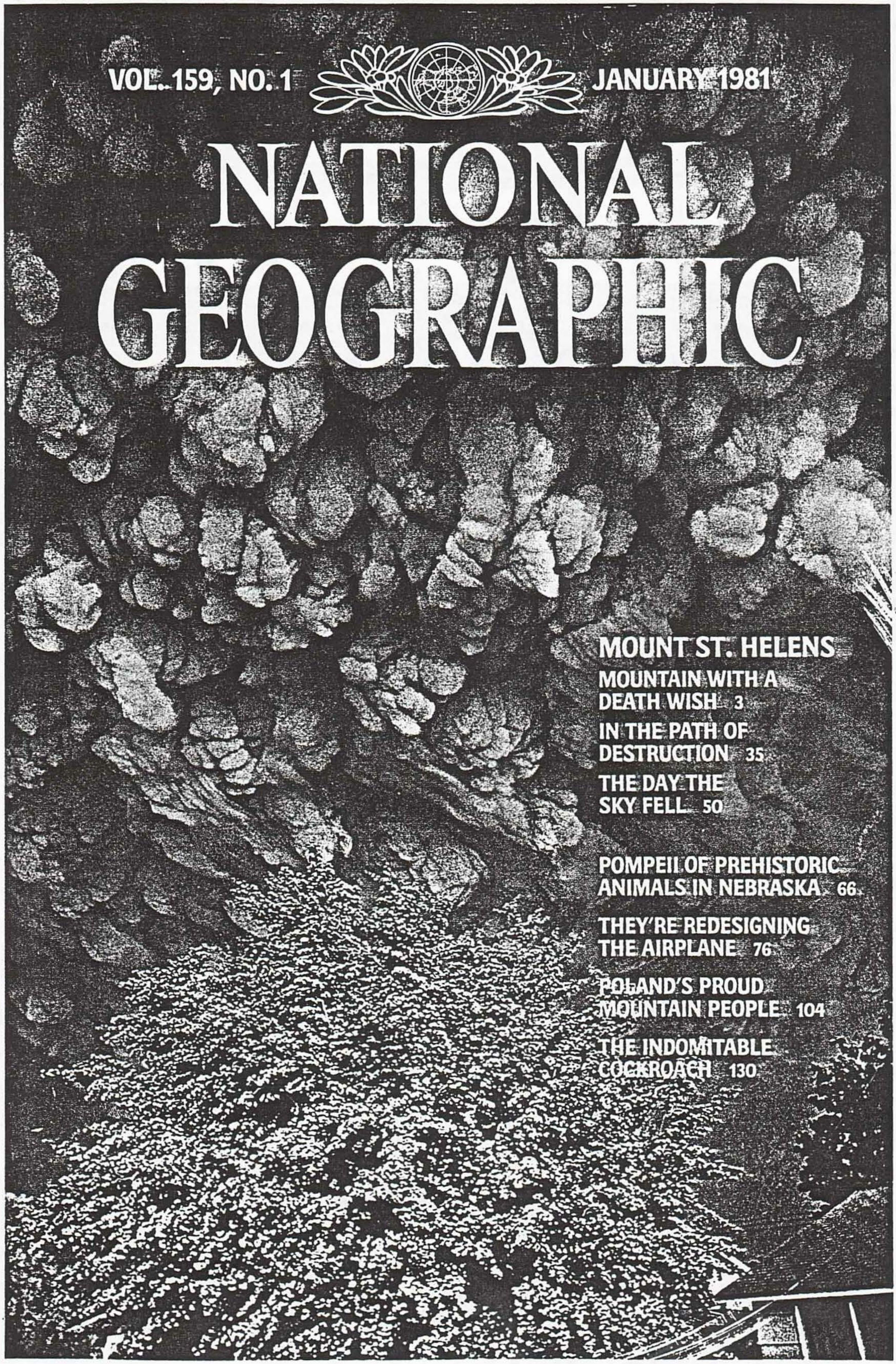

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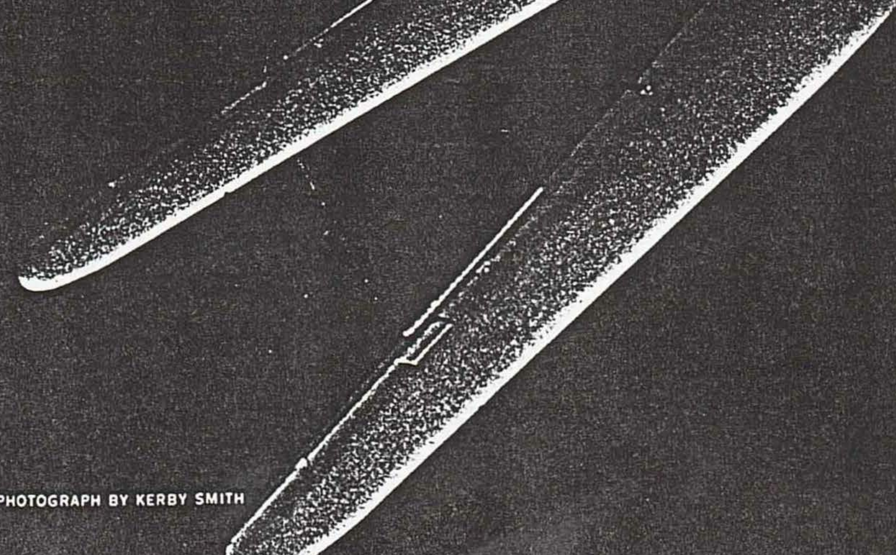
NATIONAL GEOGRAPHIC

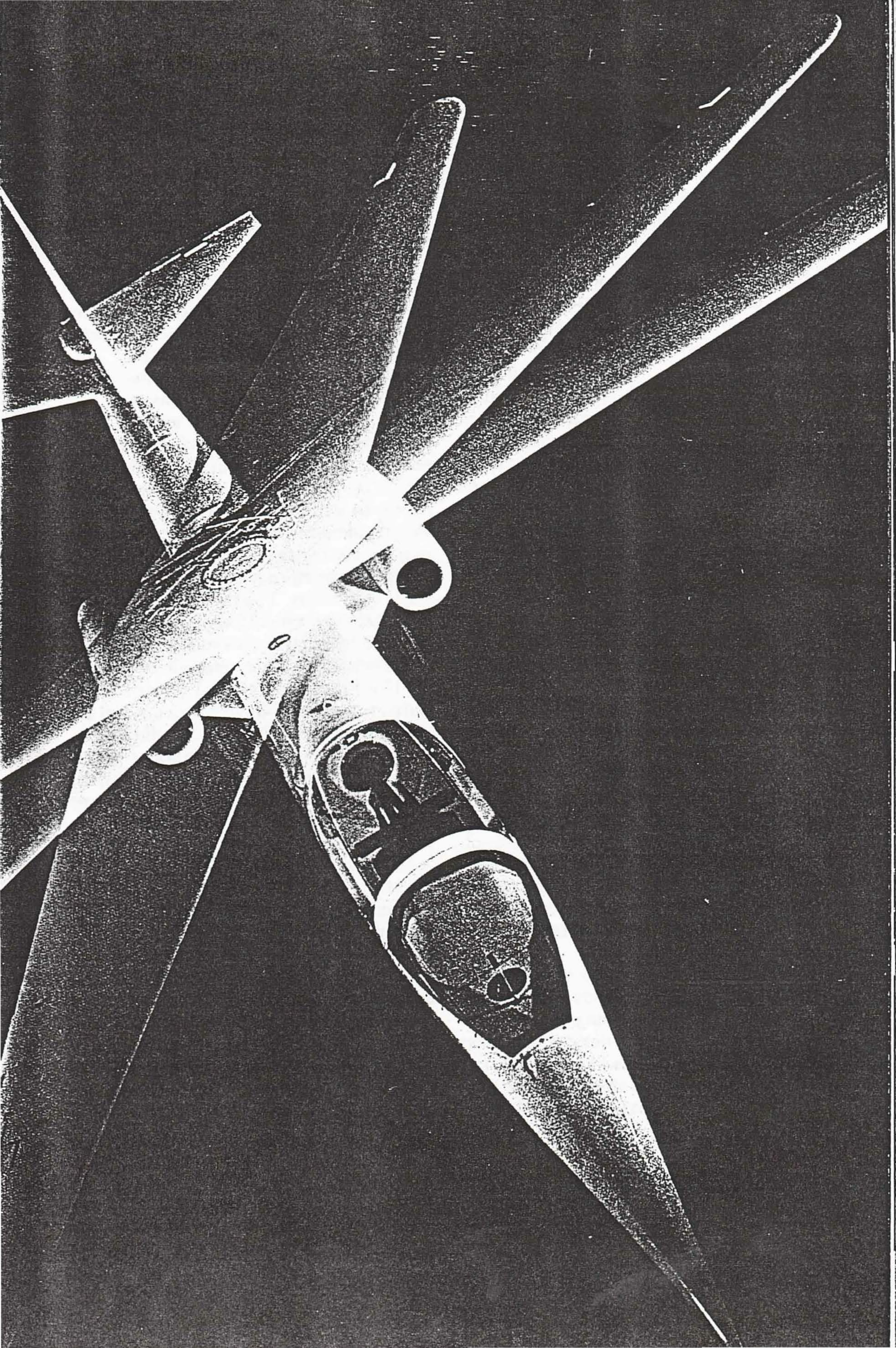
SEE "ETOSHA: PLACE OF DRY WATER" WEDNESDAY, JANUARY 7, ON PBS TV

THEY'RE REDESIGNING THE AIRPLANE

Bold concepts take wing, and the old familiar airplane may never look the same. Computer-smart electronic systems are changing the way airplanes are designed, built, and flown. A wing that pivots 60 degrees (right) promises a fuel-efficient, speed-of-sound jetliner, whose sonic boom would dissipate before reaching the ground. How fast or efficiently man flies depends only on the soaring of his imagination.



PHOTOGRAPH BY KERBY SMITH



NEARLY EIGHTY YEARS after the Wright brothers flew, the airplane is finally catching up with the hummingbird. This summer, in a series of test flights, a specially modified United States Air Force F-16 fighter will exhibit hummingbird-like maneuvering qualities, summed up by Lt. Gen. Thomas P. Stafford as the ability to go *Zang!*

From normal straight-ahead flight and without changing wing or nose position, the fighter will suddenly dart sideways *(Zang!)*, straight up *(Zang!)*, or straight down. The airplane's nose can also rotate a bit, explained General Stafford, to afford a shot at an adversary. All this can be combined with turns, loops, rolls, and other standard maneuvers.

By MICHAEL E. LONG
NATIONAL GEOGRAPHIC SENIOR STAFF

Photographs by
JAMES A. SUGAR

The *Zangs* will be accomplished through movement of airfoils hanging like shark fins from the underside of the fighter, coordinated by a computer with other control surfaces. "In the past you could get agility like this only from a spacecraft," said former astronaut Stafford, now retired as head of Air Force research and development. "In the future," he continued, "every pilot should be able to shoot 100 percent with this kind of airplane. And when somebody tries to chase him, he just goes—*Zang*—sideways."

The ability to go *Zang* is just one of a number of recent advances in aviation technology that are producing significant, even revolutionary, changes in the way aircraft are designed, built, and flown. Consider:

• A U. S. military Stealth airplane is virtually invisible to enemy radar.

• A new generation of longer winged, fuel-efficient jetliners promises advances in creature comforts for both passengers and pilots.

• A young Californian designs airplanes that don't stall, which is like making tires that don't go flat. Stall-spin accidents total 20 percent of general aviation fatalities.*

• A British military jet carries more payload by taking off from a curved ramp that looks like a ski jump.

• A unique X-wing craft will perform like a hybrid. With rotors whirling, it will take off and land vertically, like a helicopter; rotors locked in the form of an X, it will fly and maneuver like a fixed-wing airplane at high subsonic speeds.

• Coming up as a substitute for the rivet—high-technology glue.

• In the all-electronic cockpit, multiprogram cathode-ray tubes replace conventional flight and navigation instruments.

Many of these advances, now being proved under National Aeronautics and Space Administration and military auspices, can be employed in civil aircraft. For example, the X wing, under development for U. S. Navy duty, could later come ashore as a corporate or commuter aircraft that requires no runway. The radical craft gets its fixed-wing capability from high-velocity air pumped from slots in the trailing edges of its rotors. This increases the airflow over them to create lift, enabling the locked rotors to function as conventional wings.

Learning about these marvelous things, I felt like Rip Van Winkle—I was a Marine Corps jet pilot and flight instructor, but my tour of duty ended in 1959. Nor did Ben R. Rich, vice president of Lockheed's super-secret Advanced Development Projects, the famed "Skunk Works," make me feel any better when he told me: "We did things ten years ago that you haven't even heard of."

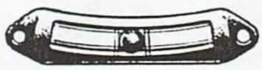
Indeed. Lockheed's high-flying U-2, built in 1955, cruised in secrecy until the Russians shot one down in 1960. Lockheed's SR-71 Blackbird flies faster than Mach 3—three times the speed of sound. But nobody will tell you how much faster, or how high it flies, even though it first flew in 1964.

Nobody's going to tell you much about the new Stealth airplane that foils enemy radar. The U. S. Department of Defense

*The author's in-depth appraisal of "The Air-Safety Challenge" appeared in the August 1977 issue.

