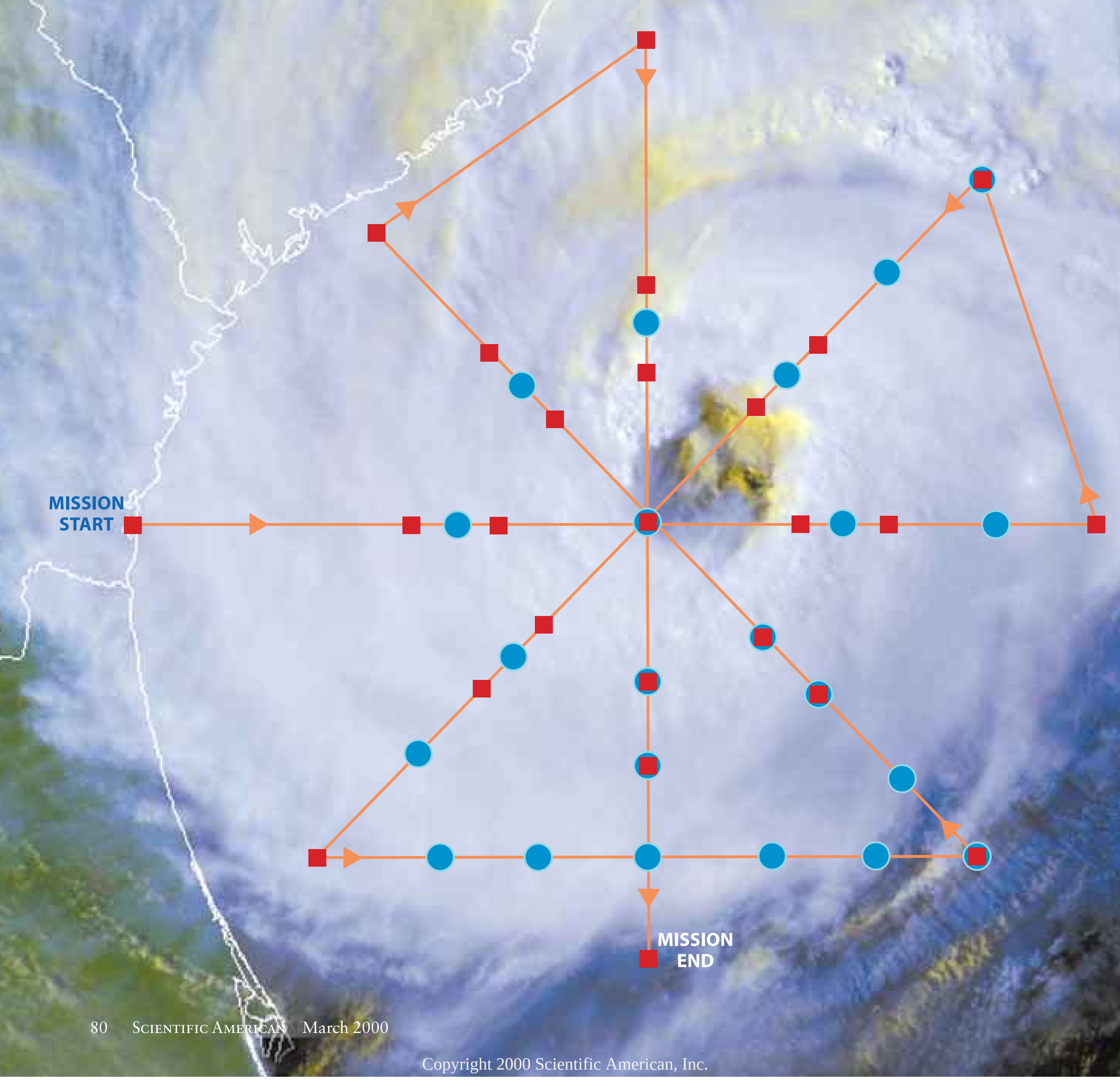
Dissecting a Hurricane



Flying into the raging tumult of Dennis, scientists suspected that the storm might transform into a monster—if they were lucky

by Tim Beardsley, *staff writer*
Photographs by Andrew Itkoff, Silver Image

MACDILL AIR FORCE BASE, FLORIDA, AUGUST 29, 1999, 1:52 P.M.: Safety lectures are over and everyone is strapped into our four-engine WP3D turboprop plane, known affectionately as *Miss Piggy*. The aircraft, jammed with computers, four different radars and a variety of other instruments, is at last surging down the runway. The past few hours have been a metaphorical whirlwind: quickly arranged travel, a 6 A.M. flight from Baltimore, then briefing sessions with the flight crew interspersed with hurried explanations from Frank D. Marks, the lead scientist on the flight.

