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Proposal for no-cost extension and re-scope for UNLV TRP Project: Neutron Multiplicity Measurements for the AFCI Program (Advanced Fuel Cycle Initiative)

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Proposal for no-cost extension and re-scope for UNLV TRP Project:
Neutron Multiplicity Measurements for the AFCI Program
(Advanced Fuel Cycle Initiative**)**

February 6, 2004

Principal Investigator (PI):	Prof. Denis Beller, Department of Mechanical Engineering, UNLV, 4505 S. Maryland Pkwy, Las Vegas, NV 89154-4027 (702) 895-0423, beller@egr.unlv.edu
UNLV Collaborators:	Prof. William H. Johnson (Graduate Student Supervisor) Department of Health Physics, UNLV Graduate Student (Steve Curtis, Health Physics) Graduate Student (TBD) Undergraduate Student (Dean Curtis, Computer Science) Undergraduate Student (TBD)
AFCI Program Laboratory Collaborator:	Dr. Eric Pitcher, AFCI Experiments, LANSCE-12, Los Alamos National Laboratory Dr. Stephen Wender, LANSCE-3 Group Leader, Los Alamos National Laboratory
Other Collaborators:	Dr. Thomas Ward, UNLV Russian Collaboration Science Adviser, TechSource, Inc., Gaithersburg, MD
AFCI research Area:	Accelerator-Driven Transmutation
Requested Funds:	~$52,000 Project Year 3 ~$92,000 Project Year 4

Abstract--The U.S. Advanced Fuel Cycle Initiative (AFCI) is a program to develop economic and environmental methods to reduce the impact of waste from commercial nuclear fuel cycles. One concept for near-complete destruction of waste isotopes from used nuclear fuel is accelerator-driven transmutation. High-power accelerators would be used to produce high-energy charged particles, which then collide with heavy metal targets to create a cascade of neutrons. These neutrons then cause a nuclear chain reaction in subcritical systems. Fission neutrons then transmute fissile waste isotopes as well as other problematic isotopes such as technetium-99 and iodine-129. To design these systems, complex reactor physics computer codes and highly detailed data libraries are used to compute the reactivity of systems, reaction rates, destruction rates, and nuclear-induced damage rates to materials. In this project, we will use a Russian-built detector system to make measurements of neutrons generated in a central target by a variety of accelerators. We will also use the most advanced high-energy radiation transport code, MCNPX, to model the experiments. Experimental results will be compared to computational predictions and discrepancies will be investigated. We will conduct experiments using a 70-MeV proton cyclotron at the Crocker Nuclear Laboratory at the University of California at Davis. We will also make measurements with a 20 to 40 MeV electron linac (linear accelerator) at the Idaho Accelerator Center at Idaho State University. Finally, we will use the 800-MeV linac at the Los Alamos Neutron Science Center at Los Alamos National Laboratory.

1. Proposed Work.

Remainder of Year 3 (through August 2004):

Feb.-May 2004: Prepare to conduct an experiment using the 70-MeV proton cyclotron at the Crocker Nuclear Laboratory at the University of California at Davis (UC Davis) or with a 20 to 40 MeV electron linac (linear accelerator) at the Idaho Accelerator Center at the Idaho State University (ISU-IAC). We will first verify operation of the 60-element, Russian-built target and ^{3}He detector system. We will then design the experiment, shielding, and other measurement and monitoring systems. During this preparation time, we will predict performance of the beam/target as well as background radiation and other radiation fields. We will also make arrangements for beam time at the selected location and make arrangements for transportation of target/detector system.

Jun.-Aug. 2004: Complete planning and preparation for an experiment, move the detector to ISU or UC Davis, set up the experiment, then execute it. The remainder of the summer will be used to analyze the results and prepare a report. In this report we will compare measurements to computational predictions and begin the examination of discrepancies.

Year 4 (through August 2005):

Sep.-Nov. 2004: Prepare to conduct an experiment at the university that was not visited during the second half of Year 3. In addition, we will simultaneously be making plans to conduct an experiment on the 800-MeV linac at the Los Alamos Neutron Science Center at Los Alamos National Laboratory (LANSCE).

