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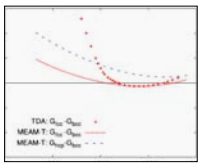

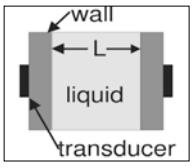

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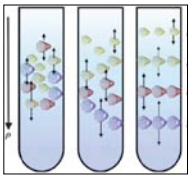

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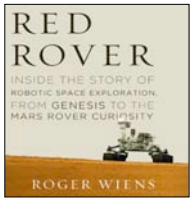
Roger Wiens authors book on robotic space exploration



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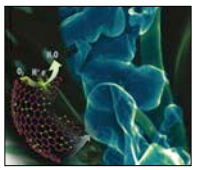

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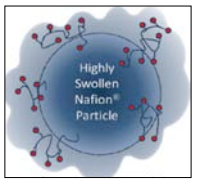

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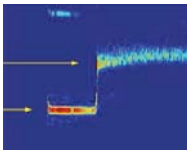

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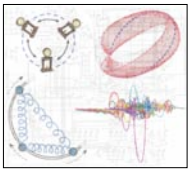


PADSTE HIGHLIGHTS April 17, 2013

AWARDS AND RECOGNITIONS

Atomistic modeling featured in journal's 2012 best papers compilation
A journal issue of the best papers published during 2012 in the ***Journal of Physics: Condensed Matter*** includes an article describing modeling of the thermodynamic equilibrium and polymorphism of iron. An international editorial board chose the papers based on referee comments, downloads from readers, and scientific impact.

Correct predictions of the relative stability and transitions among multiple phases of a given material are of fundamental importance. The computational cost of such first-principles calculations is demanding, and their application is typically limited to comparatively small systems with simple configurations at zero temperature. Simulation at the atomic level with an effective interatomic potential can be an efficient technique using the Monte Carlo (MC) method or molecular dynamics (MD). These methods enabled the team to compute both the thermodynamic equilibrium and long-time scale dynamics of physical properties for a sufficiently large system with arbitrarily complicated geometry.

Scientists in Materials Science in Radiation and Dynamics Extremes (MST-8) and a collaborator proposed two new modified embedded-atom method (MEAM) potentials for iron to reproduce the experimental phase stability with respect to both temperature and pressure. They fitted these simple interatomic potentials to a wide variety of material properties of body-centered cubic (bcc) iron in close agreement with experiments. The researchers used Monte Carlo simulation at finite temperatures to examine these models. The team attempted to reproduce the experimental iron polymorphism at finite temperature by means of explicit free energy computations. They used two MEAM potentials to represent the observed structural phase transitions in iron. The scientists concluded that the correct reproductions of iron phase stability with respect to both temperature and pressure are incompatible with each other due to the lack of magnetism in this class of empirical potentials. The MEAM potentials correctly predicted the self-interstitial in the ⟨110⟩ orientation to be the most stable configuration in the bcc structure, and the screw dislocation to have a non-degenerate core structure. The findings are in contrast to many embedded-atom method potentials for bcc iron in the literature.

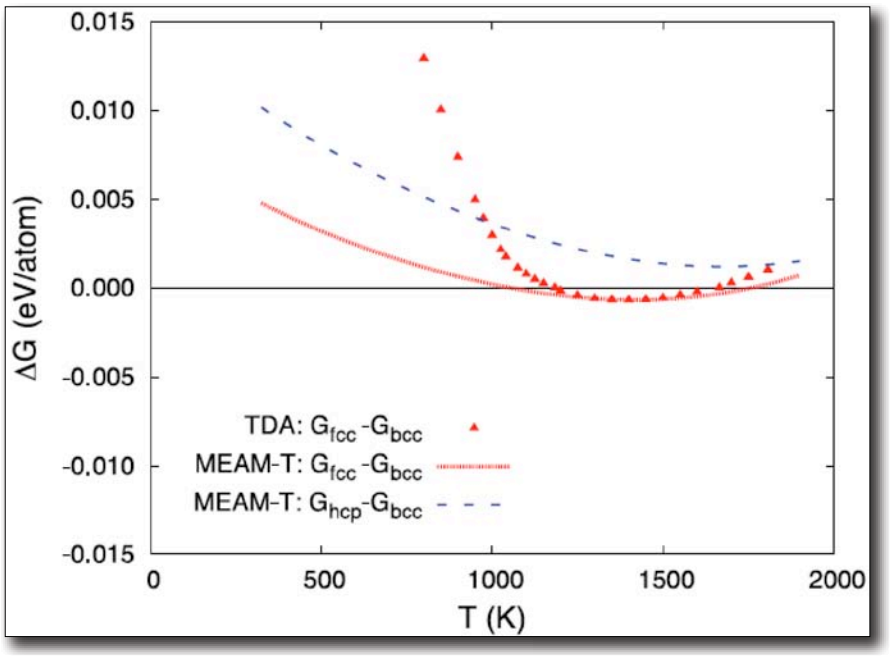


Figure 1. Temperature dependence of relative free energies calculated at zero external pressure from one of the MEAM potentials developed in this study. Thermodynamic assessment (TDA) data are shown.

Reference: "Atomistic Modeling of Thermodynamic Equilibrium and Polymorphism of Iron," ***Journal of Physics: Condensed Matter*** *24*, 225404 (2012). MST-8 researchers include Tongsik Lee, Steven Valone, and Michael Baskes (also University of California, San Diego); and collaborator J. D. Doll (Brown University). NNSA funded the work, which supports the Nuclear Deterrence mission area and the Information, Science, and Technology and Materials for the Future science pillars. Technical contact: *Tongsik Lee*

Acoustic measurements in harsh environments selected as journal Research Highlight
Editors of the ***Review of Scientific Instruments*** chose a paper describing a portable measurement cell for evaluating the acoustic properties of fluids at high temperatures, high pressures, and in chemically and mechanically harsh environments, as a 2012 Research Highlight. The journal gives this distinction given to fewer than 10 percent of the journal's articles.

Sensors and Electrochemical Devices (MPA-11) scientists invented the device. Similar in size to a hotdog in a bun, the measurement cell represents an advance in the established room temperature swept frequency acoustic interferometry (SFAI) measurement for liquid sound speed determinations. To demonstrate the measurement cell, the researchers compared their data with the internationally accepted standard, IAPWS-IF97. The precision achieved with the measurement cell is significantly better than 0.1%. The team also reported two sets of experimentally measured sound speeds in liquid water. The first data set data revealed sound speed as a function of temperature up to 250° C at pressures corresponding to the liquid-vapor coexistence line. Scientists collected the second data set near room temperature as a function of pressure up to 3000 psig.

