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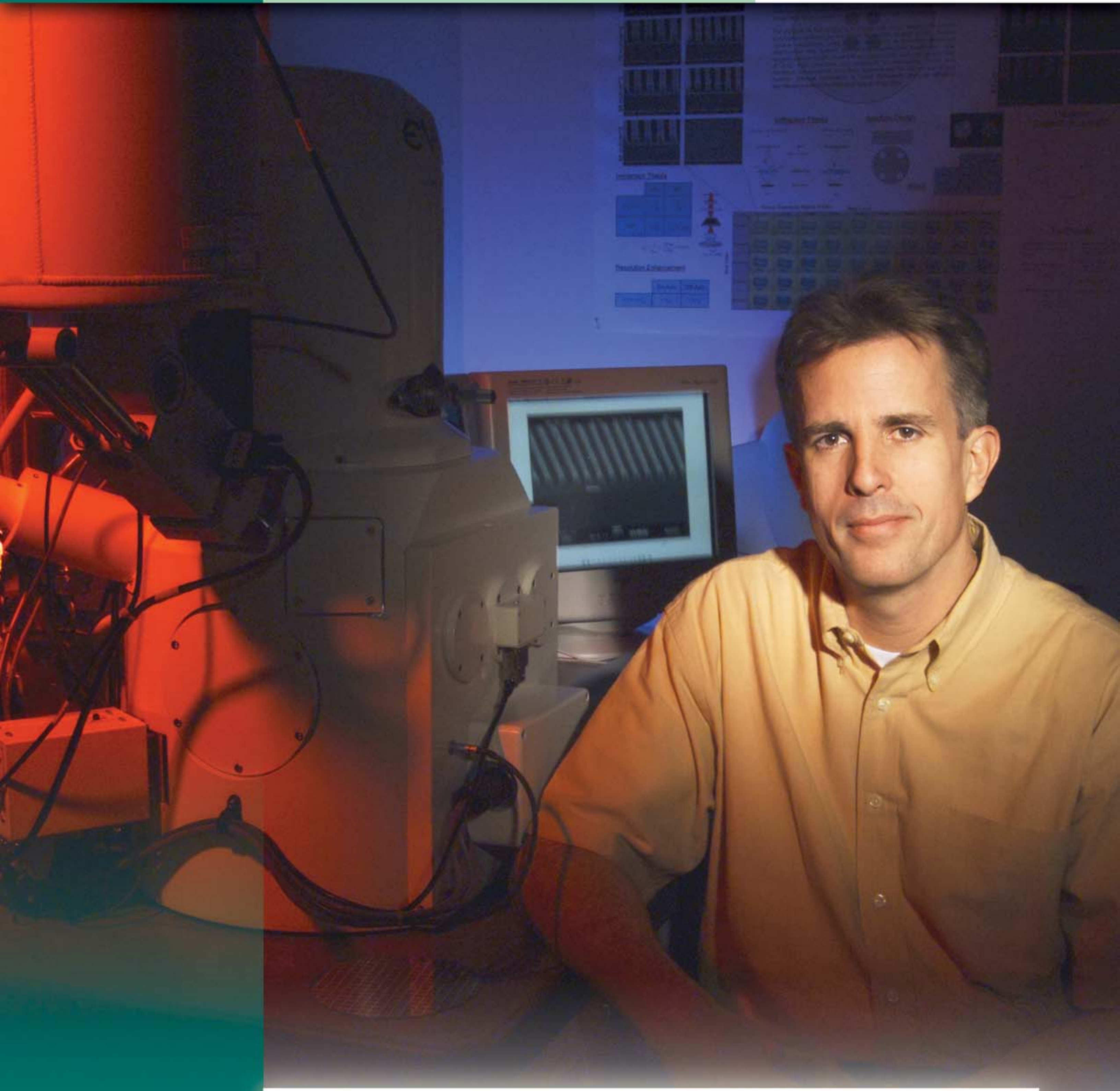


