DEPARTMENT OF

Electrical & Computer Engineering

UNIVERSITY OF FLORIDA

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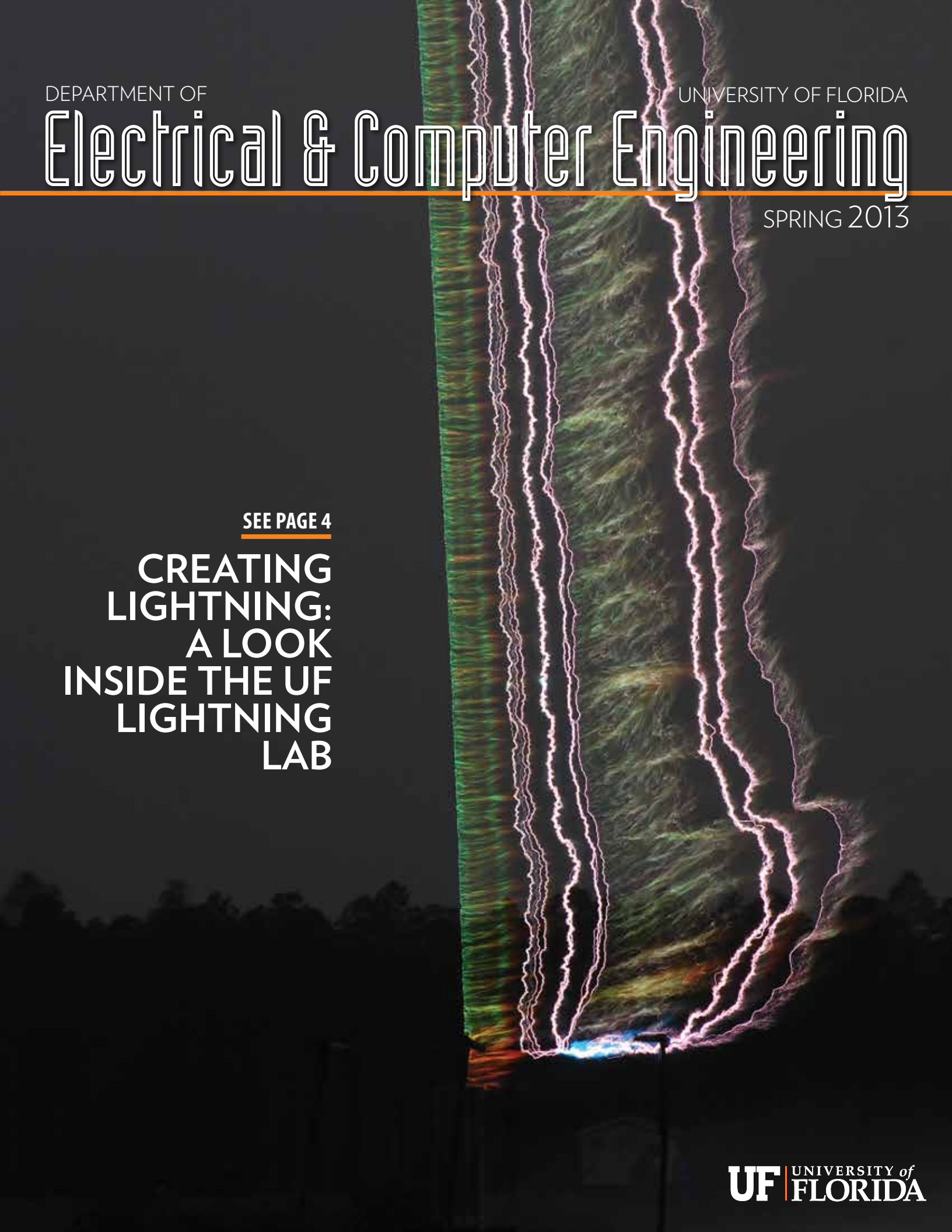

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CREATING LIGHTNING: A LOOK INSIDE THE UF LIGHTNING LAB

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Meet the Lightning Lab Experts: from left to right: Martin Uman, Robb Moore, Doug Jordan, and Vladimir Rakov. (Photo by Eric Zamora).

In This Issue

On the Cover: Triggered lightning at the ICLRT during Tropical Storm Debby 2012.
Photo by Dustin Hill

Kathie Russell, Managing Editor

John Harris, Department Chair

University Relations, Layout & Design

Contributors
Martin Uman, Vladimir Rakov, Doug Jordan, Robb Moore, Toshi Nishida, Marcy White, Angela Medyk

Photo Credits
Dustin Hill, Eric Zamora, Kathie Russell Shannon Kalahar

Department of Electrical and Computer Engineering
University of Florida
P. O. Box 116200
216 Larsen Hall
Gainesville, FL 32611-6200
352-392-0911

www.ece.ufl.edu

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Message from the Department Chair

Welcome to the Electrical and Computer Engineering Department at the University of Florida. I am now halfway through my second year as department chair, and it is still a humbling experience for me to run the ECE department with our top-notch faculty and staff. It is a pleasure to help inspire a new generation of eager, enthusiastic students. In Fall 2012, ECE graduated another crop of outstanding engineers: 44 Bachelors, 36 Masters, and 12 Doctoral degrees. Congratulations to our students and faculty for their hard work.

