ARCHWAYS

THE SEARCH FOR DISCOVERY AT TEXAS TECH UNIVERSITY SPRING 2006 / VOL. I NO. I

Wind defines West Texas as much as her wide horizons.

Wind has a natural beauty that is painted in motion and energy.

But the heavens forever will have the potential to wreak havoc.

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ALWAYS WILL

By Kippra D. Hopper

ARCHWAYS

THE SEARCH FOR DISCOVERY AT TEXAS TECH UNIVERSITY

WIND PIONEERS



K METHA, PHO

Kishor Metha has helped to develop building codes that protect property and persons. He is an elected member of the National Academy of Engineets for his work in wind engineering.



IS DESCRIBED IN

Richard Peterson is studying how nocturnal low-level jet streams develop in the summer in West Texas.



E MIDSHING DATE

Ernst Kiesling developed the first in-residence storm shelter. Tornadoes have proven the safety of shelters.



C MERCHANIC OF REAL

Jim McDonald designed and constructed the "tornado cannon," a debris missile launcher to test building materials from dangerous flying objects in storms.

EDITOR'SNOTE

ARCHWAYS is a new serialized monograph focusing on sponsored research at Texas Tech University. The premiere issue concerns wind research, in which scholars have taken Mother Nature's extreme wind events to shape what now is conventional wisdom about surviving tornadoes and hurricanes. The 1970 Lubbock tornado spawned a team of pioneering researchers who studied that tragedy and many others that followed during the next 35 years across the United States and abroad. Furthering other Wind Science and Engineering Research Center endeavors, engineers are finding ways to harness the wind, making Texas the United States leader in megawatts produced through wind energy. Researchers are using wind energy to desalinate water. Researchers at Texas Tech University are studying a naturally occurring phenomenon and a natural resource—wind—and are finding ways both to protect lives and property and to find environmentally friendly solutions to the world's energy and water needs.

Proposa W. Hoppes

SPRING 2006 / PREMIERE ISSUE / VOL.1 NO.1

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Each issue of ARCHWAYS (Library of Congress ISSN pending), a serialized monograph of the Office of the Vice President for Research, reflects major, multidisciplinary, funded research endeavors at Texas Tech University. Editor of Archways is Kippra D. Hopper, Director of Research Communications, who can be reached via e-mail at hippra.hopper@ttu.edu or 806.742.3905, address P.O. Box 41075, Lubbock, TX 79409-1075. Articles and photographs from ARCH-WAYS may be reprinted with permission of the editor as long as credit is given to the Office of the Vice President for Research at Texas Tech University. ARCHWAYS is a member of the University Research Magazine Association, www.urma.org. Texas Tech is committed to the principle that in no aspect of its programs shall there be differences in the treatment of persons because of race, creed, national origin, age, sex or disability. Equal opportunity and access to facilities shall be available to all. Direct inquiries to the Office of Equal Employment Opportunity, 323 Administration Building, Texas Tech University, Lubbock, TX 79409-1073, 806.742.3627. Persons with disabilities who may need auxiliary aids or services are requested to contact the Office of the Vice President for Research. Copies of this publication have been distributed in compliance with the State Depository Law and are available for public use through the Texas State Publications Depository Program at the Texas State Library and other state depository libraries. @Copyright 2006, Texas Tech University.

We see the wind and its forces on the grasslands of West Texas where a dust devil can stir up at any time and where the rain may burst down upon an unprepared wanderer. The skies of the Great Plains hold both wonder and magnificent energy. COVER AND CONTENTS PHOTOS BY ARTIS LIMMER

The Winds Always Will Blow
Texas Tech University Wind Science and Engineering Research
Center scholars are ready to calm the storm by preparing for the force of winds. BY KIPPRA D. HOPPER // PHOTOS BY ARTIE LIMMER

From the Eye of the Storm

The Hurricane Intercept Team deploys scientific measurement devices in the paths of ocean storms. BY JEROD FOSTER // IMAGES BY JOEY HERNANDEZ

Catching a Breeze

Wind and water always have been natural resources on the West Texas semiarid lands, BY KIPPRA D. HOPPER // IMAGES BY ARTIE LIMMER

Structural Integrity

Protecting people and property from wind-borne debris, engineers use a tornado cannon and wind tunnels to test the strength of structures.

BY IFROD FOSTER # IMAGES BY JOEY HERNANDEZ & ARTIE I IMMER

The Fujita Papers

Meticulous and copious records of every major wind event since World War II are saved and studied by scholars throughout the world.

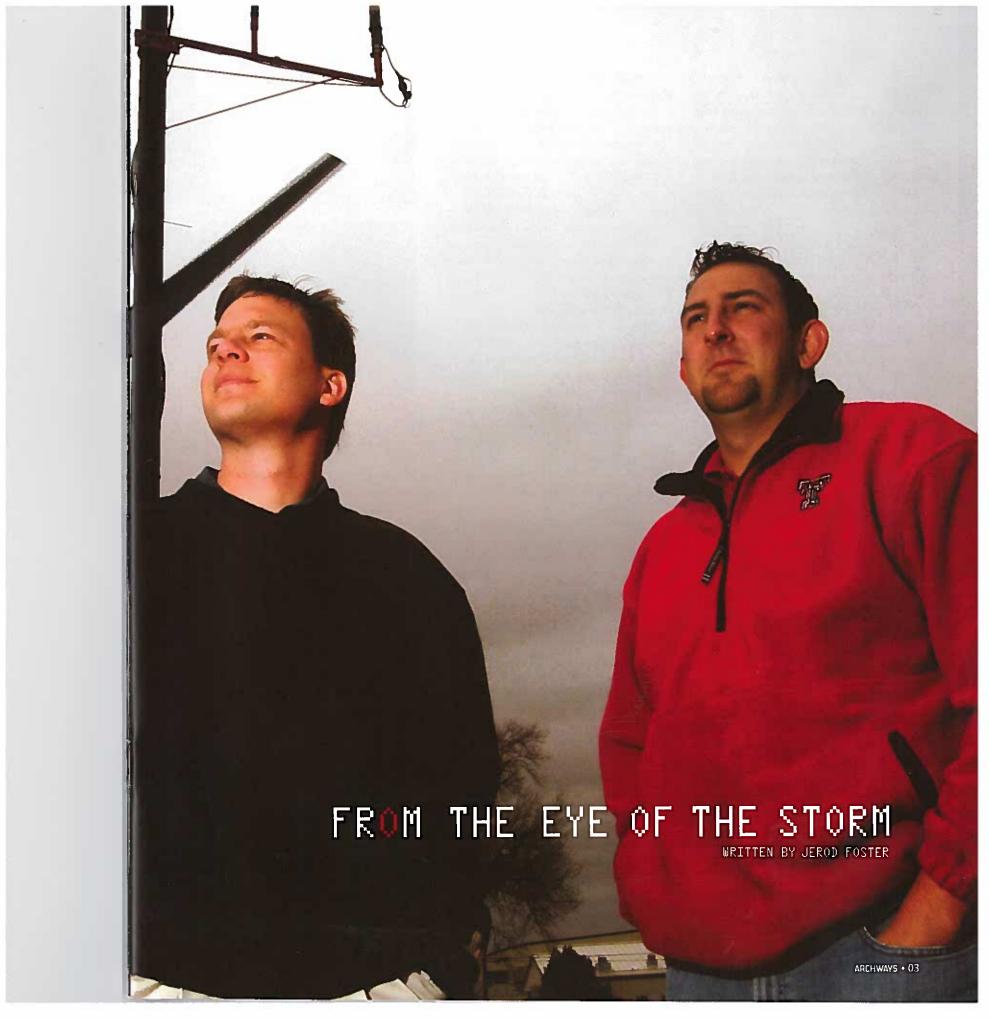
BY LARISSA K. TRUE // IMAGES COURTESY OF SOUTHWEST COLLECTION

THE MEDIA DESCRIBED THE DEWASTATION

that wrecked the Gulf Coast region during the 2005 hurricane season as extraordinary, eerie and frustrating. Scientists were faced with historical information spawned from the extremities of the numerous storms with above-average statistics. The most lasting element of all was that the people living in the Gulf states found the season as forever changing their lives, with more than a half a million people without jobs and even more without homes.

Ian Giammanco, field director for Texas Tech University's Hurricane Intercept Team and a doctoral student in atmospheric science, is no stranger to the areas where the hurricane season unleashed its fury. Growing up in Baton Rouge, Louisiana, Giammanco always was excited by hurricanes and extreme weather conditions. "Hurricane Andrew really got me interested in tropical meteorology, and that got me into weather," he comments. "I remember staying at my grandmother's house in New Orleans when I was a child during Hurricane Juan when the city had to be evacuated. That was my first experience with hurricanes." With his father as a physics professor at Louisiana State University, Giammanco became interested in the natural sciences through several elementary science teachers who impacted him. After finishing

LEFT TO RIGHT: JOHN SCHROEDER, PH. D., AND IAN GIAMMANCO STAND NEXT TO ONE WEMITE TOWER THAT HELPS THEM TO MEASURE WIND SPEEDS AND OTHER FACTORS IN HURRICANES.



high school, he attended the University of Louisiana in Monroe for his bachelor's degree in atmospheric science. Upon coming to Texas Tech University, he earned his master's degree in atmospheric science and now is completing course work for his Ph.D. His interests lie in studying hurricanes on the coast and chasing tornadoes on the Great Plains.

iammanco has devoted himself to the Hurricane Intercept Team (HIT), a group of individuals who deploy instruments to collect data from major hurricanes by first predicting the path of the storms' landfall, especially in the Gulf Coast and Atlantic Basin regions. His own studies pertain to wind energy rather than severe weather conditions, but his enthusiasm and passion for chasing storms is evident. "The Hurricane Intercept Team is comprised of people who have had experience deploying instruments in the path of storms and who have a vested interest in the data collection." Giammanco says.

The HIT team is headed by John Schroeder, Ph.D., an associate professor in atmospheric science who initially came to Texas Tech as a graduate student with an interest in tornadoes. The team collects information that is utilized by the National Weather Service and the National Hurricane Center and serves as a database for researchers. The team determines ideal locations that offer vantage points for recording the chaotic elements of a hurricane, such as extreme wind and heightened precipitation. Deployment locations are set approximately three miles inland, where the towers and radars are anchored in solid ground versus the coastal sand nearer the water. Area disaster managers give permission for the research team's deployment locales. "What we're looking for in a site is an open area, and airports serve as the best," Giammanco says. "Typically, we look at a site that is eight feet above an elevation because of storm surges. We try to get the closest to the coast as we can because we want the highest wind intensity. As wind crosses land, the friction reduces the wind speed. We are able to see the most damage from being close to the coast. From an engineering perspective, we want to see the highest winds so that we can relate those measurements to how buildings will react to winds."

