The 2000s: Era of the New and the Uncertain

Chapter 10

The era of the 2000s began with both hope and anguish. On January 1, 2000, some people wondered if the world might end with the beginning of the new millennium. Others worried if our interconnected world would survive a 1999 to 2000 computer programming glitch.

As we all know, the world did not end, and careful planning resulted in a smooth computer transition. The predicted catastrophes proved to be of no consequence.

Then came September 11, 2001 – the infamous day in history that changed the U.S. and the world forever.

Now we are five years into the 2000s, and the nation is fighting another war in Iraq. The price of oil has broken the $55-per-barrel mark for the first time in history. Consider that the cost per barrel was just $3 at the beginning of the energy crisis in 1973. Wow!

Uncertainty and turmoil have shifted federal priorities to homeland security and more defense spending. These shifts have also changed federal and state energy policy.

One significant, positive change occurred in January 2003, when, during his State of the Union address to Congress, President Bush cited the need for developing hydrogen as a fuel source for the U.S. Are we finally seeing recognition in Washington that the era of fossil fuels may be beginning to close? Hydrogen technologies had taken center stage at FSEC long before President Bush's comments. FSEC's hydrogen research program has led to new highs in funding and the addition of many new staff members.

Gasoline price (September 2002)

Gasoline price (March 2005)

During the 2000s, FSEC will mark a significant milestone – its 30-year anniversary. As the Center grows older, so do the personnel who built the original programs and who are now at or near retirement age. But, as the old era is rapidly closing, a new one is quickly unfolding.

The following pages highlight the technology programs of the 2000s.

Photovoltaics Program

The SERES and thin-film programs of the '90s continued to mature into the 2000s. Some notable PV program activities follow.

Florida Photovoltaic Buildings Program

The Florida Photovoltaic Buildings Program begun in the '90s continues in the new decade as a utility systems project. This collaborative project joins efforts by FSEC, the Florida Energy Office (which supplied the PV buy-down funding), Sandia National Laboratories, Florida municipal utilities and the photovoltaic industry. It places strong emphasis on increasing the value of rooftop PV systems and transferring the technology to nine target end-user groups. FSEC activities include efforts to develop markets, identify high-value applications, monitor performance, remove institutional and commercial barriers, compare costs and benefits, and disseminate information to stakeholders.

In 2003, FSEC received a $750,000 contract from the Florida Energy Office to conduct work similar to that of the PV buildings program. In this project, FSEC developed and administered an educational grant program called "SunSmart Schools." About $600,000 of the total funds provided rebates for photovoltaic systems installed on Florida schools. The program also provided teachers with hands-on professional development workshops, as well as standards-based educational tools. The program Web site, www.energywhiz.com, provides access to real-time PV performance data and curriculum-based games and activities.

Roof integrated PV on Florida Nature Conservancy, Kissimmee, FL (January 2000)

PV on New Smyrna Beach residence (January 2002)

The program resulted in installation of 29 new utility-interactive PV systems with a total rated capacity of 122.6 kilowatts. These installations are projected to provide total savings of at least $14,500 annually in avoided energy costs to the schools. Jennifer Szaro has directed both the PV Buildings and the SunSmart Schools programs.

In another PV buildings-related activity, FSEC was the principal contributor in forming critical new rules for standards to interconnect photovoltaic systems to Florida's utility grid. The new rules, promulgated by the Florida Public Service Commission, became effective February 11, 2002.

Photovoltaic Certification, Testing and Training Activities

In August 2001, FSEC began operating as an American Association for Laboratory Accreditation (A2LA) accredited laboratory for testing PV hardware in accordance with standards of ISO 17025. Additionally, in December 2001, FSEC received accreditation from PowerMark Corporation to certify PV module performance ratings, grid-tied PV systems and stand-alone PV systems. PowerMark is the sole U.S. agent for the PV Global Approval Program and the only organization that meets requirements for international reciprocity. FSEC is now the only U.S. laboratory with international authorization to test and certify such systems.

FSEC's PV practitioner training program is closely associated with standards and testing. In this area, FSEC's PV group has assumed national and international leadership in establishing standards for accrediting photovoltaic practitioner training programs by filling the international chair of the Accreditation Committee for the Institute for Sustainable Power (ISP). FSEC is also the only organization to be nationally accredited by ISP in all three categories – as a training institution, by offering continuing education programs and by being a master trainer. In addition, FSEC staff provided the primary input on the curriculum and test materials for PV installer certification programs provided by the North American Board of Certified Energy Practitioners.

