

# History of the North Dakota State University Electron Microscopy Center, 1963 to 2008

In 1960, North Dakota Agricultural College became North Dakota State University. Just three years later in 1963, electron microscopy was introduced at the new university with the purchase of a used 1957-model RCA EMU-3C transmission electron microscope from the University of Chicago for \$13,050 (about \$91,947 today). The Experiment Station was the primary contributor, but also providing funding were the College of Agriculture, the College of Arts and Science, the College of Chemistry and Physics, the Graduate School (through National Defense Education Act Fellowship Funds), and an Institutional Grant for Science. In October 1963, Dr. F. M. Salama attended a special school at the RCA plant in Philadelphia to learn about the hot and cold stages and double condenser lens, and how to service the microscope. Under the supervision of the Department of Agricultural Biochemistry, the microscope was installed (for an additional \$500) in 1964 on the fourth floor of the new Chemistry building, Ladd Hall, where a "special air conditioned room costing \$5,511" was prepared to house it. Under "favorable conditions," the 3C was capable of "direct magnifications up to 80,000 diameters."



The annual service contract for the RCA EMU-3C TEM ran \$1476, payable \$123 per month. The service contract proved to be a bargain when Dr. Salama cleaned the microscope chamber with ether, producing an explosion as the beam current was turned on, and necessitating extensive repairs. Total annual operating costs for the 1965-1966 fiscal year were estimated at \$7000-8000, including \$5700 salary for technician Miss Esther Blasl to operate and maintain the microscope as well as train new users.

Ford Motor Company Engineering and Research donated a second TEM in the 1960's, a 1956 RCA EMU-2D, but it was never operational, possibly because of improper packing that resulted in breakage of critical parts in shipping from Dearborn, Michigan, and the inability to have electron microscope parts tested "north of Minneapolis." Dr. H. J. Klosterman, Chairman of the Department of Agricultural Biochemistry, urged as early as March 1965 that, because the electron microscope served the whole campus, it should be directly and permanently supported by general University funds.

*Ford Motor Company*

The microscopy facility struggled with personnel changes, funding, and dispersion of equipment across campus rather than in a single centralized location. Little or no electron microscopy was being performed in 1968, when the Botany Department hired Thomas Freeman, a new PhD graduate of Arizona State University as an assistant professor. Dr. Freeman, who had taken a single one-hour electron microscopy class in graduate school, was informed upon his arrival that, in addition to a full teaching load of seven courses in basic botany, plant anatomy, and plant morphology, he would also be in charge of overseeing the electron microscope and its operation.

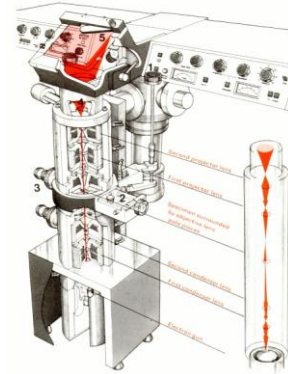
In March 1969, Dr. Klosterman, Dr. R. L. Kiesling, and Dr. Freeman formed an ad hoc committee for microscope operation. Deans Hazen, Sugihara, and Callenbach along with representatives of the departments of Plant Pathology, Biochemistry, Veterinary Science, Natural Sciences, Bacteriology, and Agronomy also were involved in planning. The committee suggested that President Loftsgard establish a trust to guarantee technician salary and travel expenses as well as the service contract. The proposed charge for use of the microscope at that time was \$20 per hour.

The electron microscope proved to be a burden for the biochemistry department in terms of space and money, considering their limited use of the instrument. Miss Blas resigned May 31, 1969, and no technician was sought to replace her. The RCA TEM went unused from May 1969 until January 1970, when interest in electron microscopy revived; the instrument was moved from Ladd Hall to a former storage room in the basement of Stevens Hall, which had been completed and dedicated in October 1968 to house the Division of Natural Sciences.

