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LLNL-TR-650294

NAS Executive Summary - Spring 2014

K. Jackson

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Executive Summary of Scientific and Technical Metrics at Lawrence Livermore National Laboratory

Spring 2014

LLNL--TR-650294

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Publication Metrics 1

i. Indicators of Productivity and Quality for Publications

Publishing research results in the peer-reviewed literature is a key to advancing the frontiers of science and engineering. LLNL scientists and engineers have established a strong record by publishing innovative and impactful journal papers and engaged an impressive array of external collaborators as coauthors. LLNL's more than 1,100 journal publications in 2012 went up sharply, topping 2011 numbers by 14%. Significantly, this followed a 10% increase in 2011 over 2010. Publication rates in 2013 have kept pace with last year's extremely strong performance.

Collaborating with peers from other research organizations is an indicator of high quality and active outreach to the broader scientific community. In 2012, there were more than 200 institutions with which LLNL scientists and engineers published 50 or more scientific articles (each). These institutions are from 45 different countries around the world. Given the Laboratory's strong historical connection with the University of California, it is not surprising that UC Berkeley leads the list of institutions having coauthors on LLNL publications, appearing on over 17% of the 2012 articles.

Citations of scientific publications are key indicators of quality. Assessments consistently show that citations to papers published by LLNL authors compare favorably to those published by peer organizations. LLNL's strong record of publishing in high-profile technical journals contributes to this distinction. In addition, the multidisciplinary nature of LLNL's research is emphasized by the fact that LLNL scientists and engineers published 50 or more papers in each of 11 science categories tracked by the Institute for Scientific Information (ISI). These publications appeared in over 250 distinct professional journals.

Physics	Papers	Citations	Citations /paper
Physics	4,674	85,223	18.23
Geosciences	1,017	32,660	32.11
Space Science	799	22,081	27.64
Chemistry	1,018	20,097	19.74
Engineering	1,759	15,703	8.93
Materials Science	680	10,959	16.12
Mol. Biol. & Genetics	200	8,267	41.34
Biology & Biochemistry	252	6,770	26.87
Clinical Medicine	243	5,324	21.91
Environment/Ecology	204	3,736	18.31
Microbiology	112	3,562	31.80
Plant & Animal Science	51	1,645	32.25
Computer Science	247	1,568	6.35
All Fields	**11,519**	**221,758**	**19.25**

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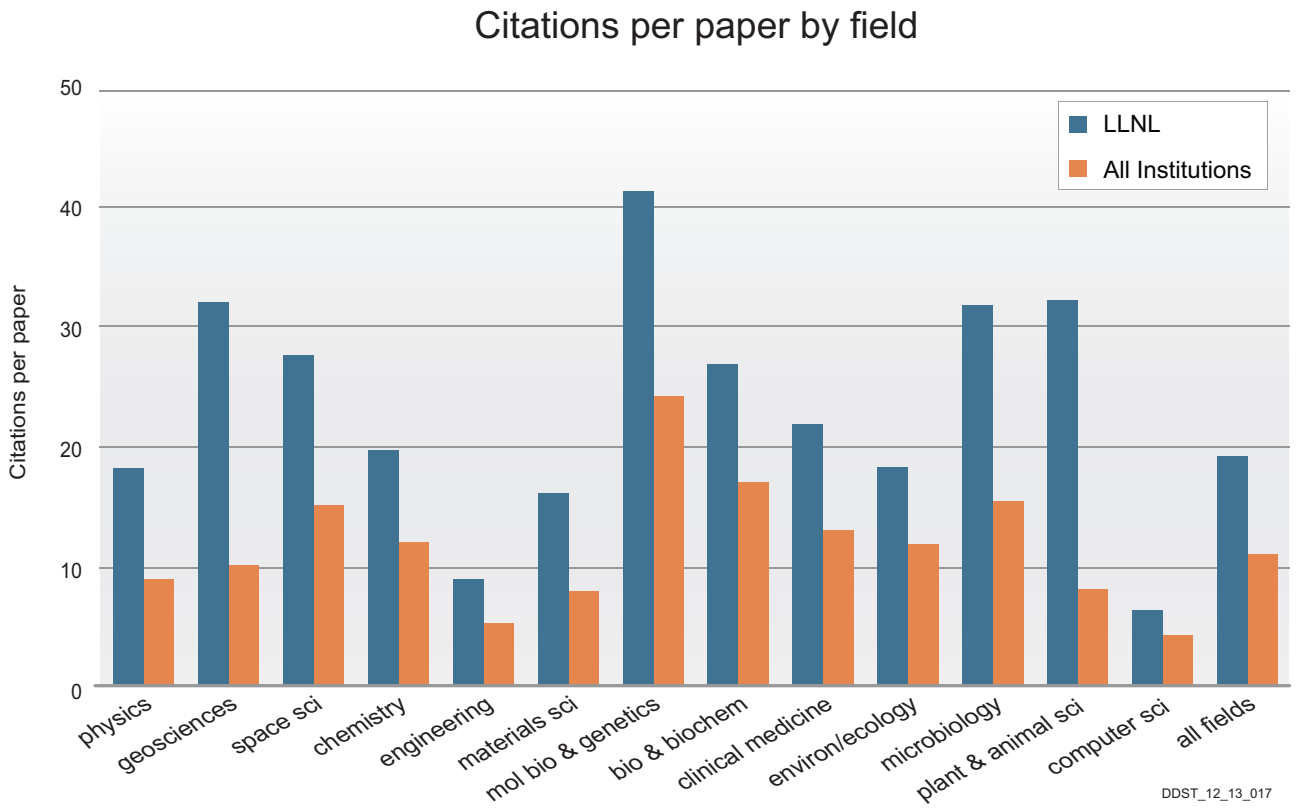
The ISI publishes Essential Science Indicators, which provide a "compilation of essential science performance statistics and science trends. The chief indicators of output, or productivity, are journal article publication counts. For influence and impact measures, Essential Science Indicators employ both total citation counts and citations-per-paper scores. The former reveals gross influence, while the latter shows weighted influence, also called impact." ISI indexes over 8500 journals and each author is associated with one of over 90,000 home institutions tracked in the database. Together, these data can be used to assess both the rate of publication (productivity) and the number of citations to papers (impact) for individuals as well as for institutions.

ISI data shown in the table above provide insight into publications authored or co-authored by scientists and engineers at the Lawrence Livermore National Laboratory (LLNL). This tabulation is for publications and citations that span the 11-year period from January 2002 through December 2012.

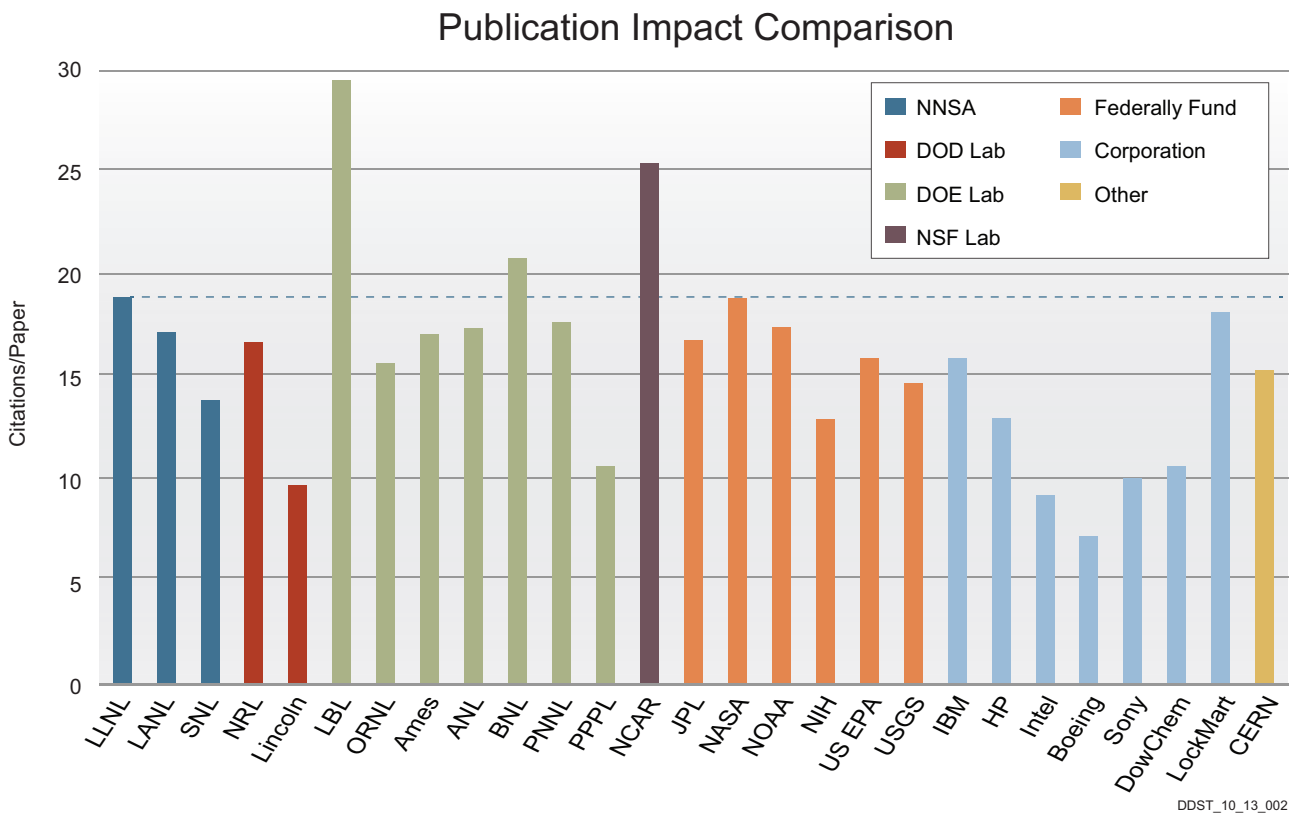
As illustrated in the table, ISI provides a way to group publications into a designated set of subject areas based primarily on the topics covered by individual journals. Areas where LLNL authors tend to publish are listed in the table as are the total and average number of citations to these papers. Clearly the bulk of LLNL's publications are in the field of physics, but a substantial number of papers also represent several other technical fields, a feature which reflects the multidisciplinary character of LLNL's workforce.