Although significant work exists in the literature on the characterization of fluids, primarily pure water, over a wide range of pressures and temperatures, the availability of experimentally determined sound speed in water between 100° C and 250° C is limited. The need to measure sound speed in liquids up to 250° C is of both fundamental interest, as in the case of basic equations of state, and applied applications, such as characterizing geothermal or petroleum downhole environments. The instrument is simply constructed with a stainless steel housing to equip it for immersion in thermally, mechanically, and chemically harsh environments.

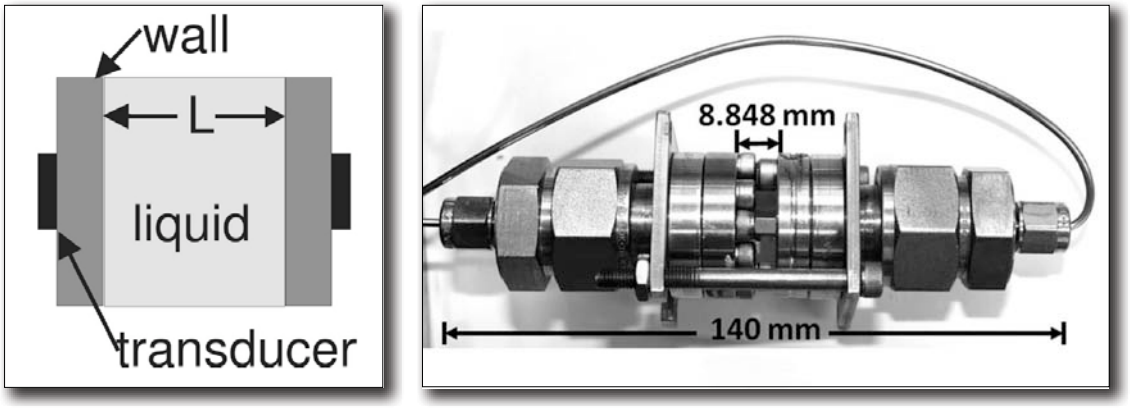


Figure 2. (*Left*): Simplified schematic of a SFAI cell. The liquid occupies the resonant cavity of length L that is bounded by two parallel walls. Piezoelectric transducers input and extract energy from the system. (*Right*): A stainless steel package protects the measurement cell's transducers, two lithium niobate ($LiNbO_3$) crystals, from mechanically and chemically harsh test environments. Two packaged transducers are arranged opposing each other for transmission mode SFAI measurements.

Reference: "An Acoustic Resonance Measurement Cell for Liquid Property Determinations up to 250° C," ***Review of Scientific Instruments 83***, 115106 (2012); doi:10.1063/1.4765746. Authors include Blake T. Sturtevant, Cristian Pantea, and Dipen N. Sinha (MPA-11).

DOE Energy Efficiency and Renewable Energy funded the research as part of the American Recovery and Reinvestment Act. The project focused on the development of high temperature-capable tools for geothermal downhole environments. The work supports the Laboratory's Energy Security mission and its Science of Signatures and Materials for the Future science pillars. Technical contact: *Blake Sturtevant*

ACCELERATOR OPERATIONS AND TECHNOLOGY

Development of LANSCE irradiation capability to produce molybdenum-99

Los Alamos worked with the NNSA NA-21 Global Threat Reduction Initiative to develop technologies for the domestic production of the radioisotope molybdenum-99 (Mo-99) without the use of highly enriched uranium. Mo-99 is the parent isotope for technetium-99m (Tc-99m), a medical isotope used in approximately 50,000 medical imaging procedures a day in the U.S., accounting for around 80% of all diagnostic imaging procedures. As part of this effort, the Lab partnered with SHINE Medical Technologies to demonstrate the use of accelerators to produce Mo-99 from low enriched uranium solutions.

Researchers developed a new irradiation capability on Weapons Neutron Research (WNR) Target 4 at the Los Alamos Neutron Science Center (LANSCE). The scientists irradiated 150 mL uranium solutions with thermalized neutrons from Target 4 to produce approximately 1 mCi of Mo-99 per irradiation. After irradiation, the scientists shipped these solutions to TA-48 for chemical separation of Mo-99 in a scaled down production column. This capability enabled the Laboratory to demonstrate solution recycling. In a first for Mo-99 production, the team irradiated and successfully processed the same uranium sulfate solution in three subsequent irradiations. The researchers are preparing for a larger scale irradiation with a spallation neutron target in LANSCE Target 2 (Blue Room) to produce 100 mCi of Mo-99 in a 5-day irradiation at the end of this run cycle.

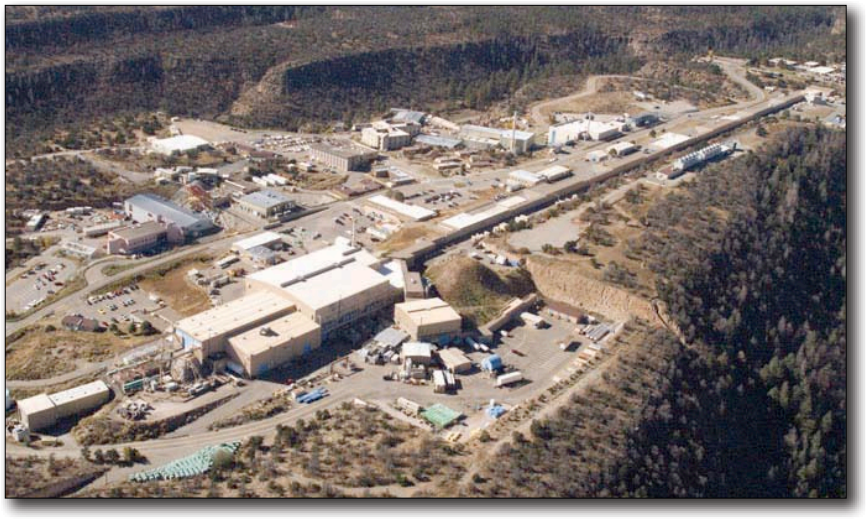


Photo. Aerial view of LANSCE.

