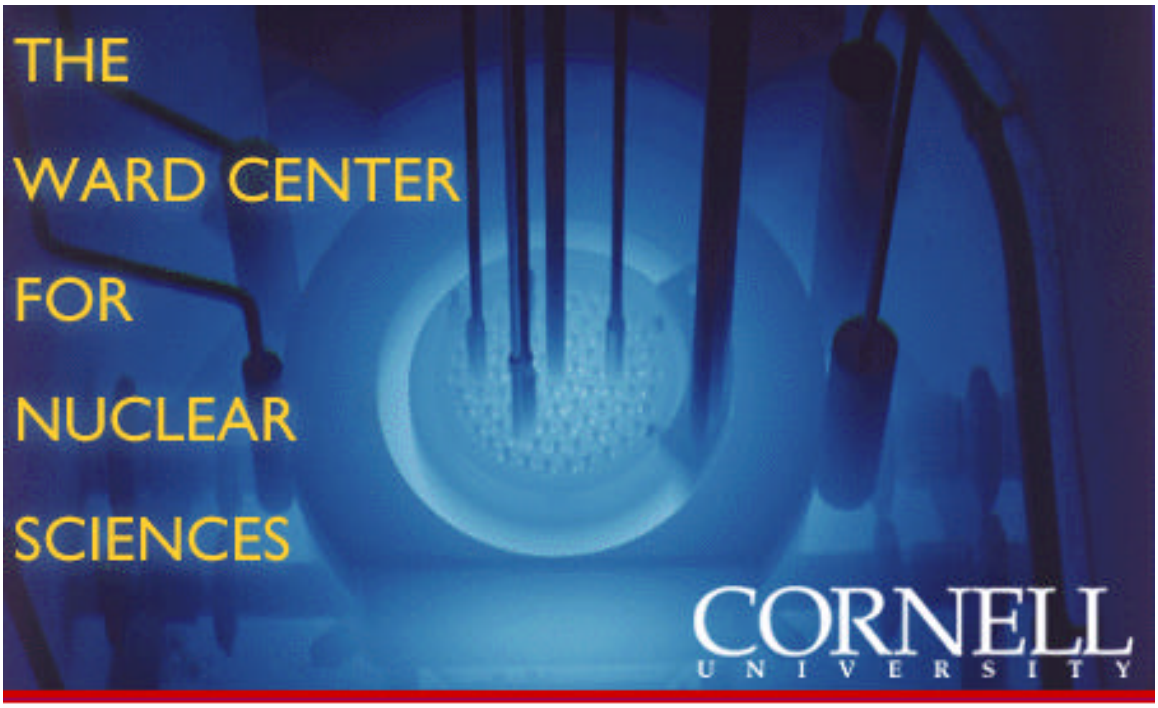

The Ward Center for Nuclear Sciences Report

The Executive Committee of WCNS
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Ward Center for Nuclear Sciences Report

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Executive Summary

The Ward Center for Nuclear Sciences was established by the University Senate and the Board of Trustees in December 1996 as a University research, service and teaching laboratory open to all members of the University Community. The reason for this establishment was diversity; the use of the laboratory is much wider than engineering and the applied sciences; it includes the social sciences, humanities and the arts. Over recent years, the Center has provided teaching and research facilities for seven of Cornell's Colleges: Engineering; Arts and Sciences; Architecture, Art and Planning; Human Ecology; Hotel School; Agriculture and Life Sciences; and Veterinary Medicine. Students across the University use Ward Center facilities, and the Center provides for-profit nuclear services to eight upstate New York companies. The Ward Center houses the only university research reactor in New York, and is one of only 15 active university research reactors in the U.S.

The appended report documents the research, instruction and service activities of the Ward Center for Nuclear Sciences for the past two years. As such, it represents factual background relevant to Cornell's current deliberations about the future of the Center. Additionally, it serves as the report mandated by the Faculty Senate when it endorsed creation of the Ward Center in December 1996.

Two years ago, after a national search, the current director, Dr. Kenan Ünlü was recruited from the University of Texas at Austin. The main task of the new director was to widen the use of the Center at Cornell for teaching and research, to bring on line new experimental and service facilities, to attract federal funding for new initiatives, and to provide increased service activities to corporations, government agencies, and academic institutions.

The utilization of Ward Center facilities in teaching, research and service activities, federal grants received, the operating budget of the center, the status of research programs, and other activities are presented in the following report. Also, an analysis of the future of nuclear research reactors in the US and at Cornell are provided. The highlights of the above activities are:

• The Center provided semester long laboratory experiments for graduate and undergraduate students in NS&E 551, NS&E 403 (also A&EP 403, ELE 403 and M&AE 458) and NS&E 121 (also A&EP 121 and ENGR 121) courses, laboratory sessions for Physics 208 (~200 students per year), MS&E 603,and MS&E 571 (20 students) and Art, Archeology and Analysis courses (PHYS 200, GEOL 200, ENGR 185, MS&E 285, ARKEO 285, and ART 372) (~75 students) and Laboratory tours for Engineering 150 students (~ 175 students). Also, students from area high schools and universities visit and use the center facilities.

• The Center facilities are used for research activities by a diverse group of Cornell faculty, staff and students. Some utilize the Center facilities continually and others are occasional users. For FY 98/99, 10 faculty members from eight different

departments and four different colleges used the Center. For FY 99/00 the number of faculty and staff using the center was 17. They are from 12 different departments and four different colleges.

• Several corporations utilize Center facilities for a variety of research, testing and development applications. The primary corporate users of the Center are companies based in upstate New York. These companies include Imaging and Sensing Technologies, Eastman Kodak, Corning, Cosense, CIDTECH, Syracuse-Bio and a government laboratory, Knolls Atomic Power Laboratory. Other major users are Intersil and Westinghouse corporations, located in Pennsylvania. Center facilities are also used by corporations based in Maryland, Idaho, California, and Connecticut.

• The Center's federal funding was $3,000 in 97/98. The total amount of federal funds increased to $29,495 in 98/99, $421,450 in 99/00 and $622,843 in 00/01. Currently, three proposals are pending for a total of $971,367.

• The Center's operating budget is ~$500K per year. The operating budget includes salaries of the Director and the staff (80-85%) and operating expenses (15-20%). The income generated or received for the Center's budget consists of University contributions, external user fees, sponsored funds, Ward endowments and internal user fees. The university contribution has only been $200K yearly since the establishment of the Center (1996/97). While the University contribution stayed at the same level over the last four years, income from external users and sponsored funds has increased steadily to defray the cost of salary improvement program and other expenses. The Center can be considered financially independent of the University, if the Center is credited with the overhead it generates and the teaching and research services it provides to the university faculty.

• A new Neutron Activation Analysis (NAA) laboratory for dendrochemistry applications has been established with NSF funds, an Eastman Kodak gift, and Ward Center funds. A collaborative/multidisciplinary study has begun with eight Cornell scientists seven students, and a technician. A proposal to analyze several thousand years of absolutely-dated tree rings from the Aegean Dendrochronology Project's archives in order to investigate signatures of environmental stress has been submitted to NSF ($589K).

• A conventional Neutron Depth Profiling (NDP) facility has been developed to measure depth versus concentration of some light elements in semiconductor metals and alloys. The components of the conventional NDP systems are being tested. With recent research funds from DOE a time-of-flight NDP will be developed. This facility will be the first TOF-NDP facility in the world.

• Relocating the current neutron radiography system to a permanent facility location and completion of a cold neutron source prompt gamma activation analysis facility is now possible due to recent funding from DOE and the Electric Power Research Institute and by the recruitment of two new graduate students.

• Development of a portable cold neutron irradiator using Cf-252 source proposal is pending. The development and applications of Neutron Induced Auto-Radiography and Boron Neutron Capture Therapy are in the pre-proposal stage.

We believe the formation of the Center four years ago as a university-wide facility has been an unqualified success that has allowed new facilities, new users, better funding, and a bright future for nuclear sciences at Cornell.

Background

The central mission of the Ward Center for Nuclear Sciences (WCNS) is to provide safe analytical and testing facilities for the research and education activities of faculty, staff and students at Cornell University. Its resources are also available to users outside Cornell as part of the public service functions of the University, symbolized by its status as the Land Grant University of the State of New York.

The construction of Ward Laboratory was completed in 1960, and the TRIGA reactor achieved criticality on January 12, 1962. Initial reactor power was 100 kWt. The power level increased to 500 kWt in steady state and in pulse operation in 1983. The Ward Laboratory was built using funds from the National Science Foundation, the Atomic Energy Commission (now DOE) and J. Carlton Ward, an alumnus. The largest facilities at the WCNS are TRIGA Mark II Pulsing Nuclear Research Reactor and a Cobalt-60 Gamma Cell. There are also several radiation detection and measurement facilities available at the Center. The Cornell TRIGA has been extensively utilized during the last 38 years of operation by a diverse group of users within Cornell University, by governmental institutions, and by industrial companies. Instruction and research activities were first initiated in the field of Nuclear Engineering at Cornell's School of Applied Engineering Physics and then as the Nuclear Science and Engineering Program. The Ward Laboratory at Cornell, which houses the Cornell TRIGA reactor, became the Ward Center for Nuclear Sciences in January 1997. With the approval of the Cornell Board of Trustees, the Ward Center became a unit under the Vice Provost for Research. This administrative change makes the Cornell TRIGA reactor the core of a true university-wide research and teaching facility to provide interdisciplinary teaching and research capabilities to students and faculty in all colleges at Cornell.

