Australian ITER Forum Website News Update 4/18

B.J.Green (16/4/18)

1. Physicists decry cuts to inertial fusion program

Basic research in astrophysics and other fields also would be set back by the reprioritizing of the Department of Energy's weapons program.

David Kramer

https://physicstoday.scitation.org/doi/full/10.1063/PT.3.3895?utm_source=Physics+Today&utm_medium=email&utm_campaign=9331039_NQ+-+April+2018+TOC&dm_i=1Y69%2C5JZVJ%2CE1OV2B%2CLK9KL%2C1

Academic users of the University of Rochester's Omega laser expressed alarm at the Trump administration's proposal to close the device in three years; they warn that closure will devastate the growing field of high-energy-density (HED) physics and cripple the training of scientists who are required to maintain the nuclear weapons arsenal. The winding down of Omega is the most striking feature of a 20% proposed overall cut to the Department of Energy's inertial confinement fusion (ICF) program for fiscal year 2019. The cut also entails a 70% reduction to ICF efforts to attain ignition, the point at which the fusion reaction becomes self-sustaining.

Roberto Mancini of the University of Nevada, Reno, who chairs the 400-member Omega users' group, says that experiments on the laser cover topics such as laboratory astrophysics, radiation hydrodynamics, atomic and nuclear physics, materials and equations of state under extreme conditions, relativistic laser–plasma interactions, magnetized plasmas, and alternative fusion concepts. A news story on page 20 of this issue reports on an experiment on Omega that confirmed a theory of how magnetic fields form in the interstellar medium.

Making the necessary tradeoffs for higher priorities was the only response that Steven Erhart, then acting administrator of DOE's National Nuclear Security Administration, would provide for the reductions to the budget. The FY 2019 NNSA budget proposes large increases in funding for weapons production and associated infrastructure. NNSA officials didn't respond to several requests for further comment.
The administration's FY 2019 budget blueprint, released on 23 February, provides $40.4 million for Rochester's Laboratory for Laser Energetics (LLE), which houses Omega, compared with this year's $66.8 million. The proposal also calls for terminating the $8.5 million krypton fluoride laser program at the US Naval Research Laboratory, also part of the ICF program, and ending the NNSA's contract with General Atomics for ICF target fabrication. That work is funded at about $24 million.
The ICF program, whose budget next year would decline overall by $104 million, to $418 million, has long had laboratory-scale fusion as its main focus. But the program also serves to validate computer simulations of how materials behave at extreme pressures and temperatures, the conditions that occur during nuclear detonations and in stars. The program's three major facilities—the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory, Omega, and the Z pulsed-power accelerator at Sandia National Laboratories—each explore a different approach to inertial fusion. The ICF program is a component of the stockpile stewardship program, the combination of high-performance computing assets and experimental facilities that supplanted underground nuclear testing in the 1990s. (See "The Big Science of stockpile stewardship" by Victor Reis, Robert Hanrahan, and Kirk Levedahl, *Physics Today*, August 2016, page 46.)

"AN EXISTENTIAL THREAT"

The budget request would end direct NNSA support for stockpile-science workforce development in HED physics. That support had grown with the end of testing, in part as a means to attract new scientists into the weapons labs to replace the retiring workforce. The $9.5 million NNSA share of a basic research grants program in HED laboratory plasmas would be deleted. Graduate students who work on those projects often go on to work in the weapons program. DOE's Office of Science is requesting $7.5 million for the basic science program next year, down from $10 million currently.

The budget proposal "is an existential threat" to HED physics, says Donald Lamb, a University of Chicago astrophysicist. (For a history of HED physics, see the article by Paul Drake, *Physics Today*, June 2010, page 28.) The ICF cuts would result in loss of US leadership in the field in the same way that the nation's preeminence in high-energy physics ended with cancellation of the Superconducting Super Collider, he maintains. "We have done this before in other fields."

Lamb, who has served on numerous advisory committees to the weapons labs, warns that without the expertise to carry out experiments that can validate computer simulations, the labs can't be confident that any changes or replacements made to nuclear weapons will work as expected.

"If you cut off the students and the young talent, they are going to be gone," says Richard Petrasso, head of the HED physics division at MIT's plasma science and fusion center. His program currently has six PhD students who are working on experiments at Omega, and four of them have also done work at NIF. About 90% of the graduate students that have earned their doctorates in HED physics from MIT have been supported by NNSA, he says.

Petrasso's students have invented multiple diagnostics for the ICF program. Seven of those have been adapted for use at NIF, including one that he describes as "like a flashbulb done with monoenergetic particles" that backlights experiments. "You're talking about people who have the capability to understand nuclear weapons and make assessments. In this world, you have to have people who are capable of that," he says.

Carolyn Kuranz, project director of the Center for Laser Experimental Astrophysical Research at the University of Michigan, creates and studies laboratory-scale HED plasmas at Omega in regimes similar to those found in supernovas and accretion disks. “A lot of the work I and my students do there has a huge impact on national security,” she says. “I don’t know where students would get their training or how they would even hear about the field” if Omega were closed, she says. She adds that the US would quickly be overtaken in the field by China and Europe, which are building similar facilities. France’s much larger Laser Mégajoule, for example, is starting operations.

John Soares, senior scientist at LLE, says the NNSA has supported 40 graduate students at Rochester each year at Omega, typically for five years. A separate grants program run by LLE supports 25–35 graduate students from other institutions to work at the lab each year.

Although considerably smaller than NIF—30 kilojoules from 60 laser beams versus 1.8 megajoules from 192 beams—Omega’s much faster repetition rate, lower operating costs, and unclassified setting allow for a far greater number of experiments. Omega can be fired up to 15 times a day, compared with NIF’s maximum three shots a day. And at NIF, only 18 days a year are reserved for nonweapons experiments. Although very few classified experiments are performed at Omega, many are relevant to weapons physics, says Michael Campbell, LLE director.

Omega was built in 1995. A separate four-beam laser and target chamber known as Omega EP were added in 2008. They can also be operated in a joint mode to irradiate targets in the same chamber. In one such experiment, the EP has been used to perform x-ray radiography on targets as they are imploded by the larger laser.

Campbell says about 60% of the 2100 experiments on Omega each year are performed by users from outside Rochester. About 300 are done by researchers from universities in the US, Europe, and Japan. Others are conducted by national lab scientists. Much of Omega’s research is in support of NIF: Livermore scientists perform more experiments on Omega than they do on NIF, and the protocol for plutonium experiments at NIF was developed at Omega with surrogate metals.

SUPERVISION LACKING

The FY 2019 budget proposes to suspend research on the direct-drive approach to ICF. That's the method of implosion at Omega, where lasers are focused to impinge directly on capsules of fusion fuel. Ending that avenue of research would short-circuit the reassessment of the ICF alternatives that was previously planned to start in 2020 (see "NIF may never ignite, DOE admits," 17 June 2016, *Physics Today* online).

Experiments at NIF have focused on indirect drive. In that approach, beams are sent into a cylinder that houses the fuel capsules, producing x rays that drive the implosion. When NIF was completed in 2009, program managers were confident they could create ignition by 2012. That milestone has yet to be attained.

At NIF, the budget would fall by $57 million next year, to $287 million, which would force a 30% reduction in the number of shots. Facility director Mark Herrmann says the cuts at NIF would be "a real blow to everything we do for stewardship, but the ignition effort will slow down drastically or possibly stop." The reductions would come at a time when progress continues toward ignition, he says, as fusion yields obtained at NIF have doubled in the past year or so.

Worsening the budget picture for both NIF and Omega is the absence of NNSA funding for target fabrication by General Atomics. The labs would have to absorb those costs—about $16 million at NIF and $8 million at Omega.

The third ICF facility, Sandia's Z, would see its funding rise from last year's $110 million to $118 million, but only because it gets nearly half of its funding from non-ICF weapons science programs. The ICF share would fall from $63 million to $57 million.

The ICF cuts are proposed in an NNSA FY 2019 request that includes a $1.8 billion increase, to $11 billion, for all nuclear weapons activities. The proposed increase is mainly devoted to extending the lifetimes of three warhead systems and to accelerating capital improvements and overdue maintenance to the aged weapons production complex.

Two sources familiar with the program suggested the ICF cuts were due in part to the absence of a deputy NNSA administrator for defense programs. The position has been vacant since President Trump took office.

The White House announced on 26 February the nomination of Charles Verdon, currently principal deputy administrator for weapons and complex integration at LLNL, to the NNSA deputy administrator post.

Commenting on the proposed cuts to ICF a few days prior to his nomination, Verdon told a reporter that the labs hadn't done enough to educate other NNSA officials about the importance of the program.

It's unlikely that the proposed cuts to the ICF program will survive the congressional appropriations process intact. Members of New York's delegation have declared they will fight the move to shut down LLE. "Turning out the lights on Rochester's laser lab is a horrible plan," Senator Charles Schumer (D-NY) said in a statement. "It would not only slash [the jobs of] the 340 high tech engineers and scientists who work there, but it would jeopardize the safety, security, and reliability of our nation's nuclear weapon arsenal. Simply put, I will do everything possible to prevent the administration's wrongheaded effort."

Similar statements showing bipartisan support were issued by New York Representatives Louise Slaughter (D) and Chris Collins (R).

