

1. Plasma Fingers Point to the Taming of the Edge Localized Modes

ScienceDaily (June 27, 2012)

<http://www.sciencedaily.com/releases/2012/06/120627092014.htm>

New images from the MAST device at Culham Centre for Fusion Energy could find a solution to one of the biggest plasma physics problems standing in the way of the development of fusion power.

MAST (the Mega Amp Spherical Tokamak) is the first experiment to observe finger-like lobe structures emanating from the bottom of the hot plasma inside the tokamak's magnetic chamber. The information is being used to tackle a harmful plasma instability known as the 'edge localised mode', which has the potential to damage components in future fusion machines, including the key next-step ITER device.

Edge localised modes (ELMs) expel bursts of energy and particles from the plasma. Akin to solar flares on the edge of the Sun, ELMs happen during high-performance mode of operation ('H-mode'), in which energy is retained more effectively, but pressure builds up at the plasma's edge. When the pressure rises, an ELM occurs -- ejecting a jet of hot material. As the energy released by these events strike material surfaces, they cause erosion which could have a serious impact on the lifetime of plasma-facing materials.

One way of tackling the problem is 'ELM mitigation' -- controlling the instabilities at a manageable level to limit the amount of harm they can do. MAST is using a mitigation technique called resonant magnetic perturbation; applying small magnetic fields around the tokamak to punch holes in the plasma edge and release the pressure in a measured way. This technique has been successful in curbing ELMs on several tokamaks.

The lobe structures that have recently been observed in MAST are caused by the resonant magnetic perturbation, which shakes the plasma and throws particles off course as they move around the magnetic field lines in the plasma, changing their route and destination. Some particles end up outside the field lines, forming finger-like offshoots near the base of the plasma. Changing the shape of a small area of the plasma in this way lowers the pressure threshold at which ELMs are triggered. This should therefore allow researchers to produce a stream of smaller, less powerful ELMs that will not damage the

tokamak.

First predicted by US researcher Todd Evans in 2004, the lobes -- known as homoclinic tangles -- were seen for the first time during experiments at MAST in December 2011, thanks to the UK tokamak's excellent high-speed cameras. CCFE scientist Dr Andrew Kirk, who leads ELM studies on MAST, said:

"This could be an important discovery for tackling the ELM problem, which is one of the biggest concerns for physicists at ITER. The aim for ITER is to remove ELMs completely, but it is useful to have back-up strategies which mitigate them instead. The lobes we have identified at MAST point towards a promising way of doing this." The lobes are significant for another reason; they are a good indicator of how well the resonant magnetic perturbation is working: "The length of the lobes is determined by the amount of magnetic perturbation the plasma is seeing," explains Dr Kirk. "So the longer the 'fingers', the deeper the penetration. If the fingers are too long, we can see that it has gone too far in and will start to disturb the core, which is what we want to avoid." The next phase of the research will involve developing codes to map how particles will be deposited and how the lobes will be formed around the plasma.

"We already have codes that can determine the location of the fingers but we cannot predict their length due to uncertainties in how the plasma reacts to the applied perturbations. Our measurements will allow us to validate which models correctly take this plasma response into account," said Dr Kirk. "New codes will mean we can produce accurate predictions for ITER and help them tame the ELM."

2. Princeton researchers working at forefront of 'exascale' supercomputing

[July 2, 2012](#) By Gale Scott

<http://phys.org/news/2012-07-princeton-forefront-exascale-supercomputing.html>

Tromp and his collaborators are using computer images to map the interior of the Earth and create earthquake simulations. This sequence of three snapshots illustrates wave propagation in Southern California. Credit: Santiago Lombeyda

Scientists at Princeton University are composing the complex codes designed to instruct a new class of

powerful computers that will allow researchers to tackle problems that were previously too difficult to solve. These supercomputers, operating at a speed called the "exascale," will produce realistic simulations of dazzlingly complex phenomena in nature such as fusion reactions, earthquakes and climate change.

3. ORNL, Princeton partners in five-year fusion project

September 14, 2005

<http://phys.org/news6497.html#nRlv>

Knowledge gained by Oak Ridge National Laboratory researchers and colleagues through an initiative to begin this fall could answer several long-standing questions and give the United States a competitive edge in the design of future fusion power plants.

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The \$10 million five-year Department of Energy SWIM (Simulation of Wave Interactions with Magnetohydrodynamics) project combines the talents and massive computing capabilities of ORNL with resources at Princeton Plasma Physics Laboratory and several other institutions. The goal is to study high-performance fusion plasma and perform comprehensive simulations that are essential to the development of fusion.

Magnetized fusion plasmas contain electrons and the fusion fuel -- ions of deuterium and tritium. Plasma contained within a fusion device behaves very differently depending on the shape of the magnetic field and distribution of the electric current. Because no material can withstand the 100 million degree temperature of the plasma, it is the magnetic field that actually contains the plasma. Being able to control the plasma is critical to the success of fusion as a source of energy.

"High-power radio frequency electromagnetic waves can heat plasmas to the astronomical temperatures required for fusion and they can also exert control," said Don Batchelor, who heads the theory group in ORNL's Fusion Energy Division.

"For example, waves can either produce instability or prevent

instability depending on how they are used. Consequently, understanding and being able to predict the effects of radio frequency waves remains one of the key challenges."

Batchelor and colleagues plan to use computer modeling to develop a better scientific understanding of the interaction between plasma stability and radio frequency power, and to be better able to design radio frequency systems to control the instabilities inherent in plasma. Such an achievement would be huge and would remove one of the barriers to obtaining fusion power, which offers the potential of a virtually limitless source of energy with none of the disadvantages of today's energy sources.

In a distinct departure from past strategies to understand magnetically confined plasmas, the SWIM project emphasizes an integrated approach. This method, Batchelor notes, is much like those used for climate-change predictions and takes into account the many interactions and complexities inherent in plasma physics and in nature.

"We are bringing together two areas of fusion physics that have previously been studied separately," Batchelor said. "As with systems biology or climatology, the science of the whole of what takes place in a fusion plasma is far richer than the science of the pieces, and we simply cannot understand the organism, the evolution of climate or the plasma until we understand the couplings between the various contributing phenomena."

The project builds upon the successes of DOE's Scientific Discovery through Advanced Computing programs by taking several of the most advanced fusion computer codes, combining them to provide a unique tool in the worldwide fusion program and running them at the National Leadership Computing Facility at ORNL's Center for Computational Sciences.