The Cornell TRIGA reactor is the only operating university research reactor in the State of New York. The Cornell TRIGA is used as a source of radiation for numerous nuclear analytical and testing facilities. These facilities include: Neutron Activation Analysis, Fast Neutron Irradiation, Neutron Radiography, Neutron Induced Auto-Radiography, Cold Neutron Source, Prompt Gamma Activation Analysis (near completion), and Neutron Depth Profiling (near completion). In addition the development of a Boron Neutron Capture Therapy facility and a Neutron Powder Diffractometer facility are planned. Recently we completed a new neutron activation analysis laboratory with NSF funds for the analysis of dendrochronologically dated tree rings for the identification of volcanically-influenced periods of environmental change.

The academic program for nuclear sciences is organized under the graduate field of Nuclear Science and Engineering, and offers M. Eng., M.S. and Ph.D. degrees. The Cornell TRIGA reactor is utilized by the graduate programs both in courses and in design and research projects.

TRIGA Mark II Research Reactor

The TRIGA (Training, Research, Isotope production, General Atomics) Mark II nuclear reactor is the largest and most versatile facility in the center. The TRIGA Mark II reactor is an inherently safe research reactor that meets the requirements for education and research usage. Cornell TRIGA is an aboveground fixed-core research reactor. The nuclear core containing 84 fuel elements (~20% enriched, UZrH with stainless steel cladding) is located at the bottom of a 25-foot deep water-filled pool surrounded by a concrete shield structure. Approximately 21,000 gallons of purified water in the pool serves as the reactor coolant, neutron moderator, and a transparent radiation shield. Visual and physical access to the core is possible at all times.

The Cornell TRIGA research reactor can operate at power levels up to 500 kWt at steady state or in the pulsing mode where powers as high as 1000 MWt can be achieved for short times of about 10 msec. The power level of the Cornell TRIGA is controlled by four control rods. Three of these rods are sealed stainless steel tubes containing powdered boron carbide. The fourth control rod, the transient rod, is a solid cylinder of borated graphite clad in aluminum operated by pneumatic pressure to permit pulse operation. The sudden ejection of the transient rod produces an immediate burst of power.

Neutrons produced in the reactor core can be used in a wide variety of research applications including nuclear reactions studies, neutron scattering experiments, nuclear analytical and irradiation experiments. Cornell TRIGA has various in core and neutron beam facilities. In core radiation facilities include three dry tubes for neutron activation analysis, a central thimble which allows a sample to be inserted into the maximum flux region of the core and 1-MeV equivalent fast neutron irradiation facility at flat reflector surface of the core assembly.

Neutron beam tubes or ports are cylindrical voids in the concrete shield structure that allow neutrons to stream out away from the core. Experiments can be done inside the beam ports or outside the concrete shield in the neutron beams. Cornell TRIGA has seven horizontal beam ports, ranging from 4” to 8” in diameter and a 4’ x 4’ x 8’ graphite thermal column for source of well-thermalized neutrons. Currently, the following experimental facilities are developed or planned at the Cornell TRIGA beam ports; Neutron Radiography, Neutron Depth Profiling, Cold Neutron Source/Prompt Gamma Activation Analysis, Neutron Auto-Radiography (thermal column), Boron Neutron Capture Theory (planned), and Neutron Powder Diffractometer (planned).

Cobalt-60 Gamma Cell

The Gamma Cell is a dry irradiation facility, measuring 9' square by 12' high, that allows for the direct access of personnel into the experimental area through massive

hinged shield doors. The radioactive sources are stored in steel-lined wells in the cell floor and are attached to the bottom of concrete shield plugs that are raised with a one-ton overhead crane. Two manual, remote, mechanical manipulators are used to position the source pencils to provide the dose rate required while viewing the cell interior through a 3' thick lead-glass window. Twenty BNC cables are installed in the cell with an external patch panel provided at the cell control station. Access for additional instrumentation cabling is provided by three shielded 2" I.D. utility tubes. A removable concrete ceiling plug allows heavy objects to be placed in the cell utilizing a five ton crane associated with reactor operations.

The Gamma Cell contains three different sets of stainless steel encapsulated ^{60}Co source pencils of varying activities. The first source (circa1994) is comprised of 12 pencils and has an activity of ~5000 Ci of ^{60}Co. The second source (circa 1979) is comprised of 12 pencils and has an activity of ~650 Ci of ^{60}Co. The third source (circa 1962) is comprised of 20 pencils and has an activity of ~80 Ci of ^{60}Co. A ~40 Ci ^{137}Cs source is also available for irradiations requiring a source with lower energy gamma rays. Dose rates range from ~2 x 10^6 R/hr for small specimens (~1.2" O.D. x 3" long) positioned in the center of the source rack to < 1 x 10^4 R/hr for larger specimens at a distance of > 1 foot from the source. Activities and dose rates indicated above are current numbers (July 2000).

Gamma rays from ^{60}Co source used at Cornell in a wide variety of applications. These applications include irradiation of food, polymers and other materials; sterilization of soil, bovine serum, horse plasma; and testing of CCD cameras, radiation detectors, electronics and hardware for space applications, etc.

Utilization of Ward Center for Nuclear Sciences

A histogram of Mega Watt-hours Power Generation of Cornell TRIGA research reactor is given in Figure 1. The TRIGA power generation was 78.8 Mega Watt-hours in 1999 and 120.3 MegaWatt-hours in 2000. The Ward Center for Nuclear Sciences TRIGA nuclear research reactor and ^{60}Co-gamma cell facilities are utilized by faculty, staff, and students of Cornell, other academic institutions, government agencies and corporations. A summary of total operating time, number of irradiations, total experiments hours and the distribution of utilization within the users for TRIGA research reactor in 98/99 and 99/00 is given in Table 1. A detailed breakdown of TRIGA reactor usage in 98/99 and 99/00 is given respectively in Appendix A1 and Appendix A2.

Gamma Cell facility at WCNS are also utilized by Cornell users, other academic institutions/government agencies and corporations. A summary of total number of irradiations, total source use time, and the distribution of utilization within the users of ^{60}Co-Gamma Cell in 98/99 and 99/00 is given in Table 2. Details of Gamma Cell utilization can be found in Appendix B1 and B2 for 98/99 and 99/00 respectively.

Figure 1. Annual TRIGA Power Generation History

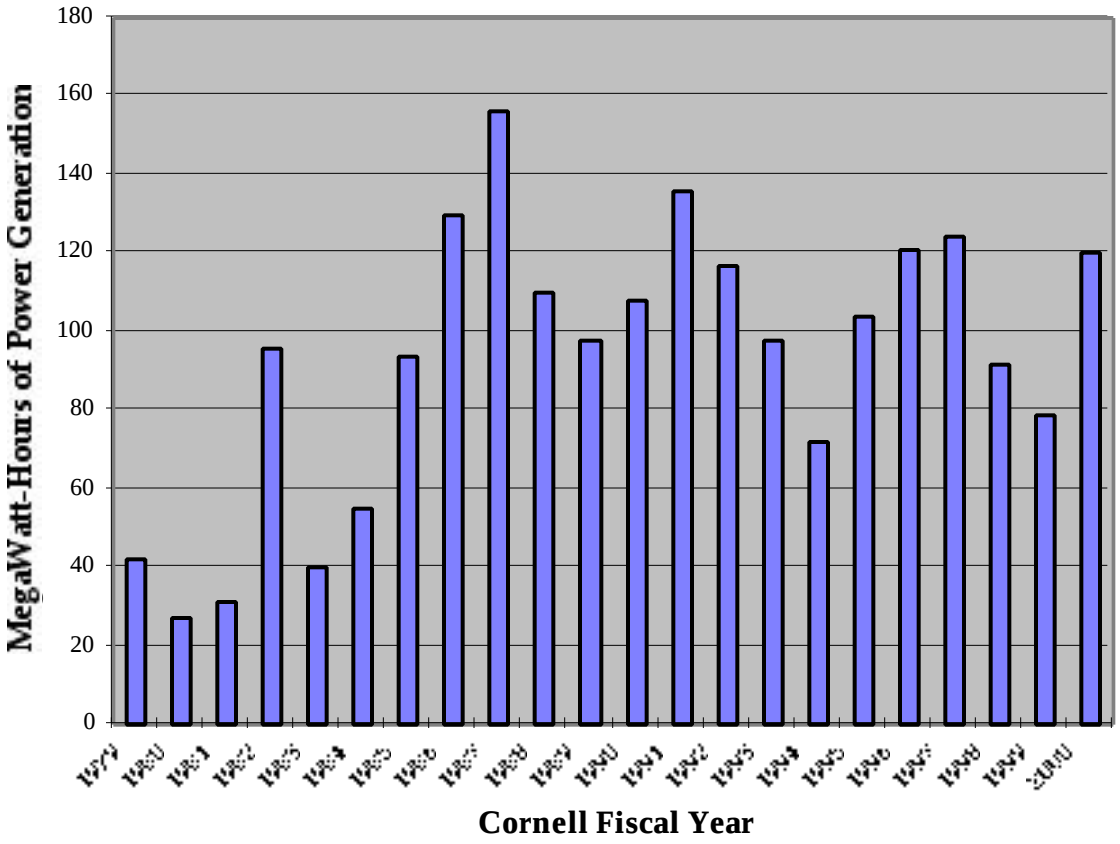

Table 1. Ward Center TRIGA research reactor utilization summary

Year	Operating Time (hours)	Number of Irradiations	Total Experiment Hours	Cornell Users [hrs –(%)]	Other Academic Institutions [hrs –(%)]	Corporate Users [hrs –(%)]
98/99	358.3	540	443.8	260 (58.7)	14 (3.3)	169.5 (38)
99/00	463.4	878	543.6	226 (41.5)	7 (1.3)	311 (57.2)

