FINAL PROJECT REPORT

Project Title: MULTI-UNIVERSITY SOUTHEAST INIE CONSORTIUM

Covering Period: September 10th, 2003 through September 30th, 2010

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Project Summary: The **M**ulti-**U**niversity **S**outheast **I**NIE **C**onsortium (MUSIC) was established in response to the US Department of Energy's (DOE) Innovations in Nuclear Infrastructure and Education (INIE) program. MUSIC was established as a consortium composed of academic members and national laboratory partners. The members of MUSIC are the nuclear engineering programs and research reactors of Georgia Institute of Technology (GIT), North Carolina State University (NCSU), University of Maryland (UMD), University of South Carolina (USC), and University of Tennessee (UTK). The University of Florida (UF), and South Carolina State University (SCSU) were added to the MUSIC membership in the second year. In addition, to ensure proper coordination between the academic community and the nation's premier research and development centers in the fields of nuclear science and engineering, MUSIC created strategic partnerships with Oak Ridge National Laboratory (ORNL) including the Spallation Neutron Source (SNS) project and the Joint Institute for Neutron Scattering (JINS), and the National Institute of Standards and Technology (NIST). A partnership was also created with the Armed Forces Radiobiology Research Institute (AFRRI) with the aim of utilizing their reactor in research if funding becomes available. Consequently, there are three university research reactors (URRs) within MUSIC, which are located at NCSU (1-MW PULSTAR), UMD (0.25-MW TRIGA) and UF (0.10-MW Argonaut), and the AFRRI reactor (1-MW TRIGA MARK F).

The overall objectives of MUSIC are: a) Demonstrate that University Research Reactors (URR) can be used as modern and innovative instruments of research in the basic and applied sciences, which include applications in fundamental physics, materials science and engineering, nondestructive examination, elemental analysis, and contributions to research in the health and medical sciences, b) Establish a strong technical collaboration between the nuclear engineering faculty and the MUSIC URRs. This will be achieved by involving the faculty in the development of state-of-the-art research facilities at the URRs and subsequently, in the utilization of these facilities, c) Facilitate the use of the URRs by the science and engineering faculty within the individual institutions and by the general community of science and engineering, d) Develop a far-reaching educational component that is capable of addressing the needs of the nuclear science and engineering community. Specifically, the aim of this component will be to perform public outreach activities, contribute to the active recruitment of the next generation of nuclear professionals, strengthen the education of nuclear engineering students, and promote nuclear engineering education for minority students.

I. Final Report

A. Program Activities:

1) Educational Enhancement

Title: Training and Education Modules in Nuclear Engineering

Objective: Development of training courses to enhance the training and education for both internal and external groups.

Status: Completed

Explanation: The development of educational modules has been completed. This includes the module utilizing the biological laboratory that was established at the Maryland reactor. Collaboration in this area was initiated within the University of Maryland and with Georgia Tech. The activities within the scope of this task resulted in the publication one articles in a peer reviewed journal and one invited presentation before the American Nuclear Society. The articles are cited below:
1. C-K Chris Wang, Xin Zhang, Ian Gifford, Eric Burgett, Vincent Adams, and Mohamad Al-Sheikhly, "Experimental Validation of the New Nanodosimetry-Based Cell Survival Model for Mixed Neutron and Gamma-Ray Irradiations" Physics in Medicine and Biology, 52, N367-N374, (2007)
2. Burgett, E., Wang, C.K., et al. (2006). "A high LET neutron irradiation facility for biological samples at the MUTR." Transactions of the American Nuclear Society Vol. 94. Reno, NV; June 4-8.

Title: Nuclear Engineering Distance Education: Virtual Laboratory Experience on the Web

Objective: The development of a course that will use a combination of distance education delivery technologies, having a classroom component as well as a laboratory component to provide students with a radiation detection and measurement laboratory experience.