Dec. 2004-Feb. 2005: Conduct the experiment at the other university (complete planning and preparation for an experiment, move the detector to ISU or UC Davis, set up the experiment, then execute it). The results will be analyzed and a report will be prepared. In this report we will compare measurements to computational predictions and begin the examination of discrepancies. In addition, an oral report will be presented at the Semi-annual AFCI Technical Review Meeting in February.

Mar.-May 2005: continue planning for the LANSCE experiments. Make plans for transporting the detector. Continue analysis of discrepancies, studies of potential modifications to the detector system.

Jun.-Aug. 2005: Conduct the experiment at Los Alamos (complete planning and preparation for an experiment, move the detector to LANSCE, set up the experiment, then execute it). The results will be analyzed and a M.S. thesis will be prepared that describes computational predictions and measurements results. Examination of discrepancies and their resolution may become a topic for a Ph.D. dissertation in a future project. In addition, an oral report will be presented at the Semi-annual AFCI Technical Review Meeting in August. In this report we will compare

2. Background and Rationale:

Accelerator-driven transmutation systems require a low level of uncertainty at a high confidence level for modeling of neutron generation and transport in complex massive targets, especially in view of the fact that the target will be coupled to a sub-critical multiplier. Higher uncertainties require engineering design margins that increase cost and risk of accelerator-driven systems. The MCNPX Monte Carlo radiation transport code is used with nationally certified data libraries of reaction rate parameters (cross sections) to predict the performance of systems. Much of the uncertainty associated with these computations is thought to be due to multiple scattering and leakage of high-energy neutrons and protons in the radial directions of thick (to neutrons) targets. Additionally, measurements have never been performed over the entire volume of the target where the neutron source is created (the "source term volume"), and no reliable method has been proposed as yet that could measure, validate, and benchmark the code calculations of such a source term volume. Previously in this project, a neutron detector system was designed in collaboration with the Khlopin Radium Institute (KRI) in St. Petersburg, Russia. The system was then constructed at the KRI and shipped to UNLV.

In the remainder of this project, we will use this detector system to make measurements of neutron generation in many different energy ranges: from tens of MeV up to 70 MeV and also at 800 MeV. At the lowest energy, few multi-neutron events will be detected. As the source energy increases, we should see increasing numbers of (n,2n), (n,3n), (n,4n), …. (n,xn) reactions. Careful analysis of these experiments should enable the quantification of systematic errors of the code systems. The detector system makes use of a 60-detector array, which will allow the correlation of the neutron multiplicity to each event. The detectors system is constructed from ^{3}He gas proportional counting tubes and a "polythene" moderator (polythene is a Russian formulation of polyethylene).

Neutron counting tubes filled with ^{3}He pressurized gas have been used for many years. These detector systems can operate at ~1 microsecond timing resolution and 256 microsecond duration. A 60-element ^{3}He-based detection system should be capable of measuring multiplicities up to ~200 neutrons per event. ^{3}He tubes are somewhat configurable with polyethylene moderator, which allows the detector system to be modular in design in order to accommodate various target designs. ^{3}He neutron detection systems have been well characterized during decades of applications; however, they are count rate limited (10-100 events per second or 1000-10,000 neutrons per second) with limited position sensitivity and relatively slow response and signal processing times. Regardless, they remain the largest installed base of neutron detector systems.

3. Research Objectives & Goals (to project completion)

The ultimate goals of this measurement project are to measure the neutron leakage and (n,2n), (n,3n), (n,4n), and higher multiple-neutron generation events from a lead target at several source-particle energies. In addition, the measurements will be compared to predictions based on sophisticated and internationally accepted radiation transport code MCNPX.

4. Technical Impact

Neutron multiplicity measurements are of major interest to spallation neutron projects such as AFCI, SNS, MUSE, MEGAPIE, and TRADE. Therefore, this project could add greatly to understanding of phenomenology of multiple-neutron generation. Operation of transmutation systems near critical (k_{eff} near 0.99) requires very accurate design parameters. These measurements will provide valuable data for validation and benchmarking the MNCPX code and associated cross section libraries.

