1990s: Advanced Technologies Take Center Stage

Chapter 8

The ‘80s proved to be a tumultuous decade for program development, including as it did the impact of the demise of the solar tax credits. By contrast, the ‘90s brought a measure of stability to program development, along with increased state and national recognition. It was also the time of one of FSEC’s most significant achievements – development, funding, design and construction of the Center’s new site and facilities. The next chapter covers the New Energy Center story, with all the details.

During the ‘90s, FSEC also made considerable progress toward the long-term goal of program diversification. This chapter illustrates that progress by specific technologies.

Photovoltaics Technologies

During the ‘90s, FSEC photovoltaics activities branched into several distinct areas. While continuing its successful systems research for the DOE-sponsored RES program, the Center also began conducting research on PV cell development.

The SE RES work focused on two general areas – application development and component research. [Reference 66]. Efforts included performance measuring, laboratory development, component evaluation and education. The next sections describe PV activities in the areas of component research, utility systems, the PVRES home, special applications, industry assistance and the thin-film program.

Component Research

The Center’s PV research efforts in the ‘90s shifted from utility-interactive to stand-alone systems. This shift focused research on system components and subsystems, including system design, battery subsystems and charge controllers. These activities led the PV staff to construct a PV charge-controller test facility, which was key in the evaluation of numerous on-the-market charge controllers. With this facility, researchers were able to characterize the effects of battery charge and discharge rates on system performance, evaluate charge controllers through thermal cycling, and test and investigate set points for a charge controller with different types of battery combinations. The results of these tests led to better understanding of charge controller operation and controller impact on battery performance and offered the solar industry critical information on system design and operation.

Lab personnel also tested and characterized the performance of 12 types of batteries charged by photovoltaics. This work resulted in new procedures to determine the performance of lead-acid batteries for use in storing energy for small photovoltaic systems. All these results led to better design criteria for both system component manufacturers and the solar industry. [Reference 67]

Jim Dunlop at PV Battery Test Facility (October 1994)

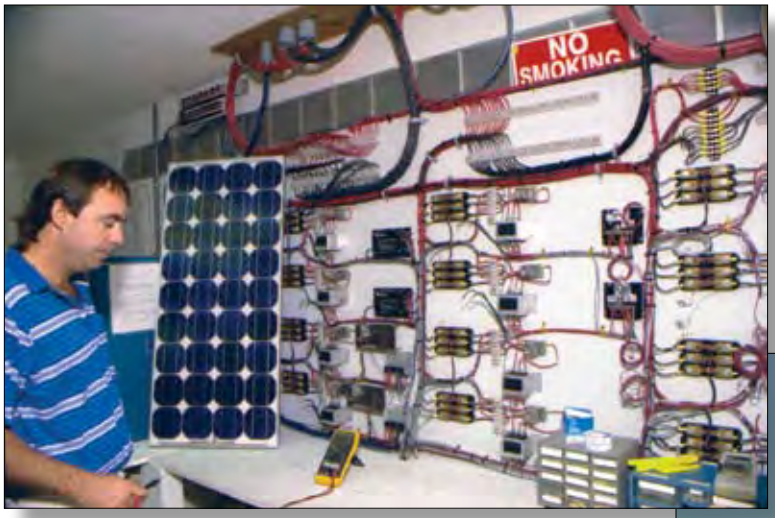
By 1993, the system applications and component testing work had gained a broad base of support, with projects being funded by DOE (Sandia National Laboratories), the Electric Power Research Institute, the Florida Department of Transportation, the Florida Energy Office and Florida electric utility companies.

In 1996, the PV Battery and Controller Test Lab was the first lab to be constructed in the High-Bay Lab wing of FSEC's new facilities. In this lab, staff continued work that characterized the performance of PV components essential to problem-free photovoltaic system operation. Staff also used the lab to conduct tests on the capacity and cycle-life of absorbed glass mat batteries. [Reference 68]

In 1998, SE RES-supported work expanded to include research on crystalline silicon PV module durability. In this effort, researchers developed an improved sample extraction process and a correlation relationship between adhesive strength, morphology and surface composition at silicon encapsulant interfaces. The work evolved as part of the thin-film and PV materials activity conducted by Neelkanth Dhere. [Reference 69]

PV component research also resulted in the development of a photometric laboratory for evaluating PV-powered energy-efficient lighting fixtures. Also constructed in the High-Bay Laboratory wing of the New Energy Center, the lab contained a goniophotometer used to measure the illuminance of light fixtures. Staff also installed and tested the performance of numerous outdoor light fixtures. They used the test results to develop standards for rating PV lighting products. The Florida Energy Office sponsored the lab's development and the lighting performance tests. By 1996, the program had performed field evaluations of more than 50 PV lighting systems. [Reference 70]

Another PV lighting project involved installation of PV lighting systems around Clear Lake at Brevard Community College.



Jim Dunlop in PV Battery Test Facility at Cape site (October 1994)

PV lights in FSEC's north parking lot (September 1998)

Neelkanth Dhere in Thin-Film Lab (August 1994)

Ramu Swami with PV-powered street light (1998)

Utility Systems

Throughout the '90s, FSEC continued a variety of PV activities focused on grid applications with Florida utility companies. The work included performance monitoring and diagnostic reliability testing of Florida Power Corporation's 15-kW amorphous silicon photovoltaic system that began operation in Orlando in 1988. [Reference 71]

In 1991, FSEC staff installed instrumentation and a data-acquisition system for automated monitoring of two 4-kWp PV systems at Florida Power & Light's Martin Power Plant in Indiantown. This project continued for another two years. [Reference 72]

In 1995, the Florida Energy Office funded the installation of a 12-kWp utility-interactive PV array on the roof of the Low-Bay Laboratory at the New Energy Center. The installation was completed in 1996 and operated for one year. In 1997, the cost of insurance required by FPL to continue operation became prohibitive, and the system was shut down. While it continues to be an embarrassment for FPL, the system is still not operating.

12-kWp PV array on low bay roof (January 1997)

PVRES Home

In 1996, FSEC researchers initiated a project called the PVRES. The program's objective was to integrate photovoltaic electrical power production with energy-efficient building design. PVRES proved to be one of the Center's most visible and successful demonstrations, and its well-documented performance was a major impetus for DOE's Zero Energy Buildings program.

The PVRES project teamed FSEC with Lakeland Utilities, Siemens Solar Industries, Sandia National Laboratories and the Florida Energy Office. It involved the construction of two homes with identical 2425-ft^2 floor plans in Lakeland, FL. One home was built with conventional design, materials and construction techniques. The other was built with an energy-efficient design, coupled with a 4-kW photovoltaic array.

Danny Parker, Brian Farhi and Steve Barkaszi at PV installation at Lakeland PV research house (July 1999)

FSEC's Danny Parker, Jim Dunlop and Jerry Ventre led the project, teaming with Lakeland homebuilder Rick Strawbridge. The project illustrates how combining the best photovoltaic system design and building energy-efficiency concepts can maximize the impact of each technology.

Both homes were equipped with instrumentation that gathered data, which provided proof of the concepts. The data compare the PVRES home's performance with the performance of the control home located 400 feet away.

With both homes unoccupied, and thermostats set to cool the houses to 75°F on a 90°F day, analysis showed the control house used 37 kWh, while the PV home used only 6 kWh. Not only did the PV home save 80 percent in cooling energy, it was also two degrees cooler.

The PV system on the PVRES used a unique split-array configuration, with 2.7 kW of the array facing south and 1.3 kW facing west. On an average day, the PV array produced more than 15 kWh. While the home used only about 6 kWh a day for cooling, the array produced more than twice that much power. In addition, the PV system produced the most power when it was most needed – during utility peak summer demand.

To complete the solar applications, the PVRES home's water was heated by a 40-ft^2 solar thermal collector.

The solar home sold quickly, while the conventional control home took much longer to sell. So, the project also showed the value of the concept to the builder.

One year of detailed performance data showed that the PVRES house, occupied by two adults, used a total of 8156 kWh of electricity. The PV system supplied 5272 kWh (fed to the electrical grid), which means the house's net annual utility energy use was 2885 kWh. So, for a year's worth of electrical power, the owners paid a total of $230 at a utility cost of $0.08 per kWh!

FSEC researchers compared the PVRES's total consumption with that of the control house. That house used 21,865 kWh – almost three times that of the PVRES. Comparing the net consumption of the PVRES house with the base consumption of neighboring homes, FSEC researchers showed that the PVRES placed only one-tenth the peak demand on the electric utility. The moral of the story: combining these two technologies results in a powerful impact. [Reference 73]

Completed PV research house, Lakeland, Florida (September 1999)

Florida Photovoltaic Buildings Program

During the '90s, FSEC teamed with the Florida Energy Office and Sandia National Laboratories on the Florida Photovoltaic Buildings Program. The program offered to buy down the cost of utility-interactive PV installations to $4/Wp to municipal utility companies with dollars supplied by the Florida Energy Office. The program envisioned the installation of 20,000 PV systems on Florida buildings by the year 2010. It placed strong emphasis on increasing the value of rooftop PV systems and transferring the technology to nine end-user target groups.

Donard Metzger installs PV light system

By 1999, two contracts had been awarded – one went to New Smyrna Electric Utility to assist in installation of 60 PV systems, and one went to Jacksonville Energy Authority for 12 systems in Jacksonville. [Reference 74]

Special Applications

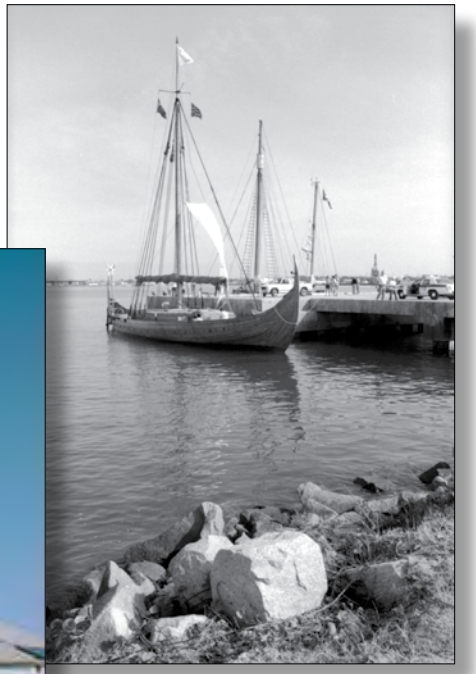
The first of FSEC's special PV applications in the '90s was a transportation sector project through a contract with the Florida Department of Transportation (FDOT). FSEC researchers identified the potential for PV to provide power for school-crossing warning lights, traffic monitoring devices, remote traffic regulation stop lights, highway sign lighting, cathodic protection for bridges, roadway message boards, and marine navigation lights for bridges. FSEC staff then designed and installed a pilot project navigational system and wrote a decision-maker's guide to assist DOT personnel in the design, installation, operation and maintenance of PV-powered operations. [Reference 75]

In 1992, FSEC played a salutary role in the voyage of Gaia, a Viking ship replica that dropped anchor in Port Canaveral on its way to Rio de Janeiro for the Earth Summit. Researchers Bill Young and Leighton (Demi) Demetrius, assisted by Jim Dunlop, Craig Maytrott and Donnie Metzger, designed and installed a PV-powered desalination system capable of producing up to 20 gallons of potable water per day for the ship's crew. The PV array was also used to charge the ship's batteries.

The devastation resulting from Hurricane Andrew initiated another special PV application. The hurricane cut a devastating swath across south Florida when it made landfall on August 24, 1992. Electrical power for everything was cut off causing inoperable street lights, traffic signals, medical equipment, and refrigeration for food and medicine plus severely handicapping rescue, relief and recovery operations. As part of a hurricane response team, FSEC worked with DOE, Sandia National Laboratories, the University of Miami Medical School and the Metro-Dade Fire Department to provide photovoltaic systems for security lighting, medical refrigeration and emergency radio communications. The experience convinced disaster relief team members that PV systems can prove useful in disaster situations where there is a need for quickly deployable, mobile power systems requiring simple setup and minimal follow-up. [Reference 76]

The program also resulted in the development of a PV-powered weather station for the National Hurricane Center. The station is designed to transmit pre-storm weather data by amateur radio stations to be mapped on computers at the National Hurricane Center.

