Fact Sheet

International Progress on Fusion Energy

How American Leadership is Slipping

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Introduction

In the past half-century, significant advances have been made in attempting to harness fusion for energy.

From the construction of the first fusion "tokamak" device, built in Novosibirsk in 1968 to current state-of-the-art facilities like the National Ignition Facility (NIF), operational at Lawrence Livermore National Laboratory in California since 2009, to the next-generation projects like the Wendelstein 7-X project in Germany, scheduled to begin operation in 2014, fusion research is attempting to turn scientific theory into a technological reality.

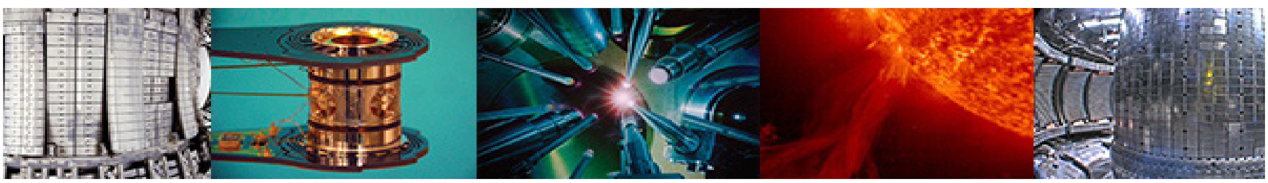
It is thus no surprise that more and more countries are investing in fusion power.

The United States has traditionally played a leading role in fusion power research and development. The skill and knowledge of America's fusion scientists are second to none. However, without new investment, there is a danger that America's role as a leader in fusion power research is slipping as other countries seek to develop fusion.

Currently, the most modern and advanced research machines are located outside of the United States. In less than a decade, America's competitors will have more facilities that are a generation ahead of those in the United States. We are in danger of ceding scientific and intellectual leadership in the field of fusion power.

This fact sheet will examine fusion power capabilities across the world.

Several countries in particular—Germany, France, Russia, China, Japan, and South Korea—are making significant investments into fusion power. These countries have ambitious plans for fusion power development, and they are investing significant time and money into these projects.

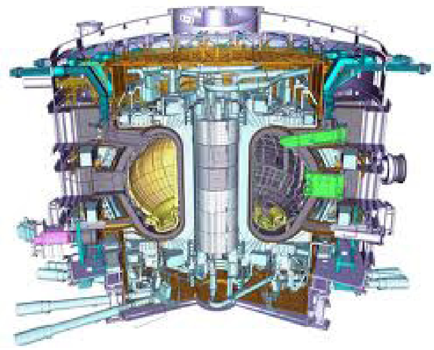


The European Union

Though not a country, the European Union is a leading entity to help finance and develop a number of fusion projects throughout Europe.

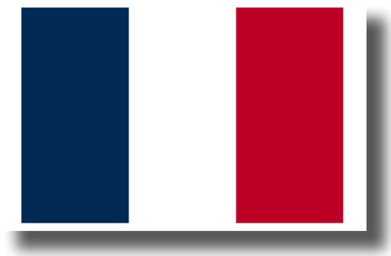
International Thermonuclear Experimental Reactor (ITER)

- Located in Cadarache, France, ITER is a magnetic confinement fusion project that is being funded and developed by the EU, China, South Korea, Japan, Russia, India, and the United States. Its estimated cost is 13 billion Euros.[1]
- Out of 13 billion Euros, 45% is financed by the EU, and the other 55% is split equally between the remaining six countries.
- The lion's share (an estimated 90%) of contributions will be delivered "in-kind." That means that in the place of cash, the Members will construct and deliver components and buildings directly to the ITER Organization.[2]
- The U.S. is a full partner, and by leveraging only a 9% contribution, American scientists will benefit from all the scientific and engineering experience gained from the ITER experiment.



The proposed ITER design. Source: http://www.iter.org

France



France is a leading country for fusion research and it is the site of the ITER project. In addition, the French military is developing laser fusion for the purposes of weapons research.

Laser Megajoule (L.M.J.)

