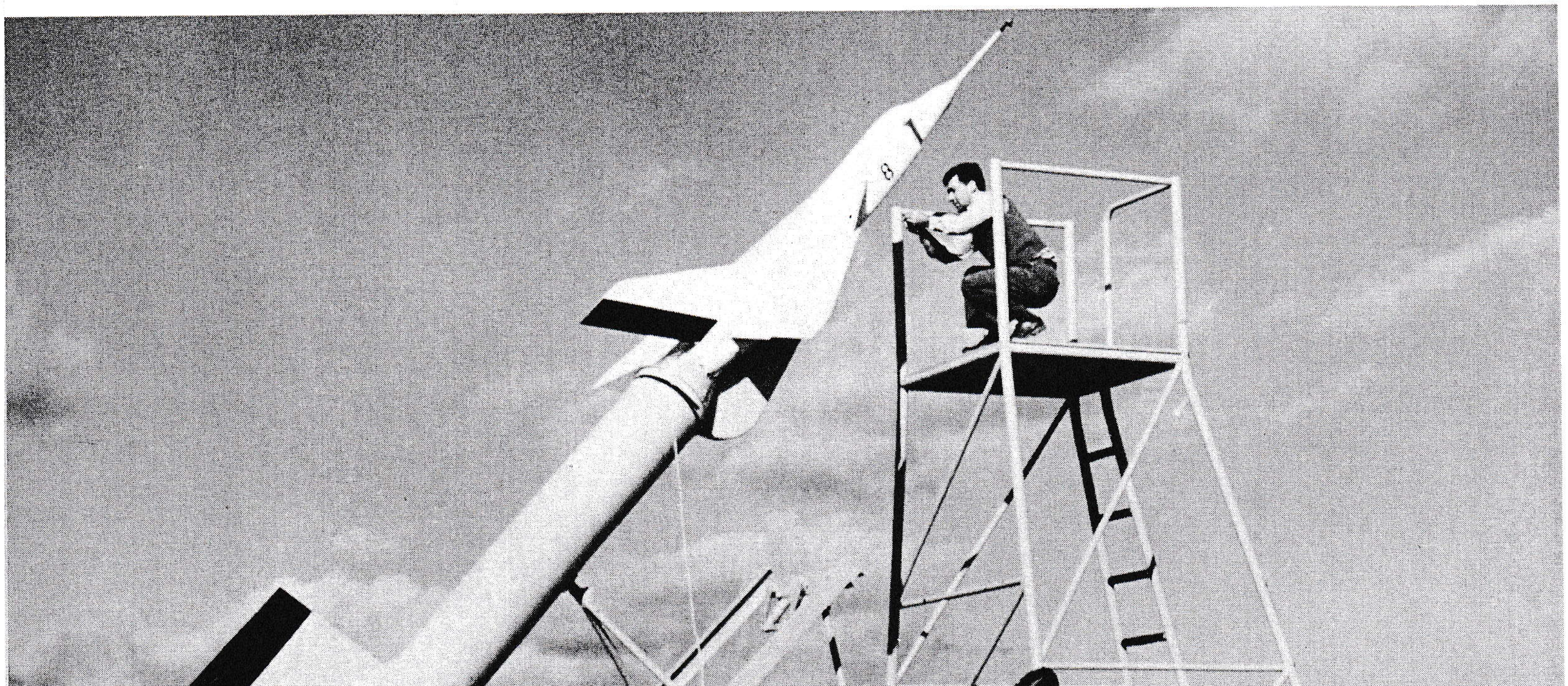
JUNE 1958





Structure of a "free-flight" model is tested at key points, with strain gauges to measure deflection. Later, the model is boosted skywards by a Nike missile.

At altitude, the free-flight model is loosed from the Nike. Instruments send to the ground information on the model's behaviour.



