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Inside the Top Secret SKUNK WORKS

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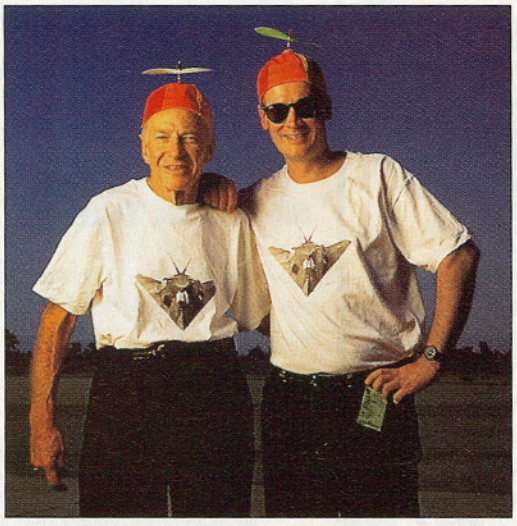
Return of the SUPERSONIC SPY DRONE
How The STEALTH FIGHTER Was Born: A Cold Warrior's Tale

EDITOR'S NOTE

A Cold Warrior's Tale

When Ben Rich inherited the reins of Lockheed's acclaimed Skunk Works—where he shepherded the most significant advances in military aircraft since the jet engine from the drawing board to the skies—he was advised: "Be quick, be quiet, be on time." For Rich, the quiet part was tough. By nature, Rich is an in-your-face kind of guy.

Consider his bravado at one of the first flight tests of the F-117A stealth aircraft prototype, Have Blue. Rich put it up against a U.S. Marine Hawk ground-to-air missile battery. Aptly named, this defensive system's powerful radar is capable of detecting a live hawk riding on a thermal from 30 miles away. Rich even went so far as to give the Hawk missile crew "aim here" guidance. But when the sun went down on the Nevada desert that day in 1979, Rich's prototype stealth aircraft still hadn't been seen by the Marine radar crew inside an air-conditioned trailer.



Skunk Worker and Skunk Works Watcher: Ben Rich and editor Stuart Brown put their propeller heads together.

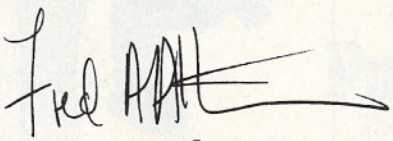
Quick to the challenges of the Cold War during his career, Rich has now jumped at the opportunity to tell the inside story of how stealth was born, and other revelations of the Skunk Works. We have excerpted some of the juicier segments of his memoirs, to be published this fall, to give you an up-close and personal sense of this fascinating Skunk Worker and the most amazing place that he worked at for some 36 years. As Rich says in his book's introduction: "It is only now, when the Cold War is finally history, that many of our accomplishments can finally be revealed, and I can stop playing mute, much like the star-crossed rabbi who hit a hole in one on the Sabbath."

However, our special report this month is not merely a look back. Rich, in his book and in an interview with Senior Editor Stuart F. Brown, which is also published in this issue, has frank and audacious views on defense spending, government secrecy, and the management of technology development. I warn you that Rich can be blunt. Yet I encourage you to hear what he has to say. This man was the toy maker to the CIA and the U.S. Air Force, a high-priority target of Soviet listening posts and spy satellites. Rich, if you will, has been there, done it, and even gotten the T-shirt (provided by staff photographer John Carnett).

The era of high-flying piloted spy planes may be in the past, but high-tech surveillance aircraft, perhaps of the robotic kind, surely have an important role to play for future peacekeeping. One of the least-known stories culled from the Skunk Works archives, that of the D-21 supersonic drone, is told in this issue. Ironically, the 1960's vintage D-21 is on the verge of a comeback as a test bed for high-speed engine research and perhaps even a future generation of two-stage-to-orbit spacecraft designs.

The story of the D-21 also speaks to Rich's fundamental message: the continued need for Skunk Works-style creativity, integrity, and risk taking, in all aspects of American life; and that bold ideas are worth pursuing, even if their immediate payoff isn't readily apparent.

"Do what's right by sticking to your convictions and you'll do OK," Rich was advised when he took the helm at the Skunk Works. There is far more than just aircraft technology to learn about from this man and this formerly very secret place.



EDITOR-IN-CHIEF

Inside the Skunk Works

Ben Rich steps out of the shadows to cast light on the cloistered world of secret aircraft technology.

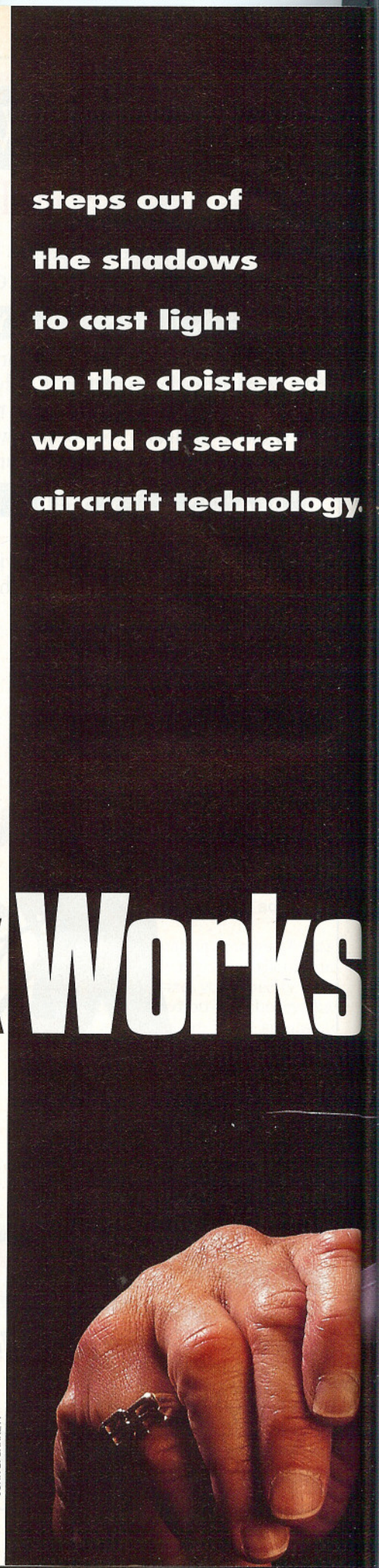
The curtain is going up on the Lockheed Advanced Development Co.—better known as the Skunk Works—the American aerospace industry's most prestigious secret brainstorming and rapid-prototyping shop. Founded during World War II in Burbank, Calif., by Lockheed's chief engineer, Clarence "Kelly" Johnson, the Skunk Works has produced many legendary aircraft, including the F-104, the world's first Mach 2 fighter; the U-2 high-altitude spyplane; and the Mach 3.2 SR-71 Blackbird.

Johnson's protege and successor was Ben R. Rich, a thermodynamicist who retired as president of the Skunk Works in 1990 after a 36-year career. During Rich's tenure, the most startling airplane of the past two decades took shape under a cloak of secrecy: the Air Force F-117A stealth attack plane.

