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The Drone That Stalked Osama bin Laden

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AIR&SPACE
Smithsonian

A Huey gunship flies low over the Mekong Delta, April 1968, to support crews of U.S. Navy river patrol boats.

TAILHOOK ASSOCIATION

Features

First spotted in Afghanistan in 2007, the Lockheed Martin RQ-170 helped target Osama bin Laden in 2014.

Let's Go Antiquing

Ten early airplanes and the pilots who dare to fly them.

BY PHIL SCOTT

Meet the Drone That Staked Out Osama bin Laden's Neighborhood

A secret piece of the intel puzzle.

BY ED DARACK

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On the brink of the biggest discovery in human history.

Would We Know Alien Life If We Saw It?

BY TRUDY E. BELL

Life Among the Gas Giants

BY CRAIG MELLOW

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BY ERIC STEWART

Campaign by Helicopter

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BY JAMES R. CHILES

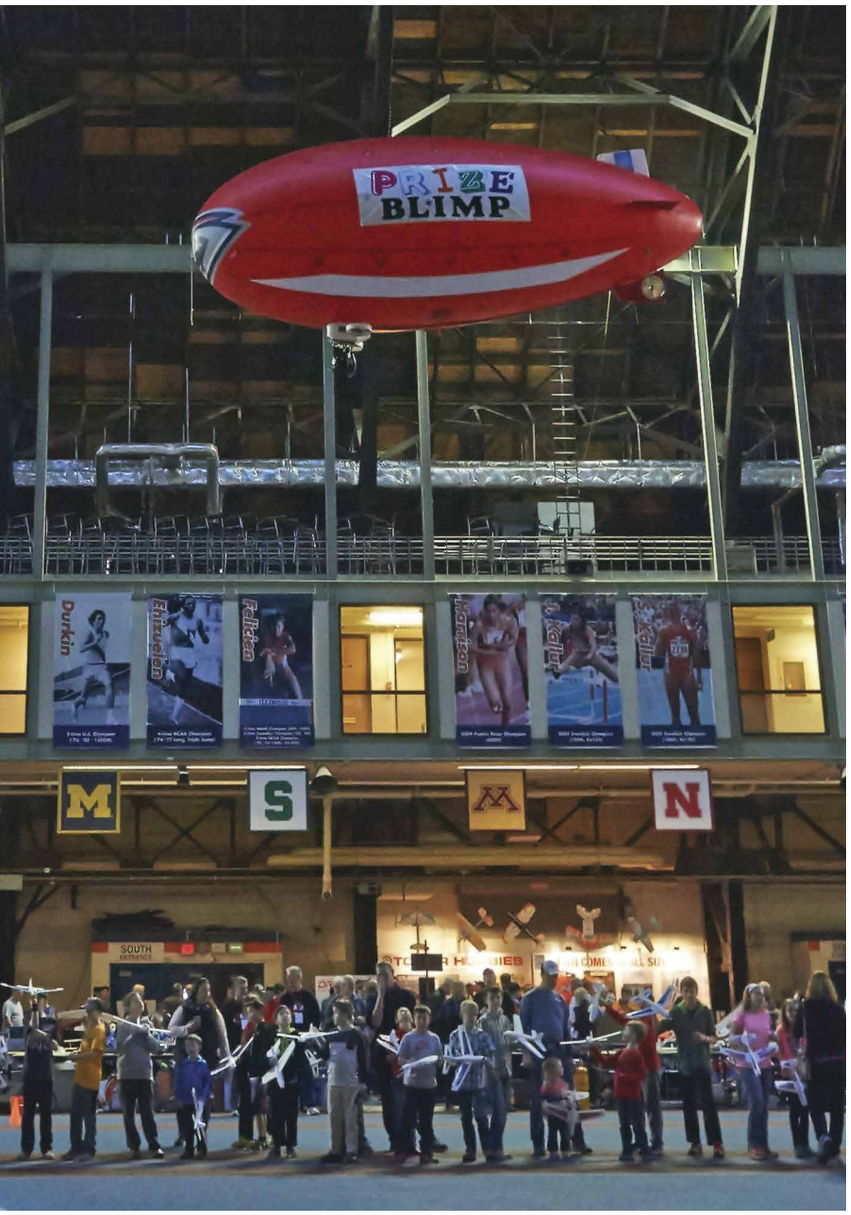
SIGHTINGS

30 Years of *Air & Space*

Record flights and X-planes, news from the International Space Station, the story of the first jet aircraft. For 30 years, we've traveled through the universe of aviation and spaceflight.

LEFT: MARCO DIRKX; RIGHT: DON "BUCKY" DAWSON

Departments



Inside the University of Illinois Armory: Hobbyists with RC model aircraft await the challenges.

Astronaut Jim Lovell started his NASA career with Gemini. In April, he will receive a lifetime achievement award from the National Air and Space Museum.

ON THE COVER: The Cassini spacecraft photographed Enceladus; we added color and placed it in a starfield. The moons of the gas giants are the next best place to search for life.

LEFT: COURTESY HOBBICO; COVER: ENCELADUS,NASA/JPL/SSI; RIGHT: NASM (NASA-68-HC-720)

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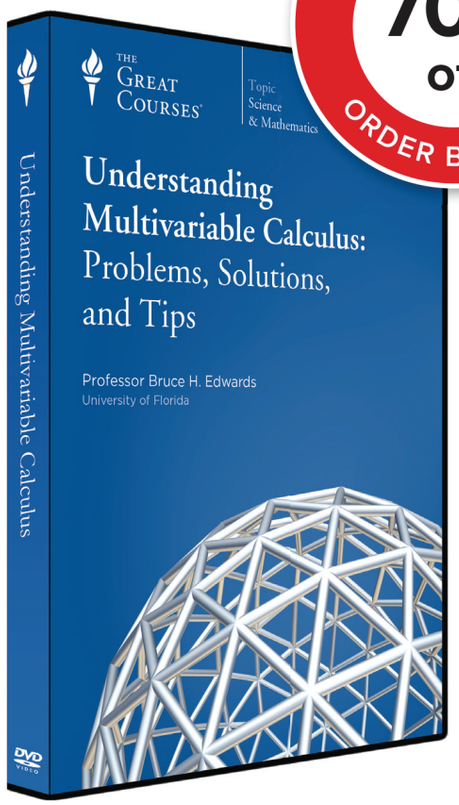

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27. Vector Fields—Velocity, Gravity, Electricity
28. Curl, Divergence, Line Integrals
29. More Line Integrals and Work by a Force Field
30. Fundamental Theorem of Line Integrals
31. Green's Theorem—Boundaries and Regions
32. Applications of Green's Theorem
33. Parametric Surfaces in Space
34. Surface Integrals and Flux Integrals
35. Divergence Theorem—Boundaries and Solids
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Viewport

FROM THE DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM

Try to Imagine

MOST OF US REMEMBER the sense of wonder we felt as we watched TV coverage of the Apollo 11 lunar landing. Even though President John Kennedy had announced the goal seven years earlier, we just couldn't anticipate what it would be like to see an astronaut on the moon. The National Air and Space Museum opened in July 1976, only four years after the final Apollo mission, and today, 40 years later, visitors are still thrilled to see Apollo artifacts. This year we are proud to award the National Air and Space Museum Trophy for Lifetime Achievement to astronaut Jim Lovell, who was so important to the success of the Apollo program. As you'll read in In the Museum, Lovell, who is best known as mission commander of Apollo 13, made contributions throughout Gemini and Apollo that advanced our knowledge of space travel.

On the seventh anniversary of the first Apollo landing, twin Viking spacecraft touched down on Mars, becoming the first spacecraft to operate on another planet. (A test model of the Viking lander is in the Boeing Milestones of Flight Hall.) The Viking mission began a search for life in the solar system that continues to this day. With the first in a series of articles, this issue recounts the history of the search and

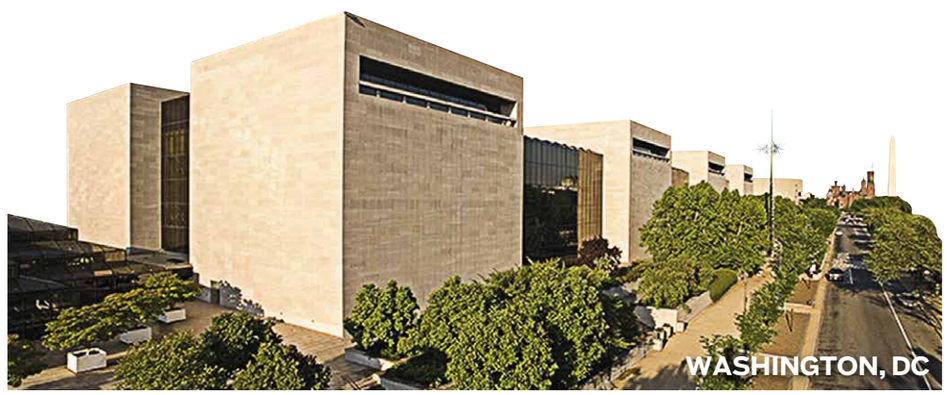
looks toward its future. If the search for life one day proves successful, it will change our world in unimaginable ways.

When the National Air and Space Museum opened in 1976, few could have imagined an exhibit like one we installed 32 years later—to showcase current unmanned flight technology. In the 1970s, I represented the Marines on a joint-service drone coordinating group, and my colleagues from the Army, Air Force, and Navy all agreed: We didn't want drones. We were remembering, perhaps unfairly, early versions of the Ryan Model 147, shot down over communist China during the Vietnam War. We've made tremendous strides since then, both in the technology of remotely piloted vehicles and in our acceptance of them.

Among the drones in our exhibit hang the Predator and Pioneer, which proved the ability of remotely piloted vehicles to fly reconnaissance missions, like those reportedly flown by the RQ-170, profiled in this issue's story. In Vietnam, we EF-10B crews couldn't imagine the luxury of assigning a drone to fly our long, monotonous Agony Orbits along the DMZ to listen for signals from surface-to-air missiles (which we never heard).

As technologies have advanced over the past 30 years—sometimes beyond what any of us could have imagined—*Air & Space* magazine has told the stories of those achievements. This, the magazine's 30th anniversary issue, makes us realize how much the world of aerospace has changed. Happy 30th birthday, *Air & Space*.

J.R. DAILEY IS THE JOHN AND ADRIENNE MARS DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM.



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Gemini 4, Apollo 9
COMMANDER

DAVE SCOTT
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BRUCE McCANDLESS
STS-41B, STS-61
First Untethered EVA

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Letters

WRITE TO US

Pared to Perfection

I commend your magazine for covering the accomplishment of Arnold Ebneter and his record-setting E-1 ("Across the Continent in a Homebuilt," Feb./Mar. 2016). Aviation has always been about taking risks and pursuing the limits, and Ebneter is part of this tradition. He exemplifies what Antoine de Saint-Exupéry described as the ultimate goal of design: "A designer knows he has achieved perfection not when there is nothing left to add, but when there is nothing left to take away."

I hope you will continue to report similar stories that highlight aviation engineers and designers who accomplish remarkable things without squandering public funds and failing to deliver their products on schedule and ready for full operation.

TODD FREDRICKS
via email

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For Sale: One Nimrod, Not Very Useful

Bill Sweetman's mention of the AEW3 project in his column ("Trials and Errors," Feb./Mar. 2016) brought back memories. When the airborne early

warning aircraft was canceled, the Nimrod MR1 airframes could not be converted back to maritime patrol aircraft, due to the lack of bomb bays. Consequently, they were sent to various Royal Air Force stations. One was used by flight engineer students at RAF Finningley for engine-starting practice. Another lay at the RAF Kinloss airfield for many years when I was flying maritime Nimrods in the late 1980s and early '90s. My next-door neighbor, a scrap dealer, eventually bought the airframe for the equivalent of about $2,000.

IAN MADGWICK
Fowey, Cornwall, England

Where the Lander Was Left

"Nine Lives of an Apollo Moon Lander" (In the Museum, Feb./Mar. 2016) reports that once the lunar mission was complete, the top portion of the lunar lander "would be jettisoned into Earth's atmosphere before reentry." This is incorrect; the top portion would be jettisoned toward the moon, where it usually crashed. The service module was the component that was jettisoned into Earth's atmosphere, before the command module's reentry.

ALAN HUNT
Ottawa, Ontario, Canada

The *Macon*'s Doomed Fleet

"The Underwater Airship" (Soundings, Feb./Mar. 2016) states that when the USS *Macon* sank into the Pacific, it was carrying a fleet of F9C-2 Sparrowhawk fighters on trapezes beneath its belly. Three of the F9Cs were on monorails inside the airship.

DONALD LAYTON
via email

A Wing, a Prayer, and a Fake

George C. Larson left one detail out of his critique of the movie *Wing and a Prayer* (Reviews

& Previews, Feb./Mar. 2016). The scene in which Ensign "Cookie" Cunningham jumps in a fighter and flies off to thwart a torpedo hit on the carrier is, to my knowledge, the only time a Hollywood movie has portrayed a takeoff that uses a hangar deck catapult.

The scene also betrays the fact that the movie used an *Essex*-class carrier—in this case, the USS *Yorktown II*. No carriers of that class had been commissioned at the time of the Battle of Midway.

JOHN A.TOTTEN
Port Charlotte, Florida

Corrections

Feb./Mar. 2016 "The Devil's Solar Observatory" (Oldies & Oddities): (1) We regret misspelling the last name of Charles Abbot. (2) Harquahala (now one word; then "Harqua Hala") is not the highest mountain in Arizona. That distinction goes to Mount Humphreys.

December 2015/January 2016 "Almost Like Being There": The photograph at the top of page 34 shows Dextre unpacking cargo from a SpaceX Dragon capsule, not from a Japanese resupply ship.

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What's Up

IN THE SKY, IN SPACE, AND IN THE NEWS

ON NOTICE: A U.S. B-52 heavy bomber joins a South Korean F-15K (right) and Korea-based U.S. F-16C (out of frame) over Osan Air Base, 40 miles south of Seoul. The January 9 flight, for which the bomber flew 2,000 miles from its forward-deployed Guam operating base, was a political signal aimed at North Korea after the opaque dictatorship's fourth successful nuclear weapons test three days earlier. North Korea claimed the weapon was a hydrogen bomb, a technology that would have been a significant leap in the nation's nuclear capabilities. On February 7, the country launched a satellite in what many believe was a test of a ballistic missile rather than civilian space technologies. Despite a 1953 armistice, North Korea technically remains at war with South Korea and the United States.

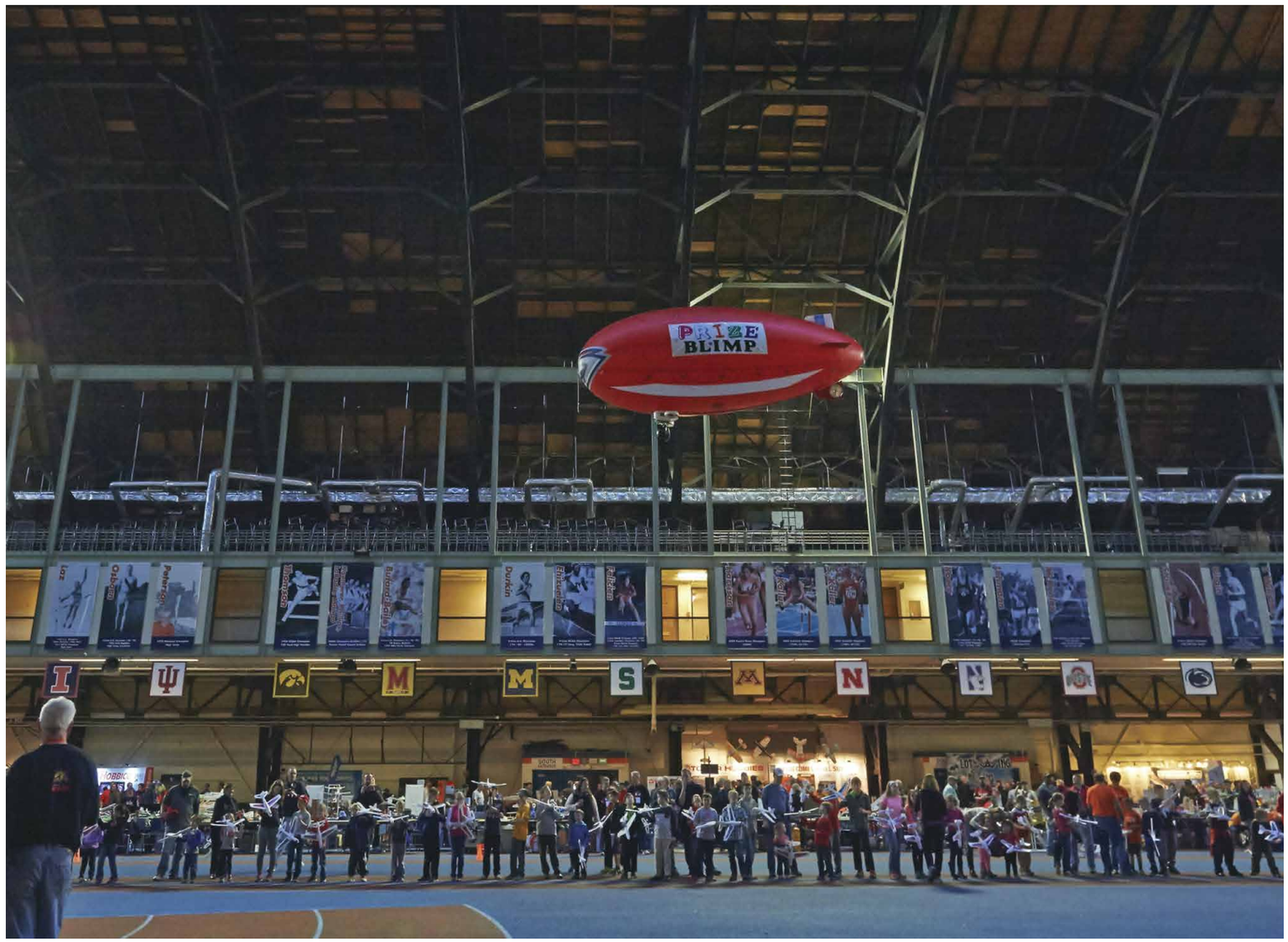
AP/AHN YOUNG-JOON

Indoor Airshow: Now With Drones

HUNDREDS OF RADIO-controlled helicopters, airplanes, and quadcopters buzzed through the Armory at the University of Illinois at Urbana-Champaign at the 10th annual E-Fest on February 6 and 7. Sponsored by RC aircraft manufacturer Hobbico Inc., the event is billed as the world's largest indoor aircraft show. Built in 1914, the Armory, with 80,000 square feet of floor space and a 100-foot vaulted ceiling, gives pilots plenty of unobstructed airspace.

"The beauty of flying models is that it teaches so many different things," said Art Pesch, senior manager at Hobbico. "You learn how to read blueprints, principles of engineering, spatial orientation."

Visitors could attend a full day of workshops: A representative from



Hobbyists filled the University of Illinois Armory to compete with RC aircraft.

COURTESY HOBBICO

Matt Slobe won the gauntlet.

the Federal Aviation Administration explained the new drone regulations, veteran RC competitor Bobby Watts spoke about using drones in the commercial film industry, and the university's drone club taught guests how to build and fly racers. Benjamin Khachaturian, a freshman at the university studying industrial design, gave a presentation recounting his six-day hiking trip to Mount Frederick William in British Columbia with a GoPro camera and Hubsan X4Pro quadcopter. He offered advice on taking video in flight, such as how to ensure propellers don't get in the camera's sight lines.

The event hosted 350 pilots, 25 vendors, and 3,000 spectators—many of whom were in attendance to watch the combat and course challenges. In the obstacle-course event, pilots navigated Dromida Vista UAV quadcopters through hula hoops and gates.

Chris Hass has been flying RC airplanes for 19 years, and started traveling from Michigan to attend the festival when it started a decade ago. He and his team competed in the gauntlet, which requires pilots to sprint through a course and repeatedly hand-launch foam and carbon-fiber airplanes through targets not much larger than the airplane itself. It's an event that tests craftsmanship as much as precision. "The pilot and the pit crew are running with glue, trying to glue the plane back together," said Hass. "It's a really fun, high-energy event. It keeps us on our toes."

According to Pesch, when the event began, it was for electric RC airplanes. Then helicopters began to have a bigger presence, but recently drones have exploded onto the scene and brought a new crowd of enthusiasts.

MEGAN JONES

COURTESY HOBBICO

WHERE WILL OUR IMAGINATIONS TAKE US NEXT?

Smithsonian's "Future" Returns

SCIENCE MEETS science fiction at *Smithsonian* magazine's fourth annual "The Future Is Here" festival, which will be held April 22 to 24 at Shakespeare Theater's Sidney Harman Hall in Washington, D.C.

"Never before has it seemed so possible to go from pipe dream to reality," says Michael Caruso, editor-in-chief of the magazine, previewing the message of the three-day event. "That's incredibly inspiring to people, whether they're working at SpaceX or on projects in their garages."

The festival will feature trailblazers in science and technology. NASA engineer Adam Steltzner, whose emphatic fist-pumping from mission control confirmed for millions that the Mars Curiosity rover had landed safely after its "Seven Minutes of Terror" descent in 2012, will offer a summary of the feats we can look forward to from the Mars 2020 mission. Maybe then when Andy Weir speaks, the dazzling displays of science in his book *The Martian* won't seem like far-off fiction.

Nikola Tesla thought his coils could generate signals that would reach Mars. Performing at The Future Is Here, the band ArcAttack will use them to generate thrills for the audience.

Do you want to believe? Chris Carter will talk about the 2016 reboot of his seminal TV series "The X-Files." Then real-life alien hunter Seth Shostak, director of the Search for Extraterrestrial Intelligence, will describe the new possibilities in the search. Now that "research suggests there are tens of billions of worlds that could be Earth's cousins," Shostak will explain "how we're looking for cosmic company, and what we might find."

You can find more information about attending the festival at **Smithsonian.com/Future.**

HEATHER GOSS

COURTESY ARCATTACK

A FAMILY THAT FLIES TOGETHER...

Pilot Andrew King (read about him in the feature on p. 20) sent us these photos after transporting a restored 1928 Travel Air 4000 from Wisconsin to owner Terry Bryn in North Dakota just before Thanksgiving last year. Terry's sister, Becky Kuhlmann, came to visit, and King took the opportunity to re-create a photo of Terry and Becky playing on the same Travel Air in 1957.

Siblings Terry and Becky on the family's Travel Air then (bottom, ages 2 and 5) and now (top).

UPDATE

RIPPLES SEEN

In February, astronomers at LIGO, the Laser Interferometer Gravitational-wave Observatories, made an incredible announcement: They observed gravitational waves for the first time ("The Universe Is Ringing," June/July 2015). The observatories, in Washington state and Louisiana, detected ripples in space-time from two black holes that collided 1.3 billion years ago. The finding confirms part of Albert Einstein's theory of relativity exactly 100 years after it was published.

THE COUNT

18,300

THE NUMBER OF AMERICANS who most recently applied to NASA to become astronauts. During the application period, which closed in February, three times as many would-be spacewalkers submitted their résumés than had applied for the last class, in 2012. The number rocketed past the previous record, 8,000 applications submitted in 1978. Of the candidates who make it through initial screening and training, only eight to 14 will be part of the astronaut class of 2017.

COURTESY ANDREW KING (2)

BACK TO CONTENTS

Chris Carter

With the return of "The X-Files," the creator of the hit TV series talks about Roswell, aliens, and ideas he'll share at *Smithsonian* magazine's Future festival this month.

I thought the Roswell scene in the new "X-Files" was beautifully done, and it had me wondering if you accept the official military explanation of Roswell.

Well, the way I understand it—and I only know what I read—is that the military had put out one account of a crashed spacecraft and then withdrew that account and said it was a weather balloon. So that sounds very suspicious to me. But if you read—I'll call it literature, and I say that with hesitation because I'm a skeptic—there were other crashes in addition to Roswell at places like Aztec [New Mexico], and they were supposed to be far better recoveries of downed craft. Now this is all what I read, and I find it fascinating. There's that poster on Mulder's wall: I

Chris Carter is the creator of "The X-Files," a fictional TV show that follows FBI special agents Fox Mulder and Dana Scully as they investigate the paranormal. FOX began airing six new episodes on January 24.

COURTESY FOX

want to believe. And I want to believe this stuff. But without hard evidence, it begs as many questions as it fails to deliver answers to us.

In this age of digital media and smartphone cameras, do you think it's possible for governments to keep secrets?
I think it's increasingly difficult. I think that is a good thing. But I also think it's difficult to determine—from all the various sources—what is the truth.

You mentioned that you're a skeptic. Do you have any reliable practices for identifying accurate reporting?
Let me preface this by saying I think of "The X-Files" as a science show before I think of it as a science fiction show. Because it's based on science: hard science, conventional science. And it's really Scully's show because she is the anchor to which the sometimes-untethered Mulder is affixed. So to come back to your question, we've always been rigorous in our science, and we have reached out to the most reputable scientists. In the original series, we had researchers who did that. Now I think more often, we—like everyone else—sit at home and with the press of a button have 500 conspiracy sites at our fingertips. We weed through all of that. We see what seems credible, and try to do our best.

Do you think that extraterrestrial intelligent beings exist?
I want to believe that we're not alone. That we have just yet to contact, discover, or recognize signs in whatever form.

Are we ready to discover irrefutable evidence of extraterrestrial beings?
It would be a game-changer, to put it mildly. I think all wars would end tomorrow if we found out.

Can you name a filmmaker you admire?
The reason I'm doing what I'm doing is because of Steven Spielberg. I was working as a journalist in my early 20s when I saw *Raiders of the Lost Ark* and *E.T.* I was blown away by both of those movies. I'll mention a second filmmaker because of the effect one of his movies had on me, and that was Francis Ford Coppola's *Apocalypse Now*. I saw it on opening night at the Cinerama Dome [a historic movie theater on Sunset Boulevard in Hollywood]. I lived about 75 miles away. I went home that night—sleepless. And I drove back 75 miles the second night to watch the movie again.

Read the entire interview at *airspacemag.com/x-files*

Bill Sweetman **Technically Speaking**

OBSERVATIONS FROM THE FRONT LINES OF AEROSPACE

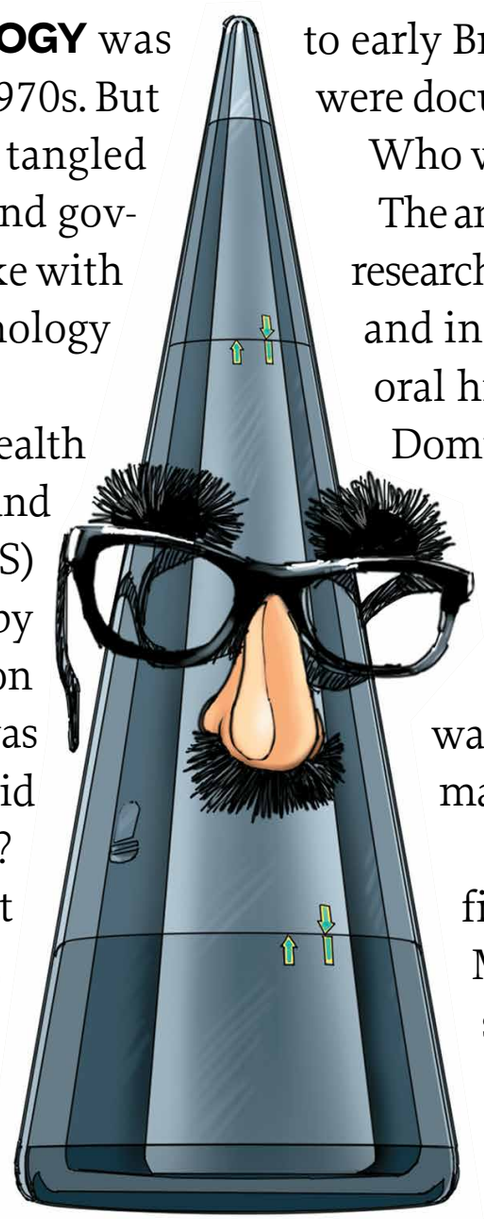
Stealth Before Stealth

MANY PEOPLE THINK STEALTH TECHNOLOGY was among the revolutionary advances of the mid-1970s. But the roots extend back much further. There is a tangled web of R & D strands from many commercial and government establishments that seldom if ever spoke with one another. The history of low-observable technology is still not complete.

And there are still mysteries: Some of the key stealth demonstrations in the 1970s, by both Northrop and Lockheed, took place at a radar cross-section (RCS) range at Gray Butte in California that was owned by McDonnell Douglas. (An object's radar cross-section is a measure of its radar reflectivity.) But Mac's was not heavily involved in stealth aircraft, so why did the company have one of the nation's best ranges?

Here's another head-scratcher: From the earliest days of the F-117, when its existence was still secret, the program included a Royal Air Force pilot.

In the early 1990s, my *Jane's* colleague Nick Cook discovered that this remarkable access had been granted to the United Kingdom in part due to early British contributions to stealth technology, which were documented in something called the Dawson Report.



HARRY WHITVER

Who was Dawson? What were these British advances?

The answers reside in a small-press book on British rocket research—C.N. Hill's *A Vertical Empire*, published in 2001—and in other sources, including a British Library Board oral history interview with British rocket "boffin" Roy Dommett, who died last November at 82.

These sources indicate that in the early 1950s, members of Britain's Royal Aircraft Establishment (RAE) at Farnborough started looking at what they called "radar echoing area"—the term "RCS" was not yet in use. Their leader was Grant Dawson, a mathematician and electrical engineer.

The first RAE experiments were low-RCS modifications to bombers, but the knights of the Air Ministry concluded that money would be better spent on electronic jamming equipment. And by the mid- to late 1950s, it was clear that the United Kingdom would not build a new high-altitude bomber. Instead, nuclear weapons would be

rained on the Soviet Union by ballistic missile. One—the de Havilland Blue Streak— was already being developed.

British planners expected that the Soviets would develop anti-ballistic-missile (ABM) weapons, and the Farnborough team concluded that one way to defeat them would be to build a reentry vehicle (RV) with a smaller RCS. That way, the early-warning radars would not pick up the warhead in time to intercept it.

The U.S. RVs at the time were blunt-ended and non-stealthy, but the RVs for Blue Streak were conical, piercing the atmosphere sharp-end first. Some designs included a coating made of a phenolic plastic reinforced with asbestos fibers, then loaded with carbon black to absorb radar waves.

The Saunders-Roe company developed a six-ton rocket, Black Knight, that could lob a scaled RV out of the atmosphere, and the United Kingdom established a test range at Woomera in Australia. Tests started in September 1958. In April 1960 Blue Streak was canceled; it was feared that, given the short flight distance between Eastern Europe and the United Kingdom, the missiles would be too easy to destroy on the ground, even in their silos. But transatlantic technology exchanges continued, and eventually a package of papers and data from the RAE's stealth aircraft and RV studies, the Dawson Report, came into U.S. possession.

From 1962 to 1965, Black Knight rockets, British RVs, and U.S. radars were all tested at the Royal Australian Air Force's Woomera Test Range in South Australia. The tests were known as Project Dazzle. By 1970, U.S. Minuteman strategic missiles were being equipped with Mk. 12 conical RVs to defeat Russia's ABM systems. Perhaps those were the mysterious Dawson Report's vital contribution.

The Farnborough team concluded that one way to defeat Soviet anti-missile weapons would be to build a reentry vehicle (RV) with a smaller RCS. That way, the early-warning radars would not pick up the warhead in time to intercept it. U.S. RVs were blunt-ended and non-stealthy; RVs for Blue Streak were conical, piercing the atmosphere sharp-end first.

To support the Mk. 12 program, the Douglas company built an RCS range in the Mojave Desert. McDonnell acquired Douglas in 1967, and thus came to own, in 1975, the only RCS range in the region. In the 1980s, Northrop and Lockheed built their own Antelope Valley ranges. Northrop located one on a site called Tejon Ranch, in the foothills of the Tehachapi mountains. Lockheed Martin chose a site in Helendale, just west of the Mojave River. Gray Butte has long been decommissioned as an RCS range, and is now the flight test center for General Atomics, makers of the Predator and Reaper unmanned air vehicles.