As you will read in this newsletter, it certainly has been exciting times in our department. Our ABET accreditation visit was October 1-2, 2012 and our EE and Computer Engineering degrees were re-accredited for another six years. Special accolades to Dr. Henry Zmuda and Laurie Edvarsson for all of their work. Our EE students were especially enthusiastic about our program and were not shy in bragging about us to the evaluator. Our advisory board chair, Gator Handley (BSEE '62), was a tremendous help. Finally, much thanks to Associate Dean and former ECE chair Mark Law who oversaw the entire process, not just for our EE degree, but for every degree in the college.

One of the pleasures of my job is interacting with our huge network of passionate alumni. You can read in this newsletter about the college's Leadership Summit on Oct 19, 2012. We had two of our notable department alums participating: Lesa Benton Roe (BSEE '86, Director of Langley Research Center, NASA) and Linda Rae (BSEE '87, President of Keithley Instruments). I am very pleased that Power Grid Engineering, LLC has supported speakers for our department seminar to discuss power systems. Power Grid Engineering President Michael Wright (BSEE '98) has been instrumental in renewing the interest of our students and faculty in this vital area. We are also grateful for Carole T. and Harlan Y. Harrell, Jr. (BSEE '61) for supporting an endowed fund for engineering ethics in our department. Chris Malachowsky (BSEE '83, Co-Founder of nVIDIA) will be the commencement speaker at our spring commencement ceremony. These are just a few of the many alumni that care and are giving back to our department, college and the university. It is wonderful to have such successful alumni and fantastic that they continue to help us further our mission.

Whether you are an alumnus, current or prospective student, faculty member, staff, friend or a curious member of the public, we welcome you to become a part of the University of Florida ECE family. Please keep in touch, and we welcome a visit when you are in Gainesville.

Best Regards,
John Harris
Professor and Chair

CREATING LIGHTNING

Each year approximately 25 million cloud-to-ground lightning flashes strike the United States. Between 5 and 10% of those flashes occur in Florida, parts of which suffer 40 ground strikes per square mile annually. In addition to killing and injuring humans, the annual cost of North American insurance payouts from lightning-related damage has been estimated to be as high as $1 billion; the airline industry estimates that lightning accounts for $2 billion annually in operating expense and passenger delay; lightning-induced fires in the Western United States lately cost $1 billion per summer to fight, and lightning induced power-outages and blackouts cost nearly $1 billion annually.

The University of Florida ECE Lightning Research Laboratory, the premier lightning research and testing facility in the world, studies not only naturally-occurring lightning, but remarkably, creates approximately 30 additional lightning flashes to ground each summer that otherwise would not have occurred and that can be studied at very close range. An example of one of these events is shown on the cover. The Lightning Lab is funded by several NSF grants (Vladimir Rakov and Robb Moore are the principal investigators on these), a NASA grant (Martin Uman, principal investigator), and a DARPA grant (Martin Uman, principal investigator). The $10 Million four-year DARPA program involves eight other university teams as UF sub-contractors, many of whom assemble for collaborative research at the Lightning Lab's outdoor research facility known as the International Center for Lightning Research and Testing (ICLRT) during the summer, lightning season. As Martin Uman points out, "in terms of research expenditures, the Lightning Lab is the top program in the UF College of Engineering."

Located on 100 acres of flat land at the Camp Blanding Army National Guard base near Starke, Florida, the ICLRT, with Camp Blanding air traffic control, launches rockets with trailing grounded wires toward the thunderclouds, "triggering" lightning from natural thunderstorms. Generally, these thunderstorms are already producing lightning, but sometimes the ICLRT triggers lightning when lightning has yet to occur (see cover photo). The 1-meter long rockets used at Camp Blanding are fitted with a special spool carrying 700 meters of Kevlar-reinforced copper wire. The triggering wire, connected to a designated strike point on the ground, unspools from the rocket as the rocket rises toward the thundercloud. Triggering usually occurs when the wire top is about 300 meters in the air, approximately the height of the Empire State Building.

Figure 1: Triggered lightning from the tower launcher at the ICLRT. The copper triggering wire explodes at the right (straight vertical green line) with the wind blowing its remains to the left. Several downward leader/upward return stroke sequences (tortuous white channels) follow at hundredths of a second intervals, also blown by the wind to the left in this time exposure. (Photo by Dustin Hill).

