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Physics Flash

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INSIDE

3
LANL diagnostic images neutrons from implosion experiment at National Ignition Facility

4
Advance in bottle scanning technology could benefit airport security

5
P-21 researchers observe ultracold atom SQUIDs mimicking superconductors

First-ever measurements will advance turbulence models

6
Physics Division is key contributor to Laboratory's top science news of the year

7
Recognizing outstanding performance

Celebrating service

8
Heads UP! Taking charge of electricity usage

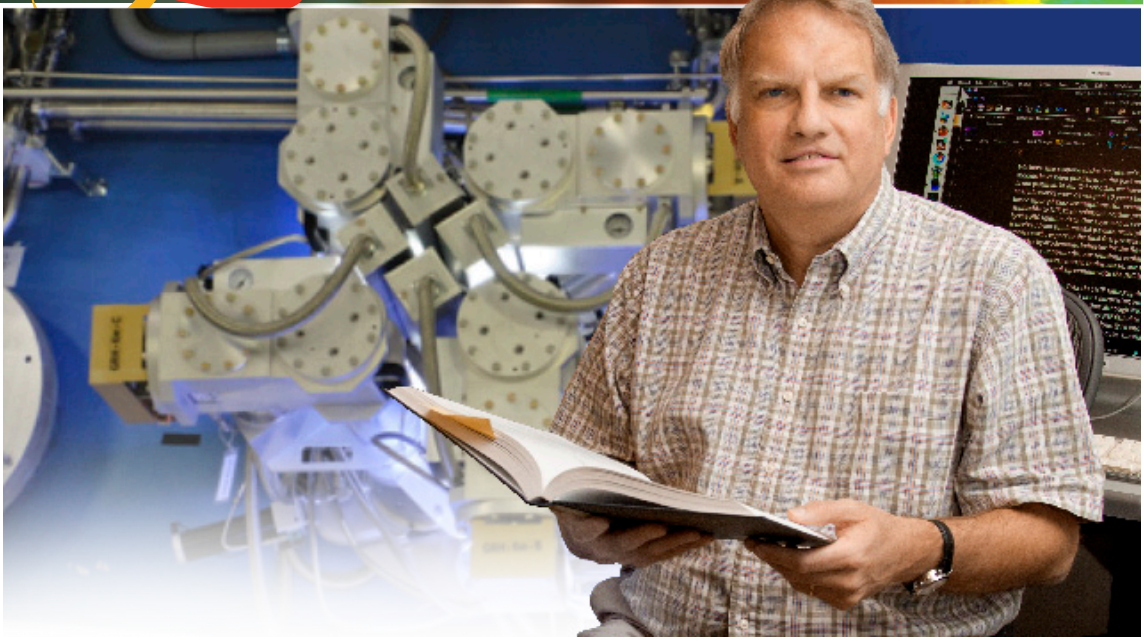


Photo by Richard C. Robinson

Steve Batha is proud that the Gamma Reaction History diagnostic (pictured in background) on California's National Ignition Facility was developed, built, and operated by his program staff. Its primary function is to measure the time of peak neutron yield.

Steve Batha

Improving future weapons models through fusion research

By Diana Del Mauro, ADEPS Communications

Name any major laser research facility in the United States, and Steve Batha can describe the physics experiments he has led or performed there. "I've known some of the people in this field for 30 years now," he said.

That combination of years of hands-on research and leadership experience has served Batha well as program manager of the Inertial Confinement Fusion (ICF) program at Los Alamos National Laboratory, a role he's filled since 2006.

"Steve has made invaluable contributions to fusion research as a scientist, as a mentor for early career scientists, and as the leader of our research in ICF and high energy density physics in general," Physics Division leader Doug Fulton said. "This is a critical area of research that accesses important states of matter that are inaccessible in any other way save for an underground nuclear test, which we have not conducted since 1992 and will almost certainly never conduct again."