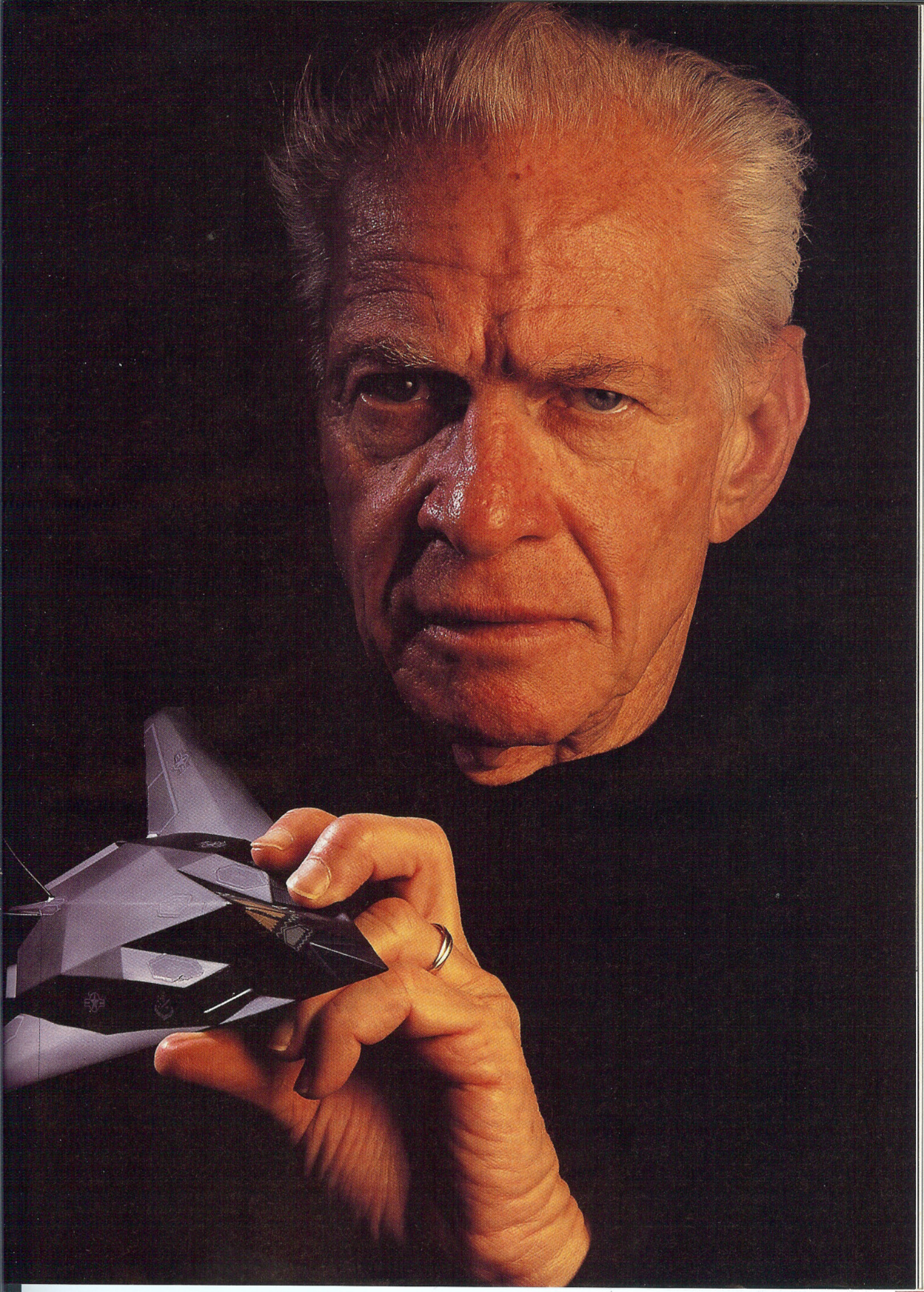
With excerpts from *Skunk Works—A Personal Memoir of my Years at Lockheed* by Rich and Leo Janos; an interview with Rich; and the story of one of the Skunk Works' least known yet most exotic spy aircraft, the supersonic D-21 drone, this special report offers an unprecedented glimpse into the cloistered world of secret Cold War technology development.

Now relocated to Palmdale, Calif., the Skunk Works got its name from cartoonist Al Capp's *L'il Abner* comic strip, which featured an outdoor still called "the skonk works" in which "kickapoo joy juice" was produced from old shoes and dead skunks. Johnson's elite engineering group was originally housed in a rented circus tent adjacent to a smelly plastics factory. One day an aircraft designer answered the telephone and said, "skonk works." The name stuck, and became today's Skunk Works—a registered trademark.

Our report begins with Rich's account of the genesis of the stealth attack plane that performed with devastating effectiveness during the Gulf War.



JOHN B. CARNETT



A SECRET BRIEFING

The stealth story actually began in July 1975, about six months after I took over the Skunk Works. I attended one of the periodic secret Pentagon briefings held to update those with a need to know on the latest Soviet technical advances in weapons and electronics.

The United States had only two defensive ground-to-air missile systems—the Patriot and the Hawk, both only so-so in comparison to the Soviet weapons. By contrast, the Russians deployed 16 different missile systems to defend their cities and vital strategic interests. Their early-warning radar systems, with 200-foot-long antennas, could pick up an intruding aircraft from hundreds of miles away. Their SAM ground-to-air missile batteries were able to engage both low-flying attack fighters and cruise missiles at the same time. The Soviet SAM-5, a defensive surface-to-air missile of tremendous thrust, could reach heights of 125,000 feet and could be tipped with small nuclear warheads. So these weapons systems posed a damned serious threat.

Most troublesome, the Russians were exporting their advanced nonnuclear defensive systems around the world. The Syrians now had nonnuclear SAM-5s. And during our Pentagon briefing we heard a chilling analysis of the 1973 Yom Kippur war involving Israel, Syria, and Egypt. Although the Israelis flew our latest and most advanced jet attack aircraft and their combat pilots were equal to our own, they suffered tremendous losses against an estimated arsenal of 30,000 Soviet-supplied missiles. The Israelis lost 109 airplanes in 18 days, mostly to radar-guided ground-to-air missiles and antiaircraft batteries, manned by undertrained and often undisciplined Egyptian and Syrian personnel.

What really rattled our Air Force planners was that the evasive maneuvering by Israeli pilots to avoid missiles—the same tactics used by our own pilots—proved to be a disaster. All the turning and twisting calculated to slow down an incoming missile made the Israeli aircraft vulnerable to conventional ground fire. If the Israeli loss ratio were extrapolated into a war between the United States and the highly trained Soviet Union and Warsaw Pact nations in Eastern Europe, a war fought using similar airplanes, pilot training, and ground defenses, our air force could expect to be decimated in only 17 days.

