FESC Research, Education and Outreach Project Progress Reports

(Attachement to Main Report)

November 1, 2012

FAMU and FAU Reports

FESC
Florida Energy Systems Consortium

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Florida Agricultural and Mechanical University

Fusion Energy Spheromak Turbulent Plasma Experiment-STPX

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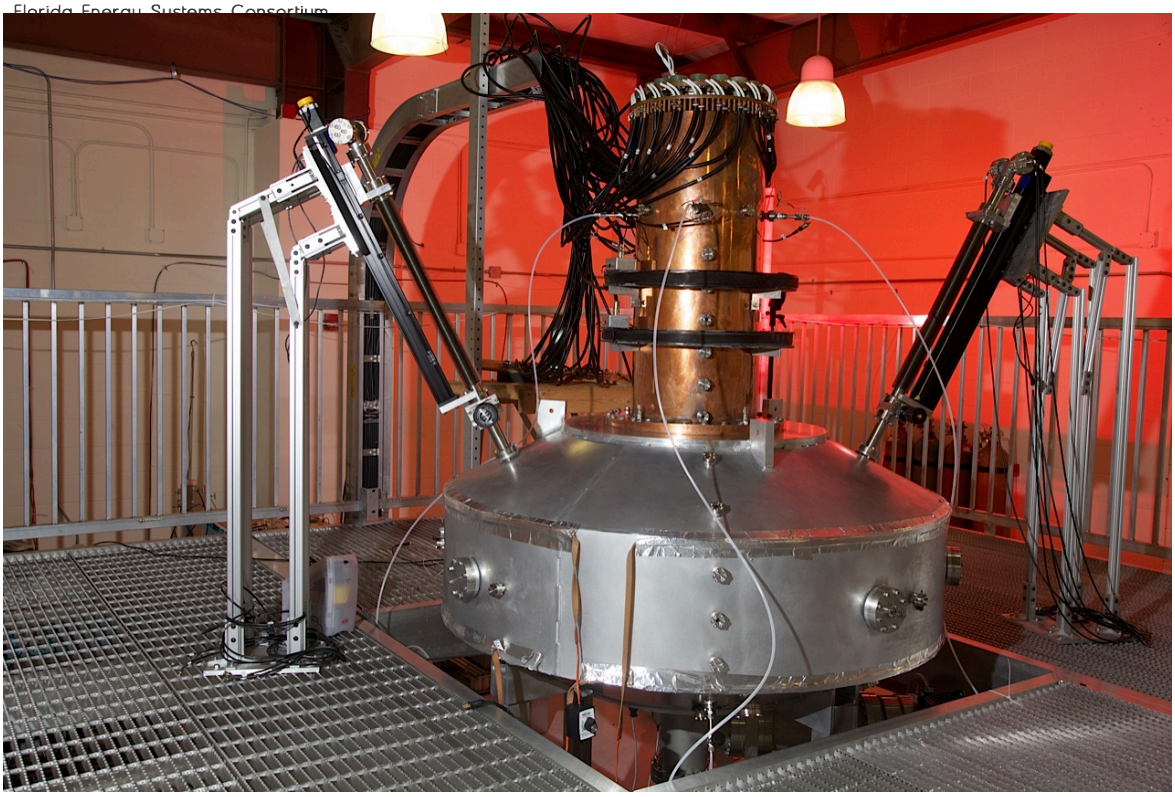
Students: Alonzo Brandon Alexander (M.S.), Yoseph Abere (Ph.D.), John Branch (Ph.D.), Staci Brown (Ph.D.), Daniel Gebremedhin (Ph.D.), Patrice Jackson (Ph.D.), James Titus (Ph.D.), Mr. Kevin Jones (B.S.), Alexander Schroeder (B.S.), Marquita Scott (B.S.), Kalisa Villafana (B.S.)

Description: The Florida A&M University's Center for Plasma Science and Technology (CePaST) has nearly completed the construction of a spheromak fusion reactor. A spheromak is one of a general class of experiments used to investigate key plasma physics principles relevant for the development of magnetically confined, controlled thermonuclear fusion as a source of electrical power. This project involves collaboration between Florida A&M University CePaST, West Virginia University, and Auburn University. The spheromak turbulent plasma physics experiment (STPX) is being constructed at FAMU in a facility especially built for the STPX experiment. Fusion research is a key element in the nation's long term energy supply strategy. The spheromak concept may be a possible alternative to the tokamak concept (deployed at ITER) which affords access to fundamental fusion science issues supportive of fusion while allowing us to maintain and nurture an American fusion scientific workforce. This project will determine, using a fast duty cycle between theory, experiment, and simulation, the essential elements required for full kinetic modeling of an entire spheromak plasma using *ab initio* MHD with direct modifications from new turbulence physics. The project will focus on the management of fluctuations and transport in a spheromak plasma using new turbulence physics models and comprehensive helicity control. We will employ high time- and spatial- resolution measurements of electron temperatures, ion temperatures, and magnetic field fluctuations to investigate, understand, and eventually control reconnection driven heating as a means of increasing the plasma temperature of spheromak plasmas. We will use divertor diagnostics of radiation and particle transport along with edge biasing for electric field control to explore the effects of driven flows on confinement and heating in spheromak plasmas with microparticles and will investigate the effects of MW pulses coupled to protons on the plasma current and confinement.

Budget: $950,000
Universities: FAMU
Universities and External Collaborators:
Dr. Earl Scime, West Virginia University
Dr. Ed Thomas, Auburn University
Dr. Simon Woodruff, Woodruff Scientific, Inc



The FAMU-STPX stands approximately 4 meters high and 2 meters wide at the vacuum vessel. The STPX achieves plasma temperatures of 300 eV, plasma currents of approximately 600 kA with a pulse duration of 5ms. The electron density is $10^{19}/m^3$. The research involves: measurements of electron and ion temperature and magnetic field fluctuations. Several innovative research activities include: manipulation of the stable Taylor state with pulsed RF and terawatt femtosecond laser pulses; controlling impurity content using the physics of microparticle transport in fusion plasmas.