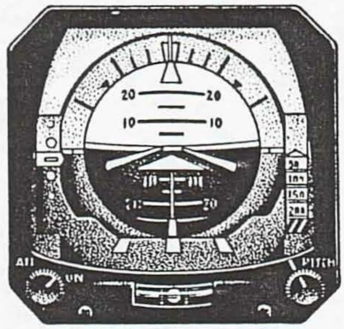
Instant cloud *bursts into being as a Grumman F-14 Navy fighter approaches the sound barrier. The resulting shock wave caused sudden temperature and pressure changes to condense water vapor. Since shock waves impair an aircraft's efficiency, to minimize them is a goal in the design of wings for new jetliners.* © PAUL A. LUDWIG

Instruments

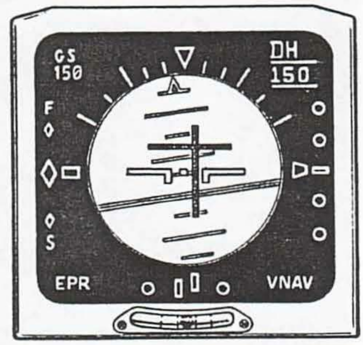


One step beyond a carpenter's level, a skid/slip indicator of the 1920s showed balanced flight when ball was centered.

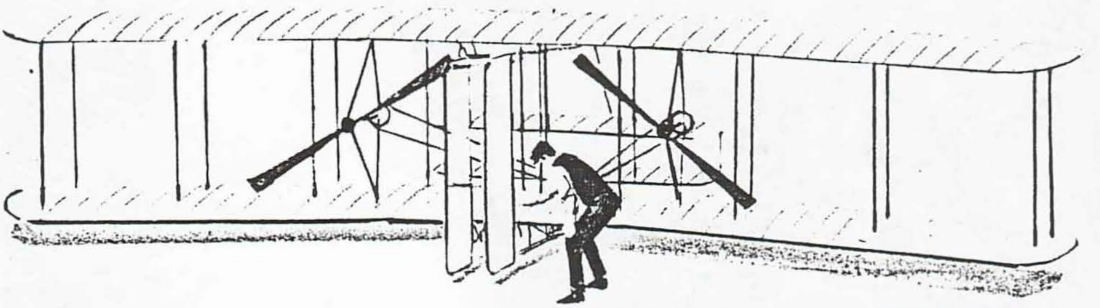
Gyroscopic artificial horizon, new in 1929, permitted true blind flight. This one from the 1940s shows a left turn.



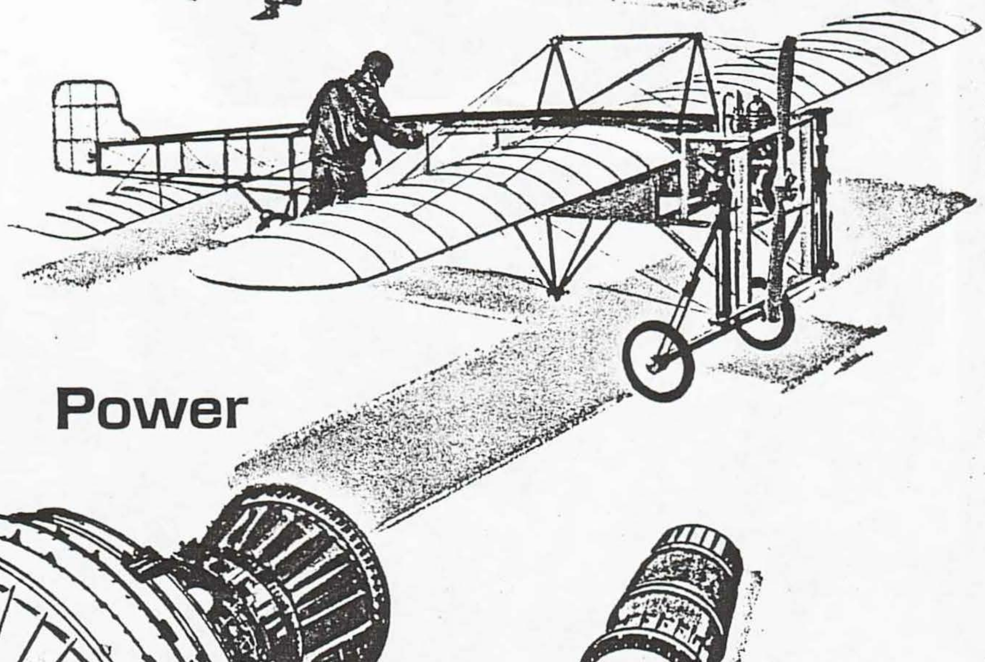
Flight directors on today's jetliners help a pilot maintain flight phases such as cruising, as well as showing him his current attitude.



Future electronic attitude and command displays can instantly give the pilot more flight data, yet the ball level, at bottom, will still have its place.

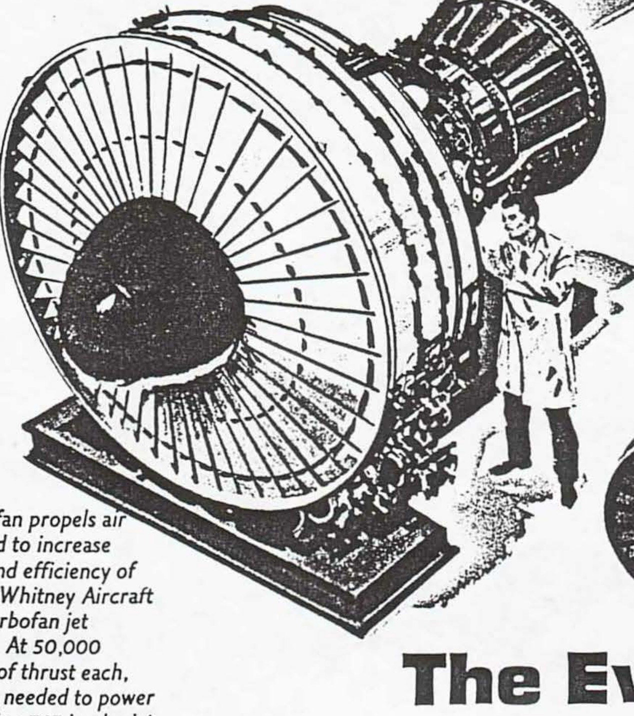


Wright Flyer I of wood, wire, and fabric used twin wings, rudders, and propellers, as well as a canard—a forward elevator—for pitch control.

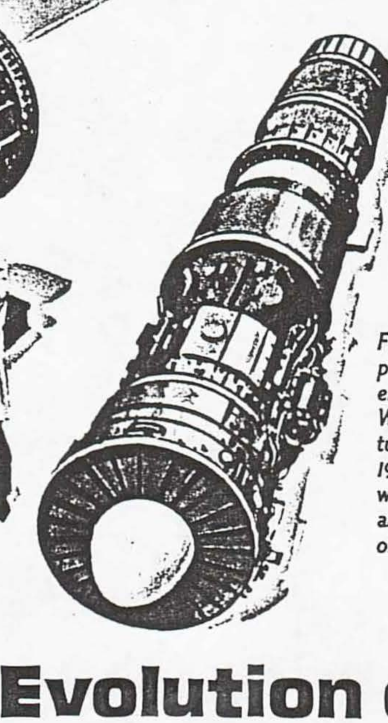


Louis Blériot's Type XI used a single wing, box-girder fuselage, control column, and rudder bar. In 1909 Blériot was first to fly the English Channel, a preview of the practical uses of the airplane.

Power

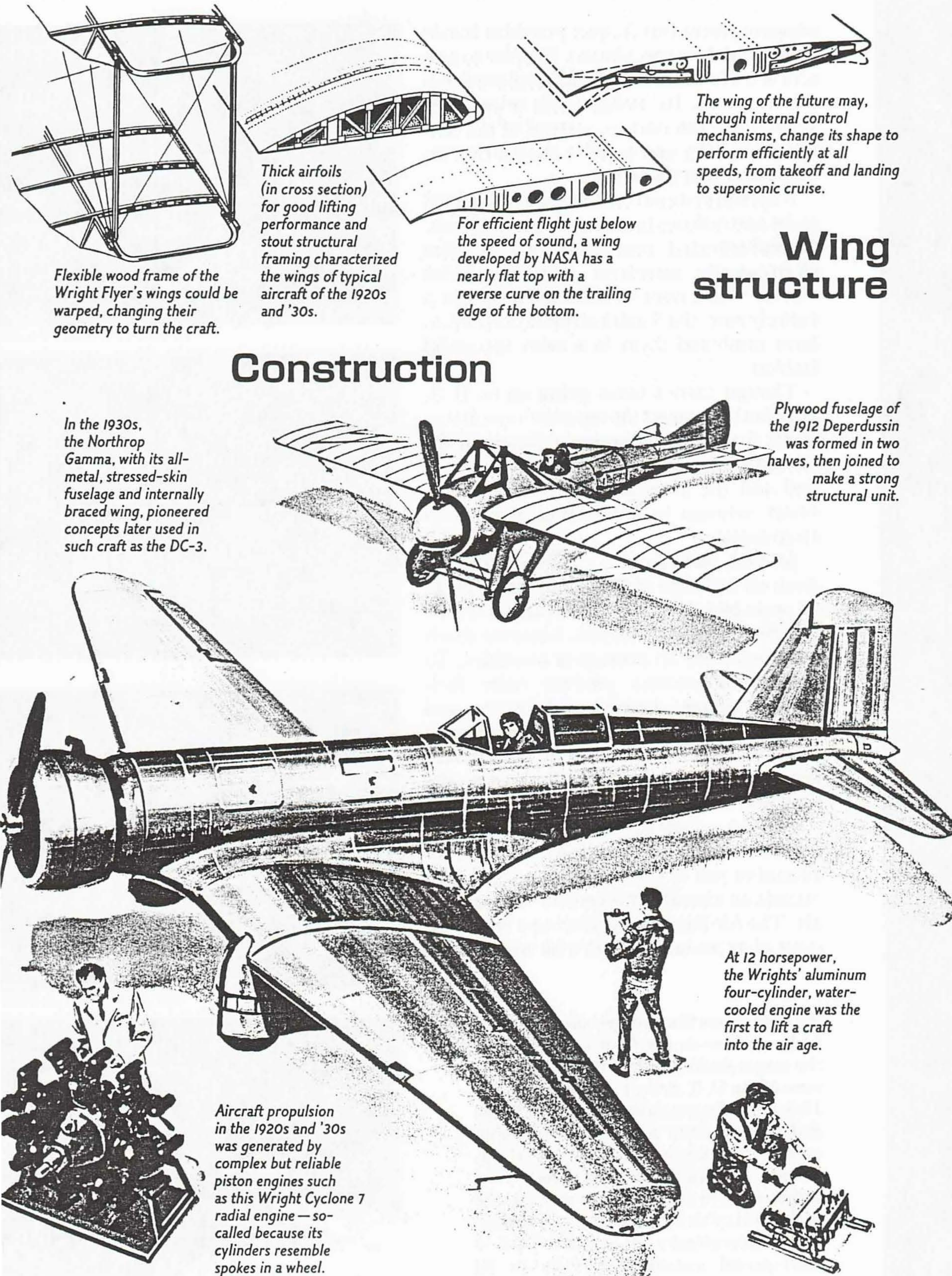


A huge fan propels air rearward to increase thrust and efficiency of Pratt & Whitney Aircraft JT9D turbofan jet engines. At 50,000 pounds of thrust each, four are needed to power the Boeing 747 jumbo jet.



First of the high-performance axial-flow engines, the Pratt & Whitney Aircraft J57 turbojet generated 19,600 pounds of thrust with an afterburner and powered airplanes of the 1950s.

The Evolution of the



Wing structure

Flexible wood frame of the Wright Flyer's wings could be warped, changing their geometry to turn the craft.

Thick airfoils (in cross section) for good lifting performance and stout structural framing characterized the wings of typical aircraft of the 1920s and '30s.

For efficient flight just below the speed of sound, a wing developed by NASA has a nearly flat top with a reverse curve on the trailing edge of the bottom.

The wing of the future may, through internal control mechanisms, change its shape to perform efficiently at all speeds, from takeoff and landing to supersonic cruise.

Construction

In the 1930s, the Northrop Gamma, with its all-metal, stressed-skin fuselage and internally braced wing, pioneered concepts later used in such craft as the DC-3.

Plywood fuselage of the 1912 Deperdussin was formed in two halves, then joined to make a strong structural unit.

At 12 horsepower, the Wrights' aluminum four-cylinder, water-cooled engine was the first to lift a craft into the air age.

Aircraft propulsion in the 1920s and '30s was generated by complex but reliable piston engines such as this Wright Cyclone 7 radial engine — so-called because its cylinders resemble spokes in a wheel.

The four airplanes pictured here represent significant early stages in construction techniques to advance the goals of high-strength-to-weight ratio, increased payload, speed, safety, and efficiency.