Dr. Freeman continued to pitch the concept of a microscopy service facility to the University administration, and the "Electron Microscope Center, a university resource, with campus-wide availability," was established. A technician position was converted to a supporting faculty position: Dr. Thomas Borg, an entomology graduate of the University of Wisconsin-Madison, was hired in August 1970 as an assistant professor, to be head of the EM Center, responsible to Vice President D. G. Worden, and to teach electron microscopy and subcellular cytology courses. Half of Dr. Borg's salary was funded by the Themis project, a large research grant sponsored by the Air Force to stimulate university research on subjects of interest to the Air Force and headed by Dr. M. S. Quraishi. Mosquito eradication was the intended focus of Themis at NDSU. Dr. Klosterman resigned as Chairman of the EM Committee in October 1970, and Dr. Worden named Dr. Borg as temporary Chairman. Despite wide acceptance of the *concept* of an electron microscopy center, no definitive funding arrangement was made.

Laboratory use and support increased as electron microscopy was recognized as a valuable research and teaching tool. In 1972, nine researchers had cooperative EM projects, and teaching for five classes utilized the TEM. Excellent working relationships had been established with the University of North Dakota Medical School and the USDA Metabolism and Radiation Laboratory. By 1973, seven courses included use of the microscope.

In March 1973, the RCA 3C TEM was traded in towards purchase of a new AEI Corinth 275 for \$39,800 (\$193,263 in 2008 dollars.) At just over half the cost of similar instruments, the 60 kV AEI, along with its vacuum system and power source, was packed into a wood-finished console desk and boasted the largest viewing screen of any electron microscope and a resolution of 7 Å. Four specimens at a time could be loaded through the airlock. The most significant difference between the Corinth and other TEMs, however, was the position of the microscope column: it was upside down, mounted at floor level and rising to a viewing height of 1.02 m. Seven steel rings formed the column, and these had to be aligned manually.



From the beginning, however, NDSU's AEI instrument was beset with problems, needing five days of on-site service in May 1973 alone. Replacement of the anticontaminator damaged before installation took eight frustrating months. Obtaining micrographs on the 70-mm roll-film camera was inconsistent because of static discharge and scratched negatives. A prototype glass-plate photographic system installed in January 1974 did not alleviate the static problem completely, and jamming was common. The cathode assembly had to be replaced in October 1974, and there were vacuum and electronic problems as well. Finally, in 1975, AEI agreed to supply from its factory in England a new tested set of vacuum electronics, lens/high-voltage regulator electronics, and polyester-roll-film camera with a new type of cassette. With those changes completed by early 1976, microscope operation was much improved.

Dr. D. G. Davis, research physiologist at the USDA Metabolism and Radiation Research Laboratory, urged the USDA in 1973 to purchase a scanning electron microscope for its electron microscopy facility to support research efforts including cooperation with NDSU scientists. The cost was estimated at \$43,000 to \$73,000. The USDA did have both a Phillips 100 TEM and an SEM, which never worked properly at higher magnifications, possibly because of vibrations inherent in the Red River Valley geology. Usage of the USDA electron microscopy lab declined after the departure of Dr. George

Gastner, who had headed the lab, and it closed late in the 1980s. Since that time, USDA scientists have been frequent users and collaborators of the NDSU facility.

Dr. Borg left NDSU for a faculty position as Assistant Dean at the University of South Carolina College of Medicine effective June 1975. Dr. L. J. Littlefield was elected Chairman of the EM Committee and directed to request permission from Dean Sugihara of the Graduate School to initiate a search for Dr. Borg's replacement. Dr. Freeman became director of the laboratory again in spring 1975. A request from the EM Center to the NDSU Special Equipment Advisory Equipment Committee for \$20,000, about half the purchase price of a scanning electron microscope, was not approved. Dr. Freeman hired part-time student technician Keith Kosse, a veteran, with the assistance of Governor Arthur Link. Ultimately, through cooperation across campus (Experiment Station, College of Agriculture, College of Science and Mathematics, and numerous departments and individual researchers), the first SEM, a JEOL JSM-35, was purchased in the spring of 1976 for \$57,150--about \$216,547 today. It was installed on the second floor of Stevens Hall in room 229, renovated for \$3600, as the basement space was too cramped to hold another instrument. That instrument more than doubled utilization of the facility. As more faculty and students began to incorporate ultrastructure into their research, the electron microscopy laboratory became a true university-wide resource. Service work, mostly performed by Dr. Freeman, was offered to all NDSU colleges and departments in December 1976. Service charges at that time are outlined in Table 1.



