Developing Novel Detector Technology: Dr. Donald Figer, director of RIT's Rochester Imaging Detector Laboratory and professor of imaging science, is a national expert in detector technology. The laboratory develops and tests novel imaging detectors, like the Teledyne H4RG detector shown above, which will enable some of the most demanding observations.

Advancing Imaging Detectors

by Kara Teske

Advancements in imaging detectors promise to make more discoveries, solve more problems, cure more people, identify more threats, and manage resources more effectively.

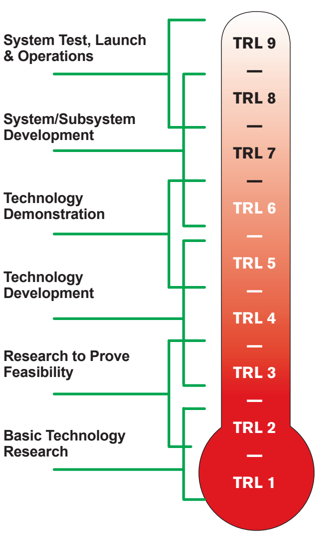
Rochester Imaging Detector Laboratory

Imaging detectors are often the limiting factor for the most ambitious observations, across a broad range of applications. Some of the most demanding challenges require high-performance detectors.

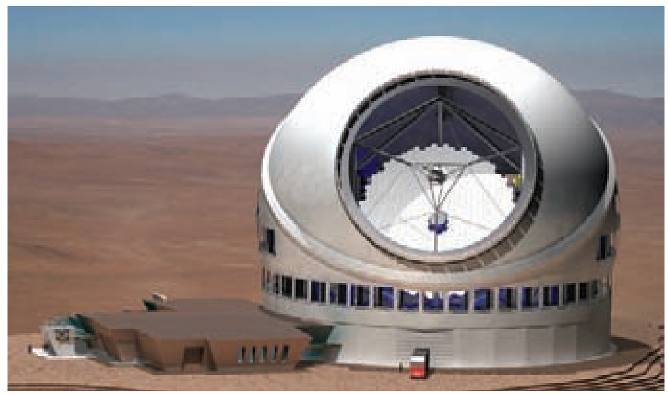
Founded in 2006, the Rochester Imaging Detector Laboratory (RIDL) is making significant contributions to design, develop, and implement advanced sensor technologies. Under the leadership of Dr. Donald Figer, lab director and professor of imaging science, the lab has established key partnerships with University of Rochester, Lincoln Laboratory at Massachusetts Institute of Technology (MIT), Sandia National Laboratory, the Jet Propulsion Laboratory at California Institute of Technology (CalTech), NASA, and other leading laboratories in an effort to advance imaging sensor technology.

RIDL aims to operate within all ranges of the Technology Readiness Level (TRL) scale, from initial conceptualization to successful deployment. TRL was developed by the Department of Defense and is used by agencies to assess the maturity of emerging technologies. At the low end—one to three—research is in its initial stages, where the idea for an invention begins. On the other end—six to seven—technology has been developed and is being tested in relevant environments. When an application is successfully deployed in its intended environment, the technology is said to reach a TRL of nine—full maturity.

"At RIDL, our desire is not simply to implement existing hardware, and not simply to invent crazy ideas, and not simply to advance technologies; it is the whole range," says Figer.



Technology Readiness Level: The Technology Readiness Level scale was developed by the Department of Defense and assesses the maturity of emerging technology. RIDL aims to operate along all levels of the scale.



Courtesy of TMT Observatory Corporation

Thirty Meter Telescope: TMT is expected to be among the first extremely large telescopes to be built over the next 20 years. The novel noiseless detector being developed at RIDL is expected to effectively quadruple the collecting power of the TMT for the faintest of objects in the Universe.