The Center for Computational Sciences, established in 1992 as a DOE high-performance computing research center, is a designated user facility with several missions, including to help solve grand challenges in science and engineering. Last year, DOE designated ORNL as the site for the National Leadership Computing Facility, which will provide the foundation to propel the U.S. back to the forefront of high-

performance computing.

"Our new computers will play a big part in making this project a success," Batchelor said. "Being able to run large-scale numerical simulations that take into account the many coupled processes at work in magnetized plasma taking place on disparate time scales is vital to the development of fusion energy."

Not only do plasma simulations serve to advance science by allowing researchers to evaluate and test basic theory through comparison with experiments, they also maximize the productivity of experimental facilities and support design decisions for new facilities. For a device like the International Thermonuclear Experimental Reactor, which will cost up to \$1 million per day, such decisions can have multi-billion dollar consequences, Batchelor said.

ITER is the experimental step between today's studies of plasma physics and tomorrow's electricity-producing fusion power plants. ITER, which will be located in Cadarache, France, represents a collaboration among The European Union, Japan, the Republic of Korea, the Russian Federation, the United States and The People's Republic of China. Completion of ITER is scheduled for 2016.

Funding for the project is provided by DOE's Office of Advanced Scientific Computing Research within the Office of Science. Oak Ridge National Laboratory is managed for the Department of Energy by UT-Battelle.

Source: Oak Ridge National Laboratory

4. Nuclear fusion research aids EUV source breakthrough

Peter Clarke

7/5/2012 10:40 AM EDT

<http://www.eetimes.com/electronics-news/4376726/Nuclear-fusion-research-forms-plasma-for-EUV>

LONDON – A University of Washington laboratory that has been working for more than a decade on nuclear fusion as a source of energy, thinks it has leapfrogged ahead of companies trying to create a viable light source for extreme ultraviolet lithography (EUV).

Zplasma Inc. (Seattle, Wash.) will be competing with such firms as Cymer

Inc., Xtreme Technologies GmbH and Gigaophoton Inc. but reckons that with a 1,000 times improvement in output energy it can easily provide the source power to make EUV lithography machine throughputs viable.

The principle methods used currently are discharged-produced or laser produced plasmas of xenon or tin (DPP or LPP) but both consume large amounts of energy. More importantly neither has reached the 100- or 200-watts power level at the intermediate focus needed to get 60 to 125 wafers per hour throughput from a EUV lithography machine, such as the NXE:3300B from ASML Holding NV (Veldhoven, The Netherlands).

"We're able to produce that light with enough power that it can be used to manufacture microchips," said Uri Shumlak, a UoW professor of aeronautics and astronautics, in a report on the University of Washington [website](#).

As with other 13.5-nm wavelength light sources, the UoW beam is based on a plasma (xenon). And the UoW fusion lab's specialty is lower-cost versions of a fusion reactor, which uses electric current rather than magnets to contain the plasma and which produces plasma that is stable and long-lived.

This has advantages over a discharge spark propagated through a tin vapor or shooting a laser at a tin droplet, the group claims. "It's a completely different way to make the plasma that gives you much more control," said Brian Nelson, a UW research associate professor of electrical engineering, in the website report.

The alternative EUV light sources produce a pulse of light that lasts between 20 and 50 microseconds The Zplasma light source lasts about 1,000 times longer and this results in more light output, and more light onto the wafer. The UoW team has been supported with grants and gifts to allow them to verify the production of 13.5-nm wavelength light and to reduce the size of the equipment.

The company is now led by Henry Berg, a technology entrepreneur, as CEO. The company is now seeking venture capital from corporate investors who can help Zplasma integrate its light sources with existing industrial processes.

5. Fusion technology leads to high-density microchip etching

5 July, 2012 [Isaac Leung](#)

<http://www.electronicnews.com.au/news/fusion-technology-leads-to-high-density-microchip>

UNIVERSITY of Washington scientists working on fusion energy have found high-energy light with short wavelengths suited for etching the ultra-small features on the next generation of

microchips.

As microchips become more powerful, the features on the silicon become denser, meaning smaller structures need to be etched. To do this, light with shorter wavelengths is needed, combined with sufficient power for actual etching.

Currently, the industry uses 193nm ultraviolet light, but this limits the size of the circuits that it can etch. To continue reducing the feature sizes, the industry needs light which has 13.5nm wavelength.

This extreme ultraviolet light is created from plasmas, the fourth state of matter where electrically charged gases are heated to such a high temperature that a portion of its particles are ionised.

While there have been many methods developed to create such a light, many of them are highly expensive, can only sustain the light for a short period of time, and do not provide enough power.

Fusion energy also has plasma at its core, but the scientists at the University of Washington are working on a low-cost fusion reactor which uses currents flowing through the material rather than magnets to contain the plasma. This produces stable and (relatively) long-lasting plasma.

Conventional techniques used in the chip industry generate a spark of light which lasts 20 to 50 nanoseconds. The researchers' method produces a light beam which lasts 20 to 50 millionths of a second. While this may not seem to be a long time, it is 1000 times longer than what the industry is currently capable of.

This directly translates into more output, and more power for etching.

The plasma, the strong generated light and the controllability of the technology, prompted the researchers to spin-out a start-up company called Zplasma, which will look to commercialise the technology.

6. **June 21, 2012**

Fusion: The Energy of Tomorrow, Today

By **Ross Pomeroy**

http://www.realclearscience.com/articles/2012/06/21/fusion_the_ene

[rgy of tomorrow today 106303.html](#)

For over a century, power plants have been regarded almost as a necessary evil, a burden for the environment, but a boon for mankind. Today, we view the stereotypical images of polluting power stations with a tacit acceptance. It is what it is, and it's what it always will be.

But imagine, in a few short decades these images can be purged from the American psyche. What was thought to be an indelible stain on our environment washed away with the tide of new, futuristic power plants shining like beacons of hope, symbols for a promising future.

It's high time that politicians, and indeed all Americans, recognize that a new dawn for American-made power may soon be at hand. And it won't come from coal, wind, solar, or even natural gas. It will come from fusion energy, the **power** of the stars.