By far Batha's most ambitious effort has been at the National Ignition Facility (NIF) in California, the biggest laser ever built. There, scientists from national labs and universi-

continued on next page

> *"We use the nation's cutting-edge facilities to reach density, pressure, and temperature ranges not achievable since nuclear weapons testing ended in 1992."*

Batha cont.

ties attempted to recreate the nuclear fusion of the sun with the hope of establishing a clean energy source for society. Though the experiment did not achieve ignition and NIF is now mainly focused on weapons-related research, Batha (Physics, P-DO) considers the effort an important source of riddles. “This is an opportunity for us to explore what assumptions we were making—or physics that we were using—that were not correct,” he said. Los Alamos experts in ignition, burning plasmas, hydrodynamics, and nuclear diagnostics are furthering that discussion with unique insights.

Batha regards NIF as a success. “It united scientists across the Department of Energy’s weapons complex to solve many problems,” he said. “Many of those problems were solved, just not all of them.”

Knowledge gained from NIF and other projects helps Los Alamos carry out its primary mission: evaluating weapons reliability and safety as well as providing data for future models through discovery science. Many people don’t realize that the Inertial Confinement Fusion program is part of the weapons program, Batha said.

“We contribute to stockpile stewardship through high energy density physics and ignition experiments,” Batha said. “We validate codes in physics regimes that are inaccessible by any other method. We use the nation’s cutting-edge facilities to reach density, pressure, and temperature ranges not achievable since nuclear weapons testing ended in 1992. Nobody in the world has these facilities and so we have many, many opportunities.”

Batha travels at least once a month to the OMEGA laser at the University of Rochester in New York, his alma mater, or NIF to develop new opportunities, solve problems, and provide peer reviews.

At Los Alamos, Batha is faced with the challenge of coordinating nearly 100 scientists across three divisions: Physics, X Computational Physics, and Materials Science and Technology. All of them work part-time for the program. “Trying to get everyone to share the same goals, values, and expectations—that’s about as good as you can do,” he said.

Fusion energy first captured Batha’s interest in the 1970s because he thought it would be the big breakthrough for the energy crisis. In college, he also grew interested in basic science, the “pure essence” of fusion research, such as investigating how a laser interacts with an ionized gas. “It turns out scientists have been researching that for 50 years, and we can’t answer that,” he said.

Batha received a doctorate in mechanical and aerospace sciences in 1989 from the University of Rochester, one of the few places that trained graduate students in this field. He worked at Lawrence Livermore, Princeton University’s Tokamak Fusion Test Reactor, and a private research lab before joining the Laboratory in 1988. As a Plasma Physics (P-24) scientist he fielded hydrodynamics experiments at the OMEGA laser and worked closely with weapon designers. As project leader for high energy density experiments, he was active at a number of experimental facilities, including Sandia National Laboratories’ Z Machine and Los Alamos’s TRIDENT laser. “I’m a product of the 1970s energy crisis,” Batha said. “Fusion won’t be it, but it has been very interesting.”

Steve Batha’s favorite experiment

What: We used the OMEGA laser to implode a cylinder.

Why: This experiment was subsequently used by Jim Fincke (XTD Integrated Design & Assessment, XTD-IDA) to validate several aspects of the Besnard Harlow Rauenzahn mix model used in the RAGE simulation code. RAGE is applied to material strength and damage problems and helped scientists understand stellar jets captured by the Hubble Space Telescope.

When: 2000-2004

Where: The OMEGA Laser Facility at the University of Rochester’s Laboratory for Laser Energetics

Who: Our team consisted of scientists from X, P, and MST divisions. We also had three scientists from the UK’s Atomic Weapons Establishment who made substantial contributions.

How: We measured the growth of mixing at an interface due to the Richtmyer-Meshkov instability, which occurs when the interface between two fluids with different densities is accelerated by a shock wave striking the interface perpendicularly.

The “a-ha moment”: We saw that linear growth extended into the nonlinear regime due to the convergence of the interface.

LANL diagnostic images neutrons from implosion experiment at National Ignition Facility

The goal of NNSA's Inertial Confinement Fusion (ICF) program is to implode small quantities of thermonuclear deuterium tritium (DT) fuel to ignition conditions using lasers at the National Ignition Facility (NIF). The convergence of these capsules may be sufficient to produce temperatures and densities that initiate a thermonuclear burn wave in the DT plasma. If successful, these small capsules will release more energy than was input by the laser drive, potentially offering a new source of energy.