Refereed Publications (2011)

1. P. Karamanis, C. Pouchan, C.A. Weatherford, G.L. Gutsev, "Evolution of Properties in Prolate (GaAs)n Clusters", Journal of Physical Chemistry C, 115, 97-107 (2011).
2. G. L. Gutsev, K. G. Belay, C. A. Weatherford, V. N. Vasilets, E. M. Anokhin, A. V. Maksimychev, O. V. Val'ba, V. M. Martynenko, S. A. Baskakov, E. S. Leskova, and Y. M. Shulga "Dimerization of Defect Fullerenes and the Orientational Phase Transition in Oxidized C60 Fullerite," Journal of Nanoscience and Nanotechnology 11, 1887-1896 (2011).
3. Daniel Gebremedhin and Charles A. Weatherford, "Two-Range Addition Theorem for Coulomb Sturmians", Progress in Theoretical Chemistry and Physics B22, 71-81, P. E. Hoggan, E.J. Brändas, J. Maruani, P. Piecuch, and G. Delgado-Barrio, editors, Springer, Dordretch (2011).
4. K. Pradhan, G. L. Gutsev, C. A. Weatherford, P. Jena, "A systematic study of neutral and charged 3d-metal trioxides and tetraoxides", Journal of Chemical Physics 134, 144305-1-10 (2011).
5. G.L. Gutsev, C.A. Weatherford, K. Pradhan, and P. Jena, "Density Functional Study of Neutral and Anionic AlOn and ScOn with High Oxygen Content," Journal of Computational Chemistry, 32, 2974-2982 (2011).

6. C. Weatherford, Kalayu Belay, Gennady Gutsev, "Theoretical and Experimental Studies of Fullerite Modified by Oxidation, Intercalation, and Radiation," 2011 Florida Energy Systems Consortium Summit, University of Florida Reitz Union, Gainesville, Florida, September 28, 2011.
7. J.L. Abot, A. Song, M.J. Schulz, V.N. Shanov, K. Belay, Y. Abere, B. Place, and C. Weatherford, "On the Development of Integrated Strain Sensors for Polymers and Composite Materials", Proceedings of the 2nd Joint US-Canada Conference on Composites, September 26-28, 2011, Montreal, Quebec, Canada.

8. Bidhan C. Saha, "Collisions of fully and partially stripped ions with H2 al low energies", in Atomic Structure and Collision processes (edt. Man Mohan) Narosa Pub. House (2011).
9. K. F. Haque, M. R. Talukder, M. Shahjahan, M. A. Uddin, A. K. Basak and B. C. Saha, "An extended empirical formula for inner-shell ionization of atoms", J. Phys. B43, 115201 (2011).
10. M. A. R. Potoary, M. Alfaz Uddin, A. K. F. Haque, M. Shahjahan, A. K. Basak and B. C. Saha, "Electron impact ionization in K-, L- , and M- shell of atomic targets", Int. J. Qu. Chem, 111, 923 (2011).
11. K. F. Haque, M. A. Uddin, M. Shahjahan, M. R Talukder, A. K. Basak and B. C. Saha, "Electron impact inner-shell ionization of atoms", in Advances in Quantum Chemistry, Vol. 61, 309-373 (2011).

Non-Refereed Publications (2011)

1. D. C. Joseph, J. P. Gu and B. C. Saha, "State selective charge-transfer in slow collisions of Si^{3+} with H", Phys. Rev. A (under consideration) (2011).
2. Nicolais. L. Guevera and Bidhan. C. Saha, "Collisions of C^{6+} with atomic and molecular hydrogen", Phys. Rev. A (under consideration) (2011).
3. L. B. Zhao, B. C. Saha and M. Du, "Circular Rydberg states of atomic hydrogen in an arbitrary magnetic field", 42nd DAMOP , Atlanta, June13-17 (2011).
4. B. C. Saha, "Inner shell ionization of atoms (Z=6 to 92) by electrons, 42nd DAMOP, Atlanta, June134-17, 2011.
5. D. C. Joseph, E. Quashie and B. C. Saha, "Charge exchange cross sections in slow collisions of Si^{3+} with Hydrogen atom", 42 nd DAMOP, Atlanta, June 13-17, 2011.
6. D. C. Joseph and B. C. Saha, "Electron capture cross sections by O^{+} from atomic He", Abst XXVI IEPEAC, Kalamazoo, MI, July 22, 2009.
7. B. C. Saha and L. B. Zhao, " H and He atoms in strong magnetic fields", Abst. XXVII ICPEAC,
8. Belfast,July, 27 –Aug2,.(2011).
9. D. C. Joseph and B. C. Saha, "State-selective charge exchange in slow collisions of Si^{3+} ions with H atoms: A molecular state close coupling treatment", Abst. XXVII ICPEAC, Belfast, July22 –Aug 2, (2011).