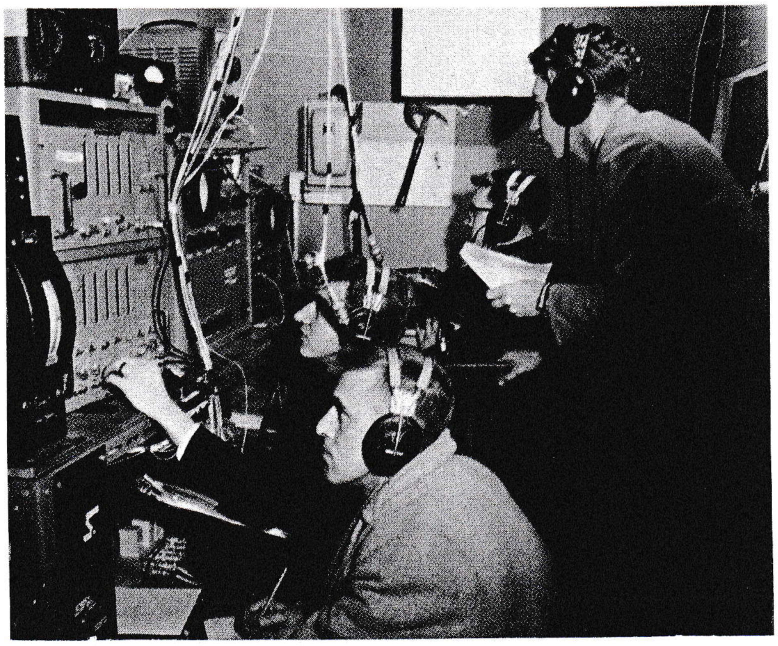
On November 12, 1906, a Brazilian by the name of Santos Dumont established the world's first air-speed record. With his peaked cap reversed to keep it on in the fierce breeze, he flew 721 feet at an average speed of 25.6 mph. Spurred by this challenge and prospects of fame and fortune, airmen have been seeking to raise the speed record ever since.

Improvements in engines and aircraft design permitted almost yearly increases at first. By 1931 a British pilot had boosted the record to 407 mph in a sleek, blue and silver Supermarine S.6B seaplane. Its engine was a special Rolls-Royce design which was built to run for only an hour before something broke. The record speed was 45 mph faster than the top speed of the Spitfire, the descendant of the record-breaker.

In 1939 Flug Kapitan Fritz Wendell captured the record for Germany in a hotrodder's version of the Messerschmitt Me.109. But then the War began and Messerschmitts, rather than records, became the objects of pursuit. Towards the end of the War, fighter pilots began to report disturbing phenomena. Diving away from attackers or pursuing an enemy, they encountered violent buffeting. Sometimes the vibrations became so great that the aircraft went out of control, or broke up in flight. This problem seemed to become more serious as the speed of sound (760 mph at sea level) was approached. Many thought it would be impossible to fly at faster speeds. To fly a single-seat fighter like the Mustang at 1,000 mph, someone calculated, would take 35,000 horsepower.

The air around us is like an ocean and if we could see all its waves and currents and eddies (as we can see some, the clouds), the theory of aerodynamics would be understood better. Engineers have long tried to design aeroplanes with the least possible wind resistance or drag. To do so, they have carefully fashioned scale models and blown air over them. When smoke is introduced into such wind tunnels, the air flow or streamlines become visible.

In the telemetering van, the tracking crew records information telemetered from the free-flight model, somewhere in the sky.



(More sophisticated techniques are used now, but the idea is the same.) Thus structures can be designed so that the air flows smoothly around curved surfaces, leaving no turbulent wake. Any departure from the ideal shape causes the breakaway of the air flow from the surface and large-scale eddies or turbulence. This churning up of the air is sheer waste, and the power to produce it makes an unnecessary call on the engine.

For bodies moving in air at speeds below that of sound, air behaves as though it were incompressible. Because of its bow wave, a plane signals the air ahead that it is coming. The air then moves smoothly out of the way. These signals, which are based on changes in air pressure, travel at the speed of sound. However, if air is travelling over a wing in excess of the speed of sound (as it may due to the curvature of the wing, even if the plane is flying at only 500 mph), the plane has no means of signalling ahead. Instead of sliding smoothly through the air, the wing rams into the "sonic barrier". The resulting shock or compression waves destroy the smooth flow over the wings, and produce great increases in drag. Both can be overcome by specially designed wings and jet engines, but the war-time pilots who encountered compressibility had neither.

Matters are complicated by the fact that the speed of sound does not remain constant, but, because of the fall in temperature, decreases with altitude. It falls continuously from 760 mph at sea level to 660 mph in the stratosphere. An aircraft flying at 600 mph in the stratosphere is much closer to the speed of sound than when flying at the same speed at sea level. The onset of compressibility is determined, not by the speed of the aircraft itself, but by the ratio of its speed to the speed of sound at the same height. This ratio is called the Mach number (pronounced *mock*, with a gutteral 'k'), after a Viennese scientist.