**Table 1. Electron Microscopy Charges in 1976**

Service	Charge
Microscope usage	\$5.00/hour
Technician's services, if used	\$6.00/hour
SEM stubs	\$0.60 each
Metallic coating	\$1.00/sample
Fixation for SEM	\$1.50/sample
Critical point drying	\$1.00/sample
Polaroid film	\$1.10/sheet
TEM sample preparation	\$5.00/sample
TEM micrographs, including 8x10" print	\$0.75 each

Annelee Donnelly was hired for technical support in 1977. She served in that position until her family moved to Colorado in 1979. A struggle to obtain a full-time

technician for the EM Center continued through the late 1970s. Salary funding had been rejected by the College of Agriculture and Experiment Station in 1977 on the basis that the microscope facility should generate enough income from service charges to support itself and a technician, despite the fact that the primary users then were scientists from the Agricultural Experiment Station. Student interest had increased to the point that fully half the qualified students had to be turned away from the formal EM courses. On May 16, 1978, administrative responsibility for the supervision of the EM laboratory was transferred from the Graduate School to the Dean's Office of the College of Science and Mathematics because laboratory operations, particularly instruction, were tied closely to activities of Science and Mathematics. According to an August 1978 letter from Associate Director (later dean and Director) Roald Lund of the Agricultural Experiment Station, the State Board of Higher Education approved hiring a laboratory technician for the EM laboratory, and the Department of Botany was to develop a Hatch level station project to cover the lab's activities. Norman Olson, who had worked in the laboratory on an hourly basis while completing his MS degree in Botany, replaced Mrs. Donnelly as full-time technician in 1979, supported by the Agricultural Experiment Station.

Growing demand for greater magnification and resolution as well as user capacity necessitated new instrumentation. The AEI Corinth alone no longer was adequate to meet educational, research, and diagnostic demands. January 1980 saw the acquisition of a new research-quality TEM (JEOL JEM-100CX) for \$139,000 (\$363,694 today), and the entire microscopy laboratory was relocated to remodeled space on the third floor of Stevens Hall.

By 1981, it was clear that the AEI Corinth electron microscope would have to be replaced. The service contract price increased by 25%, while service days were limited to ten per year. Kratos (AEI) had not manufactured electron microscopes for several years, so parts and supplies were difficult to obtain. In November 1981, a second JEOL TEM, the JEM-100S, did replace the AEI Corinth, which had been out of service a dozen times in the previous year, necessitating emergency service calls and at least 60 days downtime. The 100S cost \$94,170 (\$223,356 in 2008). In addition to several university administrative units, the North Dakota Beef Commission contributed \$10,000 toward the purchase price because of the need for a diagnostic instrument in the NDSU Calf Scour Project. Veterinarian Dr. Allan Peterson had been assigned to the laboratory to help handle the increased workload, but he was reassigned to other aspects of the project, prompting a request for an additional full-time technician to relieve the four- to six-month backlog in electron microscopy work.

A second technician, Mrs. Kathy Iverson, joined the EM Center as a half-time Laboratory Technician III in 1981, funded by the EM Lab trust fund. Mr. Olson resigned in 1982 to accept a full-time biology teaching position at Concordia College. Technical positions in the laboratory were upgraded to Research Specialists. Although Ms. Iverson was promoted to a Lab Tech IV late in 1982, she apparently received no salary adjustment for her increased responsibility until at least January 1984. Over 1000 samples were examined in 1984.