Table 2. Ward Center for Nuclear Sciences ^{60}Co Gamma Cell utilization summary

Year	Number of Irradiations	Total Source Use (hrs.)	Cornell Users [hrs–(%)]	Other Academic Institutions [hrs–(%)]	Corporate Users [hrs–(%)]
98/99	200	1760	1,349.5 (76.7)	203.5 (11.5)	207.0 (11.8)
99/00	153	1586	1,168 (73.6)	236.5 (14.9)	181.5 (11.5)

The utilization of WCNS facilities can be categorized as teaching, research, and service activities. A summary of each activity for 98/99 and 99/00 fiscal years are given below.

a) Teaching Activities

Cornell's TRIGA research reactor is used for graduate and undergraduate courses. Utilization includes semester long laboratory experiments, one or two lab sessions, laboratory demonstrations or tours of the experimental facilities with an emphasis on specific applications of nuclear analytical methods. The list of courses utilizing the Ward Center is given in Table 3.

Table 3. Academic courses utilizing WCNS TRIGA research reactor

Academic Courses	# Students 98/99	# Students 99/00
NS&E 121 - Fission, Fusion, and Radiation (also ENG 121 and A&EP 121) semester long Introductory Nuclear Methods Lab.	13	11
ENG 150 - Tours by Engineering Freshmen	146 (10 tours)	179 (13 tours)
NS&E 403 - Introduction to Nuclear Science and Engineering (also A&EP 403, ELE 403, and A&AE 488) Semester long experiments	---	13
NS&E 551 - Nuclear Measurements in Research Semester long experiments	---	3
Art, Archeology and Analysis - Tours emphasizing applications (NAA, NIAR, NRad, etc.)	74 (5 tours)	78 (9 tours)
Physics 208 - Neutron Activation Analysis Laboratory sessions	198 (18 sessions)	217 (16 sessions)
Geol 302 - Evolution of the Earth System NAA demonstrations	15 (1 session)	32 (2 sessions)
Physics 690 - Independent Study in Physics NAA demonstrations	7	---
MS&E 603 - Analytical Techniques for Materials Science NAA Laboratory Sessions	21 (6 sessions)	20 (5 sessions)
NYS 4-H - Career Exploration Program Two and a half day workshop entitled "Applications of Nuclear Technology" Includes lectures and Laboratory sessions.	10	8

Ward Center for Nuclear Sciences facilities are also toured by external academic institutions/groups. A list of organized tours are given in Table 4.

Table 4. A list of organized tours of WCNS facilities.

Tour Groups	# of Participants 98/99	# of Participants 99/00
Colgate University	12	23
Corning Community College	43	42
Newfield High School	40	---
Tompkins Cortland Community College	10	5
Dryden High School	---	16
Cornell Society of Women Engineers	11	---
MS&E Graduate Students	9	---
NYS Spectroscopy Associates	32	---
Engineering Exploration Group	---	67
Total # of Participants	157	153
Total Tours	10	12

Ward Center for Nuclear Sciences typically receives about 1,000 visitors every year. 25% of the visitors are from outside Cornell, including students and teachers from area schools or scientists from corporations or government agencies.

b) Research Activities

The Ward Center for Nuclear Sciences facilities are used for research activities by a diverse group of faculty from various departments and colleges of Cornell and academic institutions outside Cornell. A utilization list for the fiscal year 98/99 and 99/00 is below. Some users utilize the facilities continuously and others are occasional users. A breakdown of the usage for the TRIGA research reactor and Gamma Cell is given in Appendix A1, A2 and B1, B2 respectively.

Academic utilization - Cornell (98/99)

For FY 98/99, 10 faculty members from 8 different departments and four different colleges at Cornell utilized the WCNS. A list of users, their departments and brief descriptions of the projects are:

PI	Department	Project
Prof. Hover	Civil Engineering	NRad of microcracking in Concrete
Prof. Kay	Geological Sciences	NAA of igneous rocks
Prof. Cady	Nuclear Science & Engineering	Real time NRad of Wetting Instabilities of water in sand filter
Prof. Ünlü	Nuclear Science & Engineering	NAA, cold neutron source and PGAA testing and development
J. Chiment	Geological Sciences	NAA and NRad of fossils
Prof. Dubovi	Veterinary Medicine	Sterilization of Fetal Bovine Serum
Prof. Alexander	Crop & Soil Sciences	Sterilization of soils for use in bio-remediation research
Prof. Hotchkiss	Food Science	Irradiation of apples to prolong shelf life; Irradiation of plastic wrap to enhance food preserving characteristics
Prof. Pollock	Electrical Eng.	Irradiation of Lithium Fluoride crystals to induce color centers
Prof. Hunter	Agr. & Bio Eng.	Experimental verification of Computer code for modeling Cobalt source gradient

Academic Utilization – external (98/99)

	SUNY Geneseo	NAA of Graphite for use as a fast neutron detector in the University of Rochester INF Reactor.

	NYS 4-H Group Group Workshop	Summer workshop for 10 4-H Youth high school students (NAA, NRad and radiation discussions)
	Miner Institute	NAA of Cattle Forage samples
	Princeton Univ.	Polymer crosslinking
	Rutgers University	Polymer crosslinking and soil sterilization
	RPI Chem. Deprt.	Polymer crosslinking

Academic utilization - Cornell (99/00)

For FY99/00, 17 faculty members and staff from 12 different departments and four different colleges at Cornell utilized the WCNS. A list of users, their departments and brief description of projects is given below. Also, six other faculty members expressed interest in possible usage of the WCNS. These are listed as academic utilization (in progress). Currently, eight external collaborations were established involving 13 scientists from national laboratories, corporations and universities. Some of these collaborations resulted in the submittal of joint proposals and some are at the proposal writing stage.

PI	Department	Project
Prof. Kay (William Burns)	Geological Sciences	NAA of igneous rocks
Prof. Hover	Civil Engineering	NRad of microcracking in Concrete
Prof. Cady (Mark Deinert)	Nuclear Science & Engineering	Real time NRad of Wetting Instabilities of water in sand filter
Prof. Ünlü	Nuclear Science & Engineering	NAA, cold neutron source and PGAA, Neutron Depth Profiling, TOF-NDP testing and development
Prof. Taft	Art Department	Neutron Induced Auto Radiography of 16th Century Painting in Thermal Column
(Warren Bunn	Johnson Museum	Neutron Induced Auto Radiography of 16th

Sean Ulmer Frank Robinson)		Century Paining in Thermal Column
J. Chiment	Geological Sciences	NAA and NRad of Mastodons
Prof. Kuniholm tree (7 students)	Art History	NAA of Dendrochronologically dated rings (new NAA facility completed)
Prof. Ast	Materials Science and Engineering	NAA of Silicon Ribbons
Prof. Dubovi	Veterinary Medicine	Sterilization of Fetal Bovine Serum
Prof. Hotchkiss life; (Gürbüz Günes)	Food Science	Irradiation of apples to prolong shelf Irradiation of plastic wrap to enhance food preserving characteristics
Prof. Pollock to	Electrical Eng.	Irradiation of Lithium Fluoride crystals induce color centers
Prof. Alexander	Crop & Soil Sciences.	Sterilization of soils for use in bio-remediation research
Prof. Hunter gradient	Agr. & Bio Eng.	Experimental verification of Computer code for modeling Cobalt source
Prof. Bowman	Veterinary Micro-Biology and Immunology	Irradiation of Oocysts

Academic Utilization -in progress (99/00)

Prof. Thompson semiconductors,	Materials Science and Engineering	Hydrogen determination in metals using Cold neutron PGAA
Prof. Kallfeltz	Veterinary Medicine	Boron Neutron Capture Therapy
Prof. Page	Veterinary Medicine	Development at Cornell

Prof. Ganem	Chemistry and Chemical Biology	
Prof. Gleason (Elizabeth Macaulay)	Landscape Architecture	NAA of Roman Flower Pots
Prof. Finkelstein	CHESS	Neutron transmission measurements for high density concrete

Academic Utilization –external (99/00)