Status: Completed

Explanation: During the past years, the nuclear instrumentation laboratory became a routine offering as part of the USC nuclear engineering curriculum. The students are able to perform the laboratory exercises remotely by taking remote desktop control of the laboratory computers on which the spectroscopy software resides. This includes experiments in gamma-ray spectrometry using germanium and sodium iodide detectors, alpha spectroscopy measurements and an exercise in beta counting. Currently, discussions are underway to explore transferring the experience to other USIC and INIE members.

Title: Internet University Reactor Experiments for Education in Nuclear Engineering and Research in Science and Engineering

Objective: Utilize the PULSTAR reactor at NCSU for nuclear engineering laboratory experiments at The University of Tennessee and other universities.

Status: Completed

Explanation: This project established, and continues to improve, an internet based A/V and data link between The University of Tennessee (UT) and the PULSTAR reactor at North Carolina State University (NCSU). A virtual interface of the PULSTAR reactor is developed and is used to display reactor related readings and the status of key components. Remote reactor experiments performed on the PULSTAR reactor to date include: reactor startup, approach to critical, rod calibration by an incremental method, rod calibration by inverse kinetics, temperature coefficient of reactivity, heat balance calibration of neutron detectors, and flux mapping. A neutron scattering experiment is being explored, and a neutron imaging experiment is under consideration. An added capability of direct online time-dependent measurements is functional and is being used during experiments. These experiments are offered as part of a nuclear engineering laboratory class at UT, where the current class size at UT is 30. It is expected that research-based experiments will be included during the next fiscal year. This capability is also established between Georgia Tech (GT) and NCSU. During the year 2009-2010 implementation at the international scale started with a reactor laboratory course offered between NCSU and Jordn University of Science and Technology.

2) Research Innovation

Title: Boron-(or Gadolinium-) Enhanced Neutron Brachytherapy

Objective: Evaluate the enhanced cell-killing effect on human prostate cancer cells due to ^{10}B in a neutron brachytherapy.

Status: Completed

Explanation: This project focused on two aspects: first, to study the response of V79 hamster cells exposed with mixed field of fission neutrons and gamma rays, and second to evaluate the enhanced cell-killing effect on human prostate cancer cells due to 10B in a thermal neutron field. The first part has been completed. The second part is largely completed but requires further funding.

Title: Flux Maps in the University of Maryland 250 kW TRIGA Reactor: Monte Carlo Simulations and Experiment

Objective: Use Monte Carlo simulations to characterize the UMRR in support of its utilization in experimental work.

Status: Completed

Explanation: A complete model of the UMTR was created to determine the optimum configuration of the thermal column irradiation facility. The impacts of variations in graphite thickness, cadmium shields, lead and tungsten gamma shields, as well as light and heavy water moderating blocks were studied. The resulting data were used to assist UM students prepare for thermal neutron irradiations inside the thermal column. Several variations on this facility have been proposed and neutron spectra as well as dose equivalent rates for neutrons and gammas have been calculated. In addition, Measurements were performed in the University of Maryland Irradiation facilities. Two positions of interest were investigated. The west neutron beam port was investigated as a fast irradiation facility. Neutron spectral measurements were made outside the reactor using a Bonner Sphere Spectrometer and a silver foil spectrometer. Integral dose measurements were made using a Tissue Equivalent Proportional Counter (TEPC) as well as gamma dose rate measurements to further characterize the radiation field outside the reactor core at 100 kW and 250 kW. The thermal column irradiation facility was investigated prior to the design and insertion of a new cell culture incubator. Here, threshold foil activations were made to measure the thermal, epithermal and fast neutron fluence rates at 100 and 250 kW. A limited set of Bonner Sphere Spectrometer measurements were made to cover the neutron spectrum in the thermal column.

Title: Intense Positron Beam for Advanced Materials Research

Objective: To establish a slow positron beam with an intensity of 10^8-10^9 positrons per second at the NCSU PULSTAR reactor.