The average number of citations per paper is a characteristic of individual fields of research and varies considerably from one field to the next across all institutions. (For example, papers in the biosciences are commonly cited for more frequently than papers published in engineering disciplines.) This characteristic is also reflected in LLNL's citation record, but the previous below clearly illustrates that LLNL publications for each field represented in the table rise considerably above the average for that field. As illustrated at the end of this report, LLNL-authored papers have frequently been selected by journals as highlights for their covers.

ii. Comparison with Peer Organizations

Additional insight into LLNL's publications can be obtained by making comparisons with similar achievements by other organizations. The DOE National Laboratories probably provide the most direct analogs for LLNL. This is particularly true for the other two National Nuclear Security Administration (NNSA) laboratories: Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL). Other potential peer organizations include federally funded R&D laboratories and major corporations that support in-house research organizations. A sampling of these organizations is illustrated in the following chart, which plots the average number of citations for all papers published by authors from each institution. As highlighted by the horizontal dashed line, citations to LLNL-authored publications compare well with results obtained by these prestigious organizations.



Note that the data plotted in this figure are for the same 11-year period identified above and that the character of the research (e.g., classification issues or proprietary information), the size of the institution, the academic disciplines for the researchers, and the number of postdocs or students all influence these totals.

iii. Trends with Time

Over the past decade, LLNL authors have averaged well over 1,000 journal articles per year. The following table illustrates the steady increase in the number of citations per paper since the 2002-2006 interval.

LLNL Publication Trends in All Fields

5-year intervals	2003 - 2007	2004 - 2008	2005 - 2009	2006 - 2010	2007 - 2011	2008 - 2012	2009 - 2013
Number of papers	5,688	5,631	5,538	5,151	4,859	4,931	4,844
Times cited	43,338	46,154	51,154	49,338	42,865	49,664	50,372
Citations per paper	7.62	8.20	9.24	9.58	8.82	10.07	10.40

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Workforce Educational Metrics 2

i. HEEACT International School Ranking and Staff Statistics

The Higher Education Evaluation and Accreditation Council of Taiwan (HEEACT) is one of the most comprehensive rankings of educational institutions as it is international in scope and has a high degree of subject specificity. HEEACT uses publication counts, citation counts, h-index, highly cited paper subsets, and high-impact journal articles as factors in its rankings. In the eight fields in which LLNL focuses heavily (i.e., physics, chemistry, materials science, geosciences, mathematics, computer science, electrical engineering, and mechanical engineering), school rankings can be combined to select the top 38 schools, listed here in alphabetic order:

Cal Tech
Cambridge UK
Carnegie Mellon
Columbia
Cornell
Georgia Tech
Harvard
Imperial College London
Kyoto Univ
MIT
Nanyang Nat U Singapore
Northwestern
Osaka Univ
Oxford
Penn State
Princeton
Purdue
Seoul Univ
Shanghai Jiao Tong Univ
Stanford
Swiss Fed Tech Zurich
Tohoku Univ
Tsinghua Univ
Univ CO Boulder
Univ Hawaii
Univ IL Urbana
Univ Maryland College Park
Univ Michigan Ann Arbor
Univ Minn Twin Cities
Univ Paris Curie
Univ Tokyo
Univ Washington
Univ WI Madison
UC Berkeley
UC Santa Barbara
UC Los Angeles
UC San Diego

In December 2013, 725 of LLNL's scientists and engineers (27%) earned their Ph.D. degrees from one of these 38 prestigious universities.

Note that many positions at LLNL and other national security laboratories require employees with security clearances. The restrictions on granting security clearances to foreign national employees influence recruiting from some of the listed schools for these positions. It should also be pointed out that many positions at LLNL do not require clearances and that foreign national applicants can fill these appointments.

Due in part to geographic location and in part to the Laboratory's strong historical connection to the University of California, UC Ph.D.s comprise a large portion of the ST&E workforce. About 27% of Ph.D.s at LLNL earned their degrees from UC graduate school, with UC Berkeley (10%) and UC Davis (9%) a the top of the list. Over a third of LLNL's postdoc population obtained their doctorates from UC.

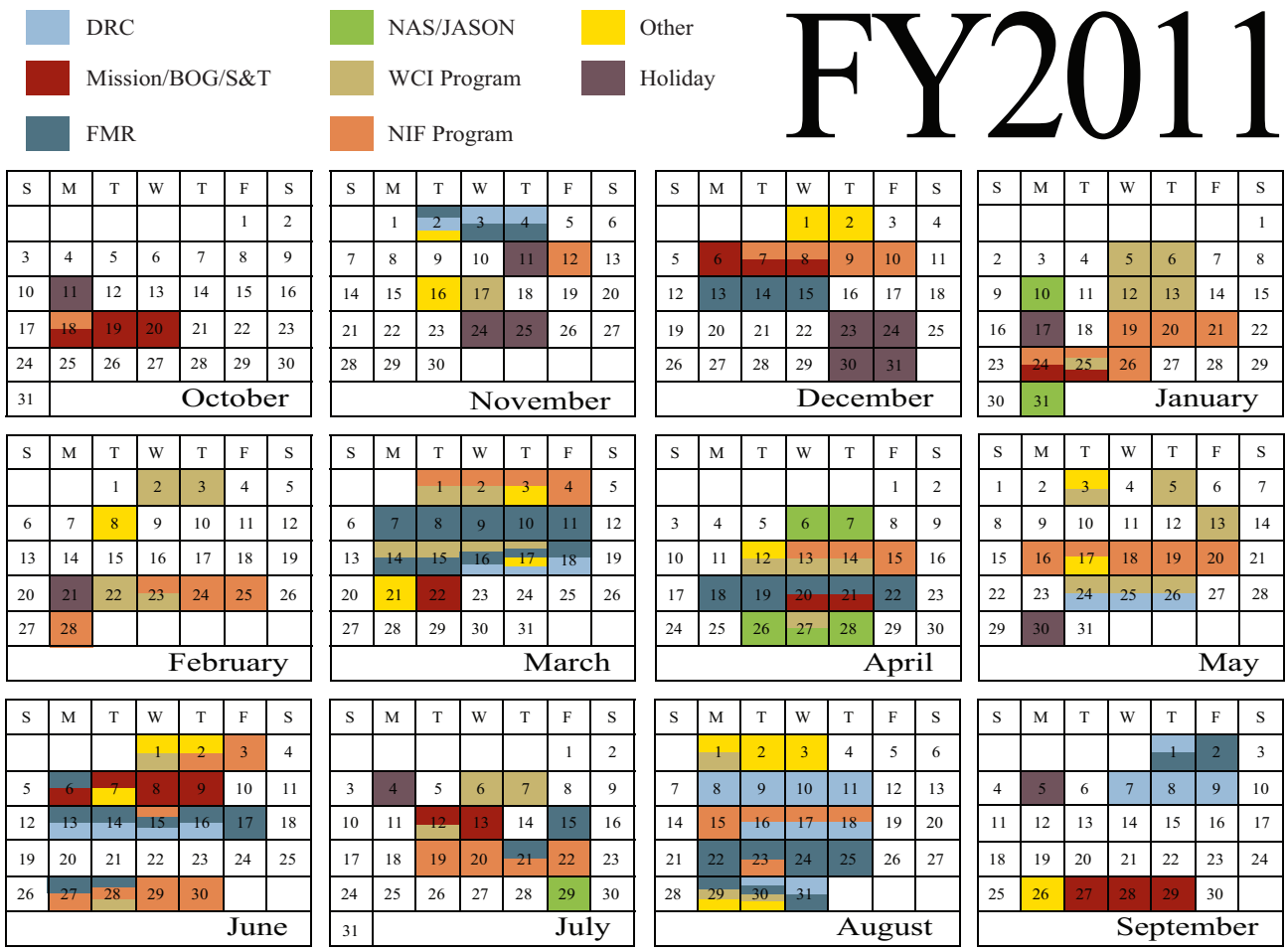
ii. University Ranking by Discipline

HEEACT rankings of the best universities world-wide vary by discipline. For LLNL organizations where physics is the predominant discipline (the Physics Division, Weapons and Complex Integration, and NIF and Photon Sciences), it is interesting to note that 41% of the Ph. D. degrees are granted by universities that rank in the top 20 worldwide and 31% of LLNL's Ph.D.s in these organizations came from universities ranked in the top 10 in physics. In LLNL's Engineering Directorate, over 46% of the Ph. D. degrees were granted by an institution that appears on HEEACT's lists of top 20 mechanical or electrical engineering departments.

Extensive External Reviews of LLNL Science & Technology 3

Livermore has an established practice of having external subject-matter experts review S&T work done both in the Laboratory's programs and in its supporting scientific discipline directorates. Such reviews are also conducted for work supported by the Laboratory Directed Research and Development Program.