PV at Dr. Phillips High School, Orlando, FL (April 2002)

PV workshop (March 2000)

Distributed Generation

In 2001, FSEC's PV program underwent an important expansion with initiation of the distributed generation program, begun as a partnership with Kinectrics, Inc., of Ontario, Canada, and the Western Solar Utilities Network. Titled Building-Integrated Distributed Power Systems: Test, Evaluation, Demonstration and Workforce Development, this partnership program began as a three-year, $1 million project funded by the U.S. Department of Energy. The primary goal of the project is to positively influence the sustained growth and commercialization of distributed power systems. Its tasks include:

- Monitoring the performance, reliability and cost of distributed power resources
- Conducting large-scale system reliability simulations and experiments
- Performing special experiments on integrating distributed resources into residential and commercial buildings and in combined heat and power applications
- Performing a needs assessment for workforce development.

The project also includes the task of constructing and operating a new 3,000-square-foot test facility that will be used for addressing the needs of manufacturers in product development; and of utilities for safety, equipment protection, power quality and grid network reliability.

FSEC's distributed generation test facility (March 2004)

FSEC and BCC began a three-year National Science Foundation-funded project in 2001 to develop and offer a program titled Distributed Energy Systems Curricula for Development of Energy Technicians. Funded for $363,000, the program's objectives are to:

- Increase the number of trained and certified technicians for distributed energy systems.
- Develop industry-based curricula and educational materials.
- Integrate the curricula and materials into existing trade and apprenticeship programs throughout the nation.

FSEC and BCC staff developed five course frameworks, which have been approved for community college instruction. Three courses – Introduction to Distributed Energy Technology, Distributed Electric Power Generation and Storage, and Energy-Efficient Buildings – have been offered at BCC.

In 2002, FSEC pursued a collaborative effort with the Uganda Ministry of Energy and Mineral Development to build and develop infrastructure to support a Ugandan rural electrification effort. One aspect of the venture involved development of an engineering curriculum in renewable energy and environmental technologies for Makerere University and for Ugandan technical colleges.

Buildings Research

The buildings research program sustained its robust growth into the 2000s. Diverse program activities focus on heating and air conditioning equipment, air distribution systems, insulation envelopes, efficient windows, daylighting, appliances and control systems. FSEC also has strong capabilities in diagnostic field testing, the development of user-friendly building energy analysis software, long-term performance monitoring and equipment testing in controlled laboratory facilities. The program consistently produces timely, applicable results, saving residential and commercial building owners in Florida and nationwide millions of dollars in energy costs.

Building Systems Research

FSEC's buildings systems research program continues as lead contractor for the U.S. Department of Energy's Building America Industrialized Housing Program (BAIHP). BAIHP's objective is to help the nation's manufactured home builders improve the energy efficiency of their products. In the 2000s, FSEC built a new manufactured home testing and training facility on the southwest area of the Center's campus.

The BAIHP also provides design assistance to many site builders, Habitat for Humanity International affiliates, Florida's first certified green-home custom builder and Camden Homes – one of the top 100 builders in the nation.

Among the BAIHP's accomplishments are:

- Certification of three Palm Harbor Homes factories (in Boaz, AL, Albemarle, NC, and LaGrange, GA) for production of Energy Star manufactured homes. With these certifications, the company now has nine certified Energy Star factories.
- Conversion of four Georgia-based Fleetwood factories to use of masticsealed air ducts. These conversions make a total of 40 factories where BAIHP has improved duct-sealing construction methods.
- Completion of BAIHP duct testing data analysis. The Model Energy Code committee used the testing data to require tighter ducts as a part of the new National Fire Protection Association Standard on Manufactured Housing (NFPA standard 501). If HUD accepts the new standard, it will improve duct construction throughout the nation's manufactured home industry.
- Providing technical assistance to site-built housing for WCI Communities, Inc. in Palm Beach Gardens and Venice, FL. This assistance resulted in construction of two highly energy-efficient homes that are expected to save 40 percent in whole-house energy bills. The BAIHP team also delivered technical assistance on the design and construction of four duplexes in North Dakota.

Manufactured Home Testing and Training Facility at FSEC (May 2003)

In another project, the buildings research team received funding to conduct national studies on energy efficiency as applied to K-12 schools. This research includes:

- A national energy survey
- An audit and retrofit project
- An energy-efficient portable classroom project
- Development of a training program for engineers, architects and school facility managers.

Other school-related activities include a project under contract to the National Association of State Energy Officials (NASEO). For this project, buildings staff conducted research and provided design specifications for construction of three prototype, relocatable classrooms. Performance enhancements should achieve 40-50 percent greater energy efficiency compared with standard classrooms. These prototypes are monitored in a side-by-side configuration with the standard model to provide comparison values in three climates around the country.