During 1985, the EM laboratory examined over 1200 samples, representing research efforts by 42 scientists and 35 graduate students from 13 university departments in four colleges, plus the USDA metabolism and radiation laboratory, and the local medical community. Workshops, seminars, laboratory experiences, and demonstrations were presented in addition to formal courses in both scanning and transmission electron microscopy. Mrs. Donnelly returned to the laboratory as a Research Specialist, but resigned again in 1986 for a position in the Graduate School.

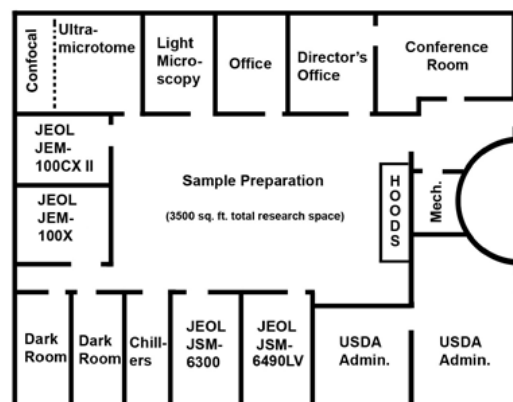
Budget problems in the Agricultural Experiment Station in 1986 stimulated discussions on alternate funding for the Electron Microscopy Laboratory. One proposal required all technical support and maintenance-contract costs to be borne by EM users, and would have necessitated a tenfold increase in service charges. Apprised of this potential change, many users wrote to Dean Lund and Dean Schnell to relate the importance of EM to their research and the adverse effects that the rate increase would have on their programs. The EM facility was reorganized through appointment of a committee of EM users and university administrators (Deans Fischer, Lund, and Schnell) to advise on policy development and user fees. The facility and its operational budget remained under the Office of Graduate Studies and Research, and the Agricultural Experiment Station continued to provide 50% salary support for Dr. Freeman and funding for one technician (reduced from 1.5 in March 1986.)

Agriculture administration in 1986 was encouraging allocation of new and existing resources to basic science, with a goal of increasing general fund dollars dedicated to non-applied research from 27% to 40% over the next four years. The Experiment Station also lobbied for federal support for a state university biological sciences building. North Dakota Senator Quentin Burdick was instrumental in redirecting that focus toward establishing a federal biological research building on the NDSU campus. The USDA-ARS did agree, however, to house NDSU electron microscopy within the proposed USDA building, and several other NDSU scientific laboratories also were located there until Loftsgard Hall was completed.

Mrs. Iverson resigned from the university in 1986 to spend more time with her young children. In 1987, Mr. Jay Bjerke was hired as a Research Specialist, and a cryogenic unit, emScope SP2000A, was added for the scanning electron microscope. The Agricultural Experiment Station helped support both actions financially.

March 1988 saw the final relocation of the Electron Microscopy Laboratory to the newly built Northern Crop Science Laboratory of the USDA Agricultural Research Service on the west edge of campus. Dr. Freeman designed the facility specifically for electron microscopy, a luxury after spending years in retrofitted and limited space. The laboratory took shape only after 2 years of planning and another 1.5 years of construction. The EM suite was the first one occupied in the new building, and in fact, the *sole* one occupied for two months, sharing space only with construction workers until other USDA research units arrived in May. The laboratory recommenced service after the move on April 4, and operated near capacity for the next eight months (assisting 44 research scientists from 13 departments) in addition to hosting 41 formal tours and over 1300 visitors. The new facility was the subject of an article in *Microscope Technology & News* in May 1989.

The EM Center occupies 3500 square feet near the main entrance of the architecturally distinctive NCSL on the western edge of the NDSU campus. A dozen rooms, including offices, instrument rooms, darkrooms, and a conference room also used for teaching, surround the high-ceilinged central specimen preparation area, which is flooded with natural light from large windows 35 feet overhead. Concrete isolation slabs in the poured-epoxy floors float free on sand to minimize vibration in the four rooms housing electron microscopes; those rooms have their own mechanically isolated electrical wiring, chilled water, and nitrogen systems. Baseboard heat in the ultramicrotomy laboratory minimizes interfering air currents. The preparation area has three powerful stainless-steel fume hoods and bench space for a range of ancillary equipment as well as copious cabinetry. A unique exhaust system vents air directly to the outside, and slight negative pressure assures that no fumes enter the rest of the USDA facility.