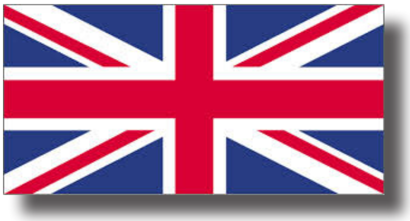
- Located in Bordeaux, the French Commissariat a l'Energie Atomique (CEA) operates the 240-beam Laser Megajoule project.[3] It is similar to the NIF project in the United States.[4]
- Its main purpose is to guarantee the safety and reliability of French nuclear weapons. Construction began in 2002.
- The project costs about 1.5 billion Euros. Once operational in 2014, Laser Megajoule will focus on producing high energy targets and ultimately obtain ignition.[5]

The Laser Megajoule Project. Source: http://www.ifsa11.org/ifsa_pictures/site/image/LMJ-tour-big.jpg

Tore Supra

- Located in Cadarache, Tore Supra is a joint CEA-European Atomic Energy Community (EURATOM) project.
- The Tore Supra reached first plasma in 1988. It holds the world record for plasma discharge time, lasting six and a half minutes.[6]

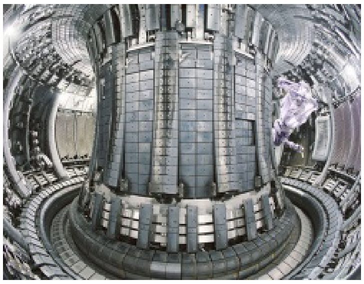
The United Kingdom



The UK has a long history in fusion research, dating back to the 1920s.

The UK hosts the Joint European Torus, which is one of the world's most important tokamaks.[7]

Joint European Torus (JET)

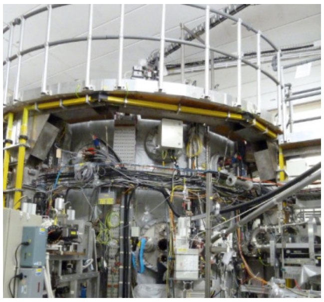


The Joint European Torus. Source: http://www.ccfe.ac.uk/introduction.aspx

- Located in Oxfordshire, JET is currently the largest and most powerful tokamak in the world. It began operating in 1983 and has since been upgraded.
- Some of the milestones at JET have included the world's first controlled release of deuterium-tritium fusion power (1991) and the world record for fusion power (16 megawatts in 1997).[8]

Mega Amp Spherical Tokamak (MAST)

- Also located in Oxfordshire, MAST is a spherical tokamak.
- Along with NSTX – a complementary experiment at the Princeton Plasma Physics Laboratory – MAST is one of the world's two leading spherical tokamaks (STs).



The Mega Amp Spherical Tokamak. Source: http://www.fusenet.eu/node/234

Russia

Russia has played an important role in fusion research, dating to Soviet-era atomic weapons and energy research.

In 1968, Russian scientists made a key breakthrough in fusion technology with the successful creation of the tokamak (a Russian acronym).[9]

Russia continues to play a leading role in fusion research. Its contributions to the ITER project are important – Russia alone is responsible for 20% of the superconductors required.[10]

Additionally, Russia has a fusion project being jointly developed with Italy and is also developing a large domestic inertial confinement fusion project.

Ignitor

- Located in Troitsk, Ignitor is a tokomak collaboration between Russia and Italy.
- Ignitor's stated goal is to obtain "ignition," the point at which energy production is self-sustaining, without the need of an external energy source.
- The Ignitor project is based on the approach taken by MIT's Alcator C-Mod, using high magnetic field intensity to confine plasma.[11]
- Construction on the reactor is projected to be completed in 2014.[12]

Fusion Laser at the Research Institute of Experimental Physics

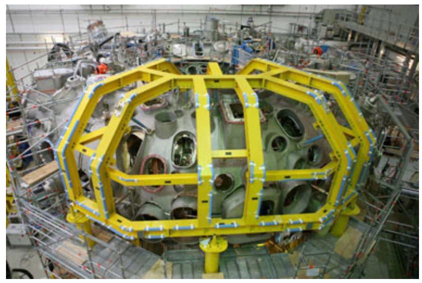
- This proposed project is a $1.5 billion laser at Research Institute of Experimental Physics. Russian media outlets claim that this inertial confinement facility will be the best in the world.
- With a capability of delivering 2.8 megajoules of energy, the Russian inertial fusion facility will surpass the capabilities of American facilities.[13] Plans are not widely available.

Germany

The Max Planck Institute for Physics oversees Germany's domestic fusion projects. Germany manages two significant fusion facilities: a stellarator and a tokamak.