Graduate students on the team deploy five Wind Engineering Mobile Instrumented Tower Experiment (WEMITE) towers, two of which are positioned atop heavier trailers that strengthen the towers to withstand Category 5 hurricane winds. The other three towers are mounted on tripod structures. All of the towers are anchored with guide wires and outfitted with several anemometers or devices that sense wind speeds and directions. Each anemometer collects a data point every tenth of a second, resulting in some rather large data files to analyze. "We try to get the towers up with at least 12 hours to spare before the hurricane makes landfall," Giammanco says. "In Katrina, we set up our last tower in the first rain band, so we still had eight to 10 hours until landfall. We got rained on, but nothing significant. For safety reasons, we try to deploy early in a storm."

Two SMART-R (Shared Mobile Radar Atmosphere Research and Teaching) radar systems are operated mainly by professors on the deployment team because of the meticulous procedures used and the overall value of the equipment. Each radar is anchored onto a 26,000-pound truck. Once positioned for the storm, the radar systems must be operated throughout the entire storm by a team of three or four people. Although the radars can be deployed closer to the coast, safety considerations mean that the radar trucks often are located close to the towers.

The research radars offer distinct advantages. "The radars are research-driven, so we can control how they scan, relative to an operational radar used by the weather service, which has a relatively rigid scanning methodology," says Schroeder. "We can change certain scanning strategies of the research radars to suit our scientific purposes. Our radars do a vari-





SCHROEDER AND GIAMMANCO DOCUMENTED THE DESTRUCTION ON THE U.S. GULF COAST, SHOWING BUILDING DAMAGE, WASHED OUT HIGHWAYS AND THE STORM SURGE THAT FOLLOWED HURRICANE KATRINA.

ety of interesting activities to help benefit the research and advance the science. We position towers at specific locations within an area. Using a radar, we can cut slices through the atmosphere and realize what is going on at a more rapid rate. Using a coupled system, we can define what is going on at a specific point with the tower, and use the radars to create a spatially continuous layer of information that can be tied down to the ground," Schroeder says, noting that the most advanced research can be accomplished through this coupling of the WEMITE towers and the radars.

"The radars sense the same precipitation information you would see on a television weather service, but it has the ability to also deduce wind velocities," Giammanco continues. Using two radars enables Texas Tech researchers to detect an actual wind speed, three-dimensionally. "All the radar can detect is wind speed away from or toward it, and that does us some good if we can point the dish of the radar into the wind. In a hurricane, we want to map the whole storm, so we scan back and forth. With two radars, we can get a complete wind field picture," Giam-

manco says. During Hurricane Frances in 2004, he conducted radio relay between the two radars, which could not quite communicate with one another. "Two other graduate students and I positioned ourselves on a bridge in between the two trucks for the radars to communicate. We knew that for the eye wall of the storm to pass between two radars where the beams collide would be ideal."

uring landfall, the team members typically pre-locate to a hotel out of the way of the storm to monitor storm activity. Sometimes, however, their location is not far enough out of the path of the storm and its effects. "With Katrina, we were 40 or 50 miles away and about five miles inland," Giammanco describes. "I was actually very tired and stressed out. I fell asleep, and Dr. Schroeder came knocking on the door making fun of me because I was sleeping. He said, 'I think the surge is across the street,' so I got up and sure enough, there was water over there. I thought it was freshwater flooding, but it kept coming up." The team ended up being trapped in the hotel for several days before they could make it back to their towers. "As a scientist, you're just kind of awe-struck," Giammanco continues. "You're just interested and it takes you a second to realize that a house across the street is completely flooded. Sometimes there is a sense of confusion because one part of you is completely interested in the storm effects, and the other part of you is thinking people are going to get hurt in this storm."

Various industries and academic institutions use the data collected by the towers and radars. Regular data collected by the Hurricane Intercept Team include wind speed and direction as well as temperature and barometric pressure. Different experiments by graduate students often warrant the collection of other various data. "We had a graduate student looking at turbulence in the wind, or studying those small fluctuations in what the wind is doing," Giammanco

says. "She's comparing hurricane winds to those of tornadoes. Graduate students here at Texas Tech have a lot of freedom to explore their own ideas, and the towers are at their disposal during storms."

Regular collected data is used extensively by engineering consultants in the improvement of structures in the storms' paths. Data from the team are assimilated into the National Hurricane Center's final cyclone report, a document that summarizes the entire life history of a single storm. "After Katrina hit, the National Hurricane Center named it a Category 4 storm after it made landfall, but after the information was analyzed, the center scientists decided the storm was a Category 3," Schroeder explains. "I believe the data we collected played a pretty significant role in that." Engineers can analyze the wind speeds and compute the approximate wind loads on buildings, or the force that wind places upon certain points of a structure. With this information, they can design economically practical buildings that can withstand strong winds. "Texas Tech is wellknown for researchers' contributions to strengthening building codes. Our faculty ensures that the information ends up with the American Society of Civil Engineers, the group that writes the building codes. Since hurricanes Katrina and Rita, we have had other significant requests for our data. It is part of our job to get the information processed and ready to be distributed."

After the storms of hurricane season 2005, Giammanco says he can see how effective the information he helps to collect can be for post-storm improvements. "Because of previous storms, we were going to places I had never been before, and I did not have a good feeling for what was what," he says. However, he was familiar with the coastal region that Hurricane Katrina hit. "I would hear of landmarks that were under water and I would realize that I had walked there. I especially wondered what was left of New Orleans, where my grandmother is from. I drove to the Mississippi coast, and within three blocks of the coast, everything was gone. Debris was stuck in the trees and it was really creepy. I think the strangest image was when I was looking across a bay in between Ocean Springs and Biloxi, and one of the casino boats was on its side, and the first three floors of hotels were just gutted. It was really strange."

Giammanco is determined that the research his team conducts will aid future development of a safer and stronger environment for humanity along the Gulf Coast of the United States. "The research is obviously valuable. After Katrina, I took a more personal approach to what I do. Whatever we can contribute to the sciences is good. That really made me want to work harder because of places I knew or have seen that were flooded or destroyed."

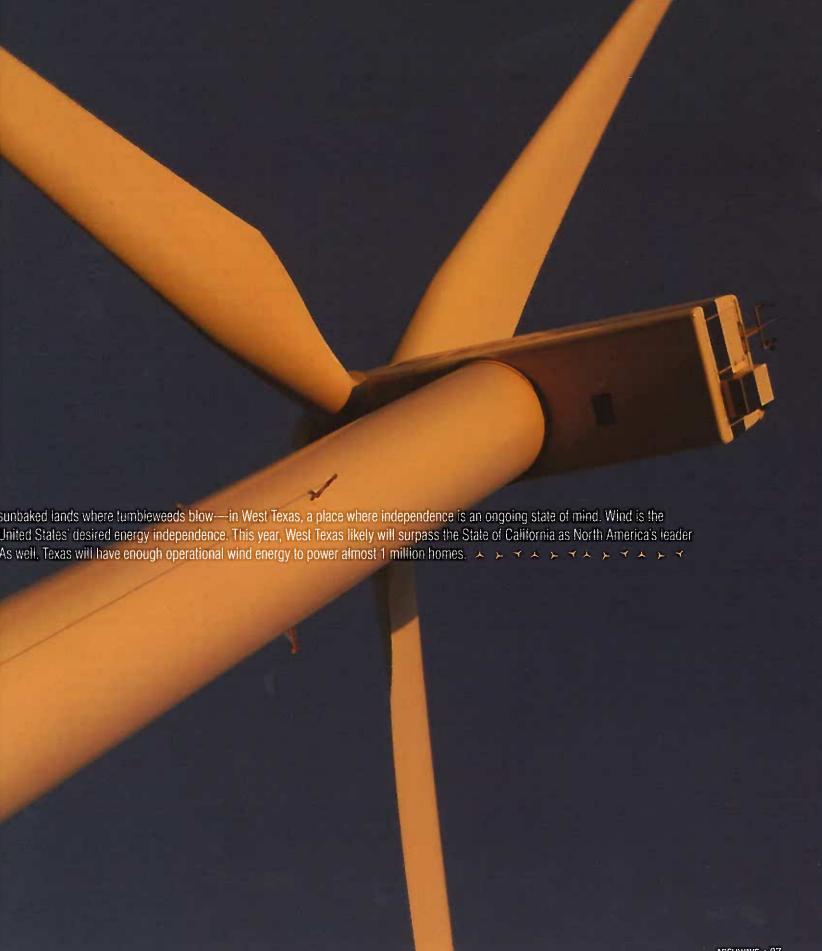
Researchers at Texas Tech will continue to chase storms to find the weather's most extreme activities. According to Schroeder and Giammanco, scientists have not yet fully documented nor comprehended all there is to know about hurricanes and their inevitable damage to people and property. The Hurricane Intercept Team is pulling together data from dozens of storms to create a greater understanding of these enormous wind and water events of Mother Nature.



CATCHING A BREEZE BY KIPPRAD HOPPER

Energy independence for the United States may come from the hardscrabble world's most appealing source of renewable energy and an important facet of among states and provinces for wind energy generation capacity and product

PHOTOS BY ARTIF LIMMER



Texas Tech University is poised to take a leadership role in the development of wind power systems through research, economic development, job creation and education. In announcing a \$1.5 million congressional appropriation to establish the Great Plains Wind Test Facility at Reese Technology Center, U.S. Sen. Kay Bailey Hutchison said that the funding for the new facility will support existing wind research initiatives at the Wind Science and Engineering Research Center (WISE) at Texas Tech. "Wind is a renewable power source, and our state will benefit from the expanded resources developed through this research," she said. "Texas has the second highest potential for wind energy in the nation, and this renewable source of energy will help address our future energy needs."