As part of the program, the "high-foot" platform uses the laser pulse-shape capability of the NIF laser to create an indirect drive 3-shock implosion that is robust against instability growth involving the ablator and also modestly reduces implosion convergence ratio. It is called high foot because the laser drive creates higher drive strength early in time to stabilize the implosion process. A Los Alamos neutron diagnostic produced images of the burning plasma in the experiment.

The researchers measured a yield of 4×10^{15} neutrons in the record neutron yielding cryo-DT experiment, N130927, which was fired on September 28. In this experiment the initial laser drive was larger than the point-design drive, resulting in an implosion along a higher adiabat than the NIF point-design ignition experiment.

This modified drive was predicted to result in a hotter and therefore larger hot spot, which is more stable against Rayleigh-Taylor processes in the implosion hydrodynamics. This experiment had a yield and shape similar to pre-shot predictions.

The neutron imaging diagnostics provided size and shape information of the DT burning hot spot and created an image of the surrounding cold fuel. The team measured the source distribution of the lower energy neutrons to obtain the cold fuel image. These low energy neutrons are initially 14-MeV neutrons from DT fusion process occurring in the hot spot that have scattered and lost energy within the cold fuel. Scientists reconstructed the source distribution from the collected images to determine the size and shape of the hot spot and cold fuel. Because this diagnostic uses the fusion neutrons to form the images, the size and shape information improves as the neutron yield increases.

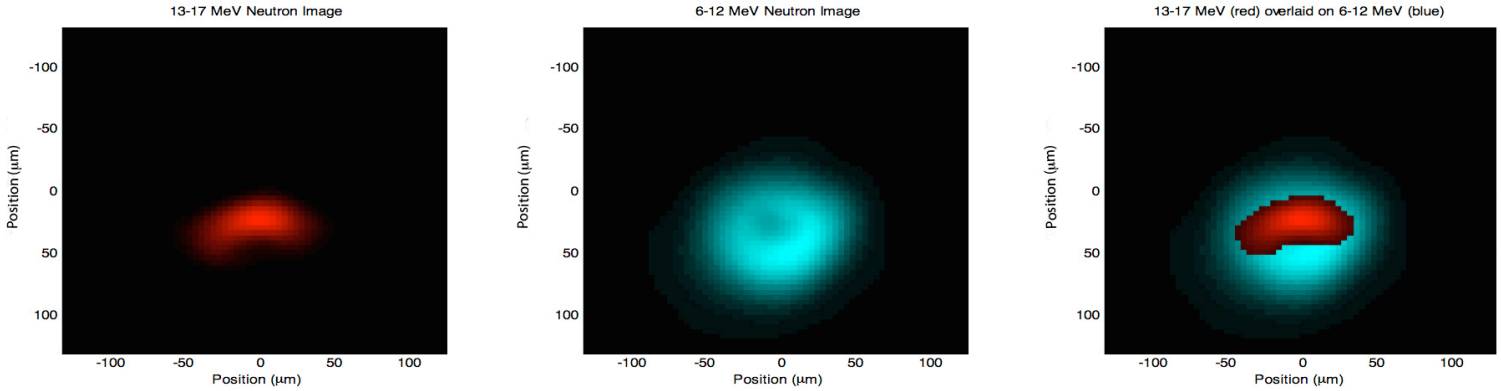
Therefore, this record yielding experiment generated the highest quality neutron images recorded to date at NIF. The diagnostic obtained "raw" pinhole images of the hot spot. Researchers used the images with LANL's newly developed multiple-pinhole reconstructions algorithms, which combine the statistics from these pinholes while taking into account the fact that each pinhole field of view is centered at a different position. Previous experiments had resulted in a toroidal hot spot. This measurement shows that the toroidal hot spot has been tuned out of these high-foot implosions. Pre-shot simulations predicted this oblate shape. Scientists used the same algorithms to reconstruct the cold fuel distribution.

The figure shows the hot spot distribution, cold fuel distribution, and the two distributions overlaid. This source reconstruction reveals a hot spot bubble of burning plasma surrounded by the cold fuel assembly. Only the neutron imaging diagnostic is capable of making this measurement, which is the first indication of the clean fuel assembly. This understanding of cold fuel distribution relative to the hot spot is critical for a proper interpretation of other nuclear and x-ray diagnostics in the drive toward ignition in the future.