Through these reviews, the Laboratory seeks advice on ways to improve our S&T work in every way possible. Reports written by the external review committees are overwhelmingly complimentary. The reviewers and subject-matter experts for 2011 came from a broad range of organizations, including those shown in the following figure.

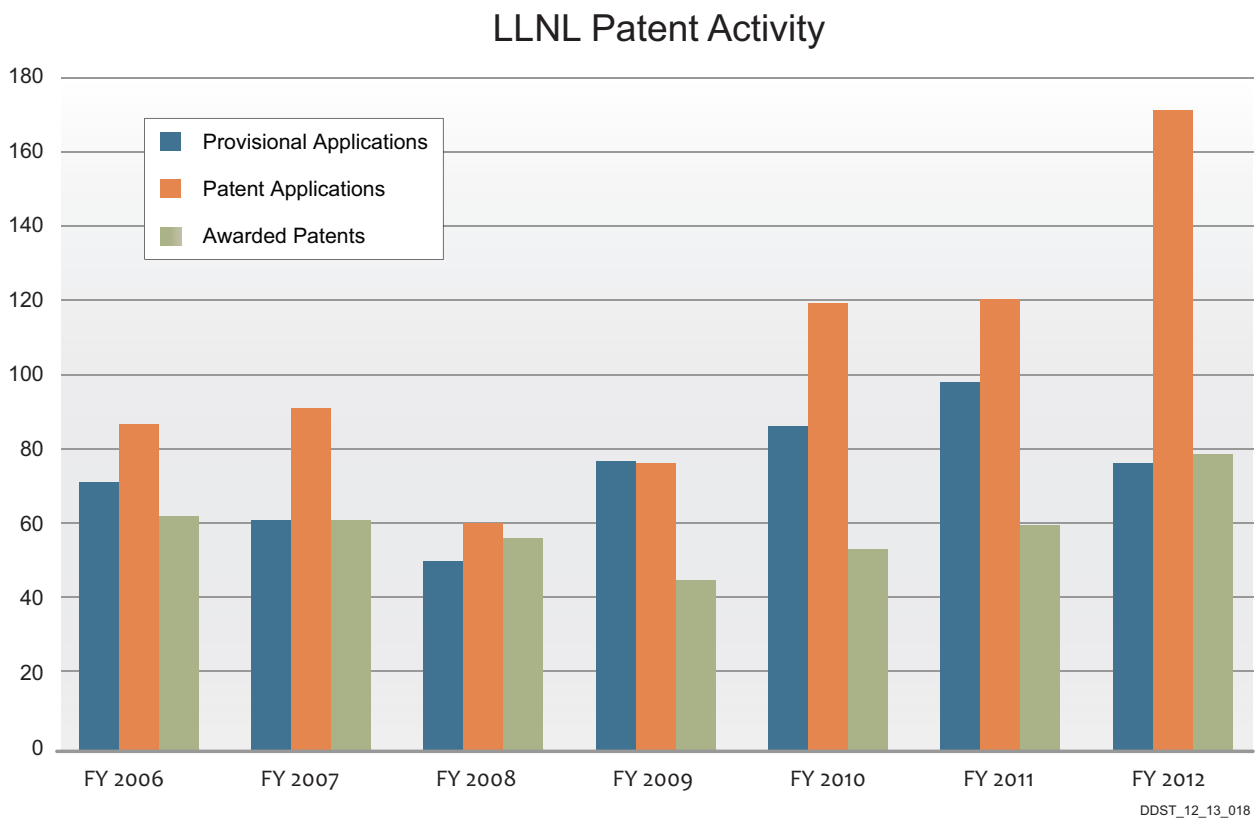


Technical Transfers and Intellectual Property 4

i. Patent Metrics

Generating new intellectual property and protecting these innovations with patents and copyrights are important steps in research and development at LLNL. The most visible metric of success in this arena is the generation of new patents, but this is a "trailing indicator" of current activities owing to the fact that the process of obtaining a patent sometimes takes several years from the time a record of invention is filed. To assess the current health of an organization's activity in the patent arena, it is important to pay attention to more immediate indicators of progress. To this end, the following chart shows LLNL's history of filing patent applications, obtaining provisional patents, and ultimately obtaining patents over the past six fiscal year periods.

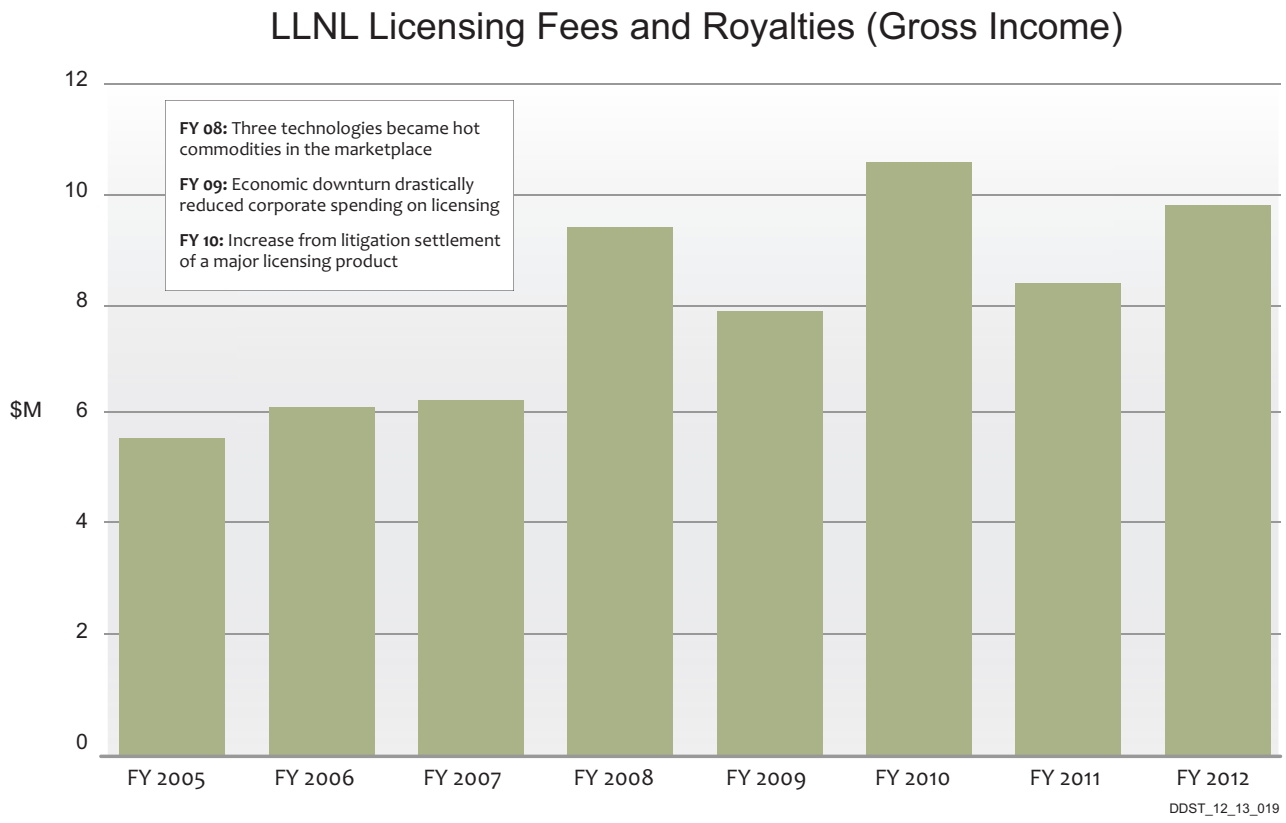
It is clear that patent activity, as measured by patent applications and provisional patent applications filed have taken a significant upturn over the past two years. It is anticipated that this will result in a similar upturn in the number of patents in future years, and it is worth noting that almost half of LLNL's patents each year derive from past investments by the Laboratory Directed Research and Development (LDRD) program.



ii. Licensing and Royalty Metrics

Licensing fees and royalties are a concrete measure of Laboratory S&T products being sought by the external marketplace. The time lag between the development of a technology through the patent process and the maturing of the technology into a marketable product is a lengthy one. In addition, market worth does not always accurately reflect technical significance. Finally, many factors in licensing fees are outside LLNL control, such as the robustness of the U.S. economy.

The Laboratory's licensing and royalty income by fiscal year is shown below, with some notations of what caused the variability. Since 2005, the Lab has averaged over $7.5 million per fiscal year. Forecasting future income is difficult because of the impossibility of knowing future market interest, unknown corporate economic circumstances, and the coming expiration of patents on technology currently generating significant income.



As an example, LLNL executed 18 licenses in FY12 alone, bringing the total number of licenses under management to 121. Cooperative Research and Development Agreements (CRADAs) with industry provide an additional measure of LLNL success in partnering with the private sector. In FY12, LLNL signed four new CRADAs and derived an income of about $4M for R&D efforts from the 34 CRADAs under management by LLNL.