	Miner Institute	NAA of Cattle Forage samples for trace minerals
	NYS 4-H Group Group Workshop	Summer workshop for 10 4-H Youth high school students (NAA, NRad and radiation discussions).
	RPI Chem. Deprt.	Polymer crosslinking
	Princeton Univ.	Polymer crosslinking
	Connecticut Agricultural Exp. Station	Sediment sterilization
	Montana State University	Soil sterilization
	Rutgers Univ.	Soil sterilization

Scientific Collaboration –external (99/00)

Dr. Dan Ingersoll	ORNL for	Epithermal neutron beam development BNCT

Dr. Roger Martin analysis for Dr. Madhavi Martin (development Dr. Charles Garten proposal)	ORNL	In situ prompt gamma activation total soil carbon determination of Cold Neutron Irradiator–pending
Dr. Ka-Ngo Leung DD Dr. Richard Firestone	LBNL	Development of cold neutron source for and DT neutron tubes
Dr. George Lamaze	NIST	TOF- Neutron Depth Profiling
Dr. Gregory Downing Plate	RGD Resrch. Inc.	TOF-NDP and testing of Multichannel Detectors
Dr. Mon Chao Chen	KAPL	NAA for SiC samples
Dr. John Kada	DOE/ Enviro. Measu. Lab.	NAA for environmental samples
Prof. Alireza Haghighat Dr. Abdul R. Dullo Dr. Bojan Petrovic	Penn State Westinghouse Westinghouse	Field deployable PGAA development
Prof. Matthew Garring	Montclair State	NAA of Geological samples
Prof. Karl Wirth	MacAlister	NAA of Geological samples
Dr. Anne Blethe	UCSB	Uranium Fission Track Dating

ORNL: Oak Ridge National Laboratory
LBNL : Lawrence Berkeley National Laboratory
NIST : National Institute of Standards and Technology
KAPL : Knolls Atomic Power Laboratory

c) Service Activities

There are several corporations using the Ward Center facilities for a variety of research and development applications. The majority of corporate users have been affiliated with Ward Center for many years. The primary corporate users of the Ward Center are companies based in upstate New York e.g., Imaging and Sensing Technologies

Corporation (ISTC), Horseheads, NY; Eastman Kodak Corporation, Rochester, NY; Corning Incorporated, Corning NY; Cosense Incorporated, Hauppauge, NY; Knolls Atomic Power Laboratory, Schenectady, NY; CID TECH Corporation, Liverpool, NY, and Syracuse-Bio, Syracuse, NY. Intersil (formerly Harris Semiconductor) and Westinghouse Corporation are in close proximity to Cornell and they are from Mountaintop and Pittsburgh, Pennsylvania. We also have corporate users from Maryland, Idaho, Ohio, California and Connecticut.

The majority of applications for corporate users involve research, development and testing. Most of the Intermediate Range Monitors, Gamma-Tips, Insulated Detectors, and BF3 detectors for Nuclear Power Plant applications in the world are tested at Ward Center. Also, all detectors used in US nuclear navy applications are tested at Ward Center. A list of the recent corporate users, along with a general description of their research activities is given in Appendix C.

Half of Ward Center's operating expenses is generated from service activities. A listing of corporate income for the year 98/99 and 99/00 is given in Appendix D1 and D2. Imaging and Sensing Technologies ($60-70K/year), General Electric/Reuter Stokes ($60-70K/year), Corning ($20-30K/year), and Eastman Kodak ($10-15K/year) are the most frequent users of the Ward Center facilities.

Grants Received from Federal Agencies

A list of grants received by Ward Center for Nuclear Sciences over the last two years are presented in Table 5. The grants are mostly from DOE and, except for the fuel assistance grant, are peer-reviewed and open to all universities with nuclear engineering departments or programs and their faculty. The fuel assistance program is a need-based grant. Periodically, DOE provides fuel to operating university research reactors.

Ward Center's federal funding was $3,000 (Reactor Sharing Grant) in 97/98. The total amount of federal funds increased to $29,495 in 98/99, $421,450 in 99/00 and $622,843 in 00/01. Currently, three proposals are pending ($971,367).

The most notable federal grant we received this year is one from DOE for the development and application of Time of Flight Neutron Depth Profiling technique for the measurement of ^{10}B distribution in ultra shallow junction devices in support of Nuclear Engineering Education Research. This award is of particular significance because out of 118 submitted proposal from US Universities, only 13 were funded. Also, Cornell was the only university to receive an increase in reactor sharing funds for the last two years. In addition, Cornell, MIT and RPI were the only institutions to receive full funding from the DOE/ Electric Power Research Institute Matching Grant funds for three years.

Operating Budget

Ward Center for Nuclear Sciences Financial Data (operating budget) is given in Table 6. The WCNS operating budget consists of two components. One is salaries of the staff, temporary wages for students, overtime payments and benefits. The second component consists of operational expenses e.g., maintenance, supplies, capital equipment purchases, communications, travel and dosimetry fees, etc. The salaries, wages and benefits account for 80-85% of the operating budget. The remaining 15-20% of the total operating budget of ~$500K is for operational expenses. The income generated or received for the WCNS budget consists of University contributions, external user fees, sponsored funds, Ward endowments and internal user fees. The University contribution has been $200K per year since the establishment of the Center (FY96/97). For the first three years, the College of Engineering transferred all of the University contribution and in FY99/00 they contributed $70K of the $200K commitment. While University contributions toward the budget stayed at the same level over the last four years, income from external users and sponsored funds has increased steadily to defray the cost of SIP and other expenses related to upgrading and development of the Center's facilities.

Internal user fees are very small. If fees were charged to internal users at a rate comparable to those of commercial corporations, the income could reach a level of $100K. Also, the steadily increasing overhead generated from federal grants was not taken into consideration when determining the Center's budget. This could be a large sum considering that we have received $622K in funding and $971 K is pending for this year.

Table 5. Federal funding for the Ward Center for Nuclear Sciences in FY 98/99- 00/01

Funding Agency / Project /PI	98/99	99/00	00/01
DOE University Reactor Instrumentation "Instrumentation for Cornell University TRIGA Research Reactor" (PI: Ünlü)	$24,495	$19,950	$47,500
DOE Reactor Sharing "Reactor Sharing Program for the Cornell TRIGA Research Reactor" (PI: Ünlü)	$5,000	$10,000	$20,000
DOE DOE/Utility Matching Grant "Nuclear Science and Engineering Infrastructure and Program Improvement at Cornell University" (PI's: Ünlü, Cady)	---	---	$360,000/3yrs.
DOE Nuclear Engineering Education Research "Development and Applications of Time of Flight Neutron Depth Profiling" (PI: Ünlü)	---	---	$195,343/2yrs.
NSF Archeology/Paleoclimate Program Equipment Grant with P. Kuniholm (PI's: Kuniholm, Ünlü)	---	$41,500	$589,200/3yrs. (pending)
DOE Fuel Assistance Program (INEEL)	---	$350,000	---
NSF ConacyT Collaborative Research Proposal "Study of Mexico City Metropolitan Area Atmospheric Aerosols" (PI's: Ünlü, Rios-Martinez)	---	---	$99,167/2yrs. (pending)
DOE/ ORNL Biological and Environmental Research "In-situ Cold Neutron Activation for Total Soil Carbon Determinations" (PI's: M. Martin, R. Martin, Garten, Ünlü)	---	---	$992,000/3yrs Cornells part $283,000] (pending)
TOTAL FUNDS RECEIVED	$29,495	$421,450	$622,843 ($971,367 pending)

Table 6. Ward Center for Nuclear Sciences Financial Data – Operating Budget

Expenses

Fiscal Year / Salaries	**98-99**	**99-00**	**00 -01**
Total Salaries	321,169	286,491	302,686
Temp Wages	----	----	--
Overtime	----	4,000	4,000
Student Wages	10,000	6,000	6,000
Benefits	120,332	93,272	104,040
Sub-Total Personnel	451,501	389,763	416,726
Capital Equipment	27,000	25,000	25,000
Supplies	14,500	15,000	15,000
Maintenance & Repairs	4,500	8,000	8,000
Communications/Telephone	15,000	15,000	15,000
Travel	3,000	10,000	10,000
Other (fees, dosimetry, etc.)	9,000	10,000	10,000
Sub-Total Operational	73,000	83,000	83,000
Total Expenses	**524,501**	**472,763**	**499,726**

Income

Fiscal Year / Sources	**98-99**	**99-00**	**00-01**
University Appropriation	200,000	200,000	200,000
External User Fees	165,000	215,000	240,000
Sponsored Funds	3,000	10,000	32,000
Ward Endowment (Interest)	20,000	16,077	20,726
Misc. Ward Gifts	----	----	----
Internal User Fees	10,153	6,000	7,000
Rolled over from previous FY	130,000	5,686	----
Total Income	**524,501**	**452,763**	**499,726**

Status of Research Programs and Activities

Neutron Activation Analysis (NAA)

A new NAA laboratory for dendrochemistry application has been developed. Funds in the amount of $41,500 were obtained from Professor P. I. Kuniholm's NSF funded Dendrochronology project grant to build the NAA laboratory facility. The new NAA laboratory includes a state-of-the-art digital spectrum analyzer (DSA-2000), Genie 2000 data analysis software, a computer and an automatic sample changer system. The NAA laboratory is capable of analyzing 96 irradiated samples in a pre-programmed counting times continuously without personnel presence.