Frank Merrill (Neutron Science and Technology, P-23) leads the Neutron Imaging Team in Physics Division. The NNSA Weapons Science Campaign 10 (Steve Batha, Los Alamos Program Manager) funds the LANL work, which supports the Lab's Nuclear Deterrence and Energy Security mission areas and the Nuclear and Particle Futures and Science of Signatures science pillars.

Technical contact: Frank Merrill

Below: Hot spot distribution (left), cold fuel distribution (center), and the hot spot and cold field distribution overlaid (right), showing the alignment of the hot spot with the cold fuel.



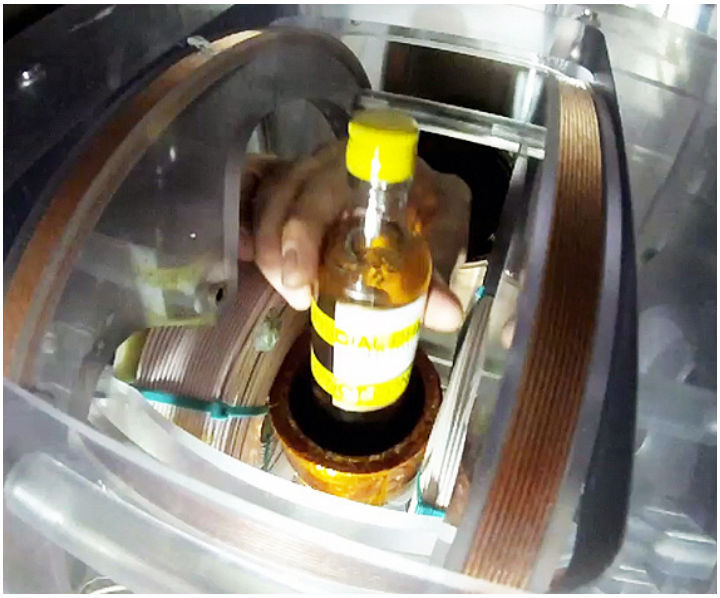
Advance in bottle scanning technology could benefit airport security

In what may provide a breakthrough for screening liquids at airport security, Los Alamos scientists have unveiled a new detection technology that combines magnetic resonance imaging (MRI) with low-power x-ray data to identify even the most challenging class of explosives.

MagRay, which builds on previous Lab technology that received a R&D 100 award, captures measurements of MRI, which is better suited for screening liquids than traditional baggage scanners, alongside x-ray density, and a new parameter–proton content–that is not available in either x-ray or MRI alone.

The researchers demonstrated the technology at the Laboratory. They had tested previous versions at the Albuquerque International Sunport and the Department of Homeland Security's Transportation Security Laboratory in New Jersey. Traditional baggage scanners, which use x-rays, have limited sensitivity for liquid discrimination, whereas MagRay quickly and accurately distinguishes between liquids that visually appear identical. For example, what appears to be a bottle of white wine could potentially be nitromethane, a clear liquid that can be used to make an explosive.

Existing airport bottle screening systems could be modified to take advantage of MagRay advances by combining the x-ray signature with that from ultra-low field MRI. The operator interface is straightforward: A red light signals a hazardous liquid, a green light signals a benign liquid. The technology could eliminate the need for the 3.4-oz container limitation (the 3-1-1 rule) for travelers.



A small wine bottle is placed inside the MagRay bottle scanner system.

The MagRay team includes Project Leader Michelle Espy, Larry Schultz, Henrik Sandin, Petr Volegov, Al Urbaitis, Andrei Matlashov, Shaun Newman, Robert Sedillo, and Jacob Yoder (Applied Modern Physics, P-21), along with James Hunter and Tim Ickes (Applied Engineering Technology, AET-6). *Physics Today* has invited the MagRay team to publish their results in a section devoted to university students. The Department of Homeland Security's Science and Technology Directorate funded a portion of the work. The research supports the Laboratory's Global Security mission and Science of Signatures pillar.

Technical contact: Michelle Espy

MagRay engineer Larry Schultz puts a bottle of surrogate material that mimics home made explosives into the MagRay bottle scanner.