In an effort to solve the problems of trans-sonic flight, scientists struggled with new theories and wind-tunnel tests. They attached model wings to weights, which were dropped from high-flying planes. Other models were secured to rockets and fired into the stratosphere, while instruments on the ground recorded their performance. Meanwhile, Allied engineers, hunting through the files of captured German test centres, discovered some exciting results. The Germans had found that sweeping back the wings greatly reduced the drag at trans-sonic speeds. The Americans, who were having trouble with a new fighter, applied this innovation to their F-86, later built in Montreal as the Sabre. The swept wings, now so common, enabled the Sabre to exceed the speed of sound in a dive. It was probably the first operational aircraft to do so, and Canadair still makes pilots who have flown faster than sound members of its Mach Busters' Club.

Other research showed that short, stubby wings and very thin wings also keep drag down. At speeds of 1,000 mph, swept wings lose their advantage, and very thin straight wings fly as well. The wings of the Lockheed Starfighter are so thin and sharp that the edges are covered with felt while the aircraft is on the ground to protect the ground crew.

Yesterday's research has produced today's fighters and will produce tomorrow's air liners. An American fighter has already travelled from coast-to-coast at an average speed of over 1,000 mph. But, as always happens in aviation, the solution of one problem brings with it two new unsolved ones.

In the Thirties, flight commanders gave orders to other planes in their formation by arm signals, much as an army officer controls a convoy of trucks. This method went out of fashion when a squadron leader tried it from a 250 mph Gladiator fighter. Used to much slower planes, he thrust his arm into the slip stream, dislocated his shoulder, and caused the plane to rear up violently in front of his dismayed wingmates. Today, the air pressures on a plane's control surfaces may equal the weight of 6 elephants. To even move his control column, the pilot must have an expensive version of power steering.

Such controls remove the variations in stick pressure which once helped a pilot fly by the seat of his pants. To give him some feeling for the speed and loads on his plane, a simulated "feel" must be built into the aircraft control system. Otherwise, he might maneuver so violently that the plane would come apart.

The jet engine has revolutionized aviation by making possible speeds which were unattainable with a piston engine and a propeller. Unfortunately, jet engines are very thirsty, and the fuel they consume requires a great deal of room. For example, the pioneering British Comet 1 jet air liner weighed 21 tons empty, and carried 22 tons of fuel and four tons of crew and payload when operating at extreme range. As aircraft design speed is raised from 300 mph to 900 mph, the percentage of the plane's loaded weight occupied by the engine and fuel increases from around 20% to about 60%. Just how much fuel would be consumed by such an aircraft can be judged from the fact that a single de Havilland Gyron turbojet at full speed would guzzle over 2,500 gallons per hour. With an afterburner (a device in which fuel is sprayed into the hot tail-pipe gases to get extra power for take-off and emergencies), the same engine would consume over 600 gallons in five minutes.

At supersonic speeds a pilot can easily rocket past his target before he has time to aim and fire. Indeed, he may not see it in time and crash into it. Consequently, today's interceptors are half-missiles, tied to a complex ground reporting and control system. The pilot simply takes off, climbs to height, and points in the general direction of the target, after which the fighter is flown automatically by radar linked to its automatic-pilot. A fire-control system in the nose "locks on" to the target and fires the missiles or guns automatically at the correct range and deflection. The black boxes which do all this may have as many tubes as 200 TV sets, and be twice as temperamental.

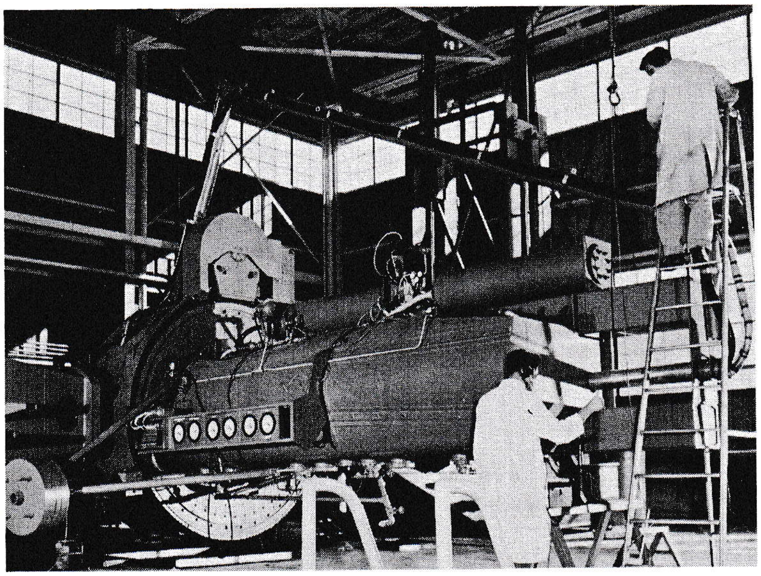
To prevent flutter — vibrations which increase until they cause wings and other parts to come off — supersonic aircraft must be as rigid as a steel beam. Instead of being built up from thin sheets and lathe-like strips, some wings are now machined complete with interior stiffeners from thick plates. Building an aircraft is now much like building a ship (except that the plane is apt to cost more.)

