McDONNELL DOUGLAS MD 520N

NOTAR

And thereby hangs a tail.

BY SETH B. GOLBEY

Last September 17, the MD 520N became the first new helicopter in almost a decade to receive FAA type certification. ■ It also became the first single-main-rotor helicopter without a tail rotor for antitorque and directional control to enter production. ■ In the past, efforts to counteract the torque generated in turning a helicopter's rotor—which results in the fuselage attempting to rotate in the opposite direction—have followed two main paths. ■ The most common solution has been to mount a small tail rotor at the end of a tailboom. The drawbacks to this design are the obvious safety hazard of locating the tail rotor where it can easily come into contact with people and objects on the ground, its susceptibility to foreign-object damage, and the noise it generates. ■ Another solution was to use two or more main rotors—mounted at opposite ends of the fuselage, at the tips of wings or outriggers, side by side, or coaxially. The downside here is weight and complexity—which help drive up cost of manufacture and operation. ■ When Hughes Helicopters (which later became the McDonnell Douglas Helicopter Company) began developing its Notar system (the acronym, which stands for "no tail rotor," is a trademark

PHOTOGRAPHY BY MIKE FIZER

of MDHC) in 1976, engineers sought a more elegant solution. They found it in the theories of Henri Marie Coanda (1885–1972), a Romanian-born aeronautical engineer and inventor who postulated that air flowing over a curved surface tends to follow the curve of that surface. We see Coanda Effect at work when air flows over the surface of an airfoil. Using Coanda Effect, the aerodynamics of the tailboom itself could be tapped to provide the bulk of the antitorque force required.

(Coanda, by the way, designed the first jet-powered airplane to fly, in 1910, using a remarkably advanced ducted-fan concept. It crashed on its first flight, due more to Coanda's shortcomings as a pilot than to any design deficiency. He later designed a solar-powered desalinization system. He was a little ahead of his time.)

The first flight of a Notar concept-demonstrator was made in December 1981. The commitment to full-scale development and production came in 1987. The first production prototype flew in December 1989, and the first production unit followed last June.

Looking at the MD 520N, you first note the seemingly massive tailboom, tipped by what is alternatively called a "direct jet thruster" or "variable-area thruster" (pilots call it the "can"). Studying the machine in greater detail, you find that appearances are deceiving.

First, the tailboom is extraordinarily light, its size being related to its aerodynamic role. Made of Kevlar and graphite, the boom, even with its fiberglass stabilizer unit, weighs less than 100 pounds, only a few pounds more than a conventional tail. It is attached to the fuselage by four bolts. Two cannon plugs provide power connections for the anticollision lights and a servo actuator for the right vertical stabilizer. A quick-disconnect plug links the control system. Two people can remove the tailboom in five minutes. The unit is so simple the company hopes to offer a 5,000-hour TBO on it. (Ironically, according to MDHC, the boom's composite construction was of greater concern to the FAA in certification than the Notar system itself.)

Second, the appearance of the can implies that vectored thrust is used for antitorque and directional control. This is only partially true, as 60 to 70 percent of the antitorque force in hover is provided by Coanda Effect. Directional control in forward flight above about 20 knots comes largely from the left vertical stabilizer, which is linked to the pilot's pedals.

In airplanes, they're generally called rudder pedals because they move that control surface; in conventional helicopters, they're called antitorque pedals because they control the pitch of the tail rotor blades. In Notar, the pedals in essence do both (and more, as we'll see below) because they also control the can, which rotates through 210 degrees. Rotating the can governs the amount of thrust by regulating the width of a slot through which air is blown and provides directional control by regulating the direction in which the air is blown. There's tremendous reserve thrust available: The helicopter can perform a pedal turn at the literally breathtaking rate of 120 degrees per second; in a hover, the slot is only open about a three-finger width.

The effectiveness of this system is such that the 520N is approved for hovering in 30-knot crosswinds and has been flown sideways at speeds significantly higher. Pilots will find the 520N requires only about one fifth the pedal displacement of a comparable conventional helicopter. Why? To take one example, the blades of a conventional tail rotor undergo constantly changing angles of attack due to changing airflow, particularly in gusty wind conditions, requiring the pilot to compensate with pedal inputs. With Notar, the issue is largely moot.