RIT RESEARCH PROGRAMS 2004 ANNUAL REPORT

ROCHESTER INSTITUTE OF TECHNOLOGY

Bruce Hartpence, Wade Robison, Kitren VanStrander, Paul Petersen, Roy Berns, Andy Harlan, Michael Stinson, Nirmala Shenoy, Bill Garno, Harvey Rhody, Stephen Boedo, Jennifer Schneider, David Merritt, Ronald Kelly, Diane Hope, Thomas Smith, Ryne Raffaelle

ASSOCIATE PROVOST'S REVIEW

SCHOLARSHIP at RIT

Donald Boyd

This past year, President Albert J. Simone led a campus-wide program to develop a new 10-year Strategic Plan for implementation beginning in 2004–05; a key dimension shaping this new plan is "scholarship." Scholarship at RIT takes four forms: applications of new technologies; integration of multiple technologies into new discoveries; the creation of new knowledge, philosophical, and artistic outcomes; and innovative methods of teaching and pedagogy. This year's research report focuses on faculty scholarship and the ways that it enhances teaching, learning, and our partnerships with industry, government, and other universities.

Design, fabrication, development, and applications of microsystems are key themes of the RIT scholarship story. The feature story of this report and the first four research short stories involve key programs in microsystems and working at the micro/nano level of materials. The feature story comes from Dr. Bruce Smith, who, along with his team of students and staff, is extending the life of current semiconductor fabrication techniques up to 10 years by using liquid immersion lithography to achieve nanometer geometries on semiconductor wafers. Dr. Stephen Boedo is investigating the tribological effects of friction, lubrication, and wear on devices such as micropumps, micromachines, and turbines, which require bearings at the micro level. Professor of Chemistry Thomas Smith and his students are

Front cover: Dr. Bruce Smith in his laboratory

continued →

2004 ANNUAL REPORT

RESEARCH FINANCIAL SUMMARY

← *from inside cover*

researching functional polymers for fuel cell membranes that maintain high proton mobility at high temperatures and low humidity. Dr. Ryne Raffaelle's nanopower team is investigating applications of nanomaterials in an innovative alpha-voltaic battery. Wrapping up the micro/nano story is the imperative to educate today's students on the technical, ethical, and social aspects of emerging applications in nanotechnology. To achieve this, the National Science Foundation is supporting Dr. Wade Robinson, Dr. Diane Hope, and Dr. Paul Petersen to develop and teach a pilot sequence of courses in these areas.

Another unique theme of RIT's scholarship is the science of imaging and imaging applications. In this vein, Dr. David Merritt is investigating the physics of black holes while Dr. Harvey Rhody is leading a team of students and staff to apply geo-imaging technology to develop the next generation airborne wildfire detection system for the U.S. Forest Service. In support of fine arts, Dr. Roy Berns of the Munsell Color Science Laboratory is using spectral imaging to achieve color accuracy of archival images in museum collections. Led by Bill Garno, the students and staff of the Printing Applications Laboratory are assisting our printing industry partners in evaluating printing processes and new substrates. Finally, the team in the Imaging Products Laboratory of the National Center for Remanufacturing and Resource Recovery, led by Andy Harlan, has discovered a way to detect defects in "wiper blades" in laser printers to reliably predict their remaining life.

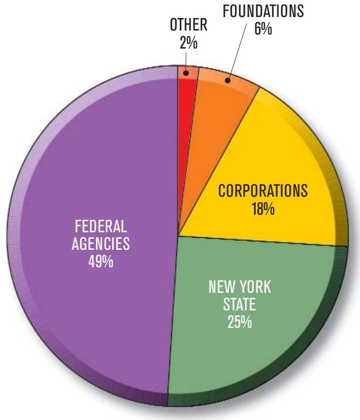
Researchers at the National Technical Institute for the Deaf are applying technology to assist deaf and hard-of-hearing students to learn and communicate more effectively. Dr. Ronald Kelly's team is using Web-based tools to assist students in the development of mathematical skills, while Dr. Michael Stinson is using voice recognition technology to achieve automated classroom interactions with hearing students and faculty.