Presentations (2011)

1. D. C. Joseph, E. Quashie and B. C. Saha, "Charge exchange cross sections in slow collisions of Si3+ with Hydrogen atom", 42nd DAMOP , Atlanta, June 13-17, 2011.
2. B. C. Saha, "Inner shell ionization of atoms (Z=6 to 92) by electrons, 42nd DAMOP, Atlanta, June134-17, 2011.
3. L. B. Zhao, B. C. Saha and M. Du, "Circular Rydberg states of atomic hydrogen in an arbitrary magnetic field", 42nd DAMOP , Atlanta, June13-17 (2011)

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6. of Si3+ ions with H atoms: A molecular state close coupling treatment",
7. Abst. XXVII ICPEAC, Belfast, July22 –Aug 2, (2011)

8. C. Weatherford, D. Gebremedhin, G. Tanaka, and X. Zhang. "Quantum Control of Helium", Gordon Conference on Quantum Control of Light and matter, Mt. Holyoke College, MA, July 31-August 5, 2011.
9. C. Weatherford, Kalayu Belay, Gennady Gutsev, "Theoretical and Experimental Studies of Fullerite Modified by Oxidation, Intercalation, and Radiation," 2011 Florida Energy Systems Consortium Summit, University of Florida Reitz Union, Gainesville, Florida, September 28, 2011.
10. K.M. Williams, E.D. Mezonlin, A.B. Alexander, C.A. Weatherford, J.A. Johnson III, "The Spheromak Turbulent Plasma Experiment: The Next Phase in Spheromak Physics", Presented at the 2011 APS Division of Plasma Physics Meeting, Salt Lake City, UT
11. K.M. Williams, A.B. Alexander, M. Scott, J. Buchanan, "Self-Organization in Hypersonic Shock Driven Plasmas", Presented at the 2011 APS Division of Plasma Physics Meeting, Salt Lake City, UT

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1. L. B. Zhao, B. C. Saha, and M. L. Du , "Calculation of excited states of He atoms in a strong magnetic field", Comm. In Theo. Physics, **57**,1059, (2012).
2. D. C. Joseph, J. P. Gu and B. C. Saha, "State selective charge-transfer in slow collisions of Si^{3+} with H", Phys. Rev. A (under consideration) (2012).
3. Nicolais. L. Guevera and Bidhan. C. Saha, "Collisions of C^{6+} with atomic and molecular hydrogen", Phys. Rev. A (under consideration) (2012).
4. M. A. Uddin, T. I. Talukder, A. K. F. Haque, A.K.Basak, B. C. Saha and F. B. Malik, "A simple model for evaluating stopping cross sections of H^{+}, He^{++}, Li $^{3+}$" , Phys. Letts (submitted)
5. (2012).
6. Gennady L. Gutsev, Charles A. Weatherford, Lewis E. Johnson, Purusottam Jena, "Structure and Properties of the Aluminum Borates $Al(BO_2)_n$ and $Al(BO_2)_n^-$, (n=1-4)", Journal of Computational Chemistry **33**(4), 416-424 (2012).
7. Yuriy Shulga, Sergey Baskakov, Vyacheslav Muradyan, Dmitriy Voilov, Vyacheslay Smirnov, Alexander Michtchenko, José Cabañas-Moreno, Kalayu Belay, Charles Weatherford, and Gennady L. Gutsev, "Colorful Polymer Compositions With Dyed Graphene Oxide Nanosheets", International Scholarly Research Networks Optics **2012**, 1-5 (2012).
8. Gennady Gutsev, Charles Weatherford, Puru Jena, Elijah Johnson, Bala Ramachandran, "Structural Patterns in Carbon Chemisorption on an Icosahedral Iron Clusters", Journal of Physical Chemistry B, **116** 7050-7061 (2012).
9. James B. Titus, Alonzo B. Alexander, Kyron Williams, Charles Weatherford, and Joseph A. Johnson III, "FAMU Spheromak and the Turbulent Physics Experiment—STPX", Technology and Innovation **14**, 1-11, 2012.
10. B. Ritchie, C. Weatherford**,** "Algebra of Physical Space and the Geometric Space-Time Solution of Dirac's Equation," International Journal of Quantum Chemistry, DOI: 10.1002/qua.24156 (2012)..
11. D.H. Gebremedhin and C.A. Weatherford, "Canonical Two-Range Addition Theorem for Slater-Type Orbitals," International Journal of Quantum Chemistry, DOI: 10.1002/qua.24319 (2012).
12. G.L. Gutsev, C.A. Weatherford, P. Jena, E. Johnson, and B.R. Ramachandran, "Structure and Properties of Fe, Fe^-_n, Fe^+_n Cluster, n=7-20", Accepted Journal of Physical Chemistry A.

Non-Refereed Publications (2012)

1. B. Ritchie, C. Weatherford, "Algebra of Physical Space and the Geometric Space-Time Solution of Dirac's Equation," Proceedings of the 52nd Sanibel Symposium, February 23, 2012, St. Simon's Island, GA.
2. Charles Weatherford and Xingjun Zhang, "Quantum Control of Diatomic Molecular Vibration States Using Space-Time Discretization", Bulletin of the American Physical Society (2012).
3. C.Y. Scarlett, H.C. Chen, R.J. Peteraon , "Proton Spectrum at the Jupiter Facility of LLNL,", arXiv 1204.3819 (2012).

Presentations (2012)

Invited

C.A. Weatherford and G. Gutsev, "Theoretical and Experimental Studies of Fullerite Modified by Oxidation, Intercalation, and Radiation", Electronic Structure Theory for Strongly Correlated Systems, May 30 to June 1, 2012, Palermo, Italy.

Contributed

1. C. Weatherford, "Algebra of Physical Space and the Geometric Space-Time Solution of Dirac's Equation," 52nd Sanibel Symposium, February 23, 2012, St. Simon's Island, GA.
2. D. Gebremedhin, E. Quashie, C. A. Weatherford and B. C. Saha,"Photoionization of H atom in electric field: Finite Element Technique", 43rd DAMOP Meeting, Orange County, CA (2012).
3. D. C. Joseph and B. C. Saha, "Si^{3+} +H collisions: role of rotational couplings", 43rd DAMOP Meeting, Orange County, CA (2012).
4. X. Zhang and C.A. Weatherford, "Evolution Strategy for Controlling Diatomic Molecular Vibration States with the Space-Time Algorithm," 14th International Congress on Quantum Chemistry, June 25-30, 2012 Boulder, CO.
5. D. Gebremedhin, E. Quashie, C. A. Weatherford and B. C. Saha,"Photoionization of H atom in electric field: Finite Element Technique", 43rd DAMOP Meeting, Orange County, CA (2012).