Dawson went on to specialize in spacecraft antennas. Details of his work on stealth technology remain classified.

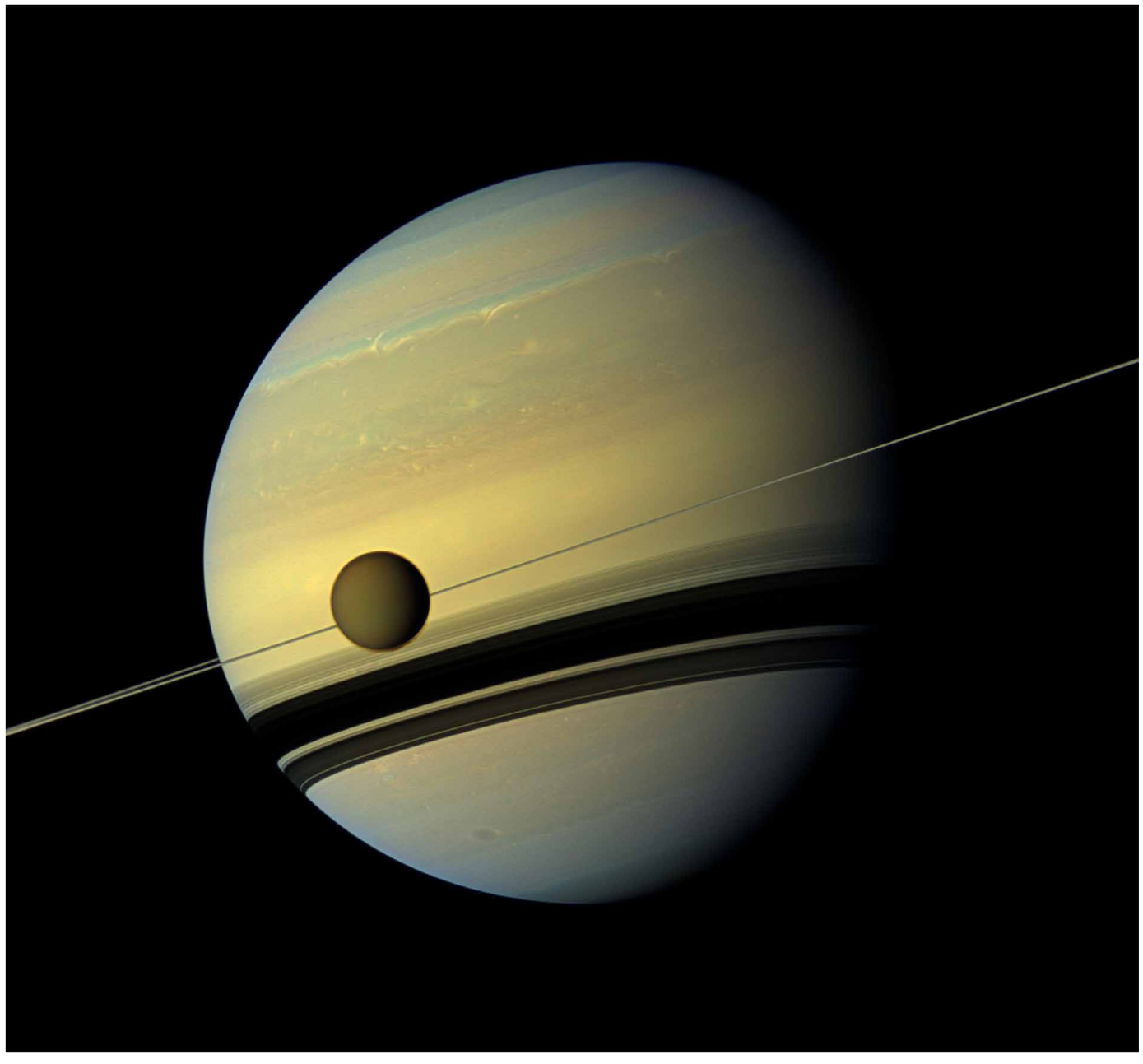
Solar System **Chatter**

A HUNDRED SATELLITES, ALL TALKING AT ONCE. HERE'S THE INTEL. **BY HEATHER GOSS**

PLANETS

Lighter Than It Looks

SOME OF SATURN'S RINGS have less material than they appear to. Using NASA's Cassini spacecraft, scientists measured spiral density waves—created when some particles in a ring, pulled by gravity from Saturn's many moons, orbit the planet faster than other particles—and discovered that Saturn's B ring has far less mass than expected. The assumption that something that's harder to see through is denser doesn't hold here. The math shows that even though parts of the B ring are nearly 10 times more opaque than the A ring, the B ring is only two or three times more massive. A less massive ring would evolve faster than a denser one, so scientists now believe that the B ring is much younger than previously thought.



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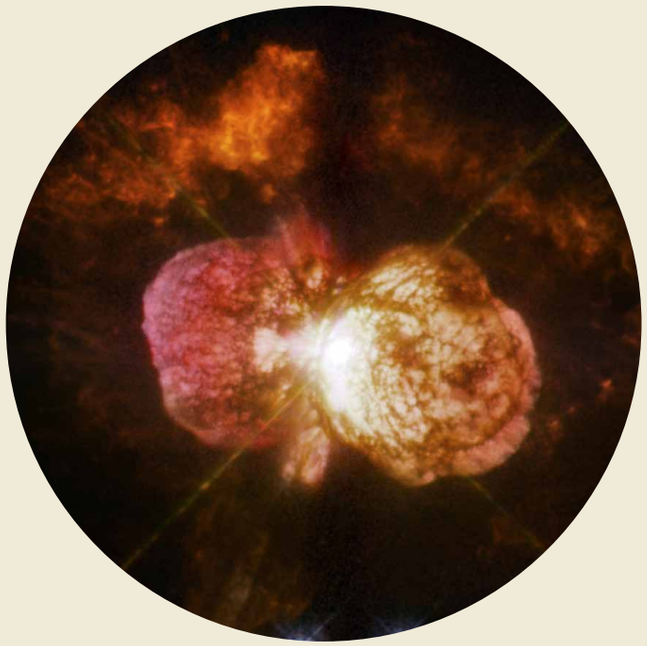


UNIVERSE

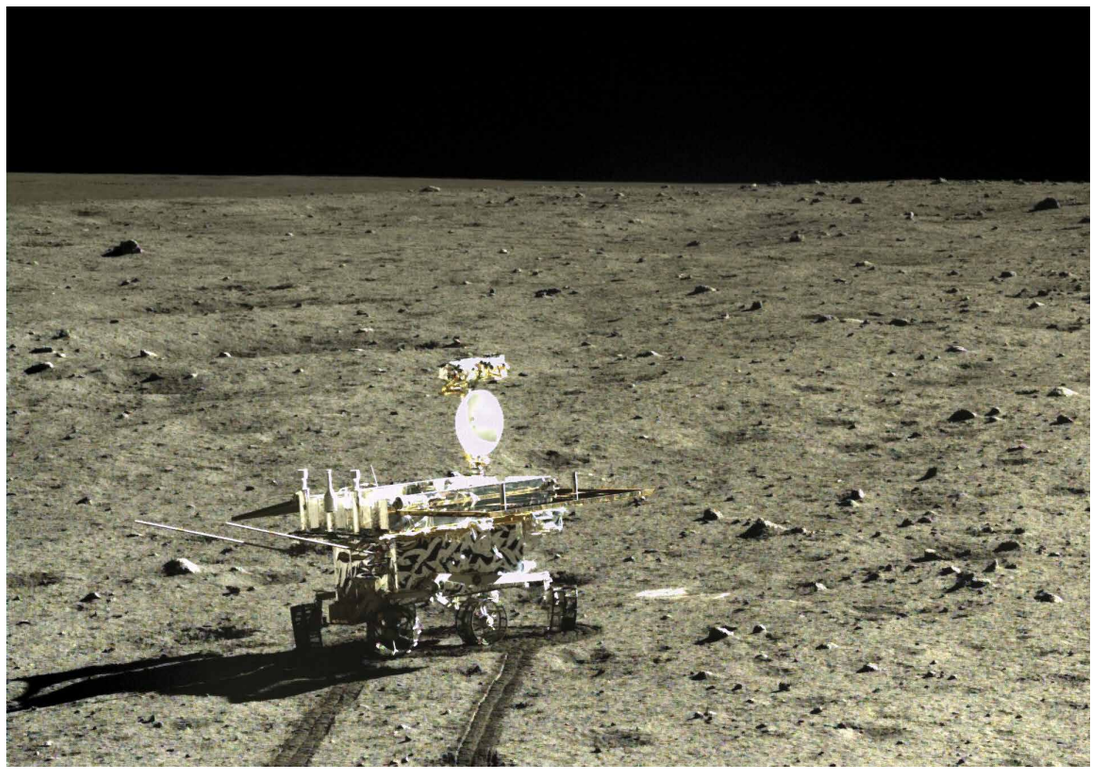
Eta's Not Alone

ONE OF THE MOST PUZZLING stars in the sky, Eta Carinae ("Mystery Star," Dec. 2015/Jan. 2016), is no longer unique. A team of astronomers studying archival data from NASA's Spitzer and Hubble telescopes has found five similar objects. With "Eta twins" to study, astronomers hope to comprehend these mysterious variable stars and their short-lived outbursts.

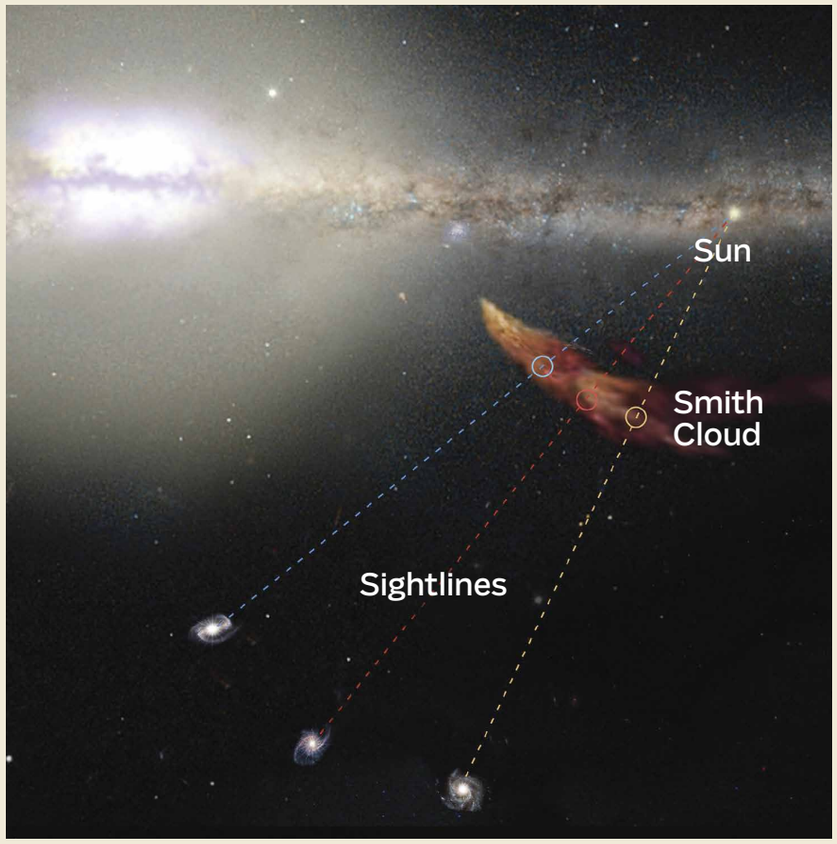
PLANETS

Moon Insights

CHINA'S MOON ROVER, Yutu, lost its roving abilities just after arriving two years ago, but it managed to probe the nearby lunar surface. It turns out the moon's mantle is much less uniform than scientists thought based on their last close-up look, in the 1970s. They now suspect that large impacts disrupted the mantle's formation three to four billion years ago.



LEFT: HUBBLESITE; RIGHT: CNAS/CLEP



UNIVERSE

Swinging Back

THE MILKY WAY EJECTED a stream of gas and dust around 70 million years ago. Now the Smith Cloud—discovered by astronomy student Gail Smith in the 1960s—is headed back for us. When it plows back through our galaxy (30 million years from now), the collisions could produce two million new stars.

PHILAE, CAN YOU HEAR ME?

Goodnight, Comet Lander

We'll always remember the Philae lander's whopping seven-hour bounce on Comet 67P in 2014. The European probe still nailed almost three days of science, but its time has come: The Rosetta orbiter hasn't heard from Philae since last summer.

THE NEXT STEP IN UNDERSTANDING SPACE-TIME

Going to Space for Gravitational Waves

The LISA Pathfinder spacecraft is paving the way to find larger gravitational waves than those recently observed on the ground. On March 1, the concept mission, using lasers and free-falling metal cubes, started testing observation methods in space.

NASA/ESA/HUBBLE SM4 ERO TEAM

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The Case of the Runaway U-2

IN THE SUMMER OF 1966, my squadron, VF-74, was flying the McDonnell F-4B Phantom II out of Naval Air Station Oceana in Virginia Beach. Our primary mission was to train for a June 1967 deployment to Vietnam with the carrier air wing CVW-17 aboard the USS *Forrestal*. As squadron training officer, I was responsible for making the training syllabus and overseeing a daily flight schedule to reinforce its lessons.

While preparing to deploy overseas, we were ordered to provide on-site support for the Joint Air Reconnaissance Control Center (JARCC) at Naval Air Station Key West, Florida. That mission entailed providing a four-airplane, six-aircrew detachment every other month. VF-74 alternated months with an F-8D squadron based at Marine Corps Air Station Beaufort, South Carolina. I was in charge of the VF-74 detachment sent to Key West.

In a photo composite, a U-2A flies over the Key West control center that monitored recon flights near Cuba in 1966.

USAF (2)

That summer, President Lyndon Johnson had banned all military reconnaissance flights over Cuba, but under JARCC control, recon flights along the periphery of the island continued daily. Should the Castro regime decide to try to shoot down one of the Air Force or Navy recon missions, my squadron, like the Marine squadron with whom we shared the mission, was ready. Our job was to have two F-4Bs, armed with live Sparrow III and Sidewinder missiles, in position to get airborne within five minutes after notification to launch. This was known as standing Alert Five.

Our job was to have two F-4Bs, armed with live Sparrow III and Sidewinder missiles, in position to get airborne within five minutes after notification to launch.

The alert aircraft were armed, fueled, and parked just steps away from an RV trailer that had been converted into a ready room. During alert periods, which normally extended from 9 a.m. to 2 p.m., the aircrews stood watch in the trailer in full flight gear except for our helmets. It was very hot and muggy in Key West in July, but the trailer had excellent air conditioning. To pass the time we had a dartboard and several board games, including Monopoly. A 10-inch bell was fixed to the wall. If the bell sounded, the two aircrews grabbed their helmets and sprinted to their aircraft.

Since the likelihood of being dispatched to protect an endangered recon aircraft was quite low, I arranged to have the bell rung at the end of the operational day, so we could hone our ability to get two aircraft into the air in under five minutes. But it was even more important to me to help our crews accumulate training hours. Each afternoon when the bell rang, two VF-74 F-4Bs went roaring down the runway and into the sweltering Key West skies. After checking in on the radio with JARCC, we were released to conduct practice intercepts. That month in Key West was about the most tedious duty I ever performed.

On July 28, the boredom was shattered. Shortly after 1 p.m. the bell went off. The timing was not unusual; we were frequently released from Alert Five status early. Still, my radio intercept officer, my wingman, and his RIO all ran to our aircraft. After a quick strap-in aided by our enlisted plane

Then came the real shocker: “Backwash 202, cleared to arm. Cleared to fire!” What?! I flipped the switch to arm the Sparrow and Sidewinder missiles, knowing full well that we were out of firing range.

captains, we radioed for permission to taxi. Key West gave us priority and cleared us for takeoff, and we turned onto the duty runway. We were airborne three and a half minutes after the bell. Bill Reynolds, my RIO, switched to JARCC frequency and checked in. We fully expected to be released to fly yet another intercept training flight.

Instead, we heard this: “Backwash 202, turn right to heading 170.”

Bill responded with typical professionalism: “Backwash 202,
roger, 170.”

What? I turned to a heading of 170 degrees, wondering what was happening.

The next thing I heard only made my heart beat faster: “Backwash 202, your bogey five right, 22.” *Bogey?!*

Bill, cool as ever, responded, “Backwash 202, roger.”

The next call explained why Bill had nothing on his radar scope. “Your bogey high. Go burner!” That spurred Bill to elevate the radar antenna and me to light the afterburners of both J-79 turbojet engines.

As we accelerated and climbed, Bill attained radar contact with the bogey. “Long Glass, Backwash 202, contact 8 right 17.” (“Long Glass” was JARCC’s radio call sign, though its meaning was as opaque as our own, “Backwash.”) The elevation marker on the scope told us that the bogey we were chasing was really, really high. We were climbing through 35,000 feet when Bill reported, “Long Glass, Backwash 202. Judy.” “Judy” was the code word that indicated our radar was locked on and tracking. As we passed 40,000 feet I saw on the radar scope that our closure rate was just under 300 knots.

Our bogey was heading south, toward Cuba.

Naval Air Systems regulations required F-4 crewmen to be in full pressure suits when operating above 50,000 feet, but I didn’t think of that as we climbed through that altitude with our bogey still above us.

Then came the real shocker: “Backwash 202, cleared to arm. Cleared to fire!” *What?!* I flipped the

switch to arm the Sparrow and Sidewinder missiles, knowing full well that we were out of firing range. As we topped 55,000 feet, my scan went from the scope to the sky above and ahead of us.

Then it was over: "Backwash 202, de-arm, your vector 355 and your signal is Romeo Tango Bravo"—Return to Base. I was not keeping track of our position in relation to Cuba, but I learned later that we were stood down and ordered back right at the 12-mile mark.

After landing back at Key West we were met by a JARCC vehicle, which transported Bill and me to the JARCC facility for a debriefing.

There I learned we had been launched to shoot down a U.S. Air Force U-2.

The U-2, piloted by Captain Robert D. Hickman, had departed Barksdale Air Force Base, just outside Shreveport, Louisiana, on a reconnaissance mission to Cuba. His mission profile required that he check in with JARCC as he passed over New Iberia just before going "feet wet" in the Gulf of Mexico. When he failed to check in, JARCC, certain that he was incapacitated, launched us to shoot down his aircraft before it defied President Johnson's order by entering Cuban airspace.

For several days after that, I was in a daze. But one thing I knew was that I was grateful Captain Hickman's U-2 had remained out of reach of our missiles. Had we closed to within firing range, I honestly don't know how I would have responded.

Captain Hickman's U-2 continued over the island without any response from Cuban air defense forces. It flew until it ran out fuel, then spiraled down and crashed on a plateau near Oruro, Bolivia. Hickman's body was recovered, and investigators determined that lack of oxygen had caused him to lose consciousness, then to suffocate. By the time I was ordered to shoot him down, he was almost certainly already dead in the cockpit.

Had I shot down his U-2, it certainly could have been filed away as one of those unfortunate incidents that occur in the fog of war. But even knowing that Hickman was already dead, had I shot him down, I would not be telling this story today. Why? Because the aircraft bearing his body would have landed in Cuba, and his wife and six children would not have had his remains to mourn and to bury. I could not have abided that.

JOHN NEWLIN

From Carriers to Space Capsules

JAMES LOVELL may be best known as the commander of Apollo 13. During that April 1970 mission, the service module's cryogenic oxygen system failed, putting the astronauts' lives in danger. For four tense days, he and crewmates John Swigert and Fred Haise, along with NASA ground controllers, worked to return their spacecraft safely to Earth.

But Lovell, the 2016 recipient of the National Air and Space Museum's

The National Air and Space Museum honors James Lovell, Gemini and Apollo astronaut, with its 2016 Lifetime Achievement trophy.

COURTESY TEXAS A&M

Gemini 12 crewmates Buzz Aldrin (left) and Jim Lovell celebrate aboard the USS *Wasp* on November 15, 1966, at the conclusion of their four-day mission.

trophy for Lifetime Achievement, is being honored for the many accomplishments during his career—which started early.

"I was interested in rockets and astronomy long before the Glenns and the Shepards of the world could *spell* rocket," Lovell joked in a 1999 oral history recorded at NASA. "I was interested in it way back in high school."

The Milwaukee boy who avidly read Jules Verne novels as a child was, by the mid-1940s, in high school and building his own rockets: He would stuff mailing tubes with gunpowder and glue, then launch them from a nearby field.

Watching nervously across the street was Marilyn Gerlach, Lovell's future wife. (They'd met in the school cafeteria lunch line, flirting shyly over meat loaf and succotash.)

"I wanted to become a rocket engineer," recalled Lovell in 1999. When the obsessed teen wrote to the American Rocket Society asking for advice, the organization suggested he attend either MIT or Caltech. Unable to afford the tuition, Lovell took an ROTC scholarship at the University of Wisconsin. After two years he transferred to the Naval Academy. He hoped to become a pilot, his choice after rocket engineer.

Three and a half hours after Lovell graduated from the academy, he and Gerlach married. Lovell immediately headed to flight school.

By 1953 Lovell was dispatched to Moffett Field in California and assigned to Composite Squadron Three, an aircraft carrier group. Six months later he made his first nighttime carrier landing, off the coast of Japan. Lovell recalled in 1999 his response to the assignment: "I told

NATIONAL AIR AND SPACE MUSEUM TROPHY AWARD

Presented annually to recognize both past and present achievements.

LEFT: NASA; RIGHT: ERIC LONG

the skipper, 'You know, I'm having a little trouble flying in the daytime yet, and you want me to go out at night?' " Flying a F2H Banshee, Lovell searched for the USS *Shangri-La*. It was slightly more challenging than he'd expected: He was using a light he'd invented to illuminate his knee board, and it accidentally short-circuited his instrument panel, so Lovell had to locate the carrier by the trails of phosphorescent algae churned up in the carrier's wake. A master of understatement, Lovell would recall the event years later: "It was a great experience, and I learned an awful lot." (The memory became a famous scene in *Apollo 13*. In the film, Tom Hanks recalls the fear of not being able to find the carrier in all that blackness, a foreshadowing of the possibility of not making it home to Earth.)

Lovell would eventually make 107 carrier landings, and go on to teach plebes how to fly the FJ-4 Fury, the F8U Crusader, and the F3H Demon. Then he headed to the naval base at Patuxent River, Maryland, to become a test pilot. His experience as a naval aviator and test pilot got him into NASA's second group of astronaut trainees—for the Gemini missions—in 1962. (A minor medical condition kept him from being one of the original Mercury 7.) Over the next 11 years he would spend a total of 715 hours in space, a record not surpassed until Skylab.

Many artifacts from Lovell's space career are in the Museum's collection. Visitors can see the small, battered Gemini 7 capsule in which Lovell and Frank Borman orbited Earth for 14 days in 1965, demonstrating that humans can live in weightlessness. Back then, NASA, worried about leaks in the spacecraft, required astronauts to wear spacesuits at all times. In his oral history, Lovell recalled the suits as hot and bulky. While Borman waited in vain for NASA to give him permission to remove his suit, Lovell shucked his, causing his young son to later exclaim, "My Dad orbited the Earth in his underwear!" Borman and Lovell—who ended up sharing a toothbrush on the mission—remain good friends. In 1999, Borman said, "Jim Lovell was a wonderful guy to spend 14 days with in a very small place."

In 1966, Lovell commanded Gemini 12, the 10th and final manned flight of the program, which helped demonstrate that an astronaut could safely work outside the spacecraft. Visitors can see many items from that mission, including the hatch-closing lanyard Buzz Aldrin used on his three spacewalks.

Lovell's next mission was Apollo 8, which some—including Lovell—argue was NASA's finest moment. "We saw the far side of the Moon, which no one had ever seen before," Lovell recalled. "That was the high point of my career. I think it was the high point of NASA's career, too." The collection contains more than 70 items relating to the six-day spaceflight, of which Lovell was command module pilot and navigator.

As spacecraft commander of Apollo 13, Lovell became the first man to journey to the moon twice. Some 140 hours into the stress-filled mission, his amiable nature remained intact: Although sleep-deprived, cold, and weary, Lovell was still able to quip

The Apollo 8 crew, including Lovell, the command module pilot, practiced water egress in the Gulf of Mexico.

to ground control, "Well, I can't say that this thing hasn't been filled with excitement."

Lovell was given the Lifetime Achievement Award for a variety of reasons, says curator Roger Launius: "His many accomplishments as a naval officer and astronaut have made a lasting impact on the aerospace program. He accumulated more than 7,000 flight hours, including 4,500 in jet aircraft and 715 hours in space. A pioneer in the American space program, Captain Lovell participated in four historic NASA missions. It's a pretty illustrious career. And he's a remarkable spokesperson for air and space activities."

REBECCA MAKSEL

The trophy awards ceremony will be held on April 5 at the Museum. Also honored will be the New Horizons Team, which will receive the National Air and Space Museum Current Achievement Award. Read more about the team at **airspacemag.com/new-horizons.**

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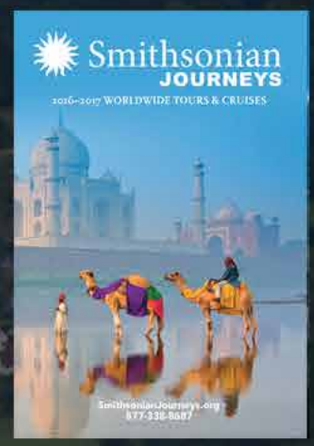

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JOURNEYS

LET'S GO ANTIQUING

What's it like to fly the earliest airplanes? Ten pilots talk about the dangers and demands.

BY PHIL SCOTT

The Fokker Dr.I Triplane (foreground) is a handful for even experienced pilots.

NEARLY EVERY AIRPLANE FLYING today, from a humble Cessna to the mammoth Airbus A380, uses the same stick-and-rudder-style controls. Moving the yoke or stick back and forth changes pitch; moving it sideways controls roll; pushing rudder pedals adjusts yaw. Airplanes great and small have almost the same feel, and until acted upon by some outside force, most will fly straight and level. That hasn't always been the case.

A few years ago, near Kitty Hawk, North Carolina, I learned to fly an exact reproduction of the Wright brothers' 1902 glider, the first aircraft that offered complete control over yaw, pitch, and roll. But there was no stick: A horizontal cross-member linked to the forward-mounted elevator controlled pitch. By rotating the cross-member with both hands, the pilot could move the elevator up or down. To control roll, the pilot shifted his hips on the cradle he was laying on. Activating the cradle twisted the wings ("wing warping," the brothers called it), and in no time they were turning like crazy. As for yaw, the rudder, which was wired to the cradle, moved in conjunction with the wings. After a few hard landings, I got the hang of it and logged a few five-second glides. But flying this aircraft felt difficult and nerve-racking. And I had to hold my neck up so long it hurt. I began to wonder about the pilots who routinely fly antique airplanes: Did they have similar reactions? Here's what I learned.

FOKKER DR.I TRIPLANE

Dutch aviation pioneer Anthony Fokker founded an airplane manufacturing company in Germany, producing such military airplanes as the renowned Dr.I, flown by German ace Manfred von Richthofen—the Red Baron.

Pilot: Mark Holliday was a pilot for the former US Airways.

"The Dr.I replica doesn't have a rotary engine, it has a modern engine. I flew it [from Fort Lupton, Colorado] to Dayton, Ohio, and I've flown it to Oshkosh. It's a lot of fun for about 15 or 20 minutes. Then after that, no. It wasn't designed for a cross-country flight. It's not bad in smooth air, but if you get up into bumpy air, you get worn out because the tail sashays back and forth and slings you around all the time, and you have to keep pressure on both rudder pedals. It doesn't carry enough fuel—thank goodness—so it flies only about an hour and 15 minutes. After that, you're just grateful to land and stretch your legs."

Andrew KIng was 19 when he first flew at the Old Rhinebeck Aerodrome in New York.

GILLES AULIARD

Dan Taylor (left) dresses to suit a Curtiss Model D. Above: The late Bill King, who instilled an appreciation for early aircraft in his son Andrew, flies a Hanriot reproduction.

CURTISS MODEL D

Introduced in 1911, the Model D was flown by the U.S. Army Signal Corps and U.S. Navy.

Pilot: Dan Taylor restores vintage aircraft, lectures on aviation history, and works as a radio personality at WCBS-FM in New York City.

"In its day, it was a very significant airplane. It was the first type to land on a ship, and many people saw flight for the first time with Curtiss exhibitions at county fairs. Sitting on the little seat racing down the runway, you're acutely aware of the engine roaring behind you. A little intimidating at first, and one of those things you have to be mindful of because if there's an accident, you're going to be first on the scene. The controls on the Curtiss Model D are borrowed from the auto and motorcycle world: a steering wheel column for rudder and pitch. The throttle is at your right foot. And like riding a bike or a motorcycle, to turn, you lean in the hinged seat from side to side. You must be careful landing. There's no suspension, so you have to land gently. It takes very little to put the wheels through the lower wing. To me though, an absolute joy to fly."

THE 1910 HANRIOT

René Hanriot founded his company in France, and his background in designing boats shows: The wood fuselage of this monoplane could pass for a crew shell.

LEFT: FRED MURRIN; RIGHT: GILLES AULIARD

Chuck Wentworth built this Fokker E.III for California's Aeroplane Collection.

Pilot: Karl Erickson ran the aviation department at the Owls Head Transportation Museum in Maine. He has restored numerous vintage airplanes.

"The first time I flew the Hanriot reproduction, it felt fairly normal, and the characteristics were as expected. I had learned to fly in a modern airplane but had spent very little time in them. Most of my early flying took place in vintage airplanes. An original Anzani-powered 1909 Blériot XI, which I had the pleasure of trying to fly, I believe to be the worst machine to control. The Hanriot, on the other hand, flies like a Piper Cub: controllable, light, and just delightful. But [the Hanriot] flies far slower than modern light airplanes, so you have to be on your game because the speed range between flying and stalling is extremely small."

FOKKER E.III

During World War I, the German air force put the E.III monoplane into combat operations in December 1915.

Pilot: A former racing pilot and a stunt pilot for the film industry, Chuck Wentworth restores antique airplanes.

"I've been flying the E.III for 20 years. The flights aren't very long—you don't go anywhere. I'd say your average flight is 15 minutes. It's a fairly similar airplane to the Blériot XI: Both airplanes have a square fuselage and wing warping. The Blériot is way underpowered. The E.III's a bigger airplane so it has a 100-horsepower engine. The airplane will go probably 90

Karl Erickson talks, restores, and flies antique airplanes.

The Aeroplane Collection has a Nieuport 24*bis* reproduction powered by an original Le Rhone rotary engine.

[mph]. No way the Blériot would go that fast. The E.III has a lot of lift, but it's also got a lot of drag. It flies very nice. It has a good climb rate, very maneuverable. But to actually roll the airplane, I'd have to climb to a thousand feet, and there's no sense risking everything."

NIEUPORT 24

It was built to replace the Nieuport 17, but in World War I, most French squadrons, plus some Allied units, went with the Société Pour L'Aviation et ses Dérivés SPAD S.VII instead. The *Rand McNally Encyclopedia of Military Aircraft* says the Nieuport 24's performance as a fighter is "uninspiring," and while many U.S. pilots trained in one, in actual combat they upgraded to a SPAD.

Pilot: Jim Record flies a North American SNJ-2 for the Geico Skytypers at airshows and is an adjunct professor at Dowling College's School of Aviation in Long Island, New York.

"We bought the Nieuport replica as an incomplete project from a guy in California.

Bob Coolbaugh (below left) built the Ely Curtiss Pusher below, now in Virginia's Military Aviation Museum.

There are no originals flying. That's the problem with old airplanes: You can't afford to risk flying them. The airframe setup is the same [as on the original Nieuport 24], only the [new, modern] engine is different. The old Nieuports had rotary engines. The first flight was fairly anticlimactic. We had prepared for it so long and so completely, and there were no issues. I was too busy verifying its flying characteristics to enjoy the flight. I was just glad that it flew as predicted. The -24 is kind of a handful to fly. As with most World War I fighters (except the Fokker D.VII), they do not exhibit much stability in pitch or yaw. As such, [the -24] has to be

LEFT: GILLES AULIARD; RIGHT: NIGEL HITCHMAN

flown every second, not just trimmed up and monitored. If you divert your attention to a chart or some navigation landmark on the ground, the ship simply points or flies wherever it wants to."