Status: Completed

Explanation: Work continued on the set up and implementation of the second generation intense positron beam at the NCSU PULSTAR reactor. Testing of the positron beam in beamport #6 of the PULSTAR reactor was successfully completed. A slow positron rate of $6x10^8$ e+/s was measured. This rate matches and exceeds those reported in other facilities worldwide. At this stage, the associated spectrometers have been completed and are currently being tested. In the 2009-2010 period, the utilization of the spectrometers has been initiated with measurements performed on Nb samples provided by ANL to understand radiation damage aspects.

Title: Advanced System for Normal and Phase Contrast Imaging with Neutrons

Objective: To establish neutron imaging capabilities at the NCSU PULSTAR reactor and study/develop novel methods of neutron radiography and tomography.

Status: Completed

Explanation: Work continued on testing the neutron imaging facility at the PULSTAR reactor. Various applications were tested including imaging of plants and fuel cells. In addition, work continued on the implementation of phase contrast neutron imaging techniques. A special pin-hole collimator was designed and inserted into the original beam-line of the imaging facility. Currently, measurements using the pin-hole collimator are being performed. So far, this work has verified the ability to perform such imaging exercises at the PULSTAR reactor. During the period 2009-2010, full implementation of phase contrast neutron imaging using single and multi pinhole systems was completed.

Title: A Source of Ultra-Cold Neutrons at NCSU

Objective: To establish an ultra-cold neutron source at the NCSU PULSTAR reactor for studies in fundamental and applied physics and engineering.

Status: Continuing

Explanation: The He liquefier system has been completed and undergone initial testing. Currently, testing of this system is scheduled for early 2008. In addition, work is underway to finalize the coating procedures for the UCN guides. Various possibilities are being considered including Ni-58, Ni-Mo alloys and Diamond like coatings. The safety evaluation is also progressing with the intention of obtaining on-campus safety approvals in 2011 and submitting a safety evaluation to the NRC before the end of 2011.

Title: Neutron Diffractometer at the PULSTAR

Objective: To establish a powder neutron diffractometer at the NCSU PULSTAR reactor for use in materials studies.

Status: Completed

Explanation: The performance of the powder diffractometer was characterized during the fourth year. A new collimator system was installed that reduced the background noise by a factor of 4. Additional background shields were installed around the sample location that resulted in further reduction in background. Currently, final modifications are underway to bring the background level of the setup to less than 5 counts/second. Recent measurements have shown a neutron flux at the sample location of nearly 0.5 x 10^5 n/cm^2.s, which is comparable to the fluxes reported at other more powerful reactors. Measurements for materials characterization have started with first measurements being on reactor-grade graphite to understand its structure for irradiated and unirradiated conditions. A new rotating-oscillating collimator was designed and installed. During the period 2009-2010, optimization of the signal-to-noise ratio continued and measurements on Gen IV reactor graphite samples were initiated.

3) Infrastructure Improvement

Title: Characterizations of University Research Reactor Irradiation Facilities

Objective: To provide neutron spectral and dosimetric characterizations of irradiation facilities at various university research reactors, including beam ports and sample irradiation locations.

Status: Completed

Explanation: Measurements were performed in the University of Maryland Irradiation facilities. Two positions of interest were investigated. The west neutron beam port was investigated as a fast irradiation facility. Neutron spectral measurements were made outside the reactor using a Bonner Sphere Spectrometer and a silver foil spectrometer. Integral dose measurements were made using a Tissue Equivalent Proportional Counter (TEPC) as well as gamma dose rate measurements to further characterize the radiation field outside the reactor core at 100 kW and 250 kW. The thermal column irradiation facility was investigated prior to the design and insertion of a new cell culture incubator. Here, threshold foil activations were made to measure the thermal, epithermal and fast neutron fluence rates at 100 and 250 kW. A limited set of Bonner Sphere Spectrometer measurements were made to cover the neutron spectrum in the thermal column.

Title: Neutronic simulations of the NCSU PULSTAR reactor

Objective: to characterize the expected performance of the PULSTAR reactor core during experiments and to satisfy regulatory requirements.

