2.4 A HANDS-ON INTERDISCIPLINARY LABORATORY PROGRAM: AN APPROACH TO STRENGTHEN THE WEATHER RADAR CURRICULUM AT THE UNIVERSITY OF OKLAHOMA

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## 1. Abstract

This paper describes the curriculum details of a recently funded NSF DUE project that will commence in the fall 2004 semester at the University of Oklahoma (OU) and will have a three year duration. This new active-learning and hands-on laboratory program is an interdisciplinary program, in which engineering, geoscience, and meteorology students are encouraged to actively participate. The program is intended to generate a unique, interdisciplinary research-oriented learning environment that will train future engineers and meteorologists in the full set of competencies needed to take raw radar data and transform it into meaningful interpretations of weather phenomena. The heart of the program is the development of a set undergraduate courses, offered by the School of Meteorology and the School of Electrical & Computer Engineering, that will provide hands-on laboratory experiences in the special knowledge and skills necessary for organizing real-time weather data, improving and preparing that data for display, and interpreting its meteorological and scientific significance. In addition, programs will be generated for K-12 students for the purpose of increasing their interest in science and engineering prior to entering college. Efforts will also be made to interest other university departments in building similar or related curricula in their programs.

## 2. Introduction

Undergraduate students are not exposed to enough real-life authentic data. This proposed program leverages on the new National Weather Radar Testbed (NWRT) to develop an interdisciplinary curriculum enhanced by hands-on laboratory exercises. The NWRT is a national resource that combines the talents of engineers and meteorologists for the study of weather. This recently engineered national facility will expose students to a cornucopia of scientific data as the atmosphere is explored.

Severe and hazardous weather such as thunderstorms, downbursts, and tornadoes can take lives in a matter of minutes. In order to improve detection and forecast of such phenomena using radar, one of the key factors is fast scan capability. Conventional weather radars, such as the ubiquitous NEXRAD (Next Generation Radar developed in the 1980's), are severely limited by mechanical scanning. Approximately 175 of these radars are in a national network to provide the bulk of our weather information.

Under the development for weather applications, the electronically steerable beams provided by the phased array radar at the NWRT can overcome these limitations of the current NEXRAD radar. For this reason, the phased array radar was listed by the National Research Council as one of the two candidate technologies to supercede the NEXRAD (NRC 2002). By definition, a phased array radar is one that relies on a two-dimensional array of small antennas. Each antenna has the ability to change its phase characteristics, thus allowing the overall system to collectively locate specific interesting regions of weather. The National Weather Radar Testbed (NWRT) is the nation's first facility dedicated to phased array radar meteorology. Figure 1 depicts the agile, electronically steerable beams, reduced scan times, and increased lead times, while Figure 2 depicts the system components of the new radar. In addition, the demand for students trained in this area will be high as new radar technologies replace the ones designed 20 years ago, and as weather radar usage extends into areas such as homeland security. From the Federal Aviation Administration's (FAA) perspective, the phased array radar technology developed at the NWRT will be used enhance the safety and

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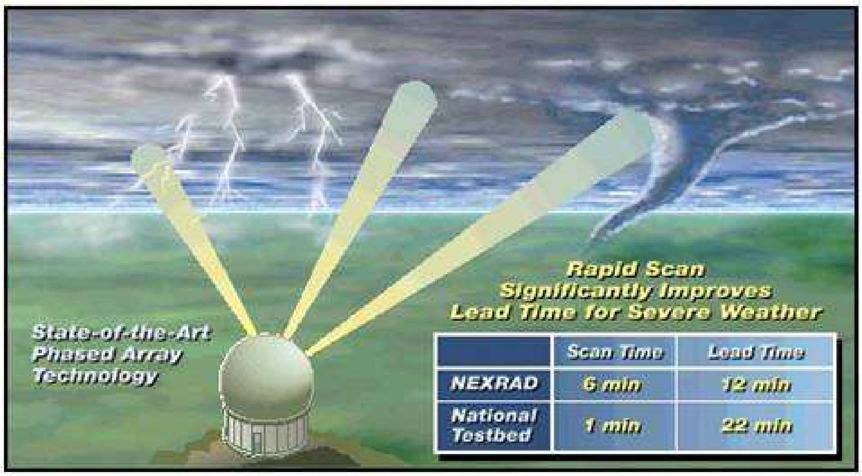


Figure 1: *New Radar – Adaptive Beam Scanning for Improved Detection.*

capacity of the National Airspace System. Moreover, this project is consistent with one of NOAA's *Mission Goals for the* $21^{st}$ *Century*: to serve society's needs for weather information (NOAA 2003).