Novel Noiseless Detector

A quantum-limited imaging detector—that is the goal of the project sponsored by The Gordon and Betty Moore Foundation and in collaboration with Lincoln Laboratory. The novel detector will be able to detect individual photons, enabling the most sensitive observations from the world's largest telescopes, including the Thirty Meter Telescope (TMT).

TMT is expected to be the first of a new generation of extremely large telescopes, with a 30-meter diameter segmented

RIDL Facilities: RIDL is equipped with a class 10,000 clean room and class 1,000 flow bench to design and evaluate new detectors.

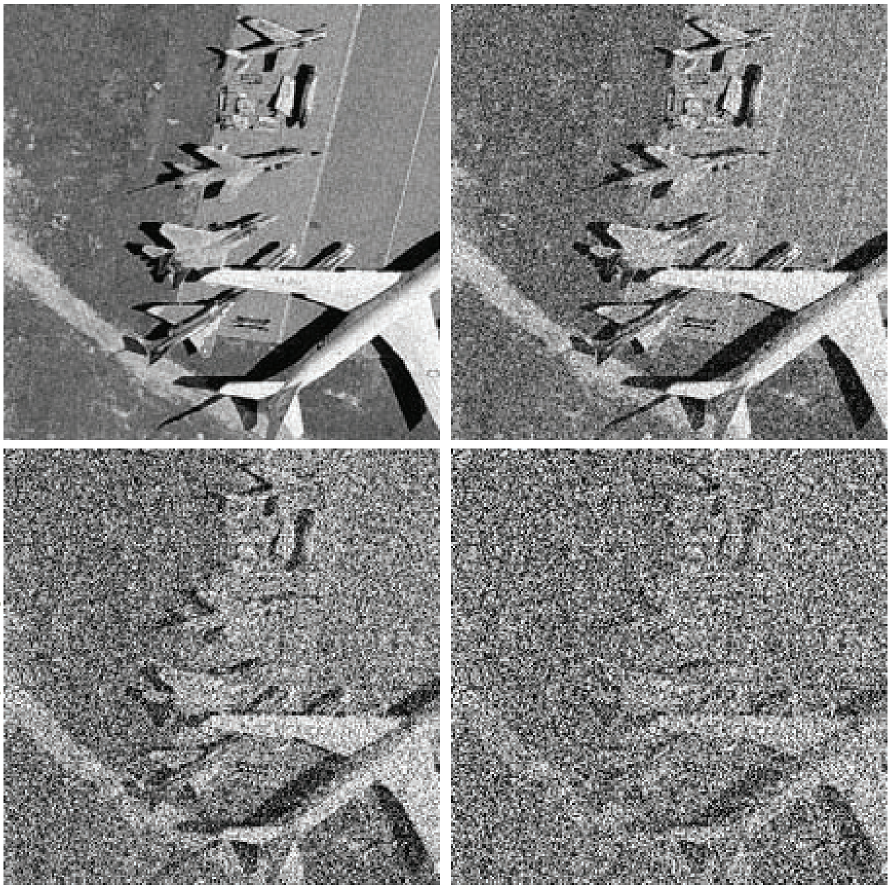
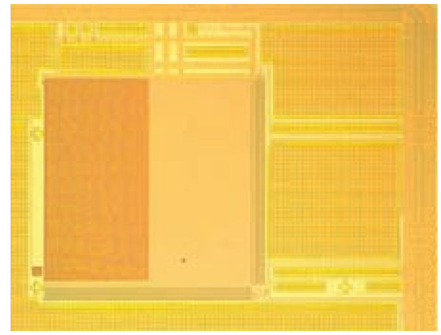
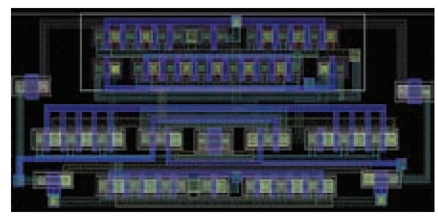


Photo credit: Michael Gartley and Don Figer.