Now that the sonic barrier has been hurdled, engineers are skirmishing with another obstacle, the so-called thermal thicket. At 1,200 mph air friction raises the temperature of an aircraft's skin by 300°F. Even at high altitudes, with the outside air temperature 50°F. below, the skin temperature may still be 40 degrees above the boiling point of water. Under such conditions a plastic cockpit canopy would blow out like bubble gum.

Many of the usual aluminum alloys lose strength at high temperatures. At the speeds encountered by hypersonic aircraft and missiles, the problem is to keep the aircraft from melting. Titanium has shown great promise for it is twice as strong as aluminum for one and one-half times the weight. Beryllium is six times stronger than steel, weighs one-third as much as aluminum and keeps its properties at high temperatures. Alas, the "stockpile" of beryllium in the United States is a sheet less than half the size of the page on which this article appears.

As air speeds increase, the aerodynamic heating problem becomes more serious, and the search for the ideal metal is intensified. It should be practically weightless, be infinitely strong, machine easily, resist any degree of heat, and cost almost nothing. This material has not been found yet, but it has been named: Unobtainium.

Man was never intended to live at 50,000 feet, so the frail pilot is a problem too. A corset-like partial pressure suit and oxygen keep him alive, though not very comfortable, while the sun beats down on his greenhouse from a deep purple sky. This heat, combined with that from air



With this rig, designed and largely built by Avro, it is possible to simulate the effect of various flight attitudes and conditions on the wing integral fuel tanks.

The Mark I Arrow being assembled. Among other astonishing statistics: the Arrow refrigeration is equivalent to 50 room air-conditioners.

friction and the numerous electronic tubes, makes a refrigeration unit essential. The system in the Avro Arrow, for example, can handle changes of temperature of 100 degrees per minute. It has the same capacity as 50 home air conditioners, and could produce 23 tons of ice a day — though not one ice cube.

All these have added greatly to the size and complication of military aircraft. Today's fighter plane may weigh four times as much as a war-time Spitfire. And as the taxpayer can guess, the price has gone up even more.

In view of the complexity and consequent costs which these problems dictate, it is surprising to find a small country attempting to compete. Yet, Canada, which had previously designed only two types of fighters, may be among the leaders. The Toronto-built Avro Arrow, which has already flown over 1,000 mph promises to be the most advanced aircraft in its class. Weighing about as much as TCA's 40-passenger Viscount air liners, the Arrow carries only a pilot and a radar navigator. The Arrow will launch guided missiles from a compartment larger than the bomb bay of a war-time B-17 Superfortress. Armed with these, and powered by two jet engines, each as powerful as all the engines of the "Queen Mary", the Arrow should be able to intercept bombers flying 12 miles up.

The Arrow is a big aeroplane, with dart-shaped wings. Shaped like the Greek letter Delta, the wings have the advantages of swept wings, plus increased stiffness (to reduce twisting in flight) and storage capacity for the under-carriage and fuel.

The Arrow came into being six years ago when Avro engineers suggested a fighter to meet the threat of potential enemy bombers. The R.C.A.F. decided no fighter on the drawing boards of friendly countries could fill their need for an interceptor which could fly at twice the speed of sound, shoot down bombers at 75,000 feet and range over Canada's vast Northland. They anticipated that missiles would not be sufficiently reliable by the time a fighter could be in service, about 1960.

Meanwhile, the first Arrow is continuing its tests. Engineers are already planning to extend its speed beyond Mach 2, which is faster than the rate at which the earth rotates. Such an aeroplane would be able to out-distance the sun. An Arrow flying westward could take-off from Montreal at sunset and arrive at Vancouver in mid-afternoon of the same day.

But Mach 2 is only the beginning. Missiles have already flown at Mach 23, and speeds of Mach 200 have been measured in the laboratory. Later this year, an American research aircraft, flown by an intrepid airman who will deserve the adjective, is expected to reach Mach 5, or one mile a second. It will be launched from a B-52 flying at 50,000 feet, and then rocket upward to a height of perhaps 160 miles. Then down it will plummet, like a fantastic roller-coaster, to land on the Muroc desert. The entire flight, from launching to landing, should take no more than eight minutes.