In an experimental project sponsored by Florida Power & Light Company, buildings researchers took field measurements on seven homes with differing roof configurations. The study's objective was to gain experimentally verified information to help homeowners choose the best color and type of roof for their homes. Results show that energy savings are most strongly influenced by the solar reflectance of roof materials. A white, galvanized metal roof saves the most energy, cutting cooling costs by 20 percent or more through high reflectance and superior ability to cool quickly at night.

Through a project for the Naval Surface Warfare Center at Dahlgren, VA, buildings staffers are developing an Immune Building Toolkit (IBTK) to be used for predicting indoor air quality in a building. The toolkit will enable military planners to predict the effectiveness of a variety of building protection systems for a given building configuration and contaminant release scenario. The IBTK will also give the military a method to design an effective protective system. In addition to developing the toolkit, FSEC staff will demonstrate and integrate developed software and provide training on its use. The software automatically extracts building data from the Industry Foundation Classes files and then uses this data for computer flow models that predict the airflow in a building configuration.

In March 2004, FSEC completed an $870,000 project funded by DOE through Oak Ridge National Lab. This project partnered FSEC as the lead institution with the Trane Company, the University of Illinois in Chicago and Airxchange, Co. (a desiccant wheel manufacturer). The project objective was to develop a manufactured prototype of a combined desiccant-air-conditioning machine that can enhance and control the amount of moisture removed from the air on a real-time basis without an operational performance penalty. This technology, invented and patented by Charlie Cromer, allows the building operator to set the desired space temperature (thermostat) and humidity (humidistat) with the equipment automatically maintaining the set-point conditions without reheat. The project resulted in a new line of equipment trademarked by Trane as CDQ™ (cool, dry, quiet), released in fall 2004. The new line of equipment could have significant applications in high-humidity climates such as in the southeast U.S.

The concept of "green" buildings has spread through the nation's energy-efficient buildings community. FSEC Buildings Research Division Director Rob Vieira was instrumental in organizing the Florida Green Building Coalition in 2000. The Coalition continues to be a very active group.

FSEC researcher Eric Martin developed another green buildings activity – *Creating a Green and Profitable Work Environment* – with funding from the Florida Department of Environmental Protection. This informative guide gives practices for cleaning and maintenance that result in efficient, productive and healthy operation of commercial buildings in Florida.

Florida's first certified "Green Home" called the DREAM Home, Clermont, FL (November 2001)

Innovative Fan Blade Inventions

FSEC researcher Danny Parker developed and patented the innovative, energy-efficient Gossamer Wind ceiling fan in 1999. His innovative fan blade design results in 40 percent more airflow at the same motor input power. The superior aerodynamic design can save $10 per year in reduced energy use, and a new light kit with a dimming fluorescent light saves consumers another $100 over the life of the fan. The fan far exceeded sales expectations by Home Depot, which sold more than 200,000 units during 2001, its first year on the shelves. It has sold more than half a million units in slightly more than two years. The invention is UCF's most financially productive invention to date.

Gossamer Wind ceiling fan (July 2000)

In 2003, Parker received another fan blade patent covering the design of efficient, quieter air-conditioner condenser fans. This fan blade design applies the innovative Gossamer Wind fan concept to air conditioner condenser units.

Building Code Activities

When the new Florida Building Code officially went into effect in 2002, it incorporated many energy changes based on FSEC research and input. Among the FSEC-inspired changes:

- A credit for using certified testers to verify leak-free ducts
- A credit for use of white metal and tile roofs
- A requirement for providing adequate return airflow from bedrooms
- Incorporation of changes in window default R-values.

FSEC also produced new EnergyGauge software used by Florida designers, contractors and energy raters in compliance with the new energy codes for residential and commercial buildings. All these changes led to improved energy efficiency in Florida residences and commercial buildings.

FSEC buildings staff also added new modeling capabilities to the U.S. DOE's EnergyPlus building energy simulation program, version 1.2.0, released in April 2004. The FSEC-modified features include models for:

- Moisture adsorption-desorption
- Air distribution systems
- Air-to-air heat exchanges to recover energy from exhaust air or preconditioned air.

In another national code activity, FSEC building researchers served as principal authors for the performance-based compliance method to be used by DOE in its proposed revision to the International Energy Conservation Code (IECC). The IECC is the nation's standard model building energy code, and FSEC's work became Section 400 of the 2004 Supplement. The FSEC code work brings the international code into closer alignment with Florida's Building Code and with national rating systems used by the secondary mortgage market to underwrite energy-efficient mortgage programs offered by Fannie Mae and Freddie Mac.