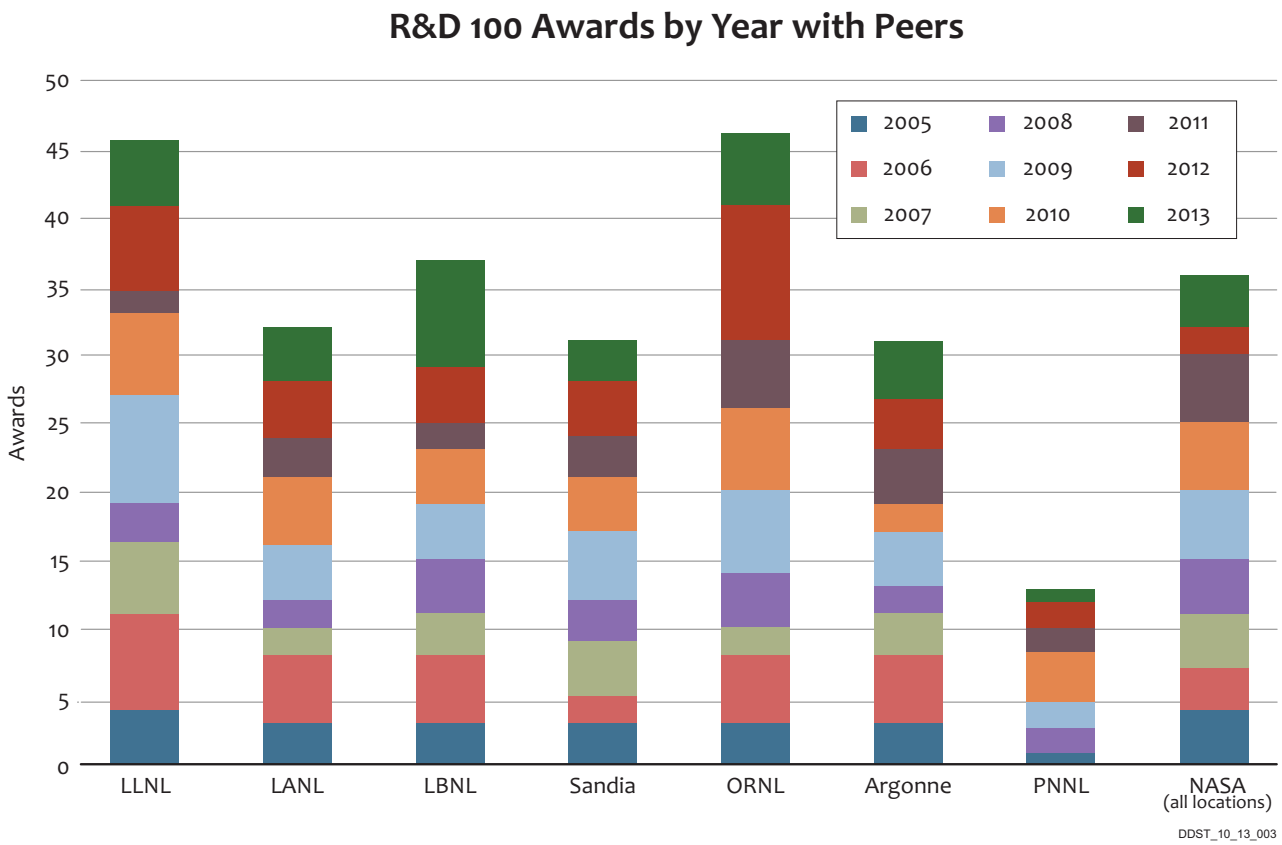
Awards and Fellowships 5

R&D 100 Awards

Each year since 1963, R&D Magazine has selected a list of the 100 most technically significant products, which they publish as R&D 100 Awards. Entries come from private industry, government agencies, universities, and research institutes throughout the world. Winners are chosen by the magazine's editors together with a panel of experts chosen from a variety of relevant disciplines. The judges look for products or processes that promise to change people's lives for the better by significantly improving our standard of living, environment, health care, or security; a key criterion for the judges is "technological significance."

Over the years, R&D 100 Awards have been given to products such as Polacolor film (1963), the flashcube (1965), the automated teller machine (1973), the halogen lamp (1974), the fax machine (1975), liquid crystal displays (1980), the touch-sensitive screen and the color graphics printer (1986), the Kodak Photo DC (1991), the Nicoderm antismoking patch (1992), the digital compact cassette (1993), Taxol anticancer drug (1993), and the Power Beat automotive battery (1994).

LLNL won its first R&D 100 Award in 1978, several years after the award was established. Since that time, LLNL researchers have been recognized with 148 of these prestigious awards, culminating with five awards in 2013. As shown in the following chart, LLNL and the Oak Ridge National Laboratory lead the DOE national laboratories with 46 R&D 100 Awards over the past nine years.



ii. National and International Awards

Professional societies, philanthropic organizations, and government agencies confer a very large number of awards; some recognize singular achievements while others recognize the cumulative accomplishments of a career. The following table lists selected national and international awards and recognition won by LLNL researchers **since 2005**.

Nobel Prize	2013	The Organization for the Prohibition of Chemical Weapons (OPCW) received the Nobel Prize in 2013, in large measure due to efforts by 21 scientific laboratories around the world, one of which is LLNL's Forensic Science Center.
	2007	Jointly awarded to the International Panel on Climate Change (IPCC) and former Vice President Al Gore for efforts to build and disseminate greater knowledge about manmade climate change. Approximately 40 LLNL employees were recognized as key contributors to the IPCC work.
National Medal of Science	2009	Berni Alder for computer methods enabling molecular dynamics simulations, experimental shock-wave simulations of fluids and solids at very high pressures, and for developing Monte Carlo methods for calculating the properties of matter from first principles
Gordon Bell Prize	2013	Simulation of cavitation collapse
	2007	Kelvin-Helmholtz instability of molten metals
	2006	Large-scale electron structure calculation of high-Z metals
	2006	Quantum chromodynamics (special achievement award)
	2005	Solidification simulations of tantalum and uranium
Presidential Early Career Awards for Sciences and Engineering (PECASE) — list includes former LLNL postdocs nominated by LLNL on the basis of work at the Laboratory	2013	Miguel Morales-Silva equation of state simulations
	2012	Heather Whitley thermal conductivity in ignition capsules
	2012	Jeffrey Banks pioneering contributions in numerical approximations to hyperbolic partial differential equations
	2011	Tina Chow simulation of atmospheric turbulence
	2011	Gang Logan Liu Surface Enhanced Raman Spectroscopy techniques
	2011	Greg Bronevetsky statistical models
	2008	Lynford Goddard photonic systems
	2007	Shawn Newsam pattern recognition and educational outreach
	2007	Jeff Kysar material deformation and fracture
	2007	Carlos Pantano turbulence models and laminar flame
E. O. Lawrence Award	2011	Thomas P. Guilderson for radiocarbon measurements of corals, advancements in understanding the paleo-history of ocean currents and ocean processes

E. O. Lawrence Award (cont.)	2009	Omar Hurricane for contribution to nuclear weapons stockpile stewardship
NNSA S&T Award	2012	Mike McCoy for pioneering work in high performance computing
DOE/NNSA Weapons Program Recognition Excellence Awards	2012	Developed and implemented physics-based models into ASC codes and used the new tools to perform integrated assessment for a range of systems and unique underground tests
	2012	Gas Gun Relocation Project
	2012	Advancement in the state of the art in generator/power flow/ pulse shaping technology
	2012	Weapon safety hydro experiment at DARHT
	2012	W84 SS21 Dismantlement Project
	2012	Collaborative Authorization Safety-Basis Total Lifecycle Environment (CASTLE) Project
	2012	Barolo Subcritical Experimental Series
	2009	Resolving a significant unknown in the fundamental nuclear data for the production of fission products
	2009	Develop modern simulation capabilities in support of the nuclear forensics
	2009	Supercomputer deployment of Dawn ahead of schedule
	2009	Photonic Doppler Velocimeter velocity diagnostic
	2008	Hydrodynamic experiment of high-priority multinational experiment at NTS
	2008	Plutonium multiphase equation of State
	2008	Sequoia procurement of 20-petaflop computer
	2008	W76 life extension project
	2008	Radiation transport experiment suite on NIF
	2007	Radiochemistry
	2007	John Castor's contributions
	2007	W80 project team
	2007	DARHT-2 refurbishment and commissioning
	2007	DAHRT support
	2007	A-Program code development team
	2007	Electrostatic weapon safety analysis
	2007	Nuclear weapon transportation safety
	2007	RRW stockpile transformation
	2007	W88 Pit production and certification
	2006	Cliff Shang's contributions
	2006	George Zimmerman's contributions
	2006	Use control analysis
	2006	Electronic redbook
	2006	Pit lifetime
	2006	Chancellor drillback

DOE Gold Award	2006	Wayne Shotts for distinguished contributions to national security
Hans Bethe Prize	2007	James R. Wilson for numerical work on supernovae core collapse, neutrino transport, and shock propagation
George Pake Prize	2005	Cherry Murray for fundamental studies in surface and scattering physics
John Dawson	2012	Laser scatter on self-generated plasma-optics gratings that enables generation and redirection of high-energy laser beams important for indirect drive inertial confinement fusion and high-power laser-matter interactions (team award)
	2006	Developing the fast-ignition inertial fusion concept and experiments (team award)
James Clerk Maxwell	2007	John Lindl for outstanding contributions to the field of plasma physics
Will Allis Prize	2008	Ken Kalander for advanced understanding of strong field ionization processes in rapidly ionizing gases
Helmholtz-Rayleigh Interdisciplinary Silver Award	2008	Jim Candy for signal processing and underwater acoustics
ASME Dedicated Service Award	2012	Ron Hafner for voluntary service to Society
ASME Nadai Medal	2006	Richard M. Christensen for techiques to simulate mechanics of materials and heterogeneous media
Al Sonntag Award	2007	Patrece Turchi for work on atomic-scale sliding friction of amorphous and nanostructured SiC and diamond surfaces
Larry Foreman Excellence in ICF	2008	Russell Wallace for innovation in target fabrication
	2006	Masaru Takagi for innovation in target fabrication
AGU Ascent Award	2012	Stephen Klein for elucidating the role of clouds in climate change
AGU James Macelwane Medal	2010	David Lobell for remote sensing, statistics, and climate modeling
	2008	Jame Bardo for his work on mineral physics