I was not too surprised. The Skunk Works had firsthand experience with the latest Soviet equipment because the CIA had scored spectacular covert successes in acquiring Soviet hardware by one means or another. We could not only test their latest fighters or new radars and missile systems but actually fly against them. Skunk Works technicians pulled these systems apart, then put them back together, so we had a sound notion of what we were up against.

That Pentagon briefing was particularly sobering because it was one of those rare times when our side admitted to a potentially serious gap that tipped the balances against us. I had our advanced planning people noodling all kinds of fantasies—pilotless, remote controlled drone tactical bombers and hypersonic aircraft that would blister past Soviet radar defenses at better than five times the speed of sound, once we solved awesomely difficult technologies.

A Skunk Works sampler (clockwise from top): a P-80, the first operational U.S. jet fighter; the Mach 3.2 SR-71 Blackbird; the F-94B, an advanced air-defense version of the P-80; a U-2R reconnaissance aircraft; the F-104, the world's first Mach 2 fighter; the F-117A Nighthawk stealth attack plane.

LOCKHEED SKUNK WORKS

From Skunk Works: A Personal Memoir of My Years at Lockheed *by Ben R. Rich and Leo Janos, to be published in October by Little, Brown and Company.*

The Rosetta Stone

I wish I could claim to have had a sudden 2 a.m. revelation that made me bolt upright in bed and shout, "Eureka!" But the truth is that an exceptional 36-year-old Skunk Works mathematician and radar specialist named Denys Overholser decided to drop by my office one April afternoon and presented me with the Rosetta Stone breakthrough for stealth technology.

The gift he handed to me over a cup of decaf instant coffee would make an attack airplane so difficult to detect that it would be invulnerable against the most advanced radar systems yet invented, and survivable even against the most heavily defended targets in the world.

Denys had discovered this nugget deep inside a long, dense technical paper on radar written by one of Russia's leading experts and published in Moscow nine years earlier. The author was Pyotr Ufimtsev, chief scientist at the Moscow Institute of Radio Engineering. As Denys admitted, the paper was so obtuse and impenetrable, only a nerd's nerd would have waded through it all, *underlining* yet!

Denys saw my blank stare. Radar cross section calculations were a branch of medieval alchemy as far as the noninitiated were concerned. Making big objects appear tiny on a radar screen was probably the most complicated, frustrating, and difficult part of modern warplane designing. A radar beam is an electromagnetic field, and the amount of energy reflected back from the target determines its visibility on radar. For example, our B-52, the mainstay long-range bomber of the

Strategic Air Command for more than a generation, was the equivalent of a flying dairy barn when viewed from the side on radar.

"Ufimtsev has shown us how to create computer software to accurately calculate the radar cross section of a given configuration, as long as it's in two dimensions," Denys told me. "We can break down an airplane into thousands of flat triangular shapes, add up their individual radar signatures, and get a precise total of the radar cross section."

Why only two dimensions, and why only flat plates? Simply because, as Denys later noted, it was still only 1975 and computers weren't yet sufficiently powerful in storage and memory to allow for three-dimensional designs, or rounded shapes, which demanded enormous numbers of additional calculations.

The result we called "faceting"—creating a three-dimensional airplane design out of a collection of flat sheets or panels. The Skunk Works would be the first to try to design an airplane composed entirely of flat, angular surfaces. I tried not to anticipate what some of our crusty old aerodynamicists might say. What emerged was a diamond beveled in four directions, creating in essence four triangles. Viewed from above, the design closely resembled an Indian arrowhead.

"Boss," Denys said, handing me the diamond-shaped sketch. "Meet the Hopeless Diamond."

"If we made this shape into a full-size tactical fighter, what would be its equivalent radar signature? As big as what—a Piper Cub, a T-38 trainer—what?"

Denys shook his head vigorously. "Ben, understand, we are talking about a major, major, big-time revolution here. We are talking *infinitesimal*."

"Well," I persisted, "what does this mean? On a radar screen it would appear to be as big as a condor, an eagle, maybe an owl, a what?"

"Ben," he replied with a loud guffaw, "try as big as an eagle's *eyeball*."

Kelly Johnson was not impressed. Unfortunately, he caught me leaning over a worktable studying a blueprint, and I never heard him coming. Kelly kicked me in the butt—hard too. Then he crumpled up the stealth proposal and threw it at my feet. "Ben Rich, you dumb shit," he stormed. "Have you lost your mind? This crap will never get off the ground."

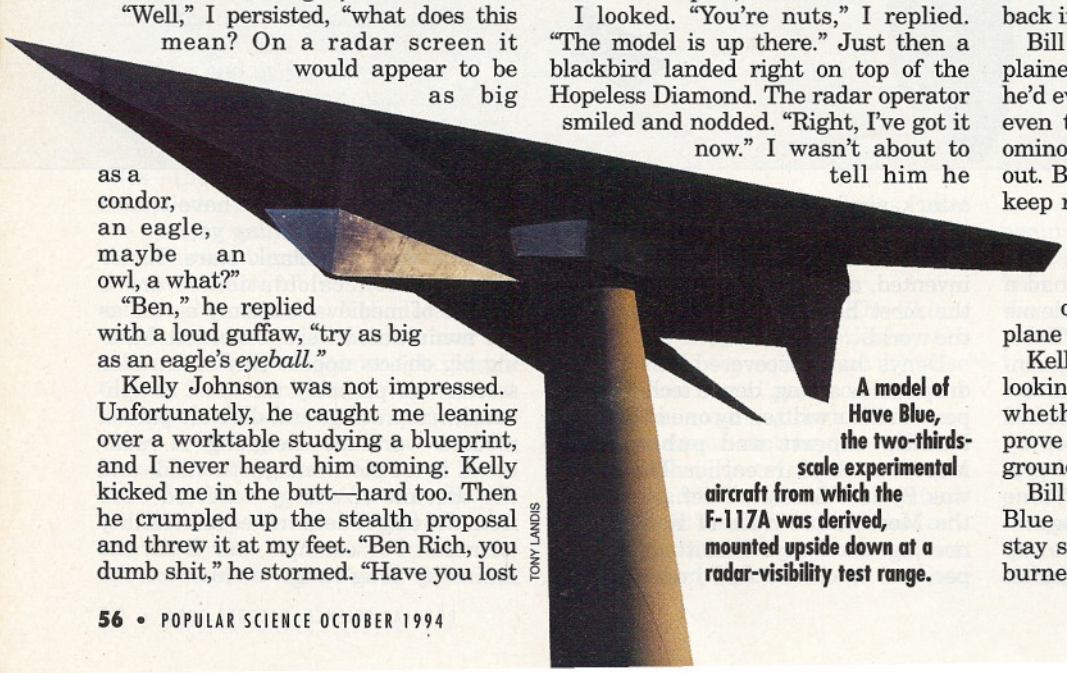
Dick Cantrell, head of our aerodynamics group, suggested burning Denys at the stake as a heretic. But after a couple of hours of listening to Overholser's explanations of stealth, Dick dropped his lanky frame onto the chair across from my desk and heaved a big sigh. "OK, Ben," he muttered. "I surrender. If that flat plate concept is really as revolutionary as that kid claims in terms of radar cross section, I don't care what it looks like. I'll get that ugly son-of-a-bitch to fly."