2. PPPL-led research enhances performance of Germany's new fusion device

By
John Greenwald
March 29, 2018
https://www.pppl.gov/news/2018/03/pppl-led-research-enhances-performance-germany's-new-fusion-device

A team of U.S. and German scientists has used a system of large magnetic "trim" coils designed and delivered by the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) to achieve high performance in the latest round of experiments on the Wendelstein 7-X (W7-X) stellarator. The German machine, the world's largest and most advanced stellarator, is being used to explore the scientific basis for fusion energy and test the suitability of the stellarator design for future fusion power plants. Such plants would use fusion reactions such as those that power the sun to create an unlimited energy source on Earth.

The new experiments amply demonstrated the ability of the five copper trim coils and their sophisticated control system, whose operation is led on-site by PPPL physicist Samuel Lazerson, to improve the overall performance of the W7-X. "What's exciting about this is that the trim coils and Sam's leadership are producing scientific understanding that will help to optimize future stellarators," said PPPL physicist Hutch Neilson, who oversees the laboratory's collaboration on the W7-X with the Max Planck Institute of Plasma Physics, which built the machine and now hosts the international team investigating the behavior of plasmas confined in its unique magnetic configuration.

Twisty, doughnut-shaped facilities

Stellarators are twisty, doughnut-shaped facilities whose configuration contrasts with the smoothly doughnut-shaped facilities called tokamaks that are more widely used. A major advantage of stellarators is their ability to operate continuously with low input power to sustain the plasma without plasma disruptions — a risk that tokamaks face — enabling the facilities to operate efficiently in steady state. A disadvantage is that the twisting stellarator geometry is more complex to design and build.

The W7-X completed its second round of experiments in December with improved heating and measurement capabilities. A special feature of the second round was its use of an "island divertor" to exhaust heat and particles leaving the plasma. This important tool consists of a chain of specially shaped magnetic fields at the edge of the plasma intersected by 10 divertor plates. Any deviation of these fields from their designed configuration can cause the divertor plates to overheat and limit the performance of the plasma.

The recent experiments demonstrated the ability of the trim coils to measure and correct such deviations, which are known as "error fields." Controlling such fields at the edge of the plasma enabled the W7-X to produce plasma discharges lasting up to 30 seconds. "The trim coils have proven extremely useful, not only by ensuring a balanced plasma exhaust onto the divertor plates, but also as a tool for the physicists to perform magnetic field measurements of unprecedented accuracy," said Thomas Sunn Pederson, Max Planck director of stellarator edge and divertor physics.

Achieving the control required the trim coils to perturb the magnetic field in a way that made clear the size of the error field. Complementary experiments by Lazerson and Max Planck scientist Sergey Bozhenkov then confirmed predictions of the needed power of the trim coils to correct the deviations — an amount that equaled just 10 percent of the full power of the coils. "The fact that we only required 10 percent of the rated capacity of the trim coils is a testament to the precision with which W7-X was constructed," Lazerson said. "This also means that we have plenty of trim coil capacity to explore divertor overload scenarios in a controlled way.

Support for this work comes from the DOE Office of Science.

PPPL, on Princeton University's Forrestal Campus in Plainsboro, N.J., is devoted to creating new knowledge about the physics of plasmas — ultra-hot, charged gases — and to developing practical solutions for the creation of fusion energy. The Laboratory is managed by the University for the U.S. Department of Energy's Office of Science, which is the largest single supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov(link is external).

3. WORLD RECORD PLASMA EXPOSURE IN MAGNUM-PSI

March 27th 2018
https://www.differ.nl/news/magnum-psi-plasma-exposure-record?platform=hootsuite

n Wednesday 21 March, the research facility Magnum-PSI at DIFFER (Dutch Institute for Fundamental Energy Research) set a new world record for longest exposure of a material to the harsh plasma conditions in future fusion reactors. Magnum-PSI exposed tungsten wall components to the equivalent of a full year of high power fusion operations in the future ITER reactor, 50 times more than the previous record. The exposure took only 18 hours to complete and shows Magnum-PSI's unique capability to investigate how materials hold up under a sizeable part of their lifetime in ITER.

ITER FUSION PROJECT

The international nuclear fusion project ITER is currently being constructed in the south of France and will start experiments in 2025. ITER is the first fusion experiment ever designed to produce more power from nuclear fusion reactions than is needed to heat and stabilize the hot, dense plasma (charged gas) in the reactor. Fusion researchers intend to use abundant fuels to mimic the nuclear reactions at the heart of the sun as a safe, clean and nearly inexhaustible energy source.

SURFACE OF THE SUN

Magnum-PSI is the only laboratory facility in the world which can reach the harsh plasma conditions expected in ITER's exhaust. These conditions are comparable to those in a welding flame, at a space craft's re-entry heat shield, or at the surface of the sun. Thanks to a superconducting magnet (operational since the start of 2017) Magnum-PSI can now maintain such a plasma for hours on end for truly long term tests of candidate materials.

"VERY IMPRESSIVE"

Greg De Temmerman, ITER's Coordinating Scientist for plasma wall interactions, proposed and participated in the record experiment at Magnum-PSI and also provided the small scale realistic tungsten mock-ups for the experiment. "The *fluence* reached here (total particle impacts per surface area) is equivalent to that expected during a full year of high power fusion operations in ITER. That is very impressive - I am very pleased to see Magnum-PSI working so well." The previous record, at a different facility, exposed materials to an equivalent of 5 ITER days.

Facility manager Hans van Eck is proud of the new achievement: "This experiment was really a test of the facility; we'd never gone to such long exposures before. In only 18 hours since Monday morning 19 March, we exposed a set of tungsten blocks to a fluence of 10^{30} impacts of deuterium ions per square meter of material, at a power load of at least 10 million Watts per square meter." Deuterium is a heavier isotope of hydrogen and forms one half of the fusion fuel mix.

After the record discharge, it is now time to examine ITER's tungsten components to see how they held up under the exposure. Thomas Morgan, who heads DIFFER's research into plasma material interactions, looks forward to analyzing the results: "We will gain the first detailed look at how ITER's wall materials will evolve during their lifetime in the reactor, something no other experiment has been able to investigate."

FACILITY ROLE: COLLABORATION WITH ITER AND EUROFUSION

As a research facility, Magnum-PSI welcomes collaboration with researchers outside of DIFFER. The record plasma exposure was performed on behalf of the international ITER project and the European fusion development consortium EUROfusion.

4. Feds extend funding for nuclear fusion project, General Atomics breathes sigh of relief

Rob NikolewskiContact Reporter

March 27, 2018 4.50 pm

http://www.sandiegouniontribune.com/business/energy-green/sd-fi-generalatomics-fusion-20180327-story.html

After months of doubt, the federal government has agreed to boost 2018 funding for the U.S. share of the world's largest and most ambitious nuclear fusion project.

That means what may be the endeavor's most important piece — a massive magnet being assembled by San Diego-based General Atomics — will continue this year without interruption.

A small portion of the enormous omnibus spending bill passed by Congress and signed into law last week by President Donald Trump included $122 million for the U.S. contribution to the ITER Project, short for the International Thermonuclear Experimental Reactor.

“I think it’s fantastic and shows a new commitment to fusion we haven’t seen from the government in some time,” said Mickey Wade, director of advanced fusion systems at General Atomics. “I think this bodes well for fusion research in the U.S. and specifically here in San Diego.”

Some 45 full-time General Atomics employees are building what is called ITER’s Central Solenoid in a giant warehouse at the company’s Poway facility. The seven 250,000-pound circular modules will eventually be shipped to Europe, where they will be inserted into the center of the ITER facility under construction in France.

The United States is one of seven countries participating in the project and is responsible for a portion of ITER’s costs, which have ballooned in the decade since construction began.

The U.S. has contributed about $1 billion and continued participation in ITER will cost about $100 million to $125 million a year for more than two decades.

The price tag generated opposition from some members of both parties in Congress, with the House of Representatives this year proposing that funding be cut in half and the Senate going so far as to call for no funding at all.

But the last-minute budget bill averted the cuts, coming two months after ITER's director-general, Bernard Bigot, made a lobbying push on Capitol Hill.

For more than six decades, scientists have talked about the awesome potential of nuclear fusion — producing a virtually unlimited amount of energy without any greenhouse gas emissions.

"We're talking millions of years of fuel," Wade said.

But fusion power has been generated only for short periods in the laboratory and no fusion reactors exist.

Even if successful, ITER will not directly result in the construction of a commercially viable power plant. Instead, the project is designed to figure out if fusion can be harnessed for practical applications.

"I think we can conquer these challenges and be able to make fusion a realty," Wade said. "I tell students it's not a matter of if we'll have fusion, it's a matter of when we'll have fusion."

But while funding has been met for this year, the annual price tag for the U.S. share of the project is expected to go up to about $200 million in fiscal year 2019.

“I think we may have turned a corner but there’s still a lot of hard work ahead of us,” Wade said. “I think the members of Congress for the first time really understood this is a real project and is on solid track to be successful.”

The seven countries taking part in the ITER project are the European Union, the U.S., Russia, China, South Korea, Japan and India. The EU has a 45 percent stake in ITER, with the other six countries contributing 9.1 percent each.