Florida Atlantic University

Southeast National Marine Renewable Energy Center (SNMREC)

PI: Susan H. Skemp **Co-PIs:** Howard P. Hanson, James VanZwieten, full list appended.
Students: Student listing is appended

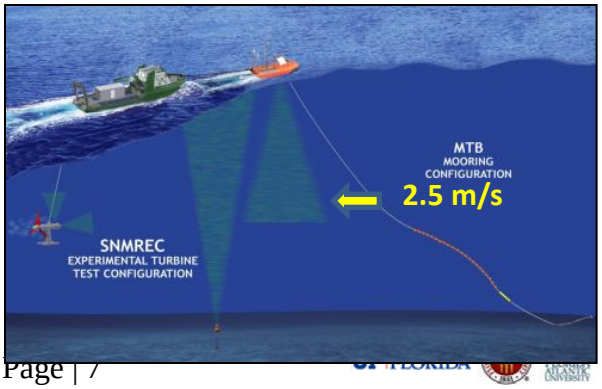
Description: The Southeast National Marine Renewable Energy Center (SNMREC) at Florida Atlantic University (FAU) was established by an award from the US Department of Energy in 2010 as an extension of FAU's Center for Ocean Energy Technology, which was originally founded in 2007 by the 2006 Florida State University System Center of Excellence Program. The SNMREC is investigating harnessing power from ocean currents, such as the Gulf Stream, as well as ocean thermal energy conversion to generate base-load electricity, thereby making a unique contribution to a broadly diversified portfolio of renewable energy for the nation's future. Key drivers for investigation are determined by the regulatory process at State and Federal levels and by market and technology gaps needed to commercialize MRE. The SNMREC's role is to bridge the gap between concept and commercial deployment of ocean energy technologies by providing at-sea testing facilities and technology development for both ocean current and thermal energy systems. Research areas span environmental, resource, economic, education, and technology topics.

Budget: $8,750,000
Universities: Florida Atlantic University, collaborating with the University of Central Florida, Florida State University, University of South Florida, Embry-Riddle Aeronautical University, University of Miami, Oregon State University, University of Washington, Pennsylvania State University, University of New Hampshire, University of Hawaii, University of Edinburgh, Heriot-Watt University, Nova Southeastern University, Virginia Polytechnic Institute and State University, and Florida Institute of Technology.

External Collaborators: Numerous industry partners, state and federal government agencies, FFRDCs such as the National Renewable Energy Laboratory, Oak Ridge National Laboratory, Woods Hole Oceanographic Institution, U.S. Department of Energy (Office of Energy Efficiency and Renewable Energy), U.S. Department of Interior (Bureau of Ocean Energy Management, Regulation, and Enforcement), U.S. Department of Commerce (National Oceanic and Atmospheric Administration), the Florida Fish and Wildlife Commission, and Florida Departments of Agriculture and Environmental Protection.

Funding Leveraged: U.S. Department of Energy and Industry - $4,245,375, $1,250,000 pending

Project Description



The Southeast National Marine Renewable Energy Center is developing an open-ocean energy laboratory and test capability to advance research on *marine and hydrokinetic* (MHK) ocean current energy and thermal potential energy. The SNMREC is moving forward with strategically selected research, developing and testing key technology, infrastructure and systems as well as standards criteria to meet this need. The successful implementation of an in-water testing infrastructure

for MHK off the coastline of Florida will be the first and only such capability globally. Already, companies from both the U.S. and internationally have expressed a desire to work with the SNMREC in defining not only their test requirements based on their design, but also are exploring both short term occupancy in Florida and potentially longer term manufacturing and grid connection in developing arrays for commercial enterprises.

An MHK lease application on the outer continental shelf (OCS) was submitted to the US Department of Interior, Bureau of Ocean Energy Management (BOEM). This is the first national application which will form the model for future lease applications. BOEM is conducting the Environmental Assessment (EA) which is a precursor to granting a lease. A draft EA was released for public comment, and BOEM is currently engaged in finalizing the EA, with an anticipated completion date of December 2012. The final action is a Consistency Determination by the State of Florida prior to the release of the EA and moving forward with the lease.

The SNMREC is engaged in sensor and instrument acquisition, deployment, and analysis to more fully characterize offshore energy resources, and the benthic and pelagic environment. Second, fabrication of a small-scale hydrokinetic turbine system is in the final stages of completion. Testing is ongoing for components, sub-systems, and major systems of the turbine. Assembly and tow testing of the prototype prior to deployment of the test infrastructure is on hold pending completion of the EA. Discussions are ongoing with over 40 companies to determine testing/validation requirements for open-ocean testing of their proposed experimental devices at the SNMREC's test facility. A centralized, standardized testing capability will be provided for testing current energy conversion prototypes; initially, scaled versions and eventually full-scale devices. In addition, critical environmental measurements will be obtained from the observational platform.

Sea trials were successfully conducted of a mooring and telemetry buoy to ready it for at-sea deployment. In-lab technology testing is underway with a scaled generator dynamometer which provides a platform to test offshore electrical systems before use and simulate offshore grids. Aerial surveys are being conducted to determine offshore turtle and marine mammal distribution and activity prior to install/test of MHK devices. Sub-sea surveys of installation sites are helping to identify deep water coral distribution and determine appropriate anchor areas.