Long-term warnings have improved greatly over the last five years and are now being used for critical decision making (NRC 1999). Further improvements are being aimed at providing longer warning lead times before severe weather events, better quantification of forecast uncertainties in hurricanes and floods, and tools for integrating probabilistic forecasts with other data sets. Many other industries, groups, and individuals use, or could use, weather information. For example, the construction industry uses weather information to schedule specific activities and to purchase materials. Fisheries managers use weather information to manage fleet operations and monitor fish stocks. The recreation industry uses weather information in a variety of ways ranging from issuing avalanche warnings, backcountry conditions, and boating conditions to managing snowmaking operations for skiing. The legal industry uses certified weather and climate information in court cases. K-12 teachers use weather data to develop math and engineering skills in their students, which is essential for the future (NSTC 2000; NCMST 2000; Camp 1997). The list of potential uses is long and growing longer as the accuracy and reliability of weather forecasting improve and the portfolio of weather services offered to the public grows (NRC 1999).

Following the classic Boyer Report, it is very important that no gap exists between teaching and research (Boyer 2002). In addition, faculty members who creatively combine teaching with research are essential to the improvement of undergraduate education (Moskal 2001; Jenkins 2003). Phased array technology is currently being explored at OU and the NSSL, and it will help forecasters of the future provide earlier warnings for tornadoes and other types of severe weather (NSSL 2003). The proposed laboratory/teaching program will provide abundant opportunities for individuals may concurrently assume responsibilities as researchers, educators, and students. The NWRT will facilitate joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

## 3. Approach

***Integrated Curriculum and Science Plan:*** The laboratory modules that accompany the proposed following suite of courses are oriented around the adaptation of a nationally known radar program at Colorado State University (CSU). The CSU-CHILL radar facility is funded by the National Science Foundation and the State of Colorado for the purpose of supporting the atmospheric research community by providing data and evaluating experimental techniques in remote sensing of the atmosphere (`http://chill.colostate.edu`). Carried further, their Virtual CHILL (VCHILL) concept at the CSU radar facility allows remotely located users to access realtime displays and control the operation of the radar *over the Internet*. Thus, the goal of the VCHILL initiative is to provide the educational experience of polarimetric radar at a remote location, without compromising the features

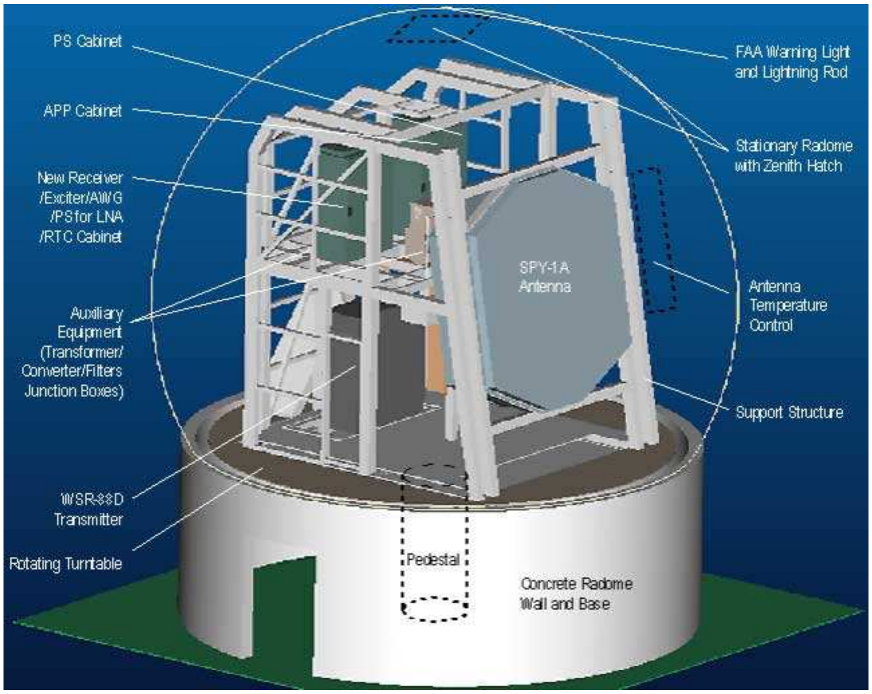


Figure 2: *Face of the SPY-1 phased array radar inside its dome – like a fly's eye, it has approximately 4000 sub-antenna elements that comprise its octagonal array.*

of an on-site radar console.

Thus, to complete the cycle of innovation, whose annulus begins with the pioneering work at CSU, extending through the state-of-the-art radar facility in Norman, Oklahoma – this project offers the development of a revolutionary laboratory and coursework curriculum that coincides with the interdisciplinary development and integration of the School of Electrical and Computer Engineering and the School of Meteorology. Several courses will be developed and each course will be cross listed within the two departments. Cross listing will strengthen the bonds of this collaborative effort and welcoming/retaining students (Kenimer 2002). A sample of course offerings are as follows; each of which will be supported by specific laboratory modules.