Airplane

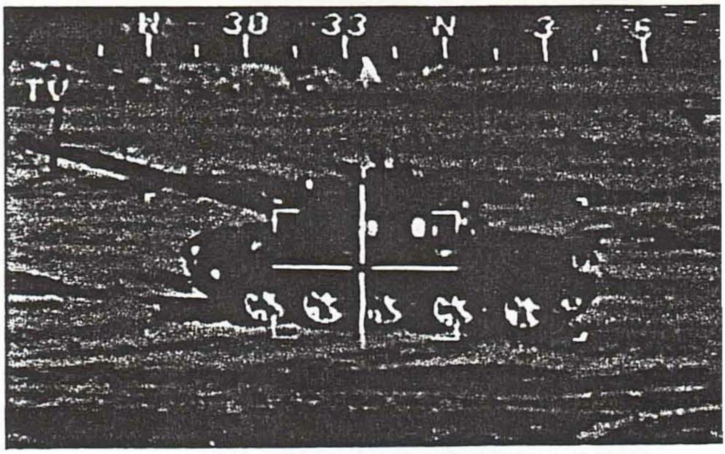
PAINTING BY FRED WOLFF, IN COOPERATION WITH AVIATION CONSULTANTS RICHARD HALLION AND TOM CROUCH announcement last August provides barely enough grist for speculation. In order to present less of a radar target, the airplane is relatively small. Its design tends toward the smooth and the curved, instead of the conventional boxy and angular shapes that reflect radar best (page 102).

A special material coating the airplane absorbs and diffuses incoming radar impulses. A sophisticated countermeasures system electronically interferes with the radar waves. While none of these technologies is entirely new, the Stealth airplane appears to have combined them in a most successful fashion.

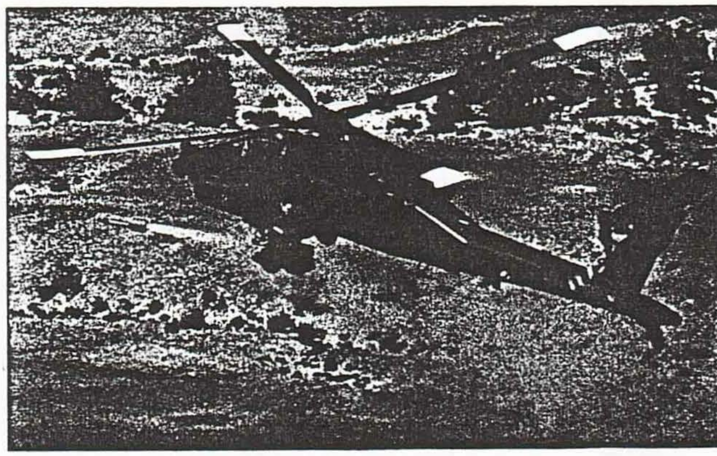
Though there's more going on in U. S. aviation than meets the reporter's eye, it's no secret that the two dominant factors in the immediate future will be the soaring cost of fuel and the amazing feats of computer-smart avionics (a contraction of aviation electronics).

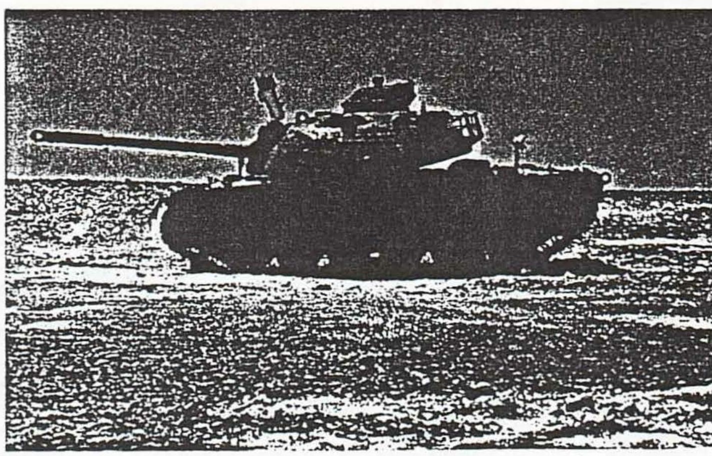
Jet fuel, just 13 cents a gallon before the Arab oil embargo of 1973, had increased to 90 cents by mid-1980. The airlines are feeling the pinch and so are you. Last year coach fares increased an average of one-third. To help manufacturers produce more fuel-efficient engines, better aerodynamics, and lighter structures, NASA embarked on a half-billion-dollar program in 1975 that is bearing fruit in the construction of new aircraft and the retrofit of older ones.

NASA's winglets, which look like wing tips bent upward, sprout from the wings of executive jets to combat drag, a force that retards an aircraft's movement through the air. The Air Force is considering a retrofit of most of its jet-tanker fleet with winglets for

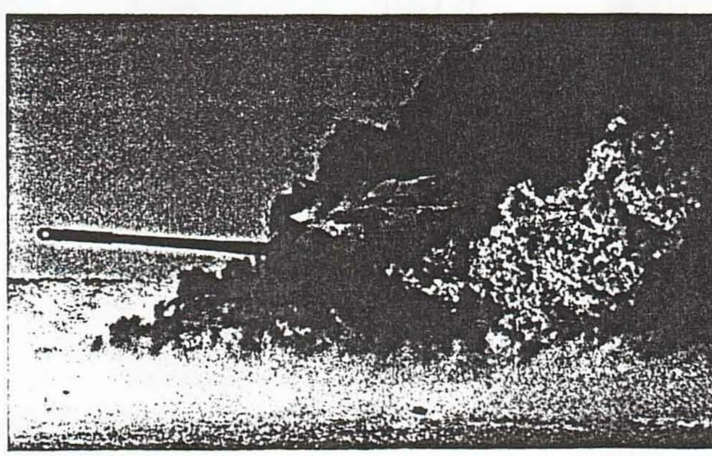


KERBY SMITH (LEFT, ABOVE, AND BELOW)



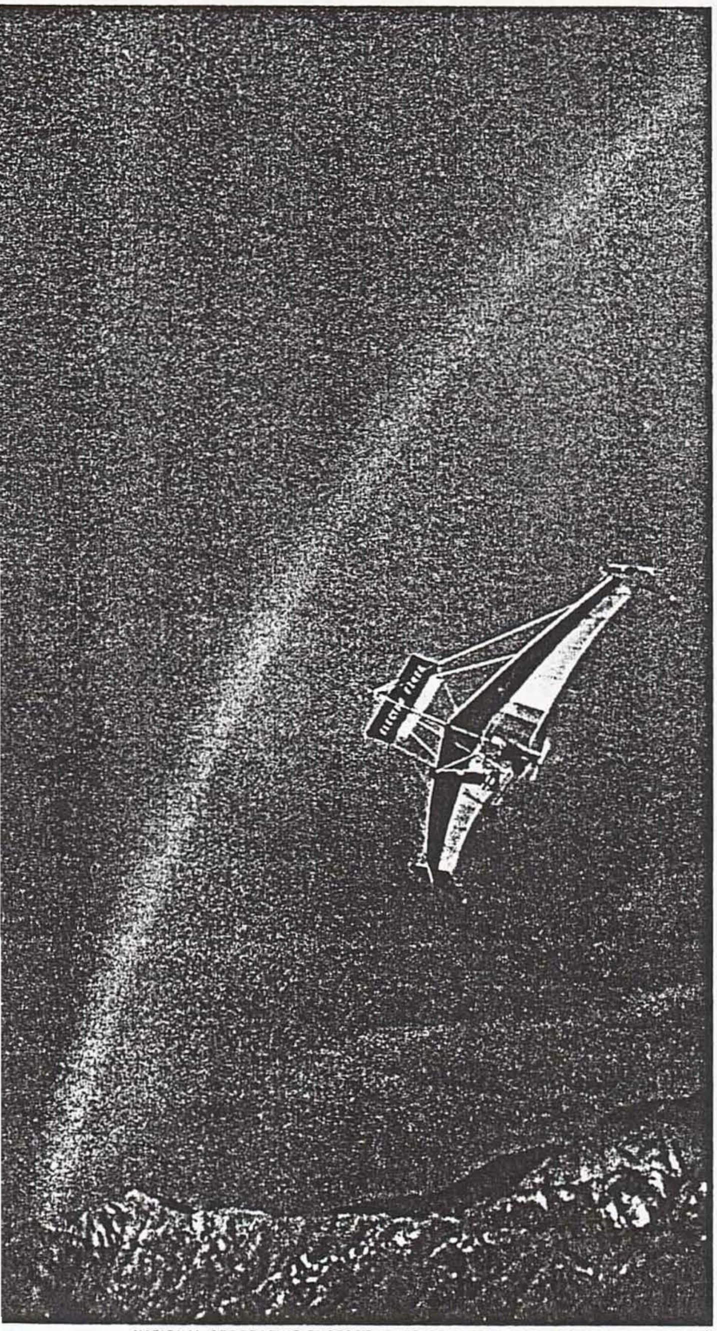


LURA SCHWARZ (ABOVE AND BELOW)



An eyeball on the enemy*—day, night, or bad weather—is the final connection in the target-finding system mounted on the nose of the U. S. Army's Advanced Attack Helicopter. In simulated combat, test pilot Bill Norton (****left****) sees in his electronic monocle an image of an enemy tank (****right, at top****). As he turns his head to follow the target, sensors in the cockpit monitor the movement of his helmet and aim the weaponry automatically. At his command, a laser-guided missile fires, runs to its target, and destroys the tank (sequence at right).*

*Every field's a Kitty Hawk for pilots of the Eagle (**facing page**), a twin-engine, single-prop flying machine designed by trans-Atlantic balloonist Larry Newman. Inspired by such diverse craft as the Wright Flyer, Rutan VariEze, "Gossamer Albatross," and XB-70, it is constructed of sailcloth over an aluminum frame. The front-mounted canard is also an elevator; twin rudders are mounted under the wing tips. With four hours' training, a novice is ready to fly over his own rainbow (**below**).*



NATIONAL GEOGRAPHIC PHOTOGRAPHER OTIS IMBODEN (ABOVE AND OPPOSITE)

estimated fuel savings of one billion dollars by the year 2000.

NASA researchers also pursue the Holy Grail of aerodynamic efficiency, laminar flow control. If achieved, airflow over a wing would be rendered glass smooth instead of slightly turbulent, reducing fuel consumption by an astounding 30 percent. One proposed method would accomplish this by means of suction slots along a wing's surface. Another NASA program raises the possibility of a comeback for that casualty of the jet age, the propeller. In wind-tunnel tests, multiblade curving propellers have shown the potential for exceeding the fuel efficiency of jets at airliner speeds and altitudes.

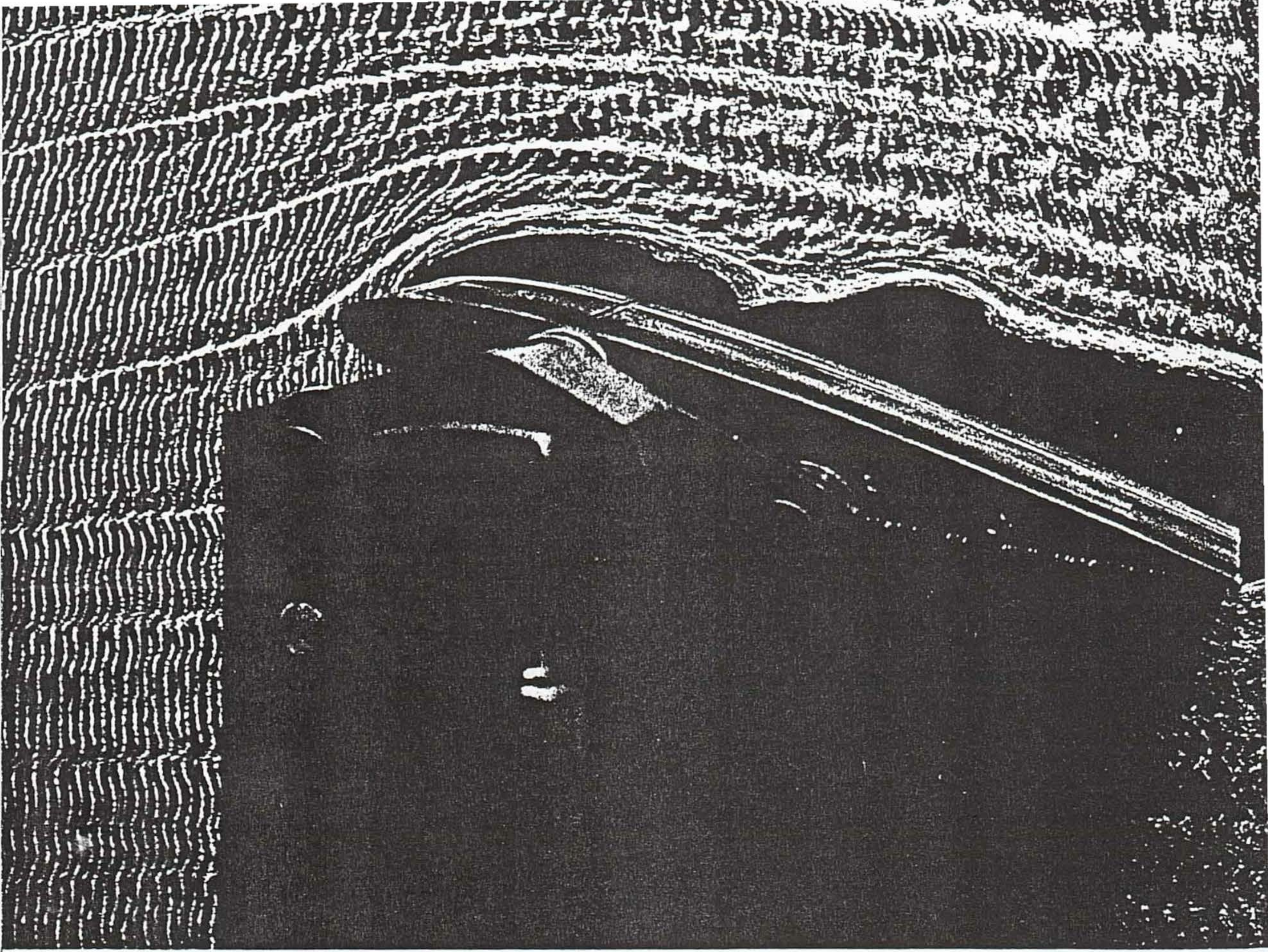
Computers Revolutionize Aviation

Meanwhile the computer is shrinking to minuscule size. At Wright-Patterson Air Force Base, a research center near Dayton, Ohio, avionics laboratory chief scientist Dr. Jesse Ryles told me: "By the year 2000 we could have the technology to put the entire avionics computing system of a 1980 aircraft"—all the black boxes that now weigh hundreds of pounds—"on a silicon chip about 12 centimeters square." That's about the size of a pair of aces held side by side.