Triggered-lightning experiments have provided considerable insight into natural lightning processes and have enabled the practical testing of various systems such as overhead power distribution lines (visible behind the tower launcher in Figure 2), underground cables, airport runway lightning systems, lightning arresters, a residential structure at the ICLRT (it can be seen just to the left of the launch tower in Figure 2), a gas pipeline,

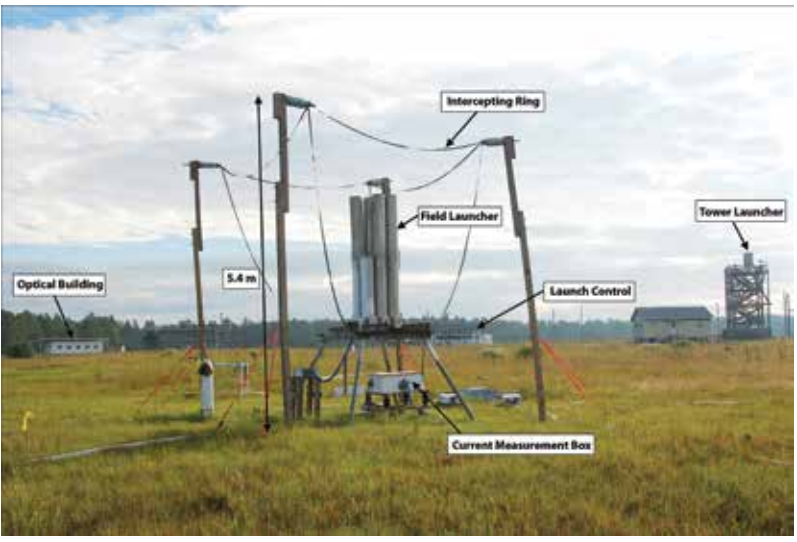

Figure 2: ICLRT Ground-based and Tower rocket launchers, Launch Control, and the Optical Building at Camp Blanding near Starke, Florida. About 100 electromagnetic and optical measurements are arrayed around the research area of the ICLRT.

and explosive material used in nuclear weapons. According to Vladimir Rakov, "As our society becomes more technological with computers and sensitive electronics, it becomes increasingly vulnerable to lightning strikes. Our goal is to understand how lightning works so we can figure out new ways to protect ourselves." Below are a few of the many new published scientific results previously obtained at the Lightning Lab:

- the thorough characterization of the electromagnetic environment (electric and magnetic fields and their derivatives) within tens to hundreds of meters of lightning, leading to new lightning testing standards;
- the discovery and characterization of x-rays produced by lightning leaders and 3D location of pulses of x-rays relative to the lightning channel;
- new insights into the lightning leader stepping mechanism;
- the first coherent picture of the mechanism of electromagnetic radiation produced by Compact Intracloud Discharges (CIDs)
- the direct measurements of the level of NOx (nitrogen oxides) production by an isolated lightning channel section.

For more information about the UF Lightning Research Lab and to see a list of reviewed journal articles related to the DARPA program, visit its website: www.lightning.ece.ufl.edu. To meet the faculty experts of the Lightning Lab, see the companion article on page 6.

TOP TEN QUESTIONS ABOUT LIGHTNING

According to Martin Uman, the research goal of the present DARPA grant is to answer the following "top ten" questions about lightning, using a combination of experimental techniques and mathematical modeling:

1. What physical mechanisms cause lightning to be initiated in the thundercloud? Are high energy processes (e.g., cosmic rays, in-cloud-generated x-rays) involved?
2. What physical mechanisms govern the propagation of the different types of lightning leaders (the lightning process following initiation) inside the cloud and between the cloud and ground?
3. What is the physical mechanism of lightning leader attachment to elevated objects on the ground and to the flat ground?
4. What is the physics of compact intracloud discharges (CIDs) that produce narrow bipolar wideband electric field pulses from apparently repeatedly-reflected (within about 1 km length) propagating current waves, accompanied by copious HF and VHF radiation?
5. By what physical mechanisms do lightning leaders emit pulses of x-rays? By what mechanism do thunderclouds generate relatively-steady gamma-radiation glows? Do x-rays and other high energy radiation play a role in cloud electrification or lightning initiation?
6. By what physical mechanisms are Terrestrial Gamma-Ray Flashes (TGFs) produced? (TGFs are primarily observed on orbiting satellites above thunderstorms, but they have been recorded twice on ground at the ICLRT). Do TGFs pose a hazard to individuals in aircraft?
7. How do cloud-to-ground and intracloud lightning affect the upper atmosphere, ionosphere, and magnetosphere? What are the physics of the lightning-associated Transient Luminous Events (TLEs) such as "sprites", "jets", and "elves" observed above cloud tops? Is lightning the primary natural driver of energetic electron precipitation from the Earth's radiation belts?
8. How exactly does the rocket-and-wire triggering of lightning work?
9. What are the power and energy of the component processes of lightning flashes and how are they distributed among electromagnetic, thermal, mechanical, and relativistic (high energy) processes?
10. What is the physics of ball lightning? Is there more than one type of ball lightning?