P-21 researchers observe ultracold atom SQUIDs mimicking superconductors

Opens doors for new ultrasensitive detectors

Work by P-21 researchers recently made the cover of *Physical Review Letters* and was highlighted as an Editors' Suggestion and a Viewpoint article. The paper has also recently been featured in a News and Views article in the journal *Nature*.

In "Experimental Realization of Josephson Junctions for an Atom SQUID," Changhyun Ryu, Paul Blackburn, Alina Blinova, and Malcolm Boshier explain how they devised an experimental setup to study the Josephson effect, a quantum mechanical phenomenon that is difficult to observe directly in cold atom systems. The Josephson effect is what empowers the quantum interference technology in dc-SQUIDs (dc superconducting quantum interference devices), making them the world's best ultrasensitive magnetometers.

The team created a dc Atom SQUID to study and use the quantum interference of currents flowing in parallel through Josephson junctions connected in a superfluid loop. They demonstrated ideal Josephson junctions in a toroidal Bose-Einstein condensate (BEC) by showing the transition between the dc and ac Josephson regimes and by measuring the critical current of the junctions. (A toroidal dilute gas BEC with a pair of Josephson junctions is a configuration that is the cold atom analog of the well-known dc SQUID).

In "Viewpoint: A SQUID Analog with a Bose-Einstein Condensate," Yuki Sato (Harvard University) said P-21's research will allow new kinds of ultrasensitive detectors. The creation of a dc-SQUID analog using a BEC atomic gas "should not only encourage studies on BEC properties in complex arrangements but also accelerate the development of an array of cold atom 'devices' that may be applied to various other investigations," Sato wrote. Further, Sato said the work "offers an exciting opportunity towards sophisticated atom circuits designed and implemented as meaningful tools. In various configurations with or without the Josephson junctions, the cold-atom system has the potential to form an ideal testing ground for phenomena seen in other analogous systems but now with more tunability. That is clear from this result, which advances the fundamental and thought-provoking analogy between the macroscopic quantum physics of superconductivity, superfluids, and BEC gases."

In *Nature*'s Research News and Views, Charles A. Sackett (University of Virginia) noted that the device "for the first time uses the complete geometry of a ring with two barriers" and the paper's demonstration is a "milestone," proving the long-held notion since the first observations of Bose-Einstein condensation that "ultracold atoms could be used to simulate and explain solid-state systems." However, Sackett cautioned that "substantial challenges remain," such as creating large currents, but said "the steady progress in this field exemplified by Ryu and colleagues' achievement is encouraging."

Experimental setup for an atom SQUID that traps ultracold atoms (lower right) within an 8-μm split-ring potential (upper right) by scanning a vertical laser beam on a horizontal laser sheet (left).

The Laboratory's LDRD program funded the work, which supports the Lab's Global Security mission and the IS&T and Science of Signatures pillars.

References: "Experimental Realization of Josephson Junctions for an Atom SQUID," *Phys. Rev. Lett.* **111**, 205301 (2013); "Viewpoint: A SQUID Analog with a Bose-Einstein Condensate," *Physics* **6**, 123 (2013): "Quantum Physics: An atomic SQUID," *Nature* **505**, 166-167 (2014).

Technical contacts: Changhyun Ryu and Malcolm Boshier

First-ever measurements will advance turbulence models

In research featured on the cover of *Journal of Fluid Mechanics*, an interdisciplinary Los Alamos team took a series of first-time measurements, providing new insights for turbulence modelers. Variable-density turbulence models are heavily used in computer simulations at the Laboratory. The team directly measured terms in such model equations, providing insights into the global nature of the mixing (e.g., faster mixing near the edges of the turbulent fluid layer when compared with the core) and identifying the dominant mechanisms governing the flow evolution (these are the terms that are critical to accurately model).

Turbulent mixing has important consequences for supersonic engines, supernova explosions, and inertial confinement fusion reactions. Richtmyer-Meshkov (RM) instabilities are created when a shock wave shakes up fluids with different densities, which can be a good thing or a bad thing. In supersonic engines, for example, RM enhances combustion efficiency by blending the fuel and the oxidizer. In inertial

continued on next page

The image on the journal's cover is an instantaneous, quantitative map of concentration of the heavy gas (SF6, in white) as it mixes into the lighter gas (air, in black). The flow structure evolves in time and rapidly begins to mix as it moves from left to right on the image.