Our destination is a real whirlwind: Hurricane Dennis, now swirling 290 kilometers east of Jacksonville, Fla., powering 145-kilometer-per-hour winds and menacing the Carolinas. On land fearful vacationers and residents on North Carolina's barrier islands are boarding up windows, throwing bags into cars and fleeing the coming storm. But Marks and his fellow scientists from the National Oceanic and Atmospheric Administration regard Dennis with hope rather than dread. If our flight through its curved arms goes as planned, this storm will shed light on a central mystery about hurricanes and typhoons: whether it is the ocean below or the winds above that wield more power in determining whether a storm will swell to greater fury or unwind into a harmless region of low pressure.

Marks is among those pushing the idea that the ocean controls how hurricanes evolve by either adding or removing energy in the form of heat. Today's forecasting models, in contrast, treat the ocean as a passive bystander.

These models have conspicuously failed to predict when storms will intensify. Hurricane Andrew startled forecasters in 1992 when it intensified abruptly while passing over the warm waters of the Gulf Stream; it later killed 15 people and destroyed property worth $25 billion in southern Florida. In 1995 in the Gulf of Mexico, Hurricane Opal transformed overnight—after the 11 P.M. television news assured Gulf Coast residents that they had little to fear—from a Category 2 to a Category 4 terror capable of extreme devastation. Opal, too, had just passed over an eddy of deep warm water. Although the storm ebbed somewhat before coming ashore, it caused more than 28 deaths altogether. And earlier in 1999 Hurricane Bret followed what now seemed to be an emerging pattern, escalating from Category 2 to 4 after passing over warm water. Fortunately, it made landfall over unpopulated farmland in Texas.

If Marks and his colleagues are right, by analyzing in detail the heart of a hurricane they should be able to tease apart the web of factors that drive the storms to live, grow and die. The scientists will need to learn the temperature of the sea at different depths during the hurricane's passage. They will also want to know as much as possible about its winds and waves.

Dennis, now a strong Category 2 hurricane, has the same ominous potential for rapid intensification as Andrew and Opal did. When Hurricane Bonnie crossed the Gulf Stream in 1998—without intensifying—Marks had been frustrated by a lack of instruments to study it. But as he watched Dennis's course in late August, he recognized an opportunity. Equipment was available, and by good fortune Eric D'Asaro of the University of Washington had just dropped three high-tech floats in an east-west line across Dennis's path. The floats move up and down, monitoring temperature and salinity in the so-called mixed layer between the sea surface and about 200 meters' depth. These data could complement observations made from *Miss Piggy*. Marks scrambled his air team to launch a detailed examination of Dennis, which is what brought us to the jetway.

Our group will scan the storm from the inside out, penetrate it with falling probes, take its temperature and clock its winds. Over the past few days NOAA's

PLANNED TRACK of a research mission into Hurricane Dennis on August 29, 1999, sliced the storm every which way to measure how winds and waves interact. The National Oceanic and Atmospheric Administration sent its WP3D research aircraft *Miss Piggy* on the demanding expedition because Dennis threatened to intensify dangerously. The actual route deviated somewhat from that planned. Red squares (■) show where the crew dropped Global Positioning System sondes to measure winds; blue circles (●) show firings of Airborne Expendable Bathythermographs (AXBTs), which measure ocean temperature.

NOAA UNIVERSITY OF WISCONSIN–MADISON SPACE SCIENCE AND ENGINEERING CENTER (*photograph*); BRYAN CHRISTIE (*graphic composition*)

TECHNICIAN James Barr loads AXBTs into firing tubes. Explosives will shoot the probes clear of the plane during the flight.

Gulfstream IV jet has charted atmospheric conditions at various altitudes in the region. Our flight is to be the crux of the assessment: four straight passes through the eye of the tempest.

Marks has weathered dozens of routine flights through hurricanes, and he likes to quip that the most dangerous part of a sortie is the drive to the airport. But he also knows that the pilots face real challenges, especially near the deep banks of cumulonimbus clouds that mark the eye wall. Winds there change speed and direction unpredictably, and intense tornadolike vortices can appear with no warning. Ten years ago Marks was flying in our sister plane, *Kermit,* through Hurricane Hugo as the storm escalated to a Category 5. An engine failed while the plane was at low altitude inside the eye, and a vortex almost threw the plane into the sea. "I am lucky to be alive after that," Marks recounts.

This morning the crew displayed an easy bravado during the preflight briefing. Some experienced members sport badges on their blue flight suits celebrating the number of eye penetrations they have survived. But as we move up Florida's eastern coast, the flight engineer seems to enjoy reminding me that hurricanes can change their character within a few hours. Our flight could last nine or more. It seems important to count the number of people on board: 19, including six scientists as well as observers, instrument technicians and the flight crew.