The funds allow the expansion of the Wind Science and Engineering Research Center's facilities for testing, characterization

and improvement of wind turbines and wind-driven water desalination systems. The money will be used to create applications that will integrate wind energy into municipal power grids; to pump and desalinate water using wind energy; and to develop the software needed to interface the variable power supplied by wind with water pumping and desalination facilities. Working with community colleges, such as Texas State Technical College, the funds also will provide for curriculum development in the implementation of training wind technicians, known as "wind-smiths," explains Wind Science and Engineering Research Director Andy Swift, D. Sc.

The 12 states that reach from the Dakotas

to Texas have more potential wind energy than all of the other contiguous United States. "In Lubbock, we are in the middle of several large wind farm installations. Texas is very progressive and business-friendly, and the people generally have a can-do attitude," says Jamie Chapman, senior research faculty member with WISE.

The Wind Science and Engineering Research Center will upgrade its facilities at the Reese Technology Center for detailed atmospheric measurements. "We are establishing a unique, world-class wind measurement facility. We are looking into advanced wind measurement systems, such as Doppler radar and other advanced, sophisticated measurement systems," Swift says. "Our objective is to carefully characterize the wind, with a focus on extreme wind events, and use that high fidelity wind data in real time with an advanced wind turbine computer model to provide the performance and structural loads data for the wind turbine."

The Wind-Water Integration and Demonstration Program focuses on the integration of wind turbines and water desalination mechanisms. Texas Tech will begin with a 5-kilowatt wind turbine, and eventually move to the utility-scale 1.5-megawatts. Each megawatt is enough power to provide electricity to approximately 300 homes. "We will start with a 5-kilowatt wind-water system, which will provide about the output of a small garden hose. Using

this bench scale system, we will develop the integration technologies leading to larger utility scale systems," Swift says.

Being a comprehensive program, says Swift, a large part of the wind engineering researchers' efforts will be to train the next generation of scientists and engineers in wind technology, wind characterization, wind hazards and wind energy.

Technicians will be needed to maintain the wind turbines, and in oil-rich West Texas, many former oil rig workers could be retrained to do the work. "In Texas, we have workers in the oil industry who are used to dealing with heavy equipment and doing dangerous tasks," Swift says.

Billions of dollars are invested in wind energy plants in the states of Texas, Colorado, New Mexico and Oklahoma. "Wind energy is here today. With the increasing cost of natural gas, wind energy is now a significant player and will be a major player in

the next five years. The question is how big of a player will wind energy be? Our energy always will be a mixture of coal, natural gas, hydropower, nuclear power plants and renewable sources. Texas' contribution is 1 to 2 percent of the state's electricity that is powered by wind. In Denmark, at certain times, they have more than 50 percent of their electricity generated by wind power, which is a huge percentage. Wind energy creates jobs, offers new technologies, presents new research and adds to the tax base—all done domestically," Swift comments.

The Wind Science and Engineering Research Center will continue to research the characteristics of the wind and to document the

unusual events of the Great Plains. "A lot of areas that have water problems also have wind. The cost of wind power has been decreasing. It is a clean power source that uses no water to generate power and is probably the cheapest new source of electricity in bulk form. Most conventional sources of power generation use large quantities of water for cooling," Swift says. "There is a synergy between wind and water so that we can begin to imagine situations with wind machines and desalinated water storage tanks in which we can store wind energy in the form of water."

Swift notes that the Great Plains has unusual weather events, such as microbursts associated with thunderstorms, tornadoes and nocturnal low-level jets. Wind turbines are designed with wind characteristics of Europe, because the design codes were devel-



Andrew Swift, D.Sc.

With the cost of natural gas, wind energy is now a significant player and will be a major player in the next five years.

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oped using European weather standards. "On the Great Plains, we encounter severe thunderstorms and have a nocturnal low-level jet stream that occurs nightly in the summertime," he says. A nocturnal low-level jet stream is a large "river of wind" that is close to the surface at nights during the summers.

Associate Director of the WISE Center, Richard Peterson, Ph.D., a researcher in atmospheric sciences and a meteorologist, has studied the phenomenon of the nocturnal low-level jet stream that is prominent on the High Plains. "The low-level jet means that we have a region a little above the surface where winds are stronger than they are on the ground and than they are higher in the atmosphere. This tends to develop during the nighttime and peaks before sunrise and then weakens," Peterson explains. "As air cools, the wind speed develops again, out of the south, bringing Gulf moisture northward."

Researchers are considering these pathological weather events in the design and the long-term reliability of wind turbines. "Researchers now realize that these speed maxima, or high speed zones, are closer to the surface than was thought. As wind turbines are constructed larger and taller, the wind characteristics matter even more," Peterson says. For example, a wind turbine rated at 5 megawatts recently was erected in Germany. Weighing approximately 400 tons, the wind turbine has a rotor diameter of 126 meters (410 feet). This puts the blades into the region of the low-level jet where speeds can vary greatly with height. With a 200-meter (650 feet) high tower at the Reese Technology Center, Peterson is trying to determine how low level jets develop.

Beneath the Ogallala Aquifer throughout the Great Plains is the Santa Rosa Aquifer, full of brackish and unusable water. Researchers at Texas Tech are linking wind power to the purification of water. Energy from the wind turbines could be used to purify water, providing more of this limited resource and saving the precious Ogallala. "What's exciting about desalinization is that water is a huge issue, both in quality and quantity, throughout the West. A lot of water that is available is of poor quality and unusable. Good quality water is becoming less and less available as the population grows," says Swift. "How can we take water of poor quality and treat it in a way to make it drinkable?" One technology becoming less expensive is reverse osmosis. With pressure, water is driven through membranes. A great deal of electrical power is required to provide the pressure responsible for sending the brackish water through the semi-permeable membranes that allow clean water to pass through and leaving the salt in the original water stream.

"The economics of wind are attractive. When we look at the economics of reverse osmosis water purification systems, we find a symbiotic relationship in that wind and water complement one another," says Chapman. "A third component is that municipalities that are dealing with a depleted Ogallala Aquifer already have water distribution, pre-treatment and water storage systems in place. When the electrical demand is highest during the daytime, we can provide electricity to residents of the city. And, at night, when electrical demands are not so great, we can use the wind turbine energy to purify the water and store the energy as water



Wind and water go together in old windmills and in new wind turbines — all of which can be viewed at the American Wind Power Center in Lubbock, Texas.

in tanks. We are responding to a real need regionally and throughout the world. Finally, and perhaps most importantly, wind systems require neither water nor fossil fuels for their operation."

In West Texas, population and personal income growth rates lag behind those for the rest of Texas as well as the United States. If the West Texas region is to remain economically viable, a new economy must emerge, says Robert Sweazy, Ph.D., economic development adviser to Texas Tech President Jon Whitmore, Ph.D. "As one of the most important economic assets in the entire region, Texas Tech University must be involved in developing the new economy," he says. Two resources—energy and water—readily must be available as the foundation and cornerstone of the future economy, he continues. "Beyond sustaining our current economic activities, abundant and affordable energy and water are essential to achieve higher rates of economic growth and diversification of the West Texas economy."

Wind and water always have been natural resources on the West Texas semiarid lands. Like the pioneers who used wind and water together in windmills, today's researchers are finding ways to advance wind energy and to preserve a dwindling supply of water, and in turn, saving the region's future.

LARRY TANNER, A RESEARCHER WITH THE WIND SCIENCE AND ENGINEERING RESEARCH CENTER, OPERATES THE "TORNADO CANNON," OR A HIGH-POWERED DEBRIS LAUNCHER, TO TEST VARIOUS BUILDING MATERIALS, SUCH AS SHEETROCK AND CONCRETE, TO HELP ENGINEERS DESIGN BETTER STRUCTURES WHERE PEOPLE CAN SURVIVE THE MISSILES OF DEBRIS THAT CAUSE DEATH AND DAMAGE IN TORNADOES. /// PHOTOS BY JOEY HERNANDEZ





INTEGRITY STRUCTURAL



THE WIND SCIENCE AND ENGINEERING
RESEARCH CENTER TESTS BUILDING
MATERIALS FOR STRUCTURAL INTEGRITY
AGAINST MISSILES OF DEBRIS THAT
FLY IN TORNADOES AND MAJOR WIND
EVENTS. USING A DEBRIS LAUNCHER,
SCIENTISTS ARE FINDING WAYS TO
BUILD BETTER SHELTERS. BY MODELING
WIND FLOW ON STRUCTURES THROUGH
EXPERIMENTS IN WIND TUNNELS, THE
W.I.S.E. SCHOLARS ARE ENSURING
SAFETY FROM THE STORMS THAT
NATURE BRINGS. /// BY JEROD FOSTER



SMALL PLASTIC TUGES MEASURE WIND PRESSURE, WHICH DETERMINES LOADS ON GUILDINGS.

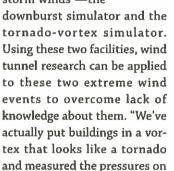
The mobile home park was not outfitted with warning sirens, storm shelters or an evacuation plan for its residents. Downburst simulations, debris cannons, vortex analysis and wind loads were more than likely not on the minds of Eastbrook Mobile Home Park residents in Evansville, Indiana, on Nov. 6, 2005. With little knowledge of what was knocking on their front doors, 20 people lost their lives, and 80 homes were destroyed after midnight.

Larry Tanner, P.E., a Texas Tech University lecturer in civil engineering and research associate with the Wind Science and Engineering Research Center (WISE), traveled to Indiana to study the effects and damage of the storms to the mobile home structures. Tanner made three key findings that came somewhat as a surprise while he was investigating the aftermath of the incident. He discovered that in some instances, the mobile home straps were loose and that many of the straps did not align with the anchors that were provided, while some straps that were anchored gave way because of intense wind loads. Shockingly enough, Tanner revealed that some of the homes were not anchored at all. "I haven't a clue why so many were not anchored," Tanner says. "Concrete pads were provided for each home and most pads contained anchoring loops cast into them. Still, some units were not connected. Mobile homes, at best, are marginally safe in high winds when anchored to the Earth and are very susceptible to even moderate winds if unanchored."

At Texas Tech, Tanner spends time researching the effects that tornadic winds have on engineered structures such as mobile homes. For the last two years, the Wind Science and Engineering Research Center researchers have conducted studies using such instruments as actual mobile homes, cargo airplanes and wind tunnels. "They set up and anchored a mobile home unit with underpinnings and then flew in an Air Force C-130 basically to blow on it," Tanner describes. "The houses had instrumentation to accurately measure wind pressures, and even though they collected decent data, our wind generator, the C-130, could not provide the type and strength of wind in a tornado. The resulting analysis was for straight-line winds, more typical of hurricanes, rather than the tight oscillating winds that occur in tornadoes."