Believe it or not, America is nearing the threshold of a fusion future. By the end of 2012, scientists at the National Ignition Facility in Livermore, California **plan** to fire the most powerful laser ever constructed into a small chamber with pea-sized fuel pellets inside. The fusion fuel contained within the pellets, two isotopes of hydrogen -- deuterium and tritium -- will **fuse** together, producing helium, a free neutron, and massive amounts of energy in the form of heat. If all goes to plan, about ten to one hundred times more energy than the amount used to ignite the fuel will be unleashed.

With this monumental breakthrough achieved, construction could begin on a fusion power plant capable of producing 400 megawatts of base-load power, with a target completion date in the early 2020s. Capital costs would roughly be the **same** as a current nuclear fission power plant, between \$6 and \$7 billion. It's a daunting cost to be sure, but one well worth funding. Besides providing a blueprint for future fusion plants, investment in such a facility will drive innovation in multitudes of fields ranging from optics to materials science.

After the completion of the fusion test plant, construction of commercial facilities producing between 1,000 and 1,500 megawatts of fusion power can get underway. These power plants will produce electricity that's hard to find fault with. The energy will be base-load -- always available. It will be clean -- there will be

no carbon dioxide emissions or hazardous waste. It will be cheap -- early **estimates** show fusion power to be cost-competitive with coal, even without a carbon tax. It will be nearly limitless -- up to 30 million years of fusion fuel exists on Earth. And most importantly, it will be made in America -- Laser Inertial Fusion Energy (LIFE) has been produced entirely within the **United States**.

The Transition to Star Power

In late March, the Environmental Protection Agency announced plans to **impose** new limits on greenhouse gas emissions from power plants. The rules require that any new power plant emit no more than 1,000 pounds of carbon dioxide per megawatt hour of electricity produced. This drew the ire of many because it makes it very difficult, almost impossible, to construct any new coal power plants. An attempt by Senate Republicans to overturn the measure were just **thwarted** yesterday.

Instead of fighting this change, Americans should embrace it with open arms. Today, coal **accounts** for a little over 40 percent of the nation's electricity production, a significant amount. But coal is an antiquated energy source, and so are the power plants that provide it. The **average** coal power plant is 43 years old, and virtually the entire U.S. fleet is set to be retired by 2060. The solution to this potential energy crisis is not to construct new plants burning fossil fuels, nor is it to install undependable renewable energy technologies. The answer is to invest in a fusion future.

Ross Pomeroy is the assistant editor of RealClearScience.

7. We need to catch up on clean energy

BY: **GILES PARKINSON** From: **The Australian** July 06, 2012

12:00AM

<http://www.theaustralian.com.au/business/opinion/we-need-to-catch-up-on-clean-energy/story-e6frg9if-1226418330972>

WITH the introduction of the carbon price, the existence of the renewable energy program, and billions of dollars in grants available, Australian politicians have managed to convince themselves that Australia is a leader in the deployment of

clean energy. Nothing could be further from the truth.

Let's take solar photovoltaics as an example. It's the technology now widely recognised as the biggest game-changer in the energy industry in the past few decades, and has attracted more investment in the past 12 months than other technologies combined.

But apart from rooftop solar, where at least individual households have recognised the value, Australia has made little headway in utility-scale installations.

The biggest installation is a 1.2MW research facility installed on the roof of a university in Queensland. One 10MW solar farm is under construction in Western Australia and will be completed soon. After that, it's pretty much a blank canvas.

As a writer on clean energy issues, I get a regular feed from a range of sources about what's going on around the world. This is just a taste of what has landed in my inbox in the past few days about utility-scale solar:

In Japan, Softbank said it would build a 111MW solar PV plant in Hokkaido by 2014 and Kyocera has just opened a 2.1MW facility in Kyoto. A 20MW solar PV plant had been opened in California (the third in eight months), while SolarPack said it had won a contract to build a 25MW solar PV plant at a Chilean copper mine next year.

A day earlier, Hareon Solar signed contracts to build a 20MW solar farm in northern China and a 40MW plant in Inner Mongolia. Media magnate Ted Turner bought a 20MW solar PV plant in Nevada that will be completed by September, Sky Solar said it would install 150MW of large-scale solar PV plants in Chile by the end of next year, and TGC Renewables said it would build an 8MW solar plant in Devon, England, this year.

A day before that, in the US state of Georgia, contracts were signed for a 19MW solar plant to be built this year. Orange County in California began installation of a 3.3MW project to be up and running by October.

In India, two projects of 110MW and 25MW began construction in Madhya Pradesh. Household retailer Habitat started construction of a 3.8MW plant near Paris and the first modules of the 230MW

Antelope Valley Solar Ranch in California were installed.

What's the significance of all these? Well, they are gleaned from just three days of news feeds and are but a taster of the transformation that is going on in energy markets around the world. For the first time last year, the amount spent on renewable energy outstripped that spent on fossil fuels, and most came in solar.

The only mention of Australia came from news that the country's largest solar project, the 250MW, \$1.2 billion Solar Dawn facility in Queensland, had its funding pulled by the state government after being unable to obtain a power purchase agreement from a state-owned utility. Australia's other Solar Flagships project, a 159MW solar PV facility to be built by AGL Energy in Nyngan and Broken Hill, NSW, probably won't begin construction until 2014.

So how can a country with some of the best R&D in solar technologies, and one of the best solar resources, get it so wrong?

Part of the reason is the grandiose, ego-driven nature of the schemes, particularly the flagship projects. Another part of the reason is the lousy advice given to governments, particularly concerning the actual cost of solar technologies and their anticipated cost curve.

So much of the ill-informed criticism of solar is based on the assumption that Australia cannot compete on module manufacturing. But that misses the point, because the cost of modules is just a small part of the overall cost.

Take Japan as an example. Right now, it has a similar amount of solar installed, mostly on rooftops (about 1.3GW, compared with 1.4GW in Australia). But Japan has set a target of 28GW by 2020, and it will achieve this by introducing some of the most generous feed-in-tariffs. The reason for this is that while modules, mostly imported from China, cost about 80c/watt, the "balance of system" installation, maintenance, finance and associated infrastructure costs about \$3.50/W.

By encouraging deployment now, Japan expects to reduce this cost to as little as \$1.60/W within a few years, by which time the tariffs will no longer be needed. In Australia, such a proposal would be drowned out by arguments about the "high cost of abatement".

The Productivity Commission produced a figure of more than \$1000/tonne of CO2 equivalent (later corrected to less than half that number), without any regard for the fact that 90 per cent of solar PV will be installed at a future time without the help of subsidies and at a negative abatement cost. But the PC argument was used by naysayers to remove those tariffs prematurely and slow down the path to parity.