**METR 4623** *Radar Meteorology*. An established course (updated with new laboratory modules) that develops the quantitative relationships between a radar and its target – *i.e.*, interpretation of the data. It is a senior level course and cross listed as ECE 4623.

**ECE 4793** *Weather Doppler Radar Signal Processing*. A new course (with additional laboratory modules) that concentrates on the radar equation, time domain algorithms, and spectral analysis. It is a senior level course and cross listed as METR 4793.

**ECE 4990** *Adaptive Digital Signal and Array Processing*. A new 3 credit course (with laboratory modules) devoted to the theory of adaptive algorithms for the discovery of interesting weather targets. It is a senior level course and cross listed as METR 4990.

The program is carefully tailored to fit within the current degree plans of both schools. Prerequisites will be carefully observed to welcome/retain students. Students may concurrently enroll in METR 4623 and ECE 4793. Profs. Yu and Biggerstaff will teach these classes and coordinate with each other to ensure student success. These two classes will optimally be taught in the spring. Finally, students will take the in-depth ECE 4990 class taught by Prof. Yeary – which will culminate all previous learning, concentrate on deep projects, and serve as a fantastic spring board into our advanced graduate level programs in both schools. This class will always be offered in the fall.

***Hands-on Laboratory Modules:*** Within the sequence of courses, the learning of scientific phenomena, such as interesting atmospheric events, is greatly enhanced when students are allowed to make measurements and construct mathematical models that govern their behavior [13]. Several teamwork-oriented laboratory modules will be integrated into *each* of the four courses. These modules will be organized around four themes: 1.) *data collection:* developing different scanning patterns, 2.) *data processing:* computing and enhanced algorithms to extract weather information from the raw radar data, 3.) *data display:* placing the composite weather information on a user-friendly computer display, 4.) *data interpretation:* scientific understanding and discovery of the displayed data – this includes the locations and dynamics of storms, precipitation, tornados, downbursts, and the like. Each of the four items complement and build upon one another – thus solidifying the interaction between the courses. These hands-on laboratory modules are similar to the CSU experiments (Chandrasekar 2001; Gojara 2001; Bringi 1997).

***Undergraduate Peer Teachers:*** We define a *peer teacher* to be someone who: 1.) is a very energetic and motivated student that will serve as a young teaching assistant, 2.) is a member of our engineering research program and radar curriculum, and 3.) is a diverse undergraduate student. The judicious use of peer teachers has been shown to be a highly effective means to motivate and retain undergraduates in engineering (Morgan 2002; Caso 2002; Garcia 1998). The peer teachers will have three primary duties: 1.) assist the instructor in the class/laboratory during periods of team-work activity, 2.) host tutoring sessions for fellow students outside of class/laboratory time, and 3.) assist with K-12 outreach (described later). Since the peer teachers are close in age to the students and highly familiar with NWRT's research plan, they will be in a position to add significant value to the integrated program.

The courses/laboratory modules supported by this project will teach students the knowledge, skills and interest necessary to transform radar data into meaningful interpretations of weather, based on information displays generated by the students themselves. Activities are included that will 1.) increase the number of K-12 students coming to college with an interest in weather radar and 2.) enable other universities to easily adopt similar programs. The evaluation plan is designed to assess how well the courses and other activities achieve their intended purposes (Angelo 1993; Bransford 2000; Bloom 1971; Fink 2003). This will involve the development of questionnaires, assessment instruments, and interview protocols for each project goal.

# 4. Conclusions

There are two special features in this research-oriented teaching program: (1) it will be the only program in the country with a full and equal collaboration between the School of Meteorology and the School of Electrical & Computer Engineering for the purpose of providing an integrated curriculum on weather radar, and (2) it will have access to weather data from the recently constructed National Weather Radar Testbed (NWRT) at the University of Oklahoma. Students will have a unique opportunity to take advantage of the weather data derived from this new phased array radar, specifically suited for weather observations. In essence, the project will decentralize this major research facility and make it available at zero-cost to a wide array of students across the nation. By placing the radar's data on a website, a diverse population of students will be able to use this state-of-the-art facility. To bolster the undergraduate education aspects of this project, a small, diverse team of six undergraduate peer teachers will be employed – differing from a limited number traditional graduate student(s) that will assist with the laboratory experiments. The judicious use of peer teachers has been shown to be a highly effective means to motivate and retain undergraduates. The principal investigators will partner with the Oklahoma Climatological Survey (OCS) to adapt and implement project materials directly to K-12 students and teachers via the OCS Earth-Storm outreach program. Finally, an assessment plan has been devised by an expert at OU who specializes in learning and course development. Moreover, assessment tools will be developed to identify at-risk students who will receive enhanced training.

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