The work supports the Lab's Global Security mission area and the Materials for the Future science pillar. Technical contact: *Greg Dale*

CHEMISTRY

Bio-inspired separation of nanotubes

A feature article in the journal ***Nanoscale*** describes advances in "armchair carbon nanotubes." They are given this name because their molecular structure makes their ends look like armchairs. These single-wall nanotubes provide ideal model one-dimensional condensed matter systems to study many-body physics, and they could serve as building blocks in nanoscale optoelectronic circuits. These nanotubes possess superior electrical properties. Electrons flow through them without resistance due to their lack of an electron band gap. If they could be synthesized and spun into wires, they might transport electricity with almost no line loss.

The tendency of synthetic processes to create a mixture of semiconducting and metallic nanotubes and the problematic isolation of the desired metallic nanotubes hampers nanotube research. The similarity of carbon nanotubes in physical dimensions and mass to DNA and proteins enabled scientists to utilize bio-inspired methods to separate the nanotubes based on various geometrical and electronic parameters.

The authors describe a novel separation method based on density gradient ultracentrifugation and DNA-based ion-exchange chromatography to produce much higher concentrators of armchair nanotubes. Their research and analysis of the fundamental optical absorption and scattering processes of metallic carbon nanotubes lay the foundation to probe many-body physical phenomena in one dimension. Moreover, the separated nanotubes might serve as seed crystals to produce gram quantities of the parent armchair nanotube. The results show potential for carbon-based condensed matter physics and materials science.

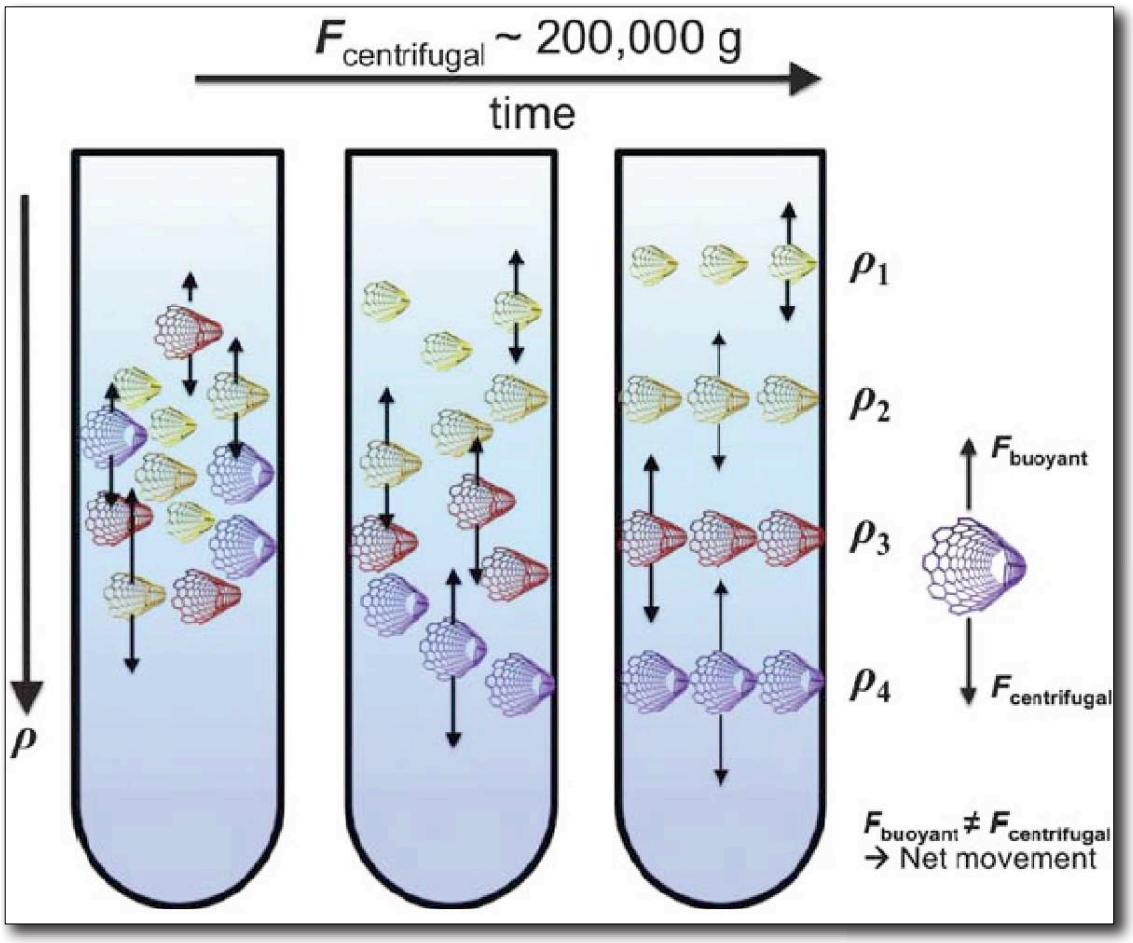


Figure 4. Nanotubes can be separated along a density gradient using ultracentrifugation. Single wall carbon nanotubes of different mass density (represented by different color tubes) are loaded into a

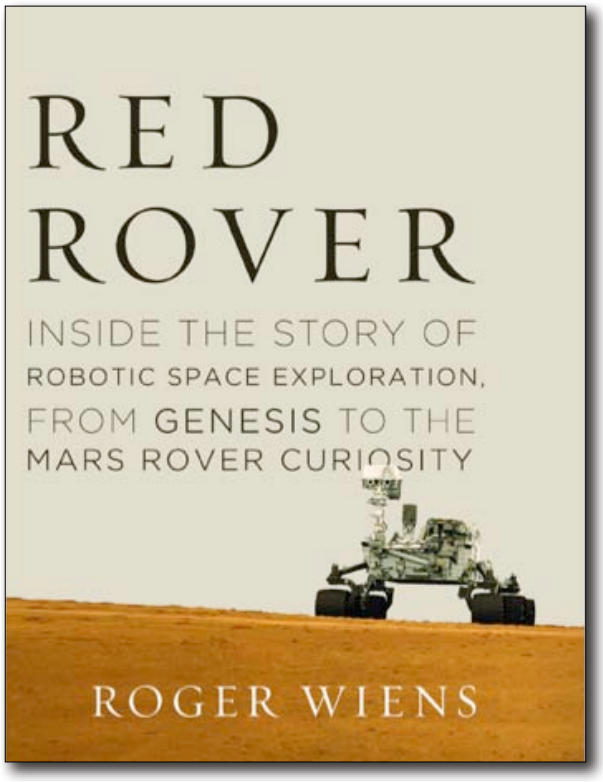
centrifuge tube containing a mass density gradient, and a strong centrifugal field is applied. The competition between the applied centrifugal force and the resultant opposing buoyant force causes the nanotubes to migrate through the gradient in space until equilibrium is reached and the forces are balanced.