William Spraragen Memorial Award	2005	John Elmer for innovation in laser-beam joining and materials interactions
McKay-Helm Award	2010	John Elmer for insight into heat transfer and fluid flow during electron beam welding of 304L stainless steel alloy
ANS Edward Teller Award	2013	Jim Hammer
	2011	Bruce Remington
	2009	Ed Moses
	2005	Max Tabak
	2005	Joseph Kilkeny
ANS Theos "Tommy" Thompson Award	2005	Robert Budnitz for work on enhancement of nuclear safety worldwide
ANS Standards Award	2006	Robert Budnitz for standards development in nuclear science and engineering
Maurice Biot Award	2005	James Berryman for contributions in poromechanics, granular materials, random composite media, tomography and inverse problems, and seismology
Alexander von Humboldt Research Award	2005	Sigfried Glenzer
Fusion Power Associates Distinguished Career Award	2010	Dmitri Ryutov
	2007	David Baldwin
Fusion Power Associates Leadership	2008	Ed Moses
Fusion Power Associates Excellences in Engineering	2011	Mike Dunne
	2010	Pravesh Patel
	2009	Jeffrey Latkowski
	2007	Brian Worth
Fusion Power Associates Special Award	2010	Chris Keane
	2008	Richard Post
	2008	John Nuckolls
Fulbright Distinguished Scholar	2009	Arthur Rodgers
	2009	Panayot Vassilevsji

LLNL Team and Individual Awards

Nano 50 Award	2008	Nanolipoprotein formation
	2008	Morris Wang career contributions
	2008	Design and fabrication of functional nanopores
	2008	Dynamic transmission electron microscope
	2008	Energetic nanocomposites
	2008	Fabricating transparent ceramics from nanoparticles
	2007	Development of new nanoporous, low-density materials
	2007	Discovery and experimental demonstration of ultrafast transport in carbon nanotubes
	2007	Pathogen-sensing nanosensors based on multi-stripped metallic nanowires
R&D 100 Awards	2013	DNATrax: DNA Tagged Reagents
	2013	Movie Mode Dynamic Transmission Electron Microscope
	2013	Efficient Mode-Converters for High Power Fiber Amplifiers
	2013	Laser Screening at High-throughput to Identify Energetic Laser Distortion (Laser SHIELD)
	2013	Mantero Suite 1.0 Software
	2012	LEOPARD
	2012	Plastic scintillators for neutron and gamma ray detection
	2012	High-performance coatings via HVLAD
	2012	Multiplexed Photonic Doppler Velocimeter
	2012	NanoSHIELD
	2012	Snowflake Power Divertor
	2011	MPDV, National Security Technology
	2011	High-Velocity Laser-Accelerated Deposition (HVLAD)
	2011	Laser Energy Optimization by Precision Adjustments to the Radiant Distribution (LEOPARD)
	2011	Plastic Scintillators for Neutron and Gamma Discrimination
	2011	Snowflake Power Divertor for Nuclear Fusion Reactors
	2011	NanoSHIELD coating strengthens components
	2010	Statistical Radiation Detection System
	2010	Strontium Iodide Scintillator for Gamma-Ray Spectroscopy
	2010	Energy Monitor for Ultrahigh-brightness X-ray Pulses
	2010	Grating Actuated Transient Optical Recorder (GATOR)
	2010	Ultrapermeable Carbon Nanotube Membranes
	2010	Microelectromechanical Systems (MEMS)-based Adaptive-Optics Optical Coherence Tomography
	2009	GeMini Spectrometer
	2009	Artificial Retina—Restoring Sight to the Blind
	2009	The FemtoScope: A Time Microscope
	2009	ROSE: Making Compiler Technology Accessible
	2009	Land Mine Locator: Eradicating the Aftermath of War
	2009	Laser Beam Centering and Pointing System

R&D 100 Awards (cont.)

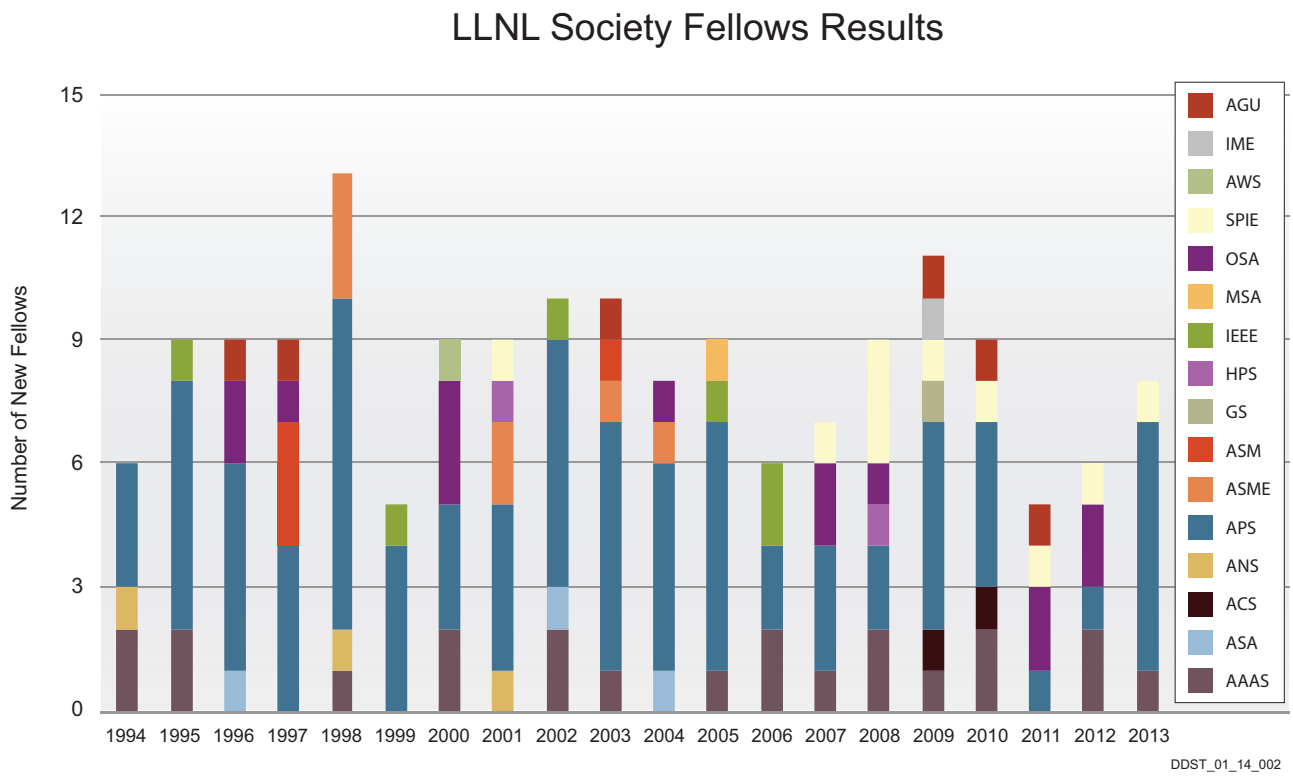
2009	Spectral Sentry—Protecting High-Intensity Lasers from Band width-Related Damage
2009	Precision Robotic Assembly Machine for Ignition Targets
2008	Dynamic Transmission Electron Microscope
2008	Autonomous Alignment Process for Laser Fusion Systems
2008	SecureBox: National Security through Secure Cargo
2007	Noninvasive Pneumothorax Detector
2007	MEMS-Based Adaptive Optics Scanning Laser Ophthalmoscope
2007	LLNL's Large Area Imager: For Illicit Radioactive Materials
2007	Hyper-Fast Solution Algorithms for Scientific Computing
2007	Continuous Phase Plate Optics Manufactured Using Magnetorheological Finishing
2006	Babel: The High Performance Language Interoperability Tool
2006	ELITE: A Pocket-Sized Trace Explosives Test
2006	Externally Dispersed Interferometry
2006	High-Average-Power Wavelength Converter
2006	Saphire: Scientific Data-Mining Software
2006	Sonoma Persistent Surveillance System
2006	Ultrahigh-Resolution Gamma and Neutron Spectrometer
2005	Adaptable Radiation Area Monitor (ARAM)
2005	Biological Aerosol Mass Spectrometry System
2005	NanoFoil
2005	Visit: A flexible, Scalable Visualization and Graphic Analysis Tool

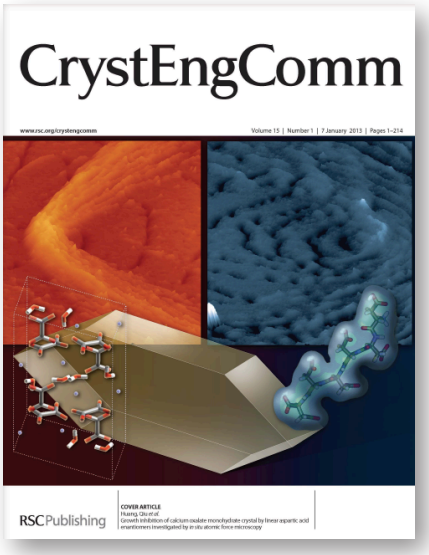
iii. Professional Societies Fellows

Many professional societies elect distinguished members and contributors to honored levels, most often called "fellows." The top professional organizations that most represent the important disciplines and technical focus areas for LLNL's staff are as follows:

Acoustical Society of America (ASA)
American Association for the Advancement of Science (AAAS)
American Chemical Society (ACS)
American Geophysical Union (AGU)
American Nuclear Society (ANS)
American Physical Society (APS)
American Society of Mechanical Engineers (ASME)
American Society of Materials International (ASM) (formerly American Society for Metals)
American Welding Society (AWS)
Geochemical Society (GS) (with the European Association of Geochemistry)
Health Physics Society (HPS)
International Society for Optical Engineering (SPIE)
Institute of Mechanical Engineers (IME)
Institute of Electrical and Electronics Engineers (IEEE)
Mineralogical Society of America (MSA)
Optical Society of America (OSA)

From 2005 through 2013, LLNL has had at least 70 staff elected as fellows in the above societies, for an average of about eight per year. The figure below gives a longer history.