In this microelectronic world of the future, the incredible could become commonplace: A computer monitoring a pilot's brain waves spots the telltale pattern shown in tests to be emitted just before a tired pilot makes a mistake—in time to alert him and to prevent the mistake. A pilot activates switches and armaments by voice command, for example, "Bang!" Or even by just thinking the command—"   ."

Computers, black boxes, microelectronics. To better appreciate the complexities of aviation's future, I accepted an invitation to experience the simplicity of its past in a classic biplane, a 1933 de Havilland Tiger Moth. My friend Tom Foxworth, a West Berlin-based Pan American pilot, suggested a flight that would retrace the first airline route from London to Paris. There was no better craft for the trip, Tom said, than the Tiger, a cousin of the de Havillands that flew the route in 1919.

A dozen patches scarred the silver fabric wings and the maroon fuselage of this oldest



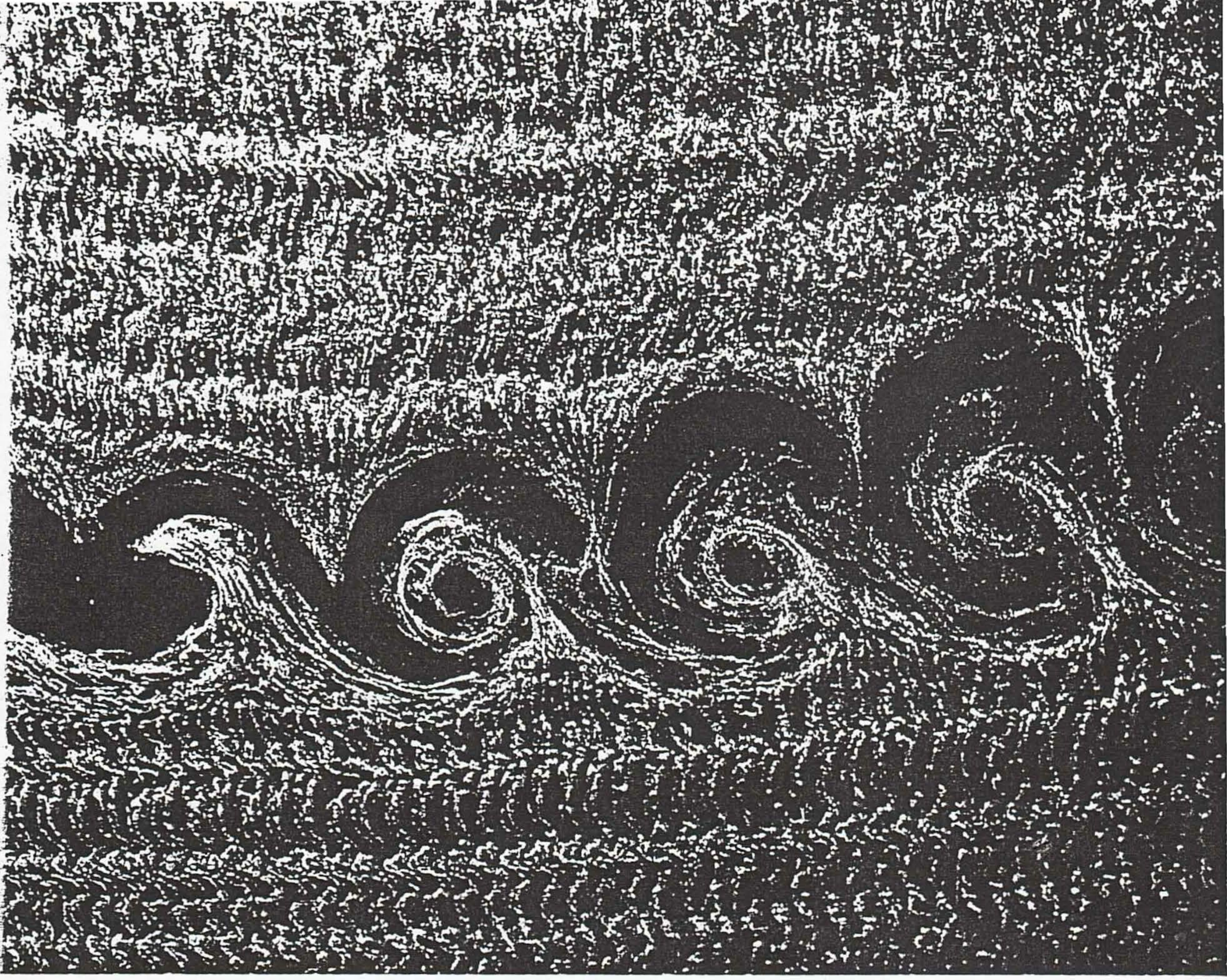
Test and test again

SUBTLE DIFFERENCES in design can have major effects—for good or ill—on aircraft performance. Stall characteristics of helicopter rotor blades are evaluated (**above**) at NASA's Ames Research Center in California. Hydrogen bubbles are generated in a water tunnel to simulate airflow and make it visible.

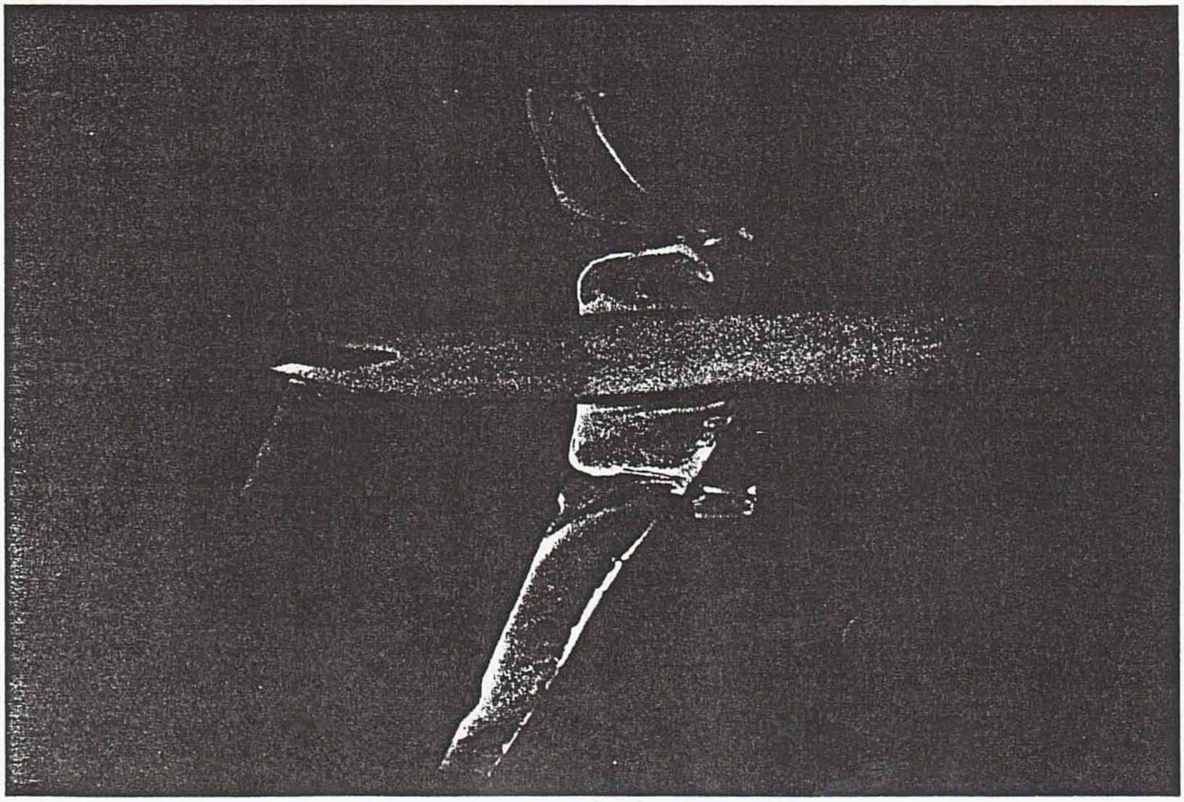
For a like purpose, a thin film of oil under ultraviolet light (**right**) shows airflow on a model of the new Boeing 767 jetliner in wind-tunnel testing.

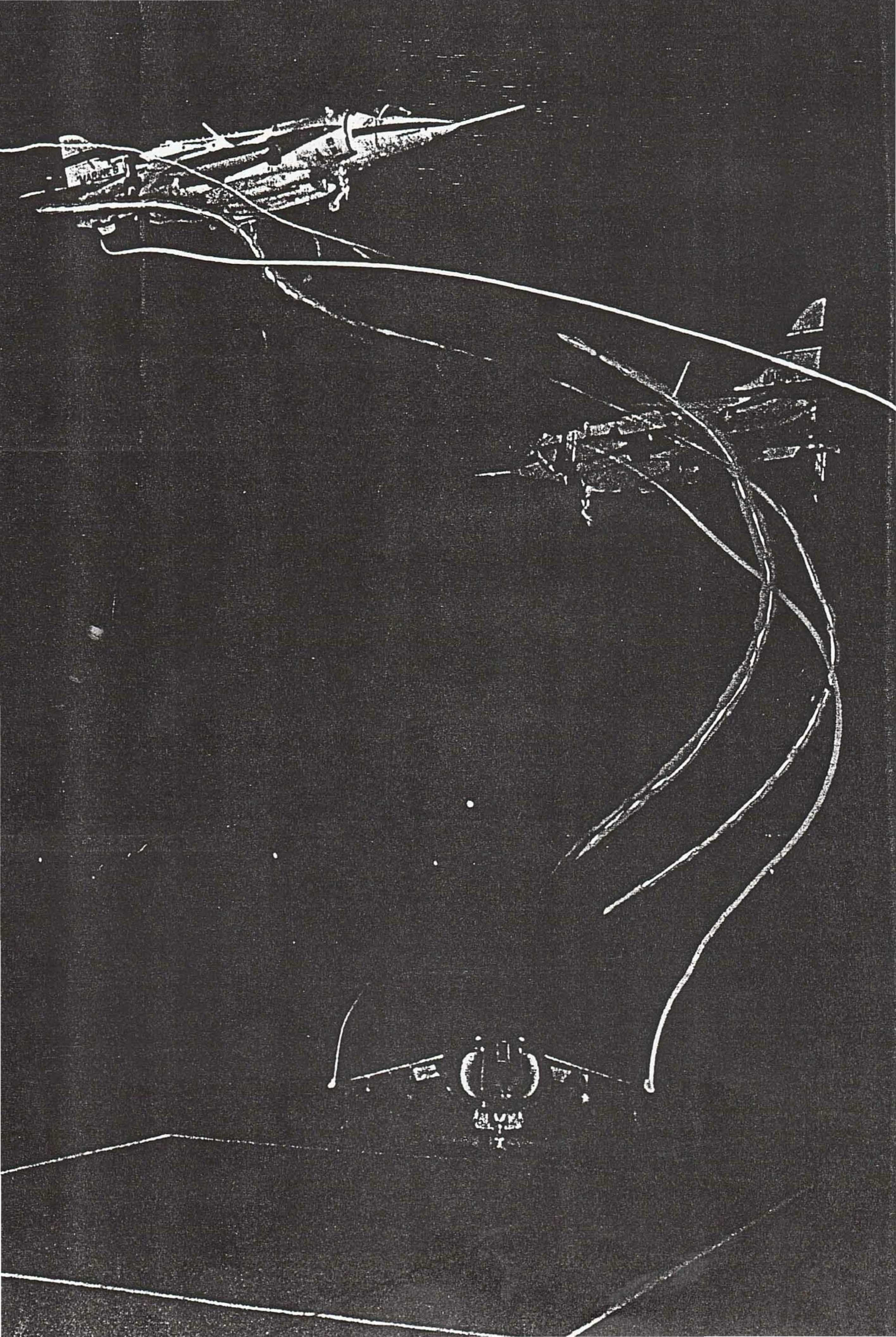
A Honeywell technician adjusts a glowing ring laser gyro (**left**). Three of them used in conjunction will give ultraprecise data on pitch, roll, and yaw of new passenger and military aircraft.