“This is a very positive signal … it will prevent ITER having to announce project delays in 2018,” Bigot told Reuters on Monday.

The news came as a huge relief for General Atomics.

“It had been a very uncertain time as far as fusion funding was concerned and a lot of negative things had happened from the point of view of funding so we were certainly elated to see it,” Wade said.

While ITER (pronounced “eater”) has run into many delays, the directors of the General Atomics say the Central Solenoid project in Poway is “right on schedule” and meeting its milestones.

The first module will be ready to be shipped next year and the last one is scheduled to head to Europe in 2021. ITER’s first operational test is slated for 2025.

5. S. Korea to send more scientists to int'l nuclear fusion reactor project: gov't

2018/03/28 12:06

http://english.yonhapnews.co.kr/news/2018/03/28/0200000000AEN20180328005000320.html

SEOUL, March 28 (Yonhap) -- South Korea said Wednesday it will send more scientists to an international consortium for the building of a nuclear fusion reactor so as to help build its own clean energy facility down the road.

The Ministry of Science and ICT said it will proceed with plans to raise the number of South Korean scientists at the International Thermonuclear Experimental Reactor (ITER) to 95 by 2026 from the current 32. The project currently employs 825 scientists from seven consortium partner countries.

The ITER, being built in Cadarache, France, is an international experiment to see if a super-hot plasma field locked in magnetic confinement, and using naturally abundant tritium and deuterium as fuel, can create an artificial sun on Earth. If the project is successful, it could provide mankind with a limitless energy resource.

Unlike light and heavy water nuclear reactors, a nuclear fusion reactor provides safer electricity as it produces very little harmful waste.

South Korea is a member of the ITER consortium together with the European Union (EU), the United States, Japan, Russia, China and India. The EU must foot 45 percent of the total cost with other countries responsible for around 9 percent of the total each.

South Korea has invested 883.8 billion won (US$824 million) in the project since 2003.

South Korea completed building the tokamak-typed nuclear fusion reactor, called the "Korean Superconducting Tokamak Advanced Research (KSTAR)," in 2007 and has been conducting research projects to produce electricity.

"It is important for us to allow more South Korean scientists to join the ITER project, as the most important asset we can get from the project is manpower," a ministry official said.

The ministry said it will nullify the 10-year limit for the work period in the consortium for South Korean scientists while allowing more scientists to join the National Fusion Research Institute (NFRI) after completing their duty at the ITER consortium.

6. BUSINESS NEWS
MARCH 27, 2018 / 12:10 AM / 7 DAYS AGO

ITER nuclear fusion project avoids delays as U.S. doubles budget

Geert de Clercq

https://www.reuters.com/article/us-nuclearpower-fusion-iter/iter-nuclear-fusion-project-avoids-delays-as-u-s-doubles-budget-idUSKBN1H2286

PARIS (Reuters) - The United States has agreed to double its planned 2018 budget contribution to the ITER project to build a prototype nuclear fusion reactor, avoiding delays to the international project this year, its director said on Monday.

Washington cut the United States' 2017 contribution from a scheduled $105 million to $50 million and had planned to cut its 2018 contribution from a scheduled $120 million to $63 million.

But in last-minute talks about the U.S. 2018 budget last week, the U.S. Congress approved a draft Omnibus Spending Bill with a $122 million in-kind contribution for ITER, which President Donald Trump signed into law on Friday, ITER said.

“This is a very positive signal ... it will prevent ITER having to announce project delays in 2018,” ITER Director-General Bernard Bigot told Reuters in a telephone interview.

He added that if the United States would make up for missing cash contributions of about $120 million for the 2016-18 period, ITER would remain on track in future years.

The International Thermonuclear Experimental Reactor (ITER) project is a cooperation between Europe, the United States, China, India, Japan, Russia and South Korea to build a prototype fusion reactor to generate electricity in a process similar to the nuclear fusion that powers the sun.

With an estimated cost of about 20 billion euros ($25 billion), the project is more than halfway towards the first test of its super-heated plasma by 2025 and first full-power fusion by 2035.

ITER member countries contributions to the project are not mainly in cash but in kind, as they finance the manufacturing of ITER components via their own national companies. These parts are then shipped to France and assembled on ITER’s Cadarache, southern France site.

But there is also a cash contribution, which for the U.S. was 30-32 million euros per year in the 2016 to 2018 period, or about 100 million euros, Bigot said.

"We hope that at least maybe a small part of the U.S. 2018 contribution could be in cash so as to give a political signal to the other ITER members," said Bigot, who was appointed ITER director in 2015.

ITER's main U.S. supplier is California-based General Atomics, which is building the project's central solenoid, an 18-metre tall pillar-like magnet that will be one of the first components to be installed by 2020.

The United States has given about $1 billion to ITER so far, and had been planning to contribute an additional $500 million through 2025.

($1 = 0.8037 euros)

Reporting by Geert De Clercq; Editing by Catherine Evans and Ken Ferris
Our Standards: *The Thomson Reuters Trust Principles.*

7. Chirping is welcome in birds but not in fusion devices – scientists show that weak turbulence makes chirping more likely

By
John Greenwald
March 16, 2018

https://www.pppl.gov/news/2018/03/chirping-welcome-birds-not-fusion-devices-–-scientists-show-weak-turbulence-makes

Birds do it and so do doughnut-shaped fusion facilities called "tokamaks." But tokamak chirping— a rapidly changing frequency wave that can be far above what the human ear can detect — is hardly welcome to researchers who seek to bring the fusion that powers the sun and stars to Earth. Such chirping signals a loss of heat that can slow fusion reactions, a loss that has long puzzled scientists.

Compounding the puzzle is that some tokamaks chirp more frequently than others. For example, chirps have commonly occurred in the National Spherical Torus Experiment Upgrade (NSTX-U) at the U.S. Department of Energy's (DOE) Princeton Plasma Laboratory (PPPL), but have been rare in the DIII-D National Fusion Facility tokamak that General Atomics operates for the DOE in San Diego. Understanding why some tokamaks chirp and some do not is important so that researchers can predict and eventually learn to avoid such chirping in the ITER tokamak, the international fusion reactor that is being built in the south of France to demonstrate the practicality of fusion energy.

In a fusion reactor like ITER, fusion reactions produce "fast ions" – highly energetic atomic nuclei that scientists rely on to maintain the high plasma temperatures needed to keep the plasma hot. Such ions are like a fast wind that, under certain conditions, can excite waves called "Alfvén waves" in the hot plasma — much like the musical notes produced by blowing in a wind instrument. If the fast ion wind is strong enough the Alfvén waves begin to chirp, which will cause loss of energy, reducing the plasma temperature and fusion power output.

Conditions that lead to chirping

Scientists led by PPPL researchers have now modeled the plasma conditions that give rise to chirping and predict when it will occur. The computer model, successfully tested on the DIII-D tokamak, describes the impact of turbulence — the random fluctuation of plasma that can lead to heat and particle loss — on the fast ions. The model shows that the turbulence in the plasma helps to break up or scatter the fast ion wind. If the scattering is strong enough the fast ions no longer have the strength to cause Alfvén wave chirping and the loss of heat from the plasma can be reduced.

Until recently, finding direct evidence for the role of turbulence in affecting the strength of the fast ion wind and its role in chirping has been challenging. Recent DIII-D experiments have now revealed the intimate connection between turbulence levels and the chirping of the plasma.

In these experiments, the fast ion wind produced a single Alfvén note in the plasma, much like a single note in a wind instrument. Then, when the plasma spontaneously transitions into a new improved state of confinement with low turbulence levels, the Alfvén note begins to chirp rapidly.

This onset of chirping is clearly tied to the reduction of turbulence, since lower turbulence can no longer scatter the fast ion wind, allowing it to build up sufficiently to drive the Alfvén waves harder and cause them to begin chirping. "The coherent motion of fast ion bunches when the turbulence decreases gives rise to chirping and the leakage and heat associated with chirping," said Vinícius Duarte, a PPPL associate research physicist and former visiting scientist from the University of São Paulo, Brazil, who is lead author of a paper describing the findings in *Physics of Plasmas* and featured as a "Scilight" — a science highlight — by the American Institute of Physics.

Why some plasmas chirp

The theory developed by Duarte also indicates why some plasmas chirp and some do not. The explanation is that turbulence is much less effective in scattering the fast ion wind in some devices compared with others. The next step will be to use this knowledge to design methods to prevent chirping in present experiments, and to use such methods in the design of future fusion reactors such as ITER.

Support for this work comes from the São Paulo Research Foundation and the DOE Office of Science using DIII-D, a DOE Office of Science user facility. Coauthors include Nikolai Gorelenkov, Gerrit Kramer, Raffi Nazikian, and Mario Podesta of PPPL; Michael Van Zeeland and David Pace of General Atomics; Willliam Heidbrink of the University of California, Irvine; and Herbert Berk of the University of Texas at Austin.

PPPL, on Princeton University's Forrestal Campus in Plainsboro, N.J., is devoted to creating new knowledge about the physics of plasmas — ultra-hot, charged gases — and to developing practical solutions for the creation of fusion energy. The Laboratory is managed by the University for the U.S. Department of Energy's Office of Science, which is the largest single supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov(link is external).