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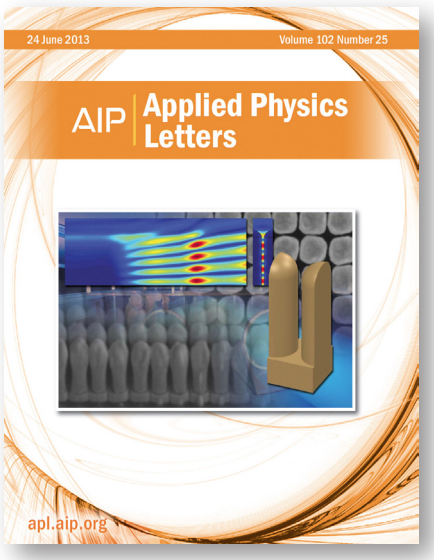
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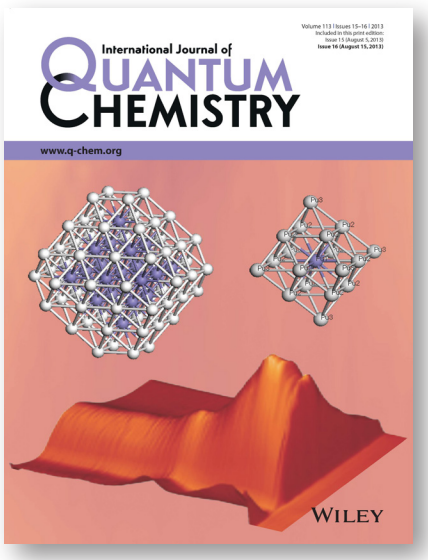
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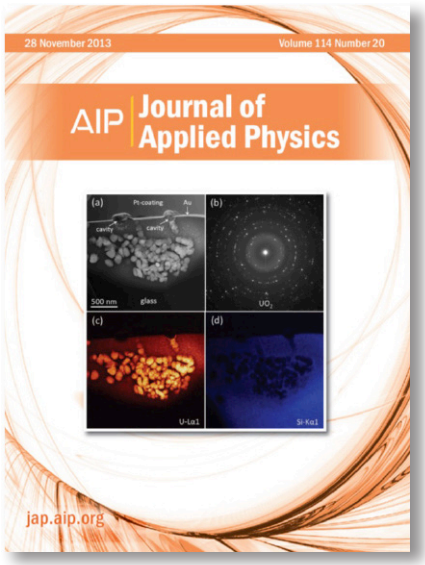
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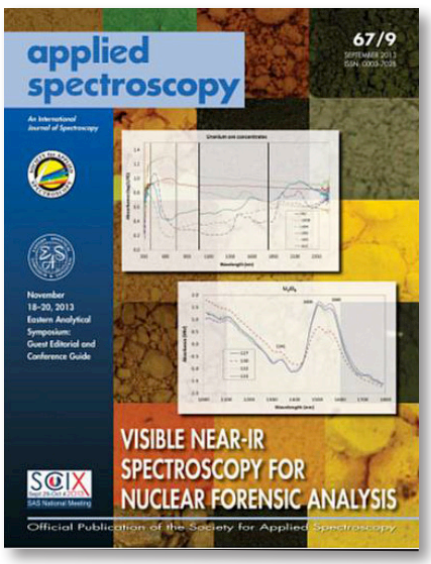
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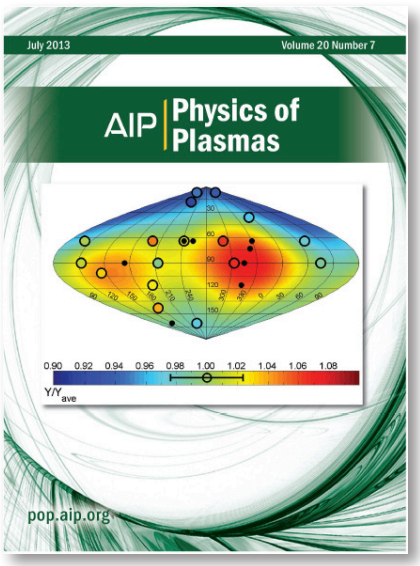
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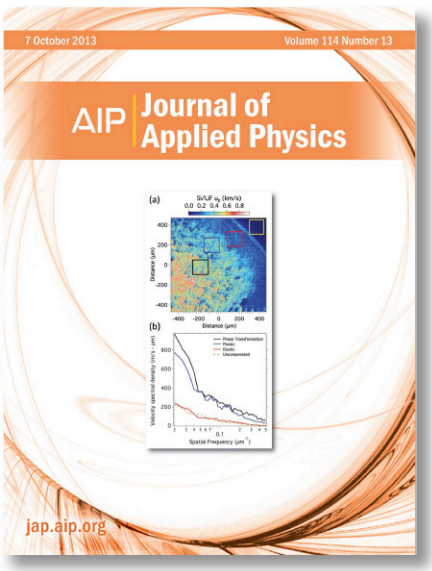
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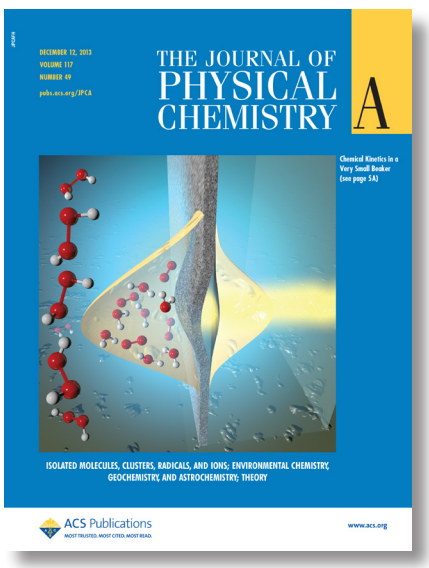
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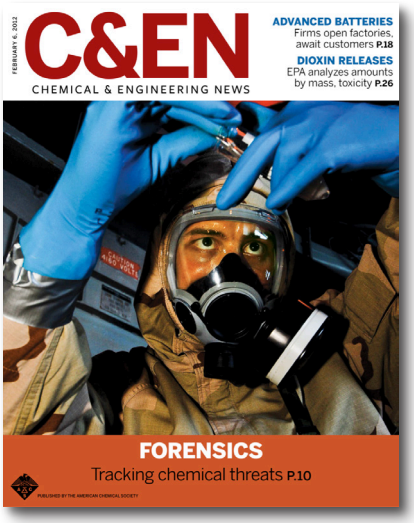
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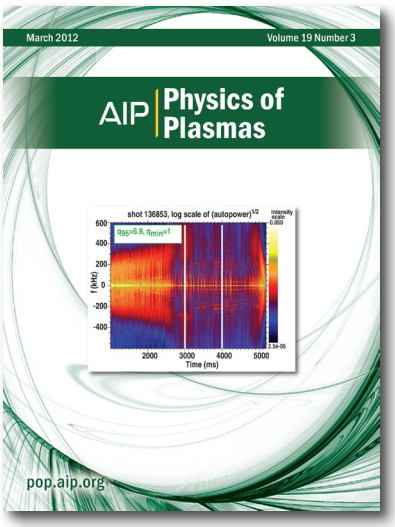
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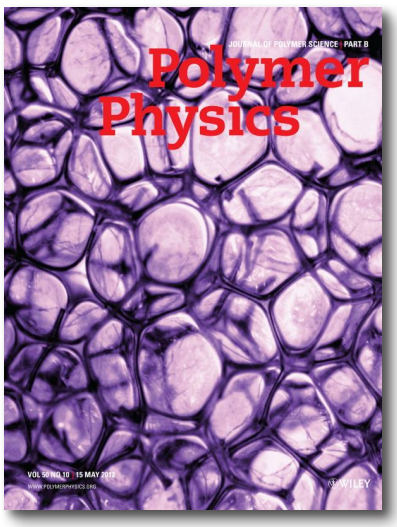
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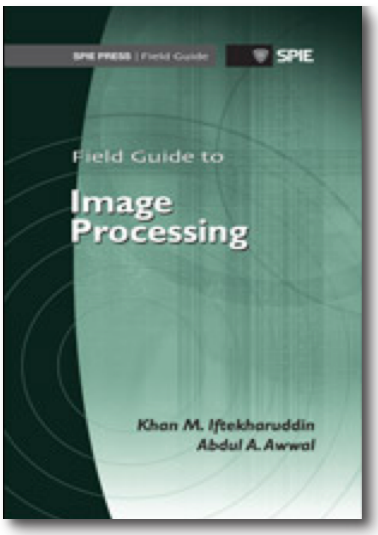
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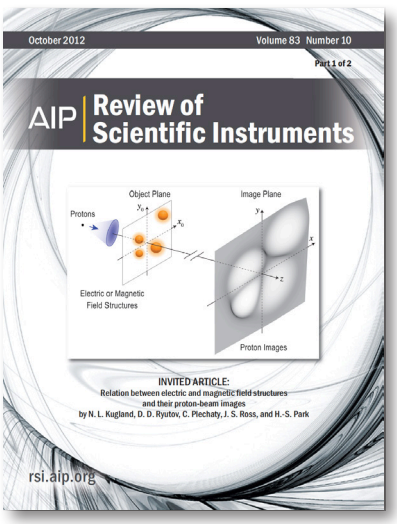