Status: Completed

Explanation: A new MCNP model for the NCSU PULSTAR reactor is developed that provides considerable flexibility for evaluating reactor core performance and for characterizing neutron and photon environments at essentially any location in the facility. In particular the new model utilizes a new feature of MCNP5 that permits objects to be represented as macrobodies that can be translated and imbedded in other geometric units. In addition, software for coupling results from MCNP with depletion calculations obtained from ORIGEN is written. Results from these codes are used for the determination of fuel composition and power distributions as a function of burnup and for characterizing conditions of experiments in the facility. Results from calculations for the reactivity of the core as a function of burnup agree well with measurements. Changes in fuel and reflector configurations are included in the computational sequence of calculation for comparison with historical data. In addition power distributions and neutron flux in various locations for experiments are obtained for several cores reloaded with new fuel. The new MCNP model has been recently extended to characterize neutron and photon fluxes in beamports and other experimental locations. The model was also modified to be consistent with modifications made to the reactor for new experiments added, or being added, to the facility.

Title: Development of Computational Models for Simulation of UFTR

Objective: To computationally characterize the UFTR in support of its utilization in experimental work.

Status: Completed

Explanation: A coarse mesh transport engine (COMET) is currently under development at the Georgia Institute of Technology for 3D whole core calculations in thermal and fast power reactors. The current version of the code was to be modified to accommodate research reactor configurations such the UFTR. Most of the effort in this project was spent on identifying the coarse mesh structure/grid and on generating MCNP multigroup cross sections for the unique coarse meshes in the UFTR grid using the HELIOS transport code. This work was almost completed except for some bladed regions due to some limitations in HELIOS. The next steps are (1) to use the cross sections in MCNP to generate response functions expansion (RF) coefficients for use in COMET and (2) to modify COMET to handle the UFTR geometry and perform the core calculations using the RFs.

4) Intra-Consortium Integration

Title: Flux Maps in the University of Maryland 250 kW TRIGA Reactor: Monte Carlo Simulations and Experiment

Objective: Use Monte Carlo simulations to characterize the UMRR in support of its utilization in experimental work.

Status: Completed

Explanation: A complete model of the UMTR was created to determine the optimum configuration of the thermal column irradiation facility. The impacts of variations in graphite thickness, cadmium shields, lead and tungsten gamma shields, as well as light and heavy water moderating blocks were studied. The resulting data were used to assist UM students prepare for thermal neutron irradiations inside the thermal column. Several variations on this facility have been proposed and neutron spectra as well as dose equivalent rates for neutrons and gammas have been calculated.

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B. Funding Allocation and Execution:

Since September of 2007 the MUSIC consortium has operated on a no cost extension until September 2010. No further funds were allocated to this project beyond what was reported in the year-4 annual report. The subcontracts between NCSU and the other universities have ended and the primary project at NCSU has been closed.

II. Cumulative Report

A. Educational Enhancements

Title: Training and Education Modules in Nuclear Engineering

Explanation: The development of educational modules was continued during the fourth year. This includes the module utilizing the biological laboratory that was established at the Maryland reactor. Collaboration in this area was initiated within the University of Maryland and with Georgia Tech. The activities within the scope of this task resulted in the publication one articles in a peer reviewed journal and one invited presentation before the American Nuclear Society. The articles are cited below:

1. C-K Chris Wang, Xin Zhang, Ian Gifford, Eric Burgett, Vincent Adams, and Mohamad Al-Sheikhly, “Experimental Validation of the New Nanodosimetry-Based Cell Survival Model for Mixed Neutron and Gamma-Ray Irradiations” Physics in Medicine and Biology, 52, N367-N374, (2007)
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Explanation: The nuclear instrumentation laboratory became a routine offering as part of the USC nuclear engineering curriculum. The students are able to perform the laboratory exercises remotely by taking remote desktop control of the laboratory computers on which the spectroscopy software resides. This includes experiments in gamma-ray spectrometry using germanium and sodium iodide detectors, alpha spectroscopy measurements and an exercise in beta counting. Currently, discussions are underway to explore transferring the experience to other USIC and INIE members.