Meanwhile, the cumbersome grants-based schemes that have promised much and delivered little are now in the hands of the newly formed Australian Renewable Energy Agency.

Hopefully, it can offer a more practical, informed and efficient approach to its investments. The sort announced in recent days by Energy Minister Martin Ferguson (see wave energy story below), are a step in the right direction. But ARENA also needs to claw back some of the funding that has been allocated, but not yet spent, to other projects. The world is moving, and Australia needs to as well.

Waving with power

\$100 a megawatt hour. Remember that number.

That was the figure that was produced by the International Energy Agency last year when it predicted what a (largely) carbon-free electricity grid might look like by 2050. Essentially, it said, if technologies wanted to compete, they needed to have a levelled cost of energy of about \$100/MWh, give or take a few dollars.

The availability of local resources, infrastructure, finance and demand would dictate what went where; and this applied for nuclear, coal with carbon capture, gas, wind, solar, geothermal, ocean energy, and anything else people could think of. And they wouldn't have until 2050 to get there. It was recommended that some time between 2020 and 2030 would be optimal. First come, first served and all that.

That made the announcements this week by a couple of aspiring Australian wave energy developers particularly interesting. Both received grants from the Australian government's \$126 million Emerging Renewables program to deploy their first full-scale versions of their wave energy technologies, and both were confident that they could reach that \$100/MW target by the end of

the decade. Or, at least, both realised that without it they would be sunk, no pun intended.

Ocean energy is a fascinating branch of the clean energy industry because, unlike wind and solar PV, where the designs are more or less homogenised, designs for wave and tidal energy are limited only by imagination, and bear little comparison with any energy-producing devices that have preceded them.

The GreenWave technology being developed by Oceanlinx looks suspiciously like a hair dryer, BioPower's bioWAVE invites comparisons with a giant clam, while Carnegie Wave Energy's Ceto technology looks like something that fell out of a plumber's tool kit. And don't be fooled by the cute designs -- these devices are massive. Oceanlinx's, for instance, weighs 2000 tonnes.

Which will be more successful? Who knows! Investors, be they in the privately held Oceanlinx and BioPower or the listed Carnegie, have been taking a bit of a punt, but that is the nature of the industry. Even in solar PV, where the designs are similar to each other, advantage is gained from the lowest-cost manufacturing techniques, and it's hard for an outsider to judge which will succeed.

The deployment of these wave energy demonstration projects over the next few years, however, will sort them out. Australia, seemingly, has an opportunity to become a world leader in ocean technology. The proof of the pudding may come in the interest of the world's biggest energy companies. Some, such as Siemens, Alstom and SSE, have already snapped up ocean energy technologies that they find prospective. France's energy giant EDF has taken an interest in Carnegie and its technology and is bankrolling some of its pilot projects.

At least, with the Emerging Renewables Program, they will have to get on a plane and come to Australia to find out.

Giles Parkinson is editor of reneweconomy.com.au

8. Coastal flooding may rise

2000-fold

BY: □ MATTHEW DENHOLM, TASMANIA CORRESPONDENT

From: □ The Australian July 04, 2012 12:00AM

<http://www.theaustralian.com.au/news/health-science/coastal-flooding-may-rise-2000-fold/story-e6frg8y6-1226416164218>

MANY Australian cities can expect regular coastal floods by the end of the century because of rising sea levels, with Sydney facing a 2000-fold increase in such events, a report suggests.

The projections are revealed in a new stocktake of global knowledge on rising sea levels released yesterday by Australia's Antarctic Climate and Ecosystems Co-operative Research Centre.

As well as concluding that melting ice has replaced warming seas as the main contributor to rises, the study meshes tide and storm-surge data with sea-level projections to predict the frequency of coastal floods.

In Australia, this work suggests that the most severe increase will be along the eastern seaboard, where waters have warmed because of changes in the east Australian current.

Based on what the authors describe as conservative interpretations of the International Panel on Climate Change sea-level projections, it suggests that Sydney could expect a 2200-fold increase in coastal flooding by 2100.

Other population centres projected to be hardest hit include Melbourne (140-fold increase), Bundaberg (260-fold), Hobart (240-fold), Burnie (200-fold), Darwin (260-fold), and Townsville (95-fold).

Co-author of Report Card: Sea Level Rise 2012 and ACECRC sea-level rise expert John Hunter said there would be an average 300-fold increase in coastal flooding nationally by 2100.

"This means that a (coastal flooding) event which presently only happens on average once every 100 years . . . will happen several times a year," he said.

This was based on sea levels rising 50cm by 2100 rather than the 80cm some studies suggested after factoring in potential additional

ice-sheet melt.

Dr Hunter said the 50cm projection was applied to historic data on tides and storm surges collected at 26 tide gauges around the country.

Australia was close to the global average for projected coastal flooding, while some regions, such as parts of the Baltic and Alaska, would not be vulnerable to rising sea levels this century due to the compensating effect of upwards movement of land.

The study concludes that since about 2000, the melting of glaciers and ice sheets has replaced the warming of water as the chief cause of sea-level rise.

Melting of glaciers and ice caps had contributed 91mm to sea-level rise between 1850 and 2005, while the glacial melt had increased since the 1990s.

"The most recent assessment shows a sea-level rise contribution from glaciers and ice caps, including those surrounding the Greenland and Antarctic ice sheets, of 1.2mm per year for 2001-05," the study says.

Melting of the Greenland ice sheet contributed 0.2 to 0.4 of a millimetre a year to sea-level rise from 1992 to 2009, rising to 0.4 to 0.7mm a year from 2002 to 2009.

Ice loss from Antarctica had contributed 0.1 to 0.3mm a year of sea-level rise since 1992, increasing to 0.2mm to 0.5mm a year since 2002.

9. Nuclear waste-burning reactor moves a step closer to reality

Feasibility study shows GE-Hitachi's proposed Prism fast reactor could offer a solution to the UK's plutonium waste stockpile

Duncan Clark

guardian.co.uk, Monday 9 July 2012 18.18 BST

<http://www.guardian.co.uk/environment/2012/jul/09/nuclear-waste->

[burning-reactor](#)

A plan to burn Britain's radioactive [nuclear waste](#) as fuel in a next-generation reactor moved a step closer to reality on Monday when [GE-Hitachi](#) submitted a thousand-page feasibility report to the UK's [Nuclear Decommissioning Authority](#) (NDA).