In other areas, Dr. Nirmala Shenoy and Professor Bruce Harpence of RIT's B. Thomas Golisano College of Computing and Information Sciences are developing a framework for seamless roaming across cellular and wireless local area networks. Dr. Jennifer Schneider, of the College of Applied Science and Technology, and Kitren VanStrander, director of the OSHA Education Center at RIT, are assessing the safety needs of small businesses and developing training materials for them.

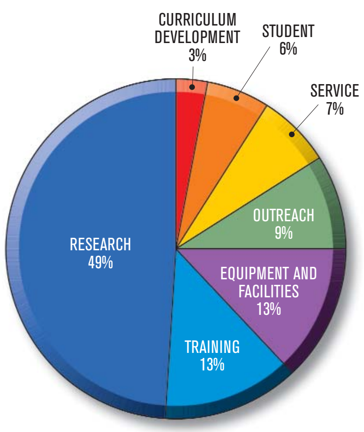
These are just a few of the faculty accomplishments that were motivated by the carefully crafted goals of achieving scholarship while extending RIT's history of partnership with industry and government. As to financial outcomes, the accompanying pie charts summarize the source, purpose, and disciplines of RIT's sponsored research. These charts depict a five-year total of over $132 million of research activity with an average annual growth rate of more than 26 percent. With a 175-year tradition of career-focused education and an increasing focus on faculty scholarship, RIT will continue to grow in reputation and prominence in our fields of technical strength.

Best Regards,

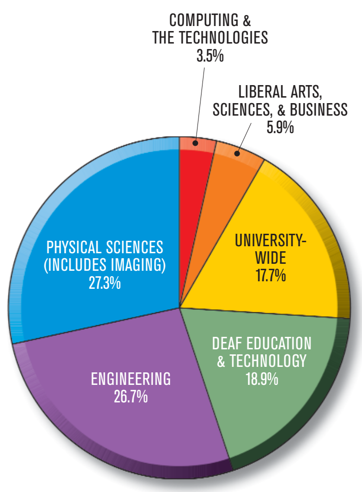
Donald L. Boyd, Ph.D.
Associate Provost for Outreach Programs



SOURCE OF FUNDS



GRANT ACTIVITY BY PURPOSE



DISCIPLINE

All figures represent a five-year total of awards (1999–2004).

RIT RESEARCH PROGRAMS

FACULTY RESEARCH AND SCHOLARSHIP

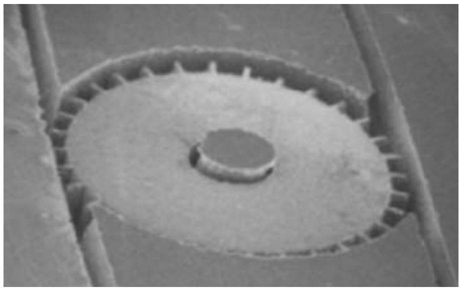
Dr. Bruce Smith in the immersion lithography laboratory

IN THE SPOTLIGHT: Immersion Lithography

Dr. Bruce Smith, Intel Professor of Microelectronic Engineering and associate dean of the Kate Gleason College of Engineering at RIT, is pioneering nanolithography research to shrink semiconductor and related device geometry to nanometer levels. By pushing the limits of optical imaging, Dr. Smith's students and research staff are conducting fundamental studies required to meet the needs of semiconductor manufacturing technology for the next five to 10 years.

Dr. Smith and his team are applying ultraviolet and vacuum ultraviolet excimer laser

Tribology at the Microscale



Scanning Electron Microscope image of a microbearing test fixture currently under development at RIT

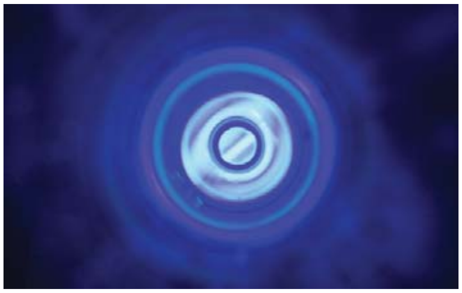
Stephen Boedo, associate professor of mechanical engineering, and his students are investigating the tribological effects of friction, lubrication, and wear on the performance of microscale journal bearings. Their research is focused on fundamental studies of reliable micropowered turbines, micropumps, and micromachines requiring bearings. Dr. Boedo has developed analytical models of bearing dynamics at the microscale level, allowing him to identify the effects of surface roughness, slip flow, and structural compliance. He has also developed a microbearing text fixture to quantify stiction and wear performance. Dr. Boedo's research is supported by the Department of Energy and the National Science Foundation.