Over fifty upper-division graduates and Principle Investigators have been engaged in research in marine renewable energy (MRE) to date. The Center developed a curriculum for upper-division high-school students to introduce the topic within secondary education.

To date, with the State of Florida funding, the SNMREC has successfully leveraged $3,935,375 of U.S. Department of Energy funds. An additional $1,250,000 is pending, awaiting release of funds. Industry sponsored funding is at a level of $155,000.

3. Annual Progress Report 10/11 – 9/12

3.1 Introduction

SNMREC is developing and installing the first open-ocean current energy conversion test facility in the U.S. consisting of at-sea equipment (Figure 1) for the purpose of investigating current energy conversion devices in the Florida Current, approximately 12 miles offshore Fort Lauderdale, Florida. Initially, the capability will be limited to scaled devices (⅛ – ¼ scale, or up to 7 meter diameter rotors or 100kW instantaneous maximum power production). The SNMREC facility will provide a centralized, standardized approach to testing for current energy conversion prototypes. In addition, the facility will serve as an observational platform from which critical environmental measurements can be obtained.

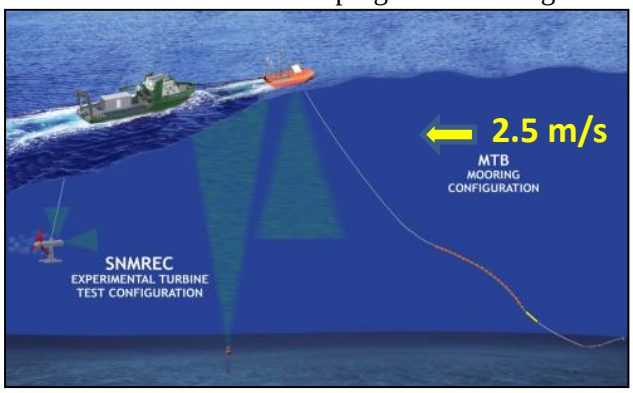
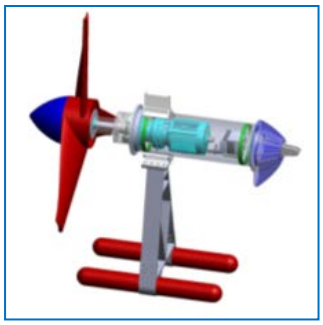


Figure 1. SNMREC Ocean Current Test Facility setup



A 3-meter rotor diameter, 20kW generically designed experimental research turbine (Figure 2) will provide a non-proprietary platform for component development at small scales. The test procedure/plan is laid out to incorporate monitoring and failure prediction systems, to gain experience in at-sea operations of this nature, and to support standards and protocol development. Industrial beneficiaries will be able to use the results of testing to enhance and accelerate prototype development. A major challenge, obtaining an outer continental shelf lease, is nearly met.

Figure 2. SNMREC 3-meter diameter Rotor, 20kW Instantaneous Max Power Prototype

3.2 Areas of Significant Progress

3.2.1 Resource Assessment

The global analysis of ocean thermal energy conversion (OTEC) potential, a DOE-funded project undertaken jointly with the Lockheed-Martin Marine Systems and Sensors Division, has been completed, producing a publically available GIS database that is accessible at http://maps.nrel.gov/mhk_atlas. This GIS tool provides information pertinent to both OTEC and sea water air conditioning (SWAC). A screenshot of this tool is shown in Figure 1. Detailed assessments of both the OTEC and SWAC resources off Florida have also been conducted. Using the Hybrid Coordinate Ocean Model (HYCOM) results produced in data-assimilation mode by the Naval Research Laboratory (NRL) and *in situ* data, estimates of the net electric power that could be created utilizing a representative 100 MW OTEC plant have been made. It is estimated that such a plant could produce an average up to 112 MW of power if located off Key West, with power production decreasing with latitude up the east coast of Florida (Figure 3).

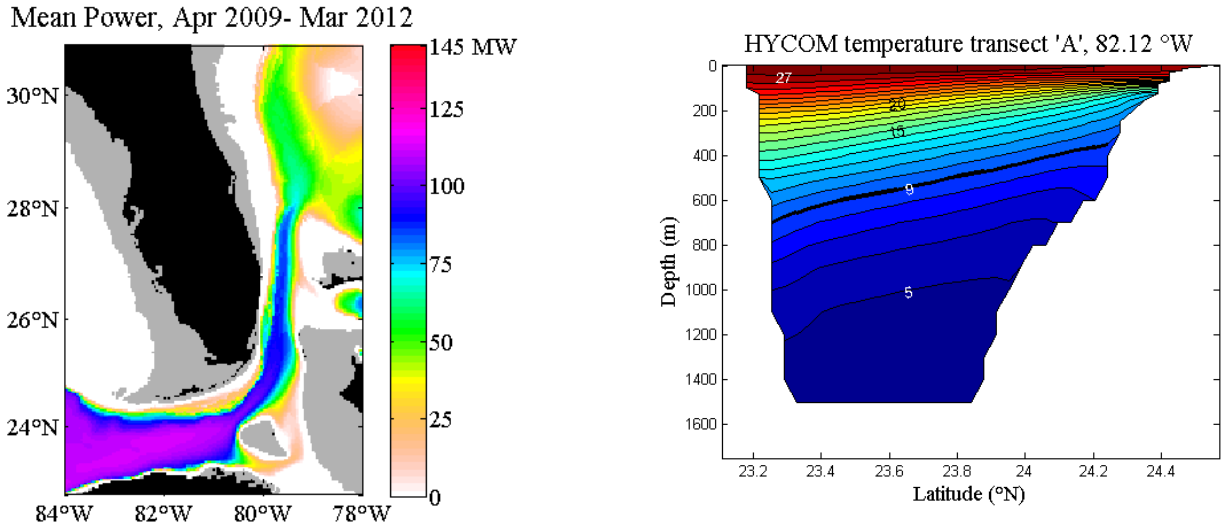


Figure 3. Average net electric power produced from a single representative 100 MW OTEC