National Geographic, January 1981



JAMES A. SUGAR WITH DAVE HUTCHINSON, THE BOEING COMPANY (BELOW)





airworthy Tiger, a fond possession of the Tiger Club at Redhill Aerodrome in Surrey, south of London. Aircraft engineer Adrian Deverell explained to me that the 24-foot-long airplane was a veteran of 15,000 flight hours and several crashes, and had served as a tutor to dozens of English fighter pilots in World War II.

"She's a bit long in the tooth," advised Deverell, "but she has no vices. The wood in her wings is solid spruce, and the glue's still sound. Her fuselage structure is steel tube, so she bends instead of shattering in a crash. Why, I saw a bloke spin a Tiger right into the ground once. He stepped out of the plane, staggered, and said, 'Gad, it was exciting while it lasted.' "

Deverell made it clear that he thought the pinnacle of aviation technology had already been achieved: "You can't beat the old biplanes—they're natural. Show me a tin aeroplane with a lid on it and I'll turn me nose up. Ah, you might as well sit in a car."

On a windy September afternoon Tom and I sat in the Tiger's open cockpits, donned leather helmets and goggles, and then Tom took off into a leaden sky. "We'll cross the Channel and turn right at the French coast," he had explained. "Then we'll fly down to the Somme River estuary and follow the river inland until we pick up the highway to Paris." So much for the navigation part.

Under Tom's expert hands the Tiger performed without fault. No matter that our airspeed was only 70 miles an hour, that it was bone-chilling cold, that we hollered ourselves hoarse trying to talk to each other. This is the way it was when flying was new.

You get the feel of flight in an airplane like this. Even though the instrument panel has an airspeed indicator, the hum of the wind in the wing-strut wires tells you the same thing. The stick in your hand is directly linked by cables and pulleys to the control surfaces—rudder, elevators, and ailerons.

It was a memorable flight—over the gray chop of the Channel, past coastal bunkers from World War II, over neat farm fields where fresh-cut hay was wrapped in rolls like tape. Then a landing at Paris's Charles de Gaulle Airport under the very nose of a Boeing 747 waiting to take the runway.

As Tom turned off the runway, a yellow car sped up, and an official excitedly emerged. "Monsieur, you must hurry. The jet plane wants to take off!"

Yes, that 747 . . . the blast from its engines could damage the fragile Tiger . . . yes, we must hurry . . . Tom asks me to jump out and run beside the wing tip; the airplane has no brakes and could ground-loop . . . finally we are parked in front of an Air France Concorde (page 94).

New Glue Dooms Rivets

In a way Adrian Deverell is right, and I share his fondness for this airplane that is one with the air, as a sailboat is one with the sea. But with jet engines and swept wings the world doesn't travel at 70 miles an hour any more. Let's see how some other things have changed in the way airplanes are built and flown today.

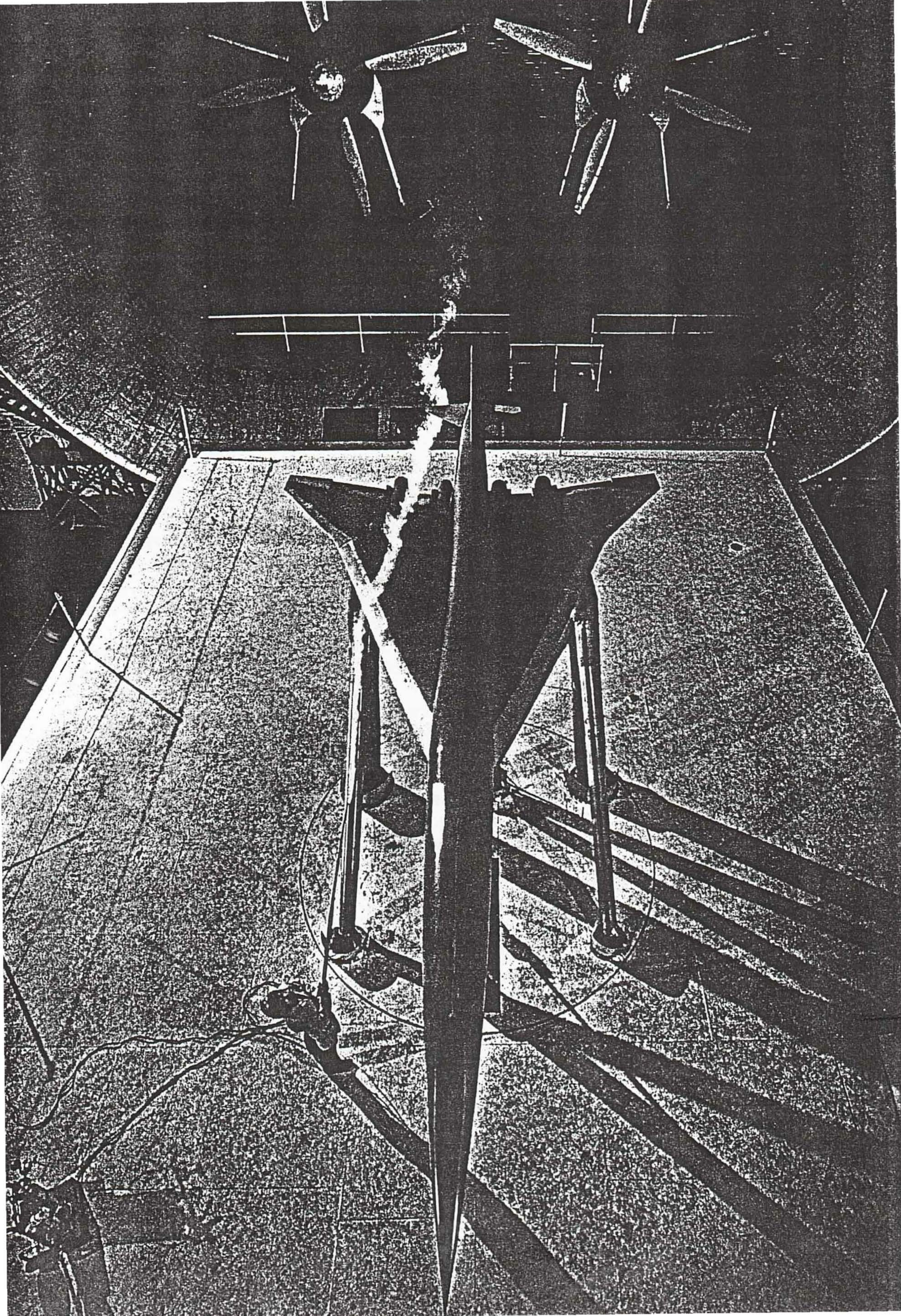
• Structures: Not one rivet marks the surfaces of fuselage panels that have completed four normal aircraft lifetimes in an Air Force-sponsored fatigue test at the Douglas Aircraft Company in Long Beach, California. Deverell, as well as model-airplane builders galore, should applaud the substance that bonds the fuselage members together—epoxy glue. Its use promises to save weight as well as increase structural durability. No rivets, no holes.

Another weight saver for fuel-conscious designers is graphite epoxy, a composite of graphite fibers in an epoxy matrix that is much lighter than aluminum but as much as four times as strong. By using the composite material in portions of its new 767 jetliner, set for delivery in 1982, Boeing plans to save 1,100 pounds. "That means five more passengers in the payload," says Ken Holtby, vice president for new programs.

While others are easing cautiously into the

***Corkscrew landing** is one in a big bag of tricks available to the advanced Harrier attack jet. With swiveling nozzles that change the direction of engine thrust, the airplane can take off vertically or from a short ski-jump ramp. At battle speeds it can make quick, unorthodox dogfight maneuvers.*

JAMES A. SUGAR WITH NELSON H. BROWN AND LARRY D. KINNEY



use of composites, William P. Lear, inventor of the Learjet, has gone all the way. Before he died in 1978, Lear designed a turboprop corporate airplane structured almost entirely of graphite epoxy. Now his company, LearAvia of Reno, Nevada, is evaluating a prototype, the Lear Fan. On paper Lear's venturesome airplane flies farther, more quietly, and with greater fuel efficiency than its corporate cousins. If it proves out in the air, competitors may take off for their drawing boards.

Loaded Harrier Gets an Assist

• Aerodynamics: While the Tiger and most other airplanes make rolling takeoffs and landings, the maverick British Aerospace Harrier can take off and land vertically. Through movable nozzles, the engine's exhaust is directed downward for vertical flight and aft for horizontal flight.

But there's a catch. The Harrier's engine, generating 21,500 pounds of thrust, cannot lift the airplane vertically when it is fully loaded with weapons and fuel at 25,000 pounds. So a short takeoff roll is necessary. For aircraft-carrier operations, the resourceful British have taken this an incredible step further—a full-payload takeoff from a ski-jump ramp 130 feet long and just 40 feet wide. "Coming off the ramp, you're not yet flying," explained Harrier expert John Fozard, "but like a ski jumper, your momentum is upward. Meanwhile you are rotating the engine nozzles aft, and the aircraft is accelerating to flying speed.

"So you've bought yourself a runway in the sky," Fozard continued. "And from a pilot's point of view, there's all that lovely, dry air between you and the horrid, wet sea."

When Harrier test pilot Mike Snelling briefed me before a demonstration ride off the ski jump at the 1978 Farnborough Air Show, he stated that it would be "uneventful." However, he advised, in the remote chance of engine failure as we came off the ramp, "there will be no time for a conference. You will see me eject, and you may take that as your cue that all is no longer well."

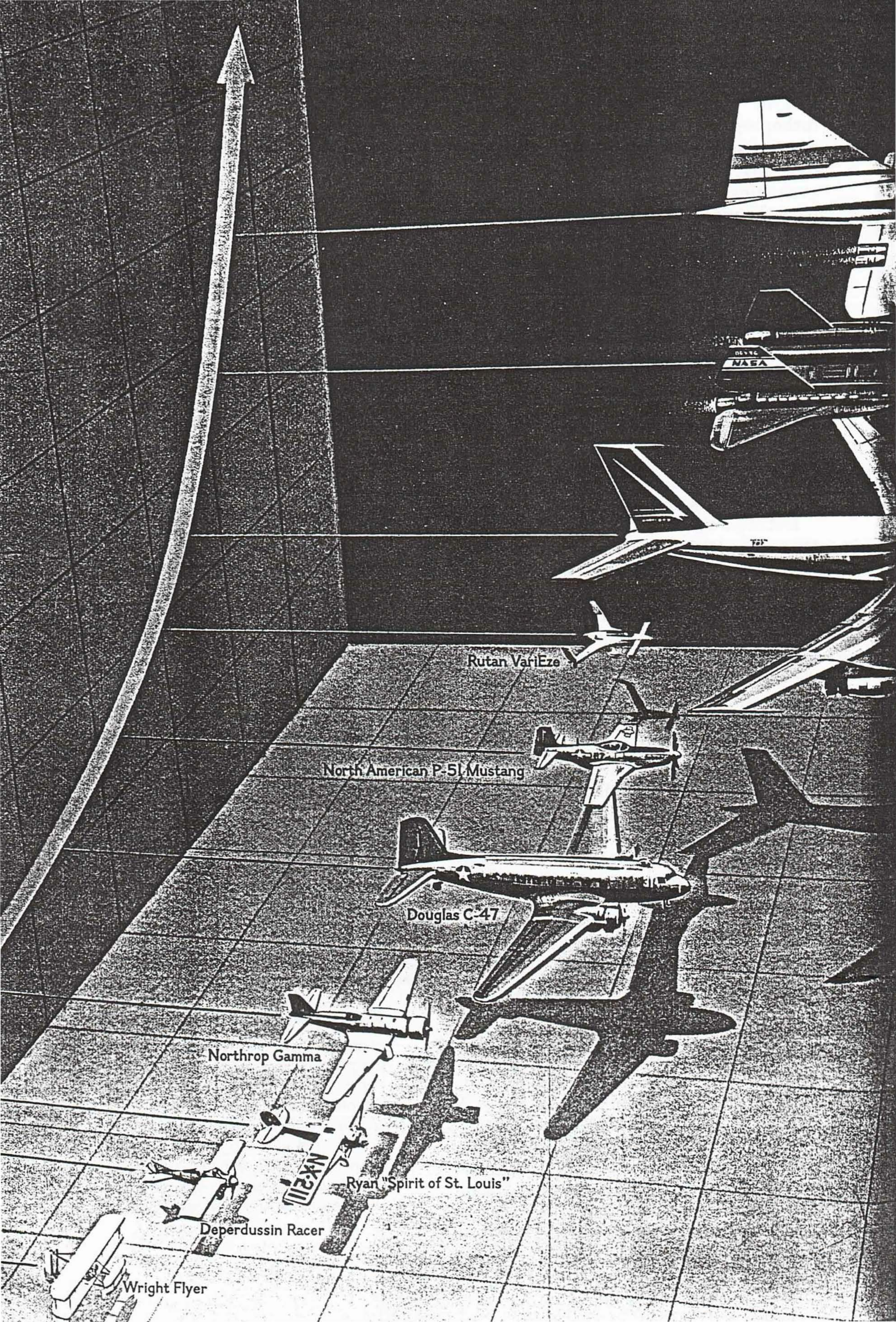
All went well, however, and the Harrier's ski-jump takeoff is something of an aeronautical event. The U. S. Marine Corps plans portable ski jumps for battlefield use that can be set up in just six hours. The Navy figures that there may be a place in its future for small ski-jump carriers to augment its big-deck force.