The idea of using Coanda Effect is not new; Lockheed tried it without real success in the 1950s. Hughes/MDHC engineers discovered why earlier attempts had failed. Simply put, the early assumption was that, to make Coanda Effect work, air must be under great pressure. As the designers learned, the Effect relies on moving a great mass of air, rather than putting air under high pressure. The Notar design relies on low-pressure, high-mass airflow, hence the large volume of the 520N's boom. (The pressure in the boom is less than 2 psi higher than ambient air pressure.)

From the tailboom attach point forward, a 520N is virtually identical to MDHC's conventional 500-series helicopters. But where the tail rotor drive shaft once exited the transmission, there is now a 19-inch stub shaft connected to the gearbox of a high-speed (5,800-rpm) fan. A 15-inch shaft connects the fan gearbox to the fan, housed just forward of the tailboom attach point.

Air is drawn into the fan (assisted by rotor downwash) through a duct aft of the rotor mast. The pitch of the fan blades is controlled by the pilot's pedals to keep the air pressure in the boom constant. In addition to the variable slot in the can, air escapes through two long fixed slots on the right side of the boom. Air exits the slots at about four times the velocity of the rotor downwash to help keep the downwash attached to the curvature of the boom, resulting in a horizontal component of lift, just like a vertical wing. Presto: Coanda Effect generates antitorque force.

The exhaust stack for the 520N's derated 450-shaft-horsepower Allison 250-C20R turboshaft engine is canted to the left, contributing its own thrust to the antitorque effort.

But aside from the gleam of high technolo-


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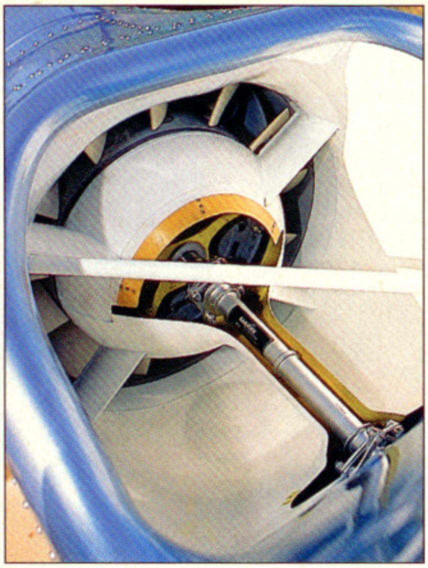
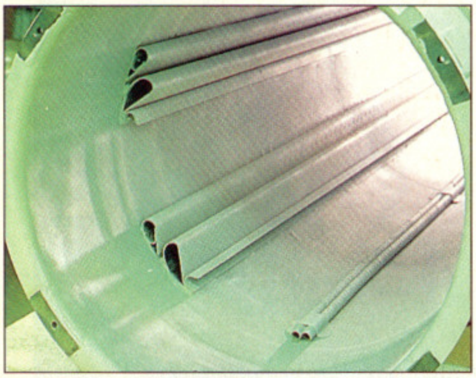
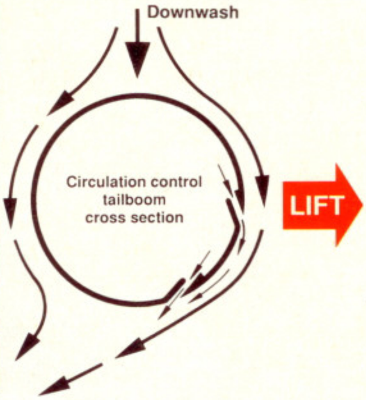
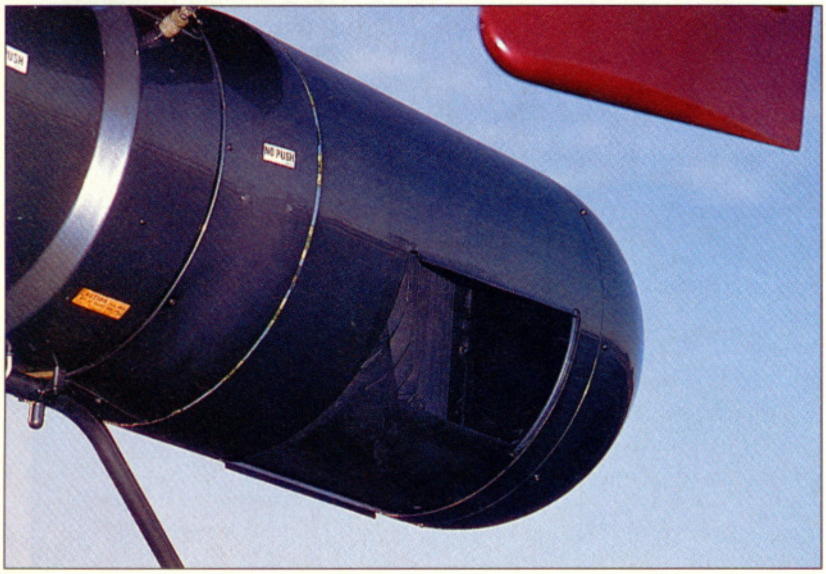
PHOENIX POLICE