Bill Young and Demi Demetrius at Gaia PV installation (December 1991)



Gaia PV installation (December 1991)

PV-powered traffic light (July 1992)

Bill Young at PV-powered weather station for early storm warnings (July 1998)

Olympic games PV parking lights at FSEC (April 1996)

PV and diesel hybrid system (September 1998)

The 1996 Olympic games in Atlanta offered FSEC the opportunity to participate in another special PV project. With DOE, FSEC developed the conceptual plan and technical specifications for photovoltaic-powered outdoor lighting for use during the Olympics. The project showcased 140 U.S.-made lighting systems at a staging area of the Martin Luther King, Jr., National Historical Site and Monument in Atlanta. The project also resulted in installation of three of the Olympic light systems in the parking lot of FSEC's new facilities. [Reference 77]

Yet another special application involved the installation and testing of a PV-diesel hybrid system. Such systems can be used to power remote telecommunications and village power stations. FSEC researchers studied long-term performance under variable load conditions and evaluated sizing estimation algorithms for different levels of PV input.

FSEC staff also performed tests on small systems for rural home lighting and communications applications in developing countries for the Solar Electric Light Company. These 50-watt systems, which consist of a single module, batteries and a charge controller, are designed to operate lights and radios in remote villages. The company had plans to install thousands of systems in Africa.

Industry Assistance

In 1990, FSEC established the Photovoltaic Design Assistance and Training Center. The center provides training programs and coordinates contacts with manufacturers, vendors and consumers. It receives hundreds of design assistance inquiries every year and is still a major ongoing effort.

Thin-Film Program

FSEC initiated research on thin-film PV development when Neelkanth Dhere came onboard in the early '90s. The program began in 1992 with research on development of polycrystalline thin-film photovoltaic cells from such advanced materials as cadmium telluride and copper indium diselenide using magnetron sputtering deposition techniques.

Expanding the PV program to include PV cell research and development required construction of a Thin-Film Laboratory. The original lab at FSEC's original site housed two vacuum deposition chambers that used magnetron-sputtering and high-vacuum pump technologies for thin-film depositions. Through careful design, planning and engineering, the laboratory was constructed by FSEC staff at one-tenth the cost of similarly equipped labs elsewhere.

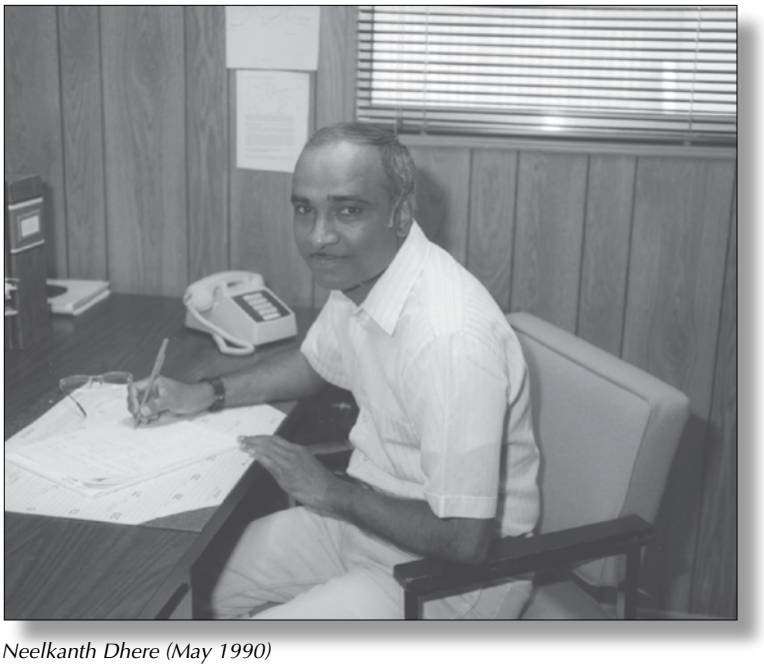
At the new site, the thin-film PV cell work was re-established in a new lab in the Low-Bay Lab. Lab results have demonstrated a thin-film manufacturing process for copper-indium-gallium-selenide cells, rated at 9 percent efficiency, using a process that lends itself for conversion to scale-up manufacturing. [Reference 78]

PV Thin-Film Lab (March 1993)

People of the Photovoltaics Division

The previous chapter recognized the PV work of Jerry Ventre, Jim Dunlop, Gobind Atmaram, Leighton Demetrios and Donnie Metzger. In this section, the PV individuals of the 90s are recognized. They are presented in alphabetical order.

- *Dr. Neelkanth Dhere – Neelkanth started work at FSEC on May 14, 1990, coming to the Center from SERI (now NREL). He brought to FSEC many years of PV cell experience and was hired to begin FSEC's activities in thin-film photovoltaics. Upon arrival, he immediately began construction of the first thin-film laboratory and continues his work in the state-of-the-art thin-film deposition laboratory at the new site. Neel is also well-known for hiring graduate students to work with him in the lab and for his research in PV cell degradation.*



Neelkanth Dhere (May 1990)

Brian Farhi (March 1999)

- *Brian Farhi – Brian was hired on March 9, 1998, after graduating with a Master's degree from the University of Colorado. In addition to his work in the PV systems area, Brian initiated FSEC's Energy Managers Workshops. Brian resigned on August 15, 2003, to join a California PV company.*

Noreen Grandbouche (August 1999)

- *Noreen Grandbouche – Noreen started work in the PV Division on December 3, 1993, and continued work there until June 2000, when she transferred to the Business Division as office manager. Noreen now handles FSEC's personnel activities.*

- *Kevin Lynn – Kevin started at FSEC as a UCF Master's degree student working under Dr. Dhere. Upon graduation, Kevin was hired on April 30, 1998, to work in the PV program, where he focuses on the systems and education areas.*

Kevin Lynn (August 1999)

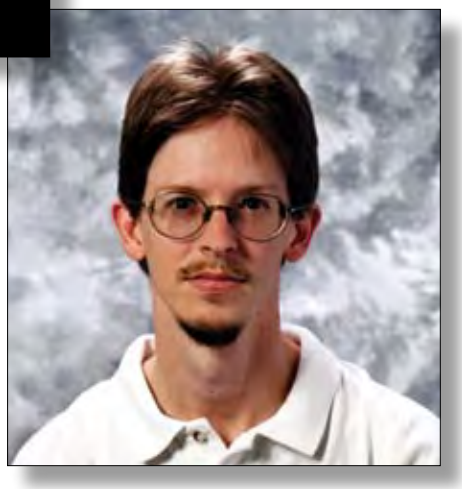
- *Kelly Slattery-Snavely – Kelly began work at FSEC on September 18, 1998, in the PV Division. Kelly provides assistance to the educational programs in addition to her normal activities.*

Kelly Slattery-Snavely (August 1999)

- *Jennifer Szaro – Jennifer was hired on March 11, 1998, to work in the PV area. Jennifer is a Florida International University graduate who had previously worked in the environmental area. At FSEC, Jennifer has worked with the PV industry and has been responsible for the PV rebate and utility programs.*

Jennifer Szaro (August 1999)

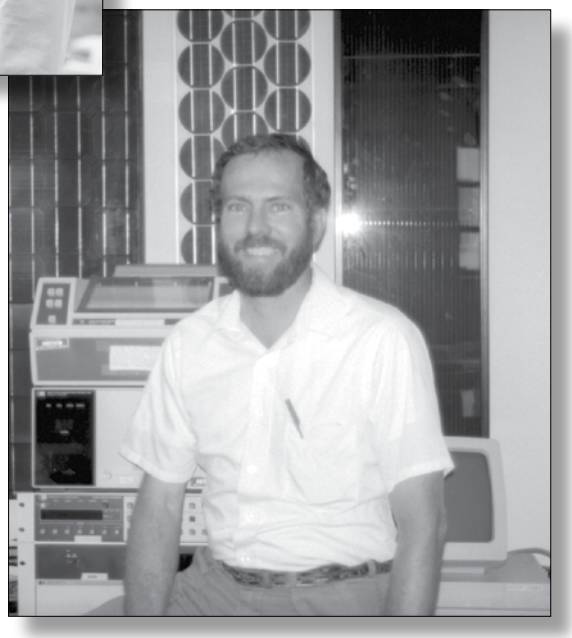
- *William Wilson – William began work at FSEC as a student in 1994 and became a full-time employee on September 19, 1997. He has worked in the PV systems area and has also been involved in FSEC's communications system.*



William Wilson (August 1999)

Dianne Wood (August 1997)

- *Dianne Wood – Dianne began work at FSEC in the PV Division on April 28, 1995. In September 2000, she transferred to the Public Affairs Office, where she spearheads FSEC's presence on the World Wide Web. Dianne also provides assistance for the educational programs.*



Bill Young (September 1990)

- *Bill Young – Bill is a long-time PV employee, who began work at FSEC on June 22, 1990, after working for General Electric in Daytona Beach. He is known for his work on electric and alternative-fuel vehicles, and has initiated and coordinated alternative-fuel vehicle races for many years. He has also been FSEC's representative in the DOE Clean Cities Program and is involved in PV disaster equipment design and training.*

One additional individual deserves special recognition for his support of the PV program. Charlie Cromer, previously recognized for his work in the Buildings Research Division, moved to the PV program in the '90s and became the PV&AT Division Interim Director after Jerry Ventre's retirement on October 31, 2003.

Charlie Cromer (August 1980)

Buildings Research

Initiated in the '80s, FSEC's energy-efficient buildings program advanced to high levels of achievement in the '90s, gaining national recognition. Four areas defined the program through this decade; energy-efficient industrialized housing, building systems and monitoring, indoor air quality and the Florida building code.

Subrato Chandra at Spirit of Today house dedication (January 1995)

Energy-Efficient Industrialized Housing

Energy-efficient industrialized housing, or EEIH, was the largest and most recognized of the DOE-funded FSEC buildings research programs. Although the effort was initiated during the late '80s, it gained significant stature and results in the '90s.

The EEIH project's success was due in large part to Subrato Chandra. Chandra started the project in 1989 as its principal investigator and he has led the project ever since. Chandra's work was critical in winning a national competition for EEIH in 1999, when the project's partner status moved from the University of Oregon to Washington State University and FSEC assumed the project leadership. Chandra was also key in engaging other buildings staff members in EEIH program activities. These staff members included Philip Fairey, Rob Vieira, Armin Rudd, Neil Moyer, Danny Parker, David Beal and Janet McIlvaine. With the exception of Armin Rudd, all are still FSEC staff members.

Danny Parker with Lou Divone (DOE) and Bob Kripowicz (Congressional Office) (March 1993)

In the early '90s, it was becoming more and more difficult to build affordable homes for the 21st Century. Fewer and fewer people could afford to own a home, and housing starts were down. Through its EEIH program, DOE tackled the problem by developing advanced housing designs and manufacturing concepts. The overall goal was to develop high-quality, affordable and exportable industrialized housing that was 25 percent more energy-efficient than current housing, had lower first cost, and had a competitive edge in a growing international market. This goal was to be achieved through a variety of activities.

One of the first activities was undertaken in the summer of 1991. The activity was to design and to test the energy performance of two prototype structures compared with a baseline standard 2x4 stud-wall prototype. This project attracted participation and cost-sharing from GE Plastics, Dow Chemical, Integri Homes (a division of Penn-Lyon Homes), American Ingenuity and American Foam

Manufacturers. Industrial partners have been a hallmark of EEIH ever since. [Reference 79]

Project researchers also developed the EQUIP concept (Energy and Quality Unit Improvement Program), through which they conducted in-plant quality control testing of homes using infrared photography and blower door tests. EQUIP testing at the factory highlighted dramatic energy improvement opportunities, which were then incorporated into the EEIH manufacturer's program. The manufacturer's program also included time and motion factory analyses by the UCF Industrial Engineering Department. Bill Swart began this effort, which has continued under the direction of Mike Mullens. [Reference 80]

By 1993, EEIH grew to be the Center's largest externally funded program. The program focused activities in energy-efficient housing through work with modular, panelized and production home builders and suppliers. In fact, modular manufacturers used the FSEC infrared test videotapes as a training and quality control tool for insulation installers on the production line.

During the same time frame, EEIH and the Structural Insulated Panel Association tested the winter heating performance of two side-by-side 1,200-square-foot houses in Louisville, Kentucky – one was built with conventional construction, and the other was made from stress-skin core-insulated panels. Armin Rudd monitored the energy use, and his analysis of the two houses showed that panelized construction offered a 12 to 15 percent heating energy savings – even greater savings than predicted by computer simulations. [Reference 81]

With Subrato Chandra at the lead, the EEIH team greatly advanced the perceived value of EEIH in 1994 through participation in the design and construction of the Spirit of Today house in Orlando, Florida. The house demonstrated that the quality and efficiency of panelized construction can result in a 50 percent increase in energy efficiency, while incorporating both environmental and handicap accessibility concepts. The Spirit of Today House, which was the cover story for the October 1994 issue of Better Homes & Gardens, was completed and dedicated in 1995. [Reference 82]

EEIH peer review meeting: Subrato Chandra, Mike Mullens, Bill Swart and Janet McIlvaine (November 1991)

In the mid '90s, the EEIH program also began to focus on indoor air quality (IAQ) concerns. The Spirit of Today House incorporated IAQ technologies as part of its demonstration. EEIH staff soon began to conduct field tests and computer simulations on homes in Florida and Alabama to detect inefficiencies in air distribution systems and to identify methods of reducing energy losses. By 1997, EEIH had completed year-long monitoring of homes in Oregon, Michigan and Florida to document their energy efficiency performance and indoor air quality. This effort led to development of the design and monitoring plan for a Health House demonstration project in Orlando.