5. Research Approach

- Immediately begin planning for experiments at UC Davis, ISU-IAC, and LANSCE.
- Verify operation of the detector system.

- Investigate requirements for modification of electronics for triggering circuits for different accelerator systems/sources.

6. Capabilities at UNLV, Other Universities, and International Laboratories

UNLV: The Harry Reid Center for Environmental Studies (HRC) will provide laboratory and office space as well as Internet connections for the PI, one graduate student, and one undergraduate student during the duration of this project. The detector system is currently located within a detector laboratory in the HRC. Dean Curtis, an undergraduate student who has been with the project since its initiation, uses a three-year-old personal computer to execute the MCNPX code for design and analysis.

Prof. Denis Beller is a Research Professor in the Mechanical Engineering Department at the University of Nevada, Las Vegas. He is also a Visiting Research Professor and the national Director for the AFCI Reactor-Accelerator Coupling Experiments Project (RACE) at the Idaho State University, with responsibility for overall design, planning, execution, and budget. He will serve as Principal Investigator for this project. Prof. Beller has a long career in nuclear engineering, reactor physics, systems analysis and radiation effects.

Dr. William Johnson is a Professor in the Health Physics Program in the School of Health and Human Sciences at UNLV. He advises a second graduate student who does not receive a stipend because of his full-time employment with the U.S. DOE.

Dr. Steve Wender is the Director of the Neutron and Nuclear Science Group at LANSCE. He is responsible for fielding experiments.

Dr. Eric Pitcher is a nuclear engineer at LANSCE at the Los Alamos National Laboratory. He directs and conducts experiments for measuring reaction cross sections.

7. Project Timetable and Deliverables

Work under the re-scoped project will begin in March 2004 with planning for experiments at ISU and/or UC Davis. This project will involve moving the detector system and conducting experiments at three other locations approximately in June and December 2004 and June 2005. Technical reports and/or theses will be written on each experiment. During the year, meetings may include one or two AFCI Semi-annual Technical Program Reviews, working group meetings, and possibly others. Participation in some of these meetings will be necessary for the PI and student to learn from and work with other collaborators. Travel expenses for the PI will be shared with or completely covered by other AFCI tasks. Because of the many meetings of AFCI participants from eight national laboratories and thirty universities, a $1,000 travel contingency is included in the budget each quarter.

Time Schedule and Major Milestones

	Year 3						Year 4											
	Qtr 3			Qtr 4			Qtr1			Qtr2			Qtr 3			Qtr 4		
TASKS	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1. Prepare for exp.	X	X	X	X	X													
2. Conduct exp.					X													
3. Report on exp.						X												
4. Prepare for exp.							X	X	X	X								
5. Conduct exp.										X								
6. Report on exp.											X	X						
7. Prepare for exp.								X	X	X	X	X	X	X	X	X		
8. Conduct exp.																X		
9. Report on exp.																	X	X
10. Quarterly reports				1			2			3			4			5		6
11. Semi-annual Report							1						2					3
12. Oral AFCI Semi-annual Review						1						2						3
13. Annual report draft							X											
14. Draft of final report																		X
Trips	1	2			3			4		5				6		7 8		

Trip Explanation	
Trip 1	Familiarization
Trip 2	Experiment preparation, ISU or UC Davis
Trip 3	Conduct experiment, 1 week, PI and undergrad student, ISU or UC Davis
Trip 4	Experiment preparation, ISU or UC Davis
Trip 5	Conduct experiment, 1 week, PI and grad student, ISU or UC Davis
Trip 6	Experiment preparation, LANSCE
Trip 7	ANS Conference, grad student
Trip 8	Conduct experiment, 1 week, PI and grad student, LANSCE
Other	PI trips to conferences and meetings will be shared or funded by other projects

(Work is assumed to begin March 1, 2004).