We could get the Statue of Liberty to do barrel rolls with the onboard computers that achieved aerodynamic capability by executing thousands of tiny electrohydraulic adjustments every second to an airplane's control surfaces. But even with the powerful onboard computers, getting into the sky, as Kelly's boot to my butt suggested, would be far from a cakewalk.

We had a ten-foot wooden model of the diamond, and we took it and the original wooden model for the manta-ray-shaped D-21 drone and put them side by side into an electromagnetic chamber and cranked up the juice. Hopeless Diamond was exactly as Denys had predicted: a thousand times stealthier than the 12-year-old drone. The fact that the test results matched Denys' computer calculations was the first proof that we actually knew what in hell we were doing.

Our next big hurdle was to test the model on an outdoor radar test range near Palmdale, on the Mojave desert. Our model was mounted on a 12-foot-high pole, and the radar dish was zeroed in from about 1,500 feet away. I was standing next to the radar operator in the control room. "Mr. Rich, please check on your model. It must've fallen off the pole," he said.

I looked. "You're nuts," I replied. "The model is up there." Just then a blackbird landed right on top of the Hopeless Diamond. The radar operator smiled and nodded. "Right, I've got it now." I wasn't about to tell him he was zapping a crow. His radar wasn't picking up our model at all. For the first time, I felt reassured that we had caught the perfect wave at the crest and were in for one terrifically exciting ride. I saw firsthand how invisible that diamond shape really was.



TONY LANDIS

A model of Have Blue, the two-thirds-scale experimental aircraft from which the F-117A was derived, mounted upside down at a radar-visibility test range.

Have Blue Flies

It's the first of December 1977, just after sunup, the best time for test pilots to take off. Winds are usually calmest then, but this morning the chill wind blasts through my topcoat like it's tissue paper. This flight will be every bit as important to the nation's future and the future of the Skunk Works as the first test flight of the U-2 spy plane, which took place at this very same remote sand pile more than a quarter century ago.

Back then, I was a Skunk Works rookie and this base, which we built for the CIA, was just a tiny outpost of windswept quonset huts and trailers, guarded by CIA agents with tommy guns. Kelly had jokingly nicknamed this godforsaken place Paradise Ranch, hoping to lure young and innocent flight crews to work on a dry lake bed where quarter-inch rocks blew around most afternoons. It is now a sprawling facility, bigger than some municipal airports, a test range for sensitive aviation projects. No one nowadays gains access without special clearances that include a polygraph test.

Today, the Have Blue prototype that will soon be rolling down this runway is the first built under my regime after Johnson's retirement three years earlier. But we really aren't 100 percent certain that this sucker can actually get off the ground. It is the most unstable and weirdest-looking airplane since Northrop's flying wing, built on a whim back in the late 1940s.

Bill Park, our chief test pilot, complained that it was the ugliest airplane he'd ever strapped himself into. To Bill, even the opaque triangular cockpit is ominous, especially if he has to punch out. But the specially coated glass will keep radar beams from picking up his helmeted head. The real beauty of Have Blue is that Bill's head is a hundred times more observable on radar than the airplane he will be flying.

Kelly Johnson is standing at my side, looking stoic. He's still skeptical about whether or not this prototype will prove way too draggy to get off the ground.

Bill pushes on the throttle, and Have Blue slowly begins to accelerate. To stay stealthy, Have Blue has no afterburners, and it will need almost as

much runway as a 727 loaded with fuel, baggage, and passengers bound for Chicago. Bill goes full throttle. He's chewing up a lot of runway as he sweeps past us.

Uh-oh. He's damn near off the end of the runway. Then I see him lift off. Slow as a jumbo jet a hundred times its weight, but he's up. Get up. Up, up, up. The little airplane hears me. It's heading toward the snow-powdered mountains.

Kelly slaps me on the back and shouts, "Well, Ben, you got your first airplane."

Not so fast. There are some significant foothills looming in Bill's flight path and I try to do some quick mental calculations to get him safely over the hump. I raise my binoculars and quickly try to adjust the focus. By the time the mountains come clear, our airplane is across the other side.

Stealth was our great good fortune, and our earnings skyrocketed. The stealth fighter brought in more than $6 billion. By my fifth year, I was heading a small, secret R&D outfit whose annual earnings placed it among the Fortune 500. Not bad. Not bad at all.

Stealth Navy? No Sale.

We decided to design a stealthy sub; the cigar-shaped hull was shielded by an outer wall of flat, angular surfaces that would bounce sonar signals away and also muffle the engine sounds and the noises of crewmen inside the vessel. We ran numerous acoustical tests in special sound-measuring facilities and obtained dramatic improvements. Armed with high hopes, I took our design and test results to the Pentagon office of a Navy captain in charge of submarine R&D.

That submarine captain epitomized the hidebound Navy at its worst. He frowned at my drawing and backhanded my concept. "We don't build submarines that look like that." He admitted that our test results were "interesting" but added, "Your design would probably cost us two or three knots in speed." I countered, "But why care about losing three knots when you are invisible to your enemy?"

It seemed to me that a catamaran SWATH [small waterplane area twin-hull] ship held real promise as a model for a stealthy ship. And on my next trip to Washington for a meeting on our stealth airplane design with Defense Undersecretary [now Secretary] Bill Perry, who was the Carter administration's czar of stealth, I mentioned the idea of a model stealth ship. Dr. Perry agreed and ordered the Defense Advanced Research Projects Agency [DARPA] to authorize a study contract with us.

In the early fall of 1978 I reviewed with him all our tests and the low radar returns we had managed to achieve so far. He was enthusiastic and ordered the Navy to provide research and development funding for the creation of our prototype stealth ship. The ship would be called *Sea Shadow* ["The Secret Ship," Oct. '93].

Viewed from head-on, the ship looked like Darth Vader's helmet. Some Navy brass who saw her clenched their teeth in disgust at the sight of the most futuristic ship ever to ply the seas. A future commander resented having only a four-man crew to boss around on a ship so secret that the Navy could not even admit it existed. Our stealth ship might be able to blast out of the sky a sizable Soviet attack force, but in terms of an officer's future status and promotion prospects, it was about as glamorous as commanding a tugboat.

At the highest levels, the Navy brass were equally unenthusiastic about the small number of stealth ships they would need to defend the carrier task forces. Too few to do anyone's career much good in terms of power or prestige. The carrier task force people didn't like the stealth ship because it reminded everyone how vulnerable their hulking ships really were.

On one typical night of testing, the Navy sub-hunter airplanes made 57 passes at us, and detected the ship only twice—both at a mile-and-a-half distance, so that we would have shot them down easily long before they spotted us. Several times, we actually provided the exact location to the pilots, and they still could not pick us up on their radar.

The admirals who ran the surface fleet were displaying little enthusiasm for going any speed ahead. "Too radical a design," they told me. "If the shape is so revolutionary and secret, how could we ever use it without hundreds of sailors seeing it? It's just too far out."