8. From Earth's depths to the stars, there's good news for science in spending bill

BY ALAN BOYLE on March 23, 2018 at 12:11 pm

https://www.geekwire.com/2018/earths-depths-stars-theres-good-news-science-spending-bill/

The $1.3 trillion omnibus spending bill that President Donald Trump signed into law today preserves several of the scientific initiatives his administration wanted to kill, including a West Coast earthquake warning system and the WFIRST space telescope.

It may not be popular with Senate GOP conservatives such as Rand Paul, but the bill's a hit with the likes of the American Association for the Advancement of Science.

“The scientific community is over the moon with the bipartisan omnibus bill in Congress that significantly increases funding for research and development,” AAAS CEO Rush Holt, a physicist who served in the House from 1999 to 2015, said in a statement.

AAAS’ analysis shows that total R&D spending would reach its highest point ever in inflation-adjusted dollars, amounting to $176.8 billion. Among the highlights:

- **Earthquake research:** The White House wanted to zero out federal funding for the ShakeAlert program, which aims to provide precious seconds of advance notice that a seismic shock is coming. The omnibus spending bill provides $12.9 million for continued development during the current fiscal year, which is a $2.7 million increase over the 2017 level of support. There’s also a one-time $10 million award to add more sensors to the West Coast seismic monitoring network.
- **Energy research:** The White House wanted to kill ARPA-E, a DARPA-like energy innovation agency at the Energy Department that’s one of Bill Gates’ favorites. There was also a cloud over U.S. support for the international fusion research program known as ITER. The omnibus spending bill saves both programs. U.S. contributions to ITER will rise to $122 million, more than double the previous level. ITER’s construction effort is ramping up, with completion targeted for the mid-2020s.
- **NASA:** The space agency will see its budget boosted by $1.1 billion to $20.7 billion. Earth science missions such as OCO-3, CLARREO-Pathfinder and DSCOVR will live on. So will NASA’s education program. Work can continue on WFIRST — the Wide Field Infrared Survey Telescope, which astronomers rated as one of their top priorities for the next decade. Planetary science programs will get a 20 percent boost. The bill sets aside $595 million to send a probe and a lander to Europa, a Jovian moon that may harbor an ice-covered ocean and perhaps life.
- **Environment:** The spending bill rejects the White House’s proposed $2.5 billion cut in the Environmental Protection Agency’s budget, and preserves the EPA’s core research missions at current levels.
- **Health research:** Each institute within the National Institutes of Health will receive a roughly 5 percent increase over 2017 spending levels at a minimum. The bill also directs an additional $414 million for Alzheimer’s research, and an additional $500 million for opioids research. The Cancer Moonshot, BRAIN Initiative and Precision Medicine Initiative will receive the funding mandated by the 21st Century Cures Act, which was championed by Vice President Joe Biden at the end of the Obama administration.

The House approved the budget Thursday, and the Senate followed suit hours later. Trump had hinted that he might veto the bill, but he ended up signing it to avert a government shutdown that would have been triggered at midnight tonight.

The omnibus bill authorizes spending through the end of the current fiscal year on Sept. 30, but a fresh set of budget bills will have to be drawn up for the 2019 fiscal year. Which means yet another gauntlet looms for endangered science programs. But isn't that always the way it is?

This is an updated version of a report that was originally published at 7:06 p.m. PT March 22.

9. Exel Composites and CNIM Collaborate on Glass Fibre

https://informedinfrastructure.com/37699/exel-composites-and-cnim-collaborate-on-glass-fibre-components-for-worlds-most-ambitious-fusion-project/

Parul Dubey on March 21, 2018 - in Energy

Global pultrusion company Exel Composites is collaborating with French industrial contractor CNIM on the manufacture of fiberglass components for the magnet support structure of the International Thermonuclear Experimental Reactor (ITER), the world's largest experimental fusion facility. To satisfy the stringent quality demands for the pre-compression rings, Exel Composites successfully solved the challenge of producing defect-free pultruded profiles of around 3 km in length.

The €18 billion ITER under construction in Saint-Paul-lez-Durance, France, is designed to demonstrate that fusion power can be produced on a commercial scale, providing a safe, environmentally sustainable energy source. The ITER will use hydrogen fusion, controlled by superconducting magnets, to produce massive heat energy. In the commercial machines that will follow, this heat will drive turbines to produce electricity.

The composite pre-compression rings are the cornerstone of the ITER's magnet system support structure. They will ensure the operation of the toroidal field coils employed to create a magnetic 'cage' to confine the super-hot (150 million °C) plasma. To reduce fatigue and deformation of the coils resulting from the powerful magnetic fields, three pre-compression rings will be placed on top of them and three below. An extra set of three will be manufactured in case replacement becomes necessary in future. The pre-compression rings are required to withstand maximum hoop stresses of up to 500 MPa at room temperature. Glass fibre epoxy composite with a high fibre content was selected as the most suitable material to withstand such extreme loads, avoid circulation of electromagnetic currents and deliver a long service life. The composite rings will have a diameter of approximately 5 m, a cross-section of nearly 30 cm x 30 cm and will weigh slightly more than 3 tons.

Engineers at CNIM's workshop in Toulon have been tasked with developing a manufacturing process for the spare pre-compression rings, and their subsequent production. The novel process relies on pultruded composite profiles produced by Exel Composites. Each ring will be produced by winding a 2 mm thick, 2.8 km long, flat pultruded profile around a metal tool. A 0.12 mm thick epoxy adhesive tape is wound over each layer. The completed ring lay-up is cured and then machined to the required final dimensions.

CNIM selected Exel Composites for this project based on the company's proven capability in the manufacture products of superior quality for the most demanding applications. Exel formulated a high performance epoxy resin system to meet the mechanical specifications for the pre-compression rings and ensured that the 3 km profiles supplied were defect-free along their entire length by means of online non-destructive testing (NDT). The handling of this length of profile presented a further challenge, which Exel solved by winding the product on a customised bobbin for supply to CNIM.

CNIM has already manufactured a series of prototypes, which are currently undergoing NDT and qualification tests. Production of the full-scale pre-compression rings will begin later this year. "We are proud to support the ground-breaking ITER demonstrator as it prepares the way for the fusion power plants of tomorrow," states Kari Loukola, Senior Vice President, Sales & Marketing, Exel Composites. "This represents a further example of Exel's commitment to innovation and collaboration with our customers in the pursuit of new applications for composite materials." The ITER facility itself is now 50% complete, with First Plasma (machine switch on) scheduled for 2025. ITER scientists predict that fusion plants could start to come on line as soon as 2040.

Exel Composites

Exel Composites is a leading composites technology company specialising in the design and manufacture of composite solutions for demanding applications. Exel Composites provides superior customer experience through continuous innovation, world-class operations and long-term partnerships. The core of Exel's operations is the company's proprietary technology, product range and strong market position in selected market segments where it holds a strong quality and brand image. Profitable growth is pursued by a relentless search for new applications and development in cooperation with customers. Exel Composites Plc shares are listed on Nasdaq Helsinki Ltd. For further information visit exelcomposites.com.

CNIM

Founded in 1856, CNIM is a French equipment manufacturer and industrial contractor operating on a worldwide basis. The group provides products and services to major public and private sector organizations, local authorities and national governments in the environment, energy, defense and high technology markets. Technological innovation is at the core of the group's equipment and services, which contribute to producing cleaner and more competitive energy, limiting environmental impacts of industrial activities, securing sensitive facilities and infrastructures, and protecting individuals and nation states. CNIM is listed on the Euronext exchange in Paris. For further information visit cnim.com.

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10. Will Brexit damage the UK's nuclear fusion prospects?

13 Feb 2018

https://www.soci.org/news/general-news/uk-atomic-energy-authority

Hailed by some as the future of clean energy, nuclear fusion is an exciting and promising area of research supported in the UK by the Atomic Energy Authority (UKAEA) – an organisation within the UK government responsible for the establishing the UK as a leader in sustainable nuclear energy.

JET's MASCOT telemanipulator allows scientists to remotely operate inside the vessel. Credit: Wikimedia Commons

Its core mission is for the commercial development of nuclear fusion power, a feat yet be to achieved, with research still ongoing into a feasible, large-scale reactor to convert energy from nuclear fusion into electricity.

An untapped source

Nuclear fusion occurs between two or more charged particles during a high-energy collision, with the resulting reaction producing a large amount of energy that could, at least theoretically, be converted into electricity. This reaction is only possible at extremely high temperatures and pressures, and is the process the Sun uses to generate energy.

Here on Earth, nuclear fusion is difficult to replicate, with researchers struggling to match the energy produced with the high amounts of energy needed to start the reaction, in order for it to become a feasible form of energy to power the world.

To date, the largest successful nuclear fusion reactor is the result of the Joint European Torus (JET), managed by the UKAEA at the Culham Science Centre, Oxford, UK, and used by more than 40 other European research laboratories.

Hosted at the centre since its conception in 1973, the EU project has produced the only operational reactor that can generate energy from nuclear fusion.

The JET is a tokamak – a device designed around the centrally placed fusion plasma, a fourth fundamental state of matter after solid, liquid, and air, that does not exist freely on Earth, containing the charged particles essential for nuclear fusion to occur.

Using strong magnetic fields, the tokamak confines the plasma to the shape of a torus (left) within a vacuum vessel. The plasma must be kept in this shape or it will cool and not meet the temperature needed for nuclear fusion.