On June 6, 1989, Deans Fischer, Lund, and Schnell agreed to transfer administration of the Electron Microscopy Laboratory from the College of Science and Mathematics, the Agricultural Experiment Station, and the Graduate School/Research Administration to the NDSU Biotechnology Institute, effective July 1, 1989. The Biotechnology



Institute, directed by Dr. Ross Wilkinson, reported through its Executive Committee to the Office of the President and was to comprise the Electron Microscopy Center, a DNA laboratory, and a monoclonal antibody laboratory. The Electron Microscopy Center cooperated with the Biotechnology Institute but remained a separate entity.

Mrs. Iverson returned to NDSU in 1991 on a half-time appointment as a Research Specialist II supported by the EM lab trust fund without appropriated salary. Mr. Bjerke left the University for a position with Cargill in 1992.

Dr. Freeman's appointment was transferred from the Department of Botany/Biology to the Department of Plant Pathology in the spring of 1993. The Department of Botany no longer exists: it merged with the Department of Zoology to form the Department of Biological Sciences in 2000. In 1994, EM laboratory personnel were reduced from two full-time technicians to one 3/4-time technician.

Acquisition and updating of microscopes and a full complement of ancillary equipment continued. A successful 1992 National Science Foundation grant with University match provided \$261,945 to purchase a replacement SEM, the JEOL JSM-6300, in 1993; a Noran Voyager X-ray microanalysis system was added in 1994. That instrumentation has undergone several generations of upgrades and is still in service. The trade-in value for the JEOL JSM-35 SEM was \$63,450--not bad for an instrument that had cost some \$6000 less when it was new in 1975. The JSM-6300 produces digital image files that initially were saved on optical disks. Through support from the Agricultural Experiment Station as well as the Department of Plant Pathology, Mrs. Iverson's position was changed from 1/2 to 3/4 time. Dr. Freeman's academic appointment in Plant Pathology was changed to 95% research and 5% teaching; his responsibility to the EM laboratory was unaltered. The cooperative administration and financial support of the laboratory by the Graduate School, College of Science and Mathematics, and Agricultural Experiment Station became uncertain.

Personnel changes and the hunt for equipment persisted. Mr. Scott Payne came to the Electron Microscopy Center as a half-time Research Specialist II in April 1995, with his salary at that time completely dependent on EM laboratory operations income. Ms. LaRae Ewert joined the lab staff as a part-time hourly employee in 1996. In 1998, a Codonics NP-1660 photographic network printer was purchased. That signaled a decrease in darkroom printing of SEM micrographs, and the EM staff began to produce posters for meetings and other presentations using computer graphics and large-scale plotter printouts, rather than paste-up of darkroom prints by hand onto card stock. The photographic darkrooms continued to be well-used, however, because output of the two



JEOL TEMs was (and remains) 3-1/4 x 4-inch black-and-white negative film. Mrs. Iverson was promoted to Research Specialist III in 1998, then left NDSU in 2000 to work for Eli Lilly and Company in pharmaceutical sales. Since 2000, micrographs from the JSM-6300 SEM have been archived as “read only” files on a high-speed NDSU server known as RESSTOR. Mr. Payne became Assistant Director of the Laboratory in 2002. In January 2003, Dr. Jayma Moore, a veterinarian, came to the EM Center as a 3/4-time research specialist, funded entirely by the trust; she was named Laboratory Manager in 2007.