Also, a proposal entitled "NAA of Absolutely-Dated Tree Rings: Identifying Climatically-Significant Marker events in History and Prehistory" was submitted to NSF's Paleoclimate Program. This collaborative/multidisciplinary study involves 8 scientists (7 students and a technician) from various departments at Cornell. Participants include a dendrochronologist/archaeologist, physicist/nuclear engineer, paleontologist /geologist, climatologist, plant physiologist, and environmental biologist from the Malcomb and Carolyn Wiener Laboratory for Aegean and Near Eastern Dendrochronology (P. Kuniholm), Ward Center for Nuclear Sciences (K. Ünlü, P. Dokhale), Earth and Atmospheric Sciences (J. Chiment, A. DeGaetano), Plant Biology and USGS Soil Laboratory (L. Kochian) and Boyce Thompson Institute for Plant Research (L. Weinstein, and J. Comstock).

In this proposal we request support from NSF to analyze several thousand years of absolutely-dated tree-rings from Aegean Dendrochronology Project's archives to investigate elemental signatures of environmental stress. A total of $589,200 for three years was requested. The funds include $64,000 for Ward Center reactor usage and one month of salary for a Ward Center technician.

Neutron Depth Profiling (NDP)

The vacuum chamber, vacuum control system, collimators, beam catcher, data processing computer and shielding materials are ready. Data acquisition electronics are being purchased. With recent research funds received from DOE ($195,313), we will build a Time of Flight NDP Facility to measure depth versus concentration in ultra shallow junction devices. NDP facility will be placed at 4W beam port. Currently this beam port is being used for real time neutron radiography for a graduate student’s work (Mark Deinert). It is expected that his measurements will be completed late September. The conventional NDP will be operational this Fall.

Neutron Radiography (N-Rad)

N-Rad will move to 6SW, Collimator design is to continue. Collimators will be in place before moving from 4W. Initially current shield will be used. A permanent shielding structure is being design for real time and film radiography applications.

Prompt Gamma Activation Analysis (PGAA)

Prompt Gamma Activation Analysis project has been stalled for 14 years. The control system needs to be changed. The current control system is very old and unreliable and should be updated before installing new guides. Funds and a graduate student are now available for the upgrade of control system.

Neutron-Induced Auto Radiography (NIAR)

Professor Taft, Mr. Aderhold/Lassel and others from Johnson Museum made a preliminary measurement of a16th century painting with borrowed equipment from Fuji Corporation. The results were satisfactory. We will pursue the formulation of a proposal in collaboration with Taft and the Johnson museum people involved in order to obtain the funding necessary to obtain needed equipment. Approximately $40,000 is required to purchase a Fuji screen. A 100 micron resolution would be sufficient. A vacuum table is also needed.

Boron Neutron Capture Therapy (BNCT)

Right now there are two sources of potential funding for this project. DOE and NIH. DOE gives approximately 2 million/yr., but all funding is on hold at present level awaiting the outcome of Brookhaven & MIT initiatives. AFFRI applied to NIH for $16 million for 5 years funding. If NIH supports AFFRI we would like to be 2nd in place to submit a proposal.

Initiatives – Oak Ridge National Lab – Dan Ingersoll designed the filter for the Tower Shielding Facility at Oak Ridge. He is willing work with us to help design ours. FiR1 nuclear research reactor in Finland (a 250 kW TRIGA reactor with similar design of Cornell TRIGA produces highest epithermal neutron beam flux in the world for BNCT applications) has been contacted. They agree to collaborate if we decided to build a BNCT at Cornell. Also, Cornell Vet College hired Rodney Paige and some additional positions have been created to boost radiation oncology studies at Cornell. Rodney Page and Francis Kallfelz from Veterinary Medicine, Bruce Ganem from Chemistry and Chemical Biology and Kenan Ünlü from the Ward Center are the main contributors initially for this project. Also, we are trying to involve people from Cornell Weill Medical College at New York City. There is a distance problem for human trials insofar as the Medical College is concerned. Therefore, Syracuse University Medical School may be involved since it is more closely located. The

NIH decision on the AFFRI application is key to whether we proceed or not for the proposal.

Current status of other research projects

1) DOE/Utility Matching Grant (DOE/EPRI) 120,000 /yr for 3 years (60K EPRI-60K DOE total fund $ 360,000 for three years). The funds will go to support 2 grad students (Jinyuan Yan and Zhiqiang Li), 20K for research equipment and 1/2 of a Post. Doc. salary. The Post. Doc. (Dr. P. Dokhale) will do the NAA work and relieve Reactor Supervisor/ Manager of Technical Services so he/she can concentrate on service activities and the re-licensing effort.

2) NSF – Conacy-T Collaborative research program $99,167 (2 years) Collaborate w/scientists from Mexico (Carlos Rios-Martinez).

3) ORNL – Development of Cold Neutron Irradiator with Cf-252 Source (Biological and Environmental Research Group) $992,000 (3 years) (Cornell ~$300,000) Oak Ridge National Lab (Roger Martin) on “Development of Cold Neutron Irradiator with Cf-252 Source” - Internal for Oak Ridge – Cold Source Dev’t & Neutron Beam Guide Source Dev’t sections. K. Ünlü will be responsible for the development of portable cold neutron source.

Future

a) National Trends

Nuclear engineering departments and programs were established in the US in the late 1950's and early 1960's. Most of the departments and programs were associated with nuclear research reactors. The number of nuclear engineering department/programs and nuclear research reactors were decline during the last two decades. This decline is mainly attributed to negative public notions (due to Three Mile Island and Chernobyl accidents) by associating anything "nuclear" with nuclear weapons or accidents, and the poor cooperation and communication among industry, universities and the government.

The decline of interest in nuclear engineering alarmed the US government and a strong effort was initiated to rebuild US nuclear energy research and education programs. Two years ago, the Department of Energy created a high-level advisory board, the Nuclear Energy Research Advisory Committee (NERAC), to advise the Secretary of Energy on future R&D activities in nuclear energy. This new committee was recommended by the President's Council of Advisors on Science and Technology (PCAST) who viewed with alarm the deterioration that has occurred in nuclear energy research and education in the US. The NERAC recently issued a report on "The Future of University Nuclear Engineering Programs and University Research and Training Reactors" (May 2000). An executive summary of NERAC report is

given in Appendix E. A full report can be found in www.NE.doe.gov/nerac/finelblue.pdf.

Among other recommendations, NERAC has recommended an increase in federal R&D funding for nuclear energy from its current level of $35 million (FY2000) to a new level of $280 million over the next five years (FY2005). Furthermore, committee recommended an increase of support for nuclear engineering departments/programs and university reactors from current level of $12 million per year to a new level of $45 million (FY2005).

Another finding is reported in a survey conducted by the Nuclear Engineering Department Heads Organization (NEDHO) (April 2000). The report title is "Manpower supply and Demand in the Nuclear Industry" and a full report can be found at their website at www.engin.umich.edu/~nuclear/NEDHO/. The report's finding was that the number of students graduating with nuclear engineering degrees won't be enough to keep up with the demand for nuclear engineers. The results of the survey showed that in 1998-99, 149 nuclear engineering graduates would be coming out of schools looking for jobs in the power industry, and there would be 512 nuclear engineering jobs waiting for them. In 1999-00, 174 graduates would be coming out, with 585 jobs awaiting; in 2000-01, there would be 165 graduates for 587 jobs. Projected for 2001-02 were 174 graduates for 627 jobs, and for 2002-03 174 graduates for 642 jobs.

The revitalization of US nuclear science and engineering program and university research reactors is currently taking place. Nuclear Science and Engineering curriculum and research in most universities has greatly diversified during the last decade to meet the challenges attributed to the nuclear field. The nuclear power engineering component has been de-emphasized in these programs. New expanded directions are science, technology, and medical applications of nuclear science and engineering. A few examples of this new approach by the nuclear science and engineering community are: diagnosis and treatment of certain type of cancerous tumors, characterization of materials structure, analysis of impurities and trace elements in technologically important materials, waste management and spent fuel reprocessing, storage/ mixed oxide fuel conversion/vitrification studies of excess weapons-grade plutonium.

Cornell University

Cornell TRIGA is one of 26 operating university research reactors in the United States and the only research reactor in the state of New York, Cornell is also the only Ivy League school that has a nuclear research reactor. In its current operating status, Cornell's TRIGA can be ranked in 12th place out of a total of 26 reactors. A list of operating university research reactors is given in Appendix F. After completion of the Neutron Depth Profiling facility and the Cold Neutron Source/Prompt Gamma Activation Analysis facility, the Cornell TRIGA could be ranked in 9th place. If we

can have a power upgrade to 1MW other instruments like a neutron diffractometer and/or reflectometer can be added. This upgrade could place Cornell in 5th or 6th place in terms of research utilization.

What makes Cornell unique can be summarized as follows:

* Cornell and the University of Texas at Austin are the only University Research Reactor in the US that have cold neutron facility.

* Time of Flight Neutron Depth Profiling will be the first facility in the world to measure boron content in ultrashallow junction devices with resolution 2.5 nm.