Credit: Wikimedia Commons

Although other possibilities are still being explored, the tokamak is the leading candidate for a commercially viable nuclear fusion reactor and its design is the basis for JET's successor.

Making history

In 2025, the International Thermonuclear Experimental Reactor (ITER) will run its first experiment, and if successful will be the world's largest operating nuclear fusion reactor – ten times the size of any other in the world, producing upwards of 500MW of power.

A collaborative effort between 35 nations – China, India, Japan, Korea, Russia, the US, and all 28-member states of the EU – the ITER is the EU's successor project to JET. Based in Provence, southern France, the ITER is self-championed as 'one of the most ambitious energy projects in the world today'.

By 2025, ITER will produce its first plasma, later adding tritium and deuterium – a combination with an extremely low energy barrier – in 2035 to generate energy. If successful, the work on the ITER will confirm the feasibility of nuclear fusion as a large-scale, carbon-free energy source.

Future uncertainty

But with Brexit on the horizon, many have questioned the likelihood of the UK's participation in the project, despite the UKAEA's essential work in supporting the success of JET and continued commitment to investing in the project.

Director of ITER, Bernard Bigot, has said his concerns lie with the extension of Joint European Torus (JET) – ITER's predecessor which is due to end this year. 'If JET ends after 2018 in a way that is not coordinated with another global strategy for fusion development, clearly it will hurt ITER's development,' he said. 'For me it is a concern.'

Creating a new base for training and research would be costly, and is unlikely to be favoured, and those involved in Euratom, the EU's atomic energy community and main source of JET funding, are now worried that the seven-year gap between the projected end of funding to JET and the first experiment of ITER may damage the latter's prospects of success.

In a statement on the future of JET, the UK government said: 'The UK's commitment to continue funding the facility will apply should the EU approve extending the UK's contract to host the facility until 2020.'

With hopes for JET's funding to continue until at least 2023, and the UK government announcing its intentions to leave Euratom last year, the future of the UK's ability to compete in the nuclear sector rests on the progress of Brexit negotiations in the coming months.

By Georgina Hines

- 11. NUCLEAR FUSION

- NEWS

Italy picks Frascati for fusion test facility

05 Apr 2018 Michael Banks
https://physicsworld.com/a/italy-picks-frascati-for-fusion-test-facility/

A site near Rome has beaten eight other locations in Italy to host the €500m Divertor Tokamak Test Facility (DTT). ENEA, Italy's energy and technology agency, announcedyesterday that its research centre in Frascati will host the facility with construction set to start in November. The DTT will take seven years to complete.

A fusion tokamak contains a plasma of hydrogen isotopes heated to hundreds of millions of degrees and made to fuse, generating energy. The isotopes are held in place by magnetic fields, but if they drifted to the walls of the reactor they would damage it. The magnetic fields in a reactor are therefore shaped in such a way that the plasma leaks are channelled to a divertor at the foot of a reactor chamber that dissipates the heat.

Today it is Italy that wins because it invests in knowledge and sustainable energy

ENEA president Federico Testa

The divertor at the €20bn ITER fusion reactor, which is currently being built in Cadarache, France, is made from tungsten tiles. However, this material is unlikely to be adequate for an actual demonstration fusion power plant that would feed electricity to the grid continuously. The DTT, being 10 m high and with a 5 m radius, will therefore investigate alternatives types of divertor that could suit a future reactor. The machine will use superconducting magnets to contain a plasma and would have space around the edges of its plasma chamber to incorporate divertors of different shapes to spread the heat load over a larger area. It could also test divertors made of more resistant materials, such as liquid lithium.

Scientific prospects

The nine sites around Italy, which also included Brindisi and Pescara, were evaluated based on their economic, environmental and technical benefits, with Frascati coming out on top. “Today it is Italy that wins,” says ENEA president Federico Testa. “Because it invests in knowledge and sustainable energy with a project that guarantees positive scientific and employment prospects for everyone and, in particular, for young people.”

The ENEA notes that around 1500 people will be involved in building the DTT. The project is funded by €60m from Eurofusion, a consortium of European research organisations, while another €80m will come from the Italian government. The Lazio regional government will supply €25m while China will provide €30m and ENEA partners another €50m. The remaining €250m will come from the European Investment Bank via a loan.

12. Europe’s Investment in the ITER Fusion project: mastering the power of the sun and the stars

https://ec.europa.eu/info/news/looking-back-europes-contribution-iter-over-last-ten-years-2018-apr-12_en

The EU is a strong advocate for sustainability. For years it has been taking action to cut down the emission of greenhouse gases, fighting climate change and trying to make Europe more self- sufficient in the field of energy, given the fact that its import dependency is particularly high for crude oil (90%) and natural gas (69%). Half of the energy we consume is imported at a cost of 1 billion EUR per day. So how can we reconcile our potential to grow without putting at risk our planet's well-being?

The answer lies in the energy mix of the future. And fusion can be part of it. The power of the sun and stars has several merits worth considering. Its fuel- isotopes of hydrogen- is abundant and with just small amounts we can release a lot of energy. Hydrogen the size of a pineapple can offer as much fusion energy as 10 000 tonnes of coal. The fusion reaction is inherently safe and poses no risk of a meltdown. There are no greenhouse gases and no long-lasting waste for the future generations. For this reason, the EU has invested in ITER, the biggest scientific collaboration that will test the feasibility of fusion power.

ITER brings together the countries of EURATOM (EU-28 plus Switzerland), China, Japan, India, the Republic of Korea, Russia and the US. The Parties represent 80% of the global GDP and half of the world's population. Scientists all over the world are involved in R&D activities linked to the project and companies are manufacturing millions of components that will be assembled in Cadarache, south of France, where the project is located.

Europe, being the host of the biggest fusion experiment, is financing nearly half of it. Fusion for Energy (F4E), the EU body which was set up ten years ago to manage the European contribution to ITER, counts with approximately 450 members of staff working in Barcelona (Spain), Cadarache (France) and Garching (Germany). Since its establishment, F4E has invested in Europe's economy 4 billion EUR by awarding more than 900 contracts to 440 companies, research organisations, and to 1500 of their subcontractors, working for the ITER project. Its impact in making Europe more competitive can be widely felt in the socio-economic fabric of our continent. Think of the creation of new jobs and skills, partnerships between big and smaller companies, and the transfer of know-how to develop new applications which could enter into new markets. To find out more about Europe's business potential in ITER and to read the views of some of our contractors click here.

In December 2017, ITER celebrated an important milestone having reached 50% completion of the total construction work needed for the first operation stage – so called First Plasma. The progress on the ITER construction site, which consists of 39 buildings and infrastructures under Europe's responsibility, has been impressive. Nearly 2000 people are working daily on a platform that is nearly 42 hectares. Click here to fly over the site and become familiar with the works carried out. The main building (Tokamak Complex) where the ITER machine will be installed is reaching its final level (fourth floor), and the progress of various auxiliary buildings such as the Cryoplant, which will generate the cold temperatures needed, and the Magnets Power Coversion building, which will energise the powerful magnets that will confine the super-hot plasma, are advancing. More equipment has started arriving on-site. For example, the first tooling has been delivered to the Assembly Hall, and the first Cryoplant tank has been installed.

In terms of manufacturing, Europe has celebrated a fair share of achievements. In the Spring of 2017, the most high-tech magnet in history was unveiled before going through the final stages of production. ITER will require powerful magnets to confine the hot plasma and control its shape and stability. Europe will have to deliver ten Toroidal Field coils and five Poloidal field coils. Works have also been advancing with the production of the vacuum vessel, the “metallic shell” which will host the fusion reaction. Europe is responsible for the fabrication of five sectors entrusted to a consortium of companies. Last but not least, in collaboration with the ITER Organization and Consortium RFX, F4E has invested in a Neutral Beam Test Facility to develop powerful heating systems that will eventually be used to raise the temperature of ITER’s plasma. The most powerful negative ion beam source to date has already been installed in its vacuum vessel and first operations are expected to start in summer.

ITER can be described as a big technology puzzle which will push forward our knowledge frontiers. It will give us the answer regarding the feasibility of fusion energy, its cost and financial return. Ultimately, however, it will help policy-makers take an informed decision on the energy scenarios of the future. Europe’s commitment to see this project through offers our industry and scientific community an unparalleled opportunity to demonstrate its strength, to grow and to learn how to deliver the energy of the future. The challenges we currently face require the broadest possible energy alliance to guarantee our citizens access to safe, sufficient and sustainable power supply. Let’s work together to deliver it!

To keep up to date with the progress of Europe’s contribution to ITER subscribe to F4E News and visit regularly F4E’s website

13. Fusion Research Ignites Innovation

How technologies developed for fusion have taken on second lives in industry.

http://www.newswise.com/doescience/?article_id=692483&returnurl=aHR0cHM6Ly93d3cubmV3c3dpc2UuY29tL2FydGljbGVzL2xpc3Q=

f you’re heating something to 100 million degrees — three times hotter than the core of the sun — oven mitts and aprons aren’t going to cut it. But researchers investigating how to produce fusion energy tackle this challenge every day. Fusion involves combining nuclei from two atoms into one, resulting in a small amount of mass transforming into a staggering amount of energy. Getting that reaction started and containing it requires some of the most high-tech equipment in science.