Buildings Educational Activities

The Buildings Division educational activities continue to be an important knowledge resource for building professionals. These activities include a new quarterly newsletter for building professionals.

As part of a four-member collaborative, FSEC researchers won the first solicitation of the State Technologies Advanced Collaborative. For this project, building staff received $270,000 to conduct training on efficient HVAC system design for residential homes in hot, humid climates.

With funding from the Florida Energy Office, FSEC conducted three energy educational programs for students and teachers. In one, buildings staffers developed and offered a new five-course training series called Designing the Failure-proof Building. The Florida Department of Education extensively promoted these courses, which comprised more than 5,096 student hours of instruction.

Second, FSEC staff developed a high school science unit called Building Performance Matters to increase student awareness of the comfort and energy savings benefits of energy-efficient building technologies. The Web-based, nine-lesson unit consists of two primary sections: background information and concepts, and a school lighting audit. These inquiry-based activities, which align with the National Science Standards, include online pre-tests and post-tests, teacher preparation materials and student worksheets. Five Florida teachers pilot-tested the unit for content, ease of use and effectiveness.

Third, FSEC developed a Utility Report Card system for schools through a cooperative effort with the Florida Energy Office, Orange County Schools and Walt Disney World Co. The online system allows science teachers, facility managers and school board members to compare a school's utility use over time and between schools (see **www.utilityreportcards.com/**). A visit to an Orange County school by U.S. DOE Secretary Spencer Abraham in April 2004 highlighted the project, which then spurred interest from school districts throughout the nation.

Hydrogen Research

FSEC hydrogen research activities for both the U.S. Department of Energy and NASA make hydrogen a vital FSEC program for the 2000s.

The NASA Hydrogen Research Program

On April 1, 2002, FSEC began work on launch and space-related hydrogen applications when it was awarded $5.425 million to conduct hydrogen research for NASA as part of a coordinated statewide research grant. One third of the total $8.1 million grant went to the University of Florida. FSEC's share includes the following university partners: Florida International University, Florida State University, the University of Central Florida, the University of South Florida and the University of West Florida.

This hydrogen research program supports NASA's space activities and Kennedy Space Center's launch program. The research is important to Florida not only because hydrogen is the fuel of space vehicles, but also because it creates a partnership role for Florida's high-tech and alternative fuel development initiatives. While no one knows exactly what future ground transportation and space vehicles will ultimately look like, one thing is certain: they will be fueled by hydrogen – the fuel of the future.

NASA's Glenn Research Center (GRC) and Kennedy Space Center (KSC) co-managed the initial 18-month grant effort. Following the first NASA grant, FSEC received a second, 18-month $4.9 million grant from GRC on June 30, 2003, out of a total grant of $7.5 million. The Center received a third-year grant of $4.85 million from GRC on September 10, 2004, out of a total grant of $8.0 million. The third-year funding supports another 12-month effort by FSEC and the participating universities.

The NASA-supported Hydrogen Research at Florida Universities grant encompasses seven program areas: densified propellant technology; safety and monitoring systems; hydrogen storage for spaceport and space vehicle applications; local hydrogen

NASA shuttle launch, Atlantis STS106 (September 2000)

production, transport and recovery; new propellants and cyrofuels; in-space cryogenic fluid management technologies; and education and outreach. In 2004, hydrogen-powered aeropropulsion and fuel cells were added as a new program area.

In a news release upon receiving the grant, FSEC Director Emeritus David Block said: "This research grant marks the beginning of a major cooperative research effort amongst Florida's state universities in a program to contribute their combined expertise to the benefit of both NASA's space launch future and Florida's economy." Block also commented: "The Solar Center has been conducting hydrogen research since the early 1980s, and now we have the opportunity to turn this research into a very significant new program activity. Hydrogen is the transportation fuel of the future, and the Solar Center and the state's universities are now poised to be world-class leaders in that future."

These NASA grants resulted from a state university system project developed at FSEC by David Block and Ali Raissi. University System Federal Relations Coordinator Jim Pirius and UCF Director of Federal Relations Greg Schuckman coordinated the project in Washington.

One major area of NASA hydrogen research involves local production and liquefaction of hydrogen at or near KSC. Each Shuttle launch requires that 45 semitrailer loads of liquid hydrogen be shipped from New Orleans to KSC (a distance of 670 miles) and that 70 semitrailer loads of liquid oxygen be shipped from Mims, FL, to KSC (a distance of 15 miles). This transport scheme not only adds significantly to launch costs, but it also impedes rigorous launch schedules. The research addresses the flexibility of using local and cost-effective methods for producing both hydrogen and oxygen for use and storage at KSC. Related activities focus on development of better cryogenic storage processes and media, recovery of helium, and improved sensors and safety.