Importance of Read Noise: The images above simulate varying levels of read noise in an image of airplanes at Robins Air Force Base. The image on the top left has zero read noise and the other images have read noise comparable to that found in common usage on space-based imaging platforms today. These images demonstrate the superior performance of a zero read noise detector.



Radiation Tolerant Detector: In partnership with NASA and the University of Rochester, RIDL is developing a detector that is expected to be resilient against the effects of high energy radiation. In planetary missions, radiation damage often limits the capabilities of deployed detectors.



Design for Radiation-Tolerant Detector: The device uses low power complementary metal-oxide semiconductor (CMOS) multiplexers arranged in high density.

mirror capable of observations from the near ultraviolet to the mid-infrared. With the novel noiseless detector, the collecting power from TMT will be quadrupled for low-light level applications. Quantum-limited imaging detectors will also be useful for ground-based and space-based astrophysics, Earth and planetary remote sensing, exo-planet identification, biomedical imaging, homeland safety, and even consumer imaging applications.

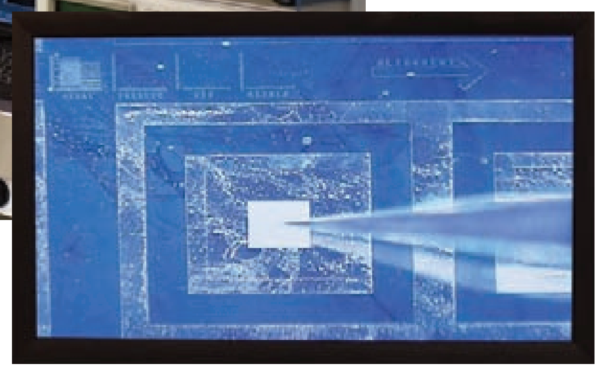
Regardless of the type, noise is often the limiting factor among most detectors. Usually caused by the device itself, noise can restrict the ability to view the image, especially in low-light conditions. "By using a digital photon counter to detect every single photon—or unit of light—our device will have zero read noise," says Figer. "A detector with zero read noise will dramatically reduce exposure times and increase the reach of the telescope."

The design is based on Geiger-Mode Avalanche Photodiode (GM-APD) circuitry. The device retains the best properties found in state-of-the-art devices, while demonstrating a 256x256 silicon focal plane array. By 2010, the detector is scheduled to be ready for testing in relevant environments. "This is a prime example of where we are inventing new technologies that are advancing the field," adds Figer.

Radiation-Tolerant Detector

For decades, we have been exploring life beyond Earth. The findings of these planetary missions often depend on the capability of deployed detectors. The challenge is long before the detectors reach their destination, the detectors must travel through harsh radiation

Probing a Test Structure: Matthew Simpson (right), 4th year biotechnology student, and Dr. Donald Figer (left) work in the clean room probing a test structure to determine properties of the detector, like dark current levels and breakdown voltage.



View of Test Structure: The test structure is an enlarged pixel and is probed to generate IV curves (electric current and voltage).

environments filled with solar particles, Galactic cosmic rays, and trapped magnetospheric plasma. And once they meet their final destination, even harsher radiation may await—near Europa and the Jovian moons, for example.

To maximize the "science return" of future planetary missions, the next generation of imaging detectors need to be immune to radiation. Through a project sponsored by NASA, and in partnership with the University of Rochester, RIDL is developing one such detector.

Current detectors for planetary missions

Journey of a Photon

Before high school students embark on their next life journey–college–Journey of a Photon gives students the opportunity to explore astronomy and detector science. The Journey of a Photon program is sponsored by NASA and led by Dr. Jacob Noel-Storr, associate research scientist at the Center for Imaging Science, and Dr. Donald Figer, director of the Rochester Imaging Detector Laboratory. The program immerses high school students in learning and communicating science by creating an interactive planetarium-like experience.