Utilizing wind-tunnel technology offers a solution to this research dilemma. Chris Letchford, Ph.D., a pro-

fessor of civil engineering, manages the wind tunnel at Texas Tech and is a key figure in the creation of two crucial simulations for the research of tornadoes and extreme thunderstorm winds —the

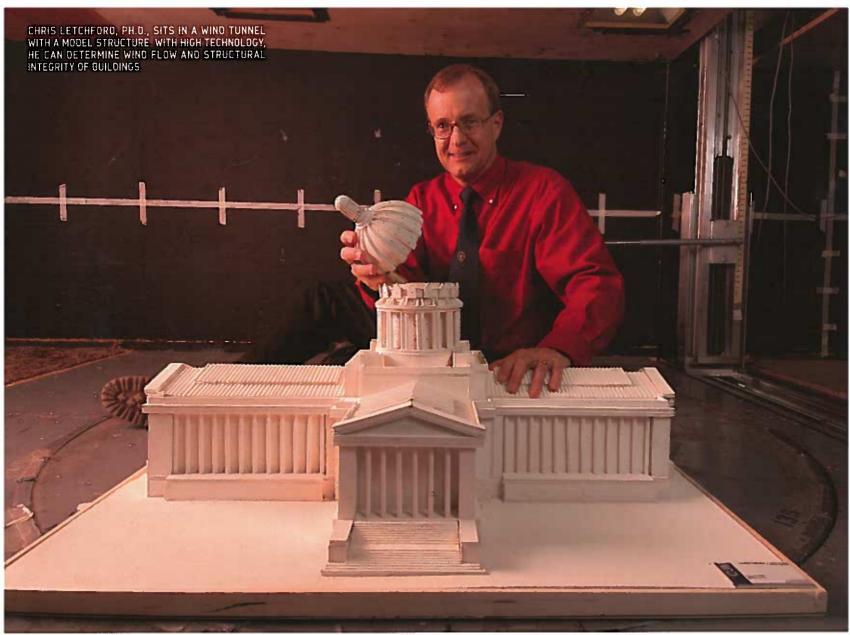




the buildings caused by the wind flow, and we've done the same thing in the downburst simulator," Letchford says. "We've come up with innovative modeling of these types of winds, which cause most of the damage throughout the majority of the country."

Researchers document the simulations conducted at Texas Tech very similarly to the way actual disasters are analyzed. Photography is utilized to accurately observe storm effects, and those images then are coordinated with data collected by instrumentation. Between full-scale observations and model-scale simulations, investigators are able to come to a better understanding of what occurs in these extreme events and also what could be strengthened in manufacturing procedures and in further research.

Tanner utilizes the data sets that are collected using wind-tunnel technology and other instruments to



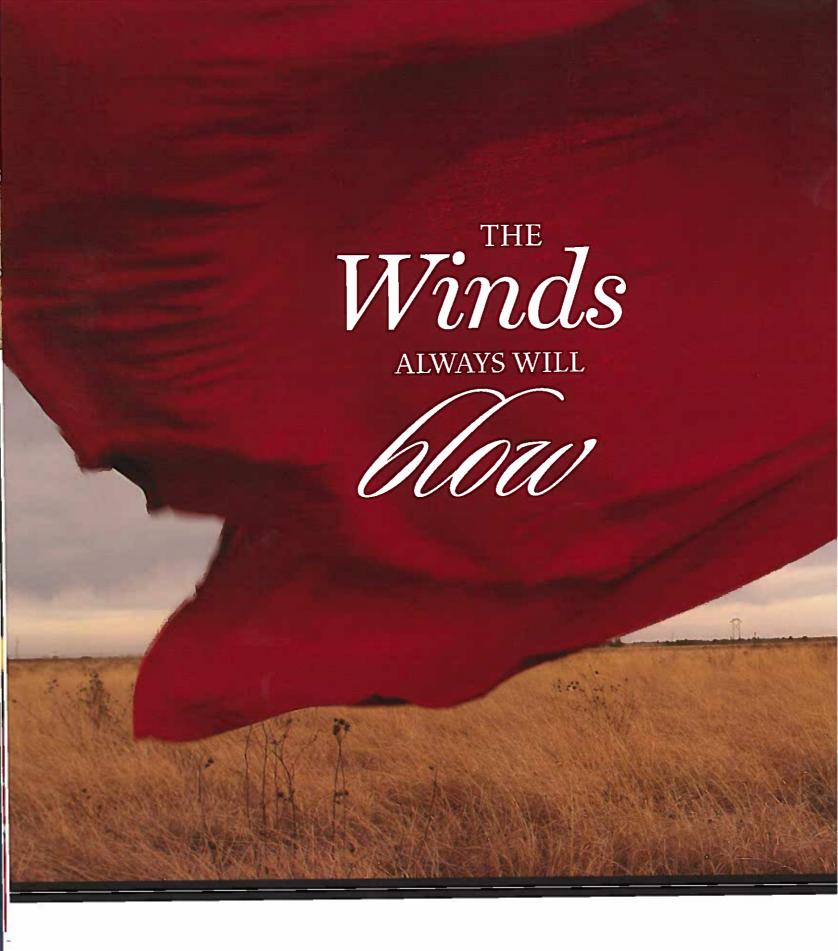
PHOTOS BY ARTIE LIMMER

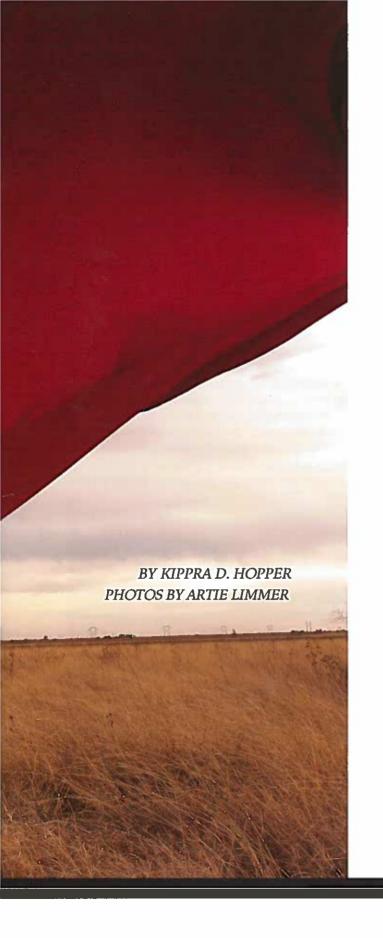
adequately inform the proper authorities responsible for the production of manufactured buildings. "Part of my role is to try to educate the public," Tanner says. "My responsibility in the Indiana storm investigation was to try and learn something, and through post-analysis reports, to increase awareness that will influence the industry. The mobile home industry is not governed by building codes because it falls under the jurisdiction of the United States Housing and Urban Development Administration (HUD). Only in the last 10 years have manufacturers developed some good standards." Mobile homes are manufactured with guidelines related to where the structures will be located. Homes placed in coastal regions are designed for stronger, hurricane-type wind loads, while inland homes are built to withstand lower pressure winds. Ironically, mobile home construction is one of Indiana's major industries.

Although regulations concerning strapping and anchoring mobile homes to the ground are set by state and federal agencies, they are not stringently enforced in some areas. Tanner believes that educating the public is one of the more important aspects of his job. When researching the effects of storms, such as the series that hit Evansville, Indiana, Tanner is concerned with the storms' abilities to affect society.

"I believe most people that live in mobile homes recognize that their homes are not a safe refuge," Tanner says, "and if they recognize that, then surely they should develop a plan as to what they should do if severe weather becomes threatening."

Wind events, as Tanner likes to describe serious weather conditions that involve extreme winds, are looked at in a different light given the tornadoes and hurricanes of 2005. Even so, proper documentation and storm-effect analysis made by researchers at Texas Tech, as well as adherence to suggestions given to agencies, would make mobile home residents safer and more aware when these wind events occur.





ind is painted in motion, and on the High Plains, the breezes are with us all the time. Wind shapes mountains over time and creates delicate patterns in fields of wheat. Wind aids in the annual

flight of migratory birds across thousands of miles. Along with its natural beauty, the wind also brings forth the heavens' extraordinary powers to wreak havoc.

The seasons of 2005 have left scars on the United States, particularly with the historic storm of Hurricane Katrina that devastated the Gulf Coast region. Texas Tech University researchers have worked for more than 35 years to leave a legacy of defending humanity from the wrath of such natural disasters. Now, Wind Science and Engineering Research Center (WISE) investigators also are looking at how to harness the power of the wind for alternative energy sources.

Spawned by the power of Mother Nature, researchers first began their studies after a tornado blew into Lubbock, Texas, the hometown of Texas Tech University, on May 11, 1970. The tornado killed 26 people and left a swath of destruction across half of the community. A few College of Engineering faculty members' interest was piqued, and they began documenting the destruction of that awful day in an attempt to learn how to protect people from such storms and to learn about the complexity and finicky nature of the wind. One of those researchers at Texas Tech was Kishor Mehta, Ph.D., now a Paul Whitfield Horn Professor of Civil Engineering and director emeritus of the Wind Science and Engineering Research Center. Mehta, who is an elected member of the National Academy of Engineers, along with faculty members Jim McDonald, Ph.D., Ernst Kiesling, Ph.D., and Joe Minor, Ph.D., decided later that same year to follow the path of destruction of Hurricane Cecilia that hit the Texas coast at Corpus Christi.

As major storms occurred anywhere in the world, center researchers tried to document their effects, now estimating that they have documented damage in 140 storms since 1970. The Wind Science and Engineering Research Center at Texas Tech University has compiled the largest database of structural windstorm damage information in the country. (CONTINUED)



"The Wind Science and Engineering Research Center is the result of a combination of the tornado hitting Lubbock at the same time that some of us were trying to find a research niche. Not many of the universities across the country were doing this kind of documentation and analysis after storms. We also real-

ized that we had resources to conduct the research and we were in a unique position," Mehta says.