The NASA grant incorporates 43 separate projects that have produced significant results. Some notable FSEC projects follow.

Air Products and Chemicals, Inc.

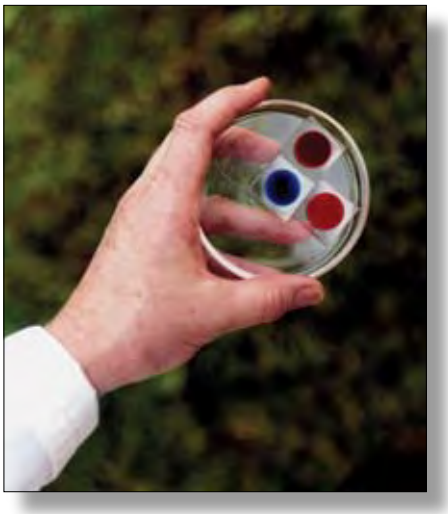
Air Products LH2 tanker with Shuttle Atlantis (January 2002)

Production Technology Projects

Every year, Florida generates more than 45 million gallons of waste lubricating oil, which is costly to dispose of in an environmentally protective manner. FSEC researchers have developed a new process that uses the waste oil to generate hydrogen at a cost of less than 40 cents per kg. NASA now pays more than $4.50 per kg for liquid hydrogen, which is made by steam reformation of natural gas. This new hydrogen production process, based on super-critical steam reformation of used automotive oils, can produce hydrogen from a locally available waste resource at extremely low prices. Analysis shows Florida produced enough waste oil to supply hydrogen for 100 Shuttle launches per year. Ali Raissi developed the process, and Karthik Kallupalayam is conducting the experimental work.

One of FSEC's long-term production research programs involves development of a thermocatalytic process to convert natural gas to hydrogen and produce high-value carbon fibers with little or no emission of greenhouse gases. For the NASA work, Nazim Muradov evaluated the use of local renewable resources such as landfill gas and biomass.

Additional research focuses on solar-driven hydrogen production technologies with significant promise. Both approaches extract hydrogen and oxygen from water by photoelectrochemical means. One approach, led by Clovis Linkous, uses organic pigments for the semiconductor material in a dual-bed process – one bed to produce hydrogen and the other bed for oxygen. The other approach, led by Neelkenth Dhere, uses multiple band-gap thin-film PV cells and a thin-film photocatalyst to obtain the over-voltage required to split water into hydrogen and oxygen.



Photoelectrochemical pigment samples (August 2001)

Nazim Muradov and thermal catalytic hydrogen production experiments (August 2001)

Karthik Kallupalayam conducting experiment on use of waste oil to produce hydrogen. (July 2004)

Yet another production technology uses solar-driven thermochemical cycles to split water. This concept uses a high-flux, high-temperature solar heat source and thermochemical water splitting cycles. Using Aspen Technologies' chemical process simulators, FSEC researchers evaluated numerous thermochemical cycles for process efficiency and cost. Another, similar thermochemical cycle process uses sub-quality natural gas as the feedstock. Ali Raissi and Cunping Huang are conducting the work, which has been supported by both NASA and DOE.

Systems analysis work in the production area aims at identifying and characterizing candidate technologies and systems for liquid hydrogen production at KSC. Total system analysis will cover producing local hydrogen, liquefying it and then storing for eventual application. Production technologies under analysis include renewable-based systems, as well as more-traditional technologies, such as steam reformation of natural gas. Conceptual system designs and economics are evaluated using the AspenPlus chemical process simulation platform.

Visit of FSEC hydrogen staff to Pad B liquid hydrogen storage tank at Kennedy Space Center (March 2003)

Storage Technologies

One storage research project evaluates new insulating systems and the hydrogen losses through detailed computational fluid dynamics modeling of the liquid hydrogen storage tanks at KSC's Pads A and B. Over time, KSC engineers determined that the Pad B tank loses approximately twice the amount of hydrogen as the Pad A tank. These losses cost KSC $280,000 per year from the Pad B tank, as compared with $125,000 from the Pad A tank. To understand and solve this problem, FSEC's Lixing Gu is conducting three-dimensional heat transfer calculations using the FLUENT computational fluid mechanics program and comparing the computational results with nighttime infrared pictures of the Pad B tank that reveal the cold spots. In addition, KSC engineers are considering refurbishment of the Pad B tank and require a near-term decision on the type of insulation to use. To assist in the process, Lixing Gu and Gary Bokerman have been evaluating soft vacuum insulation properties of perlite, glass microspheres and silica aerogels.