While sustained fusion power is still years away, several technologies that scientists have developed to research it have already moved beyond the lab. From enabling smartphones to scanning for radioactive materials, technologies originally produced for fusion research supported by the Department of Energy’s (DOE) Office of Science are keeping us safe, secure, and connected.

Enabling Improvements in Semiconductors

When manufacturers needed to make electronics increasingly smaller in the 1990s, turning to fusion researchers may not have been the first thing on their minds. To make electronics smaller, faster, and more powerful, they needed to make semiconductors much smaller as well. The grooves and lines in semiconductors and other components needed to be at the atomic level, more than 100 times smaller than a human hair.

But fusion researchers at DOE’s Oak Ridge National Laboratory (ORNL) knew something industry didn’t — how to control plasma. A separate state of matter from solids, liquids, or gases, plasma is a collection of particles with positive and negative electric charges. It occurs when high amounts of power run through a gas. As it’s chemically very reactive, it interacts readily with almost anything you put it in contact with.

The semiconductor industry wanted to put materials into chambers filled with plasma and use the resulting chemical reactions to strip off or add atoms. In theory, this process would give them the level of control they needed to make miniscule grooves and lines.

Unfortunately, the companies had unpredictable results when they used radio frequency (RF) waves to create the plasma.

“Mother Nature was not kind. It turns out that there are very complex connections between different frequencies of voltages,” said Mark Kushner, a University of Michigan professor and director of the DOE Plasma Science Center there.

Because testing the RF power levels by hand was too complex and time-consuming, they sought outside expertise.

Fortunately, ORNL scientists had been using RF waves to heat up fuel for fusion for more than a decade.

“The government’s here to help you; they can actually help you!” laughed ORNL’s Gary Bell, recalling how manufacturers felt. “We got a big kick out of that.”

Partnering with a consortium of semiconductor manufacturers and suppliers, ORNL researchers evaluated a number of RF power delivery systems and controls. Using knowledge and tools from fusion research, ORNL scientists helped companies reposition components and reprogram controls. They also helped build testing equipment and developed technician training.

“A lot of expertise that came in was developed through magnetic fusion energy research, through the people and understanding of plasma science,” said Amy Wendt, a professor at the University of Wisconsin-Madison and a member of DOE’s Fusion Energy Sciences Advisory Committee.

Modifying how they produced semiconductors allowed manufacturers to fit more components onto computer chips than ever before. Those improvements and others using plasma made it possible for companies to build smaller, lighter, more efficient cell phones, tablets, and computers.

Launching Jets From Aircraft Carriers

While smartphone components are some of our smallest technologies, fusion research has also set the stage for improving some of the world’s biggest ones: aircraft carriers.

In the 1990s, the Department of Defense (DOD) realized that they could do better than the steam and hydraulic-powered catapults on aircraft carriers in use at the time. So they released a request for proposals for a technology that could store a huge amount of energy and release it almost instantaneously — over and over again.

Researchers at the DIII-D National Fusion Facility, an Office of Science user facility run by General Atomics (GA), were familiar with those challenges. In fact, they had to solve a similar problem back in 1978 before they could get a new iteration of their reactor up and running.

“GA is in a unique position to drive technology innovations, given its long history of using scientific research results to develop cross-cutting practical applications,” said John Rawls, chief scientist at GA.

To control the 100-million-degree plasma inside of it, the DIII-D reactor produces huge magnetic fields. The machine creates and maintains these fields by running tremendous amounts of energy through giant magnets. When GA scientists designed the machine with funding from the Office of Science’s predecessor in the 1970s, they developed the controls and inverters to release and control those bursts of energy.

Based on that expertise and existing technology, DOD chose GA to develop the Electromagnetic Aircraft Launch System (EMALS). This system speeds an aircraft down the deck of a carrier using a linear induction motor coupled to the same type of inverters that provided such precise electrical and magnetic control at DIII-D. The performance of the induction motor can be finely controlled to deliver the precise amount of acceleration and velocity necessary to launch an aircraft of a specific size and weight. Because it’s much more precise than previous systems, EMALS minimizes the physical stress put on the aircraft, increasing their lifespans, and reducing costs.

Today, the U.S. Navy is using EMALS on the USS Gerald R. Ford (CVN 78). It is also installing EMALS on all future Ford-class aircraft carriers.

“We were able to advance numerous first-of-kind technologies, including the creation of the world’s most powerful linear motor and new inverter drives, to produce an integrated EMALS system that has a smaller footprint, greater efficiency, and requires less manning and maintenance to help save costs and improve reliability,” said Scott Forney, president of General Atomics Electromagnetic Systems. “To top it off, we offer a flexible design that has the potential for installation on other platforms requiring different catapult configurations and aircraft support.”

Developing New Materials for Extreme Conditions

Fusion reactions create some of the most high-stress environments in the universe. The materials used in reactors must withstand staggeringly high pressures, temperatures, and radiation.

“We’re taking materials outside their usual comfort zone,” said Steven Zinkle, a University of Tennessee professor with a joint appointment at ORNL.

The plasma bombarding a fusion reactor’s walls can remove and re-deposit a single atom a billion times a year. Through it all, the walls need to stay tough, maintain stability, and absorb as little radiation as possible in a very stressful environment for building materials.

“If you’re going to make a fusion reactor work, it’s all about the materials,” said Bell.

To build a better reactor, ORNL researchers helped develop a new type of stainless steel that could resist temperatures up to 1560 degrees F.

It turns out that fusion researchers weren’t the only ones who needed steel that could withstand extremely high temperatures. Because advanced diesel engines run hotter than conventional ones, they needed advanced materials to match. ORNL’s materials group realized that this new steel could meet that challenge. After the Office of Science’s fusion group completed the basic research, DOE’s Vehicle Technologies Office took it over, supporting an agreement between ORNL and equipment manufacturer Caterpillar to adapt the material for vehicles. In 2007, Caterpillar started using it in all of their heavy-duty highway truck engines. Since then, the material has generated millions of dollars of revenue.

Even the best steel isn’t tough enough for fusion reactors’ inner walls. To provide further protection, ORNL developed radiation-tolerant silicon carbide ceramic composites. These composites can survive temperatures of up to 2700 degrees F.

Recognizing the potential of this material, NASA and other agencies supported further design and processing research on these composites. In rocket nozzles, thrusters, gas turbines, and even conventional nuclear reactors, this material can now simplify components and increase efficiency.

While national laboratories often develop these innovative materials, they also provide equipment and expertise that enable private companies to do so as well. Using tools developed for fusion research at DOE’s Princeton Plasma Physics Laboratory (PPPL), Lenore Rasmussen found a way to use plasma to improve the attachment of her Synthetic Muscle™ technology to metal electrodes. She also used the laboratory’s resources to test the material’s resistance to extreme temperatures and radiation. Since then, NASA has tested how well the material resists radiation on the International Space Station. Rasmussen is now working to commercialize the technology. In the future, companies may use it in prosthetic limbs and robotics.

Detecting Radioactive Materials for Security

Building a fusion reactor is hard enough. Retiring it can be even tougher. Charles Gentile and his colleagues at PPPL faced this dilemma in 1999. They needed to decommission the lab's Tokamak Fusion Test Reactor that had been running for more than a decade.

Staff first needed to identify radioactive elements in the vacuum vessel, the container that housed the fusion reactions. So they created a portable detection unit to collect data, as well as software to process that data. After they finished disassembling the reactor, the technology sat on the shelf.

But in 2001, they saw the opportunity for their invention to have a second life. The federal government had put out a call for technologies that could have applications in homeland security. The team determined that their device had the potential to accurately identify in real time radionuclides that might be used in "dirty" bombs. With a $400,000 grant from the U.S. Army, PPPL staff adapted their technology. They revised it so it could run in any weather, be used by non-nuclear scientists, and detect a wider array of radioactive substances.

Now, the Miniature Integrated Nuclear Detection System is a combination hardware and software system that's the size of a thermos. In one second, it can sense one-billionth of the material needed to build a credible dirty bomb. It can scan moving vehicles, luggage, packages, and cargo for more than 20 different types of radioactive substances. So far, security firms have used it at a major bus and commuter rail center as well as major U.S. ports.

As fusion technology advances, the work that goes into it will continue to yield unexpected benefits.

As Gentile said, "It's nice that we do have these technologies that come out of the laboratory that can help people in other areas."

The Office of Science is the single largest supporter of basic energy research in the physical sciences in the United States and is working to address some of the most pressing challenges of our time. For more information please visit https://science.energy.gov.

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14. 9 APRIL 2018

Why fusion?

Robert J. Goldston

https://thebulletin.org/why-fusion11667

The 2014 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report included publication on the web of a wide range of scenarios for the future, produced by energy and environment modelers from all over the world. If we select an internationally coordinated set of scenarios that are consistent with a temperature rise of less than 2 degrees Celsius (3.6 degrees Fahrenheit) above the pre-industrial era—the upper-limit goal of the Paris Climate Accords—and average their projections, we find the projection for future electricity production in the table below, shown in units of annually averaged gigawatts electrical <GWe>.