Air enters an intake behind the rotor mast and is compressed and forced into the tailboom by a high-speed fan. It exits through a pair of fixed slots in the right side of the boom, producing Coanda Effect, and through the tail thruster for additional directional control.



gy, what does an investment in Notar technology buy for the helicopter operator? To answer that, *Pilot* went flying with the MD 520N's launch customer, the Phoenix Police Department's Air Support Unit. The unit took delivery of the first of a seven-ship order last October 31. The 520Ns, which should all have been delivered by the time you read this, will replace five 500Ds acquired in 1979 and 1980.

The most obvious benefit of Notar is safety. In 1985, in a crashworthiness study related to its LHX helicopter program, the U.S. Army found that one in five of its helicopter accidents resulting in fatalities or destruction of the aircraft were directly related to striking the tail rotor, loss of tail rotor effectiveness, or mechanical failure of the tail rotor system.

Phoenix's Air Support Unit has been flying since 1972. In almost 150,000 flight hours, its only mission-related accident involved a 500D whose tail rotor tangled with a chain-link fence. No injuries resulted, and the helicopter was soon repaired, but the event is an understandably frustrating spot on an outstanding safety record.

The unit works closely with other police department units and with other public safety services, assisting the fire department, for example, in about 25 rescues each year. The safety advantage offered by Notar for both flying crews and personnel on the ground was a major factor in the 520N's selection, according to Lieutenant Michael T. Casey, the officer in charge of the unit.

Another is quietness. According to data gathered during certification flight tests, the 520N is the quietest helicopter in its weight class (10 EPNdB—effective perceived noise decibels—below the FAA's Stage 2 regulations). It makes just half the noise of a comparable conventional helicopter. During a *Pilot* photo session, a 520N lifted off and flew to the far side of the police hangar. Subjectively, the noise coming from behind the building sounded more like a large air conditioning unit than a helicopter.

A quiet helicopter is a boon to police work, says Lt. Casey, where the "bread and butter" mission is night patrol conducted just 500 feet over the city. When orbiting in support of a ground search, helicopters fly at 300 feet agl. Being a good neighbor to slumbering, law-abiding citizens is an important concern, but so is getting the drop on the "bad guys." A 520N is virtually inaudible over the ambient daytime noise level of a city street. Casey, who appears before citizens groups to tell the Air Support Unit's story, says he's already received dozens of compliments on the quietness of the new helicopters.

Safety and quiet address two of the public's biggest worries regarding helicopters, but the 520N has other qualities to recommend it.