The Wind Science and Engineering Research Center has grown to involve researchers who are civil, mechanical, chemical and electrical engineers, atmospheric scientists, economists, mathematicians,

architects and planners. Their collaborative goal is to collect and analyze a large amount of data to understand and mitigate wind loads and their economic effects on the population. Building onto this detrimental aspect of the wind, Mehta's successor as director

of the center, Andrew Swift, D.Sc., is leading efforts to develop wind as a resource. Looking globally at wind, Mehta has concentrated on protecting lives and structures from disaster. From this same source of natural power, Swift is seeking to harness the wind, finding new ways of providing energy to our dwindling supply of other natural resources. Harnassing the power of the winds is a growing alternative to traditional energy sources. "Wind power is growing quickly as a major source of energy and is the cheapest source of new electrical power generation," Swift notes. In December 2005, Sen. Kay Bailey Hutchison formally announced a \$1.5 million appropriation from the U.S. Congress for the development of the Great Plains Wind Test Center for research and development related to wind power and its applications. With the addition of the wind test center, WISE researchers no longer solely will focus on the effects of windstorms. The research carried out at the Great Plains Wind Test Center will concentrate on the use of wind to provide energy for the region, nation and world.

"We see ourselves poised geographically and historically to offer expertise and new programs and to be a world-recognized research center for wind power systems and applications. The reliability and size of modern wind turbine generators has increased, while the cost has decreased," Swift comments. "Wind energy presently offers 1 to 2 percent of our electric energy demands, but is a growing sector in the power industry that will aid in local economic development, growth of new jobs and in the tax revenue generated by wind power plants."

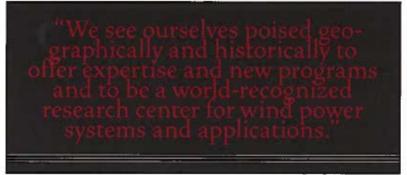
"The ultimate goal is that we should be a research center that deals with wind and its effect on society—its detrimental effects, whether by hurricane or tornado, and its potential as a resource providing wind energy on a daily basis," says Mehta.

The wind researchers have put Lubbock on the map in the same way the city was in the media in the aftermath of the springtime devastation of 1970. Under the longtime guidance of Mehta, researchers began embarking on storm site visits to

document the effects of tornados and hurricanes on structures.

"When the Lubbock tornado occurred, we found nothing in the literature that would help engineers or architects to design buildings resistant to tornadic storms. Four young faculty members jumped out into the field

young faculty members jumped out into the field and documented the damage. We had well over 100 major buildings and many houses damaged in Lubbock. Roughly one-third of the city was ravaged by the tornado, including the downtown area. Without really knowing where this work was taking us, we

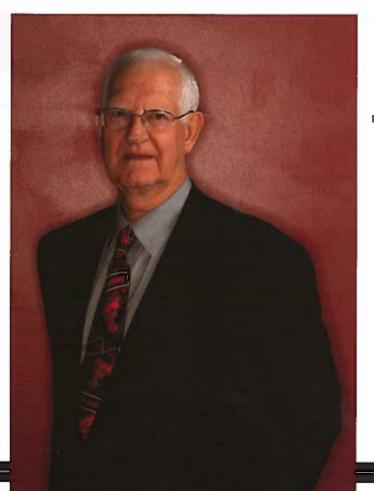


documented damaged buildings and analyzed the damage from extreme winds," says Ernst Kiesling, then chairman of the Civil Engineering Department.

With the destructive hurricane season of 2005 came storms Katrina, Rita and Wilma that caused devastation along the U.S. Gulf Coast. Texas Tech's wind researchers did what they have done for 35 years: deployed equipment to the areas to determine wind speeds and other data; sent expert observers to see the destruction first-hand and to document successes and failures of structures; and made recommendations for rebuilding not only that area but for structures throughout the world.

When researchers examined data after several early storms, Mehta says the first thing the investigators noticed was that the real damage from tornadoes and hurricanes was not that different. Wind was the common denominator of the destruction. "At that time, a lot of myths about tornadoes existed. People thought that buildings would explode because of the pressure change in a tornado. The actual damage was caused by wind uplifting the roof or causing walls to fail under debris impact. People used to think they should open a window when a tornado was approaching. Our research showed that opening windows was not useful."

JIM MCDONALD, PH.D., designed and constructed the "tornado cannon," a debris missile launcher.



During a major outbreak of tornadoes in 1974, more than 300 people were killed in a 48-hour period when 140 tornadoes struck the United States. Texas Tech Wind Science and Engineering Research Center researchers took turns going out to as many sites as possible, traveling to Ohio, Kentucky, Indiana and Alabama to collect evidence. The researchers gave the information to the National Weather Service, and new information about surviving the storms was released. "We knew that a person could survive a tornado. At that time, people thought that if a tornado struck, they should say goodbye and good luck," Mehta says. "We also discovered that the best place for survival and shelter is in a small room in the middle of a house in the case where the house has no basement. We determined that any action will not prevent some damage in a tornado and that people should focus on saving themselves."

Expecting to see some differences between hurricane and tornado damage, researchers began wondering why they were seeing little difference. "Both tornadoes and hurricanes have high wind speeds, and although a twisting motion is involved in tornadoes, both storm types are powered by a vortex, with hurricanes having a very large vortex. As far as a building is concerned, whether struck by tornado or hurricane, the wind causes damage in similar patterns."

second early finding was discovered by another founder of the

center, Joe Minor, at that time a doctoral student in civil engineering. His dissertation work involved gathering data about window breakage in storms. Window glass was largely damaged by wind-borne debris.

Minor made a survey of roof gravel, determining what kind of gravel is used on roofs. He collected roof gravel after the Lubbock tornado and the Corpus Christi hurricane and compared the gravel to what went on inside the buildings during the storms. Minor's findings were the first evidence in the field that roof gravel was causing much window damage. "Debris, like pieces of wood and other objects, undoubtedly causes window damage, but in a city, there is lots of roof gravel," Mehta says. "In 1978, Joe Minor predicted in an article that if a hurricane hit Houston, there would be tremendous property damage because of the great amounts of glass in tall buildings and surrounding roofs that are covered with gravel. Gravel is the most economical way to cover a roof to prevent the sunlight from heating the tar. Furthermore, falling shards of glass can hurt people, while ingress of wind and rain will cause a great deal of property damage. When Hurricane Alicia came ashore in Houston in 1983, Minor was vindicated. The storm produced more property damage to and inside tall buildings than ever before," notes Mehta. (CONTINUED)

he third major early development for the center was Ernst Kiesling's design of an in-residence storm shelter. "Everyone thought you had to have a basement or a cellar to survive a tornado and that it had to be underground," Mehta says. "But we determined that it was possible to design an above-ground shelter that is relatively economical. A strong room with certain criteria can help a person to survive."

strong room with certain criteria can help a person to survive." Jim McDonald worked on this research, eventually creating a "tornado cannon," the first of its kind debris-launcher that replicated the force of windborne debris by firing various materials, such as timber 2 X 4s, into differing constructed walls to determine how they can withstand the missile impact.

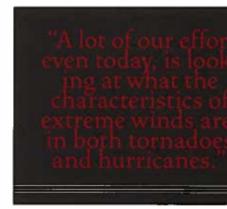
In the 1970s, the researchers decided to work as a team, with each individual specializing in certain aspects of wind damage. McDonald focused on tornadoes and was working with the Nuclear Regulatory Agency to determine strengths needed to protect nuclear power plants from tornadic winds. McDonald became involved in studying flying debris, and he designed and constructed the debris missile launcher. "When we started in



1974, we went to the tallest building on campus, which is the Architecture Building, put cables down the side and dropped the missiles down the side of the building. The experiment was crude, but it gave us some initial input and developed a couple of concepts that we have stayed with. Dr. McDonald developed the first tornado cannon so that we could do more laboratory testing. The development of shelter designs went much better after that," Metha says.

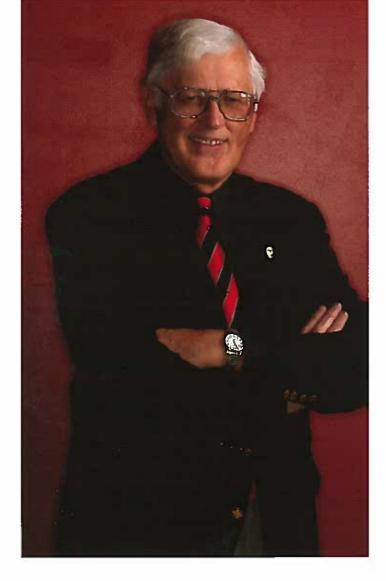
The center's first grant from the Defense Civil Preparedness Agency, a predecessor to today's Federal Emergency Management Agency, allowed center researchers to publish a pamphlet describing how to design above-ground shelters and what criteria for construction are required. "All the criteria that we established in 1975 still hold true, although we have refined the construction designs for more flexibility. We have larger rooms now, even providing shelters for public schools and community centers," Mehta says.

Kiesling has worked his entire career to create safe shelter from the storm. What researchers discovered early on was that in many instances, even if a house was destroyed or ravaged, some small part of that house still would be standing. "In several instances, we noticed that a centrally located bathroom, a pantry or some



small room would remain standing. It's structurally logical because a higher concentration of structural members contains a small room, and in a bathroom, the plumbing might help anchor the space. It's easy to determine that smaller rooms would have more structural integrity than the house itself. We reckoned that we could harden and strengthen that small room, or start by building that small room in an economical way to provide a high degree of occupant protection. That was the birth of the concept of the in-residence above-ground storm shelter," says Kiesling.