So I held back. I had a design for an aircraft carrier that would show up on radar no bigger than a life raft. But having been turned down by the Navy for designing a submarine—out of sight under the ocean—that no one would ever recognize as such, I could only imagine their reaction to designing an aircraft carrier three football fields long that looked like a New Age pyramid.

Stealth Over Baghdad

U.S. Air Force pilot Col. Barry Horne: *Bats.* Bats were the first visual proof I had that stealth really worked. At night the bats would come out and feed off insects. In the mornings we'd

A Conversation with Ben Rich

Popular Science Senior Editor Stuart F. Brown spoke to former Skunk Works president Ben R. Rich at his seaside home in California.

PHOTOS BY JOHN B. CARNETT

Q: THE SR-71 BLACKBIRD WAS THE FIRST STEALTH AIRCRAFT. WHAT DID YOU DO TO MAKE IT HARDER TO SEE ON RADAR?

A: The SR-71's radar cross section is still classified. It was about like a Piper Cub, a single-digit number under ten square meters. By comparison, a B-52 is maybe 150 square meters, and an F-15 is maybe 100 square meters.

The wing leading edge of the SR gets to 800 degrees Fahrenheit from air friction at Mach 3—as hot as a soldering iron. The only material we had that could stand the temperature was a composite made with asbestos, which is a dirty word nowadays.

We loaded the composite with iron-ferrites that absorb radar, instead of reflecting it, and made the leading edges and the tails out of this material. And we gave the fuselage, which was originally bullet-shaped, sloping chines on the sides that improved the shape of the underbelly so that it reflected radar away during level flight.

Q: HOW WELL DID STEALTH WORK FOR THE BLACKBIRD?

A: We thought that we could cut the radar cross section of the SR-71 down so far that we could overfly any target and just not be there. But we were never able to get the cross section that small because every time we turned, the airplane gave them a big belly shot that showed on radar. So instead, sometimes we had to use side-looking sensors and fly along borders.

continued

find bat corpses scattered around our airplanes inside the open hangars.

Bats used a form of sonar to "see" at night, and they were crashing blindly into our low-radar-cross-section tails. After all those years of training, we certainly believed in the product, but it was nice having that kind of visual confirmation.

As we suited up to fly into combat for the first time, one of the other pilots whispered to me, "Well, I sure hope to God that stealth shit really works."

He spoke for us all.

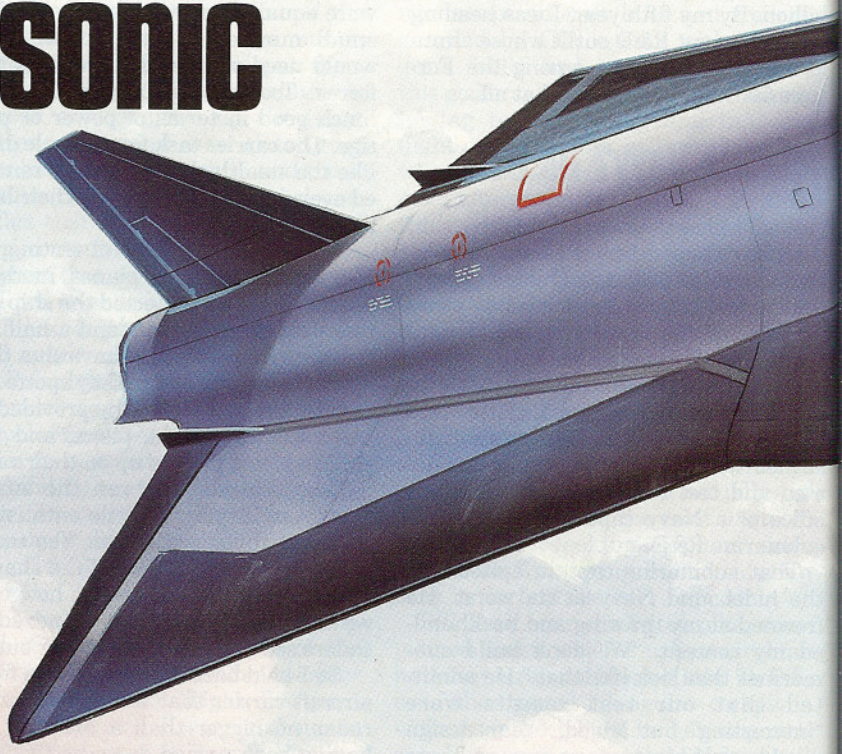
Saddam Hussein had 16,000 missiles and 3,000 antiaircraft emplacements in and around Baghdad, more than the Russians had protecting Moscow. We got the mission most hazardous to a pilot's health.

Each of us carried two hardened laser-guided 2,000-pounders designed to penetrate deep into enemy bunkers before exploding. We came at Baghdad in two waves. Ten F-117As in the first wave to knock out key communications centers, and then the second wave of 12 airplanes an hour or so later. That first night we saw French-built F-1s and Soviet MiG-29s flying around on our sen-

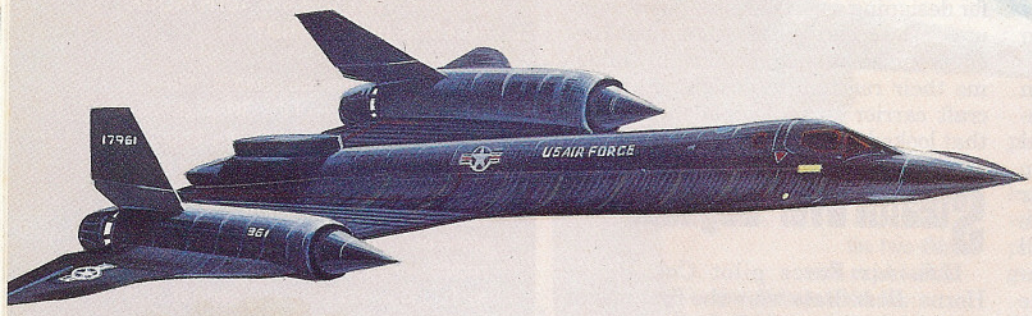
D-21

The Air Force sent 2,400-mph ramjet-powered drones on s 25 years ago. Lockheed's Skunk Works built them.