Wendelstein 7-X

- Located in Greifswald, the Wendelstein 7-X is a stellarator that will begin operation in 2014.
- It is the successor to the Wendelstein 7-A project, which operated from 1988 to 2002.[14]
- A stellarator is different than a tokamak in that it could be better at producing a stable, confined plasma.
- Its goal is to produce 30-minute electrical pulses; no timetable is given. Funding is provided by the EU and Germany.[15]

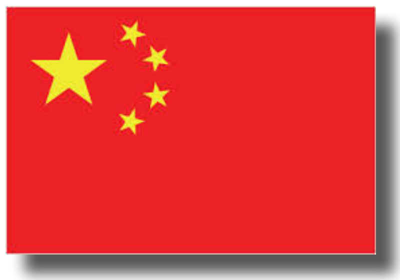


The Wendelstein 7-X. Source: http://www.ipp.mpg.de/ippcms/de/presse/pi/images/15_11_3.jpg

Axially Symmetric Divertor Experiment (ASDEX) Upgrade

- Located in Garching, the ASDEX Upgrade went into operation in 1990. It is Germany's largest fusion device.[16]
- ASDEX's purpose is to study the interaction between plasma and the confining walls of a tokamak.[17]

People's Republic of China



Since purchasing and remodeling the HT-7 superconducting tokamak from Russia in the early 1990s, China has made rapid strides in its fusion energy program. In 2011, the Chinese Government committed to training 2,000 fusion experts during the next ten years.[18]

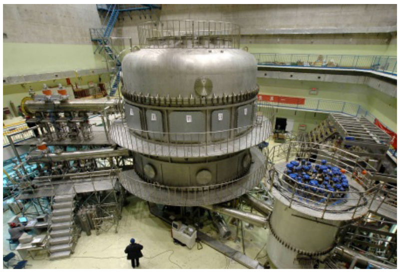
China is currently a contributor to the ITER project and it has two major domestic fusion projects underway.

Experimental Advanced Superconducting Tokamak (EAST)

- Located in Hefei, EAST was designated a "Mega Project of Scientific Research" in June 1997 by the Chinese government.
- Construction of the EAST tokamak was completed in 2006. It is the world's first fully superconduct-

ing tokamak.[19]

- The purpose of EAST is stated to be exploring various ways of creating fusion for energy. These include ensuring steady-state operation of the reactor using high-performance plasma and investigating tokamak physics.[20]

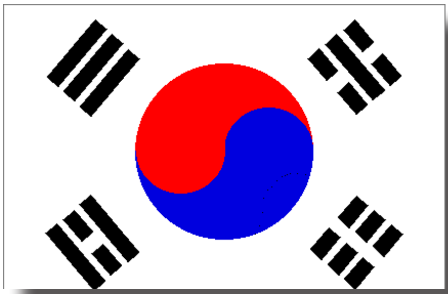


The Experimental Superconducting Tokamak. Source: http://capetown.china-consulate.org/eng/zt/nd/nd2007/W020071008813442348017.jpg

Shenguang Laser Series (SG)

- Located in Shanghai, the SG Laser Series is an inertial confinement program – similar in nature to NIF and Laser Megajoule – with a stated goal of obtaining fusion ignition by 2020.[21]
- There are three successive variations. Each one has shown improvements in laser technology. The SG-II has provided about 1,000 shots of laser beam energy since 2000.[22] The SG-III, completed in 2010, has a laser energy output of 150 kilojoules.[23]
- The SG-IV – intended to prove fusion ignition – is on schedule for completion before 2020.[24]

South Korea



The development of fusion energy is a high priority for the South Korean government. South Korea contributes to the ITER project, and currently has two major domestic fusion projects underway.

Korea is jumping ahead of its competitors by outlining the K-DEMO project, a full-scale demonstration fusion reactor which will begin operation by 2037.

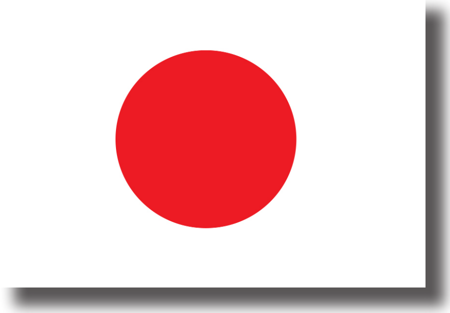
South Korea has a detailed roadmap on development of K-DEMO, including proposed test facilities, a research and development plan, and a timeline of expected progress from 2012-2021.[25]

Korea Superconducting Tokamak Advanced Research (KSTAR)

- Located in Daejon, construction of KSTAR began in 1995, with the purpose of achieving steady state-operations with high-performance plasmas.[26] It is one of the first tokamaks in the world to use fully superconducting magnets.[27]
- The first phase (2008-2012) focused on developing operational capabilities that could sustain energy with a short electrical pulse.[28]
- KSTAR incorporates some of the most advanced plasma heating technologies, and one of its goals is to sustain 300 seconds of steady-state plasma operation by 2015.[29]