The frailty of the complex equipment we are carrying is suddenly underscored when technician James Barr announces that the Doppler radar in the plane's tail is not producing intelligible data. This device, along with a second radar in the belly of the fuselage, can reveal wind speeds wherever rain is falling. Marks says we definitely want this information. The flight director approves a hold, and we fly in a circle while Barr and lead electronics technician Terry Lynch attempt a repair. They yank out equipment racks and swap a transmitter.

Ten minutes pass, but something is

RAIN CLOUDS pile up near Dennis's eye wall. The passage into the eye is the riskiest part of a hurricane flight, because winds can change strength and direction unpredictably. Within the eye, however, all is calm.

HEAVILY INSTRUMENTED *Miss Piggy* is fueled and loaded on the tarmac at MacDill Air Force Base. Researchers prefer turboprop planes because they gain lift more reliably than jets do in a downdraft. The oval structure under the belly houses one of several radars. Transfers emblazoned on the craft (*above*) record hurricanes that the plane has weathered, from Anita in 1977 to Mitch in 1998.

not right. Lynch is muttering under his breath and looking worried. After a few more anxious minutes, he declares victory. Everyone gets back to work.

At our starting point for the mission proper, off the coast a few kilometers north of the Florida-Georgia border, electrical engineer Richard McNamara takes the metallized plastic wrapping off a Global Positioning System (GPS) dropwindsonde. This device, which will be dropped into the storm, unfurls a parachute when it is in free fall and radios back its position to the plane. McNamara programs it by plugging it into his instrument rack for a few seconds, detaches it and places it in a transparent launch tube set in the floor. The flight director gives the "3, 2, 1," and then McNamara presses a trigger. The cabin air pressure blows the meter-long cylinder out of the fuselage with a loud whistling sound, and McNamara confirms the time.

Within seconds his workstation has acquired a signal: the sonde's parachute has deployed. He tracks the probe's location as Dennis whips it away from the plane, betraying the direction and the strength of the winds during its descent to the ocean. He will repeat this routine numerous times during the mission, gradually building a three-dimensional picture of the storm.

We are now heading east at 4,300 meters. The cheery banter of the early part of the flight has dwindled, and I feel a mounting excitement. As the coast recedes behind us and dark gray

LEAD SCIENTIST Frank D. Marks (*foreground*) confers with navigator Dave Rathbun early in the mission. Marks is one of a cadre of scientists who believe that most forecasters have neglected the role of the oceans in hurricanes.

clouds loom ahead, the crew tap away at keyboards controlling a suite of instruments that will make Dennis the most minutely analyzed storm ever.

At 3:15 P.M. our imperturbable pilot, Ron Phillipsborn, comes on the intercom to warn of "weather" ahead. Dense rain now streams over the windows, and the blue sky we set off in is nowhere to be seen: only whiteness all about. People have been walking in the plane since we reached our cruising altitude, but now everyone heads to their seats to strap in.

The ride remains fairly smooth, however, and soon foot traffic in the aisle resumes. The spiral form winding on the radar screens is familiar from the Weather Channel, but it is far more compelling at this moment. Operators compile the maps every 30 minutes and send them by a slow satellite link to the National Hurricane Center at Florida International University in Miami. Researcher Christopher W. Landsea, furiously editing data at one of the consoles, estimates Dennis's eye to be 80 kilometers in diameter, which is larger than that of most hurricanes. The storm is moving slowly northward, brushing the coast. Its waves are now pounding jetties as its winds tear the shingles off roofs.

When we reach the point where we have to fire a probe called an Airborne Expendable Bathythermograph, or AXBT, McNamara flips a switch on his console. An explosive charge shoots the first of the AXBTs, which are preloaded in the plane's belly, out into the storm now engulfing us. AXBTs do nothing as they fall, but when they splash into the ocean they send a thermometer on a wire down to 300 meters and radio the temperature readings along the way.

We approach the eye wall at about 500 kph, shooting out more GPS sondes and AXBTs as we go. Through occasional gaps in the dense clouds I can see the roiling ocean surface, flecked generously with patches of white.

These regions of bubbles, caused when the wind blows the tops off waves, look insubstantial in comparison to the cubic kilometers of air and water heaving all around us. But scientists suspect that they are crucial in determining how a hurricane will change, because they efficiently transfer energy between sea and air. One of the instruments we are carrying, a radiometer, can measure that foaminess by detecting microwave energy reflecting off the sea surface at six different frequencies. It can in principle, anyway. In practice, software glitches have so far hung up the device on all of its previous flights. Marks is hoping that NOAA scientist Peter Black, who is grounded in Florida with a cold, succeeded in his latest attempt to debug the code.

The fuselage shudders and heaves again, and my coffee makes a bid to escape from its plastic cup. Phillipsborn orders us back to our seats once more, but the floor and the seatbacks are now moving targets. We endure a couple of stomach-churning lurches. I start to wonder exactly how much the wings could flap like that before breaking off. McNamara, sitting across the aisle from me, is unfazed, repeatedly firing off GPS sondes alternated with an occasional AXBT. He seems too busy for any idle speculation.