In close cooperation with the American Lung Association, EEIH developed the Health House concept as a way to demonstrate technologies for energy savings and allergen reduction. The first home incorporated energy-efficient central dehumidification, a filtered fresh-air ventilation system, airtight construction with non-CFC foam wall insulation, energy-efficient walls and roof, a solar water heater, and low- or no-VOC-emitting interior finishes. After it was completed in 1996, the Orlando Health House was then featured in a cover story of the March 1996 issue of Professional Builder magazine. [Reference 83]

During the years that followed, Chandra and the EEIH group provided building design assistance to American Lung Association affiliates in Alabama, Louisiana and Florida. As a result, Health Houses were built in Jacksonville, FL; New Orleans, LA; Birmingham, AL; Huntsville, AL; and Minneapolis, MN. The Health House concept also initiated a cooperative effort with the University of South Florida Medical School, where FSEC's David Beal conducted testing of dust mite and VOC allergens in allergy-resistant and control houses. [Reference 84]

Spirit of Today house dedication (January 1995)

Orlando Health House (July 1997)

An outgrowth of the EEIH effort was a program of design assistance and training for nationwide Habitat for Humanity affiliates. [Reference 85] FSEC's Janet McIlvaine spearheaded this project phase by developing a Habitat homeowner energy handbook and holding a network of regional Habitat energy institutes. In 1997, she provided design and construction assistance and conducted workshops for Habitat for Humanity International and Habitat affiliates in Houston, TX. This work also influenced the Jimmy Carter Work Project held throughout Kentucky and Tennessee. [Reference 86]

Bert Kessler (Palm Harbor Homes), Sam Rashkin (EPA), David Block and Subrato Chandra during Palm Harbor Homes visit (Summer 1997)

Other notable EEIH results include:

- Palm Harbor Homes, a major producer of manufactured homes, with factories in 12 states, changed its air-duct construction procedures in four manufacturing plants – two in Florida, one in North Carolina and one in Oregon. The change led to energy savings and improved air quality in 3,000 homes manufactured each year and resulted in estimated energy savings of 2 million kWh per year. [Reference 87]
- Partnerships with American Lung Association affiliates in Orlando, Jacksonville, Seattle, New Orleans and Huntsville resulted in design and construction of quality homes with better indoor-air quality.
- FSEC energy performance and allergen monitoring on houses in Florida, Louisiana and Alabama showed that use of both a central dehumidification system and central vacuum system is an effective strategy to eliminate dust mites in new homes. [Reference 88]
- Continuation of work with Habitat for Humanity affiliates and volunteers throughout the country resulted in the design, construction and performance testing of more than 120 energy-efficient, affordable homes. [Reference 89]

Building Systems and Monitoring

Development and testing of building systems and building performance monitoring have long been major activities. The Buildings Research staff have undertaken numerous and diverse projects in these areas.

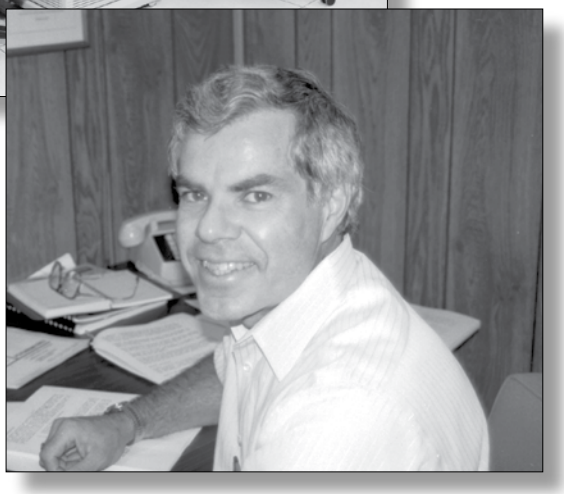
Over the years, the staff have developed and perfected automated monitoring and data quality control capabilities that are unmatched by any other organization. Long-time computer center director Safvat Kalaghchy has provided exemplary work and leadership in this area. FSEC researchers regularly collect more than 600,000 data points per day – at research sites ranging from Oregon, to New York, to Florida – with average data quality ratios exceeding 99 percent, an amazing measure of success.

Computer modeling goes hand-in-hand with data gathering, monitoring and systems analysis. FSEC's capabilities in this area are uniquely coupled with a comprehensive knowledge of building energy simulation software packages. In-house software developed by Philip Fairey, and Muthusamy Swami and Lixing Gu permits highly detailed simulation of building energy systems to include modeling of moisture transport in materials and modeling of the interactions of forced air flows (duct leakage). In Florida's hot, humid climate, these capabilities are critical to research on building systems and the interactions of building components.

Broad, economical use of air conditioning makes Florida habitable. So, FSEC has focused its research on air-conditioning equipment and the relationship of humidity to air-conditioning system performance. Related research areas include dehumidification by heat pipes and desiccant-enhanced systems.

In 1993, FSEC researchers Bruce Nimmo and Mark Thornbloom investigated a desiccant-enhanced air conditioner called DEAC. The DEAC process used a desiccant wheel to pre-cool and humidify air returning to the air conditioner before it enters the cooling coil. After exiting the coil, the air passes through the regenerated (dry) portion of the desiccant wheel and is dehumidified. The unique feature of the DEAC process is that the return air regenerates the desiccant, rather than an external heat source. Simulation studies showed an energy savings of 5 -10 percent from DEAC. The researchers also conducted field tests and computer simulations on a concept using solar-driven liquid desiccant dehumidification, followed by conventional cooling. [Reference 90]

Safvat Kalaghchy and Suzette Garnett, at FSEC computer facilities (November 1998)



Bruce Nimmo, Advanced Technologies Division Director (September 1990)

In the '90s, FSEC continued to demonstrate the use of heat pipes to maintain low humidity and comfortable temperature conditions without electrical re-heat. In 1996, Don Shirey and Rich Raustad completed investigation of the use of heat pipes in conventional air conditioners to reduce humidity in an aerospace cable manufacturing facility. The results showed a 20 - 30 percent reduction in annual electrical energy consumption, and a 40 percent demand savings.

Because roofs account for 10 to 20 percent of a home's air, conditioning load, FSEC has long focused on roofing concepts. In 1992, staff began to conduct side-by-side tests of varying roof finishes on small-scale roof structures. The results showed that clay tiles, followed by concrete barrel tile, performed best at keeping the roof deck cooler, compared with such options as asphalt shingles. These findings indicate that energy efficiency can be significantly improved simply by using the most appropriate roofing materials. [Reference 91]

In 1995, staff collected summer-season data from field tests of reflective roof finishes on 12 homes. They measured energy levels before any changes, and then after the roof colors were altered. The results showed air-conditioning energy savings averaging 20 percent after the roof colors were changed. [Reference 92]

John Sherwin conducting roof tests at FSEC's auxiliary test site

Researchers in FSEC's buildings program have always worked to provide energy efficiency information and design review services to builders and architects. In the early '90s, the group established the Building Design Assistance Center (BDAC) to institutionalize this work. In addition to providing design services, BDAC also shared information through its comprehensive database on energy-efficient equipment for commercial buildings, an electronic bulletin board and a newsletter.

The BDAC group also constructed a Lighting Test Facility in 1993. The facility featured two side-by-side office bays specifically designed to test the interaction of office lighting systems and daylighting applications.

Comparative data, collected at 15-minute intervals, evaluated electrical demand, power quality and work-place illuminance for 40 different lighting systems. The data showed the most cost-effective lighting measures for use in Florida's commercial buildings. [Reference 93]

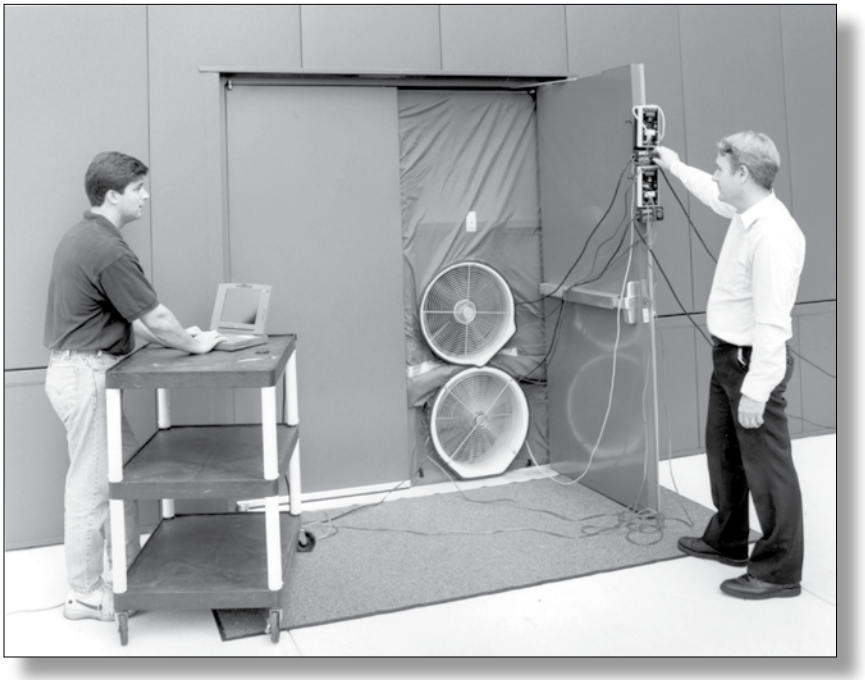
In 1992, Hurricane Andrew destroyed more than 35,000 homes in south Florida. State officials recommended that the replacement housing stock be made more energy efficient. FSEC joined in the post-hurricane residential reconstruction effort by considering both the technical feasibility and economics of the various rebuilding options. The study identified a package of measures for new home construction that would reduce annual electricity consumption by 39 percent, or 5,350 kWh, at an initial cost of about $3,000. This same package would reduce summertime utility coincident peak loads by about 1.5 kW, about 37 percent lower than that of conventional new homes. However, these results were very nominally implemented. [Reference 94]

In 1996, Robin Vieira began the Energy Star New Homes program under the sponsorship of the U.S. Environmental Protection Agency. The program provided technical assistance to builders and developers as part of EPA's Energy Star Homes program. The program resulted in construction of 6,000 new homes with heating, air conditioning and water heating energy consumption reduced by 30 percent, compared with standard homes. Over the years, the EPA project tested homes and evaluated plans for homebuilders working to meet Energy Star certification. In addition, it enrolled more than 50 home builders in the Energy Star Program. [Reference 95]

Janet McIlvaine and Rob Vieira conducting duct leakage test (October 1998)

During the '90s FSEC also conducted many building projects for Florida Power & Light Company, Florida Power Corporation, ASHRAE and the Florida Energy Office. Highlights of some of these projects are described in the following paragraphs.

Sponsored by the Florida Energy Office, Jim Cummings conducted a study of duct leakage, or uncontrolled airflow, on 70 small commercial buildings. The study showed that 69 of the 70 buildings had airflow problems. He also monitored the buildings to determine energy, humidity and air-quality improvements from airflow and HVAC retrofits. The retrofit results showed low initial cost, with outstanding energy-savings payback. [Reference 96]



Chuck Withers and Jim Cummings conducting blower door test (February 1996)

Cummings' work in duct leakage started in 1989 and has continued throughout the '90s and into the 2000s. On the national scene, his pioneering research prompted DOE, its national labs and many key states to conduct similar research. Cummings' efforts in conducting and pursuing this research are commended.