OTEC plants create power by using the temperature difference between the warm surface water and cold deep water to produce electricity. For this reason they run large amounts of both cold and warm water through heat exchangers. Therefore, a first step in assessing the environmental impact of locating an OTEC plant in the Florida Straits is quantifying the percentage of the resource that will be used by a plant. It is calculated that an OTEC plant located along the transect line "A" in Figure 4 would use approximately 0.009% of the cold water (<9° C Figure 4, right) flowing past this line. To help put this into perspective Florida utilized approximately 26 GW of power in 2005. If this entire 26 GW of power were produced using OTEC (meaning 260 of the 100 MW OTEC plants discussed here) then these plants would utilize less than 2.5% of the cold water that flows between Florida and Cuba.

Figure 4. Thermal energy resource for (a) summer, (b) winter, (c) annual average

The DOE-sponsored global OTEC resource study relied on model results, from a data-assimilation version of the global HYCOM. Recently, the NRL has adopted a more recent version of HYCOM for its simulations of the Gulf of Mexico and the Straits of Florida, which version includes both very high resolution (~4 km horizontally and more vertical layers) and improved physics. Because of this, comparisons between SNMREC field datasets and HYCOM results such as those shown in Fig. 4 have improved markedly. These results will continue to be useful for ongoing OTEC assessments for Florida's future.

Finally, during the past year, two ADCPs were deployed in November 2011 and recovered in April with additional stand-alone temperature sensors to enhance the ongoing monitoring of Florida Current hydrokinetic resources. Approximately five months of current velocity profiles and single point temperature measurements were acquired at each ADCP location. The stand-alone temperature sensors were set to the same sampling interval as the ADCP to verify the internal ADCP temperature sensor accuracy. The measurements correlated within less than 1^{o} C variance. The small variance resulted in an increase of confidence in ADCP temperature readings.

The two recovered ADCP buoys were refurbished and a new third ADCP buoy was assembled. All three buoys were set to record 5 minute current velocity averages every 10 minutes (the same settings as the previous six month deployment) to capture seasonal variability in the Florida Current at each location. On May 22nd the three buoys were deployed (minus the redundant stand-alone temperature sensors). Two buoys were deployed in the same location as the previous deployment and the third was deployed between them at 26 º 4.3´ N, -79 º 52.5´ W. All three buoys are scheduled to be recovered, refurbished, and redeployed in the November – December time period.

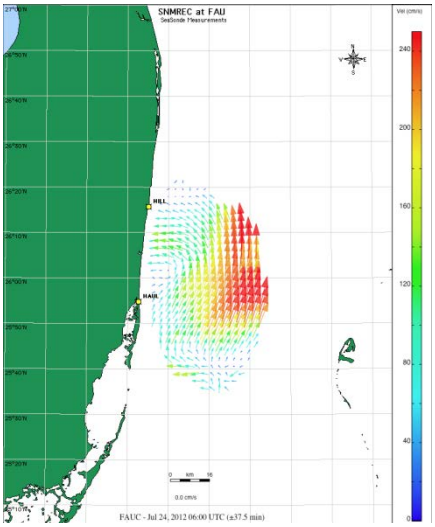


Figure 5. CODAR Installations

The ADCP measurements combined with a SeaSonde® ocean surface current measurements system will allow for estimations of the Florida Current's volumetric flow and power potential. The SeaSonde® system, manufactured by CODAR Ocean Sensors, consists of two pairs of antennas installed on land within close proximity to the shore at Hillsboro and Haulover Beach (Figure 5). At each site one antenna transmits a high frequency radar signal that is reflected on the ocean surface and received by the second antenna. At offshore locations where at least two radar signals intersect the total current speed and direction can be calculated.

Concurrently as of mid-July, SNMREC's 12 MHz SeaSonde® radar system has been collecting ocean surface current measurements. When the ADCPs are recovered the end of this calendar year, research on comparing and correlating the ADCP and SeaSonde® data will commence. First, there will be an effort to validate the SeaSonde® data by comparing to data collected from the ADCPs and drifters equipped with GPS tracking capability. When confidence in the surface current data accuracy is attained SNMREC researchers will proceed to develop algorithms to infer the current velocity profiles from the surface to the seafloor using only the SeaSonde® measurements, eliminating the need for the ADCP instruments. Eventually, wind data within the coverage area (which will be collected from the MTB anemometer when permission to deploy the MTB is granted) will be available to quantify the wind effects and improve the accuracy of the current profile prediction algorithms.

3.2.2 Regulatory Environment

Continuing evolution of state and federal agency requirements is a challenge obtaining permits for open-ocean deployment of even experimental test systems. Pursuing any research and development in renewable energy on the Outer Continental Shelf (OCS) must comply with the federal Outer Continental Shelf Lands Act. With respect to the SNMREC deployments of prototype devices/systems, the major permits, approvals, and authorized actions necessary to construct, operate, maintain, and decommission project facilities while falling outside of State of Florida waters (i.e., greater than 3 miles offshore), will involve interaction with the Florida Fish and Wildlife Commission due to its agreements with the U.S. Fish and Wildlife Service. Shore-side activities in support of the offshore deployment will be conducted within State waters, at a commercial marina under the purview of the Florida Department of Environmental Protection. These activities will also engage agencies such as the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration's Marine and Fisheries Service, the U.S. Coast Guard, the U.S. Navy, etc. SNMREC submitted the first lease application in the nation to the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) to deploy equipment related to marine hydrokinetic energy conversion device on the outer continental shelf (OCS).