Turbulence cont.

confinement fusion reactions, it can contaminate fuel and impair fusion yield.

The researchers took high-resolution mean and fluctuating velocity and density field measurements in an RM flow, which was shocked and reshocked, to understand production and dissipation in a two-fluid, developing turbulent flow field. The mixing was driven by an unstable array of initially symmetric vortices that induce rapid material mixing and create smaller-scale vortices. After reshock, the flow transitioned to a turbulent state. The team used planar measurements to probe the developing flow field. They took the first experimental measurements of the density self-correlation b= -(pv) (where p and v are the fluctuating density and specific volume, respectively) and terms in its evolution equation.

Diagnostic advances in the shock tube over the last decade have made possible the simultaneous measurement of both density and velocity on a plane. This capability permits experimental estimation of the net result of complex physics in a real or simulated system, such as a state of the flow at a given time, as well as the individual terms in model equations that are used to predict the evolution of the turbulence and mixing.

In future work, the team plans to simultaneously measure density-velocity at multiple times to probe the temporal evolution of the quantities and physics of turbulent mixing. Reference: "Evolution of the density self-correlation in developing Richtmyer-Meshkov turbulence," by Chris Tomkins (P-21), Balakumar Balasubramaniam, Greg Orlicz, Kathy Prestridge (P-23), and Raymond Ristorcelli (Methods and Algorithms, XCP-4), *J. Fluid Mech.* **735**, 288-306 (2013). The U.S. Department of Energy, via Science Campaign 4: Secondary Assessment Technologies (Program manager Kim Scott), funded the work. The research supports the Lab's Nuclear Deterrence mission and the Nuclear and Particle Futures science pillar.

Technical contact: Chris Tomkins

Physics Division is key contributor to Laboratory's top science news of the year

Take a look at the Laboratory's most intriguing science innovations of 2013 and you'll discover that Physics staff members were involved in half of the top 10 research areas. The list, compiled by the Communications Office, is based on media interest, public interest, number of website hits, and relevance to the Laboratory's mission.

Impenetrable encryption defends data from cyberterrorism
Jane Nordholt, Richard Hughes, Raymond Newell, and Charles Peterson (P-21) and members of Space Instrumentation and System Engineering (ISR-4) designed the QKarD Quantum Smart Card, which generates security at the subatomic particle level. The technology is available for licensing through the Laboratory's Feynman Center for Innovation.

Liquid-scanning technology boosts airport security
Project Leader Michelle Espy, Larry Schultz, Henrik Sandin, Petr Volegov, Al Urbaitis, Andrei Matlashov, Shaun Newman, Robert Sedillo, and Jacob Yoder (P-21), with Applied Engineering Technology (AET-6) collaborators, developed MagRay, which quickly and accurately determines whether a concealed liquid is dangerous or benign. An earlier version made the 2010 list.

Tree death worldwide linked to warming climate
Using the first globally comprehensive data set and the Lab's global monitoring system, Laboratory researchers predict losses of many forests worldwide by 2100. The work, led by EES-14 staff, adds to the Laboratory's growing body of research on climate change effects. In 2012, P-21's Espy, Jesse Resnick, and Igor Savukov studied how trees die in drought by noninvasively measuring the water content of intact trees in nature.

Improved biofuel methods: may be greener, cheaper, powerful
As part of the Laboratory's alternative energy development efforts, Pulak Nath and Chaitanya Chandrana (P-21) and Biosecurity and Public Health (B-7) collaborators genetically engineered magnetic algae to investigate alternative, more efficient harvesting and lipid extraction methods for biofuels: pulling the algae from the water with a magnet.

continued on next page

Top cont.

Portable laser tool to thwart nuclear smugglers
Plasma Physics (P-24) members Katerina Falk, Juan Fernandez, Donald Gautier, Randall Johnson, Daniel Jung, Tom Shimada, and Nevzat Guler played a significant role in the work that demonstrated for the first time that laser-generated neutrons can be enlisted as a useful tool in the War on Terror. The work is led by Safeguards Science and Technology (NEN-1).

To learn more, please see www.lanl.gov/newsroom/news-releases/2013/December/12.24-top-science.php.