The Florida Energy Office and Florida Power & Light Company in 1996 sponsored a project to quantify the impacts on energy use and indoor humidity levels that would result from new ASHRAE standards to increase the use of outdoor ventilation air in cooling systems for Florida commercial and institutional buildings. [Reference 97]

As a result of Hurricane Andrew, Jeff Sonne, Robin Vieira and Philip Fairey conducted a project with the City of Deerfield Beach under sponsorship of the Florida Department of Community Affairs. This project identified and energy-audited 16 small commercial properties for the purpose of developing disaster mitigation technologies related to energy efficiency. [Reference 98]

Sponsored by the Florida Energy Office, Danny Parker conducted detailed monitoring of several homes, showing that low airflow across air-conditioning coils was a major cause of energy waste in homes. This problem causes high air-conditioning bills and, in some cases, icing of the coils. [Reference 99]

The '90s saw development of the concept of "commissioning" energy systems in buildings to ensure that the equipment is installed according to specifications and that the building performs to equipment design standards. One FSEC commissioning activity involved monitoring elementary schools before and after installation of energy management systems and occupancy sensors. Another involved monitoring 10 energy-improved Habitat for Humanity-built homes in South Dade and comparing their energy performance with 10 similar but standard low-income homes. [Reference 100]

For FPL, FSEC staff monitored 425 Florida homes to determine energy and demand savings for a variety of building design features and options. FPL then used the results in its BuildSmart residential program in Southwest Florida. [Reference 101]

Bruce McKendry conducts duct leakage workshop (November 1991)

Janet McIlvaine conducts Habitat for Humanity workshop (June 1999)

John Sherwin at elementary school in Fellsmere, Florida (December 1994)

In 1999, FSEC initiated a project to measure time-of-day electricity use profiles in more than 200 Central Florida homes for Florida Power Corporation. The results of this work by Danny Parker and John Sherwin were interesting, but proprietary, and the results have not been released to the public.

Lixing Gu measured and analyzed the energy and thermal performance of autoclaved aerated concrete roof systems for YTONG Corporation. [Reference 102]

In another roof project funded by the Florida Energy Office, researchers Danny Parker and John Sherwin collected data from FSEC's roof research facility that showed white tile roofs can keep attics cooler and reduce ceiling heat flux by more than 75 percent compared with dark shingle roofs. [Reference 103]

Danny Parker monitors building roof energy (May 1996)

Auxiliary site roof tests (July 1997)

For Florida Power & Light Company and the Florida Energy Office, Kannan Rengarajan and Don Shirey conducted computer simulation studies to determine impacts of ASHRAE Standard 62-89 on energy use in commercial buildings. [Reference 104]

In a similar project, Don Shirey conducted a project for the Florida Energy Office that compared simulation results with field-monitoring energy use results at a Florida school. The project monitored two portable classrooms – one was the baseline and the other had its ventilation rate increased to the current minimum rate prescribed by the new ASHRAE standard. The results assessed the ability of the conventional air conditioner alone and in combination with an enthalpy recovery wheel to meet the increased load from the new standard. [Reference 105]

With support from the Florida Department of Community Affairs, FSEC's David Chasar participated in restoration of the Wellsbilt Hotel in Orlando. A popular gathering place for African-American high society and celebrities, the Wellsbilt was constructed in 1929 in Orlando's Parramore neighborhood as a dance hall that was then converted to a 5,000-square-foot hotel. In the effort to restore and preserve the building, FSEC expertise helped to install air conditioning and duct work in a building that had never been air conditioned.

One of the most interesting outcomes of buildings research in the '90s was a ceiling-fan blade design conceived by Danny Parker in 1999. Parkers' work showed an aerodynamically designed fan blade could improve fan performance and produce 40 percent more airflow per unit of energy as the traditional flat-blade design. His work resulted in two patents. Following assignment of the patents, Home Depot sold 200,000 fans (called Gossamer Wind) during its first year of sales. The patents have produced more income for UCF than any other university-developed patent – another significant accomplishment for FSEC. [References 106 and 107]

Danny Parker measures air speed from patented "Gossamer Wind" ceiling fan (October 1998)

Don Shirey at Salvador Dali Museum heat pipes demonstration (June 1990)

Wellsbilt Hotel, Orlando, FL (October 1999)

Indoor Air Quality

"Sick Building Syndrome" and indoor air quality (IAQ) became important areas of FSEC buildings research during the '90s as the issues began to attract public and legal attention in schools and other public buildings. In one example, a county courthouse, constructed at a cost of $25 million, required an additional $40 million in attempts to fix IAQ problems. Yet another $25 million in repairs were required before the building could eventually be occupied.

Blower door test (November 1991)

Homes in Florida are also susceptible to IAQ problems, especially from humidity-loving dust mites, molds and mildew. In one of three Florida homes, at least one person – most likely a child – suffers from allergies or asthma. Because more than 20 percent of the population suffers from allergy-related illnesses, IAQ continues to be a major focus of FSEC building science research. In Florida alone, the state Medicaid system spends $7 million per year to treat the 700 worst cases of asthma patients and $30 million more per year for the next 10,000 patients. Contributing to this problem is the fact that the most severe cases are among Florida's youngest and poorest citizens.

FSEC researchers believe that buildings can be designed, built and commissioned to minimize allergens and toxins in the air. A key to improving IAQ is understanding unintended and uncontrolled airflow in buildings – especially air movement of unknown or undesirable origin. Uncontrolled movement of air through a building's structure or between interior zones can degrade IAQ by impeding ventilation, drawing in pollutants, increasing humidity, and leading to growth of mold and mildew.

One "easy" solution to indoor air pollution is simply to increase controlled ventilation rates. But in Florida's climate, that also means significantly higher energy use to deal with the increased heat and humidity.

FSEC staff has conducted detailed research on airflow in many buildings over the years. These tasks involved measuring airflow in buildings; surveying ventilation system design and operation; analyzing alternative technologies through computer simulations; selecting sites to test alternatives for air quality; conducting IAQ tests on new homes; measuring indoor levels of VOCs, formaldehyde, temperature and humidity; and analyzing samples through gas chromatography and mass spectrometry.

Three Health Houses, Apopka, Florida (December 1998)

FSEC's first IAQ effort began in 1992 with a radon gas project. Working with the Florida Department of Community Affairs, the project's objective was to demonstrate effective radon-resistant construction techniques. One technique analyzed the use of sub-slab depressurization, where a ventilation mat is installed under the slab of a house and a fan is used to remove air. The process creates a higher negative pressure inside the house than that under the house, which excludes the radon gas. Staff also conducted extensive computer simulations to examine the efficacy of radon mitigation strategies for Florida commercial buildings and options for radon standards to be used in Florida building codes. [Reference 108]

Another IAQ project conducted as part of the EEIH program involved monitoring three side-by-side homes constructed in Apopka, FL. Each home had almost identical floor plans that consisted of 1,187 square feet of living space, with three bedrooms and two bathrooms, and an unconditioned two-car garage. Each home was painted in neutral shades and similarly landscaped. All three houses received the same amount of sunlight and shade. Each exceeded national minimum efficiency standards by 30 percent and the Florida Energy Code by 20 percent. All were equipped with a high-efficiency heat pump (SEER 12) and R-30 ceiling insulation.

But looks and design aside, each house was unique and incorporated distinctly different aspects designed to test energy efficiency and air quality. The exterior of the first home was built with concrete block. The middle house was constructed of autoclaved aerated concrete (AAC) block – a solid, lightweight material noted for its insulating qualities. The third was built with conventional wood frame construction.

The interior of the AAC block structure was designed and equipped for improved air quality with:

- High-density urethane carpet cushion covered by 100-percent nylon carpet
- A high-tech, odorless interior paint mix that emits low levels of volatile organic compounds (VOCs)
- Kitchen cabinets made of laminated plywood rather than pressed board
- An air-conditioning system that mixes fresh air with recycled air to dilute interior airborne toxins and odors.

Following construction, FSEC staff monitored the three unoccupied homes for one month. The results showed that the VOC levels in the AAC home were 50 percent lower than in the other two homes. The concrete block and AAC homes used about the same amount of energy, while the frame home, equipped with better windows and an attic radiant barrier, used about 20 percent less energy.

FSEC then monitored the three homes for six more weeks while they were occupied. These results showed dramatic changes in energy consumption patterns, proving again that occupancy profiles have a large impact on home energy use. [Reference 109]

Florida Energy Code Development

During the '90s, FSEC buildings researchers continued to develop more sophisticated energy analysis software they began in the '80s. Early in the decade, they completed development of the second version of the Florida Software for Environmental Computation (FSEC 2.1) for modeling innovative mechanical systems. Under contract from the Gas Research Institute, they added a groundwater model, a model to predict the behavior of attic radiant barriers, and a model to predict building pressure imbalances as a consequence of leaking duct systems. Later editions included methods to predict effects of increased ventilation on commercial building energy use (to meet new ASHRAE code requirements), to analyze alternative HVAC systems and to include life-cycle costs. Field-monitoring validated all of this work.

Beginning in 1993, with funding from the Florida Department of Community Affairs (DCA),

FSEC began to develop computer software called FLA/COM. FLA/COM was to become the commercial building energy code for Florida. By January 1994, commercial building architects and designers began using the output from FLA/COM to obtain their building permits.

The DCA-funded building code activity continued with the development of a uniform, statewide energy-efficiency rating system for new homes, followed by creation of a similar system for existing homes and public buildings. The code work on commercial buildings next incorporated nationwide criteria for new efficiency requirements in commercial buildings.

By 1995, the expanded Florida Building Energy-Efficiency Rating System included existing homes, and new and existing commercial buildings. Next, researchers modified the code software to include simplified methods for estimating duct system energy losses in homes. They also added the capability to predict energy penalties for duct system loses in residential construction based on duct placement and duct insulation levels. [Reference 110]

The Florida Energy Gauge Program

The state legislature created the Florida Energy Gauge program in 1997 as a way to provide a uniform, statewide method for rating the energy efficiency of homes and commercial buildings. Its purpose was to give buyers a marketplace yardstick that would measure the benefits of energy-efficiency improvements.

That same year, DCA contracted with FSEC to serve as its designated representative in administering Florida's building energy-efficiency rating system using the code software programs that FSEC had developed over the years. This action made FSEC responsible for the complete program, including administration, technical training, software development, software maintenance, quality assurance and database management. Through these activities, program staff developed a Windows-based version of computer software called EnGauge. This software tool determines energy-code compliance and rates the energy efficiency of existing and newly constructed buildings.

EnGauge software for Florida building code compliance (November 1996)

EnGauge allows raters to quickly and accurately calculate energy ratings, Home Energy Rating System (HERS) scores, determine code compliance and produce required reports. The software also offers additional marketing and energy rating tools. One tool enables raters to optimize home efficiency for the builder or homeowner by determining the most cost-effective energy improvements from a directory of efficiency measures. The directory itself can be amended or customized according to homebuilder or consumer preferences. The software's reporting component prints an analysis of the improvements and calculates the cost effectiveness of each measure. It also completes financial forms required by lenders to process energy-efficient mortgages. Phillip Fairey, Muthusamy Swami, Lixing Gu and Brian Hanson were responsible for conducting this work for DCA. [References 111 and 112]

The Energy Gauge program also involves education and information programs. In the education area, FSEC courses led by Tei Simmerman train qualified individuals to be certified as Class 1, 2 and 3 Energy Raters. By 1998, more than 600 individuals had received state certification. The program continues to train and to disseminate information to building professionals, the public, and the financial and regulatory sectors – a never ending task.

Chuck Withers, Steven Richardson and Jim Cummings at duct leakage workshop (April 1997)

Duct leakage workshop (October 1991)

Fenestration Project

During the '90s, Ross McCluney continued R&D in FSEC's long-standing fenestration program, with support from DOE's Sam Taylor. All fenestrations – windows, skylights, clerestories or other glazed openings – represent a significant source of energy consumption for both heating and cooling in buildings. The program's goals are to provide information on the performance of various fenestration choices.

In the '90s, the work included consideration of solar gain as part of a national window-labeling program. It also led to technological improvements in glass coatings, films and window insulation. Supporting activities included development of a window solar-heat-gain calculation procedure, design of a calorimeter for testing window solar-heat gain, and development of a computer program to aid in window design and sizing.

People of the Buildings Research Division

The Buildings Research Division added 10 new faces during the '90s. These individuals are recognized here, in alphabetical order.