A surge in interest for storm shelters happened after the Jarrell, Texas, tornado of 1997, in which a large percentage of residents of a subdivision were killed by a massive, slow-moving tornado. A *Dateline NBC* documentary gave the concept national visibility for the first time. More credibility was gained in the 1999 Oklahoma City area tornadoes. Researchers found a case in which an in-residence shelter was left standing among debris, saving the lives of two women and their pets.



ith funding from the
National Science Foundation and other
agencies, researchers studied wind
speeds and found that the wind speeds
associated with the original Fujita Scale

were too high. Texas Tech researchers found the speeds to be lower than Fujita had indicated, says Kiesling. Meteorologists and engineers used two different approaches to study wind speeds. "Engineers would determine in a wind tunnel the pressures on buildings caused by winds blowing over them. We could determine for a given wind speed what pressures are produced on a given shape or structure. Through structural analysis, researchers then could look at structures in the field and bracket wind speed damage. If the building was not damaged or destroyed, they could say that the wind was not higher than a given level. If damaged, we could say a wind speed of a given level would have been required to cause this level of damage. Engineers use this approach of basically looking at building damage, particularly on clean simple structures, such as signs and light poles. It's pretty easy to calcu-

late wind loads on these structures, even for example, on a tombstone. If a tombstone was moved during a storm, it's possible to calculate the wind speed that would have caused that. That gave us some landmarks and data points. Meteorologists, on the other hand, relied more on radar and video tapes. A number of video tapes on tornadoes were available and by monitoring debris in the vortex, meteorologists could estimate wind speeds. Now other ways are available for the accurate measurement of wind speeds, such as Doppler radar. Differences exist because the meteorologist is looking perhaps 300 feet above the ground, whereas engineers designing low-rise buildings are interested in ground-level wind speeds. A lot of our effort, even today, is looking at the characteristics of extreme winds in both tornadoes and hurricanes," Kiesling notes.

He explains the storm damage documentation process first used after the Lubbock tornado. "First of all, we would look at where the casualties occurred and the type of structural damage to buildings. The modes of failure are among the things we would look for. A rather comprehensive report was published, becoming the first technical document that was produced documenting wind damage and giving any guidance at all to the person who was trying to design a building to improve wind resistance. At that time, it was thought that tornadic winds would reach the speed of sound, about 700 to 800 miles per hour, and that it certainly was an act of God if you were hit with a tornado and survived it. One of the earliest contributions that Texas Tech made to society was to estimate realistically the wind speeds in tornadoes," Kiesling says.

Researchers have made great advancements in developing techniques and processes for gathering data of wind speeds in storms. For example, Texas Tech's West Texas Mesonet covers 32 counties on the South Plains with 48 automated surface weather stations and two atmospheric profilers in an area that covers 150 by 200 miles surrounding Lubbock. The towers stand 33 feet high and offer observations every five minutes. Humidity, wind, temperature, barometric pressure, rainfall, solar radiation, along with soil temperature and moisture, are collected at each station. The information is sent to a central station at the Reese Technology Center. Another 650-foot tower at Reese is instrumented at several levels so researchers can obtain the profile of winds according to heights. "Depending upon the surface roughness, the profile of the wind is very sharply turned at the bottom. Over a rough terrain, the wind speed at ground level is going to be considerably less than it is at some heights. That profile shape is important to determine the wind pressure. The gustiness of the wind is important to measure because we are concerned with the maximum forces. A great deal of statistical and other analyses of wind characteristics exists from the standpoint of variation with height, gustiness, and so forth. All of those things are important in the design of buildings and other structures," Kiesling says.

Since 1973, Richard Peterson, Ph.D., has taken on the atmospheric sciences aspects of wind and is WISE associate director.

(CONTINUED)

With the West Texas Mesonet, researchers can gather data about the variation of wind speed with horizontal distance, important because determining weather at a mesoscale over a large area has significance. "For example, we can determine that today, a cool front is moving through, so the power companies have to generate enough electricity to meet the demand. And if it's hot this morning, enough electricity has to be generated for air conditioning. If power companies do not reduce the power output as the cool front moves through, they could be wasting a lot of energy. Knowing what is going to happen in a given point in time at a given location is important. The Mesonet is capable of looking at the weather in each county. We can get a good regional view of the weather as well as determine what is happening at a particular location. That also is important for many other industries and applications, such as agriculture, and certainly, aviation, because some of the hazards are presented by sudden changes in weather," Kiesling says.

fter Hurricane Katrina,

Larry Tanner, a WISE research associate, spent two weeks as a member of the FEMA Mitigation Assessment Team (MAT) looking at damage in three zones, with experts look-

ing at the surge zone, other experts examining the wind zone, and with Tanner's team viewing the transition zone between the two. Together, the researchers examined the effects of surge and winds acting on the structures and the kinds of damage the buildings received. "The Gulf Coast region is a big mess and is going to be so for quite some time. Basically, about a three- to four-mile wide path of damage exists now all the way from below Mobile, Alabama, to New Orleans, Louisiana, from the coast inland. Katrina was more of a water event than a wind event. A subsequent 2005 hurricane, Wilma, was a wind event. A 'wind event' means that the majority of the damage was produced by the wind. Sometimes the damage is caused by both, but the tremendous amounts of flooding, flood surge and wave action from Katrina caused most of the destruction in that storm. Now, one-half million people are without jobs, without cars, without places to live. In the major buildings, such as hotels and casinos, relief workers and contract construction workers are housed so that they can stay in the areas in need of their services. It's a very unique scenario," Tanner says.

Tanner and his team specifically looked at damage along the Gulf Coast to the outskirts of New Orleans. "I did a preliminary aerial survey two weeks before we deployed on the ground and flew over all of the areas. We had three teams, a coastal team, a wind and water team that I led, and a wind-only team. We looked at critical facilities, such as hospitals, fire stations and police stations. We found that it was not unusual that the heavily engineered buildings, such as casinos, banks and hospitals, received some damage, but structurally all of those buildings survived quite well," he says. Tanner also surveyed Kessler Air Force Base



LARRY TANNER directs the next generation of testing the impact-resistance of building materials.

in Biloxi, Mississippi, which sustained \$915 million in damage. The hospital was out of service because of flooding to the backup generators and electrical systems. "The hospital will not be back in service until April or May 2006 at the earliest. We surveyed a number of hospitals, and even though physically the buildings looked okay, they were subjected to great water damage. Anywhere from 8 feet to 14 feet of water ended up in these buildings."

Tanner's field of research involves storm documentation and storm debris impact. He manages the debris impact testing facility at the Reese Technology Center and directs the next generation of air cannon launching to test missiles and the impact resistance of various building materials for shelter research. Tanner's role in storm documentation is to survey building performance, to see how or why buildings fail and others do not, to view those modes of failure, and to determine wind speeds, which relates to hurricanes, tornadoes and other storm events. He makes observations of debris fields to see what kind of debris is there, some of which prickle buildings, and to understand where people took shelter in various buildings, homes and businesses and how that shelter performed. He sadly also finds locales where people perished and

endeavors to determine why. "All of this knowledge becomes lessons learned," he says, noting that the information then becomes storm reports for agencies, such as the Federal Emergency Management Agency, the National Institute of Standards and Technology, the National Science Foundation and the National Weather Service. Tanner works with the Federal Emergency Management Agency a great deal in documenting large storms. He returned in early October 2005 from observing Hurricane Katrina damage in the Gulf States. "I have done this on-site investigation for enough years that I can tell in a quick glance which direction the wind was coming from, what side of the storm a particular building was facing, and the probable force of the wind."

yeing the storm, literally, John Schroeder and his Hurricane Intercept Team prepositioned weather towers in the Gulf Coast region prior to Hurricanes Katrina and Rita. Research that is focused on a broad umbrella of "characterizing the wind" includes field deployments of various facilities or platforms that make measurements from the hurricane environment. The data is important, Schroeder says, because the information helps to feed the fundamental research going on within WISE. "In most situations, most of the operational weather data collection systems in a hurricane fail due to one reason or another. A lot of times when we go back after the storm, we are trying to make sense of what happened with the damage in a particular area. Yet, before these types of mobile, pre-positioned measurement systems were brought to the coast, no record really was there to fall back on because all of the operational systems failed so there was no wind record. In starting this post-disaster investigation, researchers had no idea of what the wind speed was, and that makes the first step of damage documentation a lot harder. So the base level of this type of work provides input into just what happened. In considering the more complex nature of wind, this kind of work feeds into all sorts of areas. You may ask the question whether the wind in West Texas has the same structure as the wind in a hurricane. Or when we get a 30- or 40-mile-per-hour gust out here, is it the same as the 100-mile-per-hour gust you might see in the hurricane? Is the structure of that gust different in one scenario or another?" Schroeder ponders.

Issues related to the structure of the wind are inherent in building codes and standards, he notes. Engineering design is fed by certain assumptions about the wind flow. "We're trying to validate those assumptions in these high-wind events from a scientific and/or an engineering perspective. We determine how fast the wind field changes as the storm moves off the ocean and onto the land surface. Obviously a change in surface roughness or a change in the terrain will change the wind. Over the water, we have open space, and on land, we have houses and trees, so we determine how fast the wind field transitions. That's a big ques-

tion, a big issue right now, especially when the winds are higher," he says.

The Hurricane Intercept Team has not missed deployment to a major land-falling hurricane since Hurricane Jean. Ian Giammanco, a graduate student, has traveled with Schroeder and the team for every major hurricane event in the last three years. His main job is to place data-gathering towers in the path of the storm. "Basically, we take an extensive look at all the computer model tracks. We have to figure out which model is handling the storm the best, which one we can put the most faith in. We also look at the overall weather picture of the entire country to see what might influence track changes. We have to determine intensity and we have criteria for deploying for storms. We won't go all the way down to the Florida peninsula for a Category 1 storm," Giammanco explains. "Since June 2005, we have been pretty busy. We have deployed for four storms this year, Dennis, Emily, Katrina and Rita. We take our five WEMITE (Wind Engineering Mobile Instrumented Tower Experiment) towers down to intercept the storm landfall. In Hurricanes Katrina and Rita, we did pretty well, and in Katrina, we were just one of the few groups that obtained a complete record of the whole storm through the (CONTINUED) eye wall."

JOHN SCHROEDER, PH.D., deploys platforms in the paths of hurricanes to measure the environment.



In 2005, the United States had a record number of land-falling major hurricanes, Schroeder says. "The wind speed measurements in the past two years have been higher than we have been measuring in previous years. We have new data that is more focused on the extreme cases. We're asking if anything is different about this data compared to what we recorded the first couple

of years. The research and analysis takes many years of effort. We still have not recorded a wind field that was as strong as Hurricane Andrew in 1992. Hurricane Andrew came ashore as a borderline Category 4 or 5 storm, and to this day, the wind damage seen in Andrew has not been



matched. Even with the awful devastation in Katrina, which mostly was related to storm surge activity right along the coast-line or flooding in New Orleans, the wind damage in Katrina wasn't anywhere close to what it was in Andrew. We still have not measured a good complete wind record or wind field that is more representative of a Category 3, 4 or 5 storm."