The UK has a large stockpile – around 100 tonnes – of [plutonium waste](#). This is considered a security risk and the government is considering options for its disposal. The current "preferred option" is to convert the plutonium into mixed-oxide fuel (Mox) for use in conventional nuclear reactors.

But a previous Mox plant in the UK was deemed a failure, and [GE-Hitachi](#) claims that its Prism fast reactor – a completely different design fuelled by plutonium and cooled by liquid sodium – [offers a more attractive solution](#).

One of the potential benefits of fast reactors is that they could extract large quantities of [energy](#) from nuclear waste. In February, David MacKay, the chief scientist at the Department of Energy and Climate Change (Decc) [told the Guardian](#) there was enough energy in the UK's waste stockpile to power the country for more than 500 years.

The NDA initially dismissed fast reactors as being decades from commercial viability. But after the Prism proposal was submitted by [GE-Hitachi](#), the NDA agreed to review the evidence. Monday's report – a summary of which has been seen by the [Guardian](#) – is designed to persuade the NDA that the Prism is technically credible and commercially attractive.

The report includes an assessment from consultancy firm [DBD Limited](#) that suggests there are "no fundamental impediment(s)" to the licensing of the Prism in the UK. It also includes an outline of the proposed business plan, which would involve the plant being owned by a private company and the government paying a fee for each tonne of plutonium processed.

Senior figures at [GE-Hitachi](#) told the [Guardian](#) that this "service model" was designed to reduce the risk to the taxpayer. But they declined to give any detailed cost estimates and acknowledged that the government would still need to contribute towards the cost of building the plant.

The NDA has also received three other proposals for disposing of the plutonium. Two were from individuals and weren't considered credible. The third involves burning Mox fuel in a Canadian-style [Candu reactor](#). A detailed feasibility report on this option is currently being prepared.

A spokesman for the NDA said it will review the Prism and Candu reports and update its advice to the government towards the end of the year. The government will then make a final decision and the proposal selected will be referred to the [Office of Nuclear Regulation](#).

Whichever technology is selected, there will be an extensive licensing and consultation process. This and the construction of the new facility will most likely take around 10 years, according to the NDA, which said it expects the new plant to be up and running in "the early years of the next decade".

10. The Fukushima report hides behind the cultural curtain

By claiming the disaster was 'made in Japan', an official report reinforces, yet does not explain, unhelpful stereotypes

<http://www.guardian.co.uk/commentisfree/2012/jul/06/fukushima-report-disaster-japan>

More than a year after a catastrophic earthquake and tsunami struck Japan on 11 March 2011, the Fukushima nuclear accident independent investigation commission [released an 88-page report](#) this week delivering the indictment that Fukushima could not be considered a natural disaster but a "profoundly man-made disaster".

It went on to state that "this was a disaster 'made in Japan'. Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the programme'; and our 'insularity'."

At first glance, the opening message from the commission's chairman, Kiyoshi Kurokawa, reads like an apology to the global community for Japan's mishandling of the Fukushima nuclear

disaster: a mea culpa for it going so terribly pear-shaped for the Japanese – and the world as a whole. It is striking that it is explained to the global community as a peculiarly "Japanese" problem. As there has been much culturally couched coverage of the earthquake and tsunami victims as being "stoic", "resilient" and so on, the official explanation reaffirms cultural stereotypes of Japan and the Japanese.

The appeal of the "made in Japan" explanation remains powerful. For much of its modern history, Japan has been categorised as unique and enigmatic. More than 100 years ago, [Inazo Nitobe, a Japanese Quaker](#), attempted to explain the spiritual backbone of the Japanese that had propelled the country's break-neck modernisation, by writing – in English – the highly influential book, [Bushido](#) (The Way of the Samurai), which argued for samurai values to be the model for a code of ethics governing the Japanese people. Even HG Wells got into the spirit of things and named the elite class of people in his 1905 novel, *A Modern Utopia*, the "samurai".

Of course, this was not simply a two-way conversation between Japan and the west, and the concept was even more enthusiastically taken up in the non-western world, including by illustrious thinkers such as India's [Rabindranath Tagore](#) (though he became disillusioned by Japanese imperialism rather quickly).

Fast-forward to the post-war economic miracle of Japan in the 1950s and 60s, when the Japanese people became intensely preoccupied with their identity. This led to a flood of pseudo-cultural analysis of why the Japanese people were unique (largely to explain their economic success) – a huge body of popular literature known as the [Nihonjinron](#) (discourse on Japaneseness).

It seems only yesterday that Japan Inc ruled the Wall Streets of the world, and all and sundry were trying out Japanese business practices in order to emulate Japanese success. Japanese essentialism has an appeal not only to the Japanese but also to the outside world, because it enables both sides to hide behind the "cultural curtain" and refrain from probing deeper.

Tellingly, there is no mention of the "made in Japan" explanation in the Japanese original of Thursday's report. Instead, it explains the disaster in terms of "regulatory capture" – that is, that the relationship between the regulators and the regulated was much

too close, enabling the regulated to subject the regulators to undue pressure and influence. By referring to regulatory capture, the Japanese report points the finger of blame at the complex entanglement of political, bureaucratic, and financial interests dating back to the heyday of high economic growth, a thinly veiled criticism of the one-party Liberal Democratic party rule that has dominated Japan's politico-industrial world for much of the post-1945 era. In the English edition, regulatory capture appears in the main report but not in the chairman's message.

Bringing out the "made in Japan" argument is not helpful. It panders to the uniqueness idea and does not explain, but rather reinforces, existing stereotypes. Moreover, the supposedly Japanese qualities that the report outlines, such as obedience, reluctance to question authority, "sticking with the programme" and insularity, are not at all unique to Japan, but are universal qualities in all societies.

Putting a cultural gloss on the critical investigative report sends a confusing message to the global community – particularly when it comes from a country that is a world leader in technological sophistication.

11. **'Trophy Molecule' Breakthrough May Result in Cleaner, Cooler Nuclear Energy**
ScienceDaily (July 2, 2012) — Experts at The University of Nottingham are the first to create a stable version of a 'trophy molecule' that has eluded scientists for decades.

<http://www.sciencedaily.com/releases/2012/07/120702133535.htm>

In research published in the journal *Science*, the team of chemists at Nottingham has shown that they can prepare a terminal uranium nitride compound which is stable at room temperature and can be stored in jars in crystallized or powder form.