1911 ELY CURTISS PUSHER

In November 1910, Eugene Ely took off from the deck of the USS *Birmingham* in a Curtiss Model D (see p. 21). On another flight two months later, he landed on the USS *Pennsylvania*. Both takeoff and landing were firsts, and both succeeded on the first try—a good omen for aircraft carriers as the future of naval aviation.

Pilot: A retired captain for Continental Airlines, Bob Coolbaugh enjoys restoring and barnstorming Golden Age airplanes.

"This airplane has almost 160 hours, and 95 hours are mine. This is a full-scale replica: The wingspan and fuselage length and material used in it match the original drawings. But changes were made for safety's sake. You don't want to die in an airplane you built. Unfortunately, we built the airplane too close to the original, so it flies like crap, to be honest. It's not the airplane's fault; it's just the result of the state of aerodynamics in 1911.

You have to have a lot of patience with this airplane. It has marginal control stability in roll and pitch with tremendous parasitic drag. This is one of the only airplanes I have ever flown that decelerates when pointed down.

On October 8, 2010, we were sitting on the deck of the USS *George H.W. Bush* [the Curtiss had been hauled there with a crane to celebrate the birth of U.S. naval aviation]. I could have made a takeoff, a landing, and another takeoff, but they wouldn't let us do it. Basically the response was 'risk management.' It's the way the world is nowadays."

1909 BLÉRIOT XI

The Blériot XI is the aircraft in which French aviator Louis Blériot made the first airplane flight across the English Channel, on July 25, 1909. (That aircraft is now on display at the Musée des Arts et Métiers in Paris.) Another Blériot XI, part of the Shuttleworth Collection in England, is the oldest airworthy airplane in the world.

Pilot: Roger "Dodge" Bailey is chief pilot of the Shuttleworth Collection of historic aircraft in Bedfordshire, England.

"The aircraft is only just capable of flight and has virtually zero excess power for climbing. This limits our flying to straights along a [2,300-foot] grass runway.

My first impression of the Blériot is that there is a need for a continuous push force on the stick for the entire flight. It's not possible to determine whether this is due to the aircraft being out of trim or statically unstable longitudinally; probably it's a bit of both. It's important to understand the deficiencies of the design and work with them. One has to fly this aircraft with your head, not your heart.

I don't think I will ever feel comfortable in our Blériot, as the performance margins are too small. Bearing in mind I don't fly it very high—eight to 10 feet—I have not been able to explore its full flight envelope. Within the envelope I have explored, I think I now know where the difficult areas are and try to cope with them. But that is not to say I can always avoid them. Given sufficient engine power to get the airplane to a reasonably low angle of attack, the handling qualities may improve somewhat. However, we are always flying at high angle of attack, and in that regime, the Blériot is a thoroughly unpleasant

At the Old Rhinebeck Aerodrome, Hugh Schoelzel taxis a Blériot XI, North America's oldest flying airplane.

GILLES AULIARD

aircraft. It is certainly not comfortable—not least because the pilot and his goggles are liberally doused with oil within about a minute. My guess is that [Louis] Blériot was of the 'Let's just get it airborne' mindset."

CURTISS JN-4

America entered World War I late, and to train pilots, the military bought thousands of two-place Curtiss JN-4 "Jennys."

Pilot: Andrew King owns an airplane restoration shop in Virginia. He has logged 3,700 hours in 130 aircraft types.

"I tell people that you can teach anyone's grandmother to fly the Jenny. In calm weather, it's pretty stable. The controls are heavy [they require a lot of strength to move them]. It's a high-drag airplane. The

Frank Schelling spent 30 years restoring his Curtiss JN-4, a rare H model, fitted with an equally rare Hispano-Suiza engine.

GILLES AULIARD

biggest rule is to not get too slow. You don't want to stall out of a turn, so you keep the speed up. It's a pretty amazing airplane. If you look out through the top of the cylinders, the rocker's arms are wagging up and down, which makes a neat framework from which to look out at the world."

AVRO TRIPLANE IV

After making its first flight in September 1910, the Avro Triplane served as a training aircraft at a flight school in Surrey, England.

Pilot: Rob Millinship flies for the Shuttleworth Collection. The Shuttleworth Avro Triplane is a replica built for the 1965 film, *Those Magnificent Men and Their Flying Machines*.

"It took three or four flights of around eight minutes each before I started to settle down in [the Triplane replica], although my first flight was rather longer: Every time I reduced speed to descend and land, I wasn't entirely sure that I was still in control. Fortunately, it was one of those perfectly still evenings, and we have a fairly large grass airfield to aim at.

How can you be confident about an airplane with wing-warping instead of conventional ailerons for roll control? All I could do was read as many reports on flying the airplane as I could find, and talk and listen to the very few pilots who had flown it.

The roll power is very low by comparison with aircraft fitted with ailerons. All you have is a steering wheel, which, by means of pulleys and cables, twists one wingtip upward and the other down. It can be quite alarming to watch the whole wing twisting as you turn the wheel.

A former U.S. Navy jet pilot, Jim Record flew airshows at Rhinebeck for 10 years.

DARLENE RECORD

Prior to and during a flight in the Triplane, it is a very serious undertaking. But after landing, it normally takes me a couple of days to get rid of the grin.

FOKKER D.VII

The Fokker D.VII appeared on the Western Front in May 1918, drawing respect from Allied pilots.

Pilot: Bill Gordon has been an airshow pilot for more than 25 years. He has restored many vintage aircraft, including a Fokker D.VII at the Old Rhinebeck Aerodrome.

"My first flight in the D.VII was on a sunny afternoon with the wind blowing from the south right down the bumpy grass runway at the Old Rhinebeck Aerodrome. I was surprised at how fast the aircraft became airborne. I flew around for about 30 minutes, getting the feel of and making friends with it. I did some slow flight, some stalls, then moved on to steep turns and wing-overs.

For a World War I aircraft, the D.VII is very easy to fly. It has a steerable tail skid and a long fuselage that make for a very docile aircraft during landing. The D.VII has a very thick airfoil, produc-

Rhinebeck's Fokker D.VII (flown by Ken Cassens) was restored by Bill Gordon.

ing great lift and a much slower stalling speed compared to other fighters of the era. But it would be a big jump for a nosewheel Cessna pilot to fly the D.VII, as modern pilots are used to such luxuries as forward visibility, brakes, and an airspeed indicator.

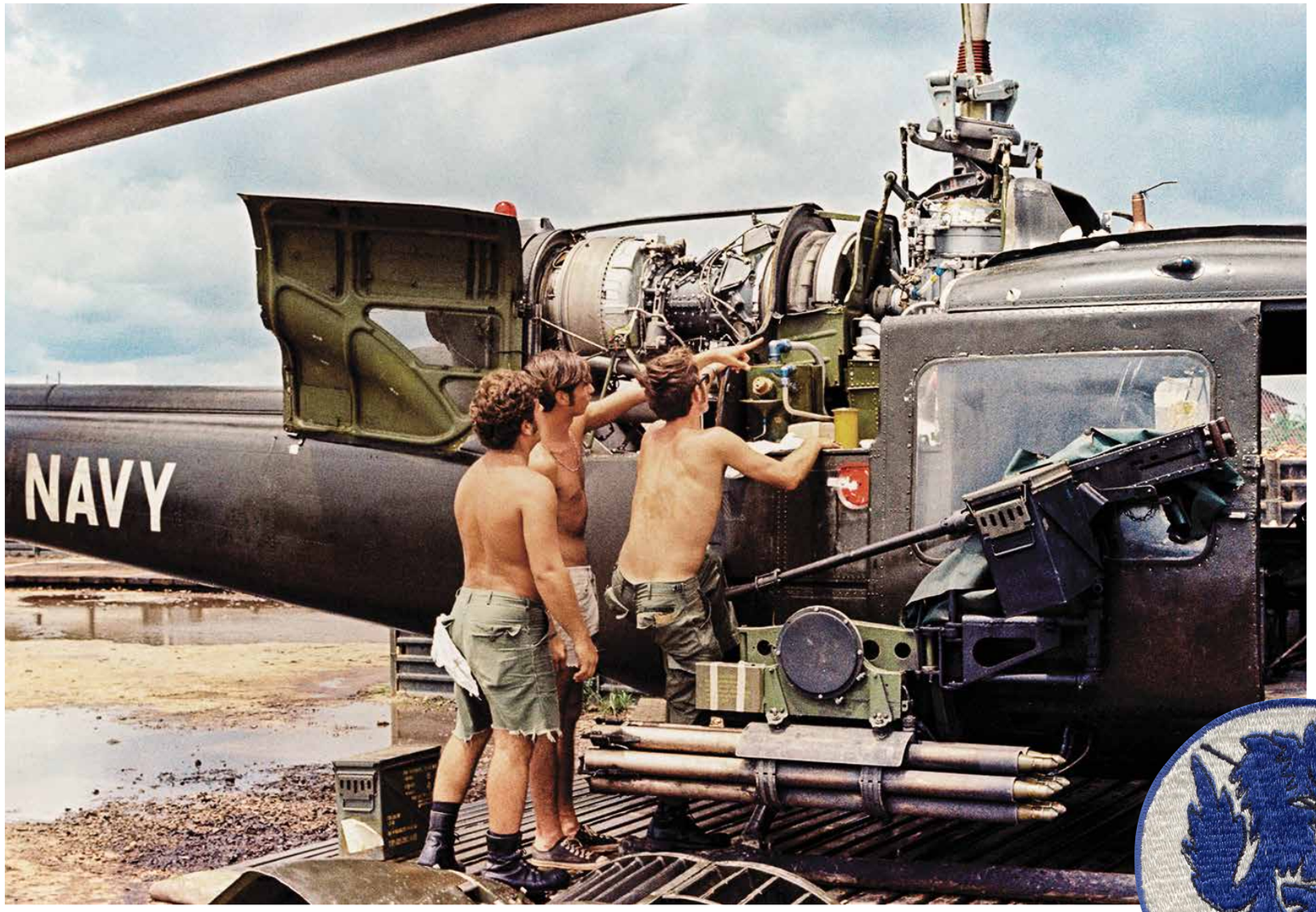
I have flown Rhinebeck's D.VII for 25 to 30 hours over six years. There's no doubt it was the best fighter of the war."

BACK TO CONTENTS

WHEN SEALS IN THE MEKONG DELTA NEEDED HELP, SALVATION CAME FROM A PAIR OF BEAT-UP HUEYS. BY ROBERT BERNIER

SCRAMBLE SEAWOLVES!

Two Bell UH-1Bs, flown by the Navy's lone helicopter attack unit in Vietnam, patrol the country's south on a 1967 mission to support Navy SEALs.



Seawolf detachments were largely self-supporting.

THE MEKONG DELTA is a vast, swampy system of more than 2,500 miles of rivers, canals, and streams covering the southern quarter of what was, before 1975, the Republic of South Vietnam. During the Vietnam War, whoever controlled the waterways controlled the area, and in 1965 communist forces did; the Viet Cong and North Vietnamese army (NVA) funneled troops and supplies around with near impunity.

That year, the United States, in the midst of a massive military buildup in Vietnam, began Operation Game Warden to take control of the waters. SEAL teams went in, backed by flotillas of river patrol boats (PBRs). Flat-bottomed, World War II-era amphibious ships, able to navigate the rivers, were hauled out of storage and reconfigured to serve as floating bases—one-stop shops with everything commanders needed.

The enemy fought back fiercely with armed junks and ambushes sprung from concealed positions ashore. To survive, the boat crews and special forces teams would need close air support, and the aircraft best suited for the job were dedicated helicopter gunships. There was just one problem: The Navy didn't fly gunships.

In early 1966, Army UH-1B Huey gunships were temporarily assigned to a dock-landing ship, the USS *Belle Grove*, to support Operation Game Warden. The Army aviator's tenure on the ship was only about five months, but the men used the time to develop many of the tactics later used by the Navy, and gave their contingent a nickname: the Sea Wolves (later compressed to one word: Seawolves). When

LARRY (FARK) FARRELL; PATCH: TAILHOOK ASSOCIATION

the Army left, the Navy kept eight of their helicopters—and the nickname.

The Navy crews, trained by the Army and equipped with the borrowed Hueys, got into their first big battle on October 31, 1966, when two patrol boats stumbled upon a fleet of around 80 sampans and junks that were transporting a Viet Cong battalion. In the ensuing battle, the Seawolf gunships sank 15 boats. Both PBR crews made it out safely (one boat crewman was awarded the Medal of Honor), and the Viet Cong suffered heavy losses. These seasoned crews formed the nucleus of the Navy's only dedicated helicopter gunship outfit of the Vietnam War, which on April 1, 1967, was formally anointed Helicopter Attack (Light)-3. Equipped with the UH-1Bs (by that time retired by the Army in favor of newer models), HA(L)-3 was split into seven detachments (later expanded to nine) that were scattered throughout the Mekong Delta, based afloat or at small outposts on mosquito-infested riverbanks. For mutual support, two helicopters always flew together in what were called fire teams, with two crews per helicopter on alternating 24-hour alert shifts. Detachments ("dets") were expected to be self-supporting, so the gunners also served as maintenance men. "We were all selected from different trades," says Mike Dobson, an aviation electrician's mate–turned–gunner. "Everything was done in-house." The crews were tasked as the primary quick reaction force for PBR crews or SEALs in trouble.

The waterways had few radio navigation aids or outstanding landmarks,

In Moc Hoa, maintainer-gunners worked on ships that flew raids into nearby Cambodia.

GARY ELY

so learning the pattern and layout of the waterways was critical. Fire teams patrolled up to four times a day to familiarize themselves with their operating areas. Like cops on a beat, they came to know their neighborhood's routines intimately. Seawolf gunships were among the most heavily armed Hueys in Vietnam. In addition to the door gunners, there were one or two forward-firing machine guns and a rocket pod on either side. Although the 2.75-inch folding-fin rockets packed the biggest punch, many pilots considered door gunners the best weapons aboard. "The Seawolf claim to fame was its gunners," says pilot Tom Phillips. "Our door gunners were astonishingly accurate, and could quickly rearrange an enemy's priorities from shooting us down to survival." The helicopters were unprotected from behind, and the Viet Cong quickly learned to let them pass overhead before opening fire. In response, door gunners developed an unofficial technique: Once the enemy started shooting, they stepped outside onto a skid with a customized M-60 light machine gun in their arms.

As the Seawolves became known in the delta to friend and foe alike, the Viet Cong grew more cautious whenever a helicopter was overhead. "I heard that a Viet Cong bounty was placed on aircrew types, and that Seawolves were on top of the list," says gunner Gary Ely. "That was always on my mind." (Among aircrew in Vietnam, such rumors were common but largely unproven.)

Floating Bases

Flying the underpowered, overloaded Hueys from the converted ship's tiny helipads was a challenge.

During launch, if the winds weren't just right, the gunship would dip dangerously close to the water. Any Seawolf veteran invariably mentions the region's heat and humidity, conditions that degrade a helicopter's performance."We had some pretty damn good pilots in the seats of those Hueys," reminisces Ely. "I flew with plenty before and after, and rarely were any as good."

Weight was so critical that sea-based gunships reduced their fuel and weapons loads, compared to what their land-based counterparts carried. Gunners became adept at quickly jettisoning rocket pods and/or dumping ammo boxes whenever they felt they were about to crash—which they occasionally did.

Those takeoffs "were thrilling, I'll tell you," says gunner Bob Christenson. Pilots, too busy flying to make the jettison call, depended on gunners who would. "Every takeoff, I would have my finger in the jettison ring of my side's rocket pod," Christenson recalls. "The other gunner would be ready with his. I dumped pods once, ammo boxes more often. It was something I never expected to be doing in my life." Christenson said he knew when they were in trouble by the rotor's sound and "hair rising on the back of my neck."

"Nighttime takeoffs were the hairiest," remembers pilot Rick Sadlier. "We were on instruments from the time we got a launch signal, and it was blacker

than hell out there. Dipping nose-down over the side of the ship was like flying into a cave."

Tet '68

Jack Williamson was a door gunner with a Seawolf detachment flying from an Army airfield near the Vietnamese provincial capital Vinh Long. In January 1968, despite a weeklong ceasefire so both sides could celebrate Tet, marking a new year on the Vietnamese lunar calendar, there were persistent rumors that the Viet Cong were going to hit the base. On January 30, an Army gunship had to make an emergency landing next to the Seawolf compound; it was so shot up it seemed an omen. Williamson helped lift a wounded gunner out of the Huey. The pilot of the gunship asked, "Are you a gunner?" When Williamson answered yes, the response was a terse "Get in."

Later that night the rumor came true: Vinh Long was hit as part of a massive series of attacks all over South Vietnam, and what became known as the Tet Offensive was under way. "All hell broke loose about midnight," recalls Williamson. "Charlie was on the base, it was bad, with bullets flying and mortars landing everywhere." The base commander and his first sergeant were killed, and the airfield nearly overrun. "We took a lot of casualties," says Williamson. "I saw a lot of body bags filled with our guys."

With the Army short-handed, Williamson spent the next few days flying with them in a grim fight to save the airfield and nearby garrisons. One mission involved escorting a Dust Off medevac chopper to Song Phu, a village that had been overrun and burned down by the VC. On a bridge hastily fortified with an armored vehicle parked at each end, surviving defenders and their U.S. Army advisers were making a last stand.

The Army Hueys approaching the bridge began taking small arms fire. "We took four or five rounds through the belly of the gunship," says Williamson, "and when we took hits through the floor, you'd feel it." Williamson remembers shooting along the treeline, trying to keep enemy heads down. The medevac picked up a wounded soldier and hurried to the nearest hospital. Williamson, then 20 years old, was the "old man" aboard; the others on the helicopter were only 19.

Once back with the Seawolves, Williamson was in continual combat. "There were 16- to 18-hour days where I came back blackened by gun soot," he says. "Army guys were great, but our pilots were better trained for night missions, so we flew a lot of nights during Tet."

Fast off the Mark

When the call "Scramble Seawolves!" went out, crews prided themselves on getting airborne quickly, the goal being two minutes or less. Pilot Tom Phillips still recalls his personal best: "From rack to air in 90 seconds."

"Everything was set up and ready to go," says Gary Ely. "We slept near the birds, so we could scramble in two to three minutes when the horn went off."

Most days followed a routine. "We'd start out in the morning," says Jack

Right: On its way to a target, a Seawolf gunship fires a 2.75-inch rocket. Seawolf Hueys were heavily armed; in addition to rocket pods, they had side-mounted M-60s ("flex guns") and door guns. Above: Seen through the windscreen of an approaching Det 9 helicopter, clusters of barges wait in the Mekong River, where they hosted a several detachment.

Williamson; "If we didn't have any calls to respond to we'd just patrol up and down the river. Most of the time those patrols turned into being fired on. We'd go into action for a short time, but occasionally it was just a quiet up and down the river. Basically it was the same thing every day." The Seawolves hauled supplies to remote outposts, provided air cover to PBRs, and acted as taxis for SEAL teams. But sometimes they were called for tasks they didn't expect and weren't meant to do.

While leading a patrol along the Bo De River in the summer of 1969, Lieutenant (junior grade) Rick Sadlier received a call from a PBR that had been ambushed from hidden Viet Cong shore positions.

LEFT: GARY ELY; RIGHT: TAILHOOK ASSOCIATION

Fighting their way out with a gravely wounded sailor aboard, the patrol boat skipper called for an immediate medevac. Sadlier promptly led his fire team into the fight, firing guns and rockets to suppress enemy fire. "We were not normally in the business of rescue," says Sadlier. With his wingman laying down covering fire, Sadlier hovered over the bobbing stern of the moving boat as sailors hoisted their wounded shipmate up toward the helicopter.

Between shoreline and helicopter, a web of tracer fire—red from the American guns, green from the enemy's—filled the sky. While one of the gunners blazed away, the other reached down and pulled the wounded sailor aboard. Sadlier watched as tracers from an enemy heavy machine gun arched toward him. "They looked like tennis balls coming at me," he recalls. After perhaps two anxious minutes, the sailor was safely aboard. Sadlier dipped to the left and skimmed the trees until the gunfire was safely behind him. The Huey escaped unscathed and delivered the wounded sailor to a field hospital in Binh Thuy.

Even by military standards, the Seawolves were a close-knit bunch, all volunteers, mostly young. Bill Rutledge had retired from a tour as an enlisted man in the Navy, but missed life in the service. "I was hot and bored in Missouri when I heard about the Seawolves," he says. "At the recruiter's office in St. Louis, they told me 'Sign here. Now go get a haircut.' " After gunnery training, Rutledge was assigned as a door gunner aboard a Seawolf Huey in 1969. He would go on to fly 1,643 combat missions, and was awarded the Distinguished Flying Cross and two Bronze Stars.

First Responders

Lieutenant Paul Plumb, former Underwater Demolition Team (UDT) platoon commander, worked closely with the Seawolves. "They were all fantastic folks who would help out immediately," Plumb says. He vividly remembers one skirmish in August 1969, when his small team was discovered by the Viet Cong along the Cua Lon River and spent a tense night exchanging fire. The Seawolves could fly at night, "but it was a bit too dicey for a night rescue, so they came for us at first light," he recalls. "They were lifesavers, because we were out of everything except a few rounds of ammunition."

The rescues were occasionally above and beyond the normal call; Plumb saw one SEAL airlifted out by clinging to the bottom of a rope suspended from a gunship. "He had punctured his foot on a punji stick and couldn't walk," says Plumb. "And suddenly there he was, dangling beneath a Seawolf flying along the Cua Lon [River] to Seafloat and safety." (Seafloat was a group of barges connected to form a huge floating base.)

One dark night in late 1970, gunner Mike Dobson's fire team was scrambled off their Solid Anchor base to aid a SEAL patrol pinned down by a large Viet Cong force. The Seawolf fire team charged into action and kept the enemy at bay, but

when the wingman suffered an equipment malfunction leaving them unable to refuel, Dobson's crew was left covering the SEALs alone.

"The SEALs were in some serious kimchee," recalls Dobson. "They were

Detachments were stationed on ships like the USS *Harnett County* (above, lower right) so they would be close enough to the sailors and SEALs they supported to reach them quickly. Seawolf crews swapped 24-hour-alert shifts, ready to get both helicopters airborne within five minutes. Gunner Jack Williamson (above, top right), with M-60 and crew microphone. Jeff Wallin joined Det 2 (left) in Nha Be in 1971 (front row, second from right). The Seawolves were disbanded a year later.

LEFT: JEFF WALLIN COLLECTION; TOP RIGHT: JACK WILLIAMSON; BOTTOM RIGHT: GARY MORSE COLLECTION

running out of ammo, we were running out of fuel." Hearing only one gunship overhead, the SEAL commander radioed, "If you go, we'll be overrun as soon as it gets light." The gunship's crew unanimously decided to land by the besieged SEALs, share their ammunition, and make a stand together.

"If SEALs were in trouble, you never left," says Dobson. Fortunately they didn't have to stay: Two other Seawolf fire teams arrived just in time to extract the SEALs. Dobson's Huey, its low-fuel warning light lit, barely made it to a nearby outpost for an emergency landing.

Winding Down

In November 1971, when Lieutenant (junior grade) Jeff Wallin arrived at HA(L)-3's Detachment 2 in Nha Be, located in the Rung Sat Special Zone (a strategic river channel leading to Saigon), HA(L)-3 was in the process of winding down as the U.S. withdrew from the conflict. Wallin, a copilot, remembers the high morale among the crews who flew, lived, and partied together, a colorful group of people unconcerned with military spit and polish. An occasional flight crew member was Det 2's mascot, a monkey named Davy, usually found scurrying around the ready room. "Davy was a smart monkey," says Wallin. "Whenever the master arm switch for the forward guns and rockets was turned on, Davy would plug his ears. Davy knew loud."

Wallin still regales friends with stories about the battle-worn surplus Army Hueys that the Seawolves flew. While dropping off visiting civilians at Saigon's Tan Son Nhut airport in late 1971, Wallin's crew received a cheery radio call from an Army pilot: "Hey Navy, got shot down in that bird in Tet of '68."

At the height of their strength, in 1971, the Seawolves fielded 29 Huey gunships, supplemented by a smaller number of unarmed UH-1Ls, or "slicks," for logistics flights. At the same time, American forces started to withdraw from Vietnam, ending involvement in what was then the longest war in U.S. history. In March 1972, after five years of continual combat, the Seawolves were disbanded without fanfare at Binh Thuy. The last American combat troops left Vietnam a year later, and in 1975 North Vietnamese forces took Saigon. Though relatively unsung in the saga of the air war in Vietnam, HA(L)-3 was one of the war's most highly decorated units, and suffered high casualties: 44 men killed and more than 200 wounded.

Though HA(L)-3 was disbanded, the Navy was out of the special forces air support role for only a brief time. Today two Navy helicopter squadrons, HSC-84 and -85, are both dedicated to special warfare and combat search-and-rescue missions (HSC-84 is scheduled to shut down in this fiscal year).

Patrick Rodgers, an ex-Army Huey crew chief and the chief pilot of the Wings & Rotors Air Museum of Murrieta, California, was helping to rebuild a UH-1B when he discovered that many of its parts were from an original Seawolf Huey. "Man, this is rare," Rodgers thought. "Their story is not well known and kind

Former gunner Bill Rutledge hovers over San Diego in the Wings & Rotors Air Museum's restored UH-1B. Seawolf 321 has appeared at events across the country.

of intrigued me," he says.

In 2009, the museum's Huey was restored to flying condition as Seawolf 321 and now visits events around the country, sometimes with former Seawolves along for the ride. But while the early-model Huey in Navy markings is a popular attraction at airshows, it's not unusual for people to question the accuracy of its livery. Mechanic and museum marketing director Shayne Meder says that people confront the team, saying, "Oh, the Navy never flew those." "Well," says Meder, "then the education begins."

USS MIDWAY MUSEUM

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MEET THE DRONE THAT STAKED OUT OSAMA BIN LADEN'S NEIGHBORHOOD.

BY ED DARACK

IN 2009, after two weeks of being embedded as an independent journalist with a small team of U.S. Marines in Afghanistan, I ended up at Combat Outpost Monti, a 14-acre camp of tents, plywood huts, a few concrete bunkers and makeshift guard towers, and a helicopter landing area, all ringed by collapsible barriers. At the outpost, one of hundreds built in Afghanistan during the 13 years of NATO combat operations, the Marines were training and fighting alongside Afghan National Army soldiers. COP Monti was less than 10 miles from the Pakistan border, near the Federally Administered Tribal Areas.

My time with the team was just about

A composite photo shows the RQ-170, shot with a telephoto lens near Creech Air Force Base, Nevada, and an unidentified soldier at Combat Outpost Monti, Afghanistan, in an area where the drone likely flew surveillance missions.

BOTTOM: US ARMY/SGT 1ST CLASS MARK BURRELL; INSET: MARCO DIRKX

An early image of the drone, at Kandahar Airfield before 2010 (left). On display in Tehran, A model of the RQ-170, which Iran claimed to have reverse-engineered after the drone landed, with little damage, on Iranian territory. Its navigation system malfunctioned or was spoofed.

up when they were ordered to move up the Kunar River valley on a large combat operation. I stayed behind with the Afghan soldiers and, before I managed to find a ride out, weathered a mortar and rocket attack from combatants who had undoubtedly planned the attack and stockpiled the weapons for it at a site across the border, in Pakistan. Even if the Marines had still been there, they could not have pursued the attackers. Al-Qaeda, Taliban, and other belligerents have hidden from the U.S. military in Pakistan's tribal areas, with varying success, since Americans entered Afghanistan in 2001.

"Everybody knows that the Taliban and other groups train, raise money, plan operations, and even recruit in the tribal areas of Pakistan," says a retired U.S. infantry officer who served two tours in Afghanistan as well as a rotation in Iraq. (All of the sources quoted in this article spoke to me on the condition that I would not name them because they do not have permission to speak on the record.) "The insurgent leadership move men and materials into Afghanistan and attack American and coalition forces and assets." Then, he says, they scurry back to Pakistan, where U.S. forces can't follow.

At least, not on the ground.

Since 2004, the United States *has* followed insurgents into Pakistan, and has spied on and sometimes killed them there. The CIA flies Predator and Reaper unpiloted aerial vehicles over the tribal

LEFT: ANONYMOUS; RIGHT: THE OFFICE OF THE SUPREME LEADER, IRAN

districts, often with the approval of Pakistani leaders, who have enemies of their own among the militants inhabiting the country's northwest. Some missions though are conducted without approval from Pakistan's authorities. For those missions, the CIA needed a different aircraft.

In late 2007, reporters and observers at Afghanistan's Kandahar Airfield discovered that a new spy had joined the team. Grainy photographs emerged of what appeared to be an unmanned flying wing. Aviation reporter Bill Sweetman (who writes a column for this magazine) nicknamed the aircraft "the Beast of Kandahar," and the name has stuck, though the airplane doesn't have the ferocity or power of a beast. It is an unarmed, stealthy observer designed to glide silently over its targets and transmit photos, video, and other intelligence to a worldwide network of users. The Air Force acknowledged it in 2009 and revealed its official name: the Lockheed Martin RQ-170 Sentinel.

The RQ-170 is operated by the U.S. Air Force 432nd Wing, which also operates Predators and Reapers. The 432nd, stationed at Creech Air Force Base, northwest of Las Vegas, declined to speak about the Sentinel, and a spokesperson for Lockheed Martin would state only that it is a "low-observable Unmanned Aerial System" and that its "primary mission is Intelligence, Surveillance and Reconnaissance."

Trying to put together a picture of how the RQ-170 might have been used in the mysterious Afghanistan-Pakistan border region, I spoke to a U.S. military pilot who had flown in the 2003 Iraq war and who had later served in a senior position in an unmanned aerial vehicle unit. "At the start of [Operation Iraqi Freedom], one of our missions was to fly right up against the Iranian border, with our targeting pods slewed to the side to scan for border activity," the pilot said. "We were right on the border, but we couldn't cross it. Their radar had us. We were doing ISR work, trying to figure out just what, if any, activity was taking place on and as far inside their border as possible." One type of activity the U.S. military was trying to follow and disrupt was the Iranian manufacture of devices called EFPs—explosively formed penetrators—and their distribution to enemies in Iraq and Afghanistan.

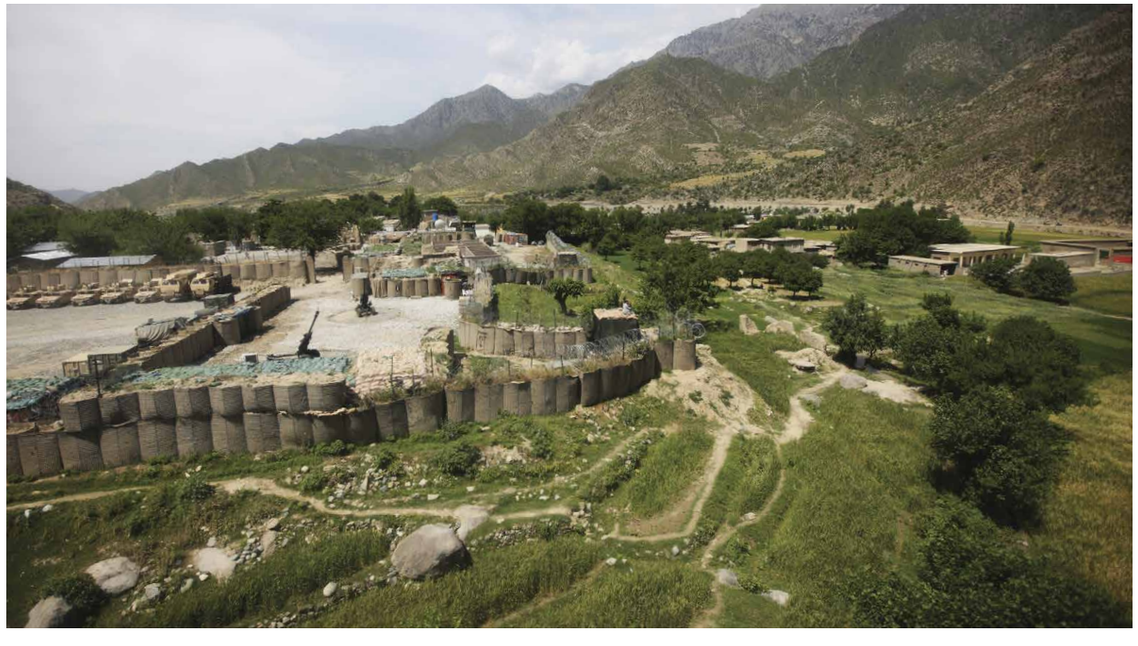
Historically, insurgencies have required bases of support outside the contested country. "When discussing the RQ-170," the pilot continued, "you have to understand that both Pakistan and Iran are outside of the ISR grasp of a targeting pod on an aircraft flying on the border, or of satellites. Sheer distance degrades certain aspects of a satellite's ability to observe."