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Explanation: This project established, and continues to improve, an internet based A/V and data link between The University of Tennessee (UT) and the PULSTAR reactor at North Carolina State University (NCSU). A virtual interface of the PULSTAR reactor is developed and is used to display reactor related readings and the status of key components. Remote reactor experiments performed on the PULSTAR reactor to date include: reactor startup, approach to critical, rod calibration by an incremental method, rod calibration by inverse kinetics, temperature coefficient of reactivity, heat balance calibration of neutron detectors, and flux mapping. A neutron scattering experiment is being explored, and a neutron imaging experiment is under consideration. An added capability of direct online time-dependent measurements is functional and is being used during experiments. These experiments are offered as part of a nuclear engineering laboratory class at UT, where the current class size at UT is 30. It is expected that research-based experiments will be included during the next fiscal year. This capability is also established between Georgia Tech (GT) and NCSU. Specifications for establishment of this capability were transferred to one more university, but it is currently not implemented. International implementation has bee initiated.

B. Research Innovations

Title: Boron-(or Gadolinium-) Enhanced Neutron Brachytherapy

Explanation: This project focused on two aspects: first, to study the response of V79 hamster cells exposed with mixed field of fission neutrons and gamma rays, and second to evaluate the enhanced cell-killing effect on human prostate cancer cells due to 10B in a thermal neutron field. The first part has been completed. The second part remains incomplete due to the delay of remodeling of University of Maryland Training Reactor (MUTR) thermal column.

Title: Flux Maps in the University of Maryland 250 kW TRIGA Reactor: Monte Carlo Simulations and Experiment

Explanation: A complete model of the UMTR was created to determine the optimum configuration of the thermal column irradiation facility. The impacts of variations in graphite thickness, cadmium shields, lead and tungsten gamma shields, as well as light and heavy water moderating blocks were studied. The resulting data were used to assist UM students prepare for thermal neutron irradiations inside the thermal column. Several variations on this facility have been proposed and neutron spectra as well as dose equivalent rates for neutrons and gammas have been calculated. In addition, Measurements were performed in the University of Maryland Irradiation facilities. Two positions of interest were investigated. The west neutron beam port was investigated as a fast irradiation facility. Neutron spectral measurements were made outside the reactor using a Bonner Sphere Spectrometer and a silver foil spectrometer. Integral dose measurements were made using a Tissue

Equivalent Proportional Counter (TEPC) as well as gamma dose rate measurements to further characterize the radiation field outside the reactor core at 100 kW and 250 kW. The thermal column irradiation facility was investigated prior to the design and insertion of a new cell culture incubator. Here, threshold foil activations were made to measure the thermal, epithermal and fast neutron fluence rates at 100 and 250 kW. A limited set of Bonner Sphere Spectrometer measurements were made to cover the neutron spectrum in the thermal column.

Title: Intense Positron Beam for Advanced Materials Research

Explanation: Work continued on the set up and implementation of the second generation intense positron beam at the NCSU PULSTAR reactor. Testing of the positron beam in beamport #6 of the PULSTAR reactor was successfully completed. A slow positron rate of $6x10^8$ e+/s was measured. This rate matches and exceeds those reported in other facilities worldwide. The associated spectrometers are now complete and undergoing testing. Initial utilization of the facility has started.

Title: Advanced System for Normal and Phase Contrast Imaging with Neutrons

Explanation: The work continued on testing the neutron imaging facility at the PULSTAR reactor. Various applications were tested including imaging of plants and fuel cells. In addition, work continued on the implementation of phase contrast neutron imaging techniques. A special pin-hole collimator was designed and inserted into the original beam-line of the imaging facility. Currently, measurements using the pin-hole collimator are being performed. The neutron imaging facility was completed.

Title: A Source of Ultra-Cold Neutrons at NCSU

Explanation: During the fourth year significant progress was achieved for this project. Major components of the He liquefier system have been received. Currently, testing of this system is scheduled for early 2008. In addition, work is underway to finalize the coating procedures for the UCN guides. Various possibilities are being considered including Ni-58, Ni-Mo alloys and Diamond like coatings. The safety evaluation is also progressing with the intention of obtaining on-campus safety approvals in mid 2011 and submitting a safety evaluation to the NRC before the end of 2011.