Another area of storage research focuses on the use of amine borane complexes, which have the potential to serve as high-density hydrogen storage compounds. Ali Raissi and Nahid Mohajeri are identifying synthesis routes for cost-effective hydrogenation of borazine to borazane, including regeneration of the compounds after use. They are also conducting laboratory tests using advanced computational techniques to assess the high-density storage potential of ammonia coordination complexes, such as alkaline earth metal halides for reversible ammonia (hydrogen) storage. They are interested in compounds capable of large amounts of ammonia uptake comparable to the weight of the absorbing salt, and vapor pressures compatible with the requirements of fuel cell systems.

Darlene Slattery is conducting research on storage using complex hydrides. These hydrides have the potential of storing greater than seven weight percent of hydrogen at temperatures compatible with the waste heat produced by proton exchange membrane fuel cells being developed for automotive applications. In a recent breakthrough, Slattery discovered a previously unknown catalyst that facilitates reversibility of certain complex hydrides.

In another hydrogen storage project, Clovis Linkous focuses on the use of lithium borohydride. This project aims at developing a crosscutting technology for solid-state storage with potential application in NASA's hydrogen fuel storage and delivery infrastructure, as well as for on-board fuel cell vehicular applications. Linkous' objectives are to develop, construct and demonstrate a prototype system for purification and storage by developing the chemical steps necessary to demonstrate a cyclical hydrogen storage system. He has discovered and submitted patent applications for catalysts that can control the rate of hydrogen delivery.

The NASA project also initiated Jong Baik's work in the area of cryogenic liquids and processes. NASA is principally interested in technologies that provide for the densification (sub-cooling) of cryogenic propellants and for the propellant's transfer, storage and mass gauging. Improving the density of hydrogen by eight percent and oxygen by 10 percent can increase payload by reducing gross lift-off weight of a launch vehicle system by up to 20 percent, saving millions of dollars per launch. Baik's objective is to develop second-generation densification systems to increase the fluid density of the cryogenic liquids. The work includes an engineering study to assess land-based zero-boil-off systems using advanced and innovative design concepts.

In another project, Baik has designed and constructed an experimental liquefaction and storage test facility for conducting experiments on densification, storage, pressurization and boil-off loss. It incorporates a 150-liter-capacity storage tank capable of refrigerating and storing liquid hydrogen to temperatures near 15K with a commercial GM cryocooler integrated into the storage tank. Integrating the refrigeration source into the Dewar allows advanced handling techniques such as zero-boil-off storage, densification, liquefaction, pressure control and recovery of chill-down losses. Preliminary experiments using liquid nitrogen will be followed by experiments using hydrogen.

Cryogenic experimental test bed (March 2004)

Other NASA Projects

One aspect of FSEC research is to produce gaseous hydrogen locally from biomass and other indigenous resources. While hydrogen produced from these sources will contain impurities, NASA's on-board fuel cells require extremely pure hydrogen. FSEC's Darlene Slattery and Mike Hampton of UCF have a research objective of identifying hydrides capable of separating hydrogen from the contaminated product stream.

Hydrogen is invisible and odorless, so leaks cannot be easily detected in hydrogen fuel lines, flanges and joints at KSC. FSEC's Ali Raissi, Nahid Mohajeri and Gary Bokerman have developed and submitted a patent application for a "smart paint" to visually identify very small hydrogen leaks. The paint, which can be directly applied to surfaces, changes color in the presence of hydrogen.

Production of Hydrogen by Thermochemical Water-Splitting Cycles

In October 2004, Nazim Muradov and Ali Raissi were awarded a competitively procured project from DOE for slightly under $4 million to conduct research on the production of hydrogen by thermochemical water-splitting cycles. This project is one where FSEC, in partnership with Science Applications International Corporation (SAIC) of San Diego, CA, and the Universidad del Turabo (UT) of San Juan, PR, will conduct a multi-year program of research and development leading to the demonstration of a cost-effective water-splitting cycle for hydrogen production using high-flux solar concentrators. Past research in solar thermochemical cycles has focused on two-step processes involving metal oxides that utilize only the thermal component of the solar spectrum. The FSEC-SAIC-UT team will develop and demonstrate a hydrogen production technique that splits water by a solar high-temperature process with "quantum boost" from solar photons to stimulate the chemical reactions.