The Supersonic Spy Drone



BY STUART F. BROWN
& JAMES C. GOODALL

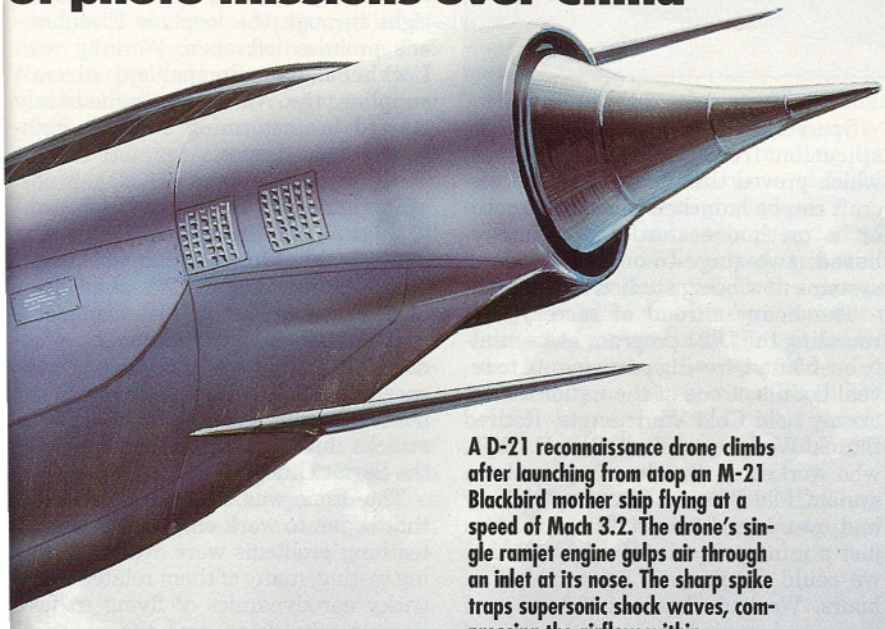


sor displays. But they gave no sign of ever seeing us.

The skies over Baghdad looked like three dozen Fourth of July celebrations rolled into one. Only it was a curtain of steel that represented blind firing. They could detect us, but they couldn't track us. They just hoped for a golden BB—a lucky blind shot that would hit home, and I couldn't see how they could possibly miss. The law of averages would have made that impossible—and so I prayed.

Then, once safely back across the border, we joined up and saw that everyone was OK and we were amazed, overjoyed, and deeply moved. No one had suffered as much as a hit or even a near miss. That stealth shit had really worked. PS

'et photo missions over China



A D-21 reconnaissance drone climbs after launching from atop an M-21 Blackbird mother ship flying at a speed of Mach 3.2. The drone's single ramjet engine gulps air through an inlet at its nose. The sharp spike traps supersonic shock waves, compressing the airflow within.

A Boeing B-52 flies west five miles above the Pacific with a manta-shaped aircraft slung under its wing. Seconds after the big bomber releases the drone about 300 miles off the Chinese coast, the unpiloted craft's rocket booster ignites, thrusting it quickly to supersonic speed. Then as the drone's ramjet engine roars to life, the expended booster falls away.

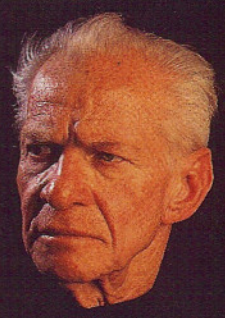
Accelerating to a speed of Mach 3.5, or 2,400 mph, at the incredible altitude of 90,000 feet, the drone streaks across the People's Republic of China. Cameras mounted in its belly shoot reconnaissance photos of military sites, including the newly constructed intercontinental ballistic missile facility west of the city of Lop Nor, located far inland near Mongolia. U.S. Navy ships in the Pacific and a circling airplane with a special retrieval hook wait to snatch the parachute-equipped package of cameras and navigation equipment released by the returning spy aircraft. A radioed self-destruct command will erase evidence of the drone's existence after the aircraft falls into the sea.

Called the D-21, the Air Force's ultrafast eye in the sky is built by Lockheed Corp.'s innovative Skunk Works team almost entirely from lightweight, heat-resistant titanium. The year is 1969. By 1971, four of the craft will be sent on missions over China, but something goes wrong in every case, and no pictures are recovered.

Though the highly classified D-21s were written off as an intelligence-gathering failure, the program's aeronautical achievements continue to intrigue engineers, and drones resurrected from an Air Force long-

MARK McCANDLISH

Q: WHAT SURPRISED YOU MOST ABOUT STEALTH?



A: The size of the aircraft doesn't mean anything. Shape is the biggest thing. In fact, smallness can hurt you, because the aircraft may end up on a harmonic of the radar beam's frequency, causing a spike on the radar screen. It's easier to find a small vehicle like a cruise missile with a low-frequency radar than it is a B-2 bomber. Of course, on a larger vehicle we have a lot more area to soak up the microwaves with absorbent coatings.

Q: WHY HAVEN'T WE SEEN RUSSIAN STEALTH PLANES?

A: Ufimtsev [Russian electromagnetics physicist] was amazed when I talked to him about our success with his stealth equation. He said his people never used it. They felt the United States had only two antiaircraft missiles to fool—Hawk and Patriot—so why did they have to pay for stealth? They put their money elsewhere. Russia now has 16 different antiaircraft missiles, SA-1 through SA-16. Our stealth plane was designed to counter them.

Q: DOES THE UNITED STATES STILL HAVE MAJOR SECRET DEFENSE TECHNOLOGIES? FOR EXAMPLE, UNUSUAL "DONUTS-ON-A-ROPE" EXHAUST CONTRAILS FROM A FAST, HIGH-FLYING AIRCRAFT HAVE BEEN PHOTOGRAPHED IN THE SOUTHWEST.

A: We have some new things. We are not stagnating. What we are doing is updating ourselves, without advertising. There are some new programs, and there are certain things—some of them 20 or 30 years old—that are still breakthroughs and appropriate to keep quiet about. Other people don't have them yet.

A lot of people talk about funny contrails, but I can candidly say I'm not aware of it. This would have to use a cryogenic fuel as a coolant, and I haven't seen any such facilities in the aircraft area. Hydrocarbon fuels don't have the heat capacity for very high speeds—they just become carbon at 300 to 400 degrees Fahrenheit. But a cryogenic fuel like liquid hydrogen becomes a storage problem because it takes up so much room. We tried designing a liquid-hydrogen fueled airplane called the CL-400 in

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STUART F. BROWN

NASA's Dryden Flight Research Center at Edwards Air Force Base has obtained four unused D-21s for possible use in high-speed flight experiments.

term storage area may once again thunder through the skies.

NASA's Dryden Flight Research Center at Edwards Air Force Base in California is safeguarding four of the 17 remaining unused drones for eventual use in high-speed research. Though no funds have yet been committed, the D-21 could be stripped to its core structure and clad with temporary skins to flight test hypersonic vehicle shapes, says David Lux, NASA project manager.

"With the addition of a rocket engine, the D-21 could fly at Mach 5 or 6 to test a small scramjet [supersonic-combustion ramjet] engine. But the D-21 has one problem: There's no recovery system," Lux says. "So we would have to design a parachute or a good radio-controlled flight-control system to land it on the lake bed, as we have done with many other drones."

Spacecraft designers, too, draw inspiration from the D-21 program, which proved that one high-speed aircraft can be launched from atop another, a method essential to runway-based, two-stage-to-orbit launching systems now being studied worldwide.

The heavy shroud of secrecy surrounding the D-21 program has recently been lifted, freeing participants to reveal details of one of the nation's most closely held Cold War secrets. Retired Skunk Works president Ben R. Rich, who worked on the drone's propulsion system, told POPULAR SCIENCE, "Nobody had ever run a ramjet for more than just a minute or two. We learned that we could fly ramjets for a couple of hours. We had almost 4,000 miles of range and carried about 800 pounds of payload. It was the original supersonic cruise missile."