Reference: "Fundamental Optical Processes in Armchair Carbon Nanotubes," ***Nanoscale*** *5*, 1411 (2013); doi:10.1039/c2nr32769d. Authors include Erik H. Hároz, Robert H. Hauge, and Junichiro Kono (Rice University); Juan Duque (Physical Chemistry and Applied Spectroscopy, C-PCS); Xiaomin Tu, Ming Zheng, and Angela R. Hight Walker (National Institute of Standards and Technology); and Stephen K. Doorn (Center for Integrated Nanotechnologies, MPA-CINT). PhysOrg reviewed the feature article: http://phys.org/news/2013-02-comprehensive-fundamentals-desirable-nanotubes.html#jCp.

Laboratory Directed Research and Development (LDRD) and the Center for Integrated Nanotechnologies (CINT), a DOE Basic Energy Sciences user facility, funded different aspects of the Los Alamos work. The research supports the Lab's Energy Security mission area and the Materials for the Future science pillar. Technical contacts: *Juan Duque* and *Steve Doorn*

INTELLIGENCE AND SPACE RESEARCH

Roger Wiens authors book on robotic space exploration



Roger Wiens (Space and Remote Sensing, ISR-2) has written a book about some of the NASA space exploration projects. It is ***Red Rover: Inside the Story of Robotic Space Exploration from Genesis to the Mars Rover Curiosity.*** Los Alamos researchers played a significant scientific role in all of the projects described in the book.

The publisher states "Mars serves as our twenty-first century New World; its explorers robots, shipped 350 million miles from Earth to uncover the distant planet's secrets. Its most recent scout is Curiosity – a one-ton, Jeep-sized nuclear-powered space laboratory – which is now roving the Martian surface to determine whether the red planet has ever been physically capable of supporting life. In ***Red Rover***, geochemist Wiens, the principal investigator for the ChemCam laser instrument on the rover and veteran of numerous robotic NASA missions, recounts his involvement in sending sophisticated hardware into space, culminating in the Curiosity rover's amazing journey to Mars."

Wiens describes one of the most exciting scientific stories of our time: the new era of robotic space exploration. From NASA's introduction of the Discovery Program in 1992, more nimble missions were

designed, and manned missions were confined to Earth orbit. This strategic shift presented huge scientific opportunities. Success depended more than ever on creative engineering and human ingenuity during a time of budget constraints. Beginning with the Genesis mission, Wiens describes the competitive, do it yourself spirit of these robotic enterprises. An inspiring account of the real-life challenges of space exploration, ***Red Rover*** vividly narrates what goes into answering the question: is there life elsewhere in the universe?

Wiens will give a Los Alamos Frontiers of Science talk on the ChemCam discoveries, entitled "Exploring Mars with Curiosity and its Laser" at the following locations:

- Tuesday, May 7 at 7 PM, Duane W. Smith Auditorium, Los Alamos
- Thursday, May 9 at 7 PM, New Mexico Museum of Natural Science and History, Albuquerque
- Tuesday, May 14 at 7 PM, James A. Little Theater, New Mexico School for the Deaf, Santa Fe
- Thursday, May 16 at 7 PM, Taos Convention Center, Taos

NASA funds the Los Alamos work, which supports the Lab's Global Security mission area and the Science of Signatures science pillar. Technical contact: *Roger Wiens*

MATERIALS PHYSICS AND APPLICATIONS

Non-precious metal fuel cell catalyst with enhanced performance durability

Hydrogen-air polymer electrolyte fuel cells (PEFCs) are a promising technology to replace internal combustion engines for environmentally clean automotive propulsion. A major drawback of current PEFC technology is the high cost, largely due to the use of platinum-based catalysts at both the anode (20%) and the cathode (80%). Los Alamos scientists led a collaboration that developed a durable non-precious metal catalyst for oxygen reduction in acid media that could decrease the cost of PEFCs. The journal ***Chemical Communications*** featured the report on its inner cover.

The team examined possible stability enhancements in the catalyst through the use of a support other than conventional carbon blacks. The scientists introduced multi-walled carbon nanotubes (MWNT) into the synthesis of non-precious metal catalysts derived from *in-situ* polymerized polyaniline (PANI) and iron (Fe) precursors. A high-temperature synthesis step enriched the catalyst in graphene sheets/bubbles. The resulting PANI–Fe–MWNT catalyst maintained stable performance for 500 hours at 0.4 V in a fuel cell. The researchers compared extensive physical characterization and catalysis results obtained for the PANI–Fe–MWNT and PANI–Fe–carbon black catalysts to provide insight into the increased performance durability.

The iron speciation information is identical in both carbon-black- and MWNT-supported iron catalysts. This finding suggests that the enhanced durability may not be directly associated with the active iron species. The unique composite structure comprised of carbon nanotubes and graphene in the PANI–Fe–MWNT catalyst benefits oxygen mass transfer, water removal from catalyst surfaces, corrosion resistance, and electronic conductivity. These properties lead to the much improved catalyst stability in acid media. The scientists conclude that the catalyst's improved durability correlates with the graphene formation, apparently enhanced in the presence of carbon nanotubes.