Robert Abernathy (August 1999)

- *Robert Abernethy – Bob is one of few FSEC technicians at FSEC not assigned to the T&O Division. He began work in the Buildings Research Division on April 13, 1993, and has supported the EEIH Program.*

Steve Barkaszi (August 1999)

- *Steve Barkaszi – Steve started work in the Buildings Research Division on June 10, 1994. He left FSEC after a few years and returned on January 7, 1998. Since then, he has worked in the areas of PV, buildings and testing.*

David Chasar (August 1999)

- *David Chasar – David began work at FSEC in 1994 and became a full-time staff member on January 26, 1996. David has worked in the air-conditioning systems and education areas and was responsible for the Wellsbilt Hotel restoration project.*

Cookie Cook (September 1990)

- *B. A. "Cookie" Cook – Cookie is a long-time staff member who has supported buildings research since joining FSEC in 1990. Her official hire date was December 11, 1992.*

- *Jo Cummings – Jo began working part-time at FSEC in September 1990, supporting the buildings research areas. She became a full-time staff member on November 22, 2002.*

Jo Cummings (August 1999)

- *Brian Hanson – Brian joined FSEC in July 1999 and handles computer software development in support of the Energy Gauge program.*

Brian Hanson (August 1999)

- *Joy Mayne – Joy started work at FSEC in 1993 and was officially hired on October 21, 1994. She has supported the daylighting research effort.*

Joy Mayne (February 1998)

- *Neil Moyer – Neil joined the FSEC buildings research team on November 13, 1998, following extensive work in air-duct leakage and indoor air quality. He has pursued re search in both of these areas while at FSEC and is a key member of the buildings indoor air quality efforts.*

Neil Moyer illustrating uncontrolled airflow in buildings (October 1998)

Tei Simmerman (August 1999)

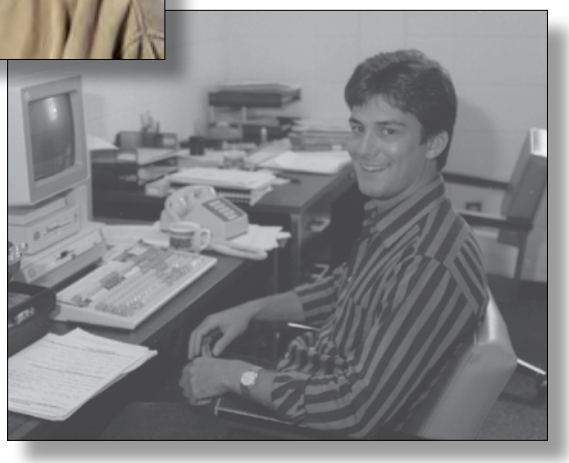
- *Tei Simmerman – Tei has led the Energy Gauge education, training and certification programs since joining FSEC in March 1998.*

Jeff Sonne (August 1999)

- *Jeff Sonne – Jeff came to FSEC on January 1, 1992, after graduating from Auburn University with a degree in mechanical engineering. He has worked on a great variety of buildings research projects.*

Jim Tait (August 1999)

- *Jim Tait – Jim worked for FSEC for slightly more than a year, from October 1999 to August 2001. Jim significantly influenced FSEC programs when he was the Director of the Florida Energy Office, prior to his work at FSEC. He was instrumental in allocating funds to make the New Energy Center energy efficient. At FSEC, he helped develop programs with utilities.*



Chuck Withers (May 1990)

- *Chuck Withers – Chuck joined FSEC in the spring of 1990, with an official start date of November 19, 1990. He has worked on a variety of buildings research programs.*

Hydrogen and Related Technologies

The 1990s was the era during which hydrogen, alternative fuels and detoxification research became major FSEC program areas. It appears that hydrogen will remain one of FSEC's prime program areas based on the research activities now being conducted for NASA and DOE.

Hydrogen is considered by many to be the perfect fuel. It produces power without pollution and provides a medium for energy storage, which makes hydrogen and solar energy perfect partners. Hydrogen can power either fuel cells or internal combustion engines, and its exhaust emissions are essentially water vapor.

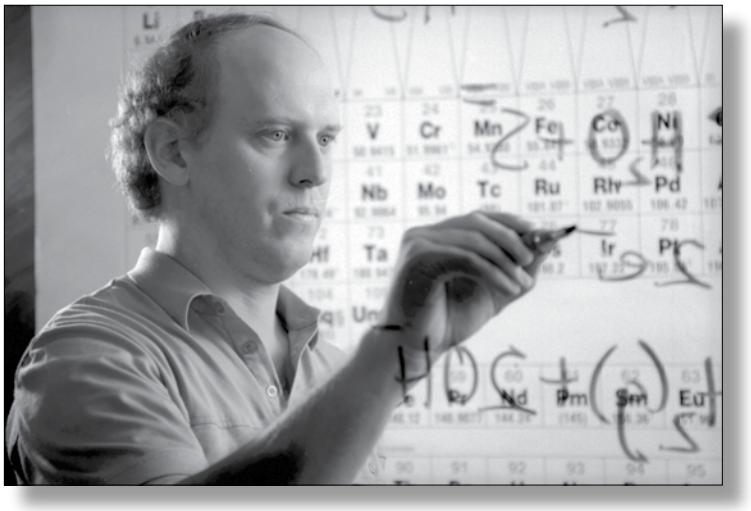
One of the nation's and FSEC's most challenging research areas is the cost-effective production of hydrogen from renewable energy resources. Solar energy can produce hydrogen by breaking down such hydrogen-rich materials as water, biomass and even industrial wastes. Renewable energy can also produce hydrogen by extracting it from fossil fuels, or by splitting water through electrolysis or high-temperature thermochemical processes.

Over the years, FSEC's hydrogen research activities have been funded by DOE and, more recently, by NASA. These comprehensive programs have encompassed research in all areas of hydrogen technology – production, storage, utilization and transition.

UCF President Steve Altman visits Hydrogen Lab with Ali Raissi and Darlene Slattery (October 1989)

Hydrogen Lab at Port Canaveral site (October 1989)

Darlene Slattery and Hydrogen storage flash experiment (August 1991)



Clovis Linkous in hydrogen lab (August 1991)

Department of Energy Projects

The DOE-funded hydrogen activities of the '90s included the following projects.

One of FSEC's original hydrogen storage projects focused on synthesis and characterization of magnesium-based hydrides used as storage materials. This research used chemical rather than metallurgical or physical synthesis to improve kinetics of hydrogenation and dehydrogenation of the hydrides. The work was conducted by Darlene Slattery and Ali Raissi. [Reference 113]

Increasing the operating temperature of an electrolyzer to produce hydrogen reduces the electrical energy needed to split water. This project performed synthesis of novel solid-polymer electrolytes that could be used in electrolyzers for high-temperature water electrolysis. The research involved experiments to evaluate thermohydrolytic stability of various polymers, and the results served as the basis for Robert Kopitzke's doctoral thesis at the Florida Institute of Technology in May 1999. Clovis Linkous supervised the work. [Reference 114]

One unique solar-driven method to produce hydrogen involves a dual-bed process. This novel photoelectrochemical method splits water to produce hydrogen and oxygen in separate chambers. FSEC's work utilized colloidal semiconductor

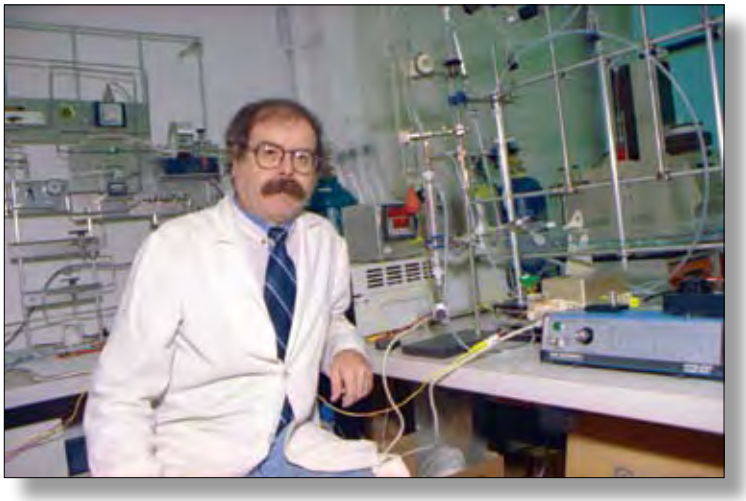
powders and organic dyestuff. The research also teamed FSEC and Swiss researchers to investigate the water-splitting ability of specially immobilized tungsten oxide. FSEC researchers later worked with Japanese collaborators to study nickel-loaded titanium dioxide. The work was conducted by Clovis Linkous and Darlene Slattery. [Reference 115]

Another novel hydrogen production process developed at FSEC is the patented thermocatalylic process that produces hydrogen without producing CO_2 gases. The CO_2 is converted into solid carbon in various forms. The feedstock can be any hydrocarbon fuel, FSEC investigated natural gas and gasoline. The work has been conducted by Nazim Muradov. [Reference 116]

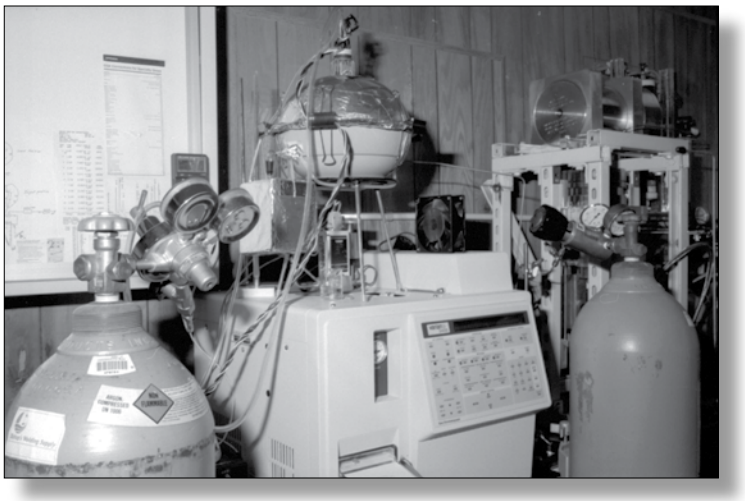
In an industry supported effort, Clovis Linkous worked in a partnership with Solar Reactor Technologies on a project to generate hydrogen through the use of a high-temperature solar reactor and a fuel cell powered by off-peak electricity. [Reference 117]

In another partnership project, Nazim Muradov and Eric Martin teamed with Energy Partners, Inc., on research to improve fuel cell performance through use of advanced proton-exchange membranes. The two FSEC researchers also worked with the Perry Foundation to design a hydrogen production prototype system for an energy self-sufficient community to be installed on Lee Stocking Island, Bahamas. [Reference 118]

High-temperature solar thermochemical cycles have high efficiencies in the production of hydrogen. In a DOE-funded project, FSEC evaluated thermochemical production cycles along with some special storage materials. Ali Raissi evaluated the cost, safety and performance of a large number of high-temperature solar thermochemical cycles. The work also identified borane-class complexes and alkaline earth metal halide ammoniates as hydrogen storage compounds for vehicular applications. The storage results on complex chemical compounds are still of great interest to DOE. [Reference 119]



Nazim Muradov (April 1996)



Hydrogen Lab experiment (September 1991)

World Hydrogen Energy Conference

Other notable hydrogen activities during the '90s included the 10th World Hydrogen Energy Conference (WHEC), which FSEC hosted in June 1994 in Cocoa Beach. More than 600 people from 36 countries attended the conference. The agenda included presentation of 250 papers on all aspects of hydrogen. Exhibits demonstrated hydrogen technologies and use of hydrogen as a transportation fuel. Highlights included presentations by four very distinguished plenary speakers:

- *Dr. Alex Tupolev – Dr. Tupolev, a Russian aircraft designer, was intimately involved in the design and testing of the epoch making TU-155, which in 1987 used hydrogen fuel for the entire flight cycle – take-off, cruise and landing – to power one of its engines. He also developed various other Russian supersonic jets with his father, A.N. Tupolev, including the TU-144.*
- *Dr. Alan C. Lloyd – Dr. Lloyd was chief scientist at the Southern California Air Quality Monitoring Department's Technology Advancement Division. Dr. Lloyd was chairman of the California Air Resources Board, which oversees California's air pollution activities.*
- *Dr. James E. Funk – Dr. Funk is a founding member of the International Association for Hydrogen Energy and a pioneer in the area of thermochemical hydrogen production. He is a longtime FSEC associate.*
- *Mr. Franklin E. Lynch – Mr. Lynch is president of Hydrogen Consultants, Inc., and a longtime hydrogen advocate. His research focuses on the use of hythane, a blend of natural gas and hydrogen, for use in internal combustion engines.*

World Hydrogen Energy Conference program brochure

David Block organized and chaired the conference, with assistance from Ingrid (Melody) Norberg, Carolyn Burby and Suzette (Arrigo) Garnett. [Reference 120]

Other Hydrogen Projects

Hydrogen also formed the basis for a cooperative project with the Research Institute of Innovative Technologies (RITE), Kyoto, Japan. This project focused on hydrogen production using band-gap engineered thin-film compound semiconductor electrodes. The work was led by Neelkanth Dhere of FSEC, and Katsumi Okada and Kiroaki Mametuka of RITE. [Reference 121]

The cost to produce hydrogen is a critical hurdle in the advancement of hydrogen technologies. FSEC activities in PV and PV-electrolysis set the base case for renewable hydrogen production costs by addressing present PV-electrolysis costs and efficiencies, as well as the costs of PV electrolysis 20 years into the future. The work then compared PV-electrolysis costs with costs and efficiencies for photoelectrochemical processes. The results showed that, of the renewable energy production processes, the dual-bed reactor process offered the least-cost alternative to PV electrolysis. David Block conducted this work. [Reference 122]

One unique method of producing hydrogen was developed by Clovis Linkous with funding by the Gulf Coast Hazardous Substances Research Center at Beaumont, TX. This method separated hydrogen from hydrogen sulfide, a waste natural gas product, by a photocatalytic process. This FSEC-patented process produces hydrogen and sulfur, both of which can be sold. It also has the potential to help oil and gas refineries meet on-site hydrogen demand by extracting hydrogen from their hydrogen sulfide waste. [Reference 123]

In 1995, the hydrogen program hosted a technical exchange with the Electrotechnical Laboratory of Japan's Ministry of International Trade and Industry at Tsukuba Science City. Research chemical engineer Takuya Doi spent three months at the Center researching a solar-driven, chemical heat-pump system. This reactor was a critical part of a joint effort to develop the next generation of chemical heat pumps. Ali Raissi and Nazim Muradov were involved in this joint effort. [Reference 124]

Kirk Collier and PV-powered hydrogen production unit (December 1993)

Single-cell electrolyzer with parabolic dish (June 1991)

In 1997, FSEC was named one of DOE's Centers of Excellence in Hydrogen Research and Education when FSEC established the Hydrogen Research and Applications Center (HRAC). FSEC created the Center to respond to NASA's hydrogen needs because of its proximity to both the Kennedy Space Center and Cape Canaveral Air Force Station. HRAC's goal is to apply FSEC's extensive technical expertise to strengthen the research and launch capabilities of both launch facilities and to support applicable synergies for terrestrial hydrogen use.