**Table 2. Technical Staff of the NDSU Electron Microscopy Center**

<b>Name</b>	<b>Tenure</b>	<b>Funding Source</b>
Keith Kosse	1975-1977	Graduate Office
Annelee Donnelly	1977-79, 1985-86	Trust
Norman Olson	1979-1982	Experiment Station
Kathy Iverson	1981-1986	College of Science and Mathematics
Jay Bjerke	1987-1992	Experiment Station
Kathy Iverson	1991-2000	Trust (1/2 time 1991-1993); Experiment Station (3/4 time 1992-2003)
Scott Payne	1995-present	Experiment Station (<60%) + Trust (>40%)
LaRae Ewert	1996-present	Trust (part-time)
Jayma Moore	2003-present	Trust (3/4 time)
Kelly Benson	2004-2005	Trust

The first JEOL JEM-100CX TEM developed an instability in the high-voltage lens tank in 2002, and required more than eight weeks of continuous service. Replacement parts for the 25-year-old instrument were hard to find, and it was retired in 2003. With the assistance of JEOL, the 100CX was replaced by a JEM-100CX II that had been at the University of Chicago, the same institution that had provided NDSU’s first TEM forty years previously. Crating, storing, shipping, and installing the 100CX II cost \$10,337.

The Infrastructure Improvement Program of the North Dakota Experimental Program to Stimulate Competitive Research (EPSCoR) in 2003 provided just under \$100,000 for a CARV (spinning disk) confocal imaging system with Nikon light microscope. In an ongoing search for new major-instrument funding, the Electron Microscopy Center staff prepared unsuccessful Major Research Instrumentation grant proposals for the National Science Foundation in 2003, 2004, and 2005. A proposal for \$287,690 finally was funded in 2006. Using that NSF money, the JEOL JSM6490LV variable-pressure SEM with Thermo energy-dispersive X-ray analysis system and remote-operation capability was purchased in 2006. Because of the design of the instrument, it required addition of an active vibration isolation system, which prolonged installation by

months, until summer 2007. A Nikon SMZ AZ100 stereo light microscope was obtained in 2007 as well. Also in 2007, Drs. Dean Webster and Bret Chisholm of the Department of Coatings and Polymeric Materials and the Center for Nanoscale Science and Engineering purchased an RMC Powertome XL + CRX cryoultramicrotome for ultrathin sectioning of materials like polymers that cannot be embedded traditionally. The cryoultramicrotome is housed in the Electron Microscopy Center, where the EM staff does the sectioning.

The Electron Microscopy Center has adapted to meet current and changing needs of the research community, while attempting to provide stability and continuity of service. The past decade has seen a marked increase in imaging and x-ray analysis for materials and engineering. However, veterinary diagnostic microbiology (pathogenic virus identification) continues to be the primary use for the 100S TEM, with calf scours still a problem today as it was in 1981. Long-term commitments to cooperative projects have increased as a way to secure reliable funding for personnel, and principal research areas involved have included ultrastructural studies of the glassy-winged sharpshooter (*Homalodisca coagulata*); greenhouse, giant, and silverleaf whiteflies (*Bemisia* and *Aleurodicus* spp.) and their parasites; and damage to wheat caused by the Hessian fly (*Mayetiola destructor*). Over the past 15 years, through a creative mix of funding options, Dr. Freeman has obtained nearly \$1.75 million for equipment, supplies, and salaries to support the NDSU Electron Microscopy Center: cooperative agreements with USDA-ARS personnel comprised \$469,170; NSF funding amounted to \$418,326; EPSCoR provided \$99,532; and other competitive grants accounted for \$758,540. Total purchase price to date for equipment acquisition within the EM Center exceeds \$1.5 million.

Unlike most service facilities, which have large hard-money budgets, the EM Center receives minimal appropriated dollars through the Agricultural Experiment Station, covering only a portion of the salaries of the director and assistant director. The rest, along with essential supplies, are unsupported by the state, and depend entirely on income from operations. Funding and administrative oversight of the center continue to be issues of concern. Continued university support through service contracts has been essential to survival, as well as cost-effective: the annual cost of the service contracts always has been much less than the hourly cost of parts and repair service received.

Dr. Freeman marked his fortieth year as director of NDSU's electron microscopy capability in 2008.