Recognizing outstanding performance

A total of seven Physics staff members serving on two team efforts recently received Distinguished Performance Awards, in appreciation for job performance above and beyond what is normally expected.

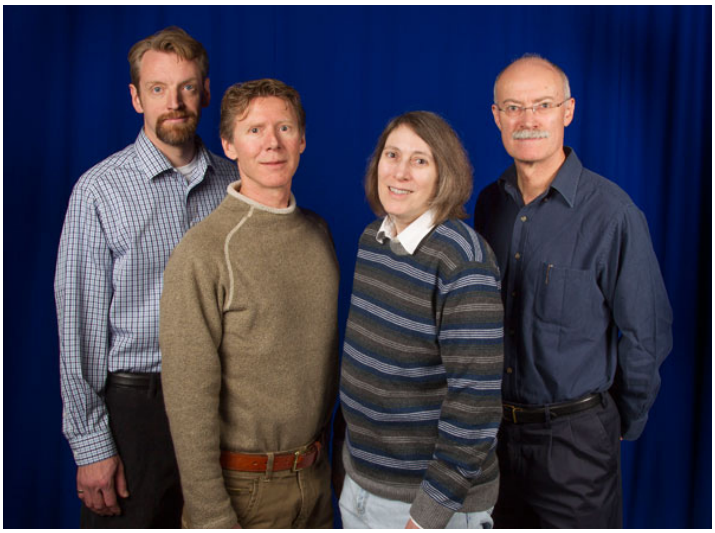
A small team winner, the Quantum-Secured Communications team (photo above right) is composed of Richard Hughes, Raymond Newell, Jane Nordholt, Charles Peterson (P-21), and Joysree Aubrey (Intelligence, Analysis and Technology, IAT-DO). The communication networks controlling critical infrastructure, such as the electric grid, are increasingly Internet-connected and so increasingly vulnerable to cyber attack. The Quantum-Secured Communications team has provided a solution to this problem with its Quantum-Secured Communications (QSC) system.

A large team winner, the Gemini Experimental Series Core team (photo at right) included three P-23 members: Mike Furlanetto, Todd Haines, and David Holtkamp. Gemini was a series of two experiments at the U1a facility at the Nevada National Security Site: the Castor confirmatory experiment and the Pollux subcritical experiment. Over two years, culminating in 2012, this multidivisional Los Alamos team led the Gemini Experimental Series project, working with National Security Technologies, Sandia National Laboratories, and the NNSA's Kansas City Plant. At the Laboratory the team drew upon scientific, technical, and support staff from more than three dozen divisions.

Celebrating service

Congratulations to the following Physics Division employees celebrating service anniversaries recently:

William Wood, P-23 ..... 20 years
Thomas Intrator, P-DO ..... 15 years
Raymond Newell, P-21 ..... 10 years



PhysicsFlash

Published by the Experimental Physical Sciences Directorate

To submit news items or for more information, contact Karen Kippen, ADEPS Communications, at 505-606-1822, or kkippen@lanl.gov

For past issues, see www.lanl.gov/orgs/p/flash_files/flash.shtml

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HeadsUP!

Taking charge of electricity usage

The UI-FOD has provided information on electricity usage in ADEPS buildings. While ADEPS staff share many of these buildings with folks from other directorates, the data is, nonetheless, revealing. We also note that in buildings with experimental areas, it is not surprising that all forms of energy usage may vary, sometimes greatly, from quarter-to-quarter and year-to-year.

As can be seen in the data, ADEPS electricity usage increased 5% from FY12 to FY13. Electrical usage has a significant monetary and environmental impact to our bottom line.

Please remember to turn off/unplug equipment when not in use, lower room thermostats in the winter at nights and when common areas (conference rooms) are unattended, and turn off office and common area lights if you are the last one out. Lastly, always look for energy-efficient alternatives when they do not affect mission delivery.

A good adage to follow: "If you do it at home (shut off lights and lower thermostats at nights and vacations), then why not do it at work too?" Take responsibility for protecting and sustaining our environment! Thank You.