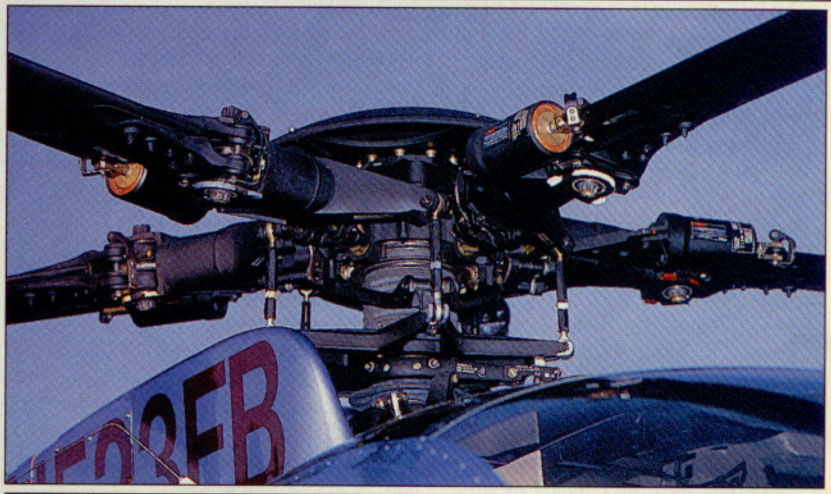
The helicopter boasts increased payload compared to its conventional forebears. It can lift a ton on its cargo hook, which the police use for rescue work. Speed—the ability to move from one side of the 460-square-mile sprawl of Phoenix to another in 10 minutes—is a quality the Air Support Unit exploited in its 500Ds. The unit's 520Ns aren't quite as fast as the helicopters they're replacing because they carry several hundred pounds more mission equipment—some of it externally mounted. Standard in the new ships are a forward-looking infrared (FLIR) system, an improved spotlight, and a vastly more capable avionics suite that offers crews access to 5,000 communications frequencies, compared to 12 in the old ships.

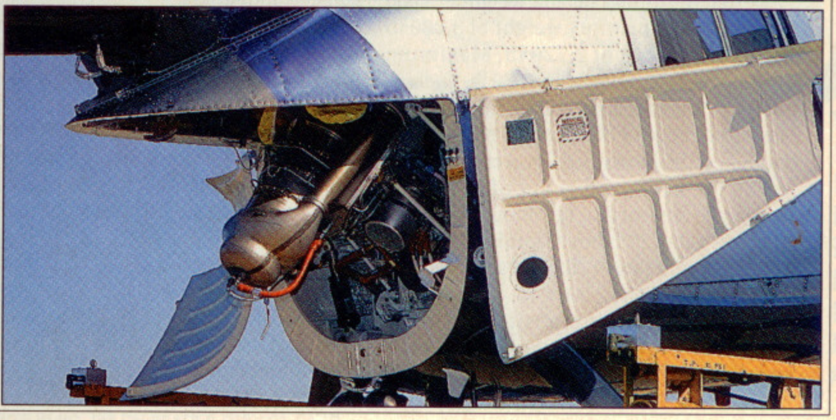
The tactical advantage of the new equipment was demonstrated during a recent spate of uncharacteristically bad weather in Phoenix. Thick fog was used as cover for a series of automobile break-ins; the perpetrators were apprehended using FLIR from atop the solid cloud deck.

The handling improvements made possible by Notar also help the cops do their job. Six of the Air Support Unit's 16 pilots are specially qualified as part of a joint police/fire department Firebird Rescue Team. ("Firebird" is the Air Support Unit's call sign.) The day of *Pilot's* air-to-air photography was characterized by high winds and turbulence in the lee of the mountains; the pilots half-joked that it seemed mountain rescue calls always come on such days, as one did just before Christmas. A hiker on a steep trail near the top of the city's 2,600-foot Squaw Peak suffered what appeared to be a stroke. Rescuers feared the man would not survive being carried back down the trail. A 520N was dispatched and lifted the victim off the mountain in a litter steadied at the end of a 90-foot cable by a paramedic. The man was delivered to a waiting ambulance at the base of the mountain. (He is recovering.)

Rescue team pilots are trained for that kind of long-line work; for one-skid landings in the rough, mountainous desert terrain around the city; for white-water river rescues; and for high-rise building fire fighting and other efforts in which personnel rappel from a hovering helicopter.

Police crews typically fly two two-hour patrols each night. The unit responds to about 14,000 Priority One calls (generally involving felonies in progress or pursuits), assists in about 1,400 felony apprehensions, and amasses about 5,000 flight hours each year. At these performance levels, the improved handling and diminished work load that combine with Notar's greatly reduced vibration level to mitigate pilot and passenger fatigue are greatly appreciated. And the lower parts count—





stemming mainly from the elimination of the tail rotor, drive shaft, and gearbox—should increase reliability, decrease maintenance, and lower operating costs.

Because the 520N's flying qualities are very similar to the 500D's, Lt. Casey says, the unit was able to put greater emphasis on mission equipment familiarization than on aircraft handling during transition training. The similarity to the older ships is good news too for the unit's maintenance personnel. MDHC offers a five-hour pilot transition course and refresher training through factory-approved training centers.