Abbreviated Curriculum Vitae
Dr. Denis E. Beller

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Las Vegas, NV 89154-4027

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Education

Ph.D., Purdue University, May 86, (areas: nuclear engineering, reactor physics, fusion)
M.S. in Nuclear Engineering, Air Force Institute of Technology, March 81, (Honors)
B.S. in Chemical Engineering, University of Colorado, May 76, (Honors)

Current Occupation

Research Professor — July 03 to present

Department of Mechanical Engineering, University of Nevada, Las Vegas, NV

Conduct nuclear criticality analysis, radiation transport and shielding, and thermal analysis for developing separations processes for recycling used fuel for the Advanced Fuel Cycle Initiative of the U.S. Department of Energy. Write research proposals, counsel students, write reports.

Visiting Research Professor — July 03 to present

Idaho Accelerator Center, Idaho State University, Pocatello, ID

Direct the Reactor-Accelerator Coupling Experiments project at ISU, University of Texas at Austin, and Texas A&M University for the Advanced Fuel Cycle Initiative of the U.S. Department of Energy. Plan the experimental program; conduct nuclear criticality analysis, radiation transport and shielding, and safety analysis; supervise post-docs and students. Direct national efforts and integration with international programs.

Principal Nuclear Engineer — July 03 to present

TechSource, Inc., Santa Fe, NM

Develop university programs and intercollegiate collaborations for the U.S. Advanced Fuel Cycle Initiative of the U.S. Department of Energy. Plan workshops, initiate collaborations between university researchers and laboratory technical specialists.

Previous Experience

Transmutation Research Project Intercollegiate Collaborations Leader — April 01 to July 03

Harry Reid Center for Environmental Studies, University of Nevada, Las Vegas, NV

Coordinated intercollegiate collaborations between U.S. national laboratories, U.S. universities, and UNLV and Idaho State University for participation in the Advanced Fuel Cycle Initiative of the U.S. Department of Energy. Arranged research programs, reviewed and recommended funding levels, recruited faculty and students, reported successes. Co-PI on AFCI research projects ongoing at UNLV, visiting research professor at ISU's Idaho Accelerator Center.

Technical Staff Member Apr 98 to March 01
Los Alamos National Laboratory (University of CA), Los Alamos, NM

As LANL ATW, AAA, and AFCI University Programs Leader, coordinated research projects among several laboratories and universities that annually supported more than 100 students nationwide. Managed seven LANL-funded university research contracts for the LANL AFCI Program Office. As Technical Staff Member in Systems Engineering and Integration, analyzed systems related to long-term national and global deployment of nuclear energy in conjunction with LANL's AAA program and Nuclear Materials Management Systems projects. Key contribution to DOE's Roadmap for Accelerator Transmutation of Waste. Analyzed thorium-uranium fuel cycle coupled to accelerator-driven transmutation of waste; demonstrated resource savings, reduction of proliferation risk, and greatly reduced waste for permanent disposal. Primary Investigator on DOE Nuclear Energy Research Initiative project to investigate Direct Energy Conversion Fission Reactors. Adjunct professor with Purdue University's School of Nuclear Engineering.

Consultant, Nuclear Technology and Education, Bellbrook, OH, 1995-1998: Advised Lawrence Livermore National Lab on the design of a system for neutron effects testing: established requirements, developed innovative design, performed radiation transport computations to demonstrate neutron physics and material feasibility. Coordinated work of scientists and engineers at three national laboratories. Developed public education program in conjunction with the American Nuclear Society. Created, planned, coordinated, and conducted activities of students and other volunteers to operate exhibits that provided nuclear information to more than one hundred thousand people.

Division Head, Information Exploitation, National Air Intelligence Center, Wright-Patterson AFB, OH, 1994: Managed more than 100 civilian and military personnel and an annual budget of $10 M for the Information Services Business Unit--provided information acquisition, storage, and retrieval and translation services in 45 languages for hundreds of customer organizations worldwide in the DoD, the CIA, and other U.S. agencies. Maintained capabilities during a 25% downsizing by reorganizing along product and service lines, reducing management, building quality teams and processes, and securing external funding to offset budget reductions.