The program fosters relationships among students, science teachers, and the local scientific community. Students interact with researchers to understand the science issues involved with the Journey of a Photon, from its creation to its detection. At the conclusion of the program, final projects will be exhibited this fall at the Rochester Museum and Science Center to correspond with the International Year of Astronomy and the Coalition On the Public Understanding of Science (COPUS) Year of Science.

"The goal is to engage students so that they may enter a science discipline when they head off to college," adds Noel-Storr.

2009 Quantum-Limited Imaging Detector Symposium

On March 2-3, 2009, RIT hosted scientists and researchers from academia, government, and industry to advance the field of quantum-limited imaging detectors. The realization of quantum-limited imaging detectors would enable the ability of some of the most demanding measurements.

Experts from a broad range of fields shared critical application needs and new technology developments that could help to address those needs. Presenters included Andrew Berger of The Institute of Optics at the University of Rochester, Tim Tredwell of Carestream Health, Jim Beletic of Teledyne Imaging Sensors, Jeff Puschell of Raytheon Space and Airborne Systems, Dan Newman of ITT, and Brian Aull of Lincoln Laboratory.

Through collaborative breakout groups, participants identified key activities to enable the realization of quantum-limited detectors. "By bringing together such exceptional talent and experience, we were able to spark new ideas and create new opportunities that will bring our field just another step forward," add Dr. Donald Figer, event coordinator.

More information about the event is available online at http://www.rit.edu/research/itc/symposium/.

Advancing the Field: Jim Beletic, director of Astronomy and Civil Space at Teledyne Imaging Sensors, led a session on critical needs and applications for astrophysics at the Quantum-Limited Imaging Detector Symposium hosted at RIT.

use advance forms of the basic Charge-Coupled Device (CCD) or Complementary Metal–Oxide–Semiconductor (CMOS) multiplexers. By taking advantage of the performance approach in CCD and the low-noise capability of the CMOS architecture, RIDL is merging proven technology to improve the performance and provide excellent noise properties of CCDs.

The technology of the device instantly converts electromagnetic signals into digital information, pixel by pixel, eliminating the ability for radiation to affect the signal. "With the instant conversion, radiation doesn't have time to affect the signal. Once the data is digitized, it's nearly impossible to pick up noise," notes Figer.

To accurately assess the device's immunity to radiation, the device will be tested in three relevant environments, including the particle beam at UC Davis Crocker Nuclear Laboratory. When successfully deployed, the radiation-tolerant detector will enable greater information gathering capabilities in future planetary missions.

A Solution for Sandia

Much of RIDL's research and development focuses on detector technology, but the lab is also developing firmware and software applications to support these technologies.

Daniel Pontillo and John Frye, RIT computer engineering graduate students, are working with Sandia National Laboratories to develop hardware description language (HDL) software that is compatible with a specific infrared camera. The research students are investigating the feasibility of customizing a standard Field Programmable Gate Array (FPGA) chip to acquire data in a format compatible with the infrared camera in real-time.

"We have been able to implement a digital system within the FPGA that allows us to display the data on the computer," says Frye. "The next step will be to develop the software. While the challenge is rather rudimentary, it has allowed me to apply my knowledge of detectors and has given me exposure to a national laboratory. That experience is unmatched."

This research will help Sandia evaluate new sensor technology against critical mission areas.

Future of Detectors

In just three years, RIDL has established a national reputation for helping to advance detector technology. "The applications are wide—from making new discoveries outside our planet to having a better view of the innermost parts of the body. It is our hope the technology we create here may help to address some of the world's most pressing challenges," adds Figer.