The Project involves three phases. In Phase 1, FSEC will assess the state of the technology for solar thermochemical hydrogen production based on high-temperature water-splitting cycles. SAIC will work with FSEC to develop a preliminary design of the pilot-scale solar reactor and solar concentrator and to perform economic analysis. The result of the Phase 1 work will be identification of one or two promising cycles and/or processes and a receiver, reactor and concentrator concept. Gas separation and purification issues will be addressed by the researchers at UT. In Phase 2, the SAIC-FSEC team will develop a thermochemical reactor-solar receiver system for use with the selected cycle, test a bench-scale system, and develop a pilot-scale unit using an SAIC dish concentrator. The Phase 3 work will involve the installation and demonstration of a 50-kW solar-powered hydrogen production unit in Tempe, AZ.

Florida Hydrogen Initiative

Following President Bush's State of the Union Address in January 2003, Congressman Dave Weldon asked FSEC to help lead Florida's participation in the nation's new $1.7 billion hydrogen initiative. With the Congressman's support, FSEC formed the Florida Hydrogen Partnership among universities, industry, government agencies and other organizations on the Space Coast and throughout the state. With these partners, FSEC drafted and submitted a funding request that resulted in a $2 million U.S. DOE appropriation. With the appropriation, the partnership was renamed the Florida Hydrogen Initiative, Inc., and began the process of requesting proposals.

Other Hydrogen Activities

In the early 2000s, FSEC completed many DOE projects begun in the 1990s. With the addition of the NASA project, FSEC's hydrogen research staff began to leverage space-related research activities with opportunities for research and development on terrestrial hydrogen applications. In 2003, FSEC submitted a Hydrogen Center of Excellence proposal that placed fifth in the Governor's Emerging Technology Commission Initiative. Since beginning their NASA efforts in 2002, hydrogen staff members have submitted more than 40 proposals, for a combined value of over $30 million to conduct additional hydrogen research.

In conjunction with the NASA hydrogen activities, the hydrogen staff has also developed a new hydrogen Web site. The site at **http://hydrogenresearch.org** presents an extensive amount of hydrogen-related information.

Finally, as a part of the NASA work and with funding from DOE through the University of South Florida, Clovis Linkous has expanded FSEC's hydrogen efforts to work on high-temperature fuel-cell membranes for airplanes and vehicular applications.

Hydrogen Summit Meeting

FSEC organized the Hydrogen Summit Meeting, held October 24 and 25, 2000, in Tallahassee. Opening presentations by Florida Lt. Governor Frank Brogan, the Honorable Tom Feeney and Department of Community Affairs Secretary Steven Seibert emphasized Florida's commitment to

- Maintaining its position as the nation's spaceport
- Solving the state's increasing transportation problems
- Meeting its energy commitments.

The summit resulted in a Hydrogen Plan for Florida that creates a national hydrogen center of excellence and uses Florida's expertise and high-technology base to develop a new, expanded hydrogen industry.

Solar Thermal Program

The long-term goal of FSEC's solar thermal program is to provide consumer confidence in solar equipment, design assistance to manufacturers, and training to solar practitioners. The program also offers solar program development and technical assistance to other states, energy agencies and international organizations.

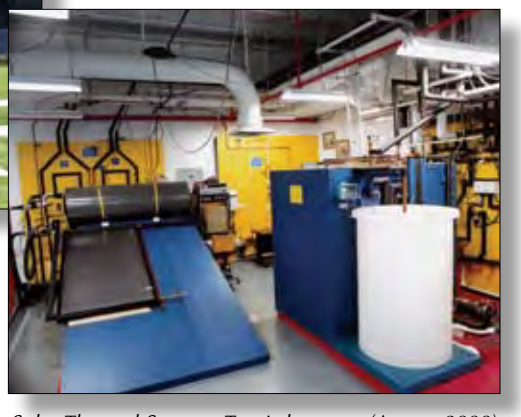
Testing and Certification Program

FSEC continues its long-term testing and certification program, which tests and certifies solar equipment for performance and durability as required by Florida statute. During a typical year, FSEC tests and/or certifies more than two dozen new solar systems and collectors. In partnership with the solar industry, staff members also conduct tests that result in design improvements.

In 2004, FSEC initiated an update of standards by which solar thermal systems are tested and certified in Florida. The changes would align FSEC's requirements and test methods with international standards, which, in turn, would allow Florida's solar industries to be more competitive in the international market. The standards update began with a detailed evaluation of existing solar thermal collector and system standards, which resulted in revised FSEC standards. FSEC then disseminated the new standards to interested external parties and industry for comment. Following comment evaluations, FSEC will apply for a rule change and final adoption of the new standards.