Title: Neutron Diffractometer at the PULSTAR

Explanation: A new collimator system was installed that reduced the background noise by a factor of 4. Additional background shields were installed around the sample location that resulted in further reduction in background. Currently, final modifications are underway to bring the background level of the setup to less than 5 counts/second. Recent measurements have shown a neutron flux at the sample location of nearly 0.5 x 10^5 n/cm^2.s, which is comparable to the fluxes reported at other more powerful reactors. Measurements for materials characterization have started with first measurements being on reactor-grade graphite to understand its structure for irradiated and unirradiated conditions. A new rotating-oscillating collimator was installed. In addition, the signal to noise ratio has been optimized.

C. Infrastructure Improvements

Title: Characterizations of University Research Reactor Irradiation Facilities

Explanation: Measurements were performed in the University of Maryland Irradiation facilities. Two positions of interest were investigated. The west neutron beam port was investigated as a fast irradiation facility. Neutron spectral measurements were made outside the reactor using a Bonner Sphere Spectrometer and a silver foil spectrometer. Integral dose measurements were made using a Tissue Equivalent Proportional Counter (TEPC) as well as gamma dose rate measurements to further characterize the radiation field outside the reactor core at 100 kW and 250 kW. The thermal column irradiation facility was investigated prior to the design and insertion of a new cell culture incubator. Here, threshold foil activations were made to measure the thermal, epithermal and fast neutron fluence rates at 100 and 250 kW. A limited set of Bonner Sphere Spectrometer measurements were made to cover the neutron spectrum in the thermal column.

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Explanation: A new MCNP model for the NCSU PULSTAR reactor is developed that provides considerable flexibility for evaluating reactor core performance and for characterizing neutron and photon environments at essentially any location in the facility. In particular the new model utilizes a new feature of MCNP5 that permits objects to be represented as macrobodies that can be translated and imbedded in other geometric units. In addition, software for coupling results from MCNP with depletion calculations obtained from ORIGEN is written. Results from these codes are used for the determination of fuel composition and power distributions as a function of burnup and for characterizing conditions of experiments in the facility. Results from calculations for the reactivity of the core as a function of burnup agree well with measurements. Changes in fuel and reflector configurations are included in the computational sequence of calculation for comparison with historical data. In addition power distributions and neutron flux in various locations for experiments are obtained for several cores reloaded with new fuel. The new MCNP model has been recently extended to characterize neutron and photon fluxes in beamports and other experimental locations. The model was also modified to be consistent with modifications made to the reactor for new experiments added, or being added, to the facility.

Title: Development of Computational Models for Simulation of UFTR

Explanation: A coarse mesh transport engine (COMET) is currently under development at the Georgia Institute of Technology for 3D whole core calculations in thermal and fast power reactors. The current version of the code was to be modified to accommodate research reactor configurations such the UFTR. Most of the effort in this project was spent on identifying the coarse mesh structure/grid and on generating MCNP multigroup cross sections for the unique coarse meshes in the UFTR grid using the HELIOS transport code. This work was almost completed except for some bladed regions due to some limitations in HELIOS. The next steps are (1) to use the cross sections in MCNP to generate response functions expansion (RF) coefficients for use in COMET and (2) to modify COMET to handle the UFTR geometry and perform the core calculations using the RFs.

D. Partnerships with DOE labs, colleges and universities, utilities, and other public/private entities

MUSIC created several partnerships with national laboratories including the National Institute of standards and Technology and Oak Ridge National Laboratory. The motivation for these partnerships is the formulation of joint projects (in areas such as neutron science) and the facilitation of the transfer of technology to/from the university from/to the laboratory. This has been a strong success of INIE and is beginning to play a visible role in strengthening nuclear engineering research and education within the institutions comprising MUSIC.

E. University Commitment

No university cost sharing was recorded during the past 4 years.