• Controls: The Air Force's new fighter, the General Dynamics F-16, is the first production airplane in which the cable-and-pulley control system of the Tiger has been entirely replaced with electronics. Signals speed from the control stick along wires to a computer, and thence roundabout to the control surfaces of the 48-foot-long fighter. This fly-by-wire control system opens a whole

JAMES A. SUGAR WITH NELSON H. BROWN (OPPOSITE)

Son of SST? *McDonnell Douglas's model of an advanced supersonic transport* ***(facing page)*** *is readied for wind-tunnel testing at a NASA facility. The wing design promises as much as 40 percent better fuel economy than the Concorde's.*

Lockheed chief engineers Bard Allison ***(above,*** *at right) and Russell Hopps hold models of a subsonic transport with canards and a second-generation SST.*


Rutan VariEze
North American P-51 Mustang
Douglas C-47
Northrop Gamma
Ryan "Spirit of St. Louis"
Deperdussin Racer
Wright Flyer
NASA
NX-211

Innovation Speed Complexity

IN FEWER THAN 80 YEARS, airplanes have developed from frail curiosities to machines essential in communication, transportation, and defense. Aviation and technology have spun cycles of innovation, advancing the state of the art in many industries. Certain aircraft, such as those shown here, were breakthroughs. Some seem never to quit. Hundreds of DC-3s, paragons of utility and reliability, are still flying.

Wright Flyer *(1903) gave man his first sustained and controlled powered flight.*

Deperdussin Racer *(1912) was first to use a monocoque fuselage and exceed 100 mph.*

Ryan "Spirit of St. Louis" *(1927) carried Charles Lindbergh solo across the Atlantic and ignited world interest in aviation.*

Northrop Gamma *(1933) pioneered all-metal construction for transport aircraft.*

Douglas C-47 *(DC-3, 1935), shown in 1942 war paint, revolutionized air transport.*

North American P-51 Mustang *(1940) scored as the finest all-around fighter of World War II for its strength, arms, and range.*

Rutan VariEze *(1975), designed for building at home, may presage the future for small, safe, and efficient propeller craft.*

Boeing 707 *(1957) employed a shapely swept wing and podded engines to bring the jet-transport age to maturity.*

Lockheed YF-12C (SR-71) *(1964) can fly in excess of Mach 3—three times the speed of sound—because of breakthroughs in aerodynamics, materials, and engines.*

Anglo-French Concorde *(1969) proved that supersonic transports could fly the Atlantic safely, if not economically, at Mach 2.*

General Dynamics F-16XL SCAMP *(1980s), a proposed variant of the F-16 fighter, would use a highly efficient wing to permit sustained supersonic speed. High fuel consumption keeps current fighters subsonic except for short bursts.*

PAINTING BY FRED WOLFF, IN COOPERATION WITH RICHARD HALLION enemy in the air. The F-15 even looks superior on the ground, with its pointed nose, gracefully curving fuselage, and two engines so big they make twin bulges between its 18-foot-high vertical tail fins. This airplane wants to fly, I thought, and when Cash invited me to come along, so did I.

In the late 1950s, when I flew the Grumman F-9, one of the Navy's first jet fighters, I became accustomed to long, leisurely takeoff rolls and slow, lengthy climbs. The engine's 5,000 pounds of thrust had to work hard to propel 15,000 pounds of airplane. With the F-15, swiftest of tactical fighters, it's the other way around: Thrust (48,000 pounds) exceeds weight (43,000 pounds), and when the throttles go forward, things happen *now*.

After a takeoff roll remarkable for its brevity, the airplane seems to stand on its tail and fairly bound into the air. Colonel Cash maintains a 60-degree climb, and we pass through 9,500 feet *before* reaching the end of the runway. "No other airplane in the world can match this vertical acceleration," he says. Leveling off at 23,000 feet, he prepares for mock combat with an opponent 10,000 feet below us.

"Here he comes," says Cash, rudely whipping in 90 degrees of bank. I look down and see a speck becoming bigger, bigger, bigger—an F-15 climbing toward us like a bullet with wings. As it zooms past in a vertical climb, Cash maneuvers to keep it in sight. "I lost him, you got him?" he asks.

What I am getting is a reacquaintance with an old and tiresome adversary called g's, multiples of the force of gravity encountered when an airplane maneuvers violently, as ours is doing now.

Regaining contact, Cash turns hard to get on the tail of our opponent, who turns harder, while Cash turns harder still. The accelerometer on my instrument panel bounces between 6 and 6.5 g's, and I weigh—literally—more than 1,000 pounds. The force plasters my feet to the floor, binds my arms to my thighs, and tugs at my cheeks as if they are taffy.

After ten seconds: I'm in an invisible vise. Inflatable rubber sacs in my flight suit have automatically expanded—drum tight—against my legs and abdomen to prevent blackout. After twenty seconds: It is getting difficult to breathe and I feel tired, incredibly tired. Thirty seconds: Enough of this infernal massage. "I've had it, Cash. Let's knock it off and do something else."

Later, during a flight in the F-16 with Lt. Col. Robert Ettinger, I experienced a turn that climaxed for several seconds at 8.8 g's, more than enough to put my mortal frame into the dreamworld of blackout. However, this rarely happens in the F-16, because the seat slants 30 degrees to the rear, putting a pilot in a semireclining position that increases g tolerance. So I remained conscious, though mighty uncomfortable. Future fighter pilots may enjoy—if that is the word—greater g tolerance by flying on their backs in seats that automatically recline with the onset of g's. In tests of such a seat at the Naval Air Development Center, Warminster, Pennsylvania, pilot subjects tolerated up to 14 g's.

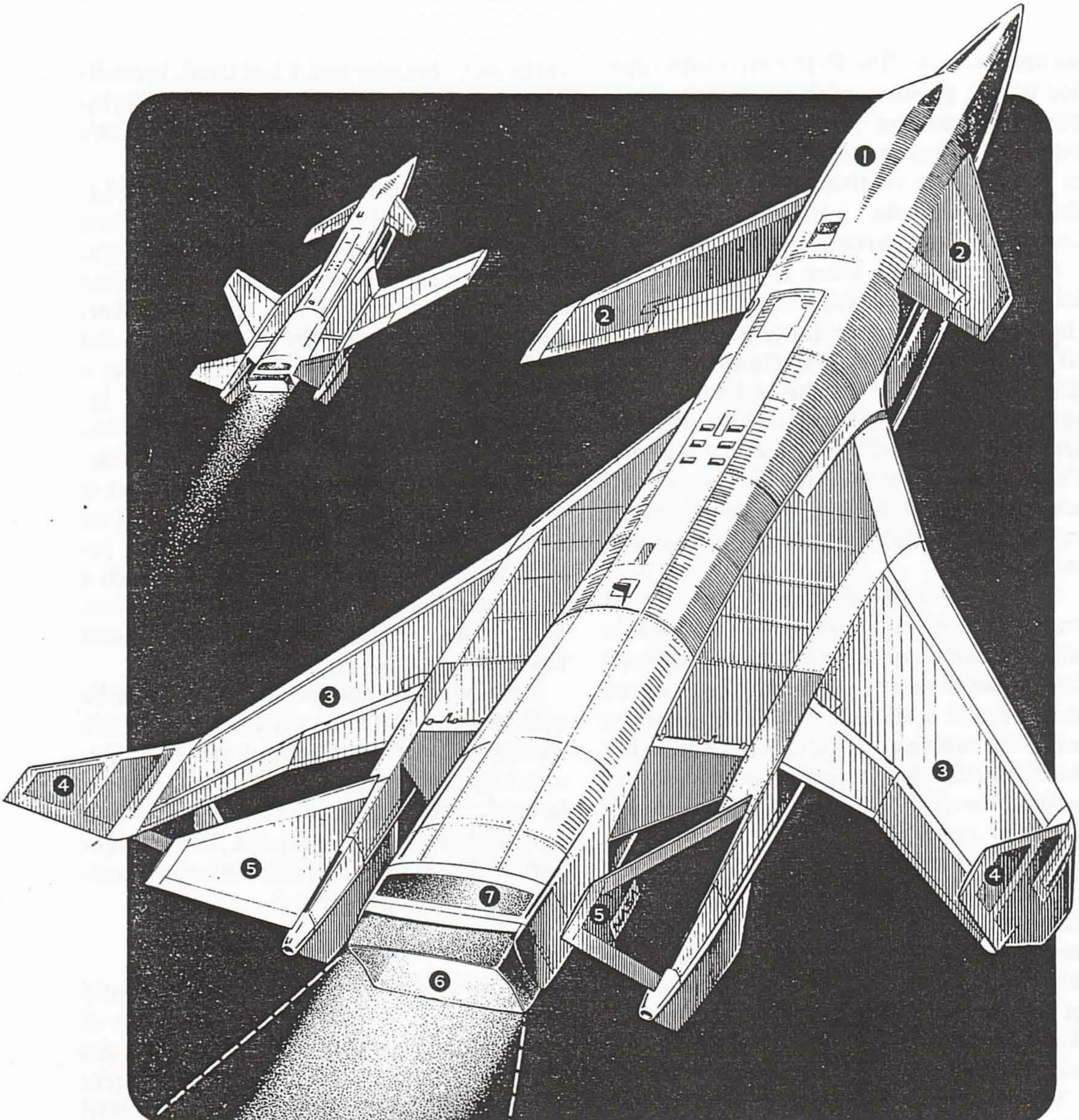
Colonel Cash explained that a new missile with sensitive infrared eyes could radically change the tactics of visual combat. "You won't have to get on somebody's tail then," he said. "Just pull hard, point your nose at him, and fire. It will be a quick, hard-fought battle," he added, "and this business is really going to get hazardous."

Pilot Flies Airplane From Ground

High above the Mojave Desert a futuristic airplane tests the maneuvering concepts of tomorrow, including the ability to turn twice as efficiently as the front-line fighters of today. Name just about any advanced technology and HiMAT—Highly Maneuverable Aircraft Technology—has it. The NASA-Air Force research craft built by Rockwell International is a flying computer on the inside—even the engine is electronically controlled. Outside, winglets and canards protrude from a skin that is almost entirely graphite-epoxy composite.

"It's the most complex project we've ever attempted," said Ike Gillam, director of NASA's Dryden Flight Research Center, where former projects have included the space-shuttle landing trials and the rocket-powered X-15 flights of the 1960s.

Everything seems to be on board HiMAT except the pilot. He stays on the ground and flies the aircraft by remote control after it has been dropped at 45,000 feet by a B-52



PAINTING BY FRED WOLFF

HiMAT's plug-in advances

TINKERTOY APPROACH will permit new components such as wings, canards, and engine nozzles ***(above)*** *to be fitted to the basic core of existing HiMATs, standing for Highly Maneuverable Aircraft Technology. This system's modularity will achieve testing flexibility while holding down costs.*

Advanced versions would share these features with current HiMATs: ***(1)*** *electronics pallet with micro-processors and forward-looking television;* ***(2)*** *canards to improve airflow over the wings* ***(3)*** *and allow extremely tight turns;* ***(4)*** *winglets to increase stability, minimize drag, and enhance lift;* ***(5)*** *twin vertical tails to give directional stability and control.*

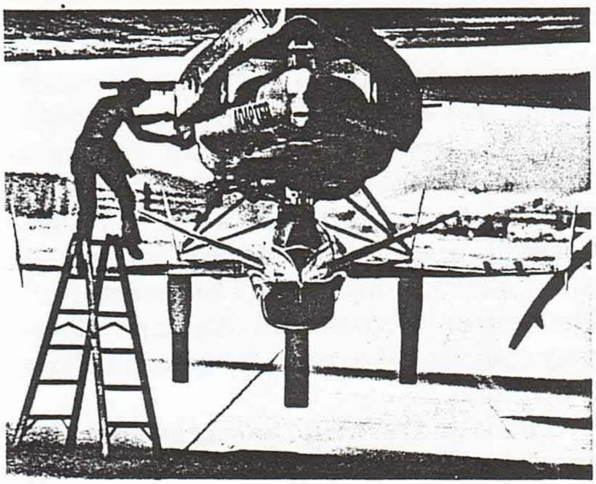
Future versions would also incorporate: ***(6)*** *engine nozzle swiveling up or down 20 degrees for abrupt and unusual maneuvers;* ***(7)*** *clamshell thrust diverter to open in flight for instant deceleration in combat.*

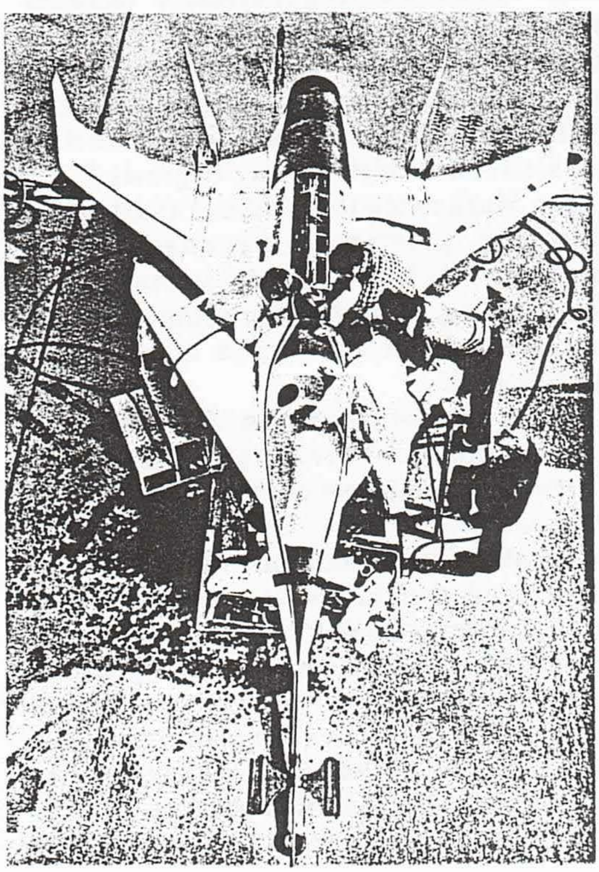
Forward-swept wing on another version (left) may improve performance during low-speed flight. In construction, both current and possible advanced HiMATs employ graphite epoxy, a composite material twice as strong as aluminum at half the weight.