As of mid-January, MDHC held firm orders for 165 MD 520Ns and options on 25 more. The company had delivered two of the Phoenix police ships plus one of a two-ship order to a South Korean concern. Forty percent of the orders are from overseas. The production rate is building toward five per month; 60 units are scheduled for delivery in 1992. Orders taken today for the 520N and 530N (powered by a derated 650-shp Allison 250-C30) will be delivered in 1994. And MDHC is considering offering Notar as a retrofit/conversion on conventional 500-series helicopters.

The Air Support Unit's transition to new helicopters has not been without growing pains. An on-site MDHC technical representative helps solve the problems that come with breaking in new aircraft. But none of the glitches so far have involved the Notar system, which has been completely reliable. All in all, pilots, mechanics, and administrators are well-pleased with the capabilities of the 520N. "The taxpayers are getting a hell of a deal," says Lt. Casey. And McDonnell Douglas is getting a challenging proving ground for its latest—and most exciting—product. □

McDonnell Douglas MD 520N
Base price: $690,000

Powerplant	Allison 250-C20R, 450 shp, derated
Length	32.1 ft
Height	8.8 ft
Rotor diameter	27.4 ft
Rotor area	586.8 sq ft
Seats	4–5
Max takeoff weight	3,350 lb
(external load operations)	3,850 lb
Empty weight	1,586 lb
Useful load	1,764 lb
(external load operations)	2,264 lb
Fuel capacity	64 gal (403 lb)
Max cruise speed	125 KIAS
V_{NE}	152 KIAS
Max range	202 nm
Max endurance	2.2 hr
Max rate of climb	1,546 fpm
Service ceiling	20,000 ft
Max hook capacity	2,000 lb
Hover in ground effect	9,300 ft
Hover out of ground effect	5,600 ft

Contact McDonnell Douglas Helicopter Company, 5000 East McDowell Road, Mesa, Arizona 85205-9790; telephone 602/891-3000.

Specifications are based on manufacturer's calculations. Performance figures are based on standard day, standard atmosphere, sea level, maximum takeoff weight conditions unless otherwise noted.

MDX

From a clean sheet of paper

• Notar would be remarkable enough even if the technology were only to be applied to derivatives of an existing product line, as it is with McDonnell Douglas's 500-series helicopters. But the 520N is only one arrow in the Notar quiver. Waiting in the wings is an entirely new aircraft, designed with considerable input from helicopter operators, called MDX. The project was announced in early 1989.

The aircraft is to be an eight-seat, twin-turbine utility helicopter costing $2.6 million in 1991 dollars. MDHC hopes the helicopter can be operated for about $320 an hour, significantly less than other helicopters in its weight class, according to its maker.

MDX will compete against a variety of five- to eight-seat, light and intermediate twin-turbine helicopters including the Aerospatiale AS 355 TwinStar, MBB BO 105LS (and its forthcoming successor, the BO 108) and BK 117, Agusta A109, and Bell's forthcoming 230. In weight, payload, cabin volume, fuel load, and price, it falls about in the middle of the pack. Its direct operating cost will be beaten only by the AS 355, according to MDHC. In standard-day in- and out-of-ground-effect hover, hook capacity, and noise, MDHC hopes to beat all comers. In fact, MDX is designed to be 20 to 40 percent quieter than any other ship in its class.

Design maximum takeoff weight is 5,800 pounds, with an empty weight of 3,080 lb and a useful load of 2,720 lb. Maximum weight with external load is 6,560 lb. Fuel capacity is 176 gallons (950 lb), allowing a maximum range of 275 nautical miles or endurance of 3.6 hours. Sea-level cruise speed will be 148 knots, with a V_{NE} of 174 knots. The ship is designed to hover out of ground effect on a day 20° above standard at 7,000 feet. Maximum rate of climb at sea level on a standard day will be 2,900 fpm.