F. Leveraging

INIE LEVERAGING		
Actual Expenditures	**Source**	**Amount**
1. Personnel (at MUSIC reactors)		$600,000
2. Student Support	NCSU	$50,000
3. Equipment	NSF	$300,000
4. Facilities		
5. Travel		
6. Other		
7. Cost Share		
Total		$950,000
In-Kind Contributions		
1. Personnel		
2. Student Support		
3. Equipment		
4. Facilities		
5. Travel		
6. Other		
Total		

G. Minority Student Involvement in INIE

This activity is initiated through the involvement of South Carolina State University with MUSIC. It will be further strengthened once the sub-contract is established. However, at all MUSIC institutions, outreach programs are currently in place to address this issue.

	06-07	04-05	03-04
BS students			
Minorities	10	16	16
Females	10	10	9
MS students			
Minorities	2	2	2
Females	3	3	3
PhD students			
Minorities	3	2	2
Females	2	3	2

H. INIE Impact

INIE had a major impact on nuclear engineering in general and research reactors in particular. Through INIE funding we were able to start research projects at the reactors that would not otherwise have been started. Consequently, this resulted in engaging faculty and students that otherwise would not have been engaged. INIE also resulted in starting a dialogue with many national laboratories. In the case of MUSIC, we have actively engaged the National Institute of Standards and Technology, and Oak Ridge National Laboratory. In some cases, this resulted in joint university/national laboratory proposals that were submitted to funding agencies such NSF and NIH. Immediate successes at NCSU and for MUSIC are the positron and ultra-cold neutron projects that have been both funded by NSF (for 3 years each) at a level of $1.0M.

The impact of the above has been clear on the personnel with nuclear engineering programs at all MUSIC institutions. The level of student interest and our ability to attract them has increased substantially. The enthusiasm and moral of the staff has also risen to new levels that are demonstrated by improvement in the quality and quantity of their work.

While INIE funding may be regarded as “small”, in many instances it is providing key seed funding that allows our faculty and research staff to start projects, prove their feasibility, and then seek further funding. In fact, the real impact of INIE should be assessed a few years from now when the seeds that have been planted by DOE are starting to blossom in the form of major funding from other sources such as NIH and NSF.

III. Major/Notable Accomplishments

1. Title: Successful leveraging of INIE funding

Explanation: INIE funds were used as seed to start major projects at the NCSU PULSTAR reactor. Since the funding that was provided during the first 2 years of the INIE program was not enough to execute these projects, funding was sought and successfully obtained from the National Science Foundation to support the "Intense Positron Beam Project" and the "Ultra-Cold Neutron Source Project." Both projects are now funded at a level of $1.0M for three years and use a combination of INIE funding and NSF funding.

2. Title: Demonstration of the Shared Remote Use of University Reactors as Centers of Education and Research

Explanation: Through the implementation of modern internet based technology the University of Tennessee, Georgia Institute of Technology and North Carolina State University demonstrated a system that enables the use of the PULSTAR reactor by UT students and faculty in education and research. The system is internet based and allows for A/V and data links between the two campuses. To date, several internet based laboratory experiments have been executed between UT and NCSU. Plans are underway to implement the system at other MUSIC and non MUSIC universities. Clearly the system can also be implemented on reactor beam ports for use in remote research experimentation.

3. Title: Successful Intra-Consortium Academic-Academic and Academic-Laboratory Collaborations

Explanation: The structure and nature of the INIE program allowed for the emergence of a strong spirit of collaboration between MUSIC academic members and between the members and the national laboratory partners. These collaborations succeeded in producing several important achievements. An example is the collaborative research in radiobiology between Georgia Tech and University of Maryland, which resulted in improved utilization of the Maryland reactor. Another example is the collaboration between NCSU and ORNL on positron research that resulted in obtaining the NSF award. A similar collaboration with ORNL is currently being initiated in the area of neutron imaging. Furthermore, the collaboration between Tennessee, Georgia Tech and NCSU on internet based reactor experiments has launched a significant demonstration of the use of university reactors on a regional basis, which should be useful to all the reactors within INIE.