The United States needed an intelligence-gathering platform that could avoid detection by Iranian and Pakistani radars. A retired military aviator who held a senior position at Kandahar Airfield during Sentinel operations pointed out that the UAV's size and shape give it a low radar cross-section—the measure of the amount of energy a target reflects toward the radar that illuminated it. "It's a large airfoil, roughly 65 to 70 feet in length," he said. "Being a main wing only, with no fuselage and tail surfaces, drastically reduces both its radar signature and aerodynamic drag." The Sentinel has the stealthy form of the 172-foot-span B-2 bomber, but is less than half its size.

At medium altitudes, the Sentinel's light gray color enables it to blend in with the sky. It must also be quiet enough that it won't be heard on the ground. An aviator who held a senior position at Kandahar Airfield during the Sentinel's operation said its sound during takeoff wasn't loud but distinctive—different from the propeller-driven UAVs and military jets that operated from the airfield.

Engine noise or heat can never be eliminated but can be reduced. "[A stealth UAV] would use a high-efficiency turbofan engine, and its exhaust would be spread out as much as possible, masking both heat and noise," the aviator said. A nozzle that spreads the exhaust elimi-

Because the Sentinel is manufactured by the company that brought us the F-22 stealth fighter and F-35 Joint Strike Fighter (and, before that, the F-117, SR-71, and U-2), we can assume that its skin uses radar-absorbent materials to further diminish radar return. Although its shape and materials keep it invisible to some radars, the aviator explained, others would be able to detect the aircraft but might not be able to track or target it.



Mountains near Combat Outpost Monti have been havens for Taliban fighters. The MC-12 (above, at Bagram Airfield) and other aircraft gather data on their activity.

TOP: US ARMY; BOTTOM: ED DARACK

nates concentrations of heat and helps mix hot exhaust with cooler ambient air.

An earlier, short-lived Lockheed Martin stealth UAV, the RQ-3 DarkStar, used a Williams-Rolls-Royce FJ44-1A turbofan, an engine favored for 1990s-era business jets, whose manufacturers claimed noise reductions. But those reductions were due partly to a change in the jets' takeoff and landing profiles. Flight profile, according to an expert in unmanned aerial systems, is key to maintaining low observability. He explained that to fly low over a location of interest, an aircraft would most likely be put into a shallow descent, with its engine throttled back, so that it would essentially glide over the target. After one pass, "it will turn and gently increase power, but in a geometry such that nobody at or near the target could hear." Once back at a higher altitude, the Sentinel would, if necessary, set up for another pass. This description suggests that maintaining continuous observation of a location would require two, possibly three, Sentinels flying overlapping patterns, not a sole craft orbiting.

IN DECEMBER 2011, one or several of the Sentinel's stealthy protections could have failed: An RQ-170 was taken prisoner in Iran. It had been on a reconnaissance mission and landed within the country, mainly intact, a few hundred miles from its home runway at Kandahar Airfield. The Iranians seized it, put it on display, and broadcast claims that they had spoofed its guidance system. Another possibility is that the UAV lost power or that its guidance system simply malfunctioned, an explanation that several Pentagon officials offered the press in the days after the incident.

"These systems have trip wires," an aviator explained. "They're meant to automatically return home, or at least to friendly airspace. But you have to consider: Was there a possibility of an oversight that the Iranians figured out they could exploit?" The guidance system, he noted, likely uses a combination of GPS and inertial navigation. With inertial navigation, highly sensitive accelerometers and gyros determine a craft's route in three axes. Inertial systems cannot be fooled, though they can drift. GPS signals and guidance systems can be jammed or fooled; receivers can be sent signals making the onboard navigation system believe that the aircraft's home airport is hundreds of miles from where the airport really is.

In 2008, at a Marine Aviation Weapons and Tactics training exercise outside Yuma, Arizona, a GPS guidance unit was accidentally spoofed, with a near-disastrous result. The unit was attached to a Containerized Delivery System, a pallet with stuff to resupply ground troops—food, ammunition, water—that had been released from a C-130 transport, and was tracking a GPS signal so it would arrive at a certain point on the ground. In the exercise with the C-130 were a number of airplanes and helicopters, many of them using electronic jamming equipment or testing electronic warfare systems. In the signal-rich environment, the CDS, instead of landing at its programmed landing point, was heading straight for the Chevy Suburban that was waiting to return the pallet to base. Seeing the CDS headed for him, the Suburban driver stepped on it, but he wasn't fast enough; the cargo crashed into the back of the van. The driver was uninjured.

Reporters have surmised that the Sentinel was in Iran to gather information about Iranian progress in developing

SEE, HEAR, SNIFF How airborne spies collect intel.

Spyplanes are filled with gizmos that gather information in three major ways.

IMINT Imagery Intelligence Still and video cameras as well as other sensors on satellites and aircraft create images of Earth's surface. The instruments can passively detect radiation in visible, infrared, even ultraviolet ranges of the spectrum or actively illuminate targets and capture the reflection. Because the RQ-170 is intended to be stealthy, its suite of imagery collection devices is almost certainly passive. (Radar and other active illuminators are the equivalents of shining flashlights in the dark, allowing sensors on the ground to detect an airplane's presence.)

SIGINT Signals Intelligence Antennas also collect a range of electromagnetic radiation, including cellphone conversations, text messages, two-way radio conversations, automated telemetry (for example: regularly transmitted diagnostic data on a fuel pipeline), Wi-Fi signals, and other forms of wireless data. This raw data goes to a processing facility, where systems decrypt (if necessary), analyze, and prepare a deliverable intelligence "product." Not all SIGINT collectors look like flying cellphone towers; some, like the F-22 Raptor, have antennas embedded in their skin.

MASINT Measurement and Signature Intelligence A senior military intelligence officer calls MASINT "the least known and understood, but arguably the most reliable form of intelligence, and one of the most important." Some sensors detect uniquely identifying spatial and temporal intervals and timing patterns in electronic transmissions; others detect uniquely identifying chemical and elemental signatures of substances and materials; still others collect data that enable analysts to identify a target by the way it moves.

The RC-12 Guardrail, the same airframe as the MC-12 Liberty (Beechcraft Super King Air), carries antennas for SIGINT.

US ARMY

nuclear weapons. Satellites can detect nuclear detonations, but to passively sniff for isotopic and other signs of uranium enrichment, analysts would need a platform much closer to the ground. Although reporters have also speculated that the Sentinel, to keep from being

A sensor operator watches the feed in an MC-12 Liberty; sensors on the RQ-170 are controlled from the ground.

On a satellite image, Osama bin Laden's compound (outlined) appears tiny; intel officers would want a closer look.

heard, flies upwards of 50,000 feet, it probably flies much lower—to be closer to its targets of observation. "Most aircraft are inaudible above 8,000 feet," says a Department of Defense UAV expert. He explains that if a sensor is operated at a high altitude, it needs to be much larger and heavier to obtain the same degree of accuracy as smaller, lighter ones operating at low altitudes.

My own experience in Afghanistan suggests other missions the RQ-170 might have flown. I often heard intelligence officers or patrol commanders request "a pattern of movement" or a "pattern of life" for targets and enemy forces. To provide that information, analysts would draw data from a number of types of surveillance and reconnaissance aircraft (see "See, Hear, Sniff," above). Learning about the capabilities of these aircraft helped me understand the kind of surveillance the Sentinel might perform.

One of the most important reconnaissance aircraft collecting data for the coalitions in Iraq and Afghanistan is also one of the least known: the Northrop Grumman RC-12 Guardrail. "The Guardrail is probably the most boring-looking airplane in the Department of Defense, but in my opinion, it brings some of the most important capabilities to ground forces," said the retired infantry officer. The RC-12 is a Hawker Beechcraft Super King Air sprouting antennas to collect signals intelligence. "Looks like a flying porcupine, with all the antennas dangling off it," the officer said. He regularly requested the Guardrail's

LEFT: USAF/SENIOR AIRMAN ANDREW BUCHANAN; RIGHT: DIGITALGLOBE

listening capabilities to identify, locate, and track insurgents and to help develop ground operations. The Guardrail does not process the data it collects; instead, it transmits it via a secure satellite link to locations in the United States or, according to a U.S. Army fact sheet, in Germany or Korea, where the data is processed and the results beamed back to the aircraft, which transmits it to the commanders who requested it. It happens fast. Within a second, the system can identify an individual's or a group's precise location. It takes a little longer to record and analyze their transmissions.

"I've tasked all sorts of assets, manned and unmanned, to look at ground targets and areas of interest," said the infantry officer. For imagery intelligence, he said, "we used Predator a lot."

He also used intelligence from the MC-12 Liberty, another King Air, this one stuffed with a more exotic sensor suite than the Predator or Guardrail has, including a "complete collection, processing, analysis and dissemination system," according to its U.S. Air Force fact sheet. The Liberty is brought to bear when commanders want to know what's going on inside a building, whether people are "manufacturing explosives, packaging opium, or something else," the officer said. The MC-12 "can sniff things out based on their chemical or metallurgical signatures. They're incredibly accurate."

But they aren't stealthy and can fly only in airspace where the enemy has no radar. So is the purpose of the RQ-170 to carry any combination of the instruments deployed on the Predator, Guardrail, and Liberty into places where those three aircraft can't go? A former unmanned aircraft systems commander answered: "Yes, definitely."

The expert pointed out the two bumps on the top of the craft: "Not one antenna but two, so it can be serving multiple, distinct tasks, simultaneously, for users all over the world."

WHEN I LEFT Combat Outpost Monti—on a blue and white Bell B412 helicopter flown not by the U.S. military but by a Canadian contracting company working for the military (with the call sign "Molson Air," for the Canadian beer)—we flew for roughly 15 minutes, then landed in a field next to a compound outside a small village. I checked my GPS; we were idling about a half-mile from Pakistan. Two U.S. military personnel, wearing camouflage and helmets unfamiliar to me, climbed aboard the helicopter. We then continued the journey to Asadabad.

After returning home, I got an inkling of what those guys in unfamiliar camouflage might have been doing there near the Pakistan border and how they may have used the RQ-170. I learned about counter-terrorism units in a program called Omega, which combined special forces with CIA teams for missions into Pakistan to conduct raids on Taliban and other insurgent and terrorist targets. Putting this information together with what my sources had described, I had little doubt that intelligence about those targets was gathered in part by Sentinels.

The joint CIA–special operations forces mission that would best show off the RQ-170's surveillance capabilities was conducted years later, in support of the SEAL team who, on the night of May 1, 2011, flew into Pakistan on two modified Black Hawk helicopters,

The RQ-170 Sentinel stands out in the clear blue sky above Nevada, where the drone is operated by the 432nd Wing.

entered a compound in Abbottabad, and killed Osama bin Laden. U.S. government officials told *Washington Post* reporter Greg Miller that stealth drones had flown dozens of missions to monitor the Abbottabad compound.

"The beauty of how intelligence gets disseminated with the systems we have in place is that you just request an intelligence product, and you get it based on classification level and need-to-know," says the aviator who served in a senior position at Kandahar Airfield. "You don't ask for a platform, just a product. Much of the time intelligence users won't know they are seeing something that was sourced from a Sentinel."

The Sentinel is one platform in a complex intelligence system that collects information from every U.S. military command around the world. Analysts at various centers process 20 terabytes of data, of all intelligence types, every day. "Once each type is processed into a product, then it gets fused together with other intelligence products to give a multidimensional picture," the aviator says.

"Think of a compound, say in Abbottabad, Pakistan, one with some walls that imagery shows to be 16 feet high. Combine that knowledge with signals collections of those in and around the structure, learn the pattern of life, maybe pick up a tall guy walking around, and maybe do some sniffing for weapons in the compound, soak up computer noise that can be analyzed, and then put that together with some human intelligence gathered on the ground about who that tall guy is." He laughs. "There you go."

MARCO DIRKX

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LIFE IN THE UNIVERSE SPECIAL

WOULD WE KNOW ALIEN LIFE IF WE SAW IT?

AND HAVE WE ALREADY SEEN IT ON MARS? BY TRUDY E. BELL

AT THIS MOMENT, seven robotic spacecraft are roving or orbiting Mars, taking photos, gathering data, and generally doing the bidding of scientists back on Earth. After 15 years of this continuous robotic presence, we know the Red Planet better than any world besides our own. And planetary scientists have an answer, finally, to one of their oldest and most fundamental questions: Could Mars support life?

The answer is yes: certainly in the past, and very possibly today. In 2013, less than a year after Curiosity touched down in the ancient lakebed Gale Crater, John Grotzinger, the project's principal investigator, announced with confidence: "We have found a habitable environment," one where substantial amounts of surface water existed billions of years ago. What's more, the Curiosity science team is convinced that the lakes and streams lasted for long periods, perhaps millions of years.

Another announcement, just as momentous, followed last September: Water still flows on Mars today—at or very near the surface. For more than a decade, NASA's strategy in exploring Mars has been to "follow the water"; the agency reasons that

Scene from a desert planet: a panoramic view of the Payson outcrop near the Opportunity rover's landing site. With its ocean long gone, Mars may yet have liquid reservoirs underground, and spacecraft have seen signs of surface flows. Life, if it ever existed, most likely followed the water.

NASA/JPL-CALTECH/USGS/CORNELL

wherever there's water, we might find life. Now, having made the case for water, space agencies are preparing to launch Mars missions whose primary purpose is to search for evidence of biology. And, unlike earlier searches, these missions have a real chance for success.

In the 1960s, the first generation of planetary scientists tried to come up with a single suite of instruments (for what became the 1976 Viking landers) that could settle definitively whether life exists on Mars. Ultimately, they failed. Scientists now suspect that past experiments in Martian biology asked questions that were too narrow or even wrong.

"Defining life is a problem," explains Carol Cleland, a University of Colorado philosopher who has spent more than a decade examining the scientific and philosophical literature on the nature of life. "If your definition is wrong, you'll look for the wrong thing—and be liable to miss all kinds of weird forms of life. Even today, we haven't gotten away from an Aristotelian definition."

More than 2,000 years ago, Aristotle defined living beings as those that metabolize (consume nutrients and eliminate waste) and sexually reproduce. That definition served well enough until the middle of the 20th century, when scientists learned about DNA and came to understand that the predominant life-form on Earth is the single-cell organism. (Indeed, complex multicellular life doesn't appear in the fossil record until less than a billion years ago.)

Many single-cell creatures defy Aristotelian ideas about metabolism and reproduction. Some don't consume organic nutrients at all. A bizarre marine microbe called *Shewanella*, for example, gets its metabolic energy by using "nanowires" that draw electrons directly from rocks. Some organisms don't need sex to reproduce: They "fragment" directly from the parent. Still others act as if they're alive at some times, dead at others. Viruses, for example, can lie dormant for centuries in a crystalline state.

In the past few decades, scientists have found many "extremophiles," which survive quite nicely in environments once thought to be lethal: in superheated geysers, on the bottoms of Antarctic glaciers, in the crushing blackness of the deep ocean.

If terrestrial life has turned out to be far stranger and more adaptable than we once thought, how much weirder could it be in an alien biosphere like Mars?

Yet there's reason to hope we'll find familiar organisms too. "The argument for water-based and carbon-based life is never stronger than on Mars," says David Des Marais, principal investigator of space science and astrobiology at NASA's Ames Research Center in California. "Some folks like to speculate that solvents other than water *might* also support life," he notes. "While one can never absolutely deny the possibility of 'weird life' based on an alternative solvent, water is particularly favorable for Mars because the environment of Earth has been more similar to that of Mars than that of any other planet in our solar system."

Since we have to start somewhere, Des Marais and others argue that we should look for familiar forms of life first; we can worry about the life-forms we don't know later. "Pick your best shot " for success, he says.

Haven't we done this before?

On July 20, 1976—the seventh anniversary of the Apollo 11 moon landing—NASA's Viking 1 set down near the equator of Mars, the first fully successful mission to the planet's surface. Six weeks later, its twin, Viking 2, landed, a bit farther north, on the opposite side of Mars. Panoramic images from the two stationary spacecraft (there were no wheeled rovers on this first expedition) confirmed a pebble-strewn, desert landscape devoid of any obvious signs of life.

Each Viking was equipped with a scoop for digging shallow trenches in the Martian "soil" (actually sandy regolith bombarded by ultraviolet radiation; it bears little resemblance to terrestrial topsoil) to obtain samples for three experiments inside the spacecraft that were designed to look for evidence of biological activity. A gas exchange experiment fed nutrients and water to the soil samples and looked for signs that organisms either consumed or released one of the nutrients. A pyrolytic release experiment exposed soil to light and a synthetic Martian atmosphere tagged with radioactive carbon-14, then removed the atmosphere and cooked the sample to release gases that were examined for evidence of biomass containing carbon-14: a proxy for photosynthesis. Astrobiologists had their highest hopes for the labeled-release experiment: Soil samples were fed organic nutrients tagged with carbon-14, and the air around the sample was monitored for radioactive carbon dioxide, which

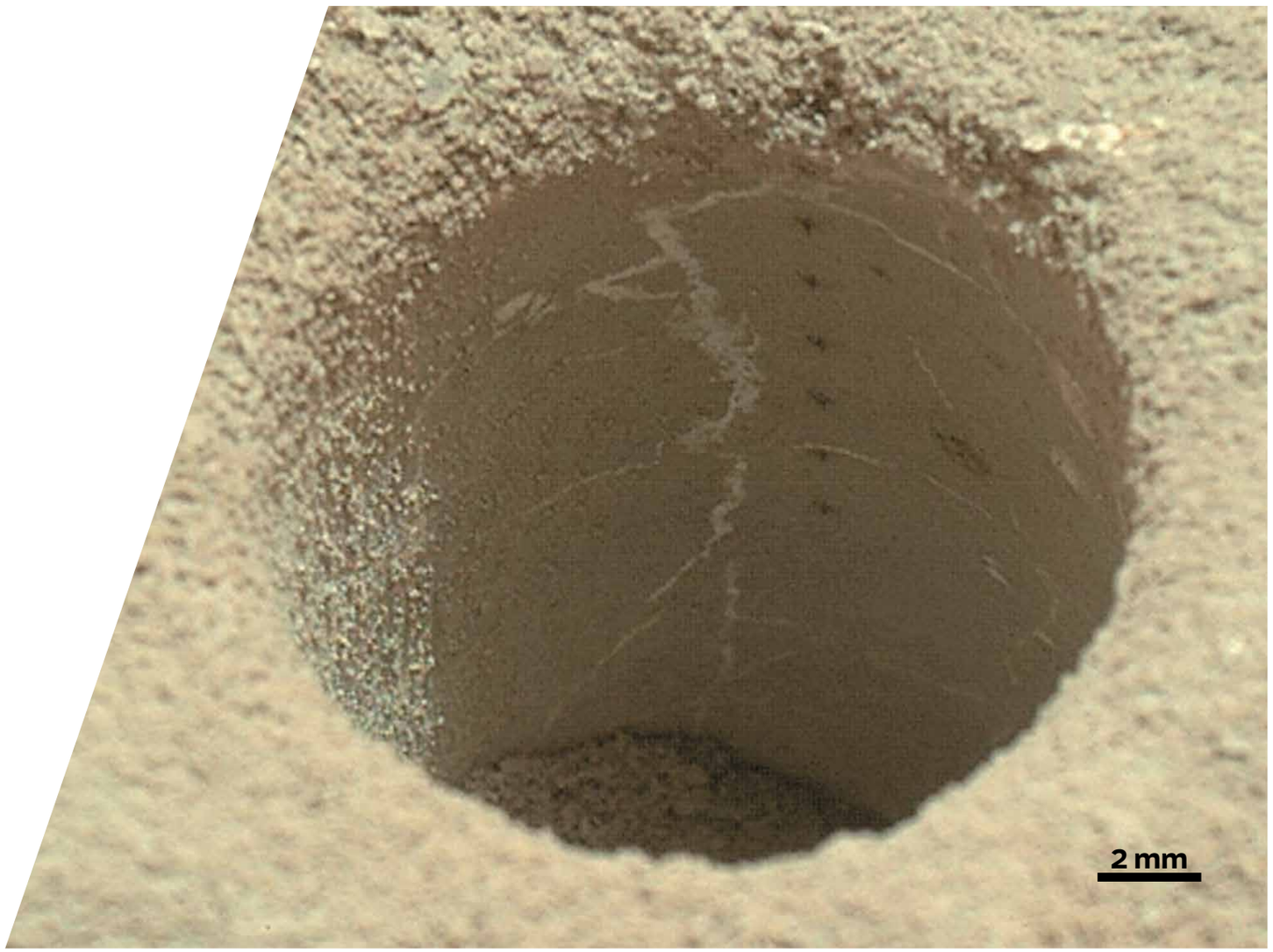
Curiosity drilled a hole in a rock called Cumberland to examine its chemistry.

NASA/JPL-CALTECH/MSSS

would have been exhaled by metabolizing microorganisms.

The results frustrated everyone. The gas exchange experiment was negative for microbes but suggested that the soil has highly reactive chemical compounds. In the pyrolytic release experiment, one sample was positive, but so was a control sample that had been sterilized, suggesting that something other than biology was at work. The labeled-release experiment on both spacecraft detected carbon dioxide at first, but not again when retried a week or two later. And the clincher: a non-biological experiment—a gas chromatograph–mass spectrometer (GCMS)—saw no trace of organic materials in the Martian regolith. This was a surprise, since organic molecules are common in meteorites, including rocks found on Earth that originated on Mars. And the apparent lack of organic matter seemed to rule out any positive results from the biology experiments. Considering all these results together, the Viking science team issued its disappointing verdict: no life at either landing site.

Another rock called John Klein from the same mudstone formation in Gale Crater contained organic molecules—the first positive detection on Mars.



NASA/JPL-CALTECH/MSSS

Did the Viking experiments work right? Was the GCMS broken? Did harsh solar ultraviolet radiation (Mars has no protective ozone layer) or some unknown chemical such as a strong alkaline oxidizer (think bleach) destroy all organic molecules on the Martian surface? Or was the design of the three biological experiments too rooted in terrestrial assumptions, and the Earth-type nutrients and water poisoned or drowned Martian organisms adapted to a hyper-arid and otherwise un-Earth-like environment?

For 40 years the ambiguous Viking results have fueled scientific debate. Gilbert Levin, principal investigator for the labeled-release experiment, is convinced to this day that Vikings 1 and 2 found evidence of life on Mars. NASA's Phoenix spacecraft, which landed near the planet's north pole in 2008, re-started the argument when it confirmed that the chemistry of the Martian soil may in fact destroy organic material—which could explain at least some of the Viking findings.

The main culprit seems to be perchlorate salts, a highly reactive oxide of chlorine found at the Phoenix landing site. At the low temperatures prevalent on Mars, perchlorates would not themselves react with organic matter, but the planet's harsh radiation could split them into more reactive compounds. In 2013 Richard Quinn at the Ames center conducted experiments in which perchlorates irradiated with gamma rays seemed to reproduce the puzzling findings of the labeled-release experiment.

Although perchlorates might destroy organic compounds exposed to radiation on the Martian surface, could microbial life exist protected within rocks or underground? In fact, last year Curiosity's Sample Analysis at Mars (SAM) instrument discovered two types of complex organic molecules in powdered samples drilled from inside a mudstone at Gale Crater. One molecule even resembled a fatty acid found in the cell walls of terrestrial organisms. Although the Curiosity scientists made no claims about Martian life, we now have proof that under certain circumstances, organic molecules can survive on the planet.

Where to go, how to look

Whether the search is for current life or for fossil evidence of past life, "follow the water" continues to be a useful strategy. Fortunately, in the 40 years since Viking, scientists have found abundant evidence of water. Data collected from orbit and from the Spirit, Opportunity, and Curiosity rovers suggest that the planet once had an ocean with a volume greater than Earth's Arctic Ocean. And the water likely shifted over time. Mars' axial tilt—astronomers use the term "obliquity"—is wildly variable, and the large historical swings in obliquity, which occur on time scales of hundreds of thousands or perhaps a million years, "could also lead to global redistributions of water," says Dirk Schulze-Makuch, a professor of astrobiology at Washington State University. Redistribution may explain surface features that look to have been carved by running

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water within the past million years, long after the large ocean disappeared.

Imagery taken from orbit, going back to Viking, has shown morning fog and mist rising from the floor of Martian canyons, leading scientists to theorize that liquid water may still be trapped under the surface. (Schulze-Makuch even speculates that Martian organisms might draw water directly from the atmosphere.) And last September, high-resolution images from the Mars Reconnaissance Orbiter revealed that even today, water—actually, brine that can stay liquid at cold temperatures—

Curiosity's study of a formation called Whale Rock revealed evidence of flowing water, one of the main clues scientists look for to assess whether a site was once habitable.

flows down steep slopes in the Martian spring and summer.

The discovery that liquid water has persisted on the surface of Mars over long periods gives hope that life arose there, and that it found a way to adapt to harsh conditions, which changed as the surface water disappeared. "Life is a kind of planetary pest," says Schulze-Makuch. "An infestation, once started, is very difficult to get rid of." Invoking Carl Sagan's famous dictum that extraordinary claims require extraordinary evidence, he adds, "I think the extraordinary claim is that Mars always was sterile."

Within five years, NASA and the European Space Agency hope to test that optimistic idea. The next major mission to the surface of the Red Planet is ExoMars 2018, a joint project of the European Space Agency and the Russian space agency Roscosmos, which is supplying the Proton

NASA/JPL-CALTECH/MSSS

rocket. Currently slated to soft-land on Mars in January 2019 (or two years later if the launch date slips, as has been rumored), ExoMars will deploy a rover equipped with a drill capable of boring down six feet. The goal, explains Mark Sims, a professor of astrobiology and space instrumentation at the University of Leicester in England, is to obtain samples from depths at which they've mostly been shielded from intense radiation that would break organic molecules apart.

In choosing a landing site for ExoMars 2018, project scientists used orbital data to scout out places with sedimentary rocks, especially fine-grained clays, that clearly formed in the presence of water, as in an ancient lakebed. The ideal sample rock would be very ancient—four billion years old or so, buried most of that time, and only freshly exposed to Mars' harsh surface environment by erosion or a relatively recent landslide. The ExoMars project narrowed the potential landing sites to four, the top candidate being Oxia Planum, a smooth, flat plain with only a light dust covering, so more of the surface rock should be exposed. Here, 18 degrees north of the Martian equator, the ExoMars rover will look for evidence of biology.

Finding visible fossils—say, the remains of bacteria like those seen in some ancient Australian rocks—would be wonderful, but for a number of reasons extremely unlikely. For one, such fossils would almost certainly be too small for the ExoMars close-up camera to resolve. So just as Viking did 40 years ago, the ExoMars search focuses on chemistry.

The rover's main instrument for life detection is called MOMA, for Mars Organic Molecule Analyser. It will use two kinds of spectrometer to analyze drilled samples for traces of organic molecules, and scientists hope to be able to distinguish compounds associated with biology from those that are non-biological. The instrument will also analyze any organic compounds' chirality, or "handedness." Amino acids and other molecules exist in either right-handed or left-handed forms. All plant and animal life on Earth is based on left-handed amino acids (although some microbes can, in a pinch, consume the right-handed versions of nutrients). An ExoMars sample with a 50-50 mixture of both chiralities would imply geologic origin, whereas a predominance of one chirality over another would suggest a biological origin—that is, if Martian life also has a preferred handedness.

NASA plans to launch its fifth rover (a near copy of Curiosity) to Mars in July 2020.

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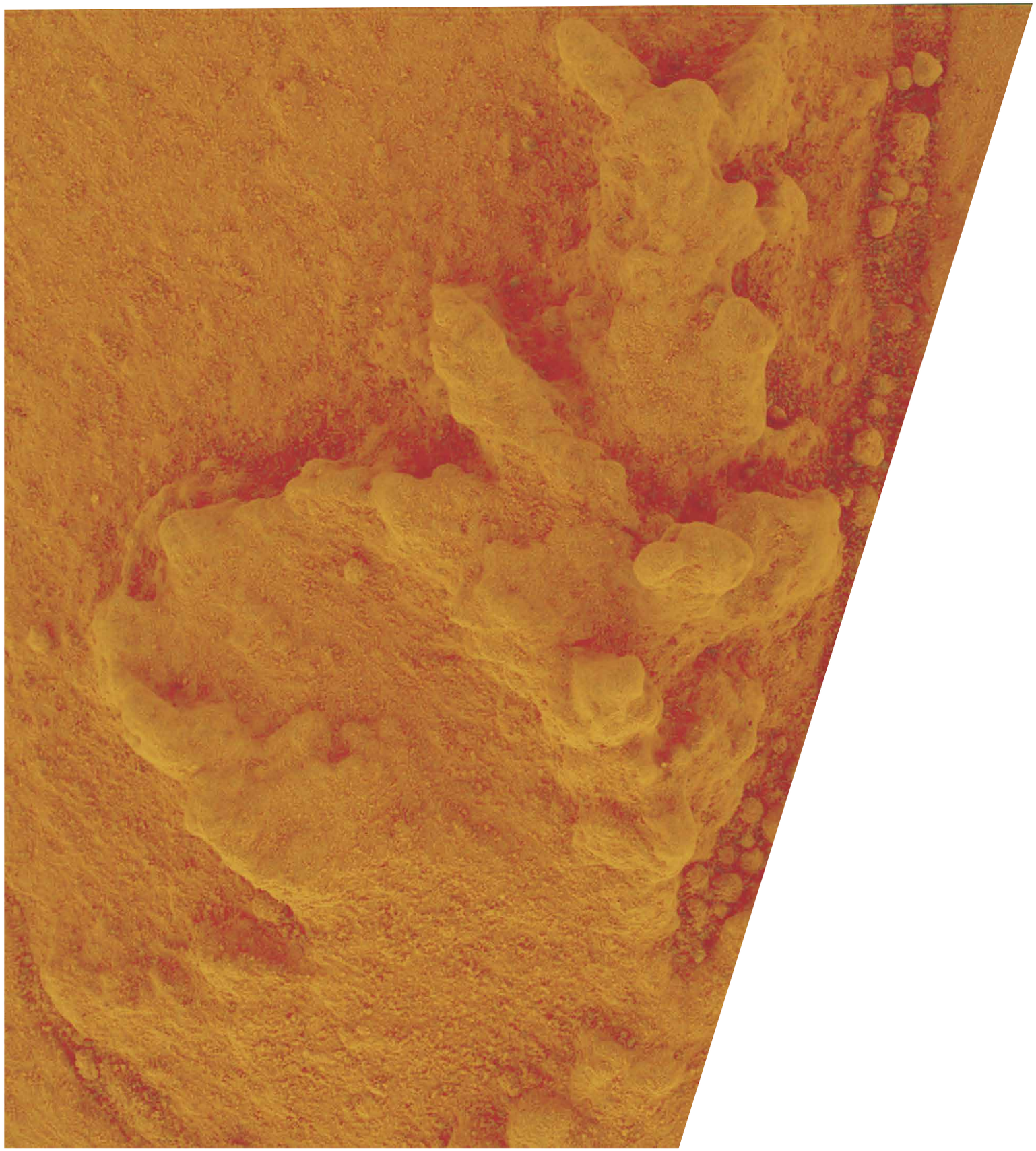
It will land seven months later and begin searching for rocks that can be sealed in a container and returned to Earth by a future spacecraft, still to be specified. Scientists have long hankered for a mission that can bring Mars rocks home, so they can analyze them on Earth with more sophisticated instruments than can fit on a lander. Mars 2020 is the first half of that mission, and it will be up to the 2020 rover to identify the precious few rocks that have the best chance of containing bio-signatures, or evidence of life.