I realize that the nausea-inducing plunges have stopped: we have pierced Dennis's eye. Overhead is the blue sky we left behind. Wind speed outside is about three knots, hardly enough to lift a flag. We hunt for the point where wind speed and pressure are lowest, to get a fix on the center. Not many kilometers distant, huge stacks of rain clouds are visible, strewn in a vast arc. We plunge into the eastern eye wall, dropping more sondes as we do so into the colossal heat engine turning around our plane.

Hours pass as we trace a compass rose centered on the eye. My tension has prevented hunger, but in the late afternoon I cautiously maneuver toward the galley for a sandwich, where I find a crew member calmly reading a newspaper.

The unpredictable drops become familiar but worsen on a slow upwind leg. The repaired Doppler radar is working imperfectly: its output will be less complete than Marks had wanted. Landsea announces that the instrument shows surface winds have reached about 160 kph. Dennis is indeed getting stronger. Yet as it intensifies, it stirs up cooler water from the depths. I learn later that Dennis cooled the water off the Georgia and South Carolina coasts by three degrees Celsius and roughly doubled the depth of the mixed water layer beneath its core. That effect in turn cooled Hurricane Floyd's fury when it passed the same way days later.

We are transmitting readings from the radiometer to the National Hurricane Center. But Marks is still uneasy about the device. Partway through the flight, he is surprised when the plane's radio operator patches through a phone call from Black. It must be urgent, because the radio interferes with the radars, so Marks figures he will be hearing about some new radiometer problem. In fact, Black exclaims that the instrument, which can reveal surface winds in detail, is working perfectly. Marks is sufficiently relieved to announce the good news over the intercom. The mood on the plane brightens noticeably.

The flight wears on. We make a long

GLOBAL POSITIONING SYSTEM SONDE is readied for launch by electrical engineer Richard McNamara. Cabin air pressure blows the devices out of a floor-mounted tube. Once clear of the plane, the sondes deploy a parachute and transmit data about where winds take them during their several-minute fall to the ocean.

traverse over D'Asaro's floats, dropping AXBTs and GPS sondes as the whiteness outside fades into the black of night. On the fourth pass through the eye we again hunt for the center to see how far it has moved: center fixes are crucial for helping forecasters judge where a storm is headed. Dennis's western side is over the Gulf Stream and presumably picking up energy there, but the eye remains farther out in the Atlantic. Marks fears a landfall in North Carolina the following day.

On the way home we make a point of firing off some AXBTs and GPS sondes as close to ground-based measurement stations and buoys as we can, so that the scientists can make cross-checks of the instruments' performance. By the time we touch down at MacDill, it is 10:24 P.M. Marks seems more pleased with the day's work than exhausted by the nearly nine-hour journey.

The next day we rise to learn that Dennis has veered slightly eastward, moving parallel to the Gulf Stream. The churning that cooled the sea surface, along with Dennis's failure to pass right over the Gulf Stream, means that it will not turn into the nightmare storm it might have. Yet it has yielded a treasure trove of information.

The radiometer data are the main prize. But the happy conjunction of *Miss Piggy*'s flight and D'Asaro's floats have made it a scientific field day in other respects, too. We had launched 30 GPS sondes, several of them right into Dennis's eye wall. We had also fired off 15 operative AXBTs; three of these splashed on the east-west line south of the eye where D'Asaro's floats were at work. The Doppler radar data are adequate for most purposes. In addition, Ed Walsh of the National Aeronautics and Space Administration successfully used a scanning radar altimeter during the flight to bring in a good haul of measurements on the direction and height of Dennis's waves. They are highly asymmetric and resemble a pattern Walsh saw earlier in Hurricane Bonnie.

All this information will be grist for hurricane modelers' data mills for years to come. No single storm will answer all the questions about hurricane evolution. But Marks and his crew of technicians and investigators have shown that they can deploy a comprehensive array of high-tech instruments in a dangerous cyclone and emerge with valuable results. As long as they and other riders on the storm are willing to continue risking life and limb for science, the mystery of what makes a hurricane intensify seems likely to diminish—and with it, the opportunities for some future tempest to turn without warning into a killer. SA

Further Information

THERMODYNAMIC CONTROL OF HURRICANE INTENSITY. Kerry A. Emanuel in *Nature*, Vol. 401, pages 665–669; October 14, 1999.

NOAA's Hurricane page is available at hurricanes.noaa.gov/

Hurricane Dennis mission summary can be found at www.aoml.noaa.gov/hrd/Storm_pages/dennis99/990829I.html

Storm Atlas of NOAA's Hurricane Research Division is available at www.aoml.noaa.gov/hrd/Storm_pages/frame.html