Ultimate model airplane, *the HiMAT research aircraft, a NASA-Air Force jet, is scaled down and piloted remotely both to save money and to avoid the possibility of pilot loss.*

After technicians check out the nearly omniscient on-board computers and button up the airplane ***(bottom)****, the craft is slung under a B-52's wing* ***(below)****. Released at 45,000 feet, it is controlled from a ground station or chase plane. Tests promise to confirm the design's potential as a fighter of the future that can outmaneuver anything now flying.*

KERBY SMITH





bomber. This technique, pioneered at Dryden, permits a smaller vehicle to be tested. A down-size version of a 17,000-pound airplane capable of carrying a man, HiMAT weighs just 3,400 pounds.

Two of the small unmanned HiMATs were built for 17 million dollars. Just one man-rated craft would have cost more than 80 million dollars. This is welcome news for taxpayers, because another dimension in which aviation technology is advancing is cost, especially with fighters. One F-14, together with spare parts and support activities, costs 23 million dollars. One F-15, 18 million dollars.

Costs Soar to Incredible Heights

"From the days of the Wright brothers through the F-18," says Norman R. Augustine, vice president for technical operations at Martin Marietta Aerospace, "aircraft costs have been increasing by a factor of four every ten years." Viewing this "inexorable trend" in relation to defense-budget increases, the former undersecretary of the Army makes a prediction: "In the year 2054 the entire defense budget will purchase just one tactical aircraft. This aircraft will have to be shared between the Air Force and Navy three and a half days each per week."

As a former marine, I protested the omission of the corps from this scenario. Augustine responded that perhaps the Marines could use the airplane on weekends, but that anyway, this would be up to the Navy.

Levity aside, Augustine is not kidding about costs. "I present this in tongue-in-cheek fashion," he told me, "but the data are real. The trend is real. In the future we're going to have to exercise discipline."

Noting that "scientific and engineering knowledge is increasing with almost bewildering speed," David Lewis, chief executive officer and chairman of the board of General Dynamics, states that "essentially any level of performance can now be designed into an airplane weapons system, if someone is willing to pay the cost."

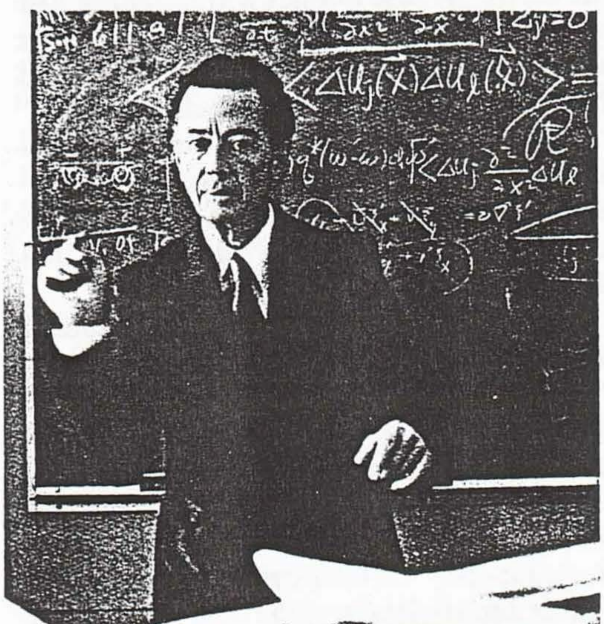
Paradoxically, technology may come to its own rescue. "Take an 80,000-pound tactical aircraft of the 1960s," says Michael Pelehach, president of Grumman International, "and redesign it with the technology of the 1980s. With advanced composite materials you could get the weight down to 53,000 pounds; with better aerodynamics, to 44,000; with new engine technology, to 37,000 pounds.

"Like steak, airplanes are bought by the pound," Pelehach told me. "The trend in the future will be to smaller, lighter, less expensive airplanes."

Dr. Hans Mark, Secretary of the Air Force, pointed out another trend—the increasing production rate of Soviet combat aircraft. "They are building four times as many warplanes as we are," he said. At this rate, Dr. Mark explained, the U. S. Air Force could completely replace its inventory of tactical airplanes every three years.

The Soviet design philosophy used to emphasize rough-and-ready serviceability. Kelly Johnson, who created the U-2, SR-71, and many other significant aircraft during a distinguished career at Lockheed, recalled a remark that the Soviet designer Andrei Tupolev made to him in 1962:

"You Americans build airplanes like fine lady's watches. Drop watch—watch break. We Russians build airplanes like Mickey Mouse clocks. Drop clock—clock stop. Pick up clock and shake—then clock work."



Largely self-taught, *Robert T. Jones of NASA's Ames Research Center became one of the world's leading aeronautical designers. Among his contributions are the principles of the swept wing and pivoting wing. His curiosity even led him to design an electronic violin.*

But in the past 15 years or so, experts note, the Russians have made the transition from Mickey Mouse to the micro-processor. "Quality has increased dramatically," Grumman's Pelehach said. "They can design as well as we can."

Vice Adm. Wesley L. McDonald, deputy chief of naval operations for air warfare, told me: "When you see the sophistication of the Backfire bomber, it is naive to think we can come up with a cheap substitute to meet its threat."

Competition Grows for American Firms

Looking at U. S. civil aviation, Dr. Mark, former director of NASA's Ames Research Center near San Francisco, expressed both pride and concern. "American airplanes comprise 85 percent of the free world's commercial jet aircraft," he said. "In 1979 our aeronautical exports amounted to nearly 12 billion dollars, second only to foodstuffs." The Boeing Commercial Airplane Company contributed a hefty 3.5 billion dollars of that total.

"This is no accident," he continued. "The investment the federal government made in wind tunnels and flight-research facilities beginning in the 1950s has led to the generation of jet transports we build today. But we are not maintaining the pace of this investment, and I think we are failing to see it as the seed from which prosperity grows."

Dr. Mark noted that Airbus Industrie—a European government-supported consortium—in 1979 moved into second place, after Boeing, in orders for commercial jet transports. "The other guys are catching up," he said.

In the race for more than 100 billion dollars in orders for civil transports by the 1990s, manufacturers emphasize fuel economy, attained by better aerodynamics, more efficient engines, electronic flight management, and weight-saving materials. The new jetliners—Boeing's 757 and 767, Airbus Industrie's A310, and McDonnell Douglas's DC-XX, still in design—won't look much different from existing airplanes, but passengers and pilots alike will experience some advances in aviation comfort.

For instance, pilots' seats in Boeing's new airplanes will be covered with lamb's wool. Taking a cue from some midwestern farmers who use lamb's wool as a seat on their tractors, Boeing engineers strapped pilots in various seats for long periods during a scientific squirm test. The results revealed that lamb's wool seats induce significantly fewer squirms, twitches, jiggles, and scratches than conventional seats. Wool from New Zealand lambs proved best.

Boeing has also modulated the flight-deck cacophony of as many as 18 warning bells, horns, buzzers, clackers, and musical tones of former aircraft to four: a bell for a fire, whoops for inadvertent proximity to the ground, a police siren for excessive airspeed and other conditions, and electronic owl-like hoots for equipment malfunctions.

New Planes Give Passengers a Break

Except for the relatively narrow-bodied Boeing 757, the new jetliners will have two aisles, and no passenger will be more than one seat away from an aisle. The 757, scheduled for delivery in 1983, will offer two sets of three-abreast seats separated by a single aisle, plus architectural niceties to convey a feeling of spaciousness. Cool pastels highlight the cabin interior. Storage bins large enough to handle a guitar, a backpack, or a set of golf clubs blend with the ceiling instead of hanging, an engineer says, "like cabinets in a kitchen."

Aboard the Airbus A310, mothers with infants will find a foldout platform in rest rooms for diaper changes; passengers in the center row of seats will have their own storage bins. In McDonnell Douglas's jetliner, passenger seats will average one and a half inches wider than those in the old DC-8. Reason: people are getting bigger. Collating anthropometric data, Douglas engineers discerned that, from a 1955 baseline, American men will be one and a half inches taller, on an average, by 1990. Women will be three-quarters of an inch wider in the hips.

Thus comfortably ensconced, passengers may not notice the major aerodynamic improvement common to the new transports —longer wings. As soaring birds and sailplanes teach us, longer wings are more energy efficient.

"The airlines first wanted an airplane that could go faster—just below the speed of sound, in fact," said Dr. Richard T. Whitcomb (below), now retired after a distinguished career with NASA. The problem was, he explained, at this speed the wing experienced high-drag shock waves.

To delay the formation of these waves, Whitcomb reshaped the wing, making it flatter on top, with a cusp on the bottom near the trailing edge. The new wing worked in flight tests.

"Then the Arabs lowered the boom on fuel," he recalled, "and suddenly people weren't the least bit interested in flying faster." So Whitcomb switched to plan B: Make the wing thicker and longer, and fly it at the former speed, .8 Mach. "By doing this, we bought a 10 to 15 percent gain in aerodynamic efficiency," he said.

With computer-smart controls, wings can be made longer without compromising structural strength. When a gust of bumpy air strikes the longer wings of the new Lockheed TriStars being purchased by Pan American and other airlines, computers will move the wings' outer control surfaces—the ailerons—upward, thus relieving the load

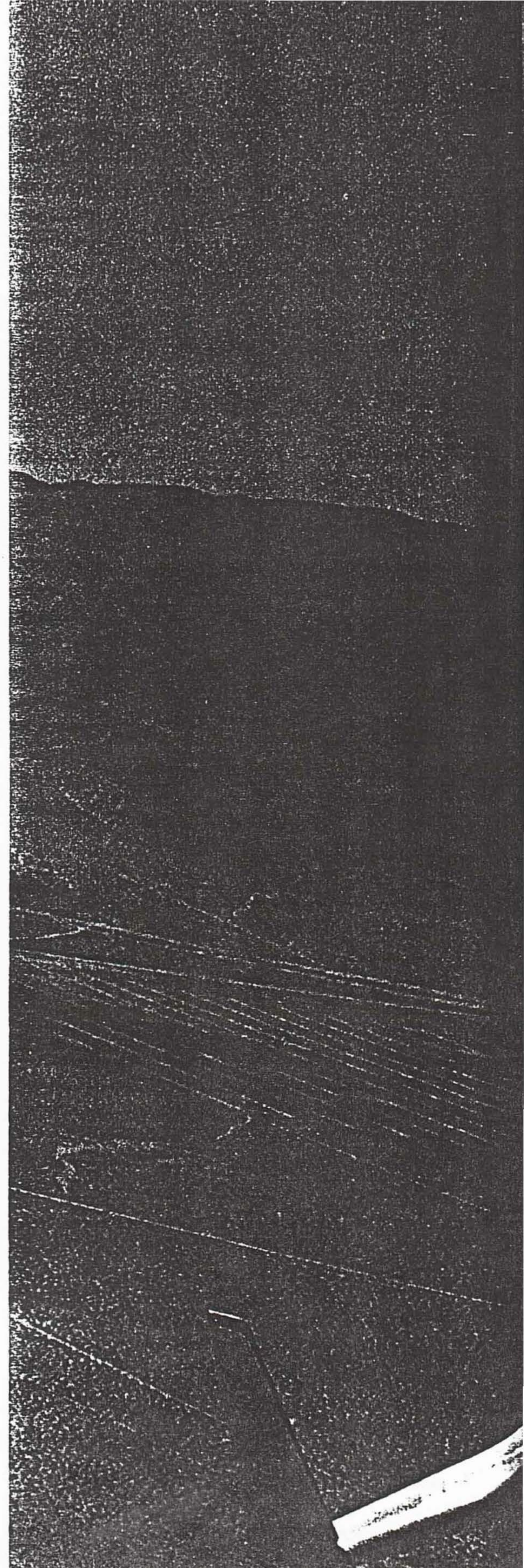
First applying theory, *NASA's Richard Whitcomb later refines his designs in practice with a metal file. His discoveries include the "Coke bottle" fuselage for practical supersonic flight, the supercritical wing for low drag at high subsonic speeds, and winglets.*

on the wings as well as smoothing out the ride for the passengers.