* Cornell TRIGA's thermal column design is similar to the FiR reactor in Finland. FiR is a 250 kW TRIGA reactor and currently has the best epithermal beam for Boron Neutron Capture Therapy applications. Due to unique geometry, we can place filters very close to the reactor core at the Cornell TRIGA and could obtain higher flux than the Finnish reactor. (Cornell TRIGA is already twice as powerful as the FiR and we could learn from their experience and design a better filter system).

* Cornell's existing Neutron Activation Analysis and Neutron Radiography facilities are comparable to MIT and Michigan. Cornell has four gamma ray spectroscopy systems and a real time and film type neutron radiography facility.

* One of the gamma ray spectroscopy systems is primarily used in geological sciences research and Professor Kay and his group have analyzed approximately 4000 samples, most frequently igneous rocks for 21 trace elements. The data obtained from these measurements are integral parts of 15 Cornell Ph.D. theses in the last two decades. Professor Kay's group is a continuous user of the Ward Center for Nuclear Sciences.

* Due to the diverse and multidisciplinary culture of the Cornell campus, a dendrochronologist/archeologist, physicist/nuclear engineer, paleontologist/geologist, climatologist, plant physiologist, and environmental biologist can work together. Such a collaboration has been initiated, a new NAA laboratory has been established at Ward Center and a proposal to NSF was submitted ($589,200 / 3 years) in order to study climatically-significant marker events in history and prehistory using NAA and dated tree ring archives of the Malcomb and Carolyn Wiener Laboratory for Aegean and Near Eastern Dendrochronology.

* The Cobalt-60 Gamma Cell facility has been utilized extensively by internal users due to accessibility at Cornell. Groups in Veterinary Medicine, Food Science, Agricultural and Biological Engineering, Electrical Engineering and Soil, Crop

and Atmospheric Sciences account for more than 70% of the gamma cell's utilization.

* Due to Ward Center's unique facilities like flat reflector surface of the core, 1-MeV equivalent irradiation facility and Cobalt-60 gamma cell several technology corporations utilize the Ward Center over the years. Most of these corporations are upstate New Your based companies, like.

Imaging and Sensing Technologies Corporation (ISTC), Horseheads, NY;
Eastman Kodak Corporation, Rochester, NY
Corning Incorporated, Corning NY
Cosense Incorporated, Hauppauge, NY
Knolls Atomic Power Laboratory, Schenectady, NY
CID TECH Corporation, Liverpool, NY
Syracuse-Bio, Syracuse, NY.

Intersil (formerly Harris Semiconductor) Mountaintop , PA
Westinghouse Corporation Pittsburgh, PA

Cornell University's Ward Center for Nuclear Sciences, with its resources, tradition of excellence, and increase federal funding is in a unique position to be part of the revitalization of nuclear science and engineering.

Breakdown of TRIGA Reactor Usage
July 1,1998 - June 30,1999

Experimenter	Operating Time Hours	Number of Irradiations	Total Experiment Hours	% Usage
Geology (CU)	52.0	196	95.2	21.5
Ward Center (CU)	140.1	48	161.1	36.3
IST Corporation	66.1	92	74.2	16.7
Corning Glass	12.7	46	18.0	4.1
Intersil Corporation	10.0	2	12.2	2.7
Westinghouse Corporation	16.0	-	16.0	3.6
Eastman Kodak	20.5	16	20.5	4.6
Miner Institute*	6.0	19	6.0	1.4
Art Department (CU)	1.0	2	1.0	0.2
Reuter Stokes	14.1	96	14.2	3.2
Hamilton Standard	6.0	8	6.0	1.4
Civil Engineering (CU)	3.0	2	3.0	0.7
USC/Earth Sci*	0.7	1	2.0	0.5
Sea Brook	1.0	1	1.0	0.2
SUNY Geneseo*	1.5	5	6.0	1.4
W. D. P. & Associates, Inc.	2.0	1	2.0	0.5
Greene Tweed Co.	5.5	5	5.5	1.2
Total	**358.3**	**540**	**443.8**	**100%**

Cornell Users : Total Utilization **260.3** hours **(58.7 %)**
Other Academic Inst.* : Total Utilization **14.0** hours **(3.3 %)**
Corporate Users : Total Utilization **169.5** hours **(38.0 %)**

Appendix A-1

Breakdown of TRIGA Reactor Usage
July 1,1999 – June 30, 2000

Experimenter	Operating Time Hours	Number of Irradiations	Total Experiment Hours	% Usage
Geology (CU)	70.0	294	104.5	19.2
Ward Center (CU)	106.5	93	109.5	20.1
Art Department (CU)	1.5	2	1.5	0.3
Miner Institute*	1.0	6	3.0	0.6
IST Corporation	59.4	85	68.9	12.7
Corning Glass	18.0	117	23.0	4.2
Intersil Corporation	109.6	19	118.2	21.7
Westinghouse Corporation	23.0	--	23.0	4.2
Eastman Kodak	30.7	122	38.2	7.0
Reuter Stokes	11.8	102	20.4	3.8
Newport News	15.5	--	15.5	2.9
Northrop Grumman	2.0	--	2.0	0.4
Brimex Aerospace	0.5	1	0.5	0.1
Cosense Corporation	1.3	2	1.3	0.2
Mat. Sci. & Engr.. (C.U.)	1.5	10	3.0	0.6
Univ. Southern Calif*.	4.0	2	4.0	0.7
Neutron Radiography (C.U.)	7.1	16	7.1	1.3
Total	**463.4**	**878**	**543.6**	**100%**

Cornell Users : Total Utilization **225.6** hours **(41.5 %)**
Other Academic Inst.* : Total Utilization **7.0** hours **(1.3 %)**
Corporate Users : Total Utilization **311.0** hours **(57.2 %)**

Appendix A-2

Ward Center for Nuclear Sciences
Summary of Gamma Cell Utilization

July 1, 1998 – June 30, 1999

The Co-60 gamma rays sources were taken out of storage for 200 separate irradiations, accounting for a total source use of 1760 hours.

The Co-60 source strength as of June 30, 1999 was:

Assay Date	Number of Pencils	Source Strength (Ci)
January 1, 1963	20	87.7
September 19, 1979	12	738.4
March 11, 1994	12	5374.2

Utilization of the gamma cell involved 11 academic departments and 3 industrial firms. The percent of total use time for each group is listed below:

USERS	Utilization (%)	Time (hr)
Soil, Crop, & Atmospheric Sciences (CU)	47.1	(830)
Microbiology & Immunology (CU)	14.9	(262)
Food Science (CU)	11.0	(195)
Imaging, Sensing & Technology Science	9.7	(171)
Connecticut Agricultural Experimental Station	6.8	(120)
Chemistry (RPI)	3.5	(61.5)
Reuter-Stokes	1.8	(31.5)
Chemistry (CU)	1.5	(27)
Physiology (CU)	1.2	(22.5)
Chemistry (Yale University)	0.9	(17)
Ward Laboratory (CU)	0.5	(10)
Chemistry (Princeton University)	0.3	(5)
CIDTEK Corp.	0.3	(4.5)
Bioengineering (CU)	0.2	(3)

Cornell Users : Total Utilization **1,349.5** hours (76.7 %)
Other Academic Inst. : Total Utilization **203.5** hours (11.5 %)
Corporate Users : Total Utilization **207.0** hours (11.8 %)

Appendix B-1

Ward Center for Nuclear Sciences
Summary of Gamma Cell Utilization

July 1, 1999 – June 19, 2000

The Co-60 gamma rays sources were taken out of storage for 153 separate irradiations, accounting for a total source use of 1586 hours.

The Co-60 source strength as of June 19, 2000 was:

Assay Date	Number of Pencils	Source Strength (Ci)
January 1, 1963	20	77.4
September 19, 1979	12	651.2
March 11, 1994	12	4739.6

Utilization of the gamma cell involved 11 academic departments and 4 industrial firms. The percent of total use time for each group is listed below:

USERS	**Utilization (%)**	**Time (hr)**
Soil, Crop, & Atmospheric Sciences (CU)	23.0	(365.5)
Microbiology & Immunology (CU)	18.6	(295.5)
Chemistry (CU)	10.5	(166.5)
Land Resources & Environmental Science (University of Montana)	9.9	(158.0)
Civil Engineering (CU)	8.4	(133.0)
Physics (CU)	8.0	(127.0)
Imaging, Sensing & Technology Science	5.8	(92.0)
Ward Laboratory (CU)	4.4	(70.0)
CIDTEK Corp.	4.4	(70.0)
Connecticut Agricultural Experimental Station	3.8	(60.0)
Chemistry (RPI)	1.01	(16.5)
Reuter-Stokes	0.9	(13.5)
Food Science (CU)	0.7	(10.5)
COSENSE Inc.	0.4	(6.0)
Chemistry (Princeton University)	0.1	(2.0)

Cornell Users : Total Utilization **1,168** hours (73.6 %)
Other Academic Inst. : Total Utilization **236.5** hours (14.9 %)
Corporate Users : Total Utilization **181.5** hours (11.5 %)

Appendix B-2

Appendix C

List of Corporate user of Ward Center for Nuclear Sciences and the description of their research and development activities

Corning Inc.