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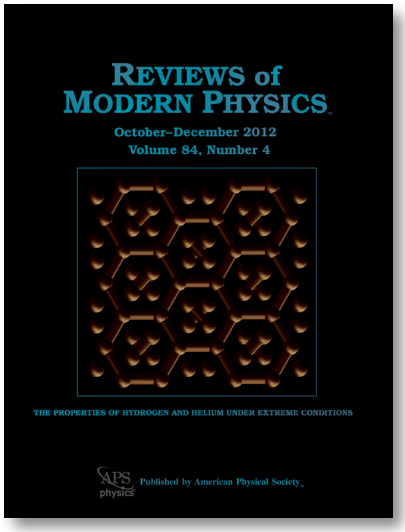
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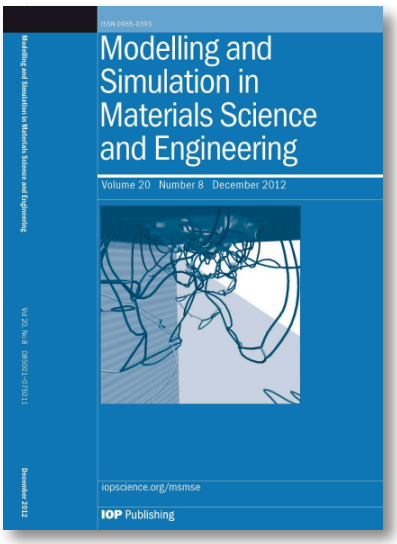
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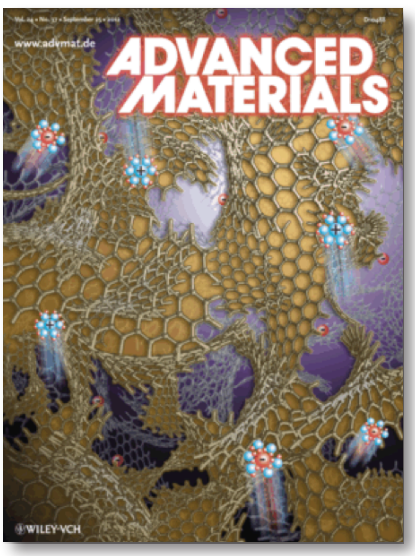
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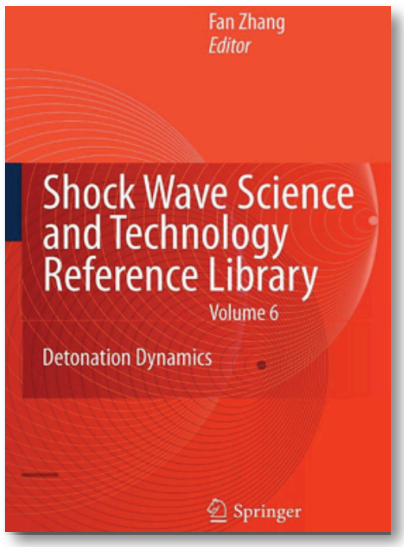
Fan Zhang
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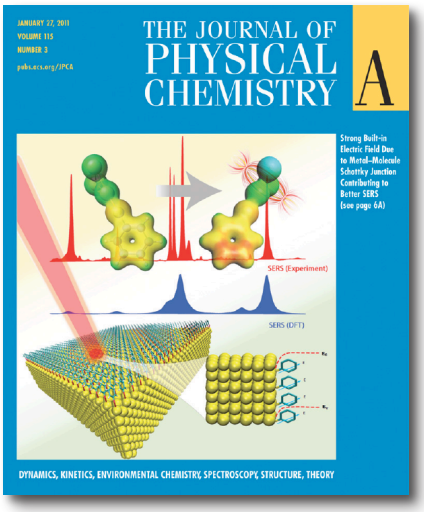
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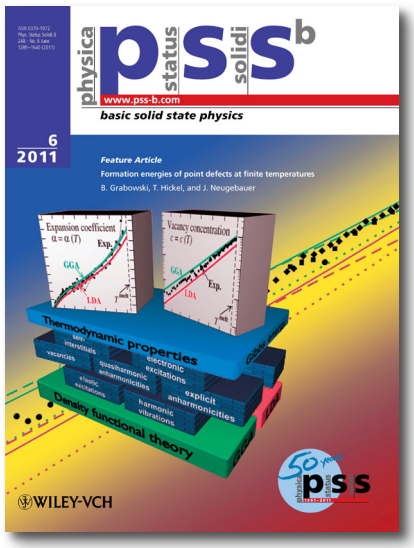
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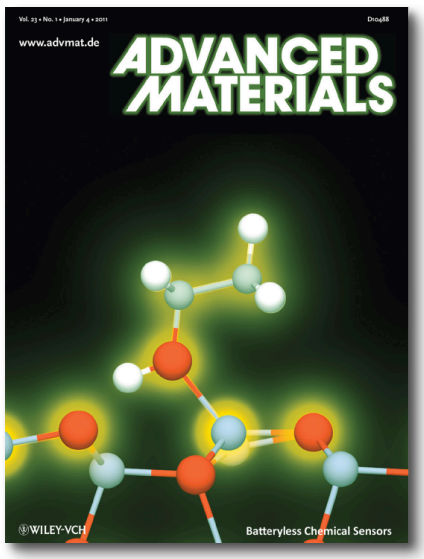
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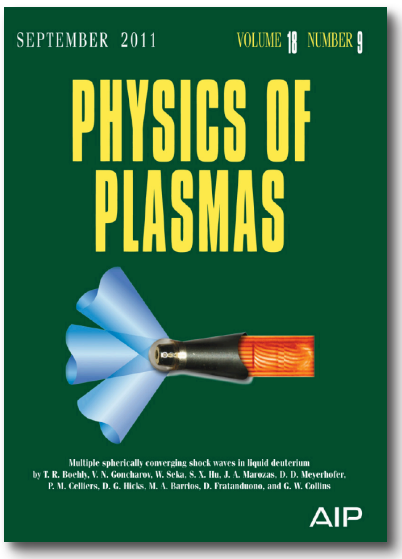
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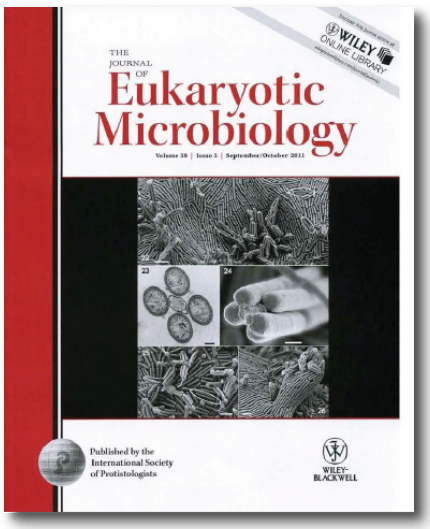
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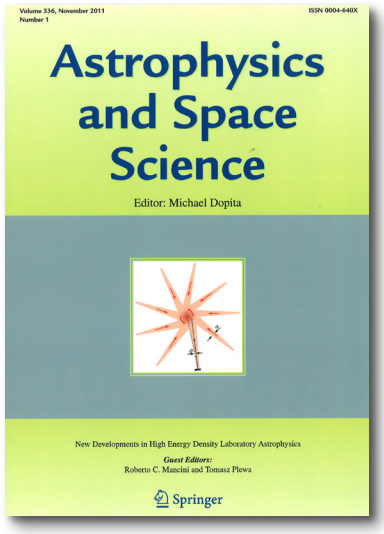
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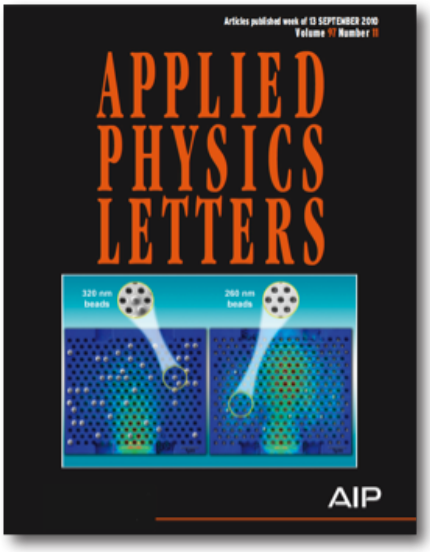
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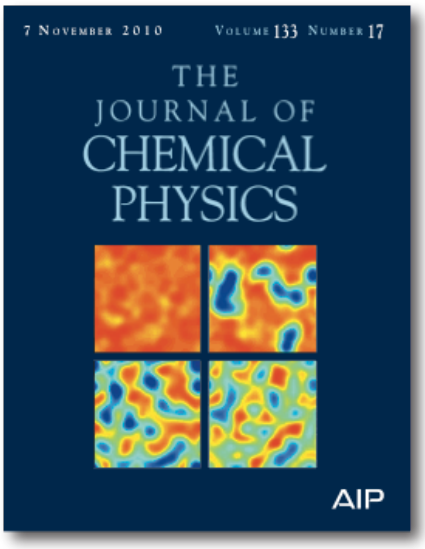