Creation of HRAC gained considerable government and public exposure to FSEC's hydrogen research. In time, this exposure led to FSEC being selected as the program manager for NASA's is hydrogen research at Florida universities, a program discussed in detail in Chapter 10. [Reference 125]

Nazim Muradov and Ali Raissi at experimental solar chemical heat pump at Port Canaveral (June 1995)

Alternative Fuels and Transportation

The alternative fuels and transportation program was an important outgrowth of the hydrogen effort. Transportation accounts for 38 percent of the state's energy budget, and inexpensive fuels are vital to the state's tourism-based economy. It is clear that transportation issues will continue to challenge Florida and the entire world well into the 21st Century.

Transportation issues will be driven by rapidly developing communications networks, expanding worldwide industrialization, peaking of world oil production and political divisiveness. With two-thirds of the Earth's proven petroleum resources located in politically unstable countries, the only solution to the next oil crisis – and there is no doubt that there will be another – is one that does not use oil. Again, the answer is hydrogen. In the transportation sector, hydrogen can be used either directly for combustion or as the energy source to power fuel-cells for electric driven cars. Both are areas of intense research.

UCF President Hitt at Engine Lab dedication (April 1993)

Hydrogen Vehicles

FSEC staff have conduced major work on use of hydrogen as a fuel for internal combustion engines. The hydrogen fuels program began in the early '90s, when FSEC converted the building used for PV systems research to an engine dynamometer test laboratory. The purpose of the test lab was to examine the prospects of mixing hydrogen with natural gas to improve engine performance and lower engine emissions. Researchers began the work by blending low amounts of hydrogen (5 to 10 percent) with natural gas. But, results showed that mixtures of more than 20 percent hydrogen would be required to achieve desired emission reductions.

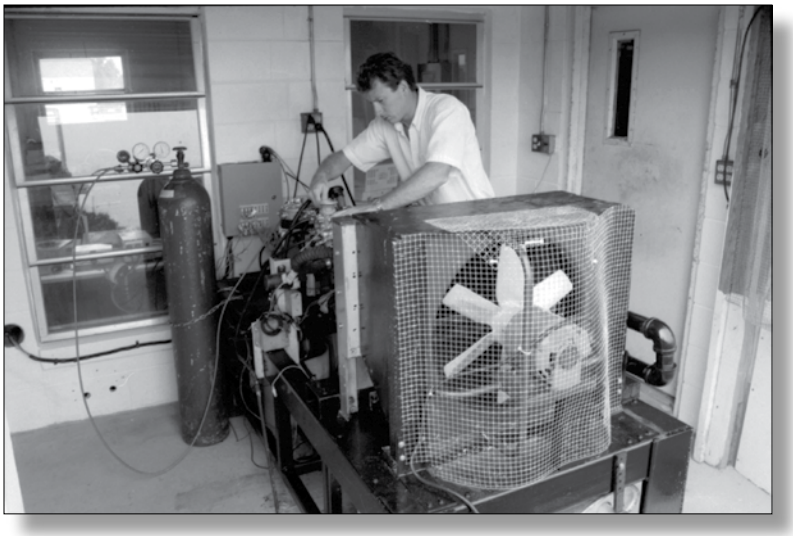
This work focused on a mixture of hydrogen-enriched natural gas that allowed for an extended "lean burn limit" and thus, lower engine emissions, without using a catalytic converter. In 1993, FSEC completed the first series of tests on a 30-percent-plus hydrogen-enriched methane mixture, which was used to run a 350-cubic-inch V8 engine. Results showed that nitrogen oxide emissions could be lowered by approximately 90 percent in comparison with a 1994 gasoline-powered car. FSEC named the hydrogen-methane mixture HYTEST™ (any hydrogen-methane fuel with hydrogen content greater than 20 percent). FSEC and UCF received a patent on the fuel. Paul Freen initiated this work, and FSEC's Doug

Hahn, Neal Mulligan and Kirk Collier, along with Bob Hoekstra of UCF, conducted the HYTEST activities. [Reference 126]

Following the engine tests, staff converted a Ford Ranger truck and Chrysler Minivan to operate on HYTEST. These tests showed HYTEST to be the cleanest practical automotive fuel known, producing fewer harmful emissions than even utility-grid-recharged electric vehicles. Additional tests showed that HYTEST increased automotive engine efficiency. [Reference 127] Staff demonstrated these vehicles at the National Hydrogen Association Conference in Washington, DC, in 1994.

In a public showcase event, a HYTEST-powered Ford Ranger pickup truck served as the pace lap vehicle of the August 1997 Goody's 500 NASCAR stock car race at the Bristol Motor Speedway in Tennessee. DOE sponsored the vehicle, and the event was witnessed by 130,000 spectators and millions of viewers on TNN television. [Reference 128]

In 1994, Ford Motor Company donated Horiba emissions testing equipment and a chassis dynamometer, valued at $750,000, to FSEC. Staff installed, configured and tested the emission equipment in FSEC's engine lab. When FSEC moved to its new facilities in 1995, the equipment was given to the UCF Engine Research Laboratory. The UCF College of Engineering designed this lab specifically to accommodate the equipment and to handle the safety and noise issues associated with research on alternative fuels. Robert Hoekstra has led this effort at UCF since 1995.



Doug Hahn at FSEC Engine Lab experiment (May 1991)

Kirk Collier and Neil Mulligan with hydrogen-powered ICE Crown Victoria owned by NASA (June 1994)

HYTEST Ford Ranger (February 1995)

HYTEST Ford Ranger refueling (February 1995)

Kristin Schwenke Photography

FSEC/UCF Ford Ranger used for pace lap at Bristol Motor Speedway in Tennessee (August 1997)

Energy lab relocated to UCF (December 1995)

Electric Vehicles

In addition to hydrogen-fueled transportation, the '90s also saw considerable research on electric vehicles. As part of this work, FSEC sponsored the SunDay Challenge. This alternative-energy road rally ran for many years from FSEC to EPCOT in Walt Disney World or to Universal Studios in Orlando. SunDay Challenge workshops and seminars educated the public and students on the design and operation of electric vehicles.

FSEC conducted five major research projects on electric vehicles during the '90s. These projects, managed by Bill Young, were supported by DARPA funding.

The initial project collected performance data on an electric vehicle operating in Florida's hot, humid environment and compared its performance with the same vehicle operating in the cold climate of Vermont. This work evaluated the performance of the heating and air-conditioning system, thermal battery box and other components. Results showed that a single vehicle design could successfully operate in both climatic regions. [Reference 129]

A second project evaluated performance of an energy-efficient electric-hybrid vehicle that integrated electric and engine generator technologies for a dual-use hybrid vehicle. Through this project, staff developed, constructed and field-tested a conventional pickup truck, a Chevy S-10, equipped with an electric drive and a natural gas engine for battery charging. [Reference 130]

Air-conditioning loads on electric vehicles are an important consideration. This project tested an electric bus air-conditioning unit in a two-cell laboratory environmental chamber. Staff varied temperature, humidity, airflow and compressor speeds to collect data on system operation of the air-conditioning unit according to ARI standards and determined coefficient of performance and energy efficiency ratings. The project was sponsored by DOE, the Southern Coalition for Advanced Transportation and the Florida Alliance for Clean Technologies. [Reference 131]

SunDay Challenge racers get the green flag from Congressman Dave Weldon (May 1996)

Performance of electric vehicles is another major consideration. This project field-tested electric vehicles with AC electric drives in military and commercial operations by gathering operational results for five buses used by the Miami Beach Transit Authority and two light-duty trucks for Patrick Air Force Base. [Reference 132]

The final electric vehicle project investigated efficient electric vehicle lighting. This project evaluated the use of light-emitting diode (LED) light fixtures in place of conventional incandescent bulbs. Results showed super-bright LEDs can replace incandescent bulbs to save energy on external lights such as turn signals, park, stop and clearance lights. [Reference 133]

These projects were all part of a five-year effort that ended in 1999. In addition to FSEC's electric vehicle work, Bill Young was also responsible for FSEC participation in the Clean Cities program for East Central Florida with help from Dianne Wood, Susan Schleith and Carolyn Burns.

The nine-county, clean city effort began in 1995 with the objective of promoting alternative-fuel vehicles and the appropriate infrastructure for their use. The Florida Space Coast Clean Cities Coalition is one of three coalitions covering the state and among many nationwide. DOE honored the Space Coast Clean Cities program as its 75th nationwide program in October 1999 with a visit to FSEC by DOE Assistant Secretary for Energy Efficiency and Renewable Energy Dan Reicher. [Reference 134]

Bill Young and William Wilson, hybrid vehicle research (May 1996)

Ivan Brace of Guatemala, Philip Fairey and Chris Rovero of Winrock International examine electric/hybrid vehicle (November 1998)

FSEC alternative-fuel vehicles (June 1999)

Pollutant Detoxification

Using technologies based on photocatalytic production of hydrogen led FSEC researchers to another technology spin-off area - photocatalytic destruction of airborne pollutants. The detoxification (detox) research began when Ali Raissi demonstrated methods to purify air contaminated with hazardous chemicals. He showed how ultraviolet light and semiconductors in a photocatalytic process could completely mineralize pollutants to the oxides of their constitute elements. The work also used a process patented by Nazim Muradov that immobilizes a semiconductor catalyst on any surface, while ensuring that the material remains active. [Reference 135] The detoxification application required additional chemical engineering reactor designs and resulted in eight U.S. patents. Ali Raissi led the detoxification work.

David Block, Dan Reicher (DOE Assistant Secretary) and Ken Sheinkopf at designation ceremony of Florida Space Coast Clean Cities Coalition as 75th member of the DOE program (October 1999)

The U.S. Navy, Army and Department of Defense have used this patented process to deal with toxic air pollutants (volatile organic compounds) emitted during various defense operations. The process was first applied in a facility located at the U.S. Naval Surface Warfare Center (NSWC), Indian Head, MD. Following bench-scale tests at FSEC, staff constructed a bench-scale prototype air-purification system and delivered it to the NSWC at Indian Head for testing. FSEC then fabricated and tested a larger-scale system that treated 50 standard cubic feet per minute (SCFM) of contaminated air. These tests resulted in design parameters for a full-scale photocatalytic air-purification system to be used for the U.S. Navy at NSWC. [Reference 136]

Trojan Technologies built the full-scale, 650-SCFM photoreactor that FSEC designed. The unit employed a unique reactor design and titanium-based photocatalytic cartridges activated by ultraviolet radiation from low-pressure mercury lamps. This photo-process featured a decoupled, single-pass flow feature, making it cost-effective and energy-efficient, while allowing for operation at low temperatures. The full-scale unit was completed in 1999 and delivered to the Indian Head facility, where it underwent testing. [Reference 137]

Through this $2 million, seven-year detoxification research project, FSEC researchers conceived, tested and produced a state-of-the-art photocatalytic air-pollution control technology that resulted in five patents for its unique photoreactor design concepts. Ali Raissi, Nazim Muradov and Eric Martin were the principal individuals involved in this effort.