Novel Fuel Cell Materials

Dr. Thomas Smith, graduate student Rohini Sajanpawar, and GM scientist Dr. Timothy Fuller

Dr. Thomas Smith, professor of chemistry, and his students are conducting research on functional polymers and their applications. In one aspect of this research, they are exploring fuel cell membranes that can maintain high proton mobility at elevated temperature (~120°C) and low relative humidity (~25 percent). Such membranes would be of significant benefit for both automotive and stationary fuel cell systems as electrode kinetics generally increase with increasing temperature, resulting in improved cell performance. Additionally, fuel cell membranes operating at ~120°C would allow for reduction of radiator size by 50 percent and use of conventional glycol coolants. Dr. Smith's work has been sponsored by General Motors Corporation and is being carried out in collaboration with Dr. Timothy J. Fuller, senior research scientist at GM Fuel Cell Activities in Honeoye Falls, NY, and visiting scholar in RIT's department of chemistry.

Alpha Voltaic Batteries



Photoluminescence from ZnS quantum dots prepared in the NPRL

Researchers in the NanoPower Research Labs (NPRL) under the direction of Dr. Ryne P. Raffaelle, professor of physics and microsystems engineering, in collaboration with research at the NASA Glenn Research Center, are using semiconducting quantum dots to develop long-lived radioisotope batteries. The concept of using a radioactive substance that emits energetic alpha particles and coupling it with a semiconductor p/n junction diode or solar cell to produce power was first proposed over 50 years ago. However, the radiation degradation in the p/n junctions dramatically limits the useful lifetimes of the devices. The NPRL is addressing this problem using new materials, such as quantum dots, and microstructured devices that have proven to be exceptionally radiation tolerant. This work is funded by the Defense Advanced Research Projects Agency (DARPA). RIT is working with a start up company, Alpha V, Inc., to commercialize this technology.

sources combined with liquid immersion imaging to achieve small feature resolution one-fifth the size of the exposure wavelength and one-fifteenth the wavelength of visible light. This latest optical resolution enhancement, known as liquid immersion nanolithography, an idea conceived over 125 years ago for microscope applications, is being applied to integrated circuit (IC) processing. Dr. Smith has turned the idea around, applying the technology to image reduction rather than magnification. Though the technical possibilities of immersion lithography had been considered in the past, application to device fabrication had not been pursued until now since the incremental extension of optical microlithography appeared to be coming to an end. The growth of the semiconductor industry is measured by Moore's law, which has predicted the complexity for minimum component cost to increase at a rate of roughly a factor of two per year. One of the main factors driving this increase is improvements in photolithography and the resulting ability to print ever smaller features. Since the mid-eighties, the demise of optical lithography has been predicted as being only a few years away, but each time it approaches a limit, some new technique pushes out the useful life of the technology. In the search for a high refractive index fluid compatible with the tools and materials used in IC processing, water has surfaced as the enabling media for this "new" technology. The optical properties of water are such that its refractive index increases significantly at wavelengths in the ultraviolet range. The attractiveness goes beyond mere resolution improvement, as existing optics and materials infrastructure are

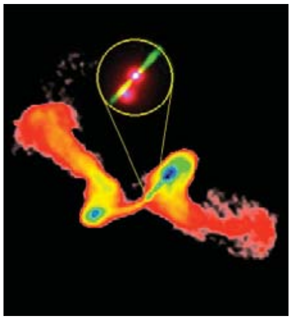
> *"This discovery makes it possible to extend the life of current methods and equipment past 2010, helping major chip makers avoid spending billions of dollars to remake their factories." –Bruce Smith*

