Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA)

University of Massachusetts Amherst

Revolutionizing our ability to observe, understand, and predict atmospheric and airborne hazards

A National Science Foundation Engineering Research Center since 2003

Partner Institutions:

- *Colorado State*
- *University*
- *University of Oklahoma*
- *University of Puerto Rico, Mayaguez*

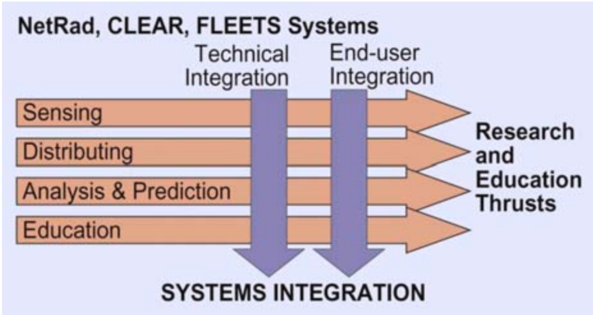
The Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) seeks to revolutionize our ability to observe, understand, and predict hazardous weather by creating distributed collaborative adaptive sensing (DCAS) networks that sample the atmosphere where and when end-user needs are greatest.

Current approaches to observing the atmosphere are based upon a long-established paradigm of widely separated, geographically fixed sensors that operate independently of both the phenomena being observed and the disparate, often conflicting, needs of multiple end users. Despite the tremendous capabilities of current ground-based Doppler radars, these systems are *fundamentally constrained* in sensitivity and resolution and are unable to measure the lowest few kilometers of the earth's atmosphere where hazardous weather forms and causes greatest impact. CASA is advancing the new paradigm of *Distributed Collaborative Adaptive Sensing* networks designed to overcome the fundamental limitations of today's state of the art. DCAS networks utilize large numbers of small solid-state radars, closely spaced to overcome blockage due to the Earth's curvature and improve the resolution degradation caused by beam spreading in long-range radars. Future DCAS radars will be highly reliable, inexpensive, and will operate in collaborative networks that are capable of targeting multiple radar beams onto atmospheric regions where threats exist in order to pinpoint the location of tornadoes, to accurately estimate rainfall levels near the ground, and to detect precursors of future storms—all in response to changing end-user needs.

Research

CASA will advance fundamental knowledge—of multi-radar electromagnetic wave-atmospheric interaction, of high-resolution atmospheric detection and prediction, and of resource allocation and optimization—as well as provide the enabling technologies and design tradespace to realize future DCAS systems. The center will also design, fabricate, field test, and deploy *system-level test beds* to demonstrate the potential of DCAS systems to improve our ability to detect, track, understand, and predict hazardous weather phenomena. "Integrative Projects" serve as a primary organizing construct of the center to focus research projects toward systems-level goals. Each such project is defined in terms of an end-to-end system that connects specific end users to field-deployed hardware and software deployed in a hazard-prone geographic region. The first such project will demonstrate DCAS concepts for high temporal and spatial resolution mapping of winds—with an emphasis on tornadoes—in western Oklahoma. This system will be deployed, beginning in Fall 2005, as a four-radar node adaptive network. The second Integrative Project is to design and test a DCAS system in Houston, TX to measure precipitation and support urban flood prediction near the Texas Medical Center. CASA's third Integrative Project, which is led entirely by a team of students, will be an "off-the-grid" DCAS system comprised of small radar nodes spaced ~ 5–20 km apart that generate their own power and communications and thus operate independently of the built infrastructure.

Figure 1



CASA is organized into three core research thrusts: *Sensing*, *Distributing*, and *Predicting*. These research thrusts (Figure 1) span the primary disciplines of electrical and computer engineering, computer science, meteorology, civil engineering, hydrology, and atmospheric science. These research teams will work synchronously to create the key components in the DCAS networks: the radars and their beams; the algorithms that extract quantitative information from the radar echoes and that detect, track, and predict hazards; the interfaces that link the system to end users; and the underlying software architecture that optimally configures the system in response to changing weather and conflicting end-user needs. A Technical Integration Team is responsible for systems engineering flow, process, and documentation needed to create system test beds. An End User Integration Team, comprised of sociologists and business leaders, will work with end users and study applied social, policy, and behavioral issues that relate to deploying the DCAS systems and to the use of these systems in hazardous decision-support.

Key research challenges are:

- Electromagnetic wave-atmosphere interaction and the physical mechanisms by which DCAS networks measure precipitation, wind, temperature, and moisture fields.
- Collaborative approaches for adaptive resource allocation, communication, and computation in a dynamic environment in which phenomena under observation, relative priorities of system tasks and goals, and available system resources change over multiple time scales.
- Understanding the atmospheric boundary layer and creating hazard detection algorithms, data analysis and assimilation systems, and numerical forecast models that operate in a real-time, dynamically adaptive manner, on high-resolution data.