Previous attempts to prepare uranium-nitrogen triple bonds have required temperatures as low as 5 Kelvin (-268 °C) -- roughly the equivalent temperature of interstellar space -- and have therefore been difficult to work with and manipulate, requiring specialist equipment and techniques.

The breakthrough could have future implications for the nuclear energy industry -- uranium nitride materials may potentially offer a viable

alternative to the current mixed oxide nuclear fuels used in reactors since nitrides exhibit superior high densities, melting points, and thermal conductivities and the process the scientists used to make the compound could offer a cleaner, low temperature route than methods currently used.

The research has been led by Dr Stephen Liddle in the School of Chemistry and much of the practical work was completed by PhD student David King. The work was also supported by colleagues at the University of Manchester.

Uranium nitrides are usually prepared by mixing dinitrogen or ammonia with uranium under high temperatures and pressures. Unfortunately, however, the harsh reaction conditions used in the preparation introduces impurities which are difficult to remove. In recent years scientists have therefore focussed their attention on using low temperature, molecular methods but all previous attempts resulted in bridging, rather than the target terminal, nitrides.

The Nottingham team's method involved using a very 'bulky' nitrogen ligand (an organic molecule bonded to a metal) to wrap around the uranium centre and to create a protective pocket in which the nitride nitrogen can sit. The nitride was stabilised during the synthesis by the presence of a weakly bound sodium cation (positively charged ion) which blocked the nitride from reacting with any other elements. In the final stage, the sodium was gently teased away, removing it from the structure and leaving the final, stable uranium nitride triple bond.

Dr Liddle said: "The beauty of this work is its simplicity -- by encapsulating the uranium nitride with a very bulky supporting ligand, stabilising the nitride during synthesis with sodium, and then sequestering the sodium under mild conditions we were able to at long last isolate the terminal uranium nitride linkage."

He added: "A major motivation for doing this work was to help us to understand the nature and extent of the covalency in the chemical bonding of uranium. This is fundamentally interesting and important because it could help in work to extract and separate the 2 to 3 per cent of the highly radioactive material in nuclear waste."

The research was supported by the UK National Electron Paramagnetic Resonance (EPR) Facility, funded by the Engineering and Physical Sciences Research Council and based in the Photon Science Institute at The University of Manchester. The uranium-nitride contains an unpaired electron and by using EPR spectroscopy it was found that it behaves differently from similar compounds prepared at Nottingham. Professor Eric McInnes, from The University of Manchester said: "EPR spectroscopy can give detailed information about the local environment of unpaired electrons, and this can be used to understand the electronic structure of the uranium ion in this new nitride. It turns out that the new nitride behaves differently from some otherwise analogous materials, and this might have important implications in actinide chemistry which is

of vital technological and environmental importance in the nuclear fuel cycle."

The research has been funded and supported by the Royal Society, European Research Council, the EPSRC, and the UK National Nuclear Laboratory.

12. Shale revolution takes the world back to the future on fossil fuels

BY: BRAD NORINGTON, WASHINGTON CORRESPONDENT

From: The Australian July 14, 2012 12:00AM

<http://www.theaustralian.com.au/business/shale-revolution-takes-the-world-back-to-the-future-on-fossil-fuels/story-e6frg8zx-1226425744364>

ANY dramatic shift in the world's energy paradigm was inconceivable only a few years ago.

Global oil supplies were known to be drying up, and prices were on the rise.

Without an obvious alternative, the US and other Western nations faced an unprecedented energy security crisis for as long as they continued to depend on oil from the Middle East.

In the worst-case scenario, the US stood to lose its status as the world's largest economy and No 1 superpower.

And Europe risked further decline, especially after a failure to boost gas production, raising the prospect of future dependency on Russia to meet energy needs.

Environmental activists relished the spectacle as grim economic reality looked set to force governments and big corporations to share the green lobby's interest in reducing fossil fuels and developing low-carbon forms of energy.

But that was before the shale revolution began with technology

and market forces establishing vast potential sources of gas and oil in the US and Europe.

"It's what we call the great revival of US oil production," Jim Burkhard, head of global oil research for IHS Cambridge Energy Associates, tells Inquirer.

"It's a tremendous story, it's an important story, not just for the United States but for the world, for geopolitics, not to mention the oil market."

Away from the glare of publicity and doomsayers predicting the worst, US-based energy companies scored a technology breakthrough by finding a way to extract huge, high-quality deposits of oil buried deep below the earth's surface that were previously judged too difficult and too costly to pursue.

Using advances in a process called hydraulic fracturing, or fracking, independent US companies Continental Oil, EOG and Chesapeake Energy drilled for oil across US states including North Dakota, Texas, Colorado, Ohio and Pennsylvania.

Big companies ExxonMobil, Shell, Chevron and BHP Billiton have since followed by buying into this potentially vast expanding new market.

Fracking involves drilling vertically several thousand metres beneath the surface and then curving well bores 90 degrees to run through difficult-to-access deposits of crude oil trapped between layers of shale sediments.

Highly pressurised fluid is pushed through the bores into the shale, allowing trapped crude oil and natural gas to escape and flow to the surface.

In 2008 the US imported 60 per cent of its oil for vehicles and industry. Imports now stand at 45 per cent, in large part because of the shale oil boom. Production has increased 1.3 million barrels a day in three years, more than double that of Russia.

The geographical area of much interest has been the "Green River Formation" stretching across Colorado, Utah and Wyoming that contains the world's largest oil shale deposit.

US-based research group Rand Corporation has estimated that about half of the deposit could eventually be extracted, or 1.5 trillion barrels of oil.

This figure, equivalent to the world's entire proven oil reserves, has stirred excited talk of the US becoming entirely self-sufficient for its energy needs in 15 to 20 years -- and potentially a big exporter of oil.

A report this week by Mark Mills from conservative American think tank the Manhattan Institute says the US is poised to become a dominant energy player, supplanting the Middle East.

"In collaboration with Canada and Mexico, the United States could -- and should -- forge a broad pro-development, pro-export policy to realise the benefits of our hydrocarbon resources," Mills writes. "Such a policy could lead to North America becoming the largest supplier of fuel to the world by 2030."

The most ambitious forecasts suggest the Green River Formation could provide enough US oil supplies for 200 years, guaranteeing the nation's economic prosperity and confirming its supremacy in a changing world order as China and India rise.