Nanocurriculum

Nanocurriculum students in the fabrication laboratory

With support from the National Science Foundation, a multidisciplinary team is developing a pilot sequence of courses in nanotechnology, integrating the technical, ethical, and social dimensions of this emerging field. The first course on technology principles and ethical implications, led by Dr. Wade Robison, Ezra A. Hale Professor of Applied Ethics in the College of Liberal Arts, explores potential harms and benefits. Dr. Paul Petersen, assistant to the provost for nanotechnology programs, coordinates laboratory experiences in six nano-related technologies. Dr. Diane Hope, William A. Kern Professor in Communications, leads the culminating course, exploring the discourse surrounding nanotechnology's potential impact on health, environment, national security, computation, and communication. Rounding out these nationally recognized authorities are 11 RIT faculty members who, through participation in this sequence, are enhancing student understanding of the ethical and societal implications of nanotechnology applications.

When Black Holes Collide



Detail of merging black holes

Professor David Merritt, with collaborators from Cornell University, MIT, and the University of Chicago, is studying the enormous bursts of gravitational energy resulting when black holes collide. The "kick" that occurs during the collision could knock the black hole out of its galaxy, and although astrophysicists have been aware of this phenomenon since the 1960s, until now no one has had the analytical tools necessary to accurately calculate the size of the effect. Dr. Merritt, his students, and colleagues have determined how fast a black hole has to move to escape a galaxy's gravitational field and have determined that the "kick" occurs because gravitational waves emitted during the collision are anisotropic, producing recoil. This research greatly increases the possibility of finding observational evidence of "kicks" and furthers our understanding of the formation of galaxies. Dr. Merritt's research is sponsored by NASA, the Space Telescope Science Institute, and the National Science Foundation.

Wildfire Airborne Sensor Program

WASP provides enhanced wildfire-fighting tools

Dr. Harvey Rhody and his research team in the Laboratory for Imaging Algorithms and Systems (LIAS) at RIT are currently performing the Wildfire Airborne Sensor Program (WASP) for NASA. This program is developing an integrated sensor and data processing system for the U.S. Forest Service to detect wildfires. A four-camera visual and infrared (IR) airborne sensor platform has been developed and demonstrated over test sites and live fires. Additionally, a real-time airborne data processing unit is under development. WASP will provide maps with integrated geographic information and fire boundaries that can be used for faster, more accurate response to rapidly changing wildfire dynamics, improving the effectiveness and safety of the firefighting teams. The LIAS work on wildfires provides the foundation for a range of research activities currently being pursued with the National Geospatial-Intelligence Agency (NGA) and others in integrated geospatial information systems.

already in place for this technology versus alternatives. This pioneering work of Dr. Smith and his team has led to the acceptance by the international semiconductor industry of this technique as the recommended approach to nanoscale lithography for future device fabrication.

Dr. Smith's efforts are supported by industry, government, and university partners, including the Semiconductor Research Corporation, International SEMATECH, and the Defense Advanced Research Projects Agency. His research has resulted in the modification of the lithography projections of the International Technology Roadmap for Semiconductors.

Laboratories and Research Centers at RIT

RIT performs applied research and outreach in partnership with ind

Chester F. Carlson Center for Imaging Science

- Laboratory for Advanced Spectral Sensing
- Laboratory for Image Algorithms and Systems
- Laboratory for Astrophysics and Photonics
- Munsell Color Science Laboratory

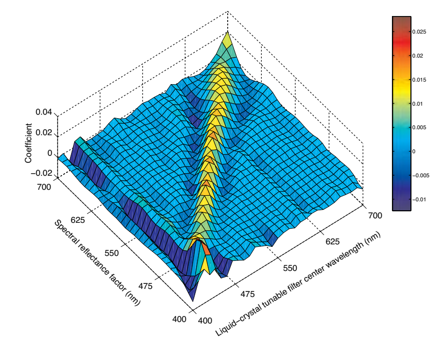
Printing and Graphic Media

- Sloan Printing Industry Center
- Printing Applications Laboratory
- Image Permanence Institute

Microsystems Technology

- NanoPower Research Laboratory
- Semiconductor and Microsystems Fabrication Laboratories
- Center for Electronic Manufacturing and Assembly
- Center for Nanolithography Research
- RF/Analog/Mixed Signal Laboratory
- Thermal Analysis and Microfluidics Laboratory