Associate Professor of Nuclear Engineering, AF Institute of Technology, Wright-Patterson AFB, OH, 1986-1993: Taught Graduate Nuclear Engineering (nuclear weapons effects program); conducted and supervised research in computational radiation transport applied to defense issues. First military professor awarded tenure in AFIT's 70-year history because of teaching excellence (award), nationally recognized and published research, consulting, and faculty and professional activities. Developed concepts for simulation of nuclear weapons effects testing with inertial confinement fusion (ICF). Research was endorsed by National Academy of Science and DOE's ICF Advisory Committee, was included in DOE's Five Year Plan, and resulted in a decision (KD-0) for $1B construction of the National Ignition Facility. Acquired grants totaling more than $750k, established Nuclear Engineering Computation Laboratory.

Laboratory Manager, Gas Operations, McClellan Central Laboratory, McClellan AFB, CA,1981-1983: Supervised 3 scientists and 25 technicians and managed production environmental measurements laboratory responsible for radio-analysis of gaseous environmental samples from the U.S. Atomic Energy Detection System.

PUBLICATIONS AND PRESENTATIONS. Authored or co-authored fourteen archival publications in *Foreign Affairs, Inertial Confinement Fusion, Journal of Radiation Effects Research and Engineering, Fusion Technology, Nuclear Instruments and Methods—A*, and *Nuclear Science and Engineering*; plus numerous proceedings and classified reports. Gave presentations (many invited) at international conferences (in the U.S., Russia, Korea, and England), to Congressional Staffers and State Legislators, joint DoD/DOE meetings, and public and academic forums.

COMPUTER SOFTWARE & HARDWARE. Installed and/or used many radiation transport codes, radiation hydrodynamics (LASNEX), mathematics, accounting, word processing and presentation, and graphics. Have used IBM, VAX, Cray, Cyber 205, Sparcstation, and PC computers; UNIX, VMS, COS, Sun OS, Windows, and DOS operating systems.

SCIENTIFIC AND PROFESSIONAL SOCIETIES, OTHER ORGANIZATIONS.

American Nuclear Society, Chairman, Public Information Committee
Accelerator Applications Division (ANS), Member of the Executive Committee
Eagle Alliance (pro-nuclear activist organization), Member of the Board of Directors, 2nd V.P.
Tau Beta Pi (national engineering honor society)

SECURITY CLEARANCE. DOE "Q" clearance. Previous DoD Top Secret/SBI (SCI).

PERSONAL. Happily married, excellent health, love to travel and fly fish.

Some of my archival publications (title and source only):

"Atomic Time Machines," *Journal of Land, Resources, and Envir. Law*, 2004 (in publication)

"Reports of DEC's Death 'Greatly Exaggerated,'" *Nucl. Engr. Int'l, 46,* 569, (2001)

"A Roadmap for Developing ATW Technology: System Scenarios & Integration," *Progress in Nuclear Energy*, 38, 1-2 (2001)

"The U.S. Accelerator Transmutation of Waste Program," *Nucl. Instr. and Meth.--A 463*, (2001)

"Disposition of Nuclear Waste Using Subcritical Accelerator-Driven Systems: Technology Choices and Implementation Scenarios," *Nucl. Tech. 132*, 1 (2000)

"The Need for Nuclear Power," R. Rhodes and D. Beller, *IAEA Bulletin, 42*, 2 (2000)

"The Need for Nuclear Power," R. Rhodes and D. Beller, *Foreign Affairs, 79*, 1, (2000)

"Contributions of the National Ignition Facility (NIF) to ICF Weapons Effects Testing in the Laboratory Microfusion Facility," *Journal of Radiation Effects Res. and Engr., 12-1A*, (1994)

"Parametric Design Study of a Nuclear-Pumped-Laser-driven Inertial Confinement Fusion Power Plant," *Laser and Particle Beams, 11*, 3 (1993)

"Use of Inertial Confinement Fusion for Nuclear Weapons Effects Simulations," *Inertial Confinement Fusion, 2*, 4 (1992)

"Initial Investigation of the Feasibility of Antiproton-Catalyzed Inertial Confinement Fusion," *Fusion Tech., 20,* No. 4, part 2, (1991)

"Conceptual Design and Neutronics Analyses of a Fusion Reactor Blanket Simulation Facility," *Nucl. Science and Engr., 97*, 3 (1987)