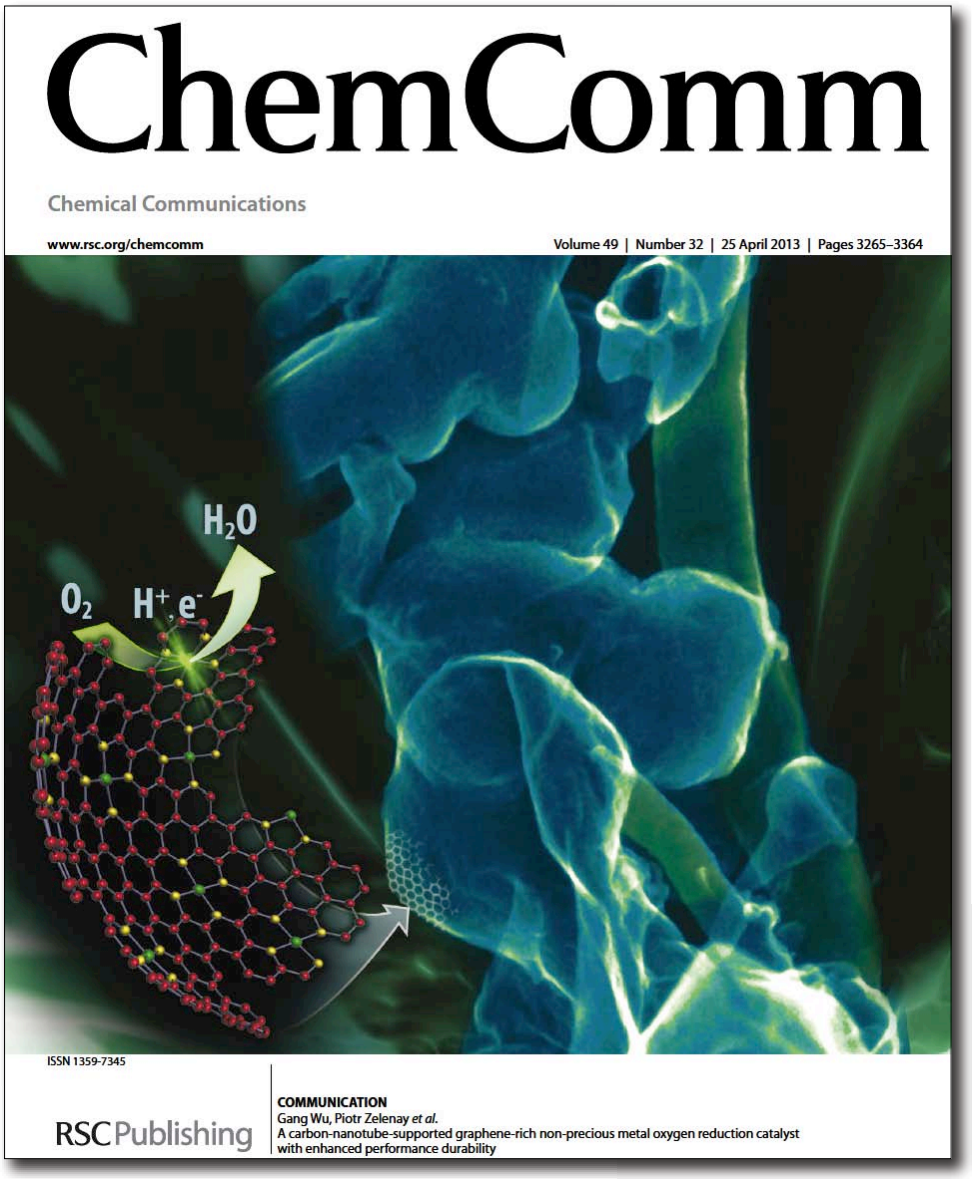


Figure 5. Journal's inside cover. (*Left*): Structure of nanotube and mechanism of molecular reduction of oxygen reaction. (*Right*): Scanning electron microscopy image of the non-precious metal catalyst supported on multi-walled carbon nanotubes.

Reference: "A Carbon-nanotube-supported Graphene-rich Non-precious Metal Oxygen Reduction Catalyst with Enhanced Performance Durability," ***Chemical Communications*** *49*, 3291 (2013); doi: 10.1039/c3cc39121c. Researchers include Gang Wu, Christina M. Johnston, and Piotr Zelenay (Sensors and Electrochemical Devices, MPA-11); Ping Xu and Hsing-Lin Wang (Physical Chemistry and Applied Spectroscopy, C-PCS); Karren L. More (Oak Ridge National Laboratory), Magali Ferrandon, Arthur J. Kropf, and Deborah J. Myers, (Argonne National Laboratory); and Shuguo Ma (University of South Carolina – Columbia).

DOE's Fuel Cell Technologies Program and the Laboratory Directed Research and Development (LDRD) Program funded different aspects of the work, which supports the Laboratory's Energy Security mission and Materials for the Future science pillar. Technical contacts: *Gang Wu* and *Piotr Zelenay*

MATERIALS SCIENCE AND TECHNOLOGY

Unexpected Nafion morphologies in dilute solvents

In work that could impact the future of automobiles that run on hydrogen fuel cells, Los Alamos scientists performed more precise structural modeling to describe Nafion (sulfonated tetrafluoroethylene based fluoropolymer-copolymer) particle morphology. The team ascertained polymer/particle shape, size, and the percentage of solvent within the particle. The ***American Chemical Society Macro Letters*** published the research.

Polymer electrolyte fuel cell manufacturers use DuPont's Nafion polymers in standard membrane and electrode materials. Because Nafion aids in ion conductivity, current state-of-the-art proton exchange membranes and electrode binders are prepared from water-based Nafion dispersions. During 2009-2011, the Los Alamos researchers developed a method to solubilize Nafion in non-aqueous single solvents. Fuel cell devices prepared from these non-aqueous Nafion dispersions demonstrated much improved performance and durability. However, researchers did not know the reason for the performance improvement. They conducted small angle neutron scattering (SANS) and ^{19}F NMR studies to examine the microstructure of Nafion in dilute aqueous and non-aqueous solvents. Their results provided insight into this performance improvement and directed improvements in Nafion-based material performance.

The studies revealed three types of Nafion particle morphology in dilute liquid media: 1) a well-defined cylindrical dispersion in glycerol and in ethylene glycol with different degrees of solvent penetration, 2) a less-defined, highly solvated large particle (>200 nm) in water/2-propanol mixtures, and 3) a random-coil conformation (true solution behavior) in N-methylpyrrolidone (NMP).