One of the unique aspects that stands out to Schroeder with Hurricane Katrina is that the data shows that the winds were lower than what most people believed. "That's a rather controversial statement in some places, but no evidence suggests, for instance, in Mississippi, that the winds were probably higher in almost every location than a borderline Category 2 storm. This is nothing close to what the general population assumed to have occurred," he says. "The water in the storm surge represented a Category 4 or 5 record storm surge type damage, but the wind field when it made landfall at least was more representative of a Category 1 or 2 storm. We base the storm surge rating off of the damage in Mississippi, where blocks of the coast are just gone, or entire water marks can be traced back to see just how high the water got. The storm surges were as big as or bigger than those in Hurricane Camille in 1969 and covered a wider area."

For about a distance of 60 miles, the storm surge rose 24 feet or more. "In the case of Katrina, the storm surge ended up in photographs and television depicting the damage. The wind itself at the time the hurricane made landfall was not as significant. If we look back at Andrew, it was the flip, with very little storm surge, but very significant wind. Hurricane Andrew caused significant damage well inland, which saw complete devastation because of the wind over a wide area," Schroeder explains.

With wind, many scales are working together. Weather systems can take up two-thirds of the country and produce low pressure systems over Colorado that are driving the wind on any given day. In other instances, a much smaller and localized event, like a thunderstorm, can produce extreme wind in a very small area. "Then we get down to the real small scales where we ques-

tion how the gusts of the wind vary. Interestingly, we try to pull together information from all of these various scales and see how they work together and feed off each other," Schroeder says.

From a research standpoint, Giammanco says, the biggest value of hurricane season 2005 is that Texas Tech researchers' deployment systems collected complete data records, whereas

National Weather Service systems found at airports often failed. "We manage to complete that data record for a given storm. Obviously, 2005 has been extremely active. This pattern of increased hurricane activity does not appear to be changing, so we'll be busy for a few more years," Giam-

manco says. Schroeder reiterates that in 2005, the intensity of the storms at landfall was higher than in previous years and may lead researchers to different conclusions about such storms. "There is still a lot to do over the next 5, 10, 20 years. We keep going back to Hurricane Andrew as a measurement because it was really the worst wind disaster that has occurred in the region's history." Working in characterizing the wind in any type of extreme events, Schroeder finds himself in the field with thunderstorms and tornadoes as well, making observations for super-cell thunderstorm environments. "Fundamentally, the question we are aiming to answer is: 'Is wind wind? Does it always look the same, no matter what the event?"

Research Center built a field laboratory west of the Texas Tech University Health Sciences Center in open country and close to campus. The field work and the laboratory are expensive in equipment and personnel, Mehta says. "We have built credibility, nationally and internationally. The field research site is analogous to the space station in space research. The laboratory is a major step toward developing theories of how the wind affects structures." Doug Smith, Ph.D., associate professor of civil engineering, works to understand the response of structures to wind in the center's field laboratory, where he runs data collection and obtains the desired angle of the attack of wind on a building to measure pressure.

"There are a lot of unknowns regarding wind-induced pressures on buildings," Smith explains. "Most of the information we know comes from model-scale experiments in the wind tunnel. Full-scale measurements are required to validate wind tunnel results and to make measurements for events that are hard to duplicate in model-scale, such as thunderstorm outflows. The approach of building codes to different types of wind events is that 'wind is wind.' Although that is a good beginning, we have come to recog-





nize that wind characteristics in hurricanes and in thunderstorms are different than those from a frontal passage. The different flow will generate different pressure characteristics on a building.

"Preliminary research indicates that the uncertainty associated with extrapolation of wind tunnel results to full-scale is fairly large. This will have a significant impact on the design wind pressures specified in the codes and standards. The structural response of members, such as beams or columns, to wind loads cannot directly be measured using wind tunnel models. With our full-scale building, we can, however, measure the effects on the structural members due to wind. In design, we use simple models to describe wind loads and to describe the response of a member to those wind loads. One of our next major efforts will be to investigate these simple models using full-scale measurements to establish how much error is involved," Smith explains.

"Hurricane Andrew was a \$30 billion event, and Hurricane Katrina is going to be far in excess of what Hurricane Andrew did. Hurricane Rita is going to be that way also. If you take a \$50 billion loss, and that is just insured loss, and add all the uninsured loss, it probably doubles the amount, and so you are talking \$100 billion or more. If you can reduce that by 10 to 20 percent, you have significantly reduced the impact of the hurricane. The overall objective is that over time, even though hurricanes come ashore or

tornadoes fall from the sky, instead of the storm being a devastating event, it is a glitch in the system," Smith says.

Field data combined with artificial wind tunnels helped experts run more conclusive experiments. With National Science Foundation grant monies, in the late 1980s, the team created a wind research field laboratory to study high winds, dust and thunderstorms. They also collaborated with researchers at Colorado State University to use the institution's wind tunnel technology. The researchers' goal is to develop a large amount of data through the center to understand building structures, wind loads and their effects on the population. The collaboration, funded for 10 years, from 1989 to 2000, produced landmark work.

rom his homeland and

university in Australia, Chris Letchford, professor of civil engineering since 1999, initially came to Texas Tech on leave of absence for two years, but he eventually took a permanent faculty position. He now runs Texas Tech's wind tunnel research.

"I've been involved in wind tunnels for 25 years. While watching a wind tunnel is a bit like watching paint dry, what is fascinating is the turbulence and chaotic motion that we can sense through instrumentation. Working out the effects of these fluctuations of wind load on structures is what drives me." Collaborating with Darryl James, Ph.D., associate professor of mechanical engineering, Letchford has extended the wind tunnel concept to evaluate the effects in complex flows generated by thunderstorm downbursts and tornadoes. "We've now developed downburst and tornado simulators to look at different types of extreme wind events and have pushed beyond the traditional wind tunnel. Our plan is to build a much larger model of our tornado simulator at the Reese Technology Center. This simulator will be large enough for someone to actually walk through," Letchford says.

The main thrust of Letchford's research has involved looking at different models of extreme wind events. The traditional wind tunnel is typically appropriate for modeling the wind in large-scale storms, such as arctic fronts and perhaps hurricanes. "Strong wind events typically travel through the north of the country, from frontal systems and winter storms, and the wind tunnel is good at modeling this sort of wind. Unfortunately, most of the country is dominated either on the coastline by hurricanes or thunderstorms throughout most of the interior, and the traditional wind tunnel does not simulate those winds at all. I've been particularly interested in simulating the winds from thunderstorms."

Letchford also has been studying the result of the hurricanes of 2005 leading a team documenting the effects of Hurricane Rita. "It will be amazing to see what the economic losses are from Hurricane Rita because it was a major wind event, not quite as

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strong as Hurricane Andrew. We don't see quite as much damage in Texas and Louisiana because of the sparse population. Katrina was a major water event, and the storm surge largely did the damage. There was perhaps 15 feet of storm surge in Rita, but that part of the coast was sparsely populated," Letchford says.

The loss of power from storms in cities' downtown areas and in hospitals will have a huge economic impact, he explains. In addition, Hurricane Rita hit the coasts of Texas and Louisiana where many oil refineries and chemical plants are located and that cannot operate without electricity. "They need raw materials, like nitrogen, oxygen and other gases. Electricity is the prime energy source for all of those different processes. So, without electricity, they can't get nitrogen, they can't cool their plant, they can't transport products. They can't move things around in a chemical plant process; they can't pump things out. So, the loss of electricity is a huge impact economically," he continues.

Because they are very large events affecting many people, hurricanes are extremely important to wind engineers, Letchford says. His team split up into three areas, looking at residential structures; engineered buildings - industrial buildings, schools and civic centers; and infrastructure lifelines - roads, bridges, transportation structures, ports and lifelines, including electricity, water and sewage systems. "Hurricane Rita probably caused one of the greatest losses of electricity transmission line structures due to wind ever in this country. At least 70 transmission line towers were lost. These are very tall structures and failed under wind loading. They also lost about half a million wooden poles for distribution around the cities. Beaumont and Lake Charles both lost power to the downtowns of the cities, where they have many tall buildings. The cities lost power for more than a week. Many of these buildings had no air conditioning for that period and suffered water infiltration during the hurricane. The insides of the buildings were warm, moist environments, and mold proliferated. This is a huge air quality problem within these buildings and the mold makes them uninhabitable. We need to make sure that the buildings' cladding and backup power is more robust and better at handling this problem." Letchford says that the engineered buildings in the hurricane's path generally performed well as far as structural damage. "One of the main reasons we do this research is to make both our infrastructure and our buildings more resistant so that they can cope better with these forces of nature. In a pure engineering sense, we have a pretty good handle on what it takes to resist the wind load. We can make a building resist the winds of even a tornado, but it's important to make sure that the brick walls, or whatever it's made of, can stand up to debris that's flying around in the wind. That's an issue that needs further attention. And, we need to have more redundancy in the electricity distribution. Although the spider web-like nature of the electricity grid is good at dealing with localized failures during small-sized thunderstorms, the huge scale of a hurricane means that perhaps the whole grid can be wiped out and power cannot be rerouted easily or at all. We need transmission line



CHRIS LETCHFORD, PH.D., runs the WISE team's wind tunnel experiments.

structures to be stronger to resist these high wind loads."

Noting that investigators have not been able to simulate downbursts before and have only modeled tornadoes but at very low speeds, he says, "We've actually put buildings in a vortex that looks like a tornado and we measure the pressures on the buildings caused by this flow, and we've done the same thing in the downburst simulator. We've come up with innovative modeling of these types of winds, which cause most of the damage in most of the country. Hurricanes are huge events, they are relatively rare, but thunderstorms happen all the time across the whole of the country from the Rocky Mountains to the Atlantic Ocean. Although they are not typically as strong, and are much smaller in location, there are many more of them. Thunderstorms cause most of the wind damage in this country, apart from hurricanes," Letchford says. "In the northeast quarter of land-falling hurricanes, circulations develop that lead frequently to tornadoes. Even in a hurricane, we get lots of tornadoes. We have been concentrating on modeling these different extreme wind fields for the last five years."