IPCC Projected Worldwide Annually Averaged Electrical Power Production <GWe>

	2020	**2050**	**2100**
Solar	30	650	3720
Nuclear	400	1120	2230
Wind	150	930	2170
Biomass	40	540	1500
Hydro	410	640	850
Coal + Oil	920	860	770
Gas	780	980	620
Geothermal	30	84	100
Total	2770	5800	11900

This IPCC-based mean scenario relies heavily on solar and wind, which vary strongly on a daily and seasonal basis. By the time these intermittent energy sources become dominant, later in the century, we may well have developed the capability to mitigate their daily variation using energy storage. Seasonal variation, however, is hundreds of times harder to compensate, and it is difficult to imagine how this can be done effectively. As solar and wind grow in scale they will need to occupy sites with higher variability, and when they become a large fraction of the energy supply, later in the century, the costs associated with their variability will grow.

The IPCC scenario also relies heavily on nuclear fission power, which carries with it well-known risks associated with safety, waste storage, and nuclear weapons proliferation. By later in the century, this scenario burns all of the world's reported identified, predicted, and speculative uranium resources. While other resources may become available, the scale of this uranium use, coupled with its uneven distribution, is likely to cause growth in the use of reprocessing technology and plutonium fuel, significantly increasing proliferation risks. Another concern is the implied requirement for geological waste storage in the absence of reprocessing, expected to be about 50 facilities with the capacity of Yucca Mountain.

Biomass, while somewhat smaller than the others listed above it, is equally important because it is assumed to provide a net sink of carbon dioxide. Vegetation extracts carbon from the atmosphere as it grows, and if much of the CO2 produced from its combustion can be captured and stored, then the overall system forms a net sink. The biomass in the IPCC scenario, however, requires using land equal to about 75 percent of all the land that is currently employed by agriculture, at a time when world food consumption is projected to more than double and the competition for water grows. The very large scale of the biomass CO2 that would need to be sequestered from the environment—for hundreds of years, in varying geological conditions—is far beyond our experience. The possibility of burning coal, oil, and gas into the future also depends on carbon capture and storage on a massive scale, in a broad range of geologies.

Consequently, solar and wind have a common limitation in most parts of the globe: seasonal variability. Meanwhile, biomass, coal, oil, and gas share a common risk—the practicality of very large-scale carbon storage worldwide. And nuclear fission introduces risks associated with safety, radioactive waste, and nuclear proliferation. These energy sources all need to be pursued vigorously to determine the degree to which their limitations, risks, and problems can be overcome at the unprecedented scale required.

In contrast, fusion energy can offer an attractive alternative. Fusion is a continuous energy source; it does not face the same safety, waste, and proliferation issues as fission; it does not require disproportionate land use; and it does not depend on the success of carbon capture and storage. Fusion can come on line later in the century, as electric power needs double between 2050 and 2100, and as the scale of electricity production puts strong pressure on the issues for other energy sources.

What sets the timescale for fusion development? Until recently, the answer has been the science. The very hot gas, called plasma, that supports fusion is tricky, and it has taken time for scientists to understand its behavior. In that time we have made immense strides. We are now able to accurately calculate, predict, and control key aspects of the behavior of fusion plasmas. We know how to heat plasmas to fusion temperature, we know how plasmas confine the heat put into them, and we know how the heat flows out. We also know how the precious tritium that is used to fuel a fusion power system circulates, and we have demonstrated that fusion devices with metallic walls retain very little of it.

There is room for innovation and improvement, but the basic outlines of how a fusion power system can work are now well-known. We have already made plasmas where we pour in 25 million watts of heating power, and an additional 16 millions watts of heat from fusion pours out. An international coalition comprised of China, Europe, India, Japan, Russia, South Korea, and the United States is building the ITER project in southern France, whose goal is to produce 500 million watts of fusion heat, ten times its input of only 50 million watts of heating power. For a practical fusion power system, this ratio needs to be increased from 10 to about 25, due to the inefficiencies of turning electricity into plasma heating, and then fusion heat into electricity. That step is left for the first fusion pilot plants to follow ITER.

It is fair to ask, why can't we have fusion sooner? The answer is that these systems are intrinsically large; you cannot test the physics and technology of fusion on a lab bench and then mass-produce fusion systems, as you can solar cells. Consequently, as we are now approaching systems on the scale of power plants, they are large, first-of-a-kind facilities, and they take time to construct. The only way that we have been able to assemble the financial resources to construct the ITER project is through international collaboration. But after ITER, the next facilities will likely be national fusion pilot plants, which will use the physics and technology developed from ITER to put net electricity onto the grid (subtracting out the energy required to operate the plant). China, Europe, and South Korea each have well-developed plans to do this. The United States should as well. Such plans put fusion on the path to supporting the continuing growth in world electricity supply as it is needed.

One author has questioned in these pages whether fusion can be an attractive energy source. Of course fusion will not be magical, but the questions raised by Daniel Jassby have answers. Fusion will require cooling like any heat-based energy source such as biomass, coal, and fission. Furthermore, fusion systems will use a fraction of their own energy production to sustain their operation—like any energy system equipped with carbon capture and storage, which uses a significant fraction of its power production to operate the capture and storage technologies. Some fusion power plant designs use liquid lead as a coolant, which is much more efficient than water and steam, and so requires reduced cooling to produce a given amount of electricity.

Fusion neutrons will surely damage the internal components closest to the plasma. In the first fusion pilot plants, materials in the regions with the highest neutron flux would need to be replaced every 6-to-12 months of full-power operation. There are options for new nano-structured materials that are more neutron-resistant. These can be developed and qualified for fusion application using computer simulations and small-scale tests, as well as tests in the pilot plants themselves and in follow-on fusion power sources, as was done for fission. Fusion will have nuclear waste, but the lifetime of this waste will be measured in decades, not millennia. Fusion neutrons can in principle be used to breed fuel for weapons. But because no breeding materials should be present in a fusion power plant, this will be much more straightforward to detect and deter, as compared with fission reactors where the production of large quantities of weapons-usable material is intrinsic to the process.

The first fusion power plants will be expensive, but one can expect that as the technology matures, costs will come down. The major safety issues that have driven up the cost of fission power plants over time are not present for fusion. In sum, while fusion energy is not magical, it has the potential to be an attractive energy source that can be deployed as major pressures rise on existing energy supply options.

It is encouraging that a number of start-up companies are now investing in fusion. They are looking for breakthrough paths to fusion energy, and every breakthrough—scientific or technological—is welcome, not to mention the contributions possible from the breadth of scientific enquiry they support.

It is not very likely, however, that these small, high-risk private ventures will come to fruition before the work of the world's large, open scientific research community. Venture capital firms generally make their profits by supporting multiple high payoff, but low probability, undertakings. Even so, the recently announced initiative by a private company associated with the Massachusetts Institute of Technology is potentially very helpful as it may open a path to reducing the size of fusion energy systems following on ITER's results, through more advanced magnet technology based on new high-temperature superconductors.

So, what is the answer to "Why fusion?" The choice of the energy sources that will power human development throughout this century is extraordinarily important. And the cost of developing fusion is tiny compared to the size of the world's energy economy. It is indeed far smaller than the subsidies provided by governments for existing energy sources. Fusion should be developed as a practical and attractive alternative, to become available at scale as other energy sources face major limitations, risks, and problems that may constrain their growth. We owe our children and grandchildren both the opportunity for further human development based on access to energy, and also the same lovely, green planet we inherited from our parents and grandparents.

Editor's note: A year ago, the Bulletin *published an article about the drawbacks of fusion as an energy source,"Fusion reactors—Not what they're cracked up to be," written by a physicist who had spent 25 years at the Princeton Plasma Physics Lab studying plasma physics and neutron production related to fusion energy research and development. The article garnered more than 100 reader comments and stirred up intense debate—so much so, that we asked the author, Daniel Jassby, to revisit the topic a few weeks ago, in "ITER is a showcase... for the drawbacks of fusion energy."*

15. Why nuclear fusion is gaining steam – again

April 9, 2018 8.42pm AES
Scott L. Montgomery
https://theconversation.com/why-nuclear-fusion-is-gaining-steam-again-93775

Back when I studied geology in grad school, the long-term future of energy had a single name: nuclear fusion. It was the 1970s. The physicists I studied with predicted that tapping this clean new source of electric power by forcing two nuclei of hydrogen to combine and release massive amounts of energy, might be 50 years off.

Four decades later, after I'd left my career of research and writing in the energy industry and begun a second career as an author and a professor, I found myself making this same forecast with my own students and readers. In what had become an ironic cliché, fusion, it seemed, would forever haunt a distant horizon.

That seems to be changing, finally.

Thanks to advances in physics research, materials science and supercomputing, scientists are building and testing multiple fusion reactor designs. About a dozen fusion startups with innovative ideas have the private investment they need to see what they can achieve. Still, it's too early to break out the champagne, and not only for technical reasons.

Underwhelming breakthroughs

One problem is that a breakthrough in the lab doesn't guarantee innovation or success in the marketplace because energy is very price sensitive. Also, fusion illustrates how few things can erode faith in a new technology like an imminent "breakthrough" that fails to materialize.

First, there was the cold fusion debacle in 1989, when two scientists went to the media with the unverifiable claim they had achieved room-temperature fusion and were ostracized by the scientific community, sullying the image of this energy source as a real option.