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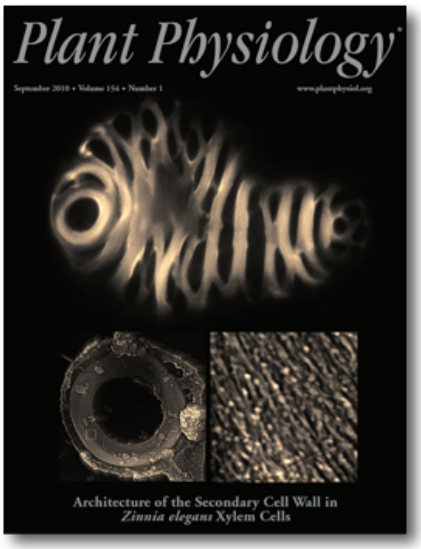
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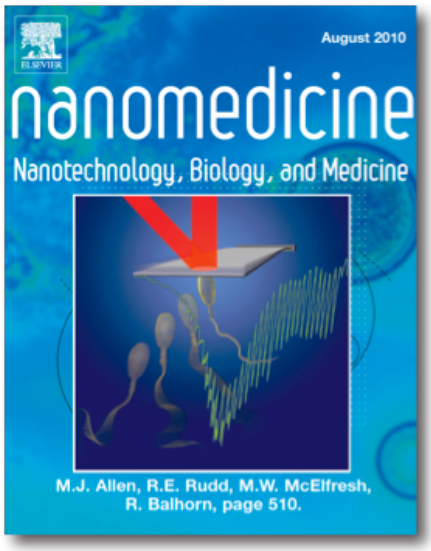
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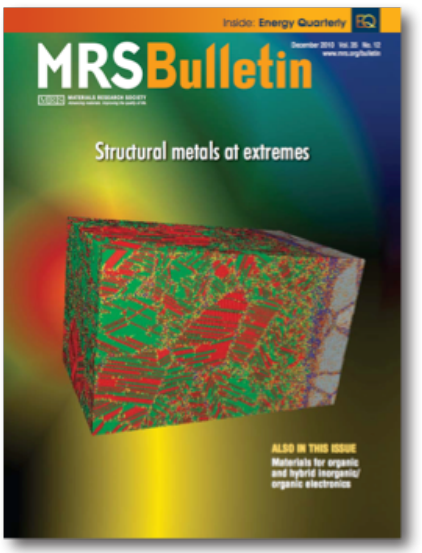
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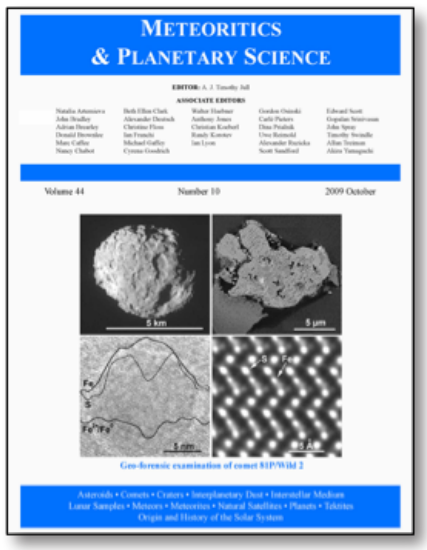
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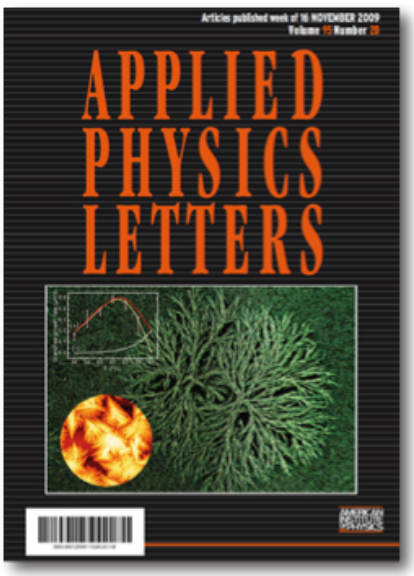
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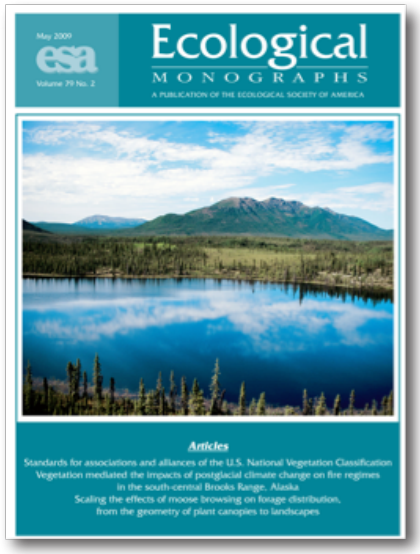
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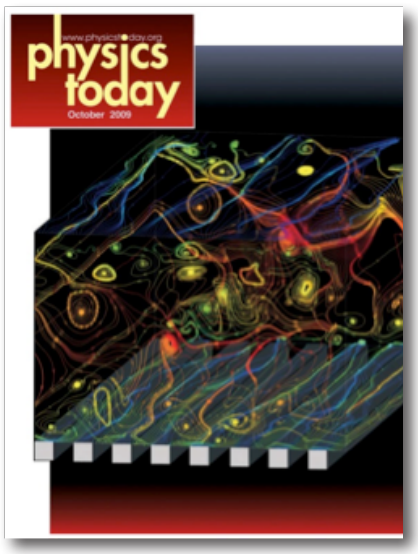
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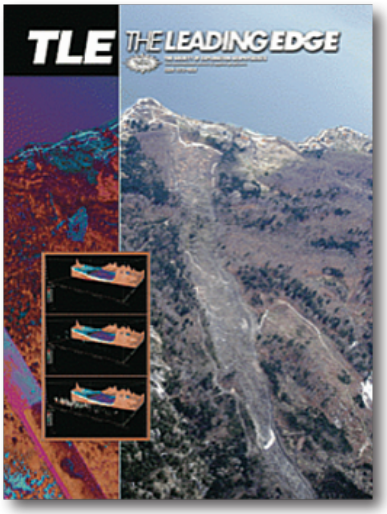
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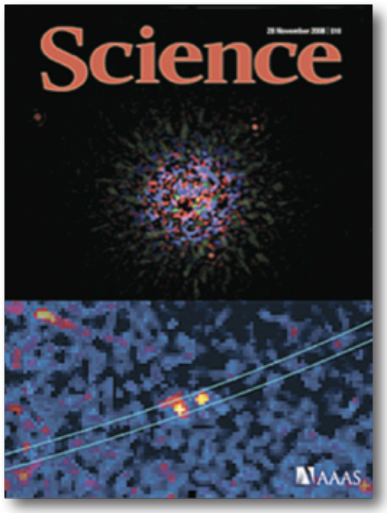
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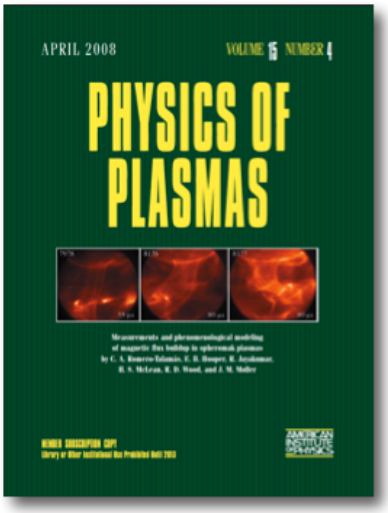
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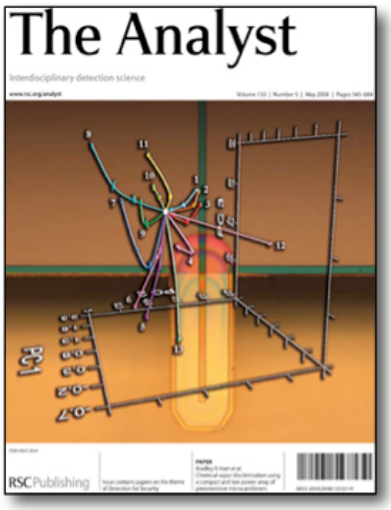
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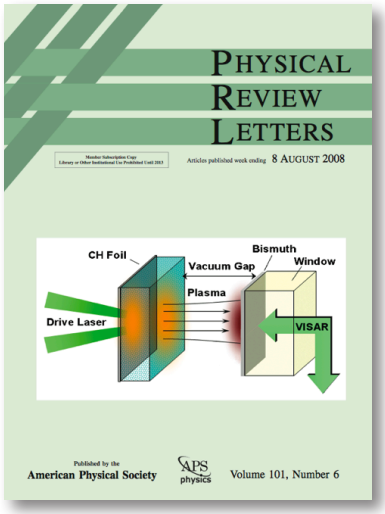
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