MDX will use a composite five-blade rotor system with a bearingless, all-composite rotor hub of advanced design. Power will be supplied by the customer's choice of Pratt & Whitney PW206A turboshafts (621 shp takeoff, 531 shp max continuous each) or Turbomeca Arrius 2C engines (634 shp takeoff, 540 shp max continuous each). A single transmission will serve both engines, with no combining gearbox. A sprague clutch will allow a failed engine to drop off line without interrupting power to the rotor. Fuel consumption will be about 412 lb per hour. The ship is designed to be the first light twin helicopter that can fly away from a hover with one engine inoperative.

Flight instruments will center on a simple liquid-crystal display called the integrated instrument display system (IIDS), which will provide engine trend monitoring and crew alerting functions.

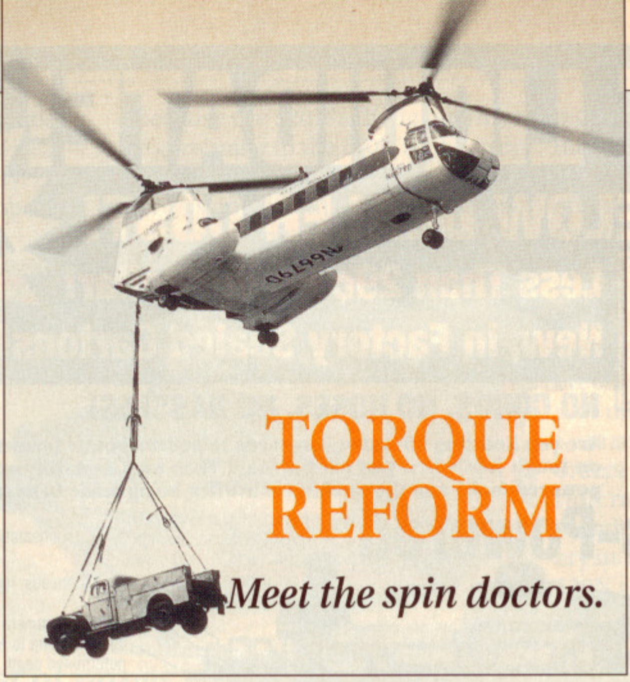
MDHC's current schedule calls for a first flight of MDX this September. FAA certification and first deliveries are anticipated for the last quarter of 1993.

A team of 15 commercial helicopter operators from around the world has been meeting with MDHC designers to make sure the new machine fits the bill for utility operations of all kinds. MDHC is also seeking to develop military applications for the new helicopter. A full-size profile painting of MDX overlooks the Apache/500-series assembly lines at the company's Mesa, Arizona, headquarters.

To finance the venture, MDHC teamed with risk-sharing partners. The first transmission, for example, was to be delivered by Japan's Kawasaki late last year. The first fuselage was to be delivered from manufacturer Hawker de Havilland of Australia early this year. The engine makers are also partners. Computer-aided design and manufacturing technology has been used throughout the development process.

The future looks even brighter for MDX than for the 520N; the company already holds orders from 122 operators in 20 countries for more than 270 ships. *—SBG*

See "Torque Reform," p. 84



TORQUE REFORM

Meet the spin doctors.

• One of the fundamental challenges in helicopter design (as opposed to autogiros, which typically do not have powered rotors) is counteracting the substantial torque that is a by-product of the energy required to spin the rotor. Uncountered, torque will spin a helicopter's fuselage in the direction opposite the rotor's rotation.

Although helicopter design dates back at least as far as Leonardo da Vinci, who sketched an "airscrew" in 1493, practical consideration of torque was moot until the late nineteenth century, when engines of sufficiently high power and sufficiently light weight to power aircraft evolved. For example, Sir George Cayley, the father of British aviation, designed an "aerial carriage" in 1843 that relied on four rotors arranged coaxially in pairs, but he could not find a suitable powerplant. In 1877, Enrico Forlanini flew an unmanned steam-powered model using a pair of coaxial, counterrotating rotors. The first rotary-wing machine to rise off the ground under its own power with a man on board was a totally uncontrollable tandem-rotor design tested by Louis and Jacques Breguet in 1907.