Then, scientists hit a milestone in 1994 when the test fusion reactor at Princeton set a new record for peak power of 10.7 megawatts, which The New York Times said at the time was "enough to power 2,000 to 3,000 homes momentarily, meaning roughly a microsecond. Scientifically, that event had great importance, though it was topped in 1997. Yet it hardly promised a power reactor just around the corner.

Along the way, the tendency of scientists and journalists to hype real progress toward fusion, whether it's to attract funding or readers, has undercut public support in the long run.

Today, in fact, various media reports continue to suggest a rash of fusion breakthroughs.

Real advances

Has there truly been some progress? To an impressive degree, yes. But mostly in terms of scientific and engineering research. If there is yet again another claim announcing that the world is now finally closing in on the solution to all energy problems, then myth is being sold in the place of truth.

Many scientists are drawn to both fission, the power source in today's nuclear reactors, and fusion, because of the spectacular amount of energy they offer. The main fuel for fission, Uranium-235, has 2 million times the energy per pound that oil does. Fusion may deliver up to seven times that or more.

The fuel used for fission is extremely abundant. The same goes for fusion, but without any long-lived dangerous waste. For fusion, the fuel is two isotopes of hydrogen, deuterium and tritium, the first of which can be extracted from seawater and the second from lithium, whose resources are large and growing.

Hence, the failure to pursue these colossal non-carbon sources might well appear to be colossally self-defeating.

Fusion is hard to harness, though. In stars, which are made of plasma, a high-energy state of matter in which negatively charged electrons are completely separated from positively charged nuclei, fusion takes place because of immense gravitational forces and extreme temperatures.

Trying to create similar conditions here on Earth has required fundamental advances in a number of fields, from quantum physics to materials science. Scientists and engineers have made enough progress over the past half century, especially since the 1990s, to make so that building a fusion reactor able to generate more power than it takes to operate seems viable within two decades, not five. Supercomputing has helped enormously, allowing researchers to precisely model the behavior of plasma under different conditions.

Reactor types

There are two reasons to be optimistic about fusion right now. Two big fusion reactors are built or being built. And fusion startups aiming to build smaller reactors, which would be cheaper, easier and quicker construct, are proliferating.

One of the two big reactors is a donut-shaped tokamak – a Russian acronym for a Soviet invention made in the 1950s that was designed to confine and compress plasma into a cylindrical shape in a powerful magnetic field. Powerful compression of the deuterium-tritium plasma at extremely high temperatures – as in about 100 million degrees Centigrade – causes fusion to occur.

ITER (Latin for "the way”) is a collaboration between the European Union and the governments of India, Japan, South Korea, Russia, China and the U.S. This consortium is now spending more than US$20 billion to build a giant tokamak in southern France. By 2035, it’s slated to generate 500 megawatts while operating on just 50 megawatts. Meeting that goal would essentially confirm that fusion is a feasible source of clean energy on a large scale.

The other is a more complex, twisted donut stellarator, called the Wendelstein 7-X, built in Germany with the same objective. Bends in its chamber twist the plasma so that it has a more stable shape and can be confined for greater lengths of time than in a tokamak. The 7-X cost about $1 billion to build, including site expenses. And if things go according to plan, it might be able to generate a significant amount of electricity by about 2040.

Meanwhile, nearly a dozen startups are designing new kinds of reactors and power plants they say can come online long before and far more cheaply – even if the requisite technology isn’t there yet.

For example, Commonwealth Fusion Systems, an MIT spin-off still tied to the university’s Plasma Science and Fusion Center and partially funded by the Italian oil company Eni, aims to create especially powerful magnetic fields to see if fusion power can be generated with smaller-sized tokamaks.

And General Fusion, a Vancouver-based venture Amazon founder Jeff Bezos is backing, wants to build a big spherical reactor in which hydrogen plasma would be surrounded by liquid metal and compressed with pistons to cause a burst of fusion. Should that work, this energy would heat the liquid metal to generate steam and spin a turbine generator, producing massive amounts of electricity.

Rich enough

With lean operations and clear missions, these startups are nimble enough to move rapidly from drawing board to actual construction. In contrast, multinational complications are costing ITER time and money.

Since future energy needs will be vast, having different fusion options available could help meet them however long they take. But other sources of non-carbon power are available.

That means fusion proponents must convince their funders around the world it is worth continuing to support this future option when other non-carbon sources, like wind and solar power (and nuclear fission – at least outside the U.S., Japan and the European Union) are scaling up or expanding. If the question is whether it's worth making a big bet on a new non-carbon technology with vast potential, then the rapid growth of renewable energy in recent years suggests they were the better gamble.

Yet if the roughly $3.5 trillion invested in renewable power since 2000 had all backed fission, I believe the advances in that technology would have led all remaining coal- and oil-fired power plants to have disappeared from the face of the Earth by now.

And if that same money had instead backed fusion, perhaps a working reactor would now exist. But the world's wealthy nations, investment firms and billionaires can easily support fusion research and experimentation along with other options. Indeed, the dream of fusion power now seems certain to neither die or remain merely a dream.

16. Fuel loading under way at Chinese EPR

11 April 2018
http://www.world-nuclear-news.org/NN-Fuel-loading-under-way-at-Chinese-EPR-1104184.html

China General Nuclear (CGN) has begun loading fuel into the core of unit 1 of the Taishan nuclear power plant in China's Guangdong province following the issuance of a permit from the regulator. The unit is later this year scheduled to become the first EPR reactor to enter operation.

CGN said the Taishan Nuclear Power Joint Venture Company - a joint venture between CGN (70%) and EDF (30%) that owns the plant - was issued with the permit yesterday afternoon in Beijing by Liu Hua, vice minister of ecology and environmental affairs and director of the National Nuclear Safety Administration (NNSA).

In a statement the NNSA said that, before the first loading of materials, it had conducted a five-year safety review of the Taishan nuclear power project and dispatched on-site supervisors for the entire construction process. The project meets the design safety goals and the construction quality is good, it added.

Operations to load the first fuel assembly into the core of Taishan 1 began at 8.18pm, CGN said.

Taishan 1 and 2 are the first two reactors based on the EPR design to be built in China. They form part of an EUR8.0 billion (USD9.9 billion) contract signed by Areva and CGN in November 2007. Construction of unit 1 and 2 began in 2009 and 2010, respectively.

Taishan 1 is expected to start up later this year, while Taishan 2 - which is in the equipment installation phase - is scheduled to begin operating next year.

The first-of-a-kind EPR at Finland's Olkiluoto plant has been under construction since 2005 and has seen several revisions to its start-up date, with grid connection now scheduled to take place in December and the start of regular electricity production in May next year. Fuel loading at the Flamanville EPR in France, construction of which began in 2007, is expected to begin the fourth quarter of this year. Two further EPRs are planned at Hinkley Point in the UK.

Researched and written
by World Nuclear News

17. Another Japanese unit resumes commercial operation

10 April 2018

http://www.world-nuclear-news.org/C-Another-Japanese-unit-resumes-commercial-operation-1004185.html

Unit 3 of the Ohi nuclear power plant in Japan's Fukui Prefecture today resumed commercial operation, Kansai Electric Power Company announced. The reactor is the sixth to be restarted after clearing the country's revised safety regulations.

Following the shutdown of all of Japan's reactors after the March 2011 accident at the Fukushima Daiichi plant, Ohi 3 and 4 were given permission to resume operation in August 2012. However, the two 1180 MWe pressurised water reactors (PWRs) were taken offline again for Nuclear Regulation Authority (NRA) inspections in September 2013.

The NRA announced in May 2017 that the two units meet safety standards introduced in July 2013. The NRA approved Kansai's plan for strengthening the units in August last year. The regulator subsequently conducted pre-operation inspections of the units to confirm that the safety countermeasure equipment complies with the approved construction plan at the plant. The governor of Fukui Prefecture approved the restart of Ohi units 3 and 4 in November.

Kansai began loading the 193 fuel assemblies into the core of unit 3 on 9 February, completing the process on 13 February. The reactor was restarted on 14 March and attained criticality - a sustained chain reaction - the following day.

Kansai announced that Ohi 3 resumed commercial operation at 4.40pm today after completion of the final periodic outage inspection - the integrated plant performance test - by the NRA.

Kansai President and Director Shigeki Iwane said, "Taking this opportunity, I would like to express my sincere gratitude, in particular to members of the public in the host region, for deep understanding and generous support toward restart of the plant." He added, "We are committed to exerting every possible effort to gain more trust and understanding in the importance and safety of nuclear power generation from members of the public while making steady steps forwards to achieve and maintain safe plant operation after restarting operation."

Ohi 3 is the sixth of Japan's 42 operable reactors which have so far cleared inspections confirming they meet the new regulatory safety standards and have resumed operation. The others are: Kyushu's Sendai units 1 and 2; Shikoku's Ikata unit 3; and Kansai's Takahama units 3 and 4. Another 18 reactors have applied to restart.

Kansai began loading the fuel assemblies into the core of Ohi unit 4 yesterday. It expects to restart that unit around mid-May.

Kyushu Electric Power Company expects to restart both units 3 and 4 at its Genkai nuclear power plant in Saga prefecture later this year.

Researched and written
by World Nuclear News