The FSEC solar thermal test laboratory received ISO accreditation in 2001 and re-accreditation in 2004. This important recognition means the testing laboratory is accredited to ISO 17025 and operates in accordance with ISO 9000. The International Association of Plumbing and Mechanical Officials also accredited the laboratory.

Solar collector being tested on mobile test platform (March 2000)



Solar Thermal Systems Test Laboratory (August 2000)

FSEC continues to operate and manage the national Solar Rating and Certification Corporation, which rates and certifies solar equipment nationwide. FSEC has filled this role for 12 years through contracts from the DOE.

Many organizations use FSEC's solar thermal expertise to develop educational and testing programs. Some notable activities include development of:

- A task analysis for use in a solar water heating installer certification program for the North American Board of Certified Energy Practitioners
- Solar thermal testing programs and laboratories for Taiwan, Botswana, Mexico, Lebanon, Syria, Jordan and Palestine, and for Pennsylvania, Mississippi and New York
- A solar cooker for undeveloped countries and international refugee camps
- Solar thermal training programs for government officials from India's Ministry of Energy, the American University of Beirut, the Delaware Energy Office and a contingent of professors from the Middle East.

Solar Weatherization Assistance Program

In 2004, FSEC inspected 200 systems installed 10 years earlier under the Florida Energy Office's Solar Weatherization Assistance Program. The inspections showed that the majority of the inspected systems were in working order, and the clients were quite satisfied with their systems. The inspections also revealed items to be considered in any future programs.

FSEC is currently working on a new program to install solar water heating systems on low-income residences throughout Florida's Front Porch communities. The program is a partnership among FSEC, the Florida Solar Energy Research and Education Foundation and the Florida Energy Office.

Educational Programs and Public Affairs Activities

FSEC continues important programs to inform the public and to train energy professionals. Continuing education programs have encompassed all of FSEC's technology areas. Another important component of FSEC's education program has been the development and implementation of K-12 science curricula for public schools, professional development opportunities for teachers and the coordination of the long-standing Junior Sprint car race every spring. The science curriculum is based on science and hydrogen energy principles and aligns with national teaching and learning standards.

The Hydrogen Sprint is a new program for high school students and is a natural progression for those graduates of the Junior Solar Sprint program.

Other program highlights are:

Federal Energy Management Program Annual Conferences

For six consecutive years, DOE has contracted FSEC to plan and handle logistics for the Federal Energy Management Program's annual conferences. The conferences have been held in Rochester, NY (2004); Orlando, FL (2003); Palm Springs, CA (2002), Kansas City, MO (2001), Pittsburgh, PA (2000) and Orlando, FL (1999). The conferences provide energy managers with the latest strategies and case studies on ways to save energy in commercial buildings. Speakers include high-level government officials and experienced energy managers. From 800 to more than 1,500 people attended these highly successful conferences, which have been conducted by Ken Sheinkopf and JoAnn Stirling.

Hydrogen Technology Learning Center

The division received funding in 2004 from the U.S. Department of Energy to direct FSEC's new Hydrogen Technology Learning Center. For this project, staff will coordinate FSEC activities, as well as the work being done by three other centers in California and New York. FSEC tasks include setting up a detailed database of community college and university programs and courses on hydrogen and fuel cells, compiling information on available displays and educational materials, and establishing a physical center with programs and activities for educators and students. This activity is being led by Ken Sheinkopf and Adrienne Henzmann.

Solar World Congress

Another major educational activity is FSEC's role as a co-sponsor of the Solar World Congress to be held in Orlando in August 2005. This is the biannual conference of the International Solar Energy Society and the annual conference of the American Solar Energy Society. More than 2,000 people are expected to attend the week-long event. Ken Sheinkopf is the conference chair.

Public Affairs Activities

Each year FSEC's public education and outreach program responds to more than 1,200 requests for information received through calls, e-mails and letters. In addition, the program distributes monthly news releases on FSEC programs and activities to state and national media. In its 19th consecutive year, the program also distributes a nationally syndicated weekly energy column to 130 newspapers around the country.

FSEC's extensive Web site, **www.fsec.ucf.edu,** informs the public on Center activities and provides helpful advice. This site currently receives approximately 70,000 visits and one million hits per month. Most FSEC fact sheets and energy notes are posted on the site to facilitate distribution, and course manuals are being scanned for Web distribution. A Question and Answer feature is updated weekly with new information.

Public Affairs staff play major roles in the Canaveral Council of Technical Societies and the 38th, 39th and 40th Space Congresses. Staff members serve as Web master, public relations director and activity advisor.