The effort got under way after the U-2 spy plane piloted by Francis Gary Powers was shot down deep inside Soviet territory in 1960—ruining an impending U.S.-U.S.S.R. summit meeting. Hoping to ease diplomatic tensions while winning Powers' release, President Dwight D. Eisenhower agreed to cease manned intelligence-gathering flights over the Soviet Union.

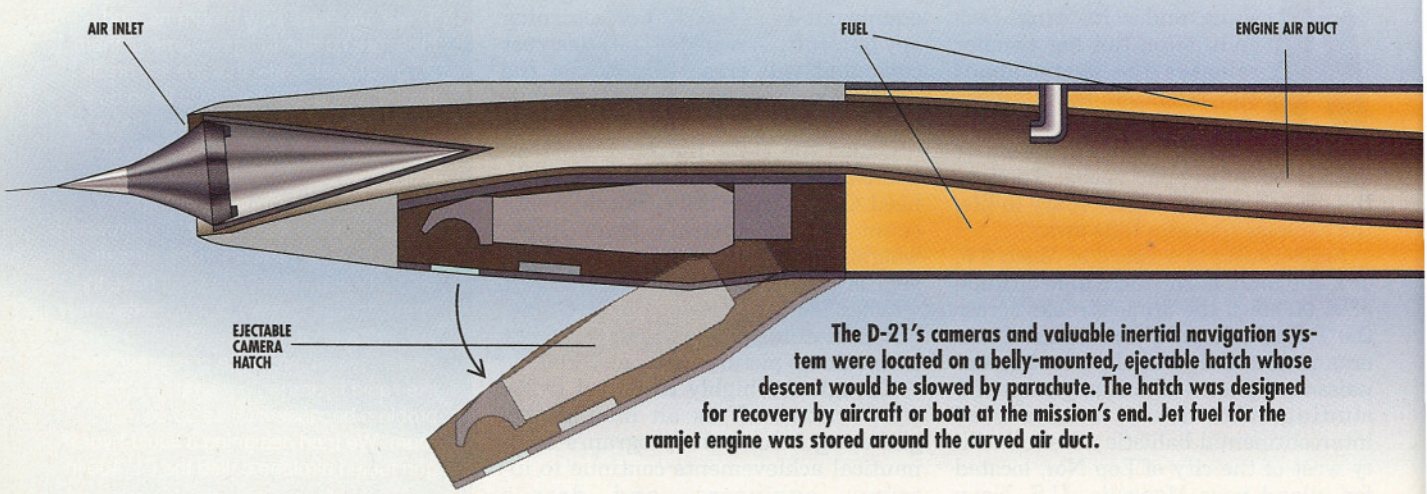
The agreement, however, made no mention of overflights by *unpiloted* aircraft, and the Air Force became interested in flying a survivable spy drone right through the loophole Eisenhower's promise left open. Working with Lockheed, its principal spy aircraft supplier, the Air Force immediately started brainstorming stealthy, high-performance drones.

Originally code-named "Tagboard," the D-21 was created by the Skunk Works engineering and flight-testing team led by chief engineer Clarence "Kelly" Johnson. Government officials and Lockheed engineers agreed in early 1960 that a cruise speed of Mach 3.5 at 90,000 feet was needed to survive antiaircraft missile attacks during overflights of China or the Soviet Union.

The drone was a bold idea, and one that began to work only after a host of teething problems were overcome during testing, many of them related to the tricky aerodynamics of flying so fast. Ramjet propulsion was the practical way to give the drone sufficient speed and range to perform useful missions. A simple and efficient engine that func-

JARED SCHNEIDMAN

ANATOMY OF A ROBOT SPY PLANE



The D-21's cameras and valuable inertial navigation system were located on a belly-mounted, ejectable hatch whose descent would be slowed by parachute. The hatch was designed for recovery by aircraft or boat at the mission's end. Jet fuel for the ramjet engine was stored around the curved air duct.

tions only at supersonic speeds, the ramjet is essentially a pinched tube that compresses and ignites fuel and air, then expands the hot exhaust to produce thrust.

An ideal supersonic launching platform for a ramjet drone was already rolling off a secret Lockheed production line: the single-seat CIA A-12 spy plane, predecessor to the two-man SR-71 later operated by the Air Force. Both versions are known as Blackbirds. They carried the first D-21s aloft.

Johnson's design team selected the A-12's curving double-delta, or ogival, wing design for the D-21. Designers had considered using the A-12's hybrid turbo-ramjet engine in the drone, but for reasons of weight and complexity dropped it in favor of a pure ramjet design. The engine was based on one used in the Boeing Bomarc, an antiaircraft missile with a rocket-powered first stage.

The Bomarc engine was built by Marquardt Corp. of Van Nuys, Calif., the leading American source of ramjet expertise. Marquardt and Lockheed engineers redesigned the powerplant to achieve the drone's needed cruise speed and altitude and modified its fuel system to burn the special high-flash-point JP-7 jet fuel used by the A-12 spy plane.

With its sharply swept-back, 19-foot-span wings and single ramjet air-inlet spike, the 43-foot-long D-21 looks like a simpler cousin to the spy plane. Like the Blackbird, the drone benefits from early stealth methods. Careful attention paid to exterior shaping details and the use of radar-absorbing materials in parts of the airframe reduce its visibility to radar.

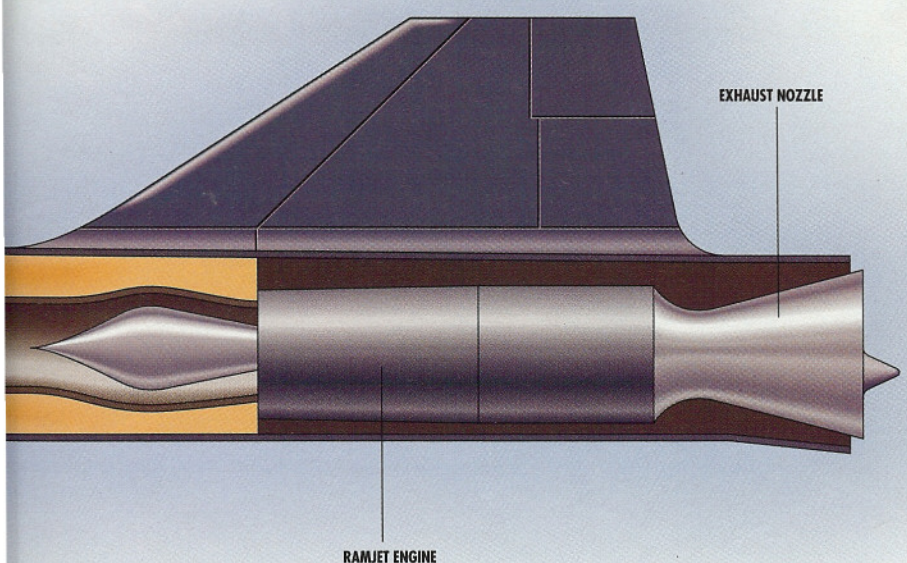
A pair of CIA A-12's were converted into M-21 drone carriers through the addition of launching pylons and other features. M stands for "mother," while the D in D-21 stands for "daughter." The daughter craft nestled between the mother ship's inward-canted tail fins with a scant 18 inches to spare. A second seat was added to the cockpit for a launch control officer whose task was monitoring the drone's mechanical health and using a periscope to confirm its liftoff from the M-21's back.