Freed from the grip of Middle East oil, the US could recast its relationship with Saudi Arabia. It could tighten economic pressure on Iran to refrain from developing a nuclear arsenal if the Islamic regime's funding from petroleum exports diminished.

Walter Russell Mead, a foreign policy expert from New York's Bard College, writes in *The American Interest* magazine this month that a geopolitical revolution has begun during the past 12 months that is bigger and more consequential than the Arab Spring, despite little media attention.

Mead says a "new age of abundance for fossil fuels is upon us" and that will shift the centre of gravity in global energy from the Middle East to North America.

"It will rearrange the global chessboard, improving the position of some powers, weakening others," he writes. "It is a powerful boost to American power, reducing America's strategic and economic liabilities while adding considerably to its assets."

While the US stood to benefit from potential production of one trillion barrels of unconventional shale oil, Canada too would become an energy giant with almost two trillion barrels of conventional oil and gas extracted from its rich tar sands.

The biggest losers, according to Mead, would be the Gulf petro-states and Russia. The Middle East's political power would not disappear because its nations would still have the world's cheapest oil to sell. "But it won't be the same," Mead writes. Meanwhile, Russia would seek to rebuild its power based on huge natural gas reserves that would keep capital flowing to Moscow. "But it could lose its ability to stop the flow of natural gas into Western Europe."

Mead acknowledges these changes would not happen overnight -- but he points to the oil boom already under way in North Dakota, where oil production is up by almost 500,000 barrels a day, as evidence of changing international trade patterns.

Burkhard is among industry experts still cautious about talking up the Green River Formation just yet because the bulk of material extracted from its wells is kerogen, a petroleum compound that requires expensive heating treatment to yield a relatively small amount of commercially viable oil and gas.

"It's a huge resource," he tells Inquirer. "And if you set aside economics, there is a lot of that stuff in rock around the world, particularly in the western part of the United States. It is just very high cost."

In the absence of improved methods, the economics of extracting kerogen in Colorado boil down to supply-side economics: the more expensive Middle East oil becomes, the more viable drilling for kerogen will become.

Burkhard does not write off the potential for improvements in technology that would make drilling for kerogen in areas such as Colorado economically feasible -- but he says it's probably a long way off. "It has a potential to increase production . . . there's no commercial production of (kerogen) right now."

The turning point for smaller independent companies that have led the way came four to five years ago when they realised they could apply advanced fracking techniques used for natural gas drilling to

also extract crude oil trapped in non-kerogen shale.

Europe's total shale oil and gas resource is estimated to be close to those of the US, but there are serious obstacles to extraction because it is mainly kerogen.

There are other problems that put Europe's land-locked oil and gas out of financial reach for now: known reserves lie beneath high-density population areas; infrastructure needed to make mining economical is often absent; regulations limit the scope for oil companies to drill; and local communities are wary of possible damage to the environment after claims that drinking water would be contaminated by chemicals used underground in fracking.

Europe will need new gas production to come on stream during the next decade -- most likely shale gas -- if it is to avoid dependency on high-priced Russian gas for the long term when North Sea reserves start drying up. In Germany particularly, the issue is politically vexing as local gas production has declined to 14 per cent of annual consumption and the Greens push hard for greater reliance on non-carbon energy.

A report issued last month by Germany's Institute for Geosciences and National Resources said several trillion cubic metres of shale gas reserves could be extracted by fracking, providing proper rules were followed.

Poland is Europe's frontrunner for shale gas development, although ExxonMobil's decision last month to cease exploration after two wells failed to demonstrate commercially viable flow rates has created new doubts. Israel's significant gas reserves could assure its energy future, but it also faces difficulties associated with kerogen.

Prospects for Dakota-style "tight oil" production outside the US are greatest in China, Russia and Argentina, which have large non-kerogen crude deposits. Australia has large areas of shale that could double its current gas reserves, although extraction could be difficult and exploration remains at an early stage.

The US has fewer of the concerns of its competitors. The Green River Formation lies beneath federal land in mostly arid areas, allowing easy access if kerogen can be made commercial.

In Dakota and Texas where the oil boom is happening, most of the land is privately owned and free from regulation. The US Environmental Protection Authority has so far sided with oil companies, finding the risk to groundwater from fracking minimal, and no definite link between fracking and earthquakes.

"The United States has the right conditions that have allowed these resources to be developed, and developed in a big way," Burkhard says. "Private ownership of mineral rights makes the United States unique. You can go to farmer Joe in North Dakota and say, 'Farmer Joe, I want to drill on your land, and if I find something, you're going to get a cut.' You align the interest of the landowners with the investors."

The emerging US oil boom clearly has OPEC cartel countries worried. They face a balancing act in keeping prices high, aware that doing so will only encourage more development of unconventional shale oil that will reduce American dependence.

Panic has gripped environmental activists. Writing in The Guardian this month, George Monbiot conceded a new oil boom had begun and all predictions of global supplies facing terminal decline were wrong.

"The problem we face is not that there is too little oil but that there is too much . . . there is enough oil in the ground to deep-fry the lot of us, and no obvious means to prevail upon governments and industry to leave it in the ground," Monbiot said.

The new boom presents a potential problem for the Gillard government in Australia as it imposes a carbon tax starting at \$23 a tonne. Climate Change Minister Greg Combet's argument that pricing pollutants will provide a strong incentive to move to clean energy sources sits oddly with a US-led global drive for more oil.

Even President Barack Obama has backed away from carbon-reducing policies to push domestic oil production as the solution to America's energy security.

The US will remain vulnerable to oil price spikes for many years because oil is traded globally with prices set by the international market. But oil is here to stay -- in a big way.

13. **First nuclear reactor to go back online since Japan disaster met with protests**

By Chico Harlan, Published: July 1

http://www.washingtonpost.com/world/asia_pacific/1st-nuclear-reactor-to-go-back-online-since-japan-disaster-meets-with-protests/2012/07/01/gJQAdlHZFW_story.html

TOKYO — Protesters thronged the wide streets in front of the prime minister’s office in Tokyo over the weekend, and across the country they gathered about a quarter-mile from the entrance of a nuclear plant. They shouted “No to the restart” and parked cars in front of the plant’s access road to block workers from coming or going, according to Japanese media.

But the workers were already inside.

At the Ohi nuclear facility on Japan’s western shoreline Sunday, those workers went through the technical steps to reboot a reactor, the first to come back online since last year’s massive nuclear accident at Fukushima Daiichi.