Art Spectral Imaging



Transformation mapping from camera signals to spectral reflectance factor

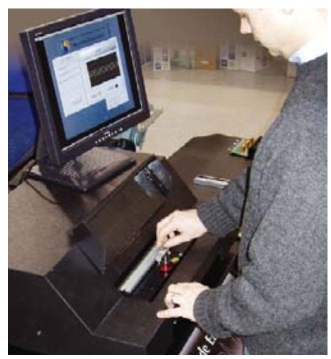
ART-SI, or Art Spectral Imaging, is an RIT research program focused on spectral-based color reproduction of fine art. The goal is to achieve accurate color archival management for museum collections. Dr. Roy S. Berns, the Richard S. Hunter Professor of Color Science, Appearance, and Technology, and his research team have formed a laboratory testbed that uses variations of spectral capture as well as soft display and ink-jet printing to develop optimal methods of image capture and reproduction. The team is evaluating three methods of spectral imaging capture; one or more of these methods will be used to build spectral-based image capture systems for the National Gallery of Art, in Washington D.C. and the Museum of Modern Art, in New York City. Dr. Berns's research is supported by the Mellon Foundation.

Applied Research in Printing

RIT's Heidelberg Web Press Laboratory

RIT's Printing Applications Laboratory (PAL), led by Director Bill Garno, plays a leading role in the printing and publishing industries by conducting applied research and educating future and current industry employees. With over 150 applied research projects per year, Mr. Garno and his staff conduct research in product development, manufacturing audits, process capability studies, and competitive assessments that provide companies worldwide with practical, measurable information necessary to understand, control, and improve the performance of their products. Research is centered around lithography, flexography, and digital printing processes, as well as comprehensive prepress and print materials analysis. The centerpiece of PAL's state-of-the-industry facilities is the new Heidelberg Web Press Laboratory, equipped with nearly $15 million of the latest web offset printing equipment, including a six-unit Heidelberg Sunday 2000 Web offset press.

Remanufacturing Imaging Components



Wiper blade defect detector

Through a grant funded by New York State, Andy Harlan and his research team in RIT's National Center for Remanufacturing and Resource Recovery (NCR^3) have assessed the potential for the remanufacture of imaging components from laser printers. Their research found that a key component known as the "wiper blade" is reusable for multiple life cycles, but only if the working edge is not damaged. An easy to use defect detector was developed by the NCR^3 team with the capability of predicting additional blade life cycles with an accuracy of 99.99 percent. The patent and rights to the design have been licensed for manufacturing and resale and the detectors are now in use in four countries. To date, more than 400,000 blades have been remanufactured, diverting over 1.5 million pounds of waste from landfills. NCR^3 is a division of CIMS, the Center for Integrated Manufacturing Studies.

ustry and government in a number of fields and through laboratories and centers:

Center for Integrated Manufacturing Studies

- National Center for Remanufacturing and Resource Recovery
- Systems Modernization and Sustainment Center
- Sustainable Systems Research Center
- Center for Excellence in Lean Enterprise
- Manufacturing Technologies Program
- Imaging Products Laboratory
- Occupational Safety and Ergonomics Excellence Program

Center for Bioscience Education and Technology

- Laboratory for Computational Biology
- Laboratory for Genetics of Human Sensory Loss
- Laboratory for Radiological Research

National Technical Institute for the Deaf

- International Center for Hearing and Speech Research
- Postsecondary Educational Network International
- Center for Technical Studies

Multidisciplinary Centers

- The *IT Collaboratory*
- Center for Quality and Applied Statistics
- ACT Center, Outreach Education and Training
- RIT High Technology Incubator

Computing and Information Sciences

- Center for Advancing the Study of Cyberinfrastructure
- Laboratory for Applied Computing
- Laboratory for Human Computer Interface Studies

Educating the Deaf and Hard of Hearing

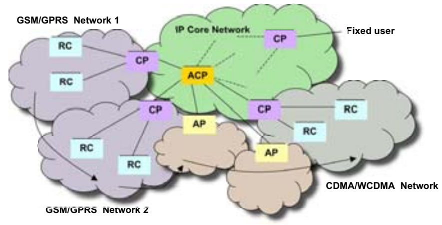
C-Print® automated speech recognition system