The initial phase of a standalone testing and evaluation infrastructure without transmission of power to shore requires an Environmental Assessment (EA), which is being conducted by BOEM. BOEM released the draft EA in April 2012 for public comment, and is in currently in the process of considering the comments in the preparation of the final EA. The latest completion date for the final EA is expected in Dec 2012, with the final step in the process being a State of Florida Consistency Determination by the end of February. Anticipating approval to proceed with the program, lease negotiations will commence with issuance of a lease by the beginning of 2012. Once a lease is finalized, SNMREC will prepare and submit a Project Plan and a Construction Plan for BOEM review. The Project Plan will include any specifics that were not detailed in the original lease application as well as any information necessary to comply with lease and EA stipulations. As this is the first such application for MHK on the OCS, there are still areas being worked out by the agencies.

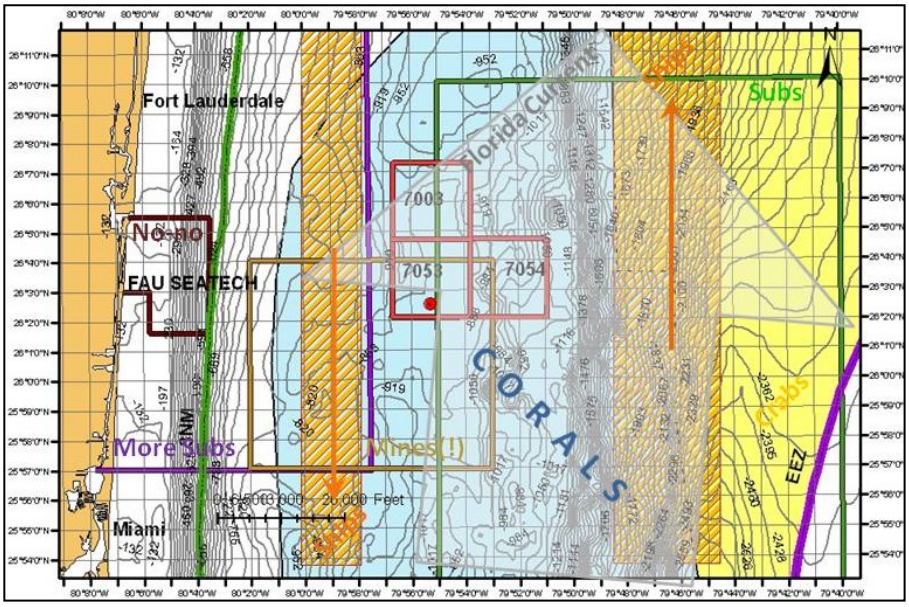


Figure 6. Map Of Snmrec Requested Ocs Lease Boem Blocks (7003, 7053 And 7054).

The three-block area of interest requested in the application includes BOEM defined blocks 7003, 7053 and 7054, as shown with red outlines in Figure 6. The map is a compilation of other identified areas of primary interests and potential user conflicts that were considered during selection of the final BOEMRE blocks.

In addition, recent research results, some of which were supported by the SNMREC, have provided additional information about a newly discovered genus of corals that inhabit the outer parts of the Miami Terrace in the Florida Straits. The vulnerability of these corals to deep-trawl commercial fishing has led the National Oceanic and Atmospheric Administration to designate a large part of the sea-bed offshore of Florida and Georgia as a Coral Habitat Area of Particular Concern. While this designation will result in relatively little disruption of the SNMREC's operations – the Center's two or three anchor systems can easily be deployed on the large, sandy patches that exist between coral beds – there will likely be significant challenges for commercial-scale deployments in the future.

3.2.3 Infrastructure

SNMREC's proposed initial deployment, approximately 12 miles offshore Fort Lauderdale, Florida which regularly experiences 3-4 kt of current, will consist of an anchored mooring and telemetry buoy (Figure 7), to be used as an attachment point for work boats to deploy prototype systems for testing, and as an observational platform for a variety of environmental and met-ocean studies. The SNMREC's buoy, a design based on the familiar NOMAD weather buoys originally developed by the U.S. Navy in the 1940s, is undergoing final tune-up modifications following a series of successful sea trials earlier this summer. The initial deployment will provide testing capabilities for devices in the 100kW class and smaller.

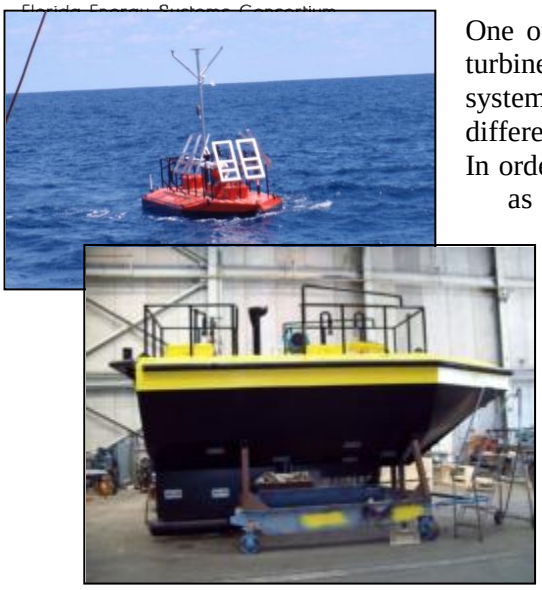


Figure 7. Mooring And Telemetry Buoy (Mtb) During Open-Ocean Sea Trials.