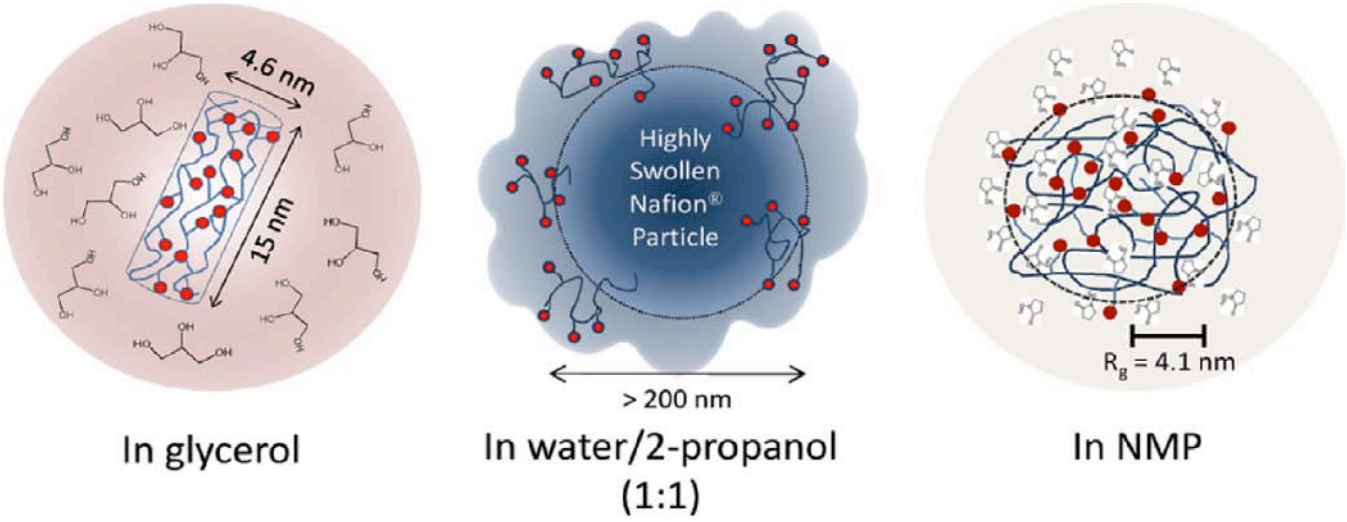


Figure 6. The three types of Nafion particle morphology observed by small angle neutron scattering (SANS) and ^{19}F NMR studies: cylinder in glycerol, highly swollen sphere in water/2-propanol, and random coil chain in N-methylpyrrolidone (NMP).

The cylindrical particle structure of Nafion in glycerol and ethylene glycol is consistent with the particle morphology suggested by previous researchers. Nafion forms cylindrical particles, which have similar radii (i.e., 22 Å) but noticeably different cylinder lengths (150 and 370 Å for glycerol and ethylene glycol, respectively). These recent results reveal additional radically different Nafion

morphologies in water/2-propanol mixtures and in the aprotic NMP solvent. In water/2-propanol mixtures, the Los Alamos team observed less-defined, highly solvated large particles (>200 nm), probably due to a strong polyelectrolyte effect between sulfonated side chains that are solvated by water. The NMP results show that Nafion polymers can be solubilized as single chains, rather than existing only in the aggregated state that is more commonly reported in the literature. The ability to tune the Nafion dispersion morphology through solvent selection gives researchers a powerful tool to control the mechanical properties of the resulting solution-cast film.

Reference: "Nafion in Dilute Solvent Systems: Dispersion or Solution?" ***American Chemical Society Macro Letters*** *1*, 1403 (2012); doi:10.1021/mz3005204. Authors include Cynthia Welch, Andrea Labouriau, and Bruce Orler (Polymers and Coatings, MST-7); Rex Hjelm (Lujan Center, LANSCE-LC); Christina Johnston and Yu Seung Kim (Sensors and Electrochemical Devices, MPA-11).

Researchers performed the SANS measurements on the time-of-flight, low-Q diffractometer, sponsored by the DOE Office of Basic Energy Sciences at the Lujan Neutron Scattering Center, and on the NG-3 beamline at the National Institute of Standards and Technology Center for Neutron Research in Maryland. The DOE Energy Fuel Cell Technologies program funded this work, which supports the Lab's Energy Security mission area and the Materials for the Future and Science of Signatures science pillars. Technical contact: *Cynthia Welch*

PHYSICS

First of their kind uniaxial second shock ejecta data

William Buttler (Neutron Science and Technology, P-23) led a team to measure first and second shock ejecta measurements on tin (Sn) samples in a special system. They characterized the total mass ejected from surfaces subjected to a second shock. Researchers are using these experimental results, which are the first of their kind in a uniaxial two-shockwave system, to develop and implement ejecta models in Advanced Strategic Computing (ASC) codes.

The measurements prove the uniaxial concept and reveal striking behavior: the "lumpy" nature of the second shock surface, and the evidence of uneven material damage in the LDV (Laser Doppler Velocimetry) and LN (Lithium Niobate piezoelectric probe) data. The uneven damage and spall observations imply wide variations in the amount of ejected mass caused by second shockwaves at the surface, which could cause unpredictable mix behavior in the presence of a gas. The dynamics also suggest that development of a second shock ejecta model will require much more labor than was involved in development of a first shock ejecta model. Researchers are implementing the first model in the Los Alamos FLAG hydrodynamic code. The team anticipates that the second shock ejecta model will be largely based on the first shock ejecta model.

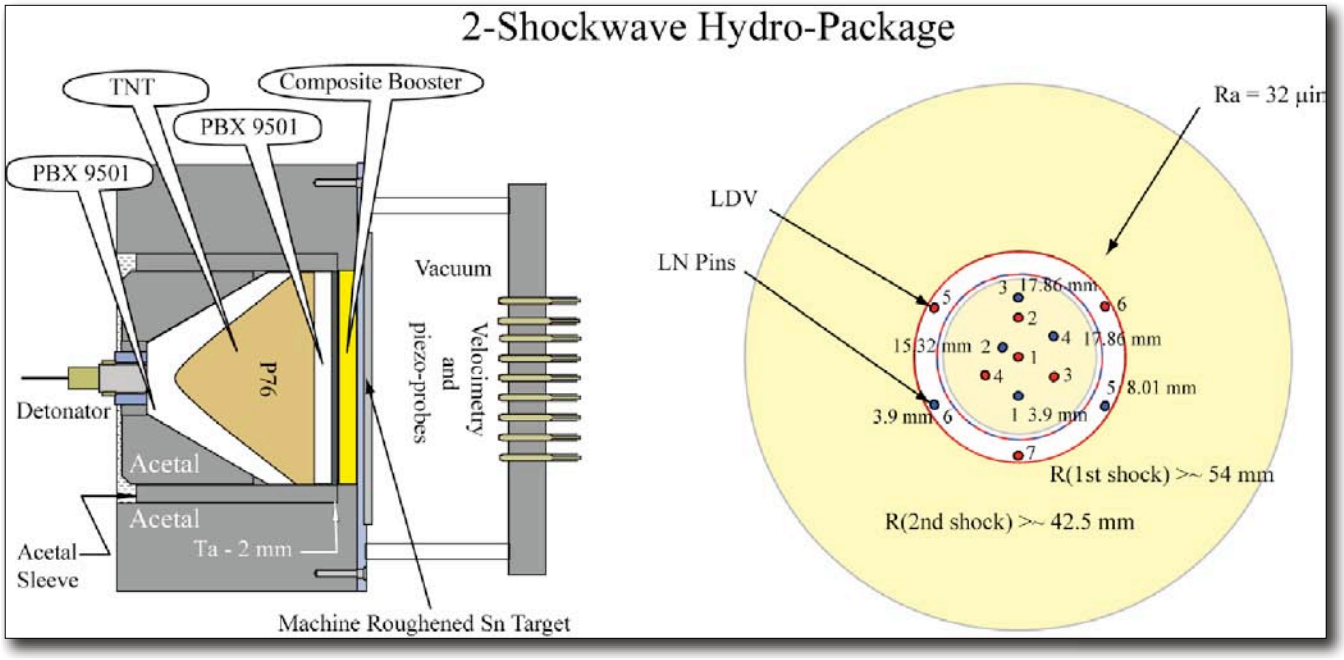


Figure 7. (*Left*): Schematic of the experimental package. (*Right*): Schematic of the diagnostic, including piezoelectric pin heights. LDV is Laser Doppler Velocimetry, and LN is lithium niobate.