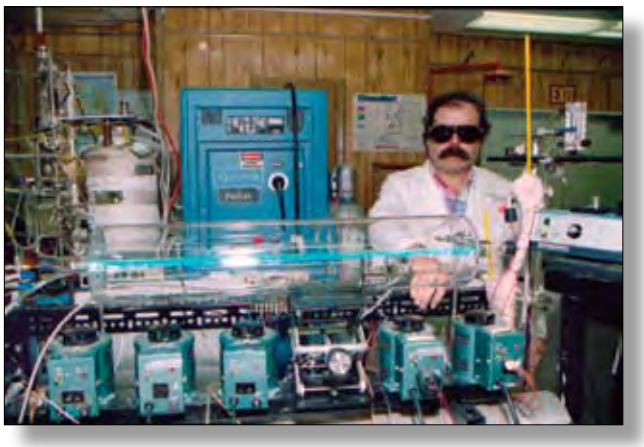
Ali Raissi and Nazim Muradov conducting detox tests (October 1997)

Ali Raissi testing FSEC detox unit testing (February 1996)

Steven Stiles (Navy), Nazim Muradov, Ali Raissi, Jeff Marquesee (ESTCP) and Chuck Painter (Navy) visit FSEC Detox Lab (July 1996)

Photo credit: Indian Head Naval Surface Warfare Center

Full-scale 650-SCFM detox reactor installed at Naval Surface Warfare Center, Indian Head, MD (October 1998)



Nazim Muradov operating detox experiment for U.S. Navy at Port Canaveral Lab (October 1994)

Eric Martin and Nazim Muradov with detox lab equipment (October 1998)

Clovis Linkous conducting algae growth inhibitor tests (April 1996)

FSEC detoxification research also included the following companion areas of research:

- *Extension of photocatalytic detoxification technology to control nuisance microorganisms such as algae growth on underwater surfaces. Clovis Linkous received a U.S. patent for this technology. [Reference 138]*
- *Technology for a photocatalytic face mask to be used for protecting personnel from airborne toxins. Ali Raissi, Nazim Muradov and Philip Fairey received a U.S. patent on this technology.*
- *Process for destroying toxic volatile toxins emitted from wall surfaces. Ali Raissi, Nazim Muradov, and Philip Fairey received a U.S. patent on this technology.*
- *Industrial waste treatment process that treats tail gases recovered from oil and gas refining to produce hydrogen. This treatment employs light photons and catalysts to decompose hydrogen sulfide into sulfur and hydrogen. Ali Raissi and Nazim Muradov received a U.S. patent for this process. [Reference 139]*

People of the Hydrogen Division

Chapter 7 recognized the four original members of the hydrogen program. These were Ali Raissi, Darlene Slattery, Clovis Linkous and Nazim Muradov, all of whom began work at FSEC within a couple of years of each other. During the mid '90s, two other individuals were added to the team.

Editor's Note: Without question, the creation, growth and vitality of FSEC's hydrogen research program are directly attributable to the interests of David Block. A former NASA engineer, Block's vision for hydrogen energy covers the entire range of economics, technologies and politics. As Center Director, he drove the development of FSEC's hydrogen program and its hydrogen activities. After retiring as Center Director, he began working full time in hydrogen research and as Program Director of FSEC's NASA hydrogen research grant.

Eric Martin (August 1999)

- *Eric Martin – Eric joined FSEC on April 18, 1997, after graduating with a degree in environmental engineering from the Florida Institute of Technology. Ali Raissi was his thesis advisor at FIT. Eric worked in the lab on both hydrogen and detoxification projects and has since moved to the Buildings Research Division.*

Becki Rubin (August 1999)

- *Becki Rubin – Becki transferred to FSEC from UCF Brevard on June 28, 1996. She initially worked in the Director's Office, but soon became the administrative assistant for the hydrogen group. Becki retired on September 30, 2003.*

Solar Thermal Programs - Testing and Operations Division

In the 1990s, the solar industry recovered from its '80s economic collapse and enjoyed a healthy growth trend. At FSEC, this growth resulted in an increasing number of requests for solar collector certifications and solar water heating information.

The number of agencies that support FSEC's work in the solar thermal area illustrates the diversity of the program efforts. These agencies include DOE, the Florida Energy Office, the New York State Energy Research and Development Authority (NYSERDA), Sandia National Laboratories, the Florida Department of Community Affairs (DCA) and the City of Tallahassee.

Mobil test tracker (January 1997)

The program covered all aspects of solar water heating and included work by all FSEC divisions. The Testing and Operations division conducted the primary activities, with the efforts being led by Jim Roland, Jim Huggins, John Harrison, Tim Merrigan, Carlos Colon, Steve Long and Tom Tiedemann.

The Solar Weatherization Assistance Program (SWAP) was the most visible solar thermal program in the '90s. FSEC, in partnership with the DCA and DOE, initiated the program and then coordinated installation of over 800 solar water heating systems on low-income residences throughout Florida. John Harrison spearheaded the SWAP program with help from Jim Huggins, Steve Long and Patrick Robinson.

For this program, staff members developed systems specifications, assisted DCA in developing administrative guidelines, and provided technical assistance and training to implement the program. In warm climates like Florida's, solar water heating is the application with greatest potential for energy savings in the weatherization program. By 1998, Florida solar companies, working through local weatherization assistance agencies, had installed more than 800 solar water heating systems on low-income housing units.

In addition to coordinating system installations, FSEC also field-monitored 33 of the 800 systems to validate their cost-effectiveness and compliance with national Weatherization Assistance Program guidelines. The monitoring showed that the systems saved clients an average of $140 per year. [Reference 140]

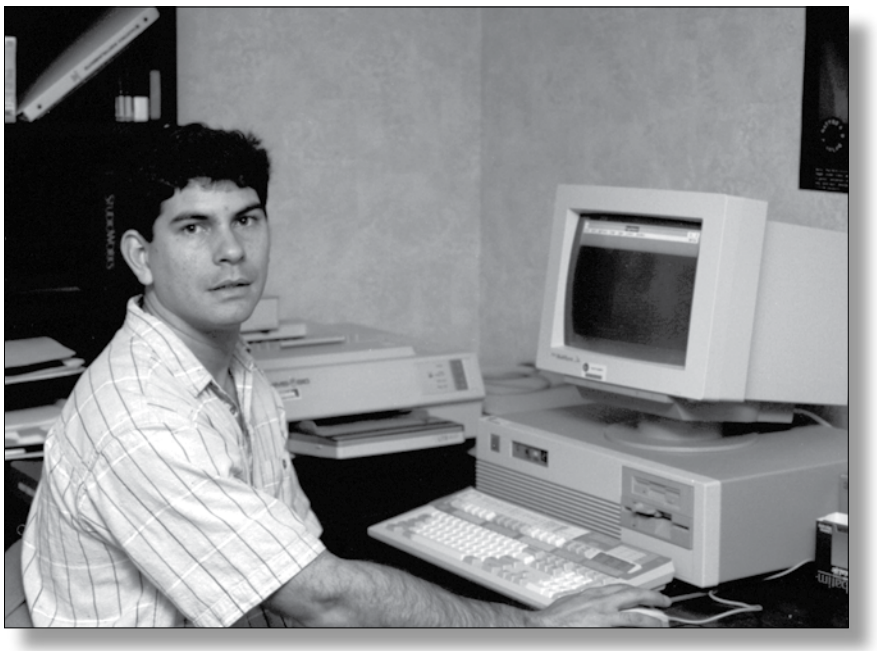
As a testimony to the SWAP program, Ms. Brenda Mobley, SWAP program manager of the Mid-Florida Community Services Agency, said, "Solar water systems don't just help with the energy bill, they also relieve other financial stress." Speaking of low-income clients in Hernando and Sumter Counties, Mobley said, "Several clients have made a point of telling me personally that the solar water heaters have cut their electric bill in half, and they have advised everyone to take advantage of this worthwhile program. The SWAP program has been very worthwhile in meeting Mid-Florida's primary mission of reducing the energy costs of low-income clients."

Based on its testing and certification activities, FSEC's solar water heating program continues to lead the nation and is now primed to become an international force. With the only solar water heater collector testing facility in operation in the U.S., FSEC received ISO certification in 1999. In1998, FSEC assumed additional national responsibilities, when the SRCC Board of Directors awarded it the contract to manage the national SRCC solar water heating certification program. This action coincided with FSEC's installation of the nation's only full-size solar thermal simulator in its High-Bay Lab, which gave the Center unmatched solar water heating research and testing capabilities. The work of Florida Energy Office officials Larry Roberson and Jim Tait is recognized for ensuring that FSEC would have these unique testing capabilities.

Patrick Robinson, Brenda Mobley and John Harrison at SWAP installation in Brooksville, FL (January 1998)

During the '90s, FSEC conducted other solar thermal research activities. They included an evaluation of the effect of the infrared portion of the solar spectrum on unglazed collectors, the effect of insulated solar collector glazings, and the development of a solar thermal systems testing laboratory and accompanying computer evaluation processes. Jim Huggins led these efforts.

In the same time frame, staff conducted solar water heating research for NYSERDA. This project analyzed 12 solar hot water systems installed in the service territories of Long Island Lighting Company, Consolidated Edison and Orange & Rockland Utilities. The project objective was to determine the time-of-day performance, cost-effectiveness and utility value of solar systems. Staff collected project data using a unique telephone-access monitoring methodology, and they compared the solar system results with electric resistance water heating. Tim Merrigan and Carlos Colon conducted the work. [Reference 141]



Carlos Colon (April 1990)

Another major solar water heating program involved design and implementation of a utility-based solar water heating program for Lakeland Electric. The utility was interested in a solar water heating program to generate revenue. Staff began FSEC involvement by installing four solar water heating systems and assisting with development of a business and operating plan for a 100-system pilot project.

The Lakeland project began in 1995 and continues today. After its initial development work, FSEC staff turned implementation over to Lakeland. As the work progressed into 2001, 29 installed systems were generating revenue for the utility. During the project's first year, an average for 27 homes showed the following solar hot water data per home:

- *Total energy used to heat water: 8.7 kWh/day*
- *Electric energy used: 3.4 kWh/day*
- *Net solar energy provided to heat water: 5.3 kWh/day (61 percent net solar fraction)*
- *Net solar fraction value at Lakeland rates ($0.0817/kWh): $158/year, or $13.17/month.*

The Florida Energy Office funded the project, which was initiated by Lakeland Utility's Bob Reedy and FSEC's Tim Merrigan. Both have since left their positions, and Carlos Colon remains FSEC's contact for the project. [Reference 142]

In the '90s, FSEC began the Manufacturing Support Initiative as an effort to help solar manufacturers. Its objective was to improve solar collector and system component performance, reduce manufacturing costs and simplify installations. This initiative resulted in FSEC oversight of the purchase of a fin-tube solar collector welding unit and the implementation of a solar collector manufacturing facility in Jacksonville. The Florida Energy Office supplied funds for purchase of the welding unit and the project was conducted by John Harrison. [Reference 143]

FSEC conducted three projects in the area of innovative solar water heating technology during the '90s. In the first, FSEC conducted a low-cost solar water heating design competition. Under the sponsorship of the Florida Energy Office, this project offered a reward to a Florida company that could manufacture and produce a low-cost solar water heating system. Don Kazimir of West Palm Beach won the competition with his design for a 20-square-foot collector that could easily be plumbed to an existing water tank and was offered at a retail price of $700. During installation of a prototype system on a house in Tallahassee, Governor Lawton Chiles visited the site and viewed the solar collector on the roof. The system never sold in large numbers because of the lack of funds to provide for the marketing. [Reference 144]

FSEC also conducted a similar project for the National Renewable Energy Laboratory, developing a low-cost, roof integrated solar hot water collector absorber designed to be used in the new-construction market. The concept proposed a low-cost polymeric solar absorber that would be installed under typical residential roofing surfaces. Following the initial design phase, FSEC staff demonstrated the second-year proof-of-concept in an 88-square-foot prototype at FSEC's auxiliary site. Tim Merrigan began the project, which Carlos Colon continued. [Reference 145]

In another project, staff monitored and evaluated a PV-powered water heating system for residential use. Invented by Hunter Fanney of the National Institute of Standards and Technology (NIST), the system used a 1-kW photovoltaic array operated by a patented controller to power a DC heating element in the water tank. FSEC operated and monitored the residential-sized system for three years. Jim Huggins led this NIST-funded effort. [Reference 146]

In the early '90s, FSEC assisted the Florida Department of Corrections in restoring to full operation a large solar water heating system at the Martin County Correctional Institution. Staff also monitored the system's performance. Jim Huggins and Tom Tiedemann conducted this project, which was sponsored by the Florida Department of Corrections. [Reference 147]

People of the Testing and Operations Division

Most people in the T&O Division are long-time employees who began their tenure in the 1980s. Jim Roland continued to lead the Division during the '90s and into 2003. This section presents T&O Division members hired during the '90s.