The main life detection instrument on the 2020 rover is called SHERLOC, for Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals. Principal investigator Luther Beegle of NASA's Jet Propulsion Laboratory describes it as "a stand-off instrument" mounted on the rover's robotic arm. "We don't want to touch samples and possibly detect life we brought with us to Mars," he says. Instead, from two inches



More evidence of water on Mars: Close-up views show features like those left on Earth after water evaporates.

NASA/JPL-CALTECH/MSSS

away, SHERLOC will shine far-ultraviolet lasers on rocks to cause their constituent chemicals to either scatter light or fluoresce (emit light). The resulting spectrum should reveal the chemical fingerprints of any organic molecules in the rocks. Promising samples would be candidates for caching—again while taking steps to avoid contamination—and eventual return to Earth.

The Mars 2020 team has yet to choose its landing site—eight candidates are in the running. Selecting the right location is critical, since the two-part mission is a multibillion-dollar investment. If no biology is found at the 2020 site, or if the answer is muddled, as with Viking, critics might say NASA wasted its money going to the wrong place.

That's one of many potential pitfalls in the search for life on Mars. Because of budget constraints, not every proposed biology experiment can fly, so some worthy approaches to life detection will go untried. A "Life Marker Chip" originally picked for ExoMars 2018 would have used antibodies to detect organic molecules, similar to tests used in the medical world. But the payload was dropped along with several other instruments to save costs and reduce weight.

First, do no harm

Another constraint on scientists looking for Martian life: the "planetary protection" requirements. By international agreement, spacecraft landing in regions on Mars where water might exist have to be cleaned thoroughly before leaving Earth, for fear of exposing possible Martian organisms to terrestrial contamination or—equally bad from a science standpoint—raising doubts as to whether a "Martian" organism actually came from Earth. Cleaning large, complex spacecraft with dry heat is difficult and expensive. For now, Mars mission planners avoid landing sites that might have liquid water, even though those are the sites most likely to have life.

The team behind a proposed mission called Icebreaker, which would send a small, Phoenix-like lander to high Martian latitudes where liquid water might exist, is trying other approaches to removing microbial contamination, such as chemical cleaning of any equipment that comes in contact with the sample. Icebreaker (at this point an unfunded concept) would carry a drill capable of penetrating three feet into the soil. An onboard Signs of Life Detector (SOLiD) would analyze the drilled samples for bio-signatures: organic molecules, proteins, polysaccharides, and nucleic acids including DNA.

Only by canvassing for a wide range of possible bio-signatures can scientists hope to avoid philosopher Cleland's terra-centric trap: looking only for the kind of biology we see on Earth. "There's a difference between searching for life on Mars and searching for *different* life on Mars," says Chris McKay, a senior scientist at the Ames center and the principal investigator for Icebreaker. "Martian life could be carbon-based and still be alien. The real hope is to find a second genesis: that is, evidence of life not related to the tree of life as it evolved on Earth."

Just as rocks blasted off the Martian surface by ancient impacts have found their way to Antarctica, organic material from Earth may have already been transported to Mars, says McKay. If that's true, any microbes found on Mars might be our

long-lost distant cousins. Hence the need to test for Earth-like nucleic acids like DNA. Says McKay: "We need to define alien life not geographically—that is, being from another planet—but biochemically."

Most biology on Earth is based on roughly 20 amino acids, but in nature there are some 500 such compounds. Discovering Martian life-forms based on different amino acids would point to a second genesis, independent of our own. So would finding Mars life that used the same amino acids as terrestrial organisms, but with right-handed chirality.

Cleland applauds any search that includes possible alien biochemistry. "We need to look for features all life would display, regardless of chemistry," she says. "Life is a self-organizing system. So look for patterns or unexpected degrees of complexity." Life, she continues, is "an out-of-equilibrium state. We need to investigate anomalies: stuff that shouldn't be there."

She is especially intrigued by repeated detections of methane gas on Mars, starting with Mariner 7 in 1969, again by Mars Express and Earth-based telescopes in the early 2000s, and most recently by Curiosity, which detected mysterious, short-lived burps of methane on the surface at Gale Crater. The methane shouldn't be there; if it originated in the distant past, it would have dissipated in the Martian atmosphere in just a few hundred years. The detections suggest that somehow it's being replenished.

The jury is still out as to whether the source is geological or biological. In a review article published last year in the *Journal of Astrobiology & Outreach*, Yuk Yung of Caltech and Pin Chen of the Jet Propulsion Laboratory give two hypotheses: the methane could be due to gas-water-rock chemistry or to microbes that exhale methane. "The former," they write, "implies the existence of environs offering liquid water and chemical sources of energy—i.e. habitability—while the latter implies the discovery of life on Mars."

The European Trace Gas Orbiter on an ExoMars mission to be launched this year (which also will drop off a small descent module to test landing technology for the 2018 mission) will collect data from orbit that should tell scientists more about Martian methane. But this one instrument is unlikely to settle the question of whether the methane comes from a biological source. In fact, write Yung and Chen, solving the puzzle will require a "research effort across many disciplines," as well as "major technological advancements."

While the prospect that living Martian organisms are exhaling methane right now is exciting, McKay cautions against being so intent on finding something alive on

"There is no ideal bio-marker, unless life walks up to you and waves," declares Mark Sims of the ExoMars team. But if finding life on Mars appears a near-impossible task, scientists have reason for optimism. We know more about biology, including weird biology, than we did in the Viking era, and much more about Mars.

Mars that we overlook how significant it would be to stumble across evidence that something lived there in the past. "A dead rabbit on Mars would be powerful evidence of life on Mars," he says. "So would the discovery of a single chlorophyll molecule—because although the molecule is not alive, you can't get to chlorophyll without life."

Perhaps the most persuasive evidence of past life would be recognizable fossils—hence the tremendous flurry of excitement in the 1990s when several scientists thought they might have discovered ancient micro-fossils of bacteria in the four-billion-year-old Martian meteorite ALH 84001, retrieved from the icy wastes of Antarctica. Most scientists now believe the claim is unfounded; most of the "evidence" can be explained non-biologically.

Even the identification of ancient micro-fossils on Earth is controversial. The "Apex chert," discovered in Australia in the 1980s, originally was believed to contain the world's oldest fossils, dating back 3.46 billion years. Almost 30 years later, more sophisticated instruments and reinterpretation of the local geology showed that the "fossils" are inanimate minerals, not the remnants of once-living bacteria.

The identification of life on Mars therefore is unlikely to rest on a single picture, or even a single piece of data. "There is no ideal bio-marker, unless life walks up to you and waves," declares Mark Sims, the ExoMars team member who led development of the now-canceled Life Marker Chip. His worry is not just false positives—evidence that wrongly suggests life on Mars. He also worries about "evidence for Martian life successfully extracted from the Martian soil but lost en route to detection." He and three colleagues wrote a paper in 2012 analyzing how various organic compounds can end up stuck to steel, titanium, and other materials commonly used in spacecraft instruments, and never even make it to the detector. If Sims sounds like a worrier, he has the scars to prove it. He was the mission manager for the British-built Beagle 2 lander, which landed on Mars in 2003 but never phoned home. He never got a chance even to begin *that* search.

Though finding life on Mars appears a near-impossible task, scientists have reason for optimism. Compared to our knowledge in the Viking era, we now know more about biology, including weird biology, and much more about Mars. Orbiting spacecraft are able to take high-resolution images and map the mineralogy of any site we choose to visit. In fact, NASA is so confident that extraterrestrial life is waiting to be discovered that last year the agency's chief scientist, Ellen Stofan, said: "I think we're going to have strong indications of life beyond Earth within a decade, and I think we're going to have definitive evidence within 20 to 30 years."

And what if we do?

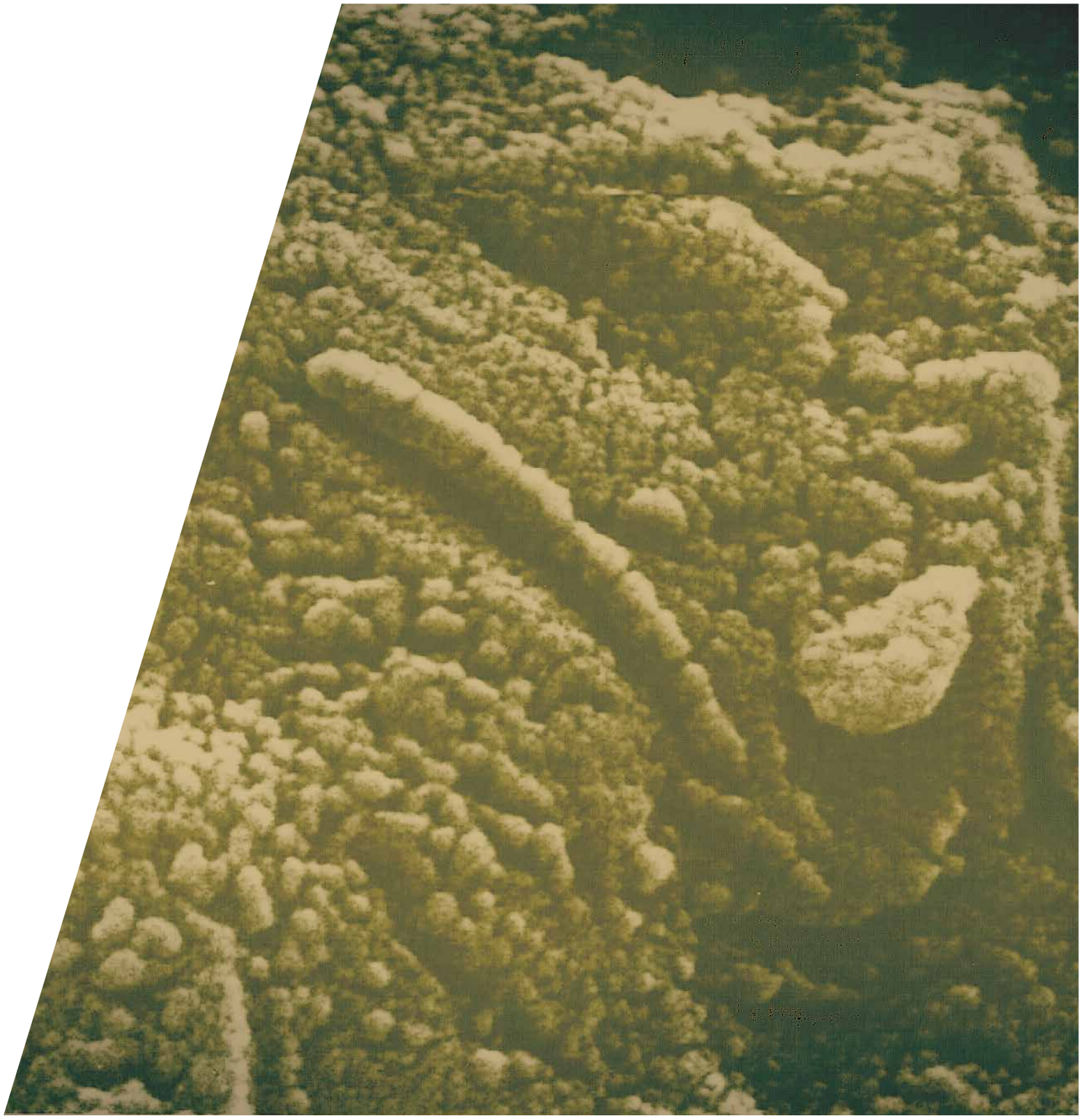
"I don't think the response should be to send Earth life to compete with it," says McKay. "We'd need to take steps to protect the second genesis." The planetary protection dilemma will only get worse as the spacecraft become more complicated. (And nobody yet knows how to do a human Mars expedition, which some consider our best bet for finding life, without compounding the risk of contamination.) In 1975, the Viking landers were assembled in clean rooms, then put into a giant oven and baked at 200 degrees Fahrenheit—what chefs would call a "cool" oven—for

In 1996, even closer microscopic views inside a Martian meteorite led to claims of fossil life—which today are mostly discounted.

30 hours. But prolonged heat would cause some modern electronics and seals to fail. Like McKay and his Icebreaker team, spacecraft engineers are hoping to come up with new cleaning methods.

"We also need to think seriously about the risk of bringing [Martian samples containing life] back to Earth, and observe isolation techniques comparable to what we do for Ebola," McKay says. His fear is not that alien organisms would cause a plague on Earth, but that they could displace some terrestrial life-forms, just as introduced species, like kudzu, have in new environments on Earth.

The best reason to be hopeful about finding Martian life may be the odds. Biology is likely either to be confined to Earth, or to be everywhere. The late, great science fiction writer Isaac Asimov once observed that phenomena in the universe are either unique or universal: Two is an impossible number.



NASA

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LIFE IN THE UNIVERSE SPECIAL

Life Among the GAS GIANTS

SOMETHING IS THERE IN THE MOONS OF JUPITER AND SATURN. BY CRAIG MELLOW

Giant Jupiter's gravity creates volcanic activity on moon Io (right) and heats an ocean underneath the ice crust on Europa (left). Could that ocean have life?

NASA/JPL/BJORN JONSSON

IN THE MYSTERIOUS REALM of the outer solar system, space probes have shown us worlds encrusted with ice, shrouded in haze, and pocked by lakes of methane. But as inhospitable as they seem, in the last few decades evidence has been piling up that several moons orbiting our solar system's gas giants may have environments suitable for life. Not at some point in history, as with Mars, but today. Europa, which orbits Jupiter, and Enceladus and Titan, Saturnian moons, are targets of the next great search for life.

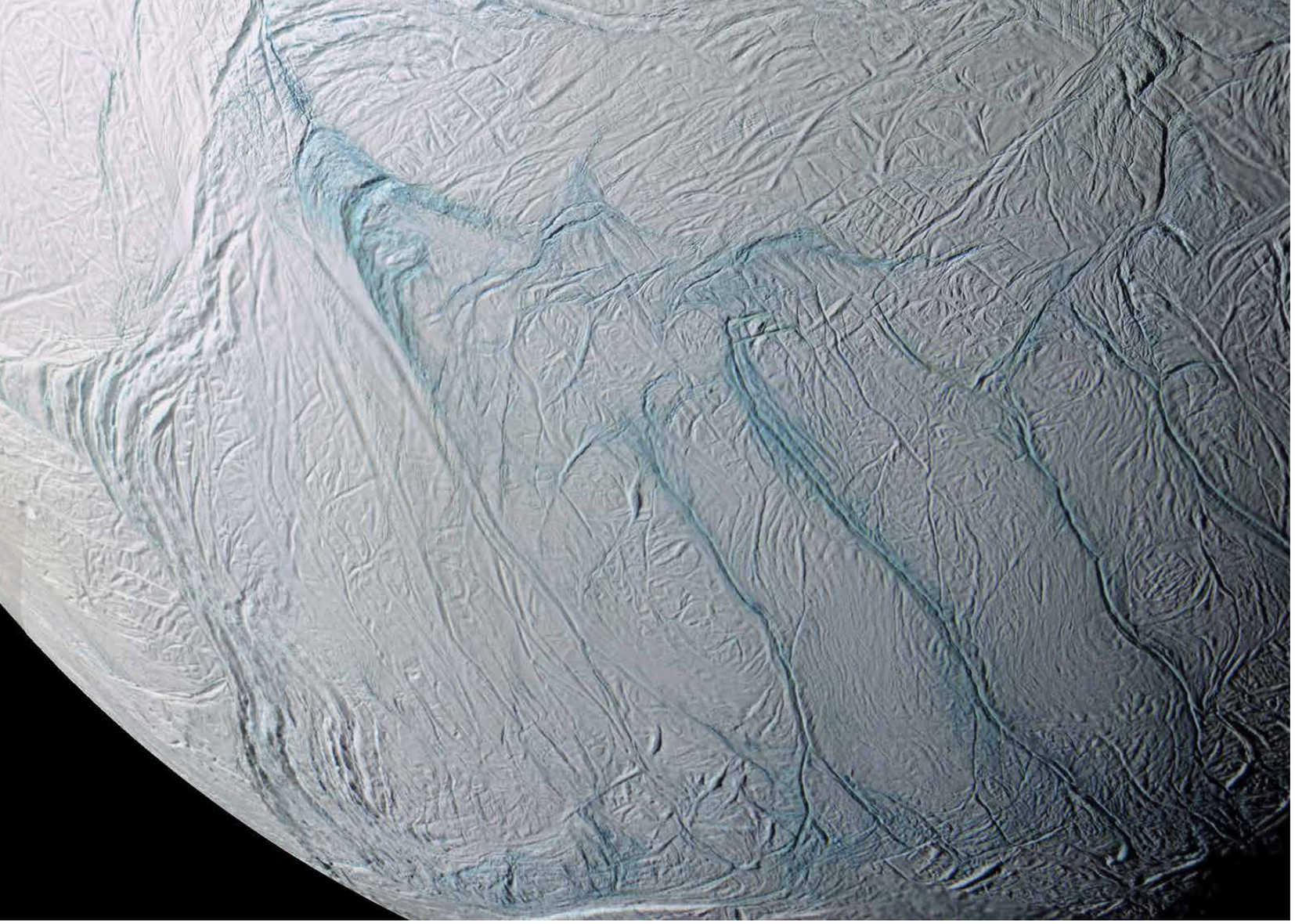
NASA has been filling in previously vague pictures of the outer solar system with the results of three planetary missions: the twin Voyager spacecraft, launched in 1977; the Galileo mission to Jupiter in the 1990s; and Cassini, which has been investigating the Saturn system since 2004. Scientists have spent decades analyzing the data from these explorers, mapping the contours and chemistry of more than 100 satellites around Jupiter and Saturn with enough accuracy to make solid guesses about where biological processes might be hidden.

If life is discovered, Kevin Hand might be the one announcing it. A planetary scientist and astrobiologist at NASA's Jet Propulsion Laboratory in Pasadena, California, Hand is on the team for the new Europa Multiple Flyby Mission. It's a mission idea that's been championed strongly for about a decade under the working name Europa Clipper and that became reality last year, when federal funding was earmarked for the spacecraft and the study of a lander with the goal to launch by the mid-2020s. Hand co-chairs the group responsible for the spacecraft's primary goal: assessing the moon's habitability.

When the two Voyager spacecraft flew past the Jupiter system, they discovered something astounding: The moon Io has active volcanoes. The gravity of the giant planet and its large satellites causes tidal forces that heat the moon's interior. Scientists quickly realized that those forces could very likely heat Europa enough to keep liquid the global ocean believed to be hidden under the smooth crust of ice on the surface. If the moon really has this large source of water, all it would need is organic material and some kind of energy to establish microscopic life forms.

When Galileo arrived to build upon the Voyager data, its measurements seemed to establish that Europa has a metallic core underneath a rocky mantle that provides the seabed for a salt water ocean—one whose volume is about twice that of all Earth's oceans combined. Just in the last few years, scientists have used Galileo data to determine the likelihood of clay-like minerals on the moon, which might mean it also has organics (carbon molecules) as a result of hydrothermal activity on the ocean floor. On Earth, hydrothermal vents create energetic interactions between water and the minerals in the rocky seabed that can sustain life without direct energy from the sun. In the search for habitable worlds, the possibility that there's carbon on Europa is provocative.

One of the intriguing features on Europa are lines that appear etched into its smooth ice crust. Scientists have come to believe



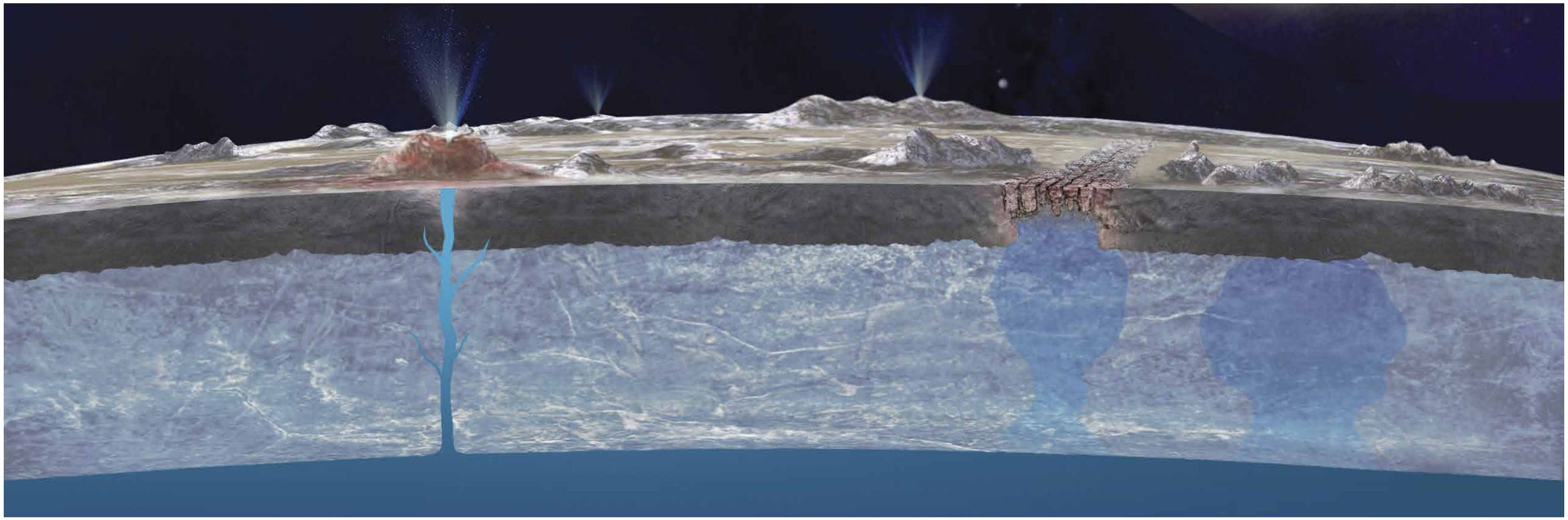
Europa looks more and more interesting, the more we learn about it. Increasing the allure: If a spacecraft could fly over the surface and find a crack in the ice, a lander could descend and sample the ocean directly. "Simply put, [Europa] is the place to go to look for living life today—life that we can someday poke and prod and see where a second origin of life has occurred in our own back yard," says Hand.

Planetary scientist Jonathan Lunine (below) thinks Saturn's moon Enceladus (left) is the best place to search for life in the outer solar system. Tidal forces crack its icy crust, and the ocean below rushes up to the surface and freezes, creating its stripes.

these are healed cracks. The tidal forces that keep the ocean liquid also cause cracks in the ice; ocean water rushes up to fill them and freezes. The melting and refreezing of the ice is likely what keeps the surface relatively smooth. "We know that Europa is geologically active over the tens-of-millions-of-years time scale because we can look at the surface and see that there are essentially no large craters," says Hand. There is one significant crater, Pwyll, and a couple others, but those are relatively young. Europa's ice surface is about as old, geologically speaking, as the oceanic crust on Earth, which is "the youngest material on our planet—or perhaps second only to very active volcanoes," says Hand.

So if you're a scientist looking for environmental traits similar to those on Earth, the one place we know life has thrived,

LEFT: NASA/JPL-CALTECH; RIGHT: CORNELL UNIVERSITY COMMUNICATIONS MARKETING

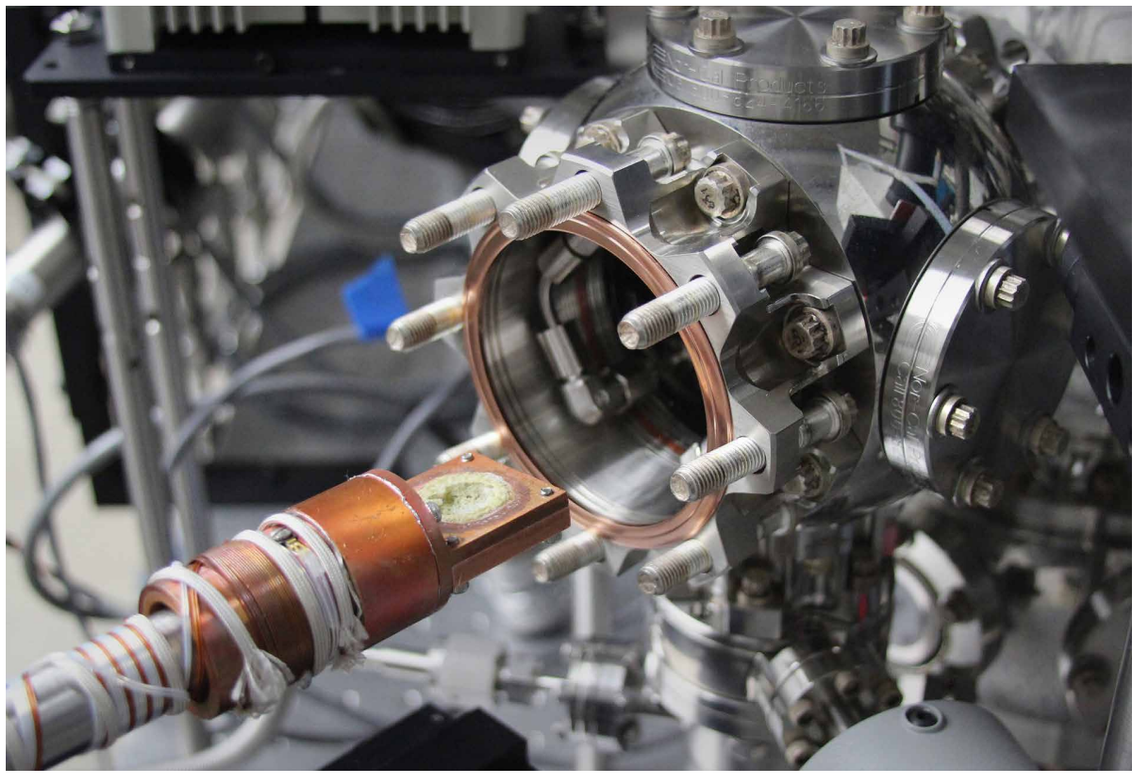


This artist's impression of Europa shows how organic molecules created on the surface by Jupiter's radiation could travel through a relatively thin ice layer to the ocean below.

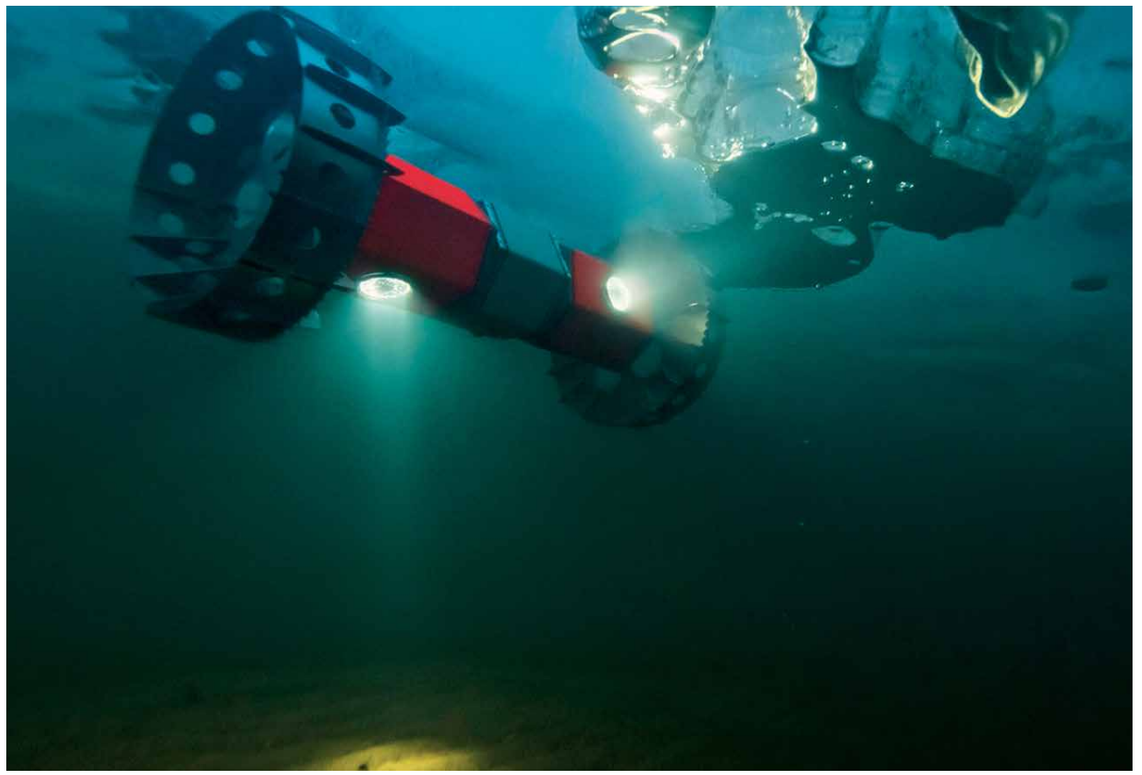
Not everyone would have made Europa Target Number One. For one thing, there might be an easier way to find a living neighbor. Instead of sending a spacecraft out to orbit a far moon and then try to land it on an ice sheet to dig around for signs of life, what if we could send an emissary to merely pass near another moon to intercept material this body is spewing into space? That's the case for Enceladus, one of many dozens of moons orbiting Saturn. This tiny world—it's not even as wide as Wyoming—was virtually unknown until Cassini arrived. About a year later the probe discovered that Enceladus is shooting out plumes of icy particles. Cassini's team was so excited they changed the spacecraft's mission path to visit the moon more often.

The plumes are more of a slow drip than an Old Faithful-like eruption, but in the vacuum of space, that drip travels far enough from Enceladus' surface for Cassini to easily fly through it. In flybys over the past decade, Cassini has recorded mounting signs of possible life on the body below. The plumes are made up of briny water in the form of gas, liquid, and solid particles. Those particles carry organics from what scientists have recently become sure is another worldwide ocean, just like Europa's. Cassini has also detected silica particles, indicating hydrothermal systems on the sea floor that are leaching material into the water. But scientists cannot use Cassini to make the next leap in discovery. It is a 20-year-old spaceship with 20-year-old instruments. No one knew it would discover a habitable moon around Saturn, and even if astronomers had, the

NASA/JPL-CALTECH



Testing salt in a lab apparatus mimicking Europa conditions indicated that a substance observed on the moon is likely sea salt.



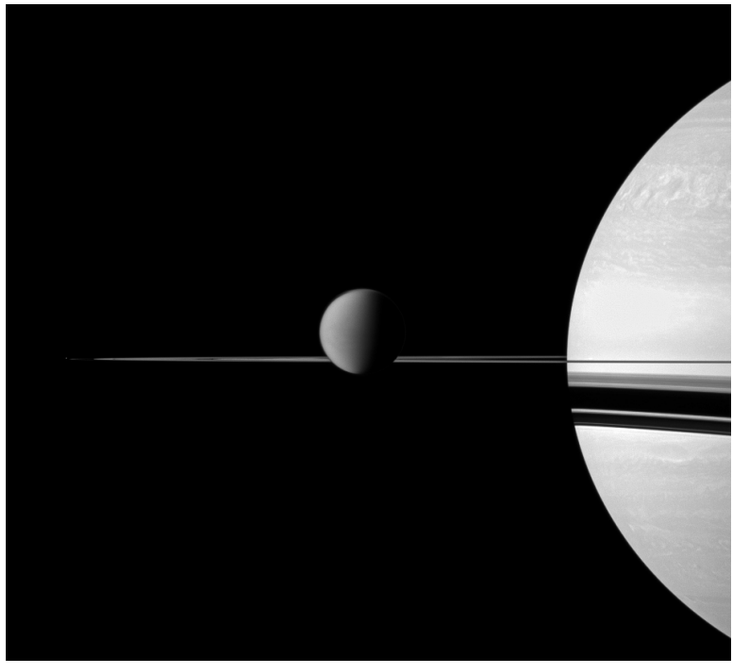
Could a probe study Europa's ocean directly? A NASA team tests a rover in an Alaskan lake that clings to the ice above.

technology available when Cassini was built would not likely have been advanced enough to find life, if it exists on Enceladus.