Helicopter development continued apace but was hindered by the weight and complexity of multiple rotor systems. The much simpler autogiro flourished for a time but was inherently incapable of truly vertical takeoff and landing. Hybrid autogiros with powered main rotors were also tested, but the first use of antitorque rotors came at the Soviet Union's Central Institute of Aerodynamics and Hydrodynamics. A 1930 design used antitorque rotors in the nose and tail. The first helicopter to use a single tail rotor for torque control was designed by Ivan P. Bratukhin and first flew in 1933. Multiple rotors continued to be viewed as the practical solution, however, and in the 1930s, the Germans flew a series of successful designs with two main rotors mounted on outriggers on either side of the fuselage (a concept echoed in one form or another by many later aircraft around the world and culminating in the Bell/Boeing V-22 Osprey tiltrotor).

The United States had its own early helicopter designers, notably Karman and Emile Berliner, who flew several models using coaxial rotors in the 1920s at College Park, Maryland. In 1939, however, Igor Sikorsky flew the VS-300 in Bridgeport, Connecticut. This machine, which used a tail rotor and was powered by a 100-horsepower Franklin engine, was the first in a line of helicopters that continues to the present. Its 1942 successor, the two-seat R-4, was the first helicopter to see military service in the United States. In late 1942, Bell Aircraft flew its first helicopter, the Model 30, which also used a single main rotor and tail rotor. The Model 30 was the precursor of the phenomenally successful Model 47, which first flew in 1943 and remained in production in the United States and under contract abroad for decades. Thousands are still flying.

Using a tail rotor for antitorque became predominant in the United States, particularly in light and intermediate helicopters, although some heavy helicopters continue to use that arrangement (like the huge, three-engine Sikorsky CH-53; Sikorsky never wandered from the tail rotor path). But tandem rotors mounted at either end of the fuselage were also popular for large helicopters, including designs by Piasecki Aircraft, Bell, and especially Boeing Vertol (today called Boeing Helicopters), whose CH-46 (pictured above) and CH-47 continue to be found in military and civil service. Boeing Helicopters is also testing a tandem-rotor technology demonstrator called the Model 360, in addition to its work with Bell on the V-22.

Kaman Aerospace had great success with its HH-43 Huskie (pictured below), which used twin, intermeshing, counterrotating, side-by-side main rotors. The Huskie was used for years by the U.S. Air Force for rescue and fire-fighting missions, and some are still flying in commercial service. For years, whenever Air Force One took off, a Huskie was hovering by the side of the runway as a safety precaution.

The Soviets' Kamov Design Bureau continued to use a coaxial twin-rotor arrangement in a long line of military and commercial helicopters.

The idea of using something other than a rotor, small or large, for torque control is not new. One of the first significant attempts was by Britain's Cierva Autogiro Company, whose last design, built in 1944, was the W.9, an experimental helicopter using an air jet in the tail. Spain's Aerotecnica fielded a two-seat, turbine-powered helicopter that used a tail jet in 1957.

Another approach was to use jets or rockets mounted at the tips of the main rotor blades. This was tried by Britain's Fairey Aviation Company (later taken over by Westland) and France's Sud-Aviation in the late 1940s and by Italy's Fiat and America's McDonnell Aircraft and Hiller Aircraft in the 1950s.

The only significant variation played on a tail rotor itself is the *fenestron* ("fan-in-fin") design launched by Aerospatiale on the Gazelle in the late 1960s and continuing to be used on its Dauphin today. This tail rotor—actually a multibladed, shrouded fan—addresses the safety problem of tail rotors with some success but at the expense of mechanical complexity.

The world has also seen a succession of compound designs that hark back to the powered-rotor autogiros—using a main rotor plus a tractor or pusher propeller—but none have achieved practical success.

The Notar design, conceived by engineers at Hughes Helicopters and consummated after that firm became McDonnell Douglas Helicopter Company, is the first commercially viable single-main-rotor helicopter without a tail rotor. For this, the concept development team won the American Helicopter Society's Howard R. Hughes Trophy for outstanding achievement in helicopter technology in 1987. Experimental test pilot Chan Morse won the Ivan Kincheloe Award for "outstanding professional accomplishment in the conduct of flight testing" in 1989 for his work on the Notar system development. The modified OH-6 concept demonstration aircraft was retired to the U.S. Army Aviation Museum at Fort Rucker, Alabama, in 1990 after accumulating 397 test hours.

Aircraft builders are sure to continue to address the problems of torque, but for now, McDonnell Douglas's combination of lightweight, high-power gas turbine engines and Henri Coanda's aerodynamic theories has achieved a defining moment in helicopter design. —*SBG*