Calculations showed that the MD-21 combination had the ability to reach Mach 3.25, well above the speed at which the Marquardt ramjet would develop significant thrust. The radar cross section (a measure of reflectivity) of the MD-21 was small, making the piggybacked aircraft quite stealthy compared to other large planes.

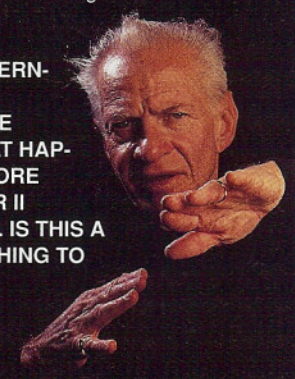
Computer models—crude by today's standards—were developed, and wind tunnel tests determined the proper weight balance and nose angles to use in mating the craft. All that remained was to prove that the two could safely separate from each other at Mach 3.25 while shrouded in the high-pressure shock waves that form around supersonic aircraft.

The first test flight of the MD-21 oc-

[*Continued on page 81*]



the late 1950s, and it grew into a big dog without enough range.



Q: THE GOVERNMENT STILL KEEPS SOME THINGS THAT HAPPENED BEFORE WORLD WAR II CLASSIFIED. IS THIS A SENSIBLE THING TO DO?

A: We overdo it, and we ought to learn when to stop. It costs us about 15 percent more money to get things done because of excessive security rules. I think a sunset law in security is the most important thing. We ought to have a review every two or three years and then decide, do we still need to keep this secret? And why?

Q: MANY COMPANIES SAY THEY OPERATE THE SKUNK WORKS WAY. DO THEY?

A: You need management that gives you free rein. Most managements won't give you that. They can't stop interfering and meddling. The middle-managers and bean counters rule the world.

Kelly's Skunk Works rules call for a very small group with a minimum of paperwork, and with a well-understood organization. You've got to have a leader who knows what he wants, and leads. Everybody knows who he reports to and where he can get an answer. You have no meetings where you don't get answers.

Pick your people and trust them. Tell them what you want. Give them the authority to do the job, along with the responsibility. Don't pay someone by the number of people who work for them. Base rewards on results. And you must have a customer who works with you. That's very important.

Q: WHAT WAS THE WORKING ATMOSPHERE IN THE SKUNK WORKS?

A: Communication is the secret of the Skunk Works. We always kept the workshop floor and the engineers close together. People just walked across the room.

Kelly used to tell this story. A guy meets another guy with a loaf of bread. They trade loaves of bread, and each walks away with a loaf of bread. But if two guys with ideas get together, each guy walks away with two ideas, because they communicated. PS

Supersonic spy drone

[Continued from page 61]

curred in 1964. Jettisonable nose and tail cones were installed on the drone to reduce aerodynamic drag at high speeds. But when the nose cone separated during the first attempted launch, it severely damaged the drone's wing leading edge and ramjet engine. Subsequent test flights were conducted without the cones, and the D-21's engine was ignited at a speed of Mach 1.24 to help the MD-21 accelerate to launch speed and altitude. Fuel burned by the drone during the climb was replenished from the mother ship's tanks.

Finally, in 1966, a D-21 was successfully launched from its carrier craft over the Pacific Ocean off California. During the third test launch, one of the drones flew 1,600 miles and completed eight programmed turns. These trials showed that the mother ship should be flown at a shallow nose-down angle as the launch point approached. The drone itself was mounted at a slight nose-up angle to help it climb through the layer of shock waves, which tended to make the two craft stick together. Then, with the D-21's ramjet powered up to match the Blackbird's speed, the unmanned craft was released.

Things didn't go according to plan during the fourth test launch. Lockheed chief test pilot Bill Park was in level flight when launch control officer Ray Torick released the drone, and the D-21 experienced an "asymmetrical unstart," a condition in which the ramjet engine produces uneven thrust. The drone rolled, colliding with the mother ship. Then the M-21 pitched nose-high and came apart. Park was rescued, but Torick drowned after they parachuted into the ocean.

"I felt the drone lift off, and the nose of the airplane started coming up. I was trying to hold the nose down. When the control stick hit the instrument panel, I knew that something was wrong," Park says. "I don't even remember feeling the D-21 hit my airplane. But the nose just continued to come up until it was vertical, and I could see a lot of fuel because the airplane had broken in half. My plan was always that if it seemed worse inside than it was outside, then I would leave. So I pulled the D-ring and ejected. I think Torick saw me leave, and he left too."

Incredibly, Park still wanted to keep trying to make the MD-21 work. "I was upset with Kelly," he says. "I believed we could fix it with something telling how much the drone was lifting, so we could give the airplane the right angle of attack."

But losing a crewman and one of the two M-21s was too high a price to pay, chief engineer Johnson felt. Future D-21 launches would be from under the wings of two modified Boeing B-52H long-range Air Force bombers.

The B-52s took off from Beale Air Force Base near Sacramento, or from the secret base at Groom Lake, Nev. With aerial refueling, the bomber could fly anywhere in the world before launching a drone. The big B-52 proved to be a safe mother ship that launched 17 drones on test flights and photoreconnaissance missions before the program was ended in mid-1971.

On all four operational D-21 missions, the film was lost due to a series of mishaps. The first craft never returned from overflying China, its fate unknown. The second and third drones made it back to their recovery points, but the reconnaissance pallets were lost. On the final mission, the D-21 was presumed shot down by heavy air defenses encountered on the final leg of its return flight.

Although the D-21 was certainly developed with the intention of flying over the U.S.S.R., records indicate none ever did. Soviet progress in high-altitude surface-to-air missiles was likely the reason. And it may have been feared that using the relatively low and slow-flying B-52 as the carrier, which could be picked up on radar from a long distance, would give the Russians the impression that a nuclear attack was under way.

Pieces of crashed D-21s have been recovered in interesting ways. When one drone malfunctioned and went off course, "we didn't know what happened to it," says Rich. "Then in the early 1980s, when the stealth fighters became operational, a CIA man brought me a piece of composite material from an aircraft. He said he got it from the KGB, and they think it's part of the stealth. So I said, 'Let them keep thinking that.' It was a piece of a wing from one of the drones."

Aircraft museums across the country are vying to add the remaining drones to their collections. Seattle's Museum of Flight now has the ultimate supersonic centerpiece for its main gallery: The sole surviving M-21 Blackbird mother ship in bare, gray titanium finish with a D-21 perched between its tails. PS