Education

CASA's education and outreach goals are to educate undergraduate and graduate engineering students, K-12 students, and lifelong learners in understanding the complexity and interdisciplinary nature of engineered systems and their impacts on society. In addition, our education programs address the many significant problems related to the paucity of females and minorities in the engineering pipeline. Highlights of our education programs are:

Collaborative PhD Program—CASA is helping to build a new Ph.D. program in Electrical Engineering at core partner University of Puerto Rico–Mayaguez (UPRM), a Hispanic-American serving institution, where no such program exists today. CASA has defined two collaborative Ph.D. programs (between UMass and UPRM, and Colorado State University [CSU] and UPRM) that will enable UPRM students to complete their Ph.D. programs at partner campuses while spending the majority of their time in residence in Puerto Rico engaged in an intensive research experience centered on a CASA test bed.

Multimedia Modules Project —This project uses instructional technology to help overcome the multidisciplinary challenges faced by CASA. A set of CD/DVD-based educational modules have been developed to provide background materials and self-study to a wide audience, ranging from incoming graduate students and faculty to end users, REU students, and K-12 teachers. Modules include video presentations, corresponding PowerPoint slides, and a sophisticated search function. Topics encompass Sensing, Distributing, and Predicting thrusts, End User Integration, Social Response to weather hazards, and end-user training.

REU Program—The CASA Research Experiences for Undergraduates program creates a research experience with a diverse group of undergraduate students in which participants are exposed to research that crosses disciplines and geographical boundaries. In addition to working closely with faculty, students attend multi-campus lectures and engage in group design using distance technology, attend national conferences together, and participate in field trips and workshops. Many of these summer REU students will be invited to continue their CASA research in the fall when they return to school. Long term, CASA expects that this early exposure to research and group design will encourage many of these students to attend graduate school.

K–12 Summer Content Institute—The Institute is designed to enable 6th–9th-grade teachers to deepen their knowledge of concepts and develop hands-on classroom activities with respect to the engineering/ technology and earth and space science curriculum frameworks developed by the Massachusetts Department of Education. The Institute will feature lectures by expert faculty, hands-on labs and activities utilizing communications technologies, a field trip, and development and/or review of classroom resources.

Industrial Collaboration and Technology Transfer

CASA's Industrial/Practitioner Collaboration and Technology Transfer program seeks to establish strong research and education partnerships among faculty, students, and private and public practitioners to accelerate the transfer of knowledge and technology for commercial and social benefit.

CASA industry members cover the range of industries that encompass the end-to-end system, from radar manufacturers and grid computing specialists to private companies that package weather data for industry.

Participation in the research and development of CASA's systems-level test beds is at the core of our industry/practitioner partnerships. Activities range from involvement in the development of component technologies (such as solid state radars and weather detection algorithms), to receiving and using the data from DCAS systems, to evaluating business models for the eventual operational deployment of DCAS systems. CASA's focus on creating a series of system test beds, with increasingly sophisticated technology and capabilities, helps to bridge the gap between industry's need for short-term results and the long-term time horizon of the DCAS research agenda.

Industry partners are involved in strategic planning and project review (through our Industrial Advisory Board), SWOT analysis, and participation in design reviews for system test beds. They are also actively involved in our education programs, since they want to recruit a diverse group of outstanding students trained in modern engineering technology and processes. Technology transfer will occur in four different ways: Knowledge transfer through the academic/practitioner partnerships, use of DCAS data for the creation of value-added weather products and decision support tools, commercialization of component technologies, and longer-term deployment. of DCAS systems.

Facilities

The ERC Headquarters is housed in the Knowles Engineering Building at the University of Massachusetts Amherst, with laboratory facilities in the UMASS Microwave Remote Sensing Laboratory and other labs in the Department of Electrical and Computer Engineering and the Department of Computer Science. The University of Oklahoma (OU) is the location of the System Operations Control Center for our first test bed, adjacent to high-powered supercomputing resources that run atmospheric data retrieval, detection, assimilation, and prediction models. Calibration and technology testing facilities are located adjacent to the CHILL radar facility at Colorado State University , a national radar facility operated through a cooperative agreement with NSF. The UPRM will use its CliMMate laboratory, the Radiation laboratory, and Student Testbed Laboratory to conduct research related to CASA. All partners are establishing state-of-the-art video conferencing facilities to facilitate cross-campus communications.

Center Configuration, Leadership, Team Structure

The academic partnership of this ERC contains expertise spanning all critical competency areas of our research initiatives through either the core partners or the outreach partners:

UMass—Microwave Remote Sensing, Microwave Engineering, Networking, Distributed and Embedded Computing, Hydrology
OU—Meteorology, Weather Data Dissemination, Flooding Hydrology
CSU—Weather Radar Processing, Polarimetric-Based Quantitative Information Extraction, High-Speed Networking
UPRM—Antenna Design/Testing, Microwave Remote Sensing.

Our academic outreach partners at the University of Delaware, Mount Holyoke College, Rice University, the University of Virginia, and the University of Colorado have expertise in the sociology of hazards response, education, urban flooding hydrology, human factors design, and distributed active antenna design.

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