On the Web

More information about this research and the Rochester Imaging Detector Laboratory is available online.
http://ridl.cis.rit.edu/

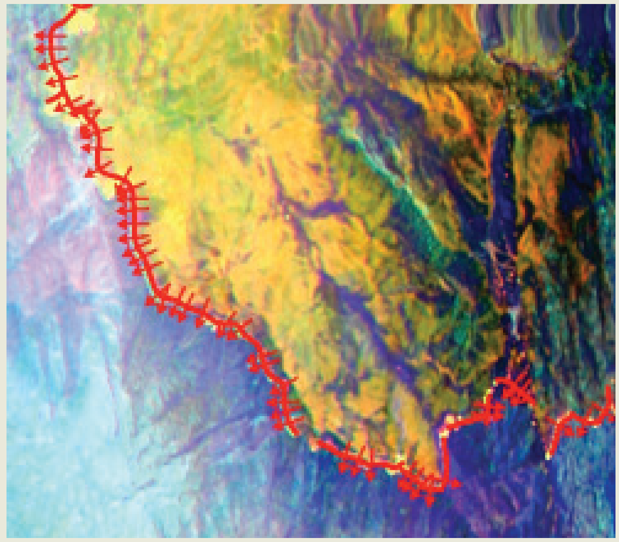
Managing Wildfires


Anthony Vodacek

RIT imaging scientist Dr. Anthony Vodacek is part of a multi-university partnership that is creating mathematical models and computer simulations to better manage and predict wildfires. Vodacek, an associate professor in the Center for Imaging Science, is utilizing imaging technology developed through RIT's Wildfire Airborne Sensor Program (WASP) in the development of new software that integrates assimilation algorithms and sensor data to produce real-time simulations of wildfire movement.

The process collects and analyzes data on fire development, local weather patterns, and wind speed to generate better predictive models on how and where a fire will spread. Additional software is then used to assimilate model data with geographic and thermal maps to help fire planners better plan emergency response and evacuations.

"A wildfire is essentially an atmospheric phenomenon that interacts with local weather patterns," notes Vodacek. "This project is creating more robust models that will assimilate what is happening on the ground and in the atmosphere with how the fire is moving."



Simulation to Predict Wildfire: A false color image of a wildfire is processed to automatically extract the position of the active fire line (red line) and the direction of propagation of the fire (red arrows) based on image processing tools.

The technology will also ultimately shed new light on how large fires affect existing weather phenomena, such as local wind patterns, allowing experts to better predict how wildfires move. The research, which is funded by the National Science Foundation and the U.S. Forest Service, also includes scientists from the University of Colorado at Denver, the University of Wyoming, and the National Center for Atmospheric Research.

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gravitySimulator Tests Einstein's Theory


David Merritt

Recent advances in technology have enabled scientists to observe stars close to the supermassive black hole at the center of our galaxy, allowing us for the first time ever to truly test Einstein's theory of relativity.

An excessive amount of dust between the Earth and the center of the galaxy makes observing this region extremely difficult. High-precision simulations will add the extra information that scientists need to interpret features that would otherwise be ambiguous.

Using the gravitySimulator, Dr. David Merritt, professor of physics, has created a star-by-star representation of the galactic center region. "We are able to look at a black hole and a number of bordering stars and evolve the system forward in time, including all the effects of relativity, as we understand it. The simulations allow us for the first time to see how much the gravitational interactions between stars can affect the motion compared with relativistic effects," says Merritt.

By observing the way stars act on each other gravitationally, as well as within the black hole, scientists will be able to test Einstein's theory.

gravitySimulator is a novel supercomputer that incorporates special-purpose hardware to solve the gravitational N-body problem. Designed by Merritt and Dr. Rainer Spurzem, an astrophysicist at the University of Heidelberg, gravitySimulator is specifically used to study the dynamical evolution of galaxies and galactic nuclei.

This work is funded through the National Science Foundation. Merritt works in collaboration with scientists at Washington University in St. Louis, Weizmann Institute of Science, University of Amsterdam, and the University of Turku.

gravitySimulator: A novel supercomputer, housed at RIT, enables researchers to study the dynamic evolution of galaxies and galactic nuclei.