- Corning (Glass) Inc. has been using the facilities at Ward Center for many years. Their R&D activities have centered around using NAA to look for trace levels of contaminants in various glass based products. In the past few years, their research has focused on high purity fused silica (HPFS) used in substrates for semiconductor devices. NAA has been performed on solid HPFS, the organic based silicon liquid raw material, and on samples of the bricks that line the firing kilns. Primary trace impurities of concern include sodium, chlorine and bromine. Detection limits have been established for the ~ 60 elements detectable using NAA.

General Electric / Reuter Stokes

- GE/Reuter Stokes has been using the facilities at Ward Center for many years. Their R&D activities have centered around using the reactor and gamma cell to develop, test and certify various nuclear instrumentation for use in nuclear power plants and naval nuclear reactors. Detector types include: IRM's (Intermediate Range Monitors), Gamma-Tips, Insulated Detectors, and BF3's.

Intersil (Harris Semiconductors)

- A 1-MeV equivalent fast neutron irradiation facility was built in the reactor pool at the reactor flat reflector face for Intersil Corporation to irradiate silicon wafers. The damage sites induced in the silicon lattice by the fast neutrons decrease the device "turn-off" time, e.g. enhance the switching speed. This facility is able to handle up to two stacks of 8" diameter wafers (total 100 wafers) for each irradiation and we have capabilities of irradiating three batches of wafers each week. All the construction expenses have been paid by Intersil Corporation.

Imaging and Sensing Technologies Corp. (ISTC)

- ISTC has been using the facilities at Ward Laboratory for many years. Their R&D activities have centered around using the reactor and gamma cell to develop, test and certify various nuclear instrumentation for use in nuclear power plants and naval nuclear reactors. Detector types include: MIC's (Miniature In-Core), CIC (Compensated Ionization Chamber), SPD's (Self-Powered Detectors), and BF3's.

Eastman Kodak Corp.

- Kodak Corp. has been using the facilities at Ward Center for many years. Their R&D activities have centered around several separate applications. The NAA laboratory at Kodak has used the TRIGA for the activation of many different types of samples, including industrial process and environmental samples. Another division of Kodak has used the gamma cell facility to test the radiation hardness of CCD cameras to be

used in radiation environments, including in outer space. Finally, another division has built a facility to activate 6" silicon wafers with the TRIGA reactor to perform activation analysis and look for impurities in the silicon.

Northrop Grumman

· Northrop Grumman has used the WCNS facilities several times over the past five years to test the operation of instrumentation used in naval nuclear reactor plants. Each test requires the relatively exclusive use of the reactor for two to three weeks and involves using multiple neutron detectors located in and around the reactor pool.

United Technologies Corp.

· UTC is a conglomerate. The Hamilton Standard division has used our radiography facility numerous times for imaging several different objects. A "ventilation unit" for outer space applications was imaged to look for improperly installed o-rings. A cast submarine propeller blade was imaged to look for inclusions causing a structural defect. A jet fighter afterburner compressor was imaged to look for fuel leaks through specialized graphite seals.

WDP & Assoc.

· This company used the radiography facilities to image micro-cracking in concrete. One of their employees recently graduated from CU's Civil Engineering program and had carried out similar work under Dr. Hover.

Westinghouse Corp.

· Historical user of Ward Lab Facilities. ISTC was a subdivision of Westinghouse and was "spun off". Upcoming project to test a new silicon carbide based solid state neutron detector.

Cosense Corp.

· Fast neutron and gamma irradiation of Ultrasonic Liquid Level Sensors used in naval nuclear reactors.

Other Corporate/Government users

· Micron Technologies: NAA of impurities in semiconductor wafers
· Siemens Corporation: NAA of Ba in silicon matrix
· Knolls Atomic Power Laboratory: NAA of SiC samples
· Lake Immunogenics: sterilize horse plasma for race horses in gamma cell.
· NRC: use gamma cell to test radiation monitoring instrumentation.
· CIDTEK: test CID type cameras in a radiation environment in gamma cell.
· Syracuse-Bio: sterilize commercial labware in gamma cell.

Fiscal Year 98-99 $ Invoiced and $ Deposited by Company

Company	$ Invoiced	Month	$ Deposited	97-98 $ Dep
Corning				
		July		
	$14,500.00	Aug		
	$3,300.00	Sept	$14,500.00	
		Oct		
		Nov		
		Dec		
		Jan		
		Feb		
	$2,700.00	Mar		
		Apr	$2,700.00	
	$2,850.00	May	$3,300.00	
		June		
		Dep Totals:	$20,500.00	$0.00
Total Invoiced	$23,350.00			
Total Dep	$20,500.00			
Total 98-99	-$2,850.00			

Company	$ Invoiced	Month	$ Deposited	97-98 $ Dep
Kodak				
		July		
		Aug		
		Sept		
		Oct		
		Nov		
		Dec		
		Jan		
		Feb		
	$4,500.00	Mar		
		Apr		
		May		
	$3,400.00	June		
		Dep Totals:	$0.00	$0.00
Total Invoiced	$7,900.00			
Total Dep	$0.00			
Total 98-99	-$7,900.00			

Company	$ Invoiced	Month	$ Deposited	97-98 $ Dep
Intersil (Harris)				
		July		
		Aug		
		Sept		
		Oct		
		Nov		
		Dec		
		Jan		
		Feb		
		Mar		
		Apr		
		May		
	$30,000.00	June		
		Dep Totals:	$0.00	$0.00
Total Invoiced	$30,000.00			
Total Dep	$0.00			
Total 98-99	-$30,000.00			

Company	$ Invoiced	Month	$ Deposited	97-98 $ Dep
ISTC				
		July		$1,660.00
		Aug		
	$18,390.00	Sept		
		Oct		
		Nov	$12,750.00	
	$5,825.00	Dec	$5,640.00	
		Jan		
	$12,060.00	Feb		
		Mar	$5,825.00	
		Apr	$7,600.00	
	$36,750.00	May	$3,560.00	
		June	$13,550.00	
		Dep Totals:	$48,925.00	$1,660.00
Total Invoiced	$73,025.00			
Total Dep	$50,585.00			
Total 98-99	-$22,440.00			

Company	$ Invoiced	Month	$ Deposited	97-98 $ Dep
MISC				
		July		
	$31,600.00	Aug		
	$40.00	Sept		
	$860.00	Oct	* $32,600.00	$985.00
	$542.50	Nov	$900.00	
	$1,200.00	Dec	$482.50	
	$10,150.00	Jan		
	$620.00	Feb	$60.00	
		Mar	$10,730.00	$1,300.00
		Apr		
		May		
	$116.00	June		
		Dep Totals:	$44,772.50	$2,285.00
Total Invoiced	$45,128.50			
Total Dep	$47,057.50			
Total 98-99	$1,929.00			

Grand Total Invoiced in 98-99:	$264,432.25
Grand Tot. Deposited in 98-99:	$136,692.50
98-99 Inv/Dep Comparison:	-$127,739.75

*deposit includes unidentif. $1,000 for HS3 included in the 31,600 payment from Northrup Grumman.

Company	$ Invoiced	Month	$ Deposited	97-98 $ Dep
GE/RS				
		July		$1,750.00
	$20,628.75	Aug		
	$8,400.00	Sept		
		Oct	$1,400.00	
		Nov	$6,300.00	
		Dec	$7,350.00	
		Jan		
	$37,100.00	Feb		
	$3,200.00	Mar	$1,750.00	
		Apr		
		May		
	$15,700.00	June		
		Dep Totals:	$16,800.00	$1,750.00
Total Invoiced	$85,028.75			
Total Dep	$18,550.00			
Total 98-99	-66,478.75			

Appendix D-1

Fiscal Year 99-00 $ Invoiced and $ Deposited by Company

Company	$ Invoiced	Month	$ Deposited	Prior Yr. $ Dep
Corning				
		July		
	$2,100.00	Aug		$2,850.00
		Sept	$2,100.00	
	$1,350.00	Oct		
	$1,500.00	Nov	$1,350.00	
		Dec		
	$9,100.00	Jan	$1,500.00	
		Feb	$4,850.00	
		Mar		
		Apr		
	$9,600.00	May	$2,700.00	
		June	$6,900.00	
		Dep Totals:	$19,400.00	$2,850.00
Total Invoiced	$23,650.00			
Total Dep	$22,250.00			
Total 99-00	($1,400.00)			

Company	$ Invoiced	Month	$ Deposited	Prior Yr. $ Dep
Intersil (Harris)				
		July		
	$2,000.00	Aug		$30,000.00
	$5,000.00	Sept	$1,000.00	
	$1,000.00	Oct	$3,000.00	
	$4,000.00	Nov		
		Dec	$2,000.00	
	$1,000.00	Jan	$3,000.00	
	$3,000.00	Feb	$3,000.00	
	$4,000.00	Mar	$2,000.00	
	$4,000.00	Apr	$3,000.00	
		May	$3,000.00	
	$7,375.00	June		
		Dep Totals:	$20,000.00	$30,000.00
Total Invoiced	$31,375.00			
Total Dep	$50,000.00			
Total 99-00	$18,625.00			