With Hurricane Katrina, federal, state and local officials, along with insurance companies, are determining the degrees of damage caused by wind or water. Kiesling says Texas Tech personnel are in the middle of the struggle. "Water damage typically is not

insured, so if the house was destroyed by storm surge, the insurance companies may not be obligated to pay for it. Homeowners are saying, 'Look, that house was destroyed by wind before water got to it'. One point of view is that because the storm surge was generated by wind then the damage was caused by wind and the homeowners are entitled to settle. There are billions and billions of dollars involved, and the insurance industry is trying to determine what damage was caused by wind and what was caused by water. Who should they turn to for answering that question but to engineers familiar with the problem? Because of Texas Tech's center and its visibility as the most expert entity for the knowledge of the effects of winds, attorneys with the Mississippi Wind Pool called us," Kiesling says. "The organization wants guidance for their insurance adjusters in the state. For example, in Mississippi, the storm left 8,000 bare slabs. Attorneys for the Mississippi Wind Pool are asking for a team of people simply to provide some instruction and guidance on what percentage of damage was caused by wind or water."

nder Kiesling's guidance, Texas Tech researchers have developed several concepts for shelters for protecting humans from the storms, including using concrete blocks filled with concrete and reinforcing bars, he explains. Researchers in the Wind Science and Engineering Research Center have written publications regarding the designs for in-residence shelters as well as school and community shelters through the Federal Emergency Management Agency. After the 1999 Oklahoma City region tornadoes struck, President Bill Clinton and FEMA Director James Lee Witt offered an incentive program for the building of above-ground shelters as part of the storm mitigation. That was the first time that a market for shelters was recognized. Funding allowed for about 6,000 shelters to be built in the region, but two to three times that many shelters were built. In 2003, another tornado went through the same area, but with the number of shelters built in the area, many lives were spared. "There were no failures of the shelters, and there were no fatalities with people in their shelters. In fact, the 2003 tornado was not as intense as the 1999 one; however, this second tornado further broadened the market for shelters in residential areas," he says. Texas Tech developed performance criteria for storm shelters and produced a number of shelter designs that are included in publications of the Federal Emergency Management Agency (FEMA). Those criteria became a requirement for the performance of shelters and give some guidance to the National Storm Shelter Association, which has as its objective to foster quality in the shelter industry. Kiesling is a founder and serves as executive director for the association. "In hurricanes, shelters are important because of the associated strong winds. Additional problems in hurricane regions exist because the traditional response to hurricanes is evacuation," Kiesling notes. "Yet, in many areas,

particularly in Florida, with the population explosion, evacuation is not a viable alternative, as we saw when Houston was evacuated with Hurricane Rita. We lost more people in Texas from the evacuation than from Rita itself. Evacuation is not an answer to all hurricane problems. With our shelter designs, there are houses and buildings outside the flood and surge zones that could protect people who stay in place."

Mehta's work led him to chair the Wind Load Standard Committee of the American Society of Civil Engineers, an entity that develops national building standards that eventually are adopted by the international building code regarding the safety of buildings from strong winds. Since 1977, Mehta has been involved in writing the national standards. "Wind speeds are different across the country, but once you know the wind speed, the way the wind will act on a building is the same whether you're sitting in Lubbock, Minnesota or Canada," he says. Kiesling currently is working on an International Code Council committee writing a standard for storm shelters, while Letchford has worked on the committee developing an International Standard Organization code for wind loading. Kiesling explains that another undertaking by researchers is to look at the usefulness of shelters for multiple hazards, including blast protection, ballistics, and chemical and biological hazards. Wind science and engineering researchers are working with The Institute for Environmental and Human Health at Texas Tech to develop filters and other technologies to protect occupants against biological and chemical hazards. "We think that this well-developed technology for storm shelters readily can be adopted and adapted to multiple hazards," Kiesling suggests.

Envisioning the future, Mehta imagines a time when wind researchers at Texas Tech will investigate jet propulsion, vacuums and probes to solve many problems. "In Lubbock, where we get cooling at night and heating during the day, we can design houses in which the air will circulate through, saving energy, and making people comfortable. We can design huge fans to gently blow breezes through summertime theme parks, making people less vulnerable to the heat. We can use mathematical models to determine levels of toxic materials through our Mesonet to find out at ground level the real data to determine evacuation plans. We knew with Hurricane Katrina that the Superdome in New Orleans would not collapse, and thus, could be used as a safe shelter through the storm," Mehta concludes.

Texas Tech University researchers are ready to calm the storm by preparing humanity for the force of winds. Other researchers are finding renewable energy sources by capturing the airflow of the High Plains. Undoubtedly, tornadoes will disturb our balmy summer afternoons, and hurricanes will stalk us through the seasons. Dust storms will cloud our views. Canada Geese will cross our skies. And just as the Earth turns on its axis, the winds always will blow.





ujita's impressive career began when he taught school in Japan during World War II. Following the dropping of atomic bombs on Hiroshima and Nagasaki in 1945 by the United States, the Japanese government dispatched Fujita to execute a survey and identify whether a weapon or a cataclysmic wind event had caused the damage. When

he went to the destroyed cities, he saw the impact of strong winds and the effect they had on structures, trees, people and houses. According to Monte Monroe, Ph.D., Southwest Collection archivist and historian, nearly 40 years later, Fujita recalled the effect of the downburst winds that accompanied the bomb blasts. The experience helped him theorize about microburst winds, such as those that caused the crash of the Delta flight at Dallas-Fort Worth Airport in the 1980s. After the war, Fujita began his scientific observations of tornadic and wind-related events that would continue for the remainder of the century and ultimately would revolutionize the field of wind science and engineering.

In the early 1950s, Fujita came to the United States to begin teaching at the University of Chicago. "Ultimately, he became the premier scholar of wind science in the world. He earned that title by being an observer. He went on the ground and looked at the patterns of wind blown grass, knocked down trees and structures, and studied how tornadoes blew across the land and destroyed objects in their path. He discovered and described the phenomenon of multiple vortices without the aid of computer modeling or modern radar," says Monroe. For roughly 50 years, Fujita cataloged every major tornadic event in the United States, including the 1970 Lubbock tornado and the "Superoutbreak" of 1974. That particular event remains the worst outbreak in tornado history, with 148 twisters touching down in 13 different states.

Monroe describes Fujita's process of research and documentation by saying, "He kept meticulous notes; he took detailed photographs; he drew charts and maps; and he did mathematical calculations - all trying to describe the destructive power of these storms. Indeed, he devised the Fujita scale, or the F-scale." Although the scale currently is being modified, the F-scale was the pilot scale for giving meteorologists, wind scientists and engineers a system that linked damage and wind speed and gave rank to each tornadic event that occurred. In February 2006, the National Weather Service announced plans to implement the Enhanced Fujita (EF) Scale to rate tornadoes to replace the original F-scale. The revised scale features a damage indicator and a degree of damage scale, and takes into account additional variables on the zero-to-five scale that will, in turn, make the new scale more efficient and accurate. Kishor Mehta, Ph.D., a Horn professor of civil engineering at Texas Tech, says, "The reason for the changes was because the old scale was not efficient. The new scale is an enhancement that will make the scale more reliable and consistent." The EF scale was developed by the Wind Science and Engineering Research Center (WISE) researchers along with an assembly of wind engineers, universities, private companies, government organizations and private sector meteorologists from across the country.

In the 1990s, scholars from Texas Tech University's world renowned Wind Science and Engineering Research Center, including Jim McDonald, Kishor Mehta and others, began working closely with Fujita on a number of wind-related projects. Through the common denominator of wind, the scholars from WISE developed a close collegial relationship with Fujita, sharing his passion for observation and documentation. When Fujita retired from the University of Chicago in 1990, his university opted not to keep his records. This proved to be very fortunate for Texas Tech University, according to Monroe. "Because of the acute interest in studying tornadic activities and other cataclysmic wind events, the scholars at WISE asked Fujita if his papers could be transferred to the facilities in West Texas. At the time, Texas Tech's WISE program was the only other institution in the world doing significant wind sciences research, and Fujita agreed to the transfer."

Ted Fujita passed away on November 19, 1998, before seeing his papers delivered to Texas Tech. Caz Fujita, Ted's son, agreed to the transferal of the papers with the exception of a small collection of hurricane-related papers that went to a museum in Japan. Professor Richard Peterson, Ph.D., an associate director of WISE, and staff member April McDowell retrieved the records from Chicago. According to Monroe, "The papers were in the possession of the WISE program for a number of years. Various scholars and graduate students used the records, but the WISE



The image on the previous page shows Fujita's wind generator laboratory where he studied downbursts. The Southwest Collection/Special Collections Library is home to Ted Fujita's compilation of invaluable wind research, the largest such documentation in the world. Scenes below show the aftermath of the Lubbock tornado, as well as data of the storm that hit at 7 p.m. on May 11, 1970.





scholars believed that they needed to be better organized, preserved and made accessible for research purposes. We were approached by Dr. Richard Peterson, Carol Ann Stanley, Chad Morris, Dr. Jim McDonald, and Dr. Andy Swift, the current director of WISE, and others at the center, about donating the records to the Texas Tech University Southwest Collection where they properly could be processed, stored and made more accessible to the general public." The Southwest Collection agreed not only to house the papers, but to establish a major wind research archive within the Special Collections Library, highlighting the famous "Fujita papers" as a cornerstone of the collection.

Today, these records are in the process of being organized by experienced archivists at the Southwest Collection/Special Collections Library. So far, more than 80 linear feet of acid-free boxes encase Fujita's historically important materials. Soon, a digital finding aid will be generated that will describe the collection to the folder level. Researchers will be able to access the descriptive index on the Web at the Texas Archival Resources Online site (TARO). In addition to the Fujita papers, the Southwest Collection also hopes to gather oral histories and other research papers from many of the internationally renowned founders of the WISE program to add to the already impressive collection. "This is an important collection. It is a major feather in the bonnet of Texas Tech University, not only for wind sciences researchers, but for historians, and others studying the socio-economic impact of tornadic or hurricane events, and for the general public," says Monroe.

This remarkable collection serves as a tribute to "Mr. Tornado," Tetsuya Fujita, whose passion for his work is evident in the long line of boxes in the archive room of the Southwest Collection/Special Collections Library. According to Greg Forbes, Ph.D., severe weather expert and director of the Weather Channel, the Fujita collection "is the nation's greatest set of original materials on historic tornado events such as the Fargo tornado, the Palm Sunday tornado outbreak, the Lubbock tornado, the 1974 Superoutbreak, and many other storms." Box after box, this contribution by the Fujita family forever will remain where it belongs, right in the heart of wind country on the Southern Plains.