Myra Dunlop (August 1999)

- *Myra Dunlop – Myra began as a student assistant in the '80s and then returned in January 1996. She became a full-time employee on March 21, 1997. Myra is involved in testing of solar collectors and solar water heating systems.*

Suzette Garnett (August 1999)

- *Suzette Garnett – Suzette began work at FSEC in the Director's Office assisting with organization and conduct of the 1994 World Hydrogen Energy Conference in Cocoa Beach. After the conference, she concentrated her efforts in computer support and was officially hired as a computer support specialist on July 19, 1996. Suzette's work is critical to computer operations; she's on everyone's "call list" to resolve their computer issues.*

Richard Groh (August 1999)

- *Richard Groh – Rich joined FSEC on September 1, 1999, with extensive experience in computer system operations. His work keeps FSEC's computer operations at the highest level.*

- *Teresa Johnson – Along with Sue Blum, Teresa provides administrative support for the Division. She joined FSEC on June 28, 1996.*

Teresa Johnson (August 1999)

Steve McSorley (August 1999)

- *Steve McSorley – Steve joined FSEC on December 11, 1998, to work in the physical facilities area. He is well-known for his ability to produce video and audio recordings for a variety of events.*

Gary Montgomery (June 1996)

- *Gary Montgomery – Gary joined maintenance operations at FSEC on December 16, 1992, and continues in this capacity today.*

- *Lavonia Scott – Lavonia is also in the maintenance area and joined FSEC on September 4, 1998.*

Lavonia Scott (August 1999)

Mark Thornbloom (August 1999)

- *Mark Thornbloom – Mark began work at FSEC on March 3, 1993. He originally worked in the Advanced Technologies Division on solar cooling. Since 2001, he has conducted solar thermal testing. Mark is active in ASME and has spent time in Africa.*

Ernestine Richardson (September 1997)

- *Ernestine Richardson – Ernestine is in the maintenance area of T&O. She joined FSEC on December 13, 1996.*

Educational and Institutional Activities

FSEC's originating language includes a mandate for education and public information, which ensures the importance of these activities. For research to realize its full potential, the results must be communicated to potential users in the marketplace.

Educational Programs

FSEC educational programs train and inform architects, engineers, contractors, utility employees and others in state-of-the-art application of both renewable and energy-efficiency systems. The educational activities involve courses and workshops for practitioners.

Bill Nolan (PAB), Ingrid (Melody) Norberg and Subrato Chandra (December 1993)

PV workshop (October 1991)

A sampling of these educational activities includes the following:

- *Duct doctoring courses for building-related professionals*
- *Radon-resistant construction techniques for new home construction*
- *Solar water heating workshops for representatives of industry, municipalities, community groups and international organizations.*

FSEC also offers education and information services to commercial building design and engineering professionals. These services include development of a comprehensive energy-efficient equipment database, electronic bulletin board, biannual newsletter and evaluation of energy-efficiency applications in educational facilities. The educational facilities area includes training seminars for those involved in the educational facility design process. The activities of the early '90s were led by Ingrid (Melody) Norberg.

In 1995, FSEC instituted a Solar Energy Certificate Program. The program offered courses in photovoltaics and solar water heating. Attendees who completed 30 hours of course work within one year were awarded a certificate of completion by the University of Central Florida. More than 100 people attended the first courses and received the certificate.

During the '90s, FSEC also worked with NASA Glenn Research Center and Savannah State University to develop facilities and instructional models for energy-related course offerings to international audiences through both terrestrial and satellite-based distance education. This cooperative program resulted in a three-credit-hour course on photovoltaics offered online by Brevard Community College. Jerry Ventre led this effort, which included development of a new PV course manual, lab manual, student guide and other materials.

The project also included experiments involving the Advanced Communications Technology Satellite and ultra-small-aperture terminals by Carol Emrich. Carol used this research in her Ph.D. dissertation.

During 1996-97, FSEC expanded in the area of international training and education. With special support from UCF Provost Gary Whitehouse, FSEC created the international Renewable Energy Training and Education Center (RETEC) to set up a worldwide train-the-trainers program. Initial efforts focused on the Caribbean, Mexico, Brazil, and other countries in Central and South America. The program targeted the use of renewable energy for solar water heating at beach-side tourist hotels, village power systems for lighting, water pumping in remote locations and power to support economic development in areas such as food refrigeration, crop irrigation, livestock watering and ventilation for poultry.

FSEC's strategy was to train educators, government officials, industry members, utility representatives, non-governmental organizations and other decision-makers throughout these countries by inviting these key individuals to extensive training programs at FSEC. The training included presentations by FSEC staff and industry representatives, along with field trips to actual renewable energy installations. At an international training program

Robert Acosta (NASA Glenn), Carol Emrich and William Wilson at small-aperture, high frequency satellite experiment (1998)

International visitors shielding their eyes from solar simulator during solar training program (August 1998)

Planet Janitor house construction for SunDay (May 1992)

held at FSEC on May 16-27, 1999, more than 30 high-level individuals from a variety of Caribbean nations participated in a four-day workshop. A second phase of the activity involved in-country training and distance-learning programs, with actual design assistance and installation and maintenance guidelines to ensure that the systems work reliably. The training and education materials were translated into Spanish and Portugese. Ken Sheinkopf and Guy Betten led the RETEC effort.

The international educational programs also looked at other important markets for U.S. renewable energy technology, including Africa, the Pacific Rim and Eastern Europe. After four-years, RETEC was downscaled for lack of resources, although the need it targeted continues today.

K-12 Educational Activities

In 1991, the Planet Janitor™ made his debut on the pages of a coloring book designed for children in pre-K through grade five. With funding from the Florida Energy Office, the program introduced the Planet Janitor to Florida's science museums and nature centers. Carolyn Burns led the effort.

The 1990's East Central Florida Environmental Education Regional Service Project (EERS) integrated environmental education into all levels of public education. EERS made its mark in the Eco-Link newsletter, school site visits, a lending library and in-service workshops for teachers. In 1993, more than 700 teachers attended 30 workshops and four institutes coordinated by the project. FSEC project coordinators Susan Schleith and Cindy Stuebben and UCF faculty worked closely with other institutions – FIT, Seminole Nature Center and the school boards of the 10 counties – to present the EERS workshops. FSEC transferred the EERS project to UCF's College of Education in 1998 after funding became difficult to maintain.

But, FSEC did maintain one outgrowth of the EERS project – the Junior Solar Sprint, a venue for middle school students to design, build and race solar model cars. This popular activity now includes model hydrogen cars. Susan Schleith and Penny Hall are responsible for the Sprint's continuation and success.

Mary Huggins as Mother Earth at SunDay Open House (April 1993)

PV Junior Sprint car (June 1992)

Middle school students at Junior Solar Sprint race (November 1996)

In 1993, FSEC began plans for the move to the new facilities. As part of these plans, FSEC helped to form the Space Coast Science Education Alliance. Joining in this alliance were: the Astronaut Memorial Planetarium, Brevard Community College, the Brevard Museum of History and Science, the University of Central Florida, the Center for Space Education at Kennedy Space Center, The Astronauts Memorial Foundation, the Space Coast Science Center, Cocoa High School and Brevard County Public Schools. The alliance integrated a complex of museums, technological resources and science centers in Central Florida into a consortium, with the goal of enhancing student interest in science. Susan Schleith led this effort, with the assistance of Penny Hall.

Susan Schleith (September 1991)

- *Susan Schleith – Susan began work at FSEC in 1991 and was hired full time on January 23, 1993. Her first major program was the Environmental Educational Regional Services Project, which she has followed with a variety of educational programs.*

- *Penny Hall – Penny started working at FSEC on November 5, 1997. She assists Susan Schleith in the K-12 education efforts.*

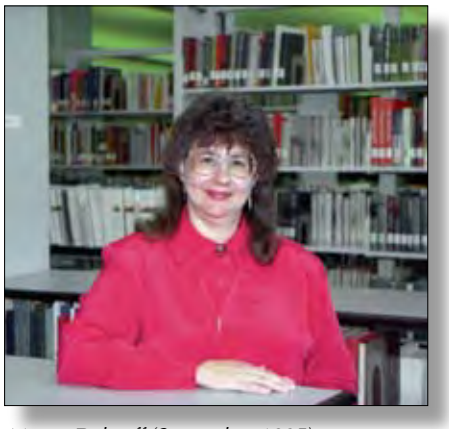
Penny Hall (October 2004)

Public Information

FSEC responds to thousands of consumer requests and hosts many public visits each year. The Public Information Office has mailed tens of thousands of consumer-friendly brochures, which cover a wide variety of energy-related topics.

The library is also an important part of FSEC technology transfer, education and public information activities. With nearly 10,000 books and journals, more than 14,000 documents, 56,000 reports on microfiche, and a substantial collection of slides, videos and films, FSEC boasts one of the largest solar energy holdings in the country. The library has steadily increased its access to information on hundreds of databases and its affiliation with electronic networks such as EPRINET, DIALOG, STN and LUIS. As mentioned in Chapter 7, the library efforts and program are a tribute to FSEC librarian, Yayi Rickling.

Two individuals are recognized for their work in the library during the '90s.



Myrna Dubroff (September 1995)

- *Myrna Dubroff – Myrna joined the library staff on April 19, 1993, as a Senior Library Technician and is still working in the library.*

Susan O'Hara (July 1991)

- *Susan O'Hara – Susan began work at FSEC on October 21, 1983, performing word-processing functions in the Director's Office. She transferred to the library in 1998.*

Other Educational Programs

In 1996, FSEC installed multimedia and interactive video equipment in two classrooms as well as the H. George Carrison Auditorium. These facilities are designed for flexibility and provide the capability for handling the most demanding applications in distance learning and video conferencing. Educational courses can be delivered via terrestrial networking (Integrated Services Digital Network or ISDN) to diverse and distant audiences representing industry, government and academia, both domestically and internationally. The facilities are user friendly and can accommodate a wide variety of teaching styles and instructional media.

In 1997, FSEC assisted Bethune-Cookman College in a $1 million minority-based energy education project that included faculty training, and curriculum and laboratory development. Florida Representative Alzo Reddick of Orlando initiated the program, which was funded through the Florida Energy Office. Ken Sheinkopf led the one-year effort to a successful conclusion.

In another PV education activity, FSEC conducted nationally recognized training programs for installers of rooftop photovoltaic systems. This program was linked with members of the National Joint Apprentice and Training Committee and was led by Jim Dunlop, Stephen Barkaszi, Donnie Metzger, Kevin Lynn, Brian Farhi, Jerry Ventre and Barbara Martin.

In 1999, FSEC organized, developed and coordinated the "Energy '99"conference in Orlando for DOE's Federal Energy Management Program. Ken Sheinkopf and JoAnn Stirling led this effort. FSEC has continued to host these conferences into the 2000s.

In 1995, FSEC moved onto the World Wide Web with the expansion of its Internet site. The FSEC home page – www.fsec.ucf.edu – has become a popular site for people seeking information on solar energy, renewable energy, energy efficiency and hydrogen. The FSEC Web site hosts hundreds of visitors each month who obtain a wide variety of information on the Center's programs and activities. Materials include press releases; abstracts of research reports and professional papers; summaries of research projects; and complete details on continuing education programs. Popular sections include a listing of available publications (with an order form), and separate sections for the Building Design Assistance Center and the Building Energy-Efficiency Rating System. The "Write to Us" section brings in more than 100 information requests each month from around the world, where questions are routed to appropriate FSEC staff for answers. During 1996, the FSEC home page received 1.3 million hits by 65,000 visitors from around the world.

Interactive Video Teaching Studio (June 1996)

Graphics

Graphics supports all the efforts of the Center, which relies on publishing to disseminate information and education. During the '90s, FSEC's graphics group moved into advanced computer technologies under the leadership of Sherri Shields. Shields came to FSEC from Johnson Controls on May 10, 1996. While working full-time at FSEC, she completed her MA in Instructional Technology from UCF in May 2002.

Sherri Shields (August 1999)

Shelli Keisling (August 1999)

Three very talented individuals, two graphic designers and one audio visual specialist, serve FSEC's graphic needs. The graphic designers are Anne Marie Anderson who joined FSEC on April 15, 1988 and Shelli Keisling who began work on August 5, 1996. Keisling is specially noted for her scanning of many of the hundreds of photos in this document and creating the layout design of the text and photos. This document is an excellent example of her outstanding graphic design abilities.

Anne Marie Anderson (August 1999)

Steven Spencer, former audio visual specialist, is also noted for his work on this document. Spencer, who was at FSEC from June 1994 to August 2003, began the job of collecting and assembling the many needed photos from the archives. Nicholas Waters is now FSEC's A/V specialist.

Steven Spencer (August 1999)