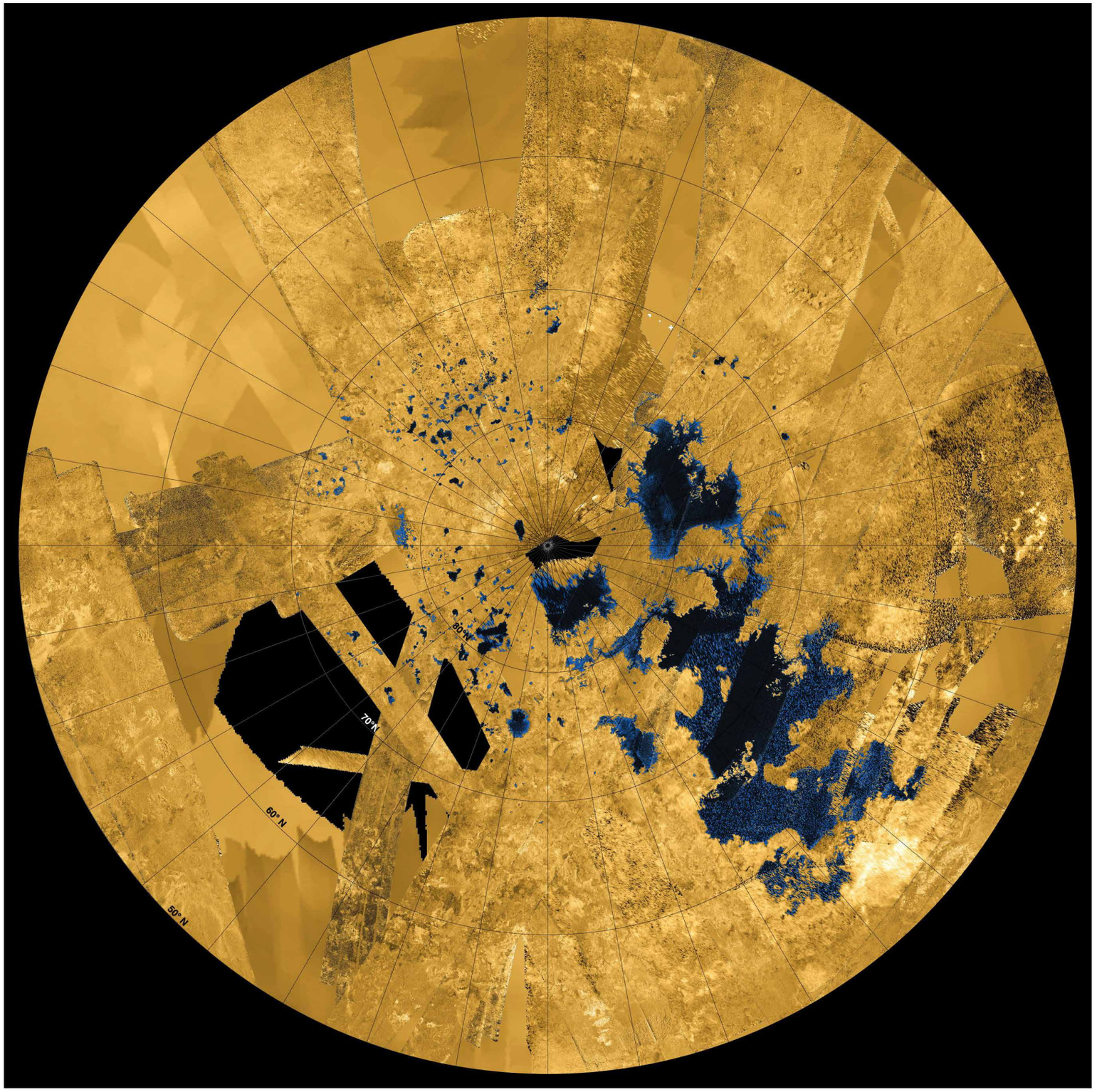
So planetary scientist Jonathan Lunine wants NASA to send a mission he's calling the Enceladus Life Finder. The Cornell professor, who has written two textbooks on astrobiology and habitable planets, developed the Life Finder with Chris McKay. A leader in the field of astrobiology and a scientist at NASA's Ames Research Center in California, McKay has spent much of his career on the Cassini mission. Lunine presented the Enceladus Life Finder in early 2015, describing it as an upgraded version of Cassini "with mass spectrometers of much higher resolution, range, and sensitivity" that would "measure key chemical indicators of just how habitable Enceladus' ocean is." But the instruments would do much more than take a closer look at the moon's environment: They would look for the patterns and processes that only biology could explain. The ELF could find life. And the best part: It could do all this in about 10 dives through Enceladus' plumes.

Lunine and McKay proposed ELF for NASA's latest round of Discovery missions. The agency chooses these cheaper solar system missions, currently capped at $450 million each, every two or three years. Mars Pathfinder, the Kepler space telescope, and Mercury orbiter MESSENGER were a few funded for the smaller amount, versus $2 to 3 billion for flagship missions like Cassini and the Europa Multiple Flyby Mission.

NASA/JPL-CALTECH (2)



The Life Finder was one of three Enceladus astrobiology missions submitted: The Jet Propulsion Lab and the California Institute of Technology proposed the Journey to Enceladus and Titan, or JET, and a large team including scientists from NASA, Arizona State University, Ball Aerospace, and the Japanese space agency—JAXA—proposed the Life Investigation for Enceladus, or LIFE, a spacecraft that would return a sample from the moon's plume on a plug of aerogel, similar to how the Stardust mission brought back samples from a comet in 2006. But when NASA selected five finalists last September, it passed over the outer-moon missions, instead opting for two missions to study Venus and three to



Alien life could be strange indeed. If it exists on Saturn's moon Titan (left), it will likely be feeding off lakes of methane in the polar region, seen above in a false-color mosaic.

LEFT: NASA CASSINI IMAGING TEAM; RIGHT: NASA/JPL-CALTECH/ASI/USGS

observe asteroids and near-Earth objects. "It was a little bit ahead of its time," says Lunine about ELF. The idea was sound, but NASA required more technical readiness for the spacecraft's instruments.

That's why the Europa mission is good news for Enceladus fans. The Multiple Flyby spacecraft will be carrying the same mass spectrometer Lunine wants for ELF, and a similar instrument to determine the composition of dust particles. (Flagship missions carry so many more instruments, NASA grants them slightly more leeway in technical readiness; if one instrument fails, the mission can still send home plenty of data.) Once those are under construction, it will make moot any questions about ELF's technical maturity.

Another issue the Europa mission might greenlight for ELF is its propulsion source. To stay under budget, the Enceladus mission would almost certainly have to use solar power. (Larger missions are powered by RTGs—radioisotope thermoelectric generators—which require manufactured plutonium, an element that is expensive and in short supply.) But NASA evidently felt that a mission to Saturn using just solar power "was still a stretch," Lunine says. Juno, the spacecraft set to arrive in the Jupiter system later this year, and the Europa spacecraft will both use solar power, and Lunine thinks that "once NASA breaks that mental barrier," ELF will be approved. "It's an important technology to validate for Saturn missions," he says. "Saturn has such an interesting set of worlds around it that we want to go back, and we're going to need solar power to do it." Lunine and his team hope that by the next time they have an opportunity to propose "it'll be a slam dunk."

There is a third moon where scientists want to look for life, and this is where everything gets weird. "I'm going to be a bit mischievous and say I'm a Titan man," says Planetary Science Institute senior scientist David Grinspoon, who was the Library of Congress' first chair holder in astrobiology in 2013. The Saturn moon has life-nurturing attributes undreamed of on its two icy rivals. It is the only moon in our solar system known to have a substantial atmosphere, one that is rich in complex organic molecules. In addition to water hiding under the surface, as on Europa and Enceladus, Titan also has liquid right at the surface. In 2014, Cassini sent back images of sunlight glinting off gigantic lakes near Titan's poles. (It also sent the Huygens probe down in 2005; scientists hoped it would land on open ocean, but our first look at the surface through Titan's haze was of soft, dry, dust-like material.) The moon has precipitation, storms, and seasons. The catch: Those above-ground lakes seem to be made of methane, which will stay liquid at Titan's typical temperature—around -300 degrees Fahrenheit. "So it's a high-stakes visit, let's put it that way, to the seas of Titan," says Lunine.

Grinspoon's response is the astrobiological equivalent of *Well, nobody's perfect.* "If we think of what life needs, chemical reactions and cyclic energetic behavior, Titan's got that," he explains. "We are focused on water-based life because that's what we are made of. But we don't know what else the universe is capable of." A few years ago, the Maryland-based firm Proxemy Research pitched NASA on a mission called Titan Mare Explorer, or TiME, which essentially would have landed a small boat with an antenna on those methane expanses. The last time NASA chose a Discovery mission, in 2012, the project made it to the final round of three competitors, but the

agency picked one more Mars explorer, the InSight lander.

"There are three places we need to go look for life, and we should be going to all of them," says Lunine. "But the strategy is different for each of these objects, and right now we know more about the habitable environment of Enceladus than we do about either Titan's or Europa's oceans." Astrobiologists mostly agree about the first part—Let's go everywhere—but they're debating the second: where to start. "If we could go to both [Europa and Enceladus] at the same time, I would do that because Enceladus' chemistry has proved to be fascinating," says Hand. But as for whether the moon has the best conditions for life, he's not convinced. "Even though we have no equation for the origin of life, we think you need liquid water, the elements needed for life [organic molecules], some energy source [like Earth gets from the sun's radiation], some sort of catalytic surface [where all those pieces can interact and kickstart a biological process], and then you need time." And it's that last one where Enceladus comes up short, Hand says: "We don't fully understand why or whether Enceladus' ocean has been around for a long time." Some models say the moon has had an ocean for as long as the Saturn system has existed, but Hand says Enceladus is so small it could have acquired its entire ocean from a relatively recent meteor impact. Europa, on the other hand, is far too big to have gotten all its water that way, so it almost surely

NASA's Kevin Hand looks forward to what the Europa Multiple Flyby Mission will find.

should have existed long enough for life to take hold.

McKay doesn't understand that argument. "Most people have the prejudice that life started on Earth, and that it took billions of years," he says. "But we have no data to support either of those statements." All he knows is that we have directly observed both water and organics on Enceladus. No such observations have been made on Europa.

There's a bigger problem to surmount at Europa. Jupiter's magnetosphere is already massive due to the planet's giant size, and made even stronger by electrical currents produced by metallic hydrogen in Jupiter's outer core, as well as the plasma produced by the volcanic activity on Io. The resulting radiation poses a problem for any spacecraft in the system. Mission planners will plaster the Europa spacecraft in protective shielding, but instruments will still have to poke out, so the craft will undertake a flyby mission, rather than orbit the moon. Its path will take big swings—45 of them—past Europa to avoid staying too long in the heat. "It's sort of like running into the fire and grabbing some valuables and running out, then waiting a little bit and going back in," says McKay. That strategy won't be possible for the potential Europa lander, though, so McKay sees this effort as a geophysical mission: one that will be helpful to map out the surface and add to the evidence for habitability—but one that's unlikely to find life itself.

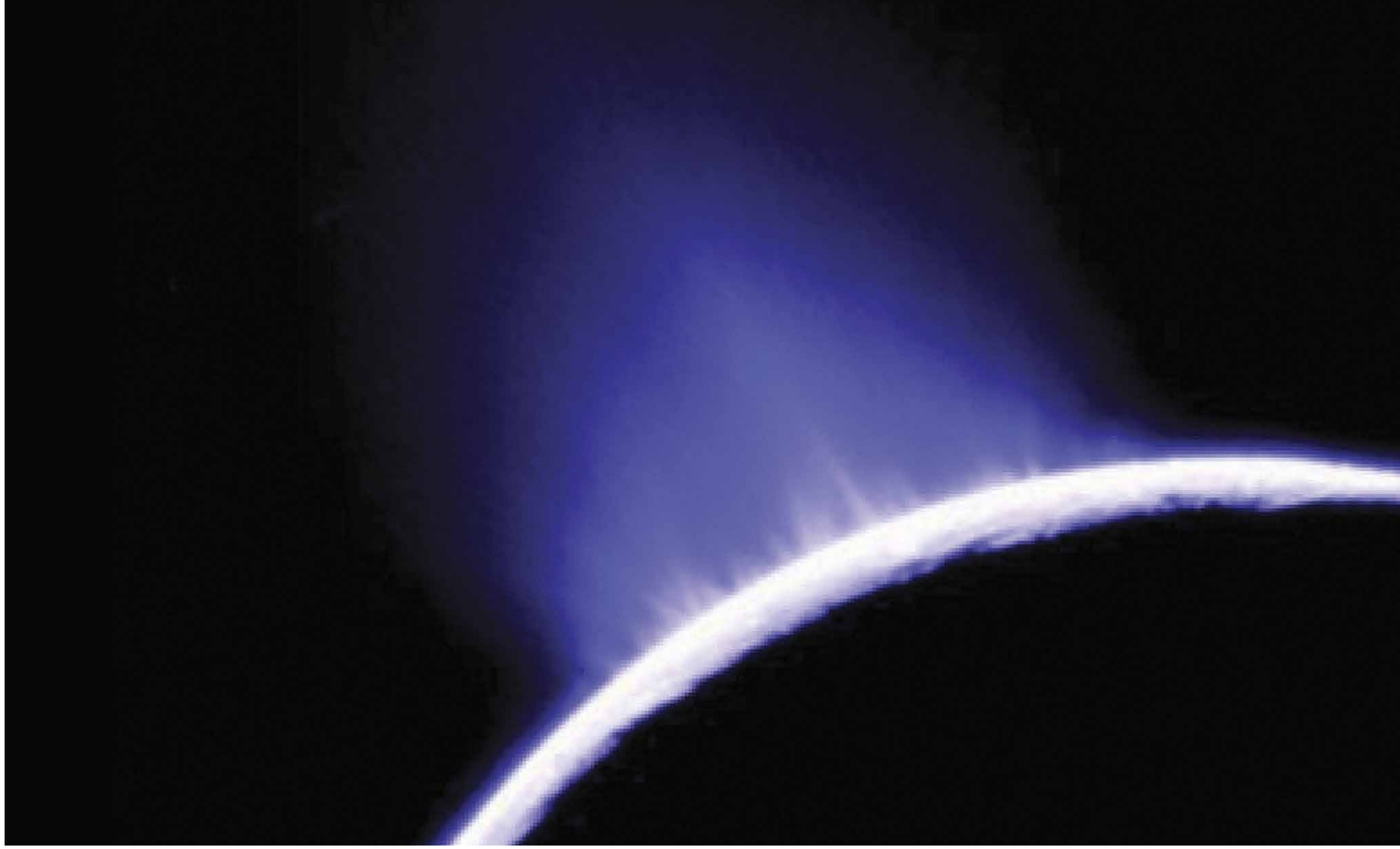
NASA/DAVID C. BOWMAN

Some think the plumes of Enceladus are an easier and intriguing target than Europa.

You might also wonder: With so much radiation there, wouldn't it kill off any life? Says Hand, "The radiation at Europa may actually be critical to the ecosystem." Any life in the ocean will be protected from direct exposure by the ice crust, and in fact, irradiation of the ice is creating things like molecular oxygen and hydrogen peroxide—"all compounds that microbial ecosystems and, frankly, ecosystems of complex organisms love to chew on," says Hand. Now the question is whether NASA's robotic lander could survive the radiation long enough to tap into any ecosystem that might be thriving because of it.

The discovery of microscopic beings beneath Europa's or Enceladus' ice would be an epic breakthrough in human knowledge. "We are searching for a second example of biochemistry that could help us understand our own," McKay explains. "Our current position is like only having an apple. Think how much more you can understand about an apple when you have an orange to compare it to." The current age of exoplanet discovery adds piquancy to NASA's hunt for tiny life forms in our own solar system, says Seth Shostak, who, as the director of the SETI Institute, searches for signals from distant intelligent life forms. "Twenty years ago we thought planets were rare," he says. "Now we think that 70 to 80 percent of stars actually have them. If Europa proves that a planet can come up with life if you give it the right chemical ingredients and leave it alone for a while, imagine what could be going on other places."

Scientists pushing for any of these outer moon missions should be buoyed by an announcement that David Schurr of NASA's Planetary Sciences division made in January: Both Enceladus and Titan are being eyed for a New Frontiers mission—a medium-class mission like Juno or New Horizons, the spacecraft that flew by Pluto. For the next few decades, astrobiology is one of NASA's priorities. If the agency's missions find what the scientists hope, the next generation of Earthlings will be the first to grow up knowing all about the alien neighbors just down the road.



NASA APOD

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Born to Race

Just how close a pair of custom-built racers came to unseating the kings of Reno. BY ERIC STEWART

DURING THE GOLDEN AGE of aviation, following World War I, air racing became a global obsession, bringing a feverish succession of new world records as aviators, contended for the titles of world's fastest man and machine. The raceplanes they flew were purpose-built: The Schneider Trophy Macchis and Supermarines, the Gee Bees, Howard Hughes' magnificent H-1—all were unique designs capitalizing on rapid advances in aeronautic and engine

Two takes on the same idea: *Pond Racer* (above) was an oddball, typical of designs from Burt Rutan's Scaled Composites. *Tsunami* (right) looked like a World War II warbird and had the power of the fighters it was built to replace: It used the same V-12 engine.

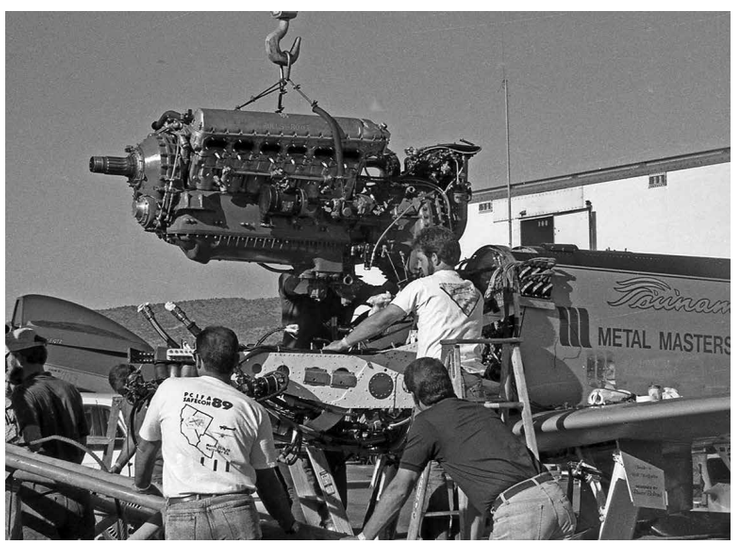
LEFT: JIM DALE; RIGHT: ROBERT F. PAULEY

technology.

After World War II, jets took over as the world's fastest airplanes, and the next fastest were cast aside. Surplus warbirds that had been fast fighters became widely available. When the National Championship Air Races started up again—in Reno, Nevada, in 1964—the only airplanes circling the pylons were Mustangs, Bearcats, and the occasional Sea Fury. Speed was now simply a matter of pumped engines, clipped wings, and a fitted canopy. By 1989, a 1946 F8F-2 Bearcat, Lyle Shelton's *Rare Bear*, was uncatchable; it set the propeller-driven three-kilometer speed record, 528 mph, and began a decade of dominance at Reno.

To break the absolute speed record

Top: *Tsunami* leads *Rare Bear* during the 1990 Reno Air Races (*Rare Bear* won). Immediate right: Bob Hoover chats with Steve Hinton and John Sandberg, *Tsunami*'s pilot and owner. *Tsunami* was built around a Rolls-Royce Merlin engine (far right). Seventy years ago Merlins were state of the art, and most Reno Unlimited racers still use one.



TOP: DON "BUCKY" DAWSON; BOTTOM LEFT: DAN WHITNEY; BOTTOM RIGHT: TIM WEINSCHENKER

and overcome the aluminum grip of ex-World War II fighters on Unlimited races (where, unlike in other classes, anything piston-powered and propeller-driven were then allowed), challengers would have to build an airplane from scratch and just for speed. Proposals and prototypes popped up, with names like *Shockwave* and *MachBuster*, but there were only two serious contenders: John Sandberg's *Tsunami* and Bob Pond's *Pond Racer*. Rarely have two aircraft designed for the same mission looked so different, and the truth is that both teams came much closer to their ultimate goal than is generally acknowledged. That no one in the last two decades has dared to follow in their footsteps is evidence that the three-kilometer absolute speed record is going to be one helluva tough nut to crack.

Tsunami first flew in 1986, but the idea had been hatched seven years earlier under blue Nevada skies, as Bruce Boland and John Sandberg watched 27-year-old Steve Hinton set a new absolute speed record in a highly modified P-51, *Red Baron* at Tonopah. *Red Baron* owner Ed Browning had hired Boland and Pete Law, Lockheed Skunk Works engineers who had worked together on air racers since 1965, to modify the airplane for the Reno races; as one reporter later noted, practically every Unlimited racer at Reno had been graced, in one way or another, by the magic touch of Boland and Law (see "Secret Pete," Sept. 2012). Sandberg ran a company that rebuilt the Rolls-Royce V-12 Merlin engines that powered many of the Unlimited class racers. While Boland and Sandberg saw Hinton set a new record of 499 mph, they saw something else: the possibility to go even faster with a clean-sheet, purpose-built design. It was a hugely ambitious undertaking that nobody had yet attempted. So when Sandberg invited Boland and Law to join the project that became *Tsunami*, they jumped.

Though it shared the same goals as *Tsunami* (victory at Reno; the 3-km absolute speed record), *Pond Racer* was born under a different star. Bob Pond had trained as a naval aviator in World War II (though he never saw combat), and after the war he turned his family's machine shop into a multimillion-dollar concern. A devoted collector of airplanes, he created a warbird museum, and in 1988 commissioned Burt Rutan's Scaled Composites to design an airplane that would so dominate the Unlimited class that warbirds would no longer be competitive—and thereby saved from the sacrilege of heavy modifications for the Reno air races, not to mention the crashes that destroyed them. Any airplane that could beat the Bearcat at the races would have no problem snatching the 3-km record.

There are only two ways to make a raceplane faster: more horsepower or less drag. With the Unlimited warbirds already grenading engines on a regular basis, wringing significantly more power out of a Merlin or a Wright radial than one's competitors was unlikely. So while both the *Tsunami* and *Pond Racer* teams focused on drag reduction, Sandberg's decision to stick with a Merlin—and hide the smallest possible airframe behind it—seemed a brilliant tactic: The engine was race-proven, and well understood. With 3,600 ponies on tap, *Tsunami* got the "more horsepower" side of the equation right. It was the airframe that was to prove troublesome.

In contrast, the Scaled Composites team had relatively few problems with Burt's

Rick Brickert (flanked by fellow racer Dennis Sanders) sits in *Pond Racer* in Ontario, California, in 1992. During a qualifier at Reno the following year, an engine failed and Brickert was killed.

***Pond Racer*'s methanol-fueled engines needed meticulous care. Among other headaches: Immediately upon shutdown, the crew had to hurry to attach cool-air blowers to each engine.**

airframe. Rutan considered a number of configurations, but the twin-boom-and-pod design, though more draggy than other layouts, kept the pilot out of the line of fire in the event of engine failure and provided excellent visibility. Chief test pilot Dick Rutan (pilot, with Jeana Yeager, of *Voyager*'s round-the-world flight in 1986) praised it for "exceptionally good flying qualities—the directional stability was like it was on rails," and Mike Melvill, who was to later pilot *SpaceShipOne* to win the Ansari X-Prize, called it "Rutan's best flying airplane straight out of the box." *Pond Racer*'s problems were almost entirely due to the difficulty of adapting a pair of 1,000-hp, methanol-fueled racecar engines to airplane use (in keeping with program goals, Pond prohibited the use of warbird engines like the Merlin). *Pond Racer* had less drag than even *Tsunami*, but was unable to pull more than 640 hp from the engines in flight. It never turned a lap at Reno faster than 400 mph.

In the world of aircraft prototypes, it is generally agreed that you should not put an untested engine in an untested airframe: New engines should go in proven airframes, and vice versa. Andy Chiavetta, renowned builder of Reno Sport Class racers, has a corollary for raceplanes: "Choose your engine, then build the racer around it."

John Knepp didn't have either of those options when Dick Rutan phoned in the summer of 1988. Knepp, an industrial physicist, owns the race-engine developer Electramotive, and in the late 1980s, the company's Nissan VG30 V-6 dominated sports car racing. "Dick called and said, 'I need an engine that fits inside a two-foot circle and makes 850 horsepower. Can you do that?' " recalls Knepp. "I answered 'You bet!' " But *Pond Racer* was Electramotive's first venture into aviation, and from the start the engine was beset with challenges. The two biggest problems were the propeller drive gearbox and the packaging: "In trying to squeeze everything into that two-foot-diameter cowling, we had planned on utilizing the space behind the firewall to place engine controls and cooling systems," says Knepp. "But that space was soon filled with airplane systems, so we kept having to move engine-related components ahead of the firewall." Space became so confined

LEFT: FRANK MORMILLO; RIGHT: DON "BUCKY" DAWSON

that the electronic engine controls had to be mounted above the 1,500-degree turbos in an insulated, air-cooled box. "Integrating everything required to get 1,000 hp [upped from the original 850 hp in order to beat *Rare Bear*'s new record] out of a 3.2-liter, 320-pound engine proved a far greater challenge than Scaled ever imagined," he says.

Knepp designed and fabricated several thousand parts for the engines, and the team slowly overcame myriad technical problems, from overcooling to engine stuttering caused by severe electromagnetic interference. Packaging remained the ever-present dilemma. "The real Achilles' heel was that we only had space for a four-quart oil sump where we'd typically have 12," says Knepp (the sump collects oil after it passes through the engine). Engine problems were exacerbated by the methanol fuel, which indirectly caused the engine to blow oil, further decreasing its already precariously low volume. "The remedy was to increase engine temps slowly, run gasoline, other stuff—patches on patches. Probably several engine failures were caused by running low on oil," says Knepp, although he also points out that the failures were always due to external systems integra-

Left: During a 1989 test flight, Steve Hinton saw a record 550 mph on the airspeed indicator (lower row, left). Sandberg (below) was perhaps too hands-on: Citing the *Tsunami* owner's excessive requests for changes, the first crew chief quit.

LEFT: DAN WHITNEY; RIGHT: FRANK MORMILLO

tion issues, rather than a failure of the core engine itself.

Knepp points out that in the design phase, oil tank size was a relatively minor detail compared to a potentially much more harrowing problem: rotational vibration between the engines, gearbox, and propeller. Such vibrations can destroy an engine, a propeller, or even a whole airplane in the blink of an eye, and yet here the team nailed it. All pilots reported the airplane was so smooth it felt as though it were running on turbines, not reciprocating engines. "I worked quite closely with Electramotive," says Bruce Evans, Pond's point man during the build and *Pond Racer*'s crew chief. "The development of that gearbox from scratch is an amazing untold story."

In addition to being chief test pilot, putting his life at considerable risk every time he flew the untested design, Dick Rutan worked as project manager of *Pond Racer* while it was a Scaled contract. He took no pay, but had a gentleman's agreement with Pond that when the racer was ready for the 3-km, he would be the pilot to attempt the record. Rutan agrees with Knepp that from a technical standpoint *Pond Racer*'s weak point was engine integration. But in Rutan's eyes, the biggest problem with *Pond Racer* was Bob Pond himself.

Though he spent an estimated $6 million-plus, according to two people who worked on the airplane, while developing one of the world's most sophisticated experimental aircraft, Pond could be inexplicably tight with money, exploding at what he perceived to be unnecessary expenses. He resisted funding the development of a proper thermostat for the engines, doing a full ground vibration test that would tell engineers if the airframe was safe from high-speed flutter, and even paying for tickets to get crew through the gates at Reno. "For him to be involved [in engineering decisions] with that little knowledge was dangerous," says Rutan, still bitter that he risked his life, only to have Pond transfer the project away from Scaled after the 1991 Reno races. The great irony is that, once Scaled's construction contract was officially fulfilled, Pond handed *Pond Racer* over to a rival, responsible for the very warbirds the *Pond Racer* team was supposed to be defeating on the racecourse: Steve Hinton and his Fighter Rebuilders, down the road in Chino, California.

Pond died in 2007, so we don't know why he transferred *Pond Racer* to Chino (the airplane spent a year in Pond's Palm Springs hangar before the transfer), but it's not hard to guess: Fighter Rebuilders restored more than 20 warbirds for Pond's museum, and owner Steve Hinton was a seasoned Reno air race veteran who had been down the 3-km road before—in *Tsunami*. If Pond was discouraged with *Pond Racer*'s progress, he may have looked to folks at the top of the racing game to set things right.

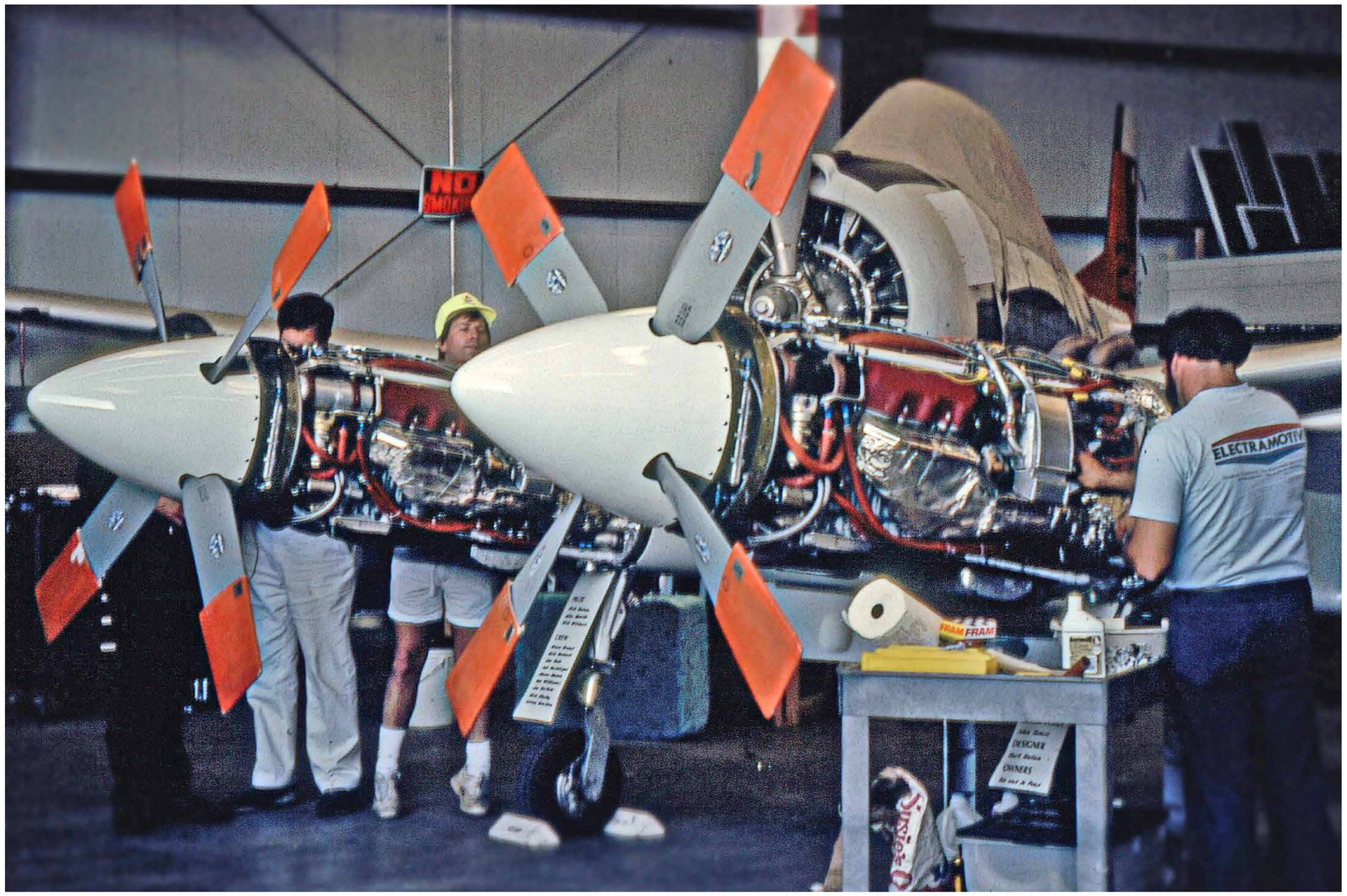
WORKING WITH ENGINEER and fabricator Ray Poe, Boland and Law spent six years designing *Tsunami*'s airframe, and drew on extensive experience at both Reno and Lockheed (Boland was an aerodynamicist and Law a thermodynamicist). Sandberg cherry-picked components to assemble the finest race engine he could, and in fact during *Tsunami*'s construction used a P-51 named *Tipsy Too* as a testbed for the engine modifications. While many people's names were painted on *Tsunami*'s gear doors as construction crew, it is these four—Sandberg, Boland, Law, and Poe—

who created it, and it was Steve Hinton who made the first flight in Chino after final assembly.