The restart at Ohi — with potentially more to follow — will avert dire power shortages and sustain the economy, Prime Minister Yoshihiko Noda has told the nation. But the restart also has divided the country, staging an increasingly hostile showdown between the government and those doubtful about its atomic safety claims.

Some political experts thought that Noda’s announcement two weeks ago about the restart of two reactors at Ohi — the No. 4 unit is scheduled to restart later this month — would quiet public opposition. Instead, Noda’s announcement fomented it, and social-media-organized protests that once drew hundreds now draw thousands. A rally Friday in front of Noda’s office drew 17,000, according to police; organizers put the number around 200,000.

The central government has so far given no indication that the public display will cause a rethinking of its nuclear restart efforts. Wide-scale protests are rare in this country, where people traditionally comply with authority figures, and Noda, who is also pushing for a consumption tax increase, faces a backlash for his pro-nuclear stance.

In a June 5 Pew Research Center poll, 70 percent of Japanese respondents said they favor a reduction in the country's reliance on nuclear power. The government, before calling for the restart, received approvals from local and regional officials near Ohi, a process that required months of persuasion.

Engineers at Ohi on Sunday night pulled out the control rods that prevent nuclear fission. By Wednesday, according to Japan's Kyodo news agency, the 1,180-megawatt reactor will begin transmitting power.

Before the series of meltdowns at the Fukushima plant, which forced the evacuation of more than 100,000 people, Japan depended on its 54 reactors for about one-third of its energy. But in the wake of the accident, those reactors steadily went offline, either because of safety concerns or for routine maintenance checks. In early May, the final reactor in Hokkaido went offline and the country briefly became nuclear free.

Noda became a voice for the restart, saying that a failure to restart the reactors would jeopardize life as Japanese knew it. The government predicted energy shortages during the sweltering summer — nearly 15 percent in one region, Kansai, which had been particularly atomic-dependent. The government picked reactors No. 3 and No. 4 at Ohi for the first to restart because they supplied the Kansai region and because they had already passed stress tests to gauge their response to disasters.

The restart comes at a time when policymakers here are planning the country's energy future. The Energy and

Environment Council is debating three options: By 2030, nuclear power will account either for 20 to 25 percent of Japan's total electricity output, 15 percent, or zero percent. The council is supposed to reach a decision in August, Japanese media have said.

14. National Ignition Facility makes history with record 500 terawatt shot

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<https://www.llnl.gov/ews/newsreleases/2012/Jul/NR-12-07-01.html>

LIVERMORE, CA. - Fifteen years of work by the Lawrence Livermore National Laboratory's National Ignition Facility (NIF) team paid off on July 5 with a historic record-breaking laser shot. The NIF laser system of 192 beams delivered more than 500 trillion watts (terawatts or TW) of peak power and 1.85 megajoules (MJ) of ultraviolet laser light to its target. Five hundred terawatts is 1,000 times more power than the United States uses at any instant in time, and 1.85 megajoules of energy is about 100 times what any other laser regularly produces today.

The shot validated NIF's most challenging laser performance specifications set in the late 1990s when scientists were planning the world's most energetic laser facility. Combining extreme levels of energy and peak power on a target in the NIF is a critical requirement for achieving one of physics' grand challenges -- igniting hydrogen fusion fuel in the laboratory and producing more energy than that supplied to the target.

In the historic test, NIF's 192 lasers fired within a few trillionths of a second of each other onto a 2-millimeter-diameter target. The total energy matched the amount requested by shot managers to within better than 1 percent. Additionally, the beam-to-beam uniformity was within 1 percent, making NIF not only the highest energy laser of its kind but the most precise and reproducible. "NIF is becoming everything scientists planned when it was conceived over two decades ago," NIF Director Edward Moses said. "It is fully operational, and scientists are taking important steps toward achieving ignition and providing experimental access to user communities for national security, basic science and the quest for clean fusion energy."

The user community agrees. "The 500 TW shot is an extraordinary accomplishment by the NIF Team, creating unprecedented conditions in the laboratory that hitherto only existed deep in stellar interiors," said Dr. Richard Petrasso, senior research scientist and division head of high energy density physics at the Massachusetts Institute of Technology. "For scientists across the nation and the world who, like ourselves, are actively pursuing

fundamental science under extreme conditions and the goal of laboratory fusion ignition, this is a remarkable and exciting achievement."

"Already the most incredibly tightly controlled and most energetic laser in the world, it is remarkable that NIF has achieved the 500 TW milestone - quite a significant achievement," said Dr. Raymond Jeanloz, professor of astronomy and earth and planetary science at the University of California, Berkeley. "This breakthrough will give us incredible new opportunities in studying materials at extreme conditions."

NIF is operating routinely at unprecedented performance levels. The July 5 shot was the third experiment in which total energy exceeded 1.8 MJ on the target. On July 3 scientists achieved the highest energy laser shot ever fired, with more than 1.89 MJ delivered to the target at a peak power of 423 TW. A shot on March 15 set the stage for the July 5 experiment by delivering 1.8 MJ for the first time with a peak power of 411 TW.

Original concerns about achieving these levels of extreme laser performance on NIF centered in part on the quality of optics existing in the late 1990s that could not withstand this intense laser light. Lawrence Livermore researchers worked closely with their industrial partners to improve manufacturing methods and drastically reduce the number of defects. Livermore scientists also developed in-house procedures to remove and mitigate small amounts of damage resulting from repeated laser firings.

NIF is influencing the design of new giant laser facilities being built or planned in the United Kingdom, France, Russia, Japan and China.

Located at Lawrence Livermore National Laboratory, NIF is funded by the National Nuclear Security Administration (NNSA), a semi-autonomous agency within the U.S. Department of Energy responsible for enhancing national security through the application of nuclear science to the nation's national security enterprise.

NIF is the latest, and arguably the most sophisticated, addition to a number of critical stockpile stewardship facilities. It is the only facility with the potential to duplicate the actual phenomena that occur in the heart of a modern nuclear device -- a goal that is critical to sustaining confidence that a return to underground nuclear testing remains unnecessary. NIF also is providing unique experimental opportunities for scientists to enhance our understanding of the universe by creating the same extreme states of matter that exist in the centers of planets, stars and other celestial objects. Additionally, experiments at NIF are laying the groundwork to revolutionize energy production with fusion energy to provide abundant and sustainable clean energy.