Company	$ Invoiced	Month	$ Deposited	Prior Yr. $ Dep
MISC				
	$22,500.00	July		$116.00
	$1,495.00	Aug		
		Sept	$1,090.00	
		Oct	$40.00	
		Nov	$22,500.00	
	$13,372.00	Dec	$365.00	
	$40.00	Jan	$92.00	
		Feb	$12,480.00	
	$1,605.00	Mar		
		Apr	$1,605.00	
	$365.00	May		
	$980.00	June	$365.00	
		Dep Totals:	$38,537.00	$116.00
Total Invoiced	$40,357.00			
Total Dep	$38,653.00			
Total 99-00	($1,704.00)			

Grand Total Invoiced in 99-00:	$224,422.00
Grand Tot. Deposited in 99-00:	$271,108.00
99-00 Inv/Dep Comparison:	$46,686.00

Company	$ Invoiced	Month	$ Deposited	Prior Yr. $ De
Kodak				
		July		
	$750.00	Aug		$3,400.00
	$1,000.00	Sept	$750.00	
	$3,000.00	Oct		
	$1,250.00	Nov	$3,500.00	
	$250.00	Dec	$1,000.00	
		Jan	$1,000.00	
		Feb		
	$750.00	Mar		
		Apr	$750.00	
	$250.00	May		
		June		
		Dep Totals:	$7,000.00	$3,400.00
Total Invoiced	$7,250.00			
Total Dep	$10,400.00	Note: There is still $4,500 outstanding		
Total 99-00	$3,150.00	from FY 98-99.		

Company	$ Invoiced	Month	$ Deposited	Prior Yr. $ Dep
ISTC				
		July		$24,500.00
	$16,205.00	Aug		
	$5,500.00	Sept		
		Oct	$8,005.00	
	$7,900.00	Nov		
		Dec	$13,700.00	
		Jan	$7,900.00	
		Feb		
		Mar		
		Apr		
	$15,125.00	May		
	$13,875.00	June		
		Dep Totals:	$29,605.00	$24,500.00
Total Invoiced	$58,605.00			
Total Dep	$54,105.00			
Total 99-00	($4,500.00)			

Company	$ Invoiced	Month	$ Deposited	Prior Yr. $ De
GE/RS				
	$3,750.00	July		$4,200.00
	$6,400.00	Aug		
	$13,850.00	Sept	$2,000.00	$13,300.00
	$10,200.00	Oct		$1,750.00
	$1,600.00	Nov	$2,800.00	
	$4,250.00	Dec		$12,800.00
		Jan		
		Feb		
	$8,035.00	Mar	$28,550.00	$14,750.00
	$2,400.00	Apr		$9,200.00
	$2,400.00	May	$3,200.00	$3,150.00
	$10,300.00	June		
		Dep Totals:	$36,550.00	$59,150.00
Total Invoiced	$63,185.00			
Total Dep	$95,700.00			
Total 99-00	$32,515.00			

*Note: There is still a total of $35,713.75 in outstanding invoices as of 6/30/00.

Appendix D-2

THE FUTURE of UNVERSITY NUCLEAR ENGINEERING PROGRAMS

and

UNIVERSITY RESEARCH & TRAINING REACTORS

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Senior Advisor to the Laboratory Director
Los Alamos National Laboratory

Kenneth C. Rogers, Commissioner (Retired)
United States Nuclear Regulatory Commission

EXECUTIVE SUMMARY

Nuclear engineering programs and departments with an initial emphasis in fission were formed in the late 1950's and 1960's from interdisciplinary efforts in many of the top research universities, providing the manpower for this technical discipline. In the same time period, for many of these programs, university nuclear reactors were constructed and began their operation, providing some of the facilities needed for research and training of students engaged in this profession. However, over the last decade, the U.S. nuclear scienee and engineering educational structure has not only stagnated but has reached a state of decline. The number of independent nuclear engineering prograrns and the number of operating University nuclear reactors have both fallen by about half since the mid-1980s. In contrast, the demand for nuclear-trained personnel is again on the rise. Workforce requirements at operating U.S. nuclear power plants are increasing and will undoubtedly remain high, given the plans for plant-life extension in the vast majority of operating light-water reactors in the U.S. Moreover, new initiatives have begun in applied radiation sciences in collaboration with industrial and medical researchers as well as new biotechnologists. Finally, nuclear science and engineennng (NS&E) continues to be needed in national security as well as providing the US Navy with effective, safe nuclear propulsion. Thus, the future of nuclear science and engineering programs must be reevaluated and refocused as the new century begins.

In November 1999, DOE Office of Nuclear Energy, Science and Technology requested that NERAC establish an ad hoc panel to consider educational issues related to the future of nuclear science and engineering; i.e., address the future of nuclear engineering programs, establish a process toward support of university research and training reactors, and identify appropriate collaborations between DOE national laboratories and university prograrns. To this end the panel is making a series of recommendations to the NERAC and the DOE.

University Nuclear Encineering Procrarns: Our vision is have DOE assist universities as they refocus these programs to enhance advances in nuclear science and engineering as applied to security, power and medicine and to maintain the necessary hurnan resource for continuing the discipline through the 21st century. These efforts would be to:

1. Enhance the graduate student pipeline to maintain the health of the discipline by increasing doctoral fellowships (~20) and masters scholarships (~40) with funds of $5 million/yr.

2. Assist universities in recruiting and retaining new faculty in nuclear science and engineering by establishing a Junior Faculty Research Initiation Grant program for peer-reviewed grants in basic research.

3. Expand research discoveries in nuclear science and engineering by increasing the Nuclear Engineering Edueational Research prograrn (NEER) to $20 million/yr (includes item 2).

4. Help improve the undergraduate nuclear science and engineering discipline and maintain a core competency in nuclear systems engineering and design.

5. Encourage and support a national activity of communication and outreach in nuclear science and engineering to identify its basic benefits for the country in the next century.

University Research and Training Reactors: University reactors are an important part of the nuclear science and engineering infrastructure that must be maintained, because experimental facilities (particularly facilities involving ionizing radiation and nuclear reactions) must be part of the educational basis of the discipline for undergraduate training and graduate research. To insure that such facilities are properly supported the panel recommends the following actions.

The panel proposes that a competitive peer-reviewed program augment current DOE financial support for these university reactors. This program would have the following elements:

I.) Maintain the current base program for university reactor assistance program, which provides funds for reactor refueling, operational instrumentation, and reactor sharing at $4.3million/yr.

2. Institute a competitive peer-reviewed university reactors research and training award program, which would provide for reactor improvements as part of focused effort that emphasizes research, training and/or educational outreach, with the following elements:
    - Specific award criteria which qualify university reactors for participation in the competition,
    - Peer-reviewed competition for innovative research, training and/or outreach proposals,
    - Multi-year grants that could involve multi-university, multi-disciplinary collaborative teams,
    - Awards for research, training and/or outreach purposes with the total competitive program funds at a level of $15 million annually.

University - DOE Laboratory Interactions: The panel exarnined several approaches that could increase collaboration between universities and laboratories. Some of these strategies have the common theme that would require exercising some level of central authority within the DOE.

- Increased Nuclear Engineering and Health Physics Fellowships: These are an excellent means of interacting with top graduate students. The panel believes that for this and other reasons the funding for NE/HP Fellowship Program should be substantially increased.

- Increase personnel exchanges between Laboratories and Universities: Laboratories could create programs such as a "Distinguished Visitor Program,"under which university faculty could spend extended periods (e.g. sabbaticals) at laboratories. Laboratories could encourage its staff to give seminars and/or spend time as visiting faculty at universities.

- Designated University Awards: Universities provide largely untapped resources that could participate more fully in DOE applied and basic research programs. To take more advantage of this resouree, DOE could negotiate a certain percentage of the laboratory's budget to be subcontracted to universities. Laboratory management could also require individual programs (or divisions or directorates) to subcontract a certain amount or percentage to universities each year.

Institution	Reactor Type or Reactor Name	Power Level kW (t)
University of Arizona	TRIGA Mark-I	100
University of California-Irvine	TRIGA Mark-I	250
Cornell University	TRIGA Mark-II	500
University of Florida	UFTR	100
Idaho State University	AGN-201P-103	0.005
Kansas State University	TRIGA	250
University of Maryland	TRIGA	250
Massachusetts Institute of Technology	MITR	4,900
University of Massachusetts – Lowell	ULR	1,000
University of Michigan	MTR	2,000
University of Missouri-Columbia	MURR	10,000
University of Missouri – Rolla	UMRR	200
University of New Mexico	AGN-201M-112	0.005
North Carolina State University	PULSTAR	1,000
Ohio State University	OSURR	500
Oregon State University	TRIGA Mark II	1,100
Pennsylvania State University	TRIGA	1,000
Purdue University	PUR-1	1.0
Reed College	TRIGA Mark I	250
Rhode Island Atomic Energy Commission	RINSC	2,000
Texas A&M University	NSCR	1,000
University of Texas	TRIGA Mark II	1,100
University of Utah	TRIGA Mark I	100
Washington State University	TRIGA	1,000
University of Wisconsin-Madison	TRIGA	1,000
Worcester Polytechnic Institute	WPIR	10

Appendix -F