Web-based Project Solve

RIT's National Technical Institute for the Deaf (NTID) is a U.S. government-funded institute focused on higher education of the deaf and profoundly hard-of-hearing community. Its mission is to educate and apply cutting-edge solutions that improve the life and careers of its 1,100 students. Currently, there are two key research projects underway that achieve this mission:

- Dr. Michael Stinson is applying automated speech recognition through a dictation mask to transmit full text to laptop computers. Deaf and hard-of-hearing students can now have complete access to lectures and interactions with their fellow students. His work is supported by the U.S. Department of Education and the Spencer Foundation.
- Professors Ronald Kelly, Keith Mousley, and Stacy Davis are pioneering an innovative, automated mathematics word problem-solving system for high school and first-year college students who are deaf and hard of hearing. Supported by grants from the U.S. Department of Education, the *Project Solve* website offers online independent learning and guided practice for deaf students to improve their analytical thinking and mathematic problem solving skills.

Seamless Roaming



Integration framework for seamless cellular/WLAN roaming

Professors Nirmala Shenoy and Bruce Hartpence of the Laboratory for Applied Computing at RIT's B. Thomas Golisano College of Computing and Information Sciences are developing a Wireless Networks Integration Framework. This framework will facilitate seamless roaming for mobile users across cellular and wireless local area networks (WLAN). This research will allow a mobile user who initiates a voice call or data session under one network to continue with his or her connection while roaming into the coverage of another cellular network or WLAN. The integration framework targets smooth transitions in call quality via predictive handoff schemes, quality of service mapping, and negotiations while crossing the networks. The team's investigations are conducted via simulation and testbed studies that are based on Internet Protocol v6 and MobileIPv6. This work is funded by a Cisco University Research Program grant.

Safety Methodology

Students Laura Smith and Joe Brandine preparing safety equipment

An Occupational Safety and Health Administration (OSHA) Harwood grant was awarded to Dr. Jennifer Schneider and Kitren VanStrander to assess the safety needs of small businesses and develop training materials to promote safety and health management systems. Dr. Schneider is a certified industrial hygienist and an associate professor of civil engineering technology, environmental management and safety. Ms. VanStrander is director of the OSHA Education Center at RIT. Dr. Schneider is working with small businesses in Western New York to identify safety issues and implement management systems that can be supported within a small business structure. This work will result in the creation of Web-based training modules for small businesses accessible through the RIT OSHA Education Center website.

First in Class

First in Class is an RIT strategic initiative to invest in emerging technologies that will provide our partners, students, faculty, and the community with the technology to be successful in a rapidly changing world.

Through First in Class, RIT:

- Creates education and research programs in emerging technologies
- Prepares graduates with tools they need for successful careers in these fields
- Supports industrial and government partners with technology, resources, and people they need to remain competitive
- Fosters economic growth by creating the workforce of the future

RIT's First in Class concentrations:

- Imaging Systems
- Computing and Information Sciences
- Microsystems Technology
- Sustainable Design
- Biotechnology and Bioinformatics
- Printing and Graphic Media

More information on the First in Class program can be found on our website at www.rit.edu/firstinclass or by contacting:

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RIT at a Glance

- Founded in 1829 and emphasizing career education, RIT is a privately endowed, coeducational university.
- The campus occupies 1,350 acres in suburban Rochester, New York.
- The RIT student body consists of more than 15,000 full- and part-time undergraduate and graduate students in 360 career-oriented programs.
- Enrolled students represent all 50 states and 90 countries.
- RIT alumni number more than 90,000 worldwide.
- Cooperative education provides career-related work experience in many degree programs, annually placing 2,600 students in co-op positions with 1,300 employers.

RIT's eight colleges:

- College of Applied Science and Technology
- College of Business
- Kate Gleason College of Engineering
- B. Thomas Golisano College of Computing and Information Sciences
- College of Imaging Arts and Sciences
- College of Liberal Arts
- National Technical Institute for the Deaf
- College of Science

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