Compared to *Pond Racer*'s engine, *Tsunami*'s was relatively conservative. By the 1980s the design was already 40-odd years old, but the Merlin was the state-of-the-art engine before being eclipsed by jets. Its high horsepower and inline, liquid-cooled design offered advantages over radial engines. "The Merlin's pretty damned reliable," says Hinton. "It's an awesome, awesome engine." *Tsunami*'s problems were predominantly due to aerodynamics and mechanical complexity. The airplane used military- and race-proven structures and where possible adapted existing components (such as landing gear). Nevertheless, modifications to the *Tsunami* airframe were made so quickly that despite extensive flight

***Tsunami* (foreground) was named for the rogue waves that can reach 600 mph.**

FRANK MORMILLO



***Pond Racer*'s troublesome engines barely fit in their cowlings.**

testing, the team was never really able to get out from behind the eight ball.

After *Tsunami*'s first flight on August 17, 1986, the team aimed to make it to the Reno races less than a month later. "We made 50 or 60 flights in a very short period of time, along the lines of World War II flight testing," says Hinton. "The rudder was extremely light: up to 250 knots, it was light; above 250 knots, it was uncomfortable; and at 280 knots—well, it wasn't fluttering, but it would have if you'd gone faster. We could only increase flight speeds 10 knots at a time, which is why it took so many flights. But you really only get one chance with this flutter stuff." In the end *Tsunami*'s rudder was redesigned with a wider chord, and the airplane made it to Reno. But a cooling systems failure kept *Tsunami* from flying in the championship race.

In the subsequent five years, victory at the races—and an absolute world speed record—always seemed just beyond reach. Sandberg was an inveterate tinkerer, and while his ideas were often brilliant, they were also often untested, and the endless changes drove team members, including even Boland himself, from the project. "At one time I think I counted well over 20 major changes we made to *Tsunami* over the years," says Jim Dale, one of the lead crew and currently crew chief for Unlimited racer *232*. "We went from a fixed horizontal to a trimmable horizontal, changed the size of the horizontal, changed the size of the elevators, changed the size of the rudder, changed every single flight control system—it might have been pushrods one year and cables the next...." Heating problems associated with the small radiator, oil cooler, and scoop took several years to sort out. (Dale points out that *Tsunami* ended up with possibly the smallest scoop of any Merlin-powered racer: "I don't think a cereal box would

DAN WHITNEY

have fit into the opening when we were done.") Finally, structural changes to the landing gear and flaps led to crashes. "The airplane should've won Reno many times—it should have, and it could have," says Hinton with a note of matter-of-fact disappointment. "The airplane was really a heartbreak airplane."

In 1986 and '87, Hinton was poised to finish strong in the Gold class at Reno only to DNF (Did Not Finish) with cooling system problems. But starting in 1988, *Tsunami* made it all the way—to the Sunday Unlimited Gold heat—four years in a row. "The third year [1988], it should have won, and it should have won every year after that," says Hinton. "The only reason it didn't win that third year was that we had some miscommunication among the crew. An adjustment was made with the water injection system before the main race without a test flight. I didn't even know they did it until I was coming down the chute. I pushed the throttle up and the induction temperature was over the redline. I radioed in and the reply back was 'Oh, we should've tested that.' That was a big disappointment."

POND RACER, MEANWHILE, changed teams. After the raceplane was transferred in early 1992 to Hinton's Chino shop, Dale took over as crew chief from Bruce Evans, and agrees with Knepp that while Burt Rutan's engineering genius was awe-inspiring, the complexity of *Pond Racer*'s engines held it back. "*Pond Racer* had systems," says Dale. "It had ECUs [electronic engine controls], turbochargers, radiators—it was systems-heavy, but that's what was required to produce that kind of horsepower."

In the hands of Rick Brickert, a seasoned race pilot Pond had hired, *Pond Racer*, despite lacking nearly half its potential horsepower, managed a respectable second place in the 1992 Reno Bronze class: 365 mph. It seemed as though the raceplane had finally found its footing, but the inability to make full power continued to vex the team, and the engine modifications continued. During a flight to test turbo modifications, Brickert experienced total engine failure. North of Chino in the high desert of Mojave, Brickert calmly feathered the prop and threaded the Cajon Pass back to the airport on a single engine.

The outcome of a similar failure later that year in Reno could not have been more different. During a qualification heat at Reno in 1993, the right engine failed, and for reasons not entirely clear, Brickert chose to belly-in on a dry lakebed adjacent to the course, rather than land at the airport. When the aircraft slammed into the lakebed and burst into flames, Brickert was killed; some evidence suggests he may already have been incapacitated by smoke from an electrical fire. This might explain why he made no radio communications on the way down, and why he made no flare or throttle adjustments at touchdown. An investigation revealed the cause of the crash to be the gremlin that had nagged at *Pond Racer* from the beginning: insufficient oil, leading to connecting rod failure and subsequent seizing of the engine.

Though *Pond Racer* had never surpassed 400 mph at Reno, the pieces were set up for a potentially brilliant end game. The team had a definitive list of fixes—including a larger oil sump. The next year at Reno could have been *Pond Racer*'s moment in the sun. Likewise, *Tsunami* seemed to have worked out the most dif-

ficult challenges, only to be undone by the failure of a $10 part.

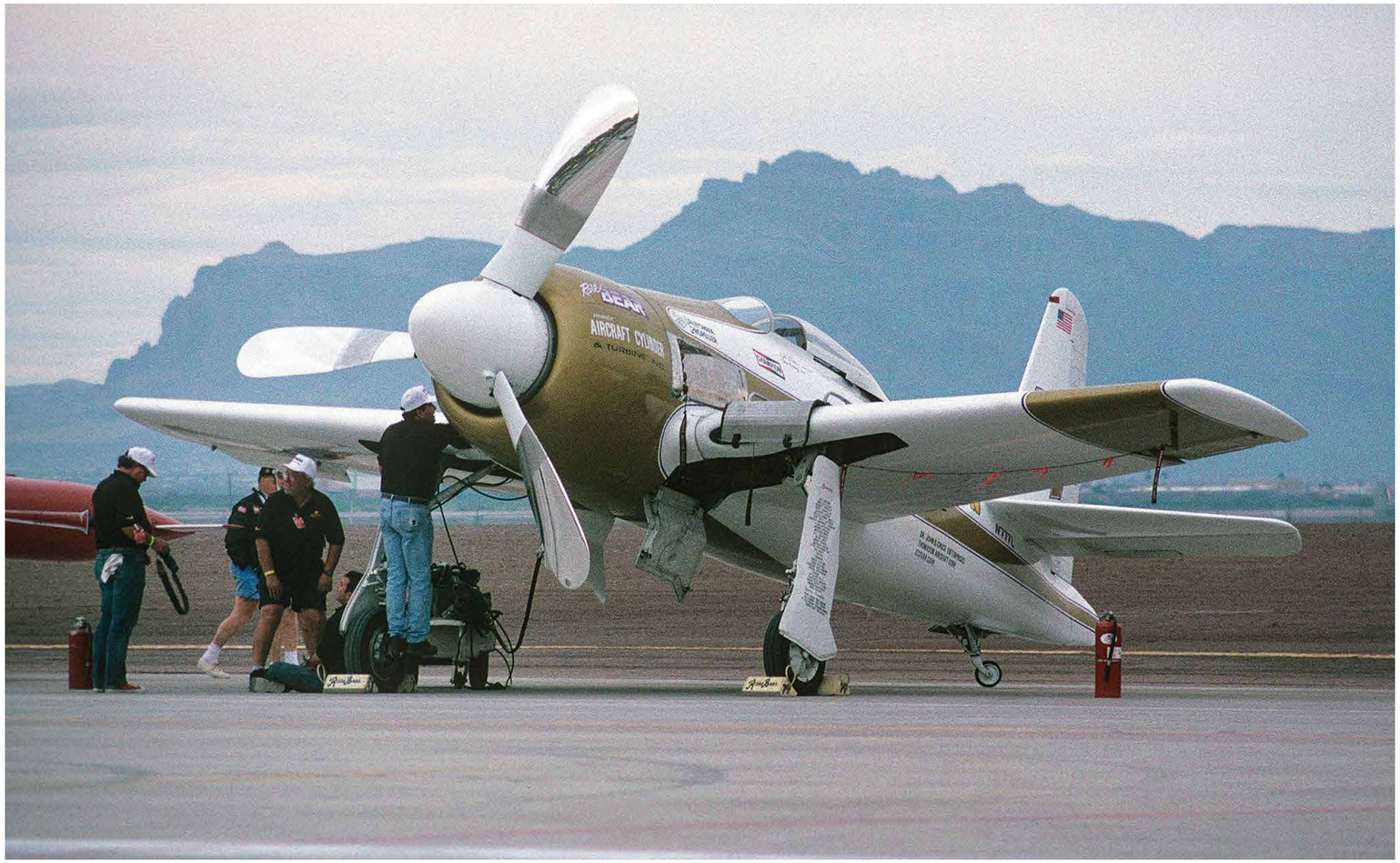
By 1989, the *Tsunami* team felt it was time to attempt the absolute speed record; in straight-and-level flight tests, Hinton had seen the racer's airspeed indicator read 550 mph. The team arrived in Wendover, Utah, in August, just weeks before the Reno races. But on August 21, Lyle Shelton broke Hinton's old record of 499 mph, with a 528 mph run in *Rare Bear* in Las Vegas, New Mexico. The ante was upped considerably: Rules require a new record to exceed the current one by

Tsunami (right, in red) and _Pond Racer_ (below) at Reno. Despite two years of overlap, they never raced against each other.

DON "BUCKY" DAWSON (2)

at least 1 percent; in this case the target was now more than 533 mph. In test runs *Tsunami* ran in excess of 500 mph, but the ground crew radioed to abort the attempt due to possible oil breathing problems. In fact two pistons had cracked. The team worked throughout the night, and the next morning Sandberg taxied out to try again—only to taxi back, having smelled gas in the cockpit. A heroic team effort to fix the leak got Sandberg back on the line later that afternoon. The test flight was a success, but a hard landing caused *Tsunami*'s landing gear to fail, and the racer swerved off the runway. The radiator was packed full of sand, and a wing spar, an aileron, and a flap were bent. The landing gear were splayed, one in, one out. The amount of damage would ordinarily have taken weeks, perhaps months, to repair, but if *Tsunami* was to race at Reno, it had to be

The Beast to Beat: *Rare Bear*, a Grumman F8F, set the absolute speed record for piston-engine aircraft in 1989.



present at registration—just four days away. The team and an army of volunteers worked nonstop. They installed a new engine, and Sandberg flew to Minnesota to fetch four new propeller blades. Bruce Evans—the future *Pond Racer* crew chief—had come to Wendover simply to watch but was soon enlisted to fabricate a new radiator scoop. By Sunday night *Tsunami* was ready to fly. Dale and a couple of volunteers from Chino sneaked back into the hangar after dinner and spent the night painting the airplane, much to Sandberg's delight the following morning. As *Tsunami* taxied out to depart, the tailwheel collapsed. More hurried repairs, and *Tsunami* arrived in Reno minutes before the close of registration. In 1991 (*Pond Racer*'s debut year; the two never raced against each other) *Tsunami* flew in what was described by observers as one of the best Unlimited finals ever. It lost Sunday's Gold race by the narrowest of margins.

On September 25, 1991, *Tsunami* was on approach to landing in Pierre, South Dakota, when one of its many untested modifications, a flap pushrod, failed. The airplane flipped over and crashed, killing Sandberg. The flaps had been a later addition Sandberg had been warned not to install; they were intended to enable him to more easily land at his home base in Minnesota.

Since 2013 the Unlimited category at Reno has been restricted to modified warbirds, so we may never see such purebred propeller-driven racers again. Dale points out that the biggest barrier may not be the speed of sound but the cost of speed. At Reno 1991, Evans, *Pond Racer*'s pre-Chino crew chief—and crew chief of *Voyager*'s round-the-world flight—commented to Dale: "I now realize it's a hell of a lot harder to go fast than it is to go far." Evans' comment appears to be accurate: Steve Fossett followed in *Voyager*'s footsteps. But *Rare Bear*'s absolute speed record remains unbroken, and unchallenged.

DON "BUCKY" DAWSON

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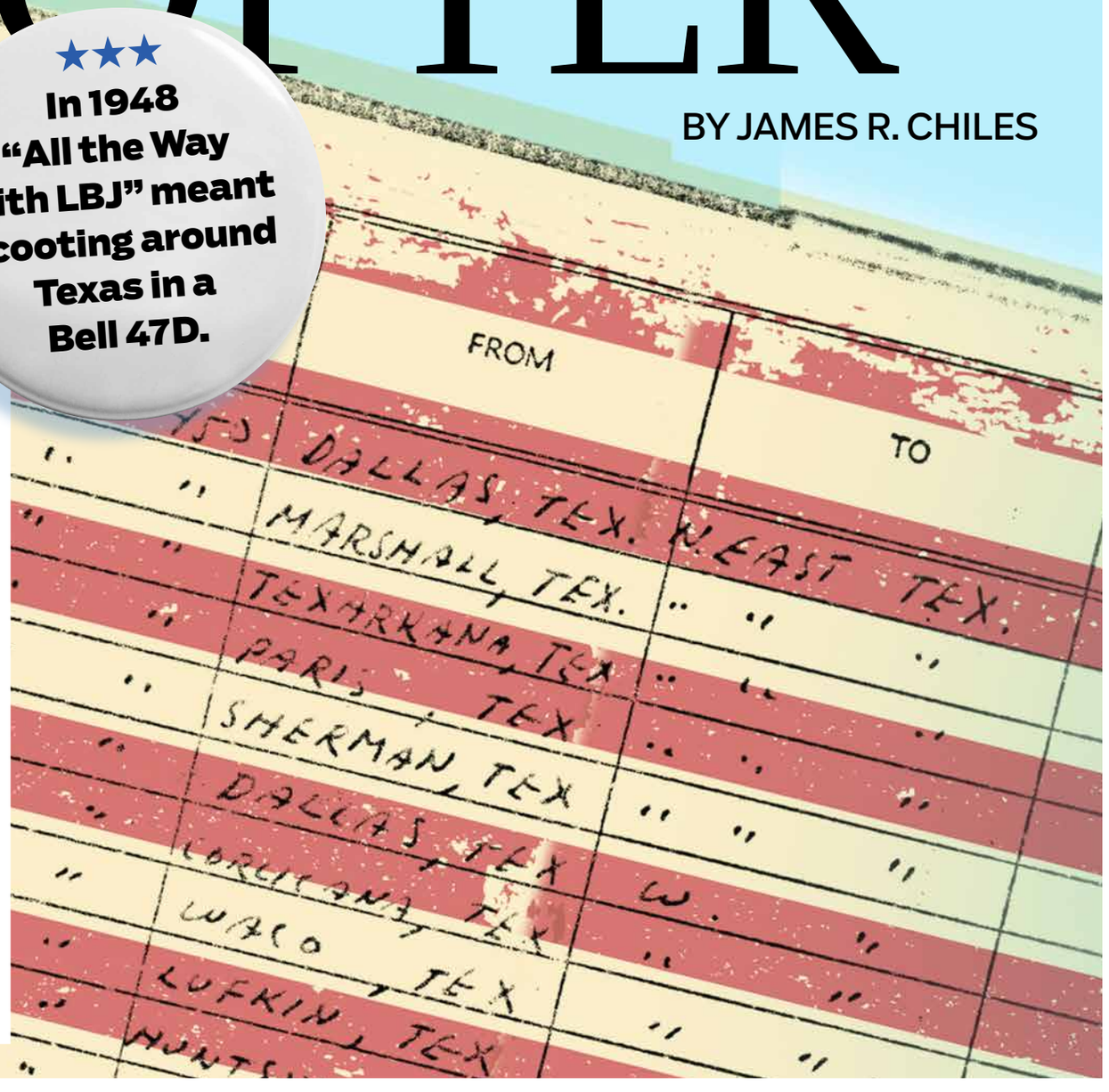
CAMPAIGN *by* HELICOPTER

BY JAMES R. CHILES

★★★

In 1948 "All the Way with LBJ" meant scooting around Texas in a Bell 47D.

During his 1948 Senate campaign, Lyndon Johnson (hat raised) won voters with novelty—a new way to travel—and convention (posing for photos).



JIMMIE A. DODD PHOTOGRAPH COLLECTION, E_JD_0061, THE DOLPH BRISCOE CENTER FOR AMERICAN HISTORY, THE UNIVERSITY OF TEXAS AT AUSTIN; LOGBOOK: LBJ LIBRARY

On campaign fliers, the helicopter got top billing. After the first, a Sikorsky S-51, was reclaimed for overhaul, Bell Aircraft's helicopter division loaned Johnson a Bell 47 and pilot Joe Mashman, above, left, for two weeks.

BEFORE THE IOWA STATE FAIR opened for business last August, presidential candidate Donald J. Trump announced that he would offer kids free helicopter rides directly from the fairgrounds. Officials said he wouldn't be launching from their property, but he was free to find another spot nearby, and he did, renting a lot a mile away and flying kids five at a time over the fair, throwing a shadow over candidates stuck on the ground. For a few minutes at least, the young passengers got to sink into Italian leather seats sporting seat belts with gold buckles, as befits a machine said to cost $7 million.

Trump's ride was a Sikorsky S-76B, a much more sophisticated model than the company's first passenger-rated civilian model, the S-51, which was also used to good effect by a politician: a young and lanky Congressman determined to land in the downtown streets and courthouse squares of 1948 Texas. Wanting crowds all around, he would risk his life in ways not understood until helicopter practices matured in the following decades.

The saga began just months before the July 1948 Democratic primary, when U.S.

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Congressman Lyndon Baines Johnson of the Texas 10th District decided to run for an open seat in the U.S. Senate. The Democratic Party was so strong in Texas that if he won the primary, he was sure to win the general election in November.

There was one problem: Every poll gave a wide lead to Coke Stevenson, who had recently retired from a long and successful career as governor. Stevenson had stood for political office 12 times, and had won 12 times. By 1948, Stevenson was known statewide as a quiet conservative who could keep government on a short leash. Johnson was little known outside his Austin-area district, and those voters knew him as a Roosevelt liberal who wanted government to lead the way.

LBJ laid out a busy campaign schedule, which within a few days was undone when he suffered an attack of kidney stones, accompanied by high fever and nausea. He was rescued by famous flier Jacqueline Cochran, who flew Johnson and his stretcher to Rochester, Minnesota, for experimental surgery at the Mayo Clinic. The procedure worked, and in days Johnson was back at his campaign headquarters in Austin, yelling for action.

And action was needed: He had just seven weeks to catch the trusted and popular Stevenson, who had been working the voters for six months. Johnson and his top aide, a young lawyer named John Connally, decided the only path to victory was getting a hard-hitting conservative message to a huge number of swing voters, who lived outside the cities. The message would be simple: Stevenson was too old for Washington, and a tool of big business and big labor besides, but Johnson was a young man—why, virtually a war hero!—who would lead Americans to Peace, Preparedness, and Progress.

But how to get attention across the vast and dusty stretches of Texas? Airplanes were timely, and Johnson was calling for a beefed-up Air Force. "We talked about a lot of different gimmicks," recalled Jake Pickle, who worked on the campaign. One was to rent an airplane that would fly west across the state and toss out flour bombs, to show the state's vulnerability to Soviet bombers.

Wisely, Johnson vetoed the idea. He favored helicopters, which offered a path to towns that no conventional candidate would bother with. Johnson had watched a demonstration of military helicopters in Washington months earlier, and knew what they could do by way of door-to-door delivery.

Better yet, the machine exuded novelty. In 1948, only a handful of rotorcraft in the world were certified to carry passengers, and while millions of Americans had watched them in newsreels, many had never seen one in person. Fortunately the Sikorsky Division of United Aircraft had one available, a used S-51 four-seater, one of two that the Greyhound Great Lakes bus line had bought to serve an experimental route in Detroit between the bus station and the airport. The service proved too costly, and Greyhound sold the helicopters back to Sikorsky; the company kept one for promotional work.

And election work. It wouldn't be the first time a candidate had used a helicopter (that was Alexander Smith, during a 1946 U.S. Senate campaign in New Jersey), but it would be the first time helicopters made a difference in the outcome.

On June 10 at the United Aircraft plant at Stratford, Connecticut, Sikorsky helicopter N92805 lifted off. At the controls was James Chudars, who had flown B-25

bombers during World War II; the crew chief was Harry Nachlin, who knew the ship well, having been crew chief on the Greyhound trials.

Four days later, Carl Phinney, Johnson's north Texas campaign manager, presented the helicopter to LBJ at Love Field in Dallas. The machine was now equipped with a loudspeaker system and painted with slogans in big block letters. Phinney told reporters that "Dallas Veterans for Johnson" would be covering the cost. Allegedly, these were 100 patients at a veterans' hospital who had contributed five dollars apiece.

"The campaign said they were paying for it," Harry Nachlin said later, "but what they paid wouldn't have covered even my salary."

LBJ's air assault on rural Texas began in Terrell, 30 miles east of Dallas, where a small crowd was waiting at a softball field. Johnson played the part of the indignant conservative, waving his arms in anger about Truman's civil rights program (a "fraud and a sham" that he would fight) and federal attempts to control schools. Then he rose up and headed off to seven more stops that day. He would fly six days a week, dawn to dusk, in what *Time* magazine called the first new gimmick to hit Texas politicking since the hillbilly band and the free barbecue.

One idea was abandoned immediately: that, in the interest of efficiency, the helicopter would hover a few feet above the ground while Johnson gave his stump speech over a bullhorn. Dust and noise made that impossible. And advance men had picked out some ridiculously small landing spots, thinking that the machine

"Wherever we saw more than two people and a big dog, we'd stop and talk," said James Chudars, who flew Johnson in the Sikorsky.

LBJ LIBRARY

only needed a space the size of the rotor disk. At the drafty headquarters in Austin during that first week of trial and error, the team worked out a solid plan for the flying circus.

An advance team pulled into each town at least a week ahead of the helicopter arrival, picked a landing spot, and cleared it with the town. They lined up a greeting committee, jotted down items of local interest—federal projects completed, water conservation, pensions—and rounded up volunteers to contact each voter by phone. They also arranged for articles and ads in the local paper.

A day or two prior, another advance team arrived to make sure that publicity was on the streets and that the landing zone was marked with yellow crepe paper or a whitewashed "X." Someone would phone final details to Johnson's traveling secretary the night before, and she would combine each town's logistics with arrangements for fuel and lodging. Nobody caught much sleep until Sunday, which was reserved for planning the next six-day blitz.

Depending on distances and weather, each flying day saw from 13 to 30 landings. Shortly before the helicopter's arrival, one or two cars with roof-mounted bullhorns raced into town, playing martial music and clamoring for everyone to "come to the speaking."

The grueling pace paid off. After one week, Johnson had climbed to second place and was just 10 points behind Stevenson, a stunning development. A man who had struggled to fill a room for his opening speech (and in his own district) was looking over crowds that exceeded a town's entire population. The Austin headquarters was taking calls from mayors and local bosses across the state, pleading for visits from the "Johnson City Windmill." Newspapers, even big-city ones that opposed him, liked the novelty angle and assigned reporters to tag along. Smaller newspapers brimmed with enthusiasm; a front-page editorial cartoon in the Tyler paper showed Johnson dropping a bomb from his helicopter, putting the old guard on the run. The bomb was tagged "Young and Vigorous Approach."

At each stop, the Sikorsky took up an orbit above the landing spot. As Johnson bellowed over the loudspeaker for attention, Chudars examined the spot for hazards. If the streets were wide and police were on hand to control the crowd, Chudars sometimes agreed to land downtown, even within a stone's throw of department stores and their plate-glass windows.

"The Congressman was enamored of the fact that that's what a helicopter was for, was to be able to get you where the people are," said Warren "Woody" Woodward, a campaign aide. "He kept pushing for sites in town."

But because of the helicopter's shortage of power, the pilot sometimes decided to scrub a close-in landing. Johnson was a micro-manager; if anyone disobeyed, the candidate's reaction would be fiery. "The only guy that could get Johnson to do what he wanted was the pilot," Nachlin said. "In fact, LBJ would introduce him that way: 'That's Jim Chudars, that's the only guy who can say no to me.' He couldn't care less what LBJ thought." So the pilot sometimes made Johnson hop out. Johnson found a silver lining to being ejected from the machine: He would take the sound truck's microphone and urge the crowd to stay and pray that the pilot might clear the trees, wires, and buildings.

Drama aside, the risk was real. Civilian helicopters were crashing at a rate 30 times higher than today's pilots face. Several times the campaign came close to raising that rate: a near-collision with a school building in New London, close encounters with wires at a ballpark between Sherman and Denison, and a fuel-related engine stoppage over east Texas as the campaign's first helicopter headed home. (The campaign's second ship, a Bell 47D, once got caught in its own downwash and plunged toward an east Texas street, narrowly missing parked cars and landing so hard it must have come close to losing the tail boom.)

The day-to-day routine was slightly less exciting: Just before landing in a town, Johnson liked to fling his cowboy hat out the door. It was a grand hat-in-the-ring gesture, but Johnson couldn't afford to give away 10 $25 Stetsons a day, so he demanded that aides chase the hat down or pay a dollar to anyone who brought it back. At the end of the seven-week blitz, the candidate claimed he'd spent a hundred dollars to get his hat back—a bargain, since sometimes he chucked it accidentally into a bramble patch or a swamp. Sometimes a dollar fell short, particularly if the audience was surly, as it was at a rodeo in Waco on June 22. That evening the helicopter spooked the animals and covered the crowd with dust, drawing angry shouts. The disruption may have encouraged one youth, who found the hat and ran off. Then the staff found that Johnson's spare hat, kept handy in a chase car, had been flattened because mechanic Nachlin had been sitting on it.

Normally things went more smoothly. As the rotor swung to a stop, Johnson and his airborne publicity man, Joe Phipps, got out and climbed into a platform or flatbed truck. Phipps warmed up the crowd with cheers such as "Ain't gonna be no runoff!"

Johnson's stump speech described his hill-country boyhood. After reminding voters of his many virtues, he took aim at a calculating, pipe-smoking opponent who refused to take clear positions on controversial matters because he was covering up corrupt bargains. Even when Johnson didn't name the rascal, all listeners knew he meant the frontrunner, Calculatin' Coke Stevenson.

Despite the energetic adversary, Stevenson showed little anxiety about getting to the Senate. His campaign routine was simple and low-tech: Stevenson would shake a few hands, then get back on the highway without bothering to make a speech.

Johnson, on the other hand, behaved like a man with demons snapping at his heels. He slept only a few hours each night. After each frenetic talk he surged into the crowd, grabbing hands and yanking each person past so he could seize the next. One reason for the pace may have been a concern that because many people had come to see the helicopter, any waning of energy would let the crowd drift away.

"Of course, mostly they came to see the helicopter," political operative Tommy Corcoran told Merle Miller, who wrote the LBJ biography *Lyndon*. "They'd never seen one before. Christ, it was brilliant as hell."

According to Phipps' book of recollections, *Summer Stock*, in his testier moments, Johnson saw the machine as upstaging him. In Victoria, Texas, a crowd of boys greatly outnumbered adults of voting age. During his talk the kids charged the aircraft, climbing on it and yelling. Johnson screamed at them, demand-

When telephone lines or crowds made space too tight for the three-passenger S-51 to land in town, the pilot would search for the nearest field.

ing to know where their parents were. Fortunately for the candidate's image as a warmhearted man of the people, all the reporters in the pool had bypassed the late-afternoon event and were already drinking at the hotel, so the meltdown went unreported.

Normally aides and reporters were on hand at each speech, but left early. Sprinting to the cars, they raced to the next town, hitting speeds of 90 mph to beat the helicopter, which could move a bit faster and in a straight line. One aide, Sam Plyler, a wartime assistant to General George Patton, wanted to make sure that when the machine landed, bystanders and particularly children were kept away from the tail rotor.

"When it was getting ready to leave, people would get back but they'd never get back far enough," Nachlin said. "The pilot would wave 'em back, and when the dust started to fly they'd wish they'd gotten back like he said." Impressively, in the hundreds of close-up landings and takeoffs, no bystanders were injured.

The Johnson City Windmill did blow one away, in a manner of speaking. One audience member in Littlefield was Dwayne Williams, age five. "The vacant field was pretty much clear other than a few folks who had probably been forewarned of his arrival," Williams recalls. "Aside from those guys, my buddies and I were the first ones to arrive." It was the first helicopter he'd seen. Looking back, he feels that Johnson's visit steered him toward a lifelong career: It started with a tour as an Army gunship pilot in Vietnam; later he became a test pilot for Bell and other manufacturers.

Between the scheduled stops, Johnson swooped down on highway crews, section gangs on the railroad, and farm workers. In the early days he took the mike and hailed them over the loudspeaker. He identified himself and asked for votes. After he realized that the rotor noise and raspy loudspeaker prevented listeners from knowing who was at the mike, he turned that job over to the pilot. Speaking in a Texas drawl, the pilot asked for votes and chucked handfuls of brochures (sometimes accidentally accompanied by a Thermos jug) out the door. Meanwhile, Johnson was able to nap between appearances.

It didn't take a very big crowd to justify a swoop: Even a lone woman picking peas in a field near Woodville was enough to get the helicopter to descend near her (she was startled nearly to death). If the aircraft had to wait out a thunderstorm, the pilot looked for a farm, whereupon Johnson jumped out and banged on the door for shelter and a vote.

Despite the rising poll numbers, by July the campaign faced two major problems. Chudars and Nachlin had told Johnson that they'd have to break off once the Sikorsky had logged 100 hours; after that, it would be due for a major overhaul back at the factory in Connecticut. As June ended and the machine approached the time limit, Johnson suggested that they come back to Texas, or that Chudars quit Sikorsky and stay to fly another helicopter. Chudars declined, and the Sikorsky duo left on July 5.

Fortunately for the campaign's momentum, Bell Aircraft's helicopter division (then based in New York) offered a Bell 47D, pilot, and mechanic. Compared with the Sikorsky, the Bell was smaller and less powerful but more maneuverable. Bell would charge nothing for two weeks of heavy use, adding up to 7,000 miles.

Bell executives figured that Johnson's use would build future business. The company had done the same when making Bells available for experimental use servicing offshore oil rigs in the Gulf of Mexico.

The second problem, hitting at the same time, was cash. Bill collectors had started lurking around the Austin headquarters, once catching an aide who was climbing out a window to escape. By July 5, the campaign helicopter sat grounded in Harlingen for lack of gas money. Johnson told his wife, Lady Bird, he was going to end the campaign. She reached out to a wealthy friend, Sid Richardson, who advanced enough credit to put the helicopter back in the air. Suddenly the campaign was rebuilding its flight sc hedule. At the same time Johnson and Joe Mashman, the new pilot, were learning to get along.

That part proved easy, because Mashman was an expert at aerial showmanship and embraced his role with an enthusiasm that bordered on derring-do. While Chudars had never tried to land his two-ton ship on a building roof, Mashman agreed to set the 1,900-pound Bell atop a gas station in Rosenberg, a town 30 miles southwest of Houston.

The helicopter's novelty had proved valuable in rural settings; as the primary season entered its last week, Johnson shifted his efforts to the cities, where it was harder to leverage that novelty. Some cities wouldn't allow off-airport landings, and some legal sites were more trouble than they were worth. Hoping for a mass night rally in Houston's Hermann Park, the campaign leaned hard on Houston Power & Light to put up poles and lights with just five hours' notice. But on the way the Bell's engine overheated (campaign literature had clogged the cooling fins), and the helicopter had to set down elsewhere. While everyone at the park was looking to the sky, Johnson pulled up in a car. Quipped the emcee to an unsmiling candidate, "That was a mighty smooth landing!"