One of the biggest unknowns in the operations of ocean current turbine (OCT) systems concerns the behavior of the generator sub-system as it experiences both variable loads and the torque differentials associated with changing currents acting on the rotor. In order to provide a capability to test generators under conditions as realistic as possible without actually having to go to sea, SNMREC has developed a computer-controlled dynamometer system, located at the FAU SeaTech facility in Dania Beach. This capability is further being developed in conjunction with oceanographic measurements and modeling to simulate rotor behavior as it would behave in the current. The 20 kW dynamometer (Figure 8) has been fitted with the SNMREC's experimental research turbine power and health management systems, and is generating data for Prognostics and Health Monitoring (PHM) research. In addition, preliminary work has been completed to emulate rotor behavior in wave conditions and from collected offshore measurements. Testing will continue to include optimization of *in situ* data integration and 20kW research turbine electrical and sensor system testing.

Figure 8. Dynamometer For Generator Testing (Left) And Full-Up Data Acquisition And Control SYSTEM (RIGHT)

3.2.4 Environmental Monitoring / Demonstration

Monthly aerial diversity and distribution surveys are being conducted to assess sea turtle and marine mammal populations. The surveys employ the currently accepted protocol – human observers viewing transect areas from a plane flying approximately 500 ft. from the ocean surface. Twenty months of cross-channel and over 40 coastal surveys have been completed to date. The use of high resolution video as alternative to human observers continue to be evaluated along with development of optimized software to automatically identify desired species targets. Additional along-shore surveys with available historical data are underway. Because preliminary data suggests significant population activity near shore, these transects will provide higher resolution data to support analysis efforts. The research team is working with the National Oceanic and Atmospheric Administration's, National Marine Fisheries Service to evaluate the SNMREC's enhanced approach as an expansion of currently accepted methods. The survey areas currently being assessed are depicted in Figure 9.

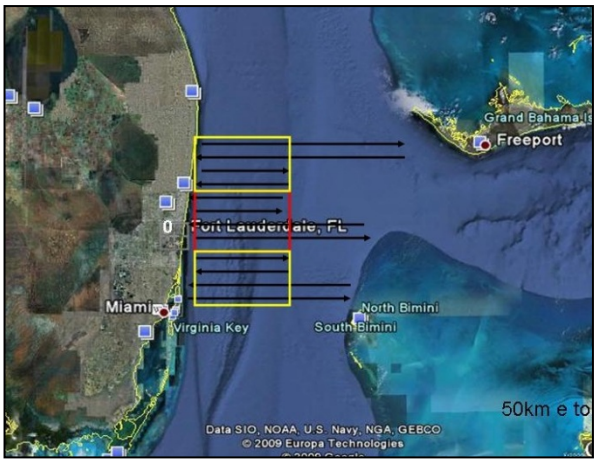


Figure 9. Aerial Survey Areas Offshore Ft. Lauderdale, To Determine Sea Turtle And Marine Mammal Population

3.2.5 Education and Outreach

3.2.4.1 Professional Community

In August, SNMREC hosted visitors from the US Department of State, International Visitors Leadership Program. Visitors included top industry officials from Greece, Scotland, Morocco, Nepal, South Africa, Tunisia, and Uzbekistan. An overview of both SNMREC's ocean energy program was provided.

SNMREC has been engaged in a number of activities with the professional and public community. Among these include seven public awareness presentations between January and April to gauge the public's perception of marine renewable energy as conducted by SNMREC. In August SNMREC participated with FESC in the Department of Agriculture's 2012 Florida Energy Summit in Orlando. SNMREC participated in the CleanTech to SpaceTech Accelerating Florida Entrepreneurship (FLCAN) Showcase in September sponsored by the Florida Energy Systems Consortium.

3.2.4.2 Education

SNMREC is engaged in creating and implementing a summer internship program with Harbor Branch Oceanographic Institute (HBOI), and the United States Coast Guard Academy for the summer of 2013. The students will be working on the internship program at HBOI. This ongoing initiative will run from July 2012- the summer of 2013

A seventh lesson is in development for the SNMREC curriculum for high school based on civics/social studies. This lesson instructs the students on the important role that the government has in renewable energy production and advancement. The lesson is based on the same educational model as the original curriculum, the "5E's"; Engaging, Exploring, Explaining, Elaborating and Evaluation. Appropriate activities and Sunshine State Standards are included.

Two MOU's were executed in May and August 2012, to support collaboration with the South Florida Science Museum in West Palm Beach and the Museum of Discovery and Science (MODS) in Ft. Lauderdale to create an interactive display, featuring the SNMREC ocean current turbine in the Gulfstream current. SNMREC is working with professors and students at FAU's School of Communications and Multimedia Studies' to create the interactive educational display game. FAU's HBOI is also collaborating with SNMREC to design and install a kiosk in the Ocean Discovery Center with the ocean turbine interactive game. Additional public funding has been secured through the University Club of FAU Foundation Inc., and from FAU's Broward Undergraduate Student Research Awards. A collaborative effort has been initiated between SNMREC and Florida Power and Light to include ocean renewable energy research and development from SNMREC in their museum display at the MODS.

SNMREC partnered with Nova SE University's marine science program, hosting the Miami Aquatic Life and Nature Camp, sponsored by Miami-Dade County Parks and Recreation Department, for two camp visits on June 11th and July 23rd. The focus was on the environmental aspects of marine renewable energy. This event highlighted SNMREC's partnership with Nova Southeastern University, and the importance of SNMREC's ocean renewable energy research combined with Nova SE University's sea turtle preservation and protection program. The campers were 8-14 years of age. A similar event, sponsored by South Broward High School's Marine Magnet Program; Ocean Science, Technology, Engineering and Math (OSTEM) for Girls Program was held in July bringing together the same partnership. Using the SNMREC curriculum as a basis, the focus of this program was on the technology also highlighting the interactions of the technology with the environment.