The ability to vary the first shockwave loading stress is important. The scientists achieved this result by using the low C_j state Calcitol HE (High Explosive) in the lowest pressure case (P_{SB} = 18.5 GPa), and by using different amounts of the explosives TNT and PBX 9501 in the second and third cases (P_{SB} = 24.4 and 26.4 GPa). The second shockwave amplitude was about 0.6 mm/ms in all three cases. The researchers plan to test the capability to vary the second shock amplitude.

Estimating the loading pressure of the second shockwave is difficult with the CTH modeling software (CTH is a multi-material, large deformation, strong shock wave, solid mechanics code developed at Sandia National Laboratories) because CTH does not have a three-phase Equation of State for tin. Earlier work by Paulo Rigg (Shock and Detonation Physics, WX-9) indicates that the second shockwave stress is probably on the order of 7 GPa, or slightly higher. The correct way to estimate the stress of the second shock requires determining the temperature and material phase of the tin after the first shock. Then, a simulation must be made for tin at this temperature and pressure prior to the arrival of the second shockwave. The geometry requires adding attenuators to vary the velocity of the material after shock to about 0.6 mm/ms (observed). The pressure at breakout would give a good estimate of the second shockwave stress.

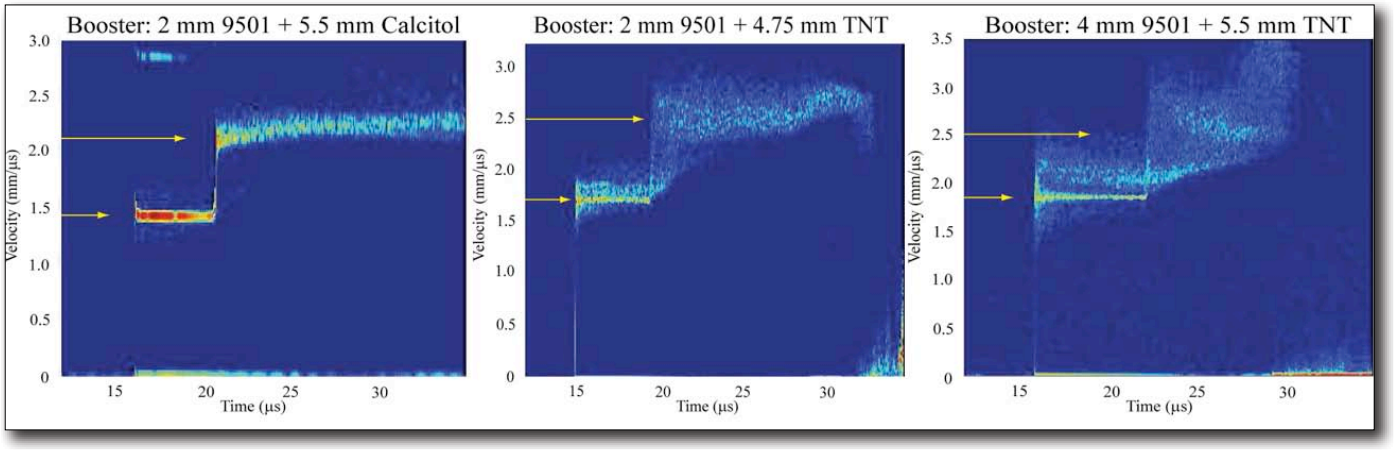


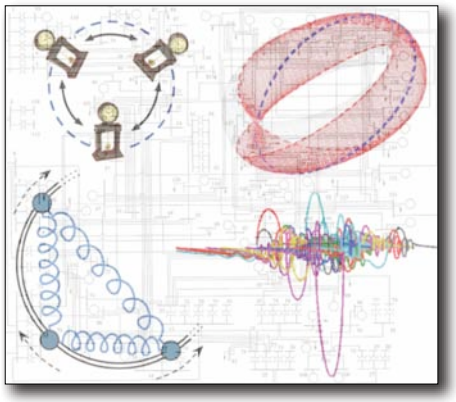
Figure 8. Velocimetry measurements from the three ejecta experiments. The yellow arrows on the left estimate the first and second shock velocity jumps. In the higher pressure experiments, the second shock velocity jumps are not as clear.

The team demonstrated an ability to achieve solid-on-release states with a two-shockwave HE drive into tin using a Calcitol (mixture of TNT and calcium carbonate) booster. However, the U.S. no longer manufactures, nor has a capability to manufacture, Calcitol. Therefore, researchers seek lower pressure C_j state high explosives. The apparent solution to this problem includes HMX in a zinc oxide plastic based explosive.

The team effort included P-23 researchers, the Polymers and Coatings Group (MST-7) for the fabrication of experimental targets, the Main Shops (Prototype Fabrication Division, PF) for the manufacture of packages, and the Shock and Detonation Physics Group (WX-9) for the experiments. NNSA Science Campaign 2 (Rick Martineau, Los Alamos Program Manager) funds the work, which supports the Lab's Nuclear Deterrence mission area and the Science of Signatures and Information, Science, and Technology science pillars. Technical contact: *William Buttler*

THEORETICAL

Synchronization in complex oscillator networks and smart grids



Networks of individual oscillating nodes often spontaneously synchronize and begin to oscillate at a coherent frequency. From heart cells to flashing fireflies to electric power grids, coupled oscillator networks are common in the natural world, but the conditions that allow these systems to synchronize are not well understood. The exact threshold from incoherence to synchrony is unknown. A Los Alamos scientist and collaborators developed a surprisingly simple condition that accurately predicts synchronization as a function of the parameters and the topology of the underlying network. ***Proceedings of the National Academy of Sciences USA*** published the work.