"We would have thought twice about buying the airplanes without this improvement," says Pan American vice president and chief engineer Lewis H. Allen. The airline expects to save at least three million dollars a year on fuel costs with its TriStar fleet.

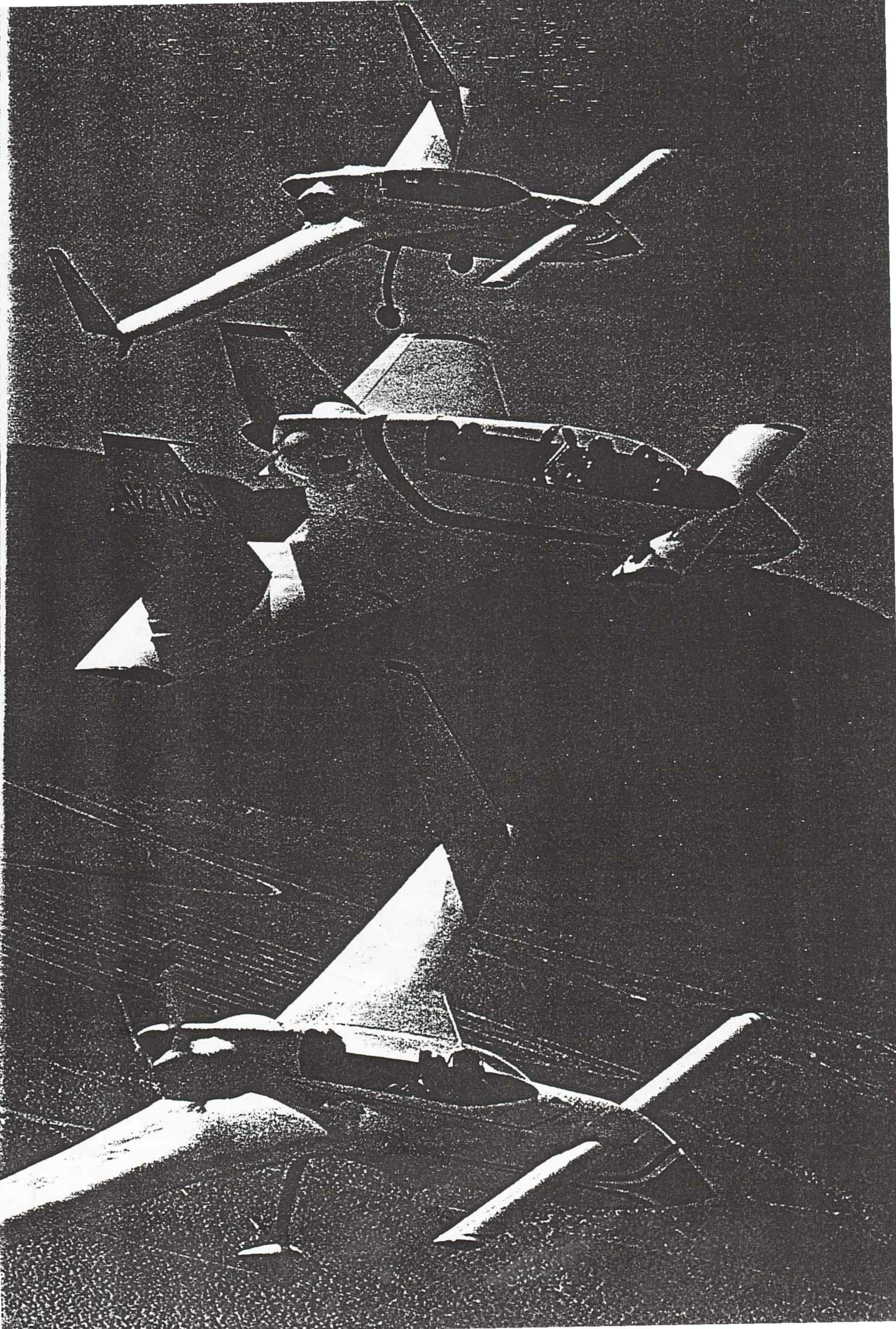
With the emphasis on fuel-efficient aircraft, prospects for an advanced supersonic transport fly into the winds of controversy generated by the Anglo-French Concorde: too expensive, too noisy, too fuel consuming. Yet a NASA research program, authorized by Congress in 1971 after the cancellation of the U. S. SST project, has produced breakthroughs in areas that plague Concorde: noise reduction, less costly fabrication of titanium, an engine that can "shift gears" to function efficiently at either subsonic or supersonic speed, and, especially, improved aerodynamics.

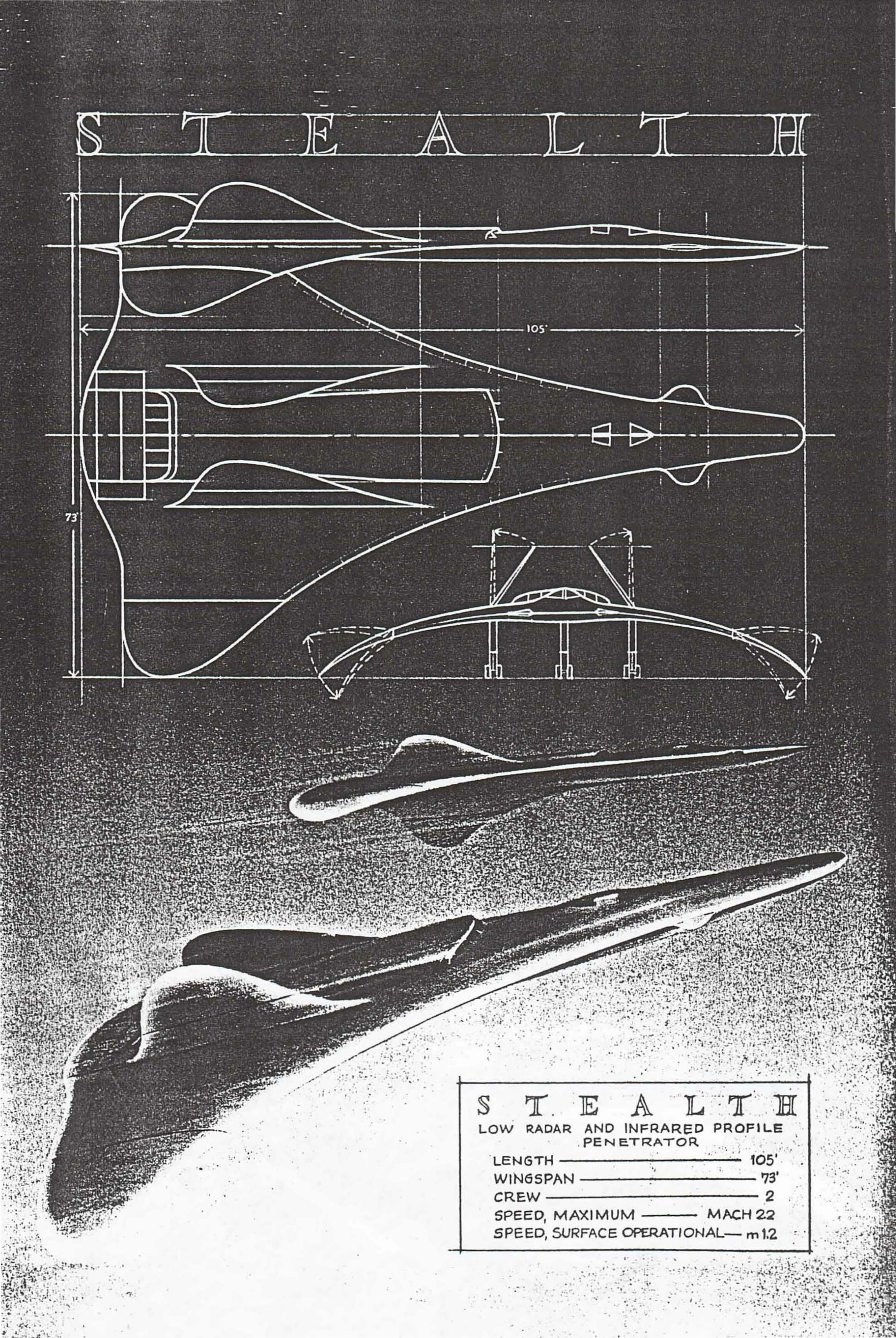
Richard D. FitzSimmons, director of advanced engineering at Douglas, says that his company's wing represents a "40 percent increase in aerodynamic efficiency over Concorde, translating into a 40 percent decrease in fuel burned." If air could bleed, this wing



***With bonelike canards** in their snouts, the backward-looking craft of independent designer Burt Rutan do not stall—a major aerodynamic innovation.*

*Available as kits, Rutan's airplanes are home built **(above)** by laying up fiberglass over a foam core.*





S T E A L T H
105'
73'
S T E A L T H
LOW RADAR AND INFRARED PROFILE PENETRATOR
LENGTH — 105'
WINGSPAN — 73'
CREW — 2
SPEED, MAXIMUM — MACH 22
SPEED, SURFACE OPERATIONAL— m 1.2

would cut. Highly swept, with razor-sharp leading edges, it resembles an arrowhead. Applying the new wing and engine technology to smaller airplanes, an exciting possibility arises—a fighter capable of sustained supersonic speed.

New Craft Recall an Old Friend

Burt Rutan, a tall Californian with muttonchop sideburns, seems to advance aviation technology all by himself. Burt is president of the Rutan Aircraft Factory, occupying a small building at the Mojave airport. He employs three people.

Burt designs airplanes mostly for home builders—you buy the plans and you build the airplane. More than 300 of his VariEze designs are flying. Burt calls the airplane that because it is "very easy" to build.

His airplanes seem a little odd because the horizontal "tail" is in the front, while the propeller is usually in the rear, leading some to wonder which way they fly. They fly well.

What is remarkable is that Burt's airplanes don't stall. A stall occurs when the angle between the airflow and the wing becomes so great that the wing loses lift and stops flying. I witnessed such an accident years ago near Pensacola, Florida, when a fellow flight instructor suffered an engine failure soon after takeoff.

He turned back toward the runway. Then his turn became tighter, his angle of bank steeper. Suddenly the airplane flipped on its back and lazily spun into the ground, killing both instructor and student.

Burt's brother Dick, a former Air Force fighter pilot, is the test pilot of the Rutan Aircraft Factory. One day I sat in the backseat of a VariEze while Dick, manning the controls in the front, throttled back and set up a glide to simulate a landing approach. Then he cranked in 60 degrees of bank and pulled 1.8 g's with full back stick. This is the recipe for real trouble in most airplanes, but the VariEze obediently made a swift 360-degree turn. I asked Dick if I could give it a try.

This time I raised the nose above the horizon before steepening the bank and pulling back stick, doing my best to help provoke a stall. Once again the airplane turned, smartly. "I've tried everything to stall it," said Dick, "and all I get is exercise. Other test pilots have asked me, 'What's wrong with this airplane? I gotta stall it and make it spin.' They get mad."

Back at the Rutan Aircraft Factory, Burt explained. The horizontal tail in front is actually a canard, which functions in this case as sort of an auxiliary wing. The canard, mounted at a greater angle on the fuselage than the main wing, does indeed stall and stops lifting. Then it drops a bit and starts flying again. Meanwhile—and this is the point—the main wing has never approached the angle of attack at which it would stall. (On the F-16 the angle of attack is limited electronically. Once a pilot reaches this maximum, the computer steps in and prevents him from increasing it further, no matter how hard he pulls on the stick.)

NASA aerodynamicists tested a VariEze model in a wind tunnel last year as well as a full-scale airplane in flight. "Remarkable, innovative, expert," was the verdict of Joe Chambers, head of the dynamic-stability branch at NASA's Langley Research Center in Hampton, Virginia.

In 1979 Dick Rutan, flying a special edition of the VariEze with extra fuel, set a world distance record for aircraft weighing less than 2,200 pounds—4,800 miles in 33 hours and 33 minutes. That's three minutes more than Charles Lindbergh took to fly the Atlantic Ocean. Dick's flight would have spanned the Pacific.

Burt Rutan is not one to let convention fuzz up his thinking, so an admirer says, and canard-equipped airplanes may look a bit odd to those who've made up their minds how an airplane should look. Aerodynamic excellence aside, his airplanes have an elegance and a simplicity that put me in mind of a—well, of a Tiger Moth. □

***Strategic hide-and-seek** has a new player, the secret Stealth. Painting **(left)** depicts what such a U. S. bomber/reconnaissance aircraft could look like, based on well-known principles as interpreted by expert Richard Hallion. To foil radar: a minimal cross section, curved surfaces for signal deflection, and composite materials with nonreflective coating. To foil infrared sensors: shielded exhaust above wing.*

PAINTING BY NATIONAL GEOGRAPHIC ARTIST WILLIAM H. BOND