On July 24, Coke Stevenson out-polled the other 10 candidates. But he didn't cross the 50 percent threshold, so a runoff election was slated for August 28. Lyndon Johnson had clawed his way onto the runoff ballot, but he trailed by 71,000 votes.

The helicopter had gotten him that far, but now he parked it and, relying on shoe leather, worked harder than ever. According to the official tally from the August 28 runoff, nearly a million votes were cast. Johnson won by 87 votes, despite charges that Johnson's people had bought hundreds of ballots from county bosses. Twelve years later, Johnson was headed to the White House.

The Sikorsky S-51 Johnson's campaign used flew commercially, mostly for constructing utility lines, until the 1970s, when it was acquired by the U.S. Army Aviation Museum in Fort Rucker, Alabama. The Bell 47D worked in the Gulf of Mexico oil patch from 1949 to 1954, when ownership shifted to a mineral exploration company in Colombia.

As president and ex-president, LBJ continued to have a soft spot for helicopter travel. He insisted on adding heliports to the Federal Building in Austin and his presidential library. Johnson invited Mashman to the ranch for social events; once he joined the pilot in the machine to help rescue people along the flooding Pedernales River.

Although Johnson didn't use a helicopter in his runoff campaign, statistics

Before the Bell could make a splashy rooftop landing in Rosenberg, the building had to be shored up with beams hauled from a lumberyard by mule teams.

from that election show that the earlier helicopter campaign may have helped him. Even though runoffs rarely see a strong turnout, a very high percentage of the voters who came out to vote for Johnson were rural—the same people he had dropped in on during seven hot and anxious weeks.

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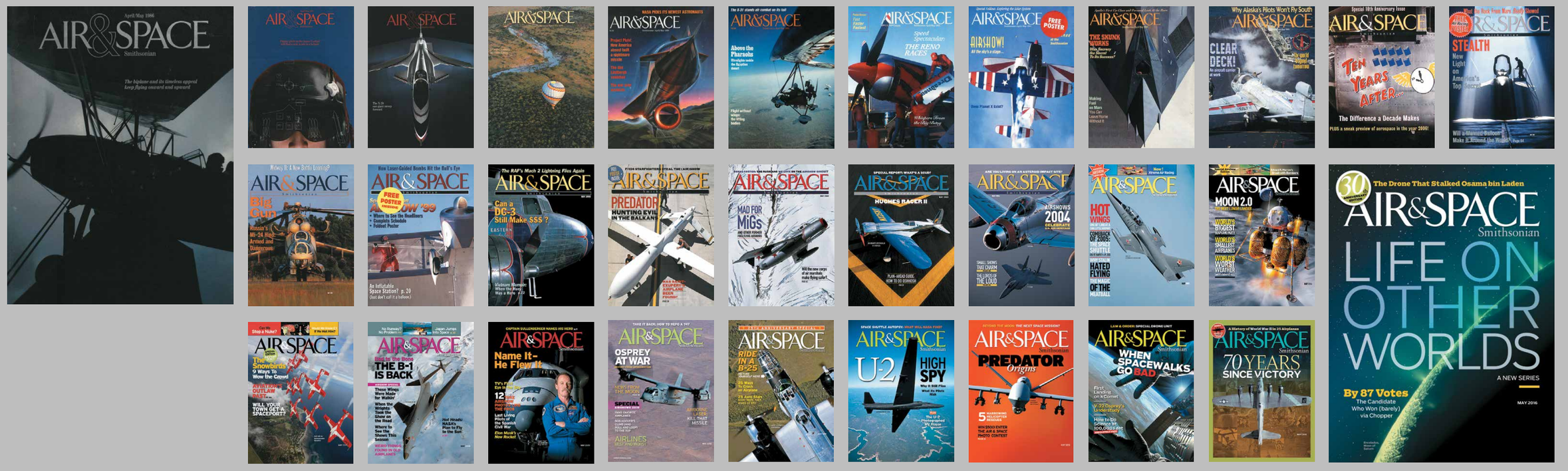
PICTURES WORTH A SECOND LOOK



30 Years of *Air & Space*

FROM BIPLANES to the space probe that may soon discover creatures living some place other than Earth, the magical craft that have paraded across the pages of *Air & Space* magazine for the past 30 years all have one thing in common: They were invented, built, flown, maintained, or restored by people with compelling stories to tell. Because this magazine has emphasized the humans behind the hardware, we have introduced you, our readers, to the most interesting people on the planet and—through archives, diaries, and interviews—to some of the most interesting people in history.

When we began publishing in 1986, the word "drone" referred to aircraft used for military target practice. We've told the stories of those who helped change the meaning of that word. Our first issue went to press within days of the tragedy that took the lives of the *Challenger* astronauts. We later told their stories and those of the people who returned the space shuttle to flight—twice—and constructed the International Space Station. In the last 30 years, we've met the people who invented stealth technology, introduced the Boeing 787, and combined a helicopter with an airplane to produce the V-22 Osprey. We have profiled entrepreneurs preparing to send tourists into space and pilots who have served in the nation's wars.

Of all these people, the most important to us are the ones reading this. Without you, there would be no magazine. Would you like to wish us happy birthday? From these 30 anniversary covers, we've picked 10 favorites and posted them online. Tell us which cover you like best. *—The editors*

Vote for your favorite at *airspacemag.com/covers*

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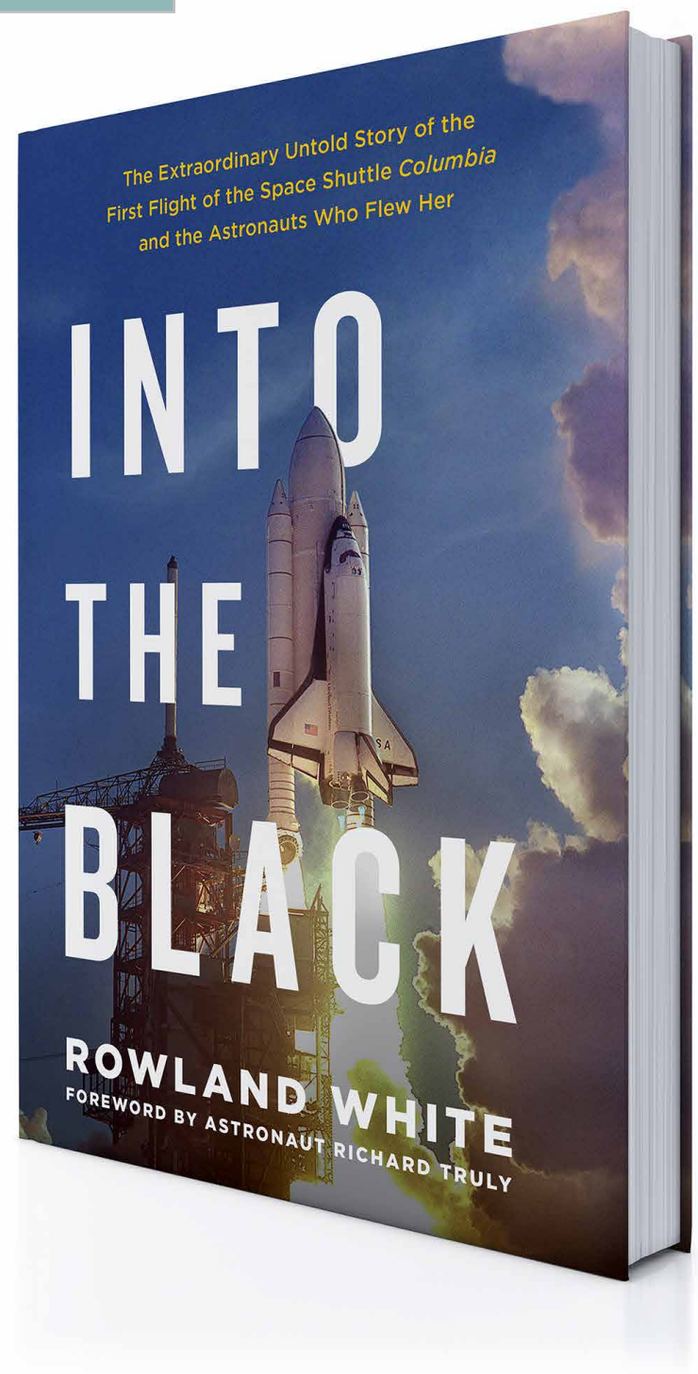
THE SHUTTLE'S FIRST CRISIS

Into the Black

by Rowland White. Touchstone, 2016. 427 pp., $29.99.

THE BOOK A detailed account of STS-1, the first space shuttle mission to reach orbit. After *Columbia*'s heat shield tiles were roughed up during launch, the National Reconnaissance Office secretly assisted NASA by using its satellites to observe the extent of the damage and help determine *Columbia*'s soundness for reentry.

"The heat shield was safe to fly. The issue of the tiles had been officially put to bed. Until John Houbolt, without any formal authority from Langley, wrote a letter directly to Houston Center Director Chris Kraft. Kraft was furious. He wasn't sure what more he could have done to demonstrate the robustness of the system."



WHY THE AUTHOR DECIDED TO WRITE IT

It was just a fantastic flying story that I felt hadn't properly been brought to life. But as it took shape, I discovered an incredible drama between NASA and the Department of Defense.

A CHAT WITH ROWLAND WHITE

Out of the many qualified candidates in NASA's astronaut corps, why do you think John Young and Bob Crippen were chosen for STS-1?

Moonwalker John Young was NASA's most storied space traveler: the head of the astronaut office with a long record of space firsts to his name, including the first manned Gemini flight, alongside Gus Grissom. Young was the obvious choice as commander. And no one knew more about the shuttle's complex systems and avionics than Bob Crippen. With such complementary skills and experience, together Young and Crippen were the perfect crew.

Rowland White has written four books about aviation history.

What caused* Columbia *to lose 16 thermal tiles during the launch of STS-1?

Amazingly, it was sound—albeit sound at a volume that would have been capable of killing anyone standing within 800 feet of it. For all the testing, modeling, and simulation prior to the first flight, much remained unknown. And when the shuttle's solid rocket boosters fired, a sonic shock wave rebounded off the pad and struck *Columbia* with a force 10 times greater than what had been expected based on 1/15-scale tests.

Was there any consideration before the flight of supplying Crippen and Young with a tile repair kit?

Plenty. A year before the first flight, NASA contracted with Martin Marietta to develop an on-orbit tile repair kit, and even announced that *Columbia* would be carrying it during the first flight. It consisted of a jet pack, a work-station-like window cleaner's cradle, and a caulking gun. Crippen spent time in a zero-G simulator and on board NASA's [reduced-gravity aircraft] training to use it. It was so unwieldy that he quickly became convinced that any effort to use it would likely only make things worse, and so the decision was taken to leave it behind.

How essential was Gene Kranz in determining that* Columbia*'s crew would not be in danger during reentry? Was Kranz's experience with crisis important in analyzing the situation?

What's interesting is the way Kranz—as he was during the Apollo 13 emergency—once again became a kind of lightning rod for everyone's concerns. More than anyone else, he was the public face of NASA during the STS-1 press conferences, but as reassuring a presence as he was, his freedom for maneuver was limited. Despite persistent questioning from reporters, he wasn't able to share the classified details of what DoD was doing in support of *Columbia*'s mission.

Did NASA and the National Reconnaissance Office work

COURTESY ROWLAND WHITE

together harmoniously in getting the KH-11 images of* Columbia*?

Where it mattered, certainly, but it might be more accurate to talk about the relationship between NASA and the Air Force. Remember that in 1981, the very existence of the NRO [National Reconnaissance Office] was still classified. A key figure in all of this was Hans Mark. A keen supporter of the space shuttle, he'd been director of NASA's Ames Research Center when the shuttle program was first announced, before becoming director of the NRO in 1977. He was one of just a handful people in mission control during STS-1 who understood the capabilities of the NRO's KH-11 satellites.

Do you get the impression that Young and Crippen's enjoyment of the mission was overshadowed by the loss of the tiles and the initial uncertainty about* Columbia*'s structural soundness? To some extent, did the crew's frequent adjustments to* Columbia*'s flight path [to synchronize with the reconnaissance satellites' orbits] infringe on their other mission activities?

On occasions you can actually hear the stress in their voices as they struggle to make the changes to the flight plan. Or when mistakes were made. The path of a spacecraft on orbit is relentless. You can't slow down. You can't buy time. If Young and Crippen—and indeed mission control—failed to ensure that *Columbia* was facing in exactly the right direction, at exactly the right time, then any chance for the Air Force controllers to capture the photographs they needed would be gone for good. And with them any possibility of properly assessing the risk to the shuttle.

Was there anything that should have been learned from STS-1 that might have prevented the loss of* Columbia *in 2003?

Yes, sadly, and it's simply that when there was any doubt at all about the condition of the orbiter, NASA should have asked DoD for help. As we know from the *Columbia* Accident Investigation Board report, the agency nearly did. But a request made for DoD imagery of *Columbia* was rescinded by Linda Ham, the chair of the Mission Management Team, after formal procedures were allowed to smother concerns from engineers at the launch site.

Anything you'd like to add?

The space shuttle was the most remarkable flying machine ever built: the highest- and fastest-flying aircraft ever to emerge from the doors of a U.S. airplane maker. And yet too often the shuttle story has been characterized either by a sort of unimpressed familiarity or by tragedy. I hope that, through bringing to life the drama and excitement of *Columbia*'s first flight, *Into the Black* helps redress the balance a bit, and helps ensure that the exceptionally courageous and capable astronauts that flew the shuttle during those audacious early test flights take their rightful place alongside the pioneers of the Mercury, Gemini, and Apollo programs in the public's imagination.

DIANE TEDESCHI IS A SENIOR ASSOCIATE EDITOR AT *AIR & SPACE/SMITHSONIAN.*

Forbidden Planet

Warner Home Video. Released on Blu-ray and DVD in 2010. 98 min. Rated G.

WITH THEIR SHINY HELMETS of Brylcreem, their uniform whiteness, and their pajama-like gray uniforms, the crew of United Planets Cruiser C-57D look pretty unconvincing, to 21st century eyes, as 23rd century explorers. And not just because they're commanded by a 29-year-old Leslie Nielsen—though his hair is not yet shock-white, he's easily recognizable as the star of *Airplane!*, *Police Squad!*, and the many other exclamation-pointed comedies he'd appear in decades later. Then there's the cruiser itself. Science fiction cinema's first starship isn't much to look at: a generic flying saucer. But nothing can be "generic" before the genre is defined, and 1956's *Forbidden Planet* is one of the seminal pictures that defined screen science fiction.

A loose retelling of William Shakespeare's *The Tempest* set 250 years in the future, *Forbidden Planet* has had a long reach. Its spiritual descendants include, most famously, *Star Trek*, which copied the idea of a spacefaring military force devoted to exploration and science—but with plenty of firepower (or fission power) at its disposal. And its most famous direct descendant? Robby the Robot, a wry but obedient mechanical slave on which MGM Studios spent a princely $250,000 (about $2.2 million in today's money). No wonder they reused the prop—which featured moving gearwork that can be seen through Robby's transparent dome of a head—in various set-in-the-present movies and TV shows unrelated to *Forbidden Planet*'s far-future storyline. As though he were a human star, Robby received billing for his role in 1957's feature *The Boy Who Turned Invisible* and a 1958 episode of the TV series "The Thin Man" (both are included as extras on *Forbidden Planet*'s Blu-ray). The various actors inside the robot suit were not so fortunate.

While the clunky Robby became an iconic character/object, *Forbidden Planet* is also remembered for the strength of its story, wherein the now-familiar sci-fi tropes—flying saucers, robots, ray guns, and a terrifying, largely unseen monster—are merely the filigree for its blunt-but-effective psychology and pathos. The plot finds Commander Adams (Nielsen) and his crew checking up on a team dispatched some 19 years earlier to survey a remote world. Expecting

to encounter an entire crew, they're met only by Dr. Morbius (Walter Pidgeon), his adolescent daughter Alta (Anne Francis), and Robby. Intra-crew jealousy over Alta—who has never seen a man younger than her father and doesn't know what kissing is—and her quick-budding, chaste romance with Adams are by far the film's most dated and tiresome elements. Far richer is the mystery about the highly evolved race of beings that once inhabited this world, and the movie's inquiries into whether humankind can be trusted to handle vast and potentially destructive power responsibly.

When *Forbidden Planet* was released, its visual effects and eerie electronic score were cutting-edge, and they remain impressive today. If they date-stamp the film as a product of the first years after the cold war, well, that's how it's always been with the best science fiction stories: Wherever and whenever they're set, they're always really about the times and the places in which they were made.

CHRIS KLIMEK IS AN *AIR & SPACE* ASSOCIATE EDITOR.

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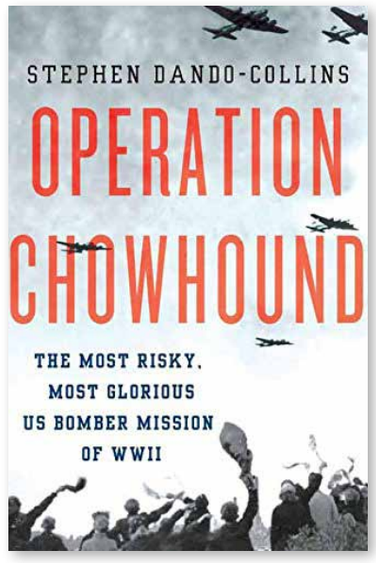
Available at *smithsonianstore.com*

Operation Chowhound: The Most Risky, Most Glorious US Bomber Mission of WWII

by Stephen Dando-Collins. St. Martin's Press, 2015. 272 pp., $28.



DESPITE THE SUBTITLE, *Operation Chowhound* doesn't likely qualify as the riskiest bomber mission or the most glorious, certainly not when compared to the 1942 Doolittle Raid on Japan or half a dozen others. And it wasn't only a U.S. mission: Chowhound was a joint effort (Great Britain called it Operation Manna) to feed starving civilians in German-occupied Holland in the spring of 1945. The plan was quite simple: Both sides promised not to shoot at each other so long as Allied bomber crews flew along pre-determined routes and dropped only food and medical supplies at pre-determined sites.

Author and historian Stephen Dando-Collins reveals a chess game of queens and generals and hungry Dutch pawns, with many moves and cunning strategy. For their part, Allied leaders seemed more concerned with getting the encircled Germans to surrender than with feeding the hungry. Doolittle, by then in charge of the Eighth Air Force, required that all personnel be volunteers, and decreed that the humanitarian missions would not count as combat missions.

While thoroughly researched, *Operation Chowhound* suffers from repetition and seems to over-stress the danger to the all-volunteer bomber crews. Yet Dando-Collins also emphasizes the mission's redemptive quality. "Because of Chowhound, [B-17 pilot Robert Miller] had come to believe that there was still some good left in the world."

A WRITER BASED IN NEW YORK CITY, PHIL SCOTT IS A FREQUENT *AIR & SPACE* CONTRIBUTOR.

Contributors

Stealth Before Stealth. Bill Sweetman is senior international defense editor for *Aviation Week & Space Technology.* The author of more than 30 books, he has written about almost every aspect of aerospace and military technology.

Solar System Chatter. Heather Goss is the departments editor at *Air & Space/Smithsonian*.

The Case of the Runaway U-2. John Newlin flew the McDonnell F3H Demon and the F4B Phantom II. He also accrued flight time in the Chance-Vought F8D Crusader and the Grumman F-14 Tomcat. He retired from the Navy in 1980.

Let's Go Antiquing. Phil Scott has logged time in more than 30 types of aircraft.

Scramble Seawolves! Robert Bernier, a retired commercial pilot, wrote "Last of the Great Flying Boats" (Feb./Mar. 2015).

Meet the Drone That Staked Out Osama bin Laden's Neighborhood. Contributing editor Ed Darack's forthcoming book, *Highest Valor* (Smithsonian Books, 2017), covers the story of the people and circumstances of Extortion 17, a helicopter shot down in Afghanistan in August 2011.

Would We Know Alien Life If We Saw It? Trudy E. Bell has been an editor for *Scientific American*, senior editor for *IEEE Spectrum*, and senior writer for the University of California's High-Performance AstroComputing Center.

Life Among the Gas Giants. Freelance journalist Craig Mellow has written for *Air & Space* from Russia and western Europe. He presently lives in Asheville, North Carolina.

Born to Race. Eric Stewart is currently building his own raceplane, the SR-1 Project.

Campaign by Helicopter. James R. Chiles blogs at *disaster-wise.blogspot.com*. He wrote *The God Machine: From Boomerangs to Black Hawks—The Story of the Helicopter*.

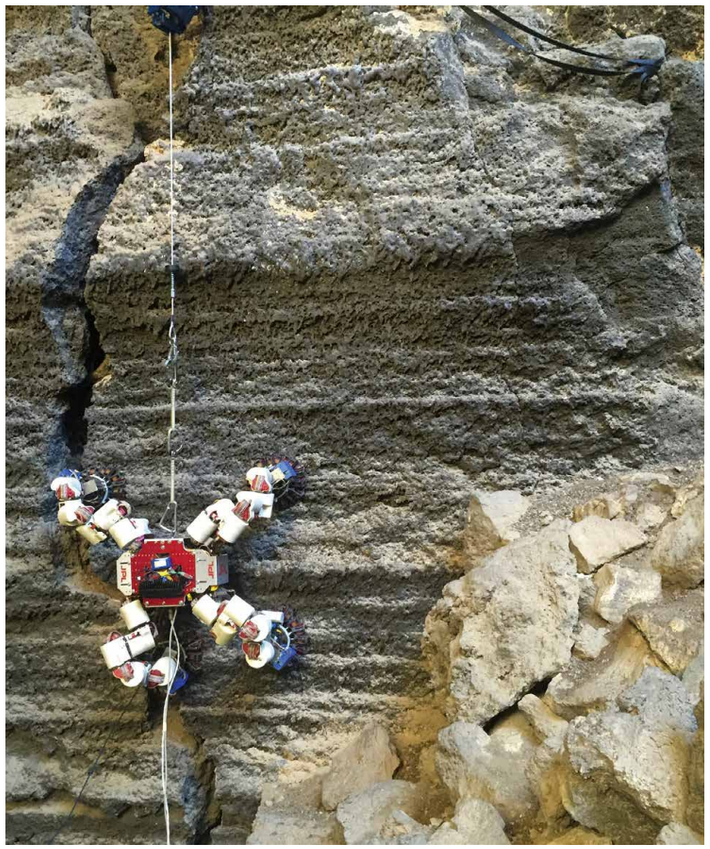
Forecast

IN FUTURE ISSUES

LIFE IN THE UNIVERSE SPECIAL, PART 2

Look Deeper

If there was life on Mars, radiation may have driven it underground. Engineers are inventing robots to search the Martian caves.



LEMUR 3, a cave-scaling robot, undergoes testing in New Mexico.

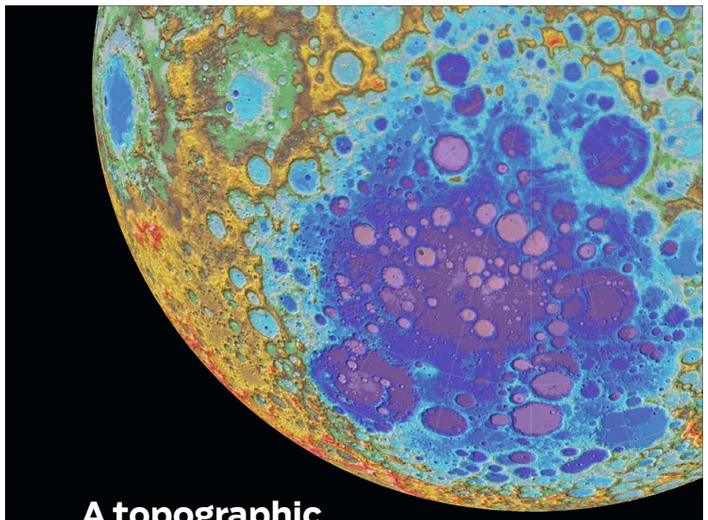
2015 Photo Contest

View the finalists and vote for your favorite in the Readers' Choice poll at ***airspacemag.com/vote.***

A 2014 Civilian category finalist.

New Moon

The National Air and Space Museum displays new pictures from the Lunar Reconnaissance Orbiter, showing an active, changing moon.



A topographic map of the moon (lighter is higher) taken from LRO data.

Shining Starliner

After more than 30 years on the ground, a Constellation will fly again, thanks to one of Lockheed's best customers.

LEFT: JPL; CENTER: RICHARD MALLORY ALLNUTT ; RIGHT: NASA/GODDARD SPACE FLIGHT CENTER/ ARIZONA STATE UNIVERSITY

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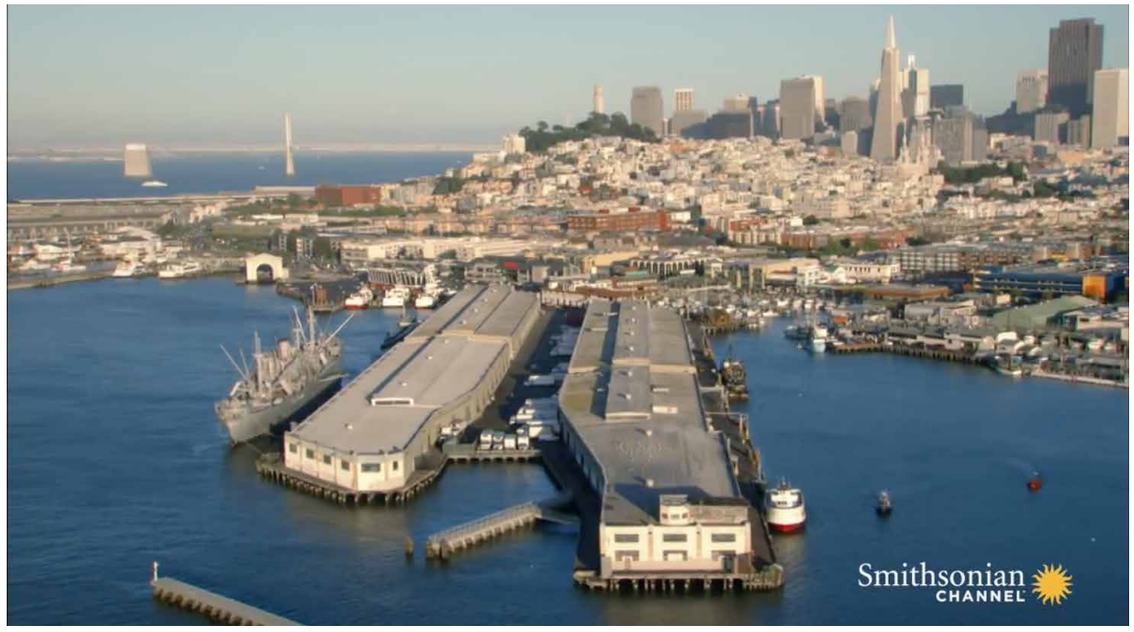

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One More Thing

FACTS ABOUT ARTIFACTS IN THE NATIONAL AIR AND SPACE MUSEUM

Mignet HM.14 Pou du Ciel "La Cucaracha" Designer Henri Mignet liked to claim that any man who could nail shut a wooden crate could assemble an HM.14, the bug-like kit aircraft he designed and sold in France and England in the mid-1930s before taking aim at the American market. He wanted it to be a cinch to fly too.

» To try to render his "Flying Flea" stall-proof, Mignet staggered its two wings. The HM.14 had no ailerons, elevators, or rudder pedals. The pilot controlled pitch by moving the stick to pivot the forward wing. To turn, he also moved the stick, which was connected to the rudder via cables (the entire rear end of the aircraft was a rudder).

» The HM.14 on display at the National Air and Space Museum was the first built in the United States. Weighing 350 pounds, it had a top speed of just under 65 mph. Powel Crosley Jr., president of the Crosley Radio Corporation, bought it in 1935.

» Crosley's personal pilot, Edward Nirmaier, flew the Crosley Flea at the All American Air Maneuvers show in December 1935—just two days after a gust of wind had flipped the Flea on its back while taxiing. In 1936, a series of fatal crashes in Europe substantially eroded public enthusiasm for the Flea. Mignet made improvements and tried to rehabilitate the HM.14's reputation, but those accidents proved to be the final nail in the design's coffin—not the wooden crate Mignet had in mind.

DANE PENLAND

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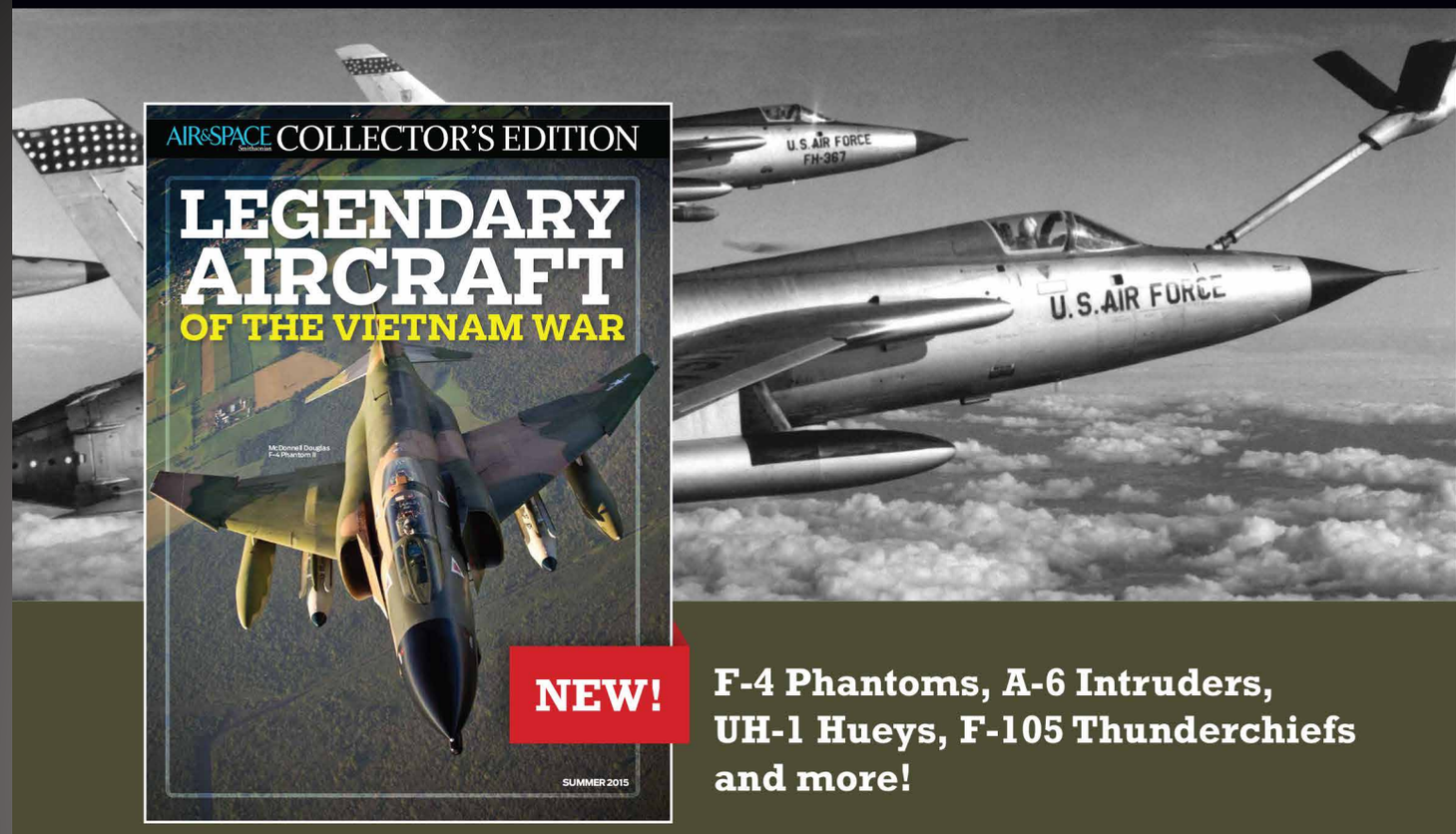

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