Your ADEPS EMS (Environmental Management System) POCs are:

Steve Glick - Physics
Jim Coy – MST
Susie Duran – MPA
Frances Aull – LANSCE

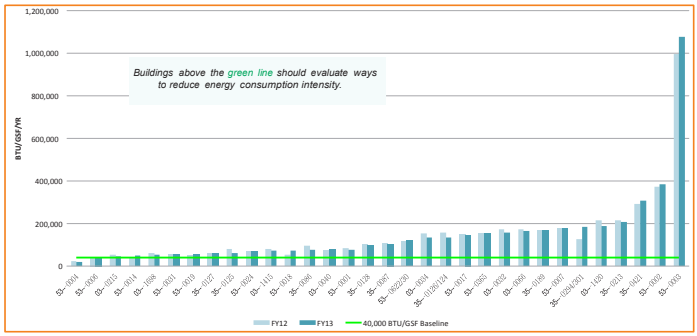
RAD Electricity Report

Fiscal Year Comparison – FY13 vs FY12

Account Number: RAD ADEPS

Billing Period: FY13

ADEPS Building Energy Efficiency – FY12 vs FY13

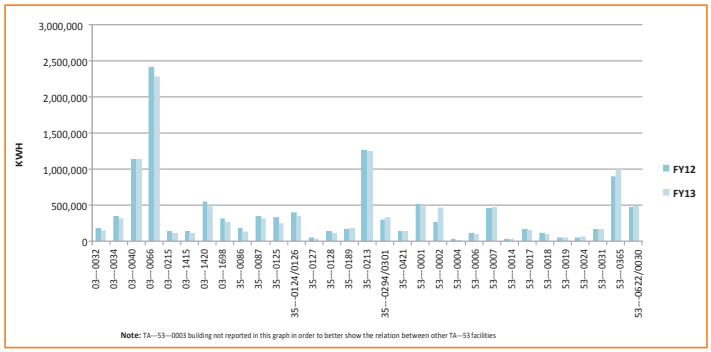


Building Energy Efficiency Comparison

This chart compares the energy efficiency of your RAD's buildings this year with FY12.

Energy efficiency can be measured by energy intensity—which for an office building is total energy use over time in relation to floor area, counting gas as well as electricity. The ***green line*** *marks DOE's standard for an efficient building: no more than 40,000 Btu/GSF per year or 10,000 Btu/GSF per quarter.*

ADEPS Building Electricity Use – Quarter 4 – FY12 vs FY13



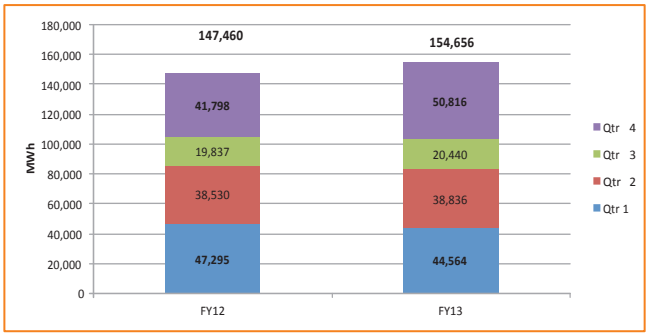
Building Electricity Use Comparison

Electrical consumption by your RAD's buildings this quarter compared to the same quarter in FY12

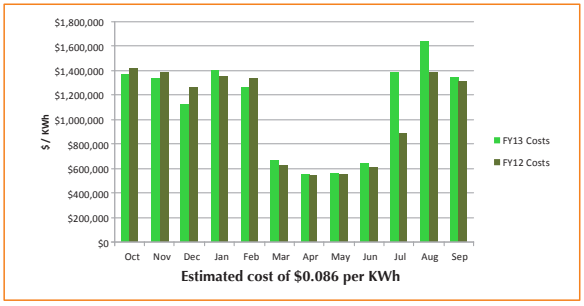
ADEPS Quarterly Electricity Use – FY12 vs FY13

Quarterly Electricity Use Comparison

Quarterly electricity use in megawatt-hours (MWh) for all metered facilities in your RAD during FY12 and FY12



ADEPS Electricity Costs by Month – FY12 vs FY13



Individual Action Steps

- Unplug unnecessary electronics.
- Turn your monitor and the lights off when you leave for a meeting or the day.
- Put your computer to sleep or in power down mode when you're not using it.

We hope this information helps you better understand and make better choices about your RAD's use of electricity.

Questions? Need more information? Go to umetering@lanl.gov