INSIDE THE LIGHTNING LAB

Over the past 15 years, the UF Lightning Research Laboratory has been featured in some 20 TV documentaries, including ABC's Nightline, PBS's Nova, National Geographic Channel, Discovery Channel, NBC Dateline, The Learning Channel, and a Weather Channel Special. In 2012, *Popular Science* magazine named it one of its feature "Labs that Go Boom" and included it on its list of "Awesome College Labs" of 2011; it has been featured in numerous articles including those in *The New York Times* and the *Financial Times of London*.

The Lightning Research Laboratory was founded in 1971 by Distinguished Professor Martin Uman soon after he arrived at UF from the Westinghouse Research Laboratories in Pittsburgh.

Meet the Lightning Lab Experts

The 2012 Lightning Lab faculty has a wide range of lightning expertise. The four faculty experts have published hundreds of journal articles, seven monographs on lightning, and hold thirty-nine patents regarding lightning. They have received numerous scientific awards for significant contributions to their respective specialties as well as academic accolades for research and teaching.

Professor Martin Uman founded the Lightning Lab in 1971, as noted above, and with Vladimir Rakov, co-founded the ICLRT in 1994 as part of the lab. Uman, who earned his PhD from Princeton University, is Distinguished Professor of ECE and was ECE department chair from 1990-2002. Uman, along with Rakov, are generally acknowledged to be among the world's top few authorities on lightning physics and protection. Uman is probably best known for his work in lightning modeling: the application of electromagnetic field theory to the description of various lightning processes. He first became interested in lightning as an associate professor at the University of Arizona; after which, he studied the physical and electromagnetic aspects of lightning and long laboratory sparks for seven years at the Westinghouse Research Labs in Pittsburgh. Uman primarily works on experiments related to the triggering of lightning at the ICLRT.

Professor Vladimir Rakov came to UF in 1988 from renowned Tomsk Polytechnic University as Russia's leading lightning expert. Rakov's areas of interest and publications span the spectrum of lightning related topics from classical atmospheric electricity to lightning physics to lightning protection problems. Presently, Rakov and his students operate the on-campus Lightning Observatory in Gainesville (LOG) located on the roof of the New Engineering Building. The LOG includes a glass cupola providing more than 180 degrees of unobstructed viewing of the horizon. They also coordinate via dedicated communication lines and analyze simultaneous measurements at the ICLRT, LOG, and a separate Starke station.

Dr. Douglas Jordan earned his PhD from UF in 1990 under Uman and is now the Operations Director of the ICLRT. He supervises all triggering operations, coordinates the activities of visiting researchers and is responsible for the equipment and facilities at the Camp Blanding research site. Prior to his position at the ICLRT, he was undergraduate coordinator for ECE and taught several core undergraduate ECE courses.

Assistant Professor Robert Moore, who received his PhD from Stanford in 2007, is the latest addition to the team. He installed and operates a year-round network of ELF/VLF radio receivers that spans the globe. The receivers are capable of detecting the electromagnetic fields generated by lightning occurring more than 10,000 km away. The ELF receiving array presently

From left to right: Doug Jordan, Robb Moore, Vladimir Rakov, & Martin Uman in the LOG cupola on the roof of the New Engineering Building. (Photo by Eric Zamora)

consists of six receivers, with three in Alaska, one in California, one in Greenland, and one in Antarctica. The VLF receiving array consists of eleven receivers, with three in Alaska, three in Antarctica, and one in each of Florida, Alabama, Texas, California, and Greenland. The VLF/ELF receiving network is primarily used to study the effects of natural and triggered lightning on the lower ionosphere and hence to determine the properties of the lower ionosphere.

The ICLRT is presently collaboratively operated by UF's primary DARPA subcontractor, the Florida Institute of Technology, led by Professor Joseph Dwyer, the world expert in high energy lightning processes (x-rays, gamma rays, runaway electrons and positrons).

In addition to the four primary researchers noted above, over the years UF has hosted about 50 international lightning researchers from 15 countries on 4 continents who participated in collaborative lightning experiments at Camp Blanding and associated data analysis. One of the Lightning Lab's important functions is training students to conduct research as part of their graduate degree requirements. In the past few years, the Lab has graduated four PhDs with nine more graduate students scheduled to be awarded PhDs before the end of the DARPA grant. In addition to the graduate students, a number of undergraduates gain practical working experience at the Lab and are essential to its successful operation.