Figure 10. Oscillator networks range from Huygens' coupled pendulum clocks to power grids.

The researchers proposed a unique, concise, and closed-form condition for synchronization of the fully nonlinear, nonequilibrium, and dynamic network. The team could state the synchronization condition elegantly in terms of the network topology and parameters or equivalently in terms of an intuitive, linear, and static auxiliary system. Their results have many benefits:

- It significantly improves upon the existing conditions advocated thus far.
- It is provably exact for various interesting network topologies and parameters.
- It is statistically correct for almost all networks.
- It applies to synchronization phenomena in physics, biology, and engineered oscillator networks.

The scientists illustrated the validity, the accuracy, and the practical applicability of their results in complex network scenarios and in smart grid applications. They envision that their method could be applied to assess synchronization and robustness quickly in power networks under volatile operating conditions. The researchers considered 10 IEEE power network test cases to validate the correctness and the predictive power of their synchronization condition. Under nominal operating conditions, the power generation is optimized to meet the forecast demand while obeying the AC power flow laws and respecting the thermal limits of each transmission line. The team validated the synchronization condition in a volatile smart grid scenario that included fluctuating loads with random power demand, renewable energy sources with severely fluctuating power outputs, and fast-ramping generation and controllable loads. Figure 11 shows a large-scale power network test case, which has been designed as a benchmark model for power flow and stability studies.

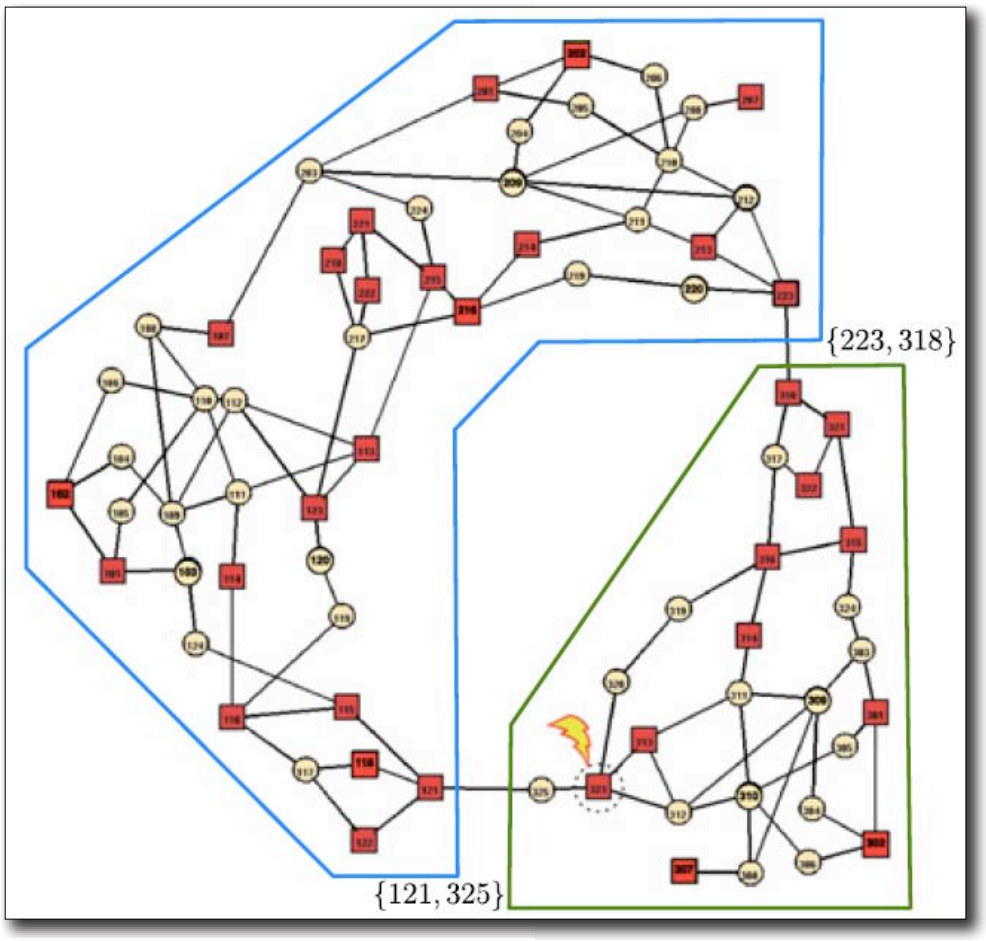


Figure 11. Illustration of contingencies in the RTS 96 power network. The RTS 96 is a multiarea model featuring 40 load buses and 33 generation buses. Square nodes are generators and round nodes are loads, large amounts of power are exported from the northwestern area to the southeastern area, and generator 323 is tripped.

The scientists assumed the following two contingencies have taken place in the smart grid, and then characterized the remaining safety margin. First, they assumed that generator 323 is disconnected, possibly due to maintenance or failure. Second, the power demand at each load in the Southeastern area deviates from the nominally forecasted demand by a uniform and positive amount, and the resulting power deficiency is compensated by uniformly increasing the generation in the Northwestern area. Correspondingly, power is exported from the Northwestern to the Southeastern area via the transmission lines {121, 325} and {223, 318}. At a nominal operating condition, the power network is sufficiently robust to tolerate each single one of these two contingencies, but the safety margin is now minimal. When both contingencies are combined, the synchronization condition predicts that the thermal limit of the transmission line {121, 325} is reached at an additional loading of 22.20%. Synchronization is lost, and the areas separate via the transmission line {121, 325}. This separation triggers a cascade of events, such as the outage of the transmission line {223, 318}, and the power network is en route to a blackout. These calculations confirm the validity, the applicability, and the accuracy of the synchronization condition in complex power network scenarios.

Reference: "Synchronization in Complex Oscillator Networks and Smart Grids," ***Proceedings of the National Academy of Sciences USA*** published online before print January 14, 2013; *110*, 2005 (2013); doi:10.1073/pnas.1212134110. Authors include Florian Dörfler (University of California – Santa Barbara), Michael Chertkov (Physics of Condensed Matter and Complex Systems, T-4), and Francesco Bullo (University of California – Santa Barbara). *This Week in PNAS* also featured the research: ***Proceedings of the National Academy of Sciences USA*** 110, 1972 (2013).

Laboratory Directed Research and Development (LDRD) funded the Los Alamos research, which supports the Lab's Energy Security and Global Security mission areas and the Information, Science, and Technology science pillar. Technical contact: *Michael Chertkov*