The Korea Superconducting Tokamak Advanced Research. Source: http://www.efda.org/wpcms/wp-content/uploads/2011/09/Kstar.jpg?5c1bd2

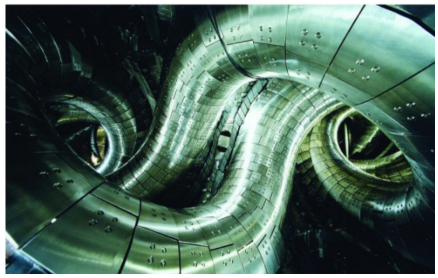
Japan



Japan, lacking natural resources and increasingly wary of nuclear fission, may see fusion as an opportunity.

Japan has developed a research plan for its fusion projects, and it is currently working on three major fusion projects. The Japan Atomic Energy Association (JAEA) also offers a timeline of Japanese fusion experiments.[30]

Large Helical Device (LHD)



The Large Helical Device. Source: http://www.differ.nl/en/node/2612

- Located in Toki, the Large Helical Device (LHD) is a superconducting stellarator, a magnetic device used to confine plasma. It is the world's largest helical fusion device.
- After the successful production of the first plasma in 1998, LHD's mission has been to increase the strength of the magnetic confinement field.[31]

JT-60 Super Advanced (SA)

- Located in Ibaraki Prefecture, the JT-60SA is an upgrade over Japan's JT-60 tokamak fusion device, which first became operational in 1985.
- The JT-60SA is being jointly constructed by the Japanese Atomic Energy Association and EURATOM.[32] With a 3 meter radius, it is one of the largest tokamaks in the world.
- The start date has yet to be finalized by Japan and the European Union, but is expected within this decade.[33]

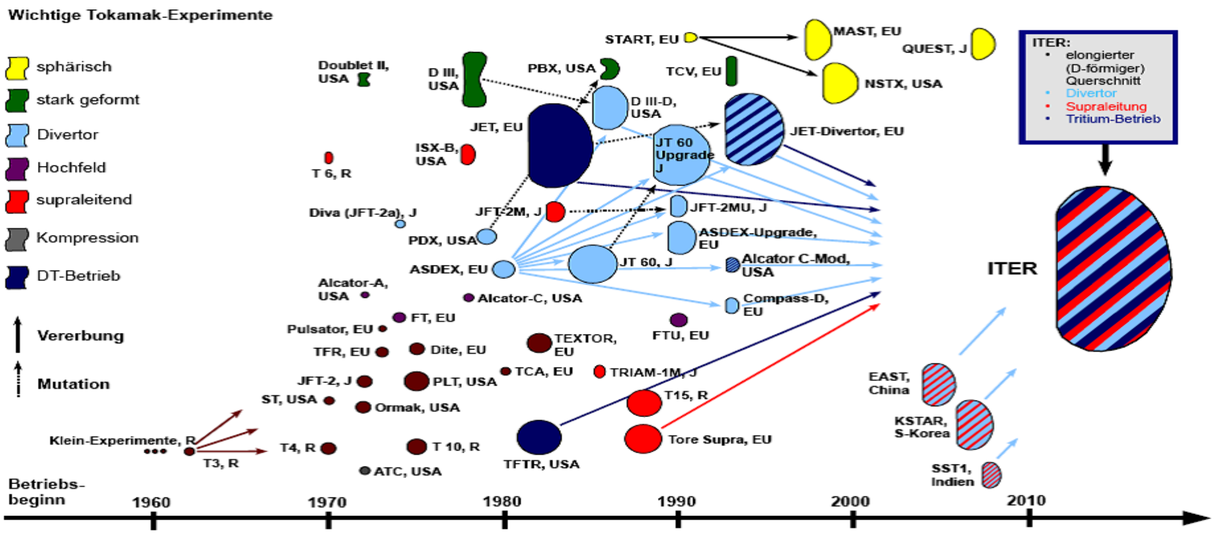
Fast Ignition Realization Experiment (FIREX)

- Located in Osaka, the FIREX project is a part of Japan's inertial confinement fusion program. This project began construction in 2003, and by 2009 FIREX conducted experiments at full power.[34]
- While not as energetic as NIF or Laser MegaJoule, Japan has ambitious plans to learn from these experiments and build a next-generation inertial fusion facility, with a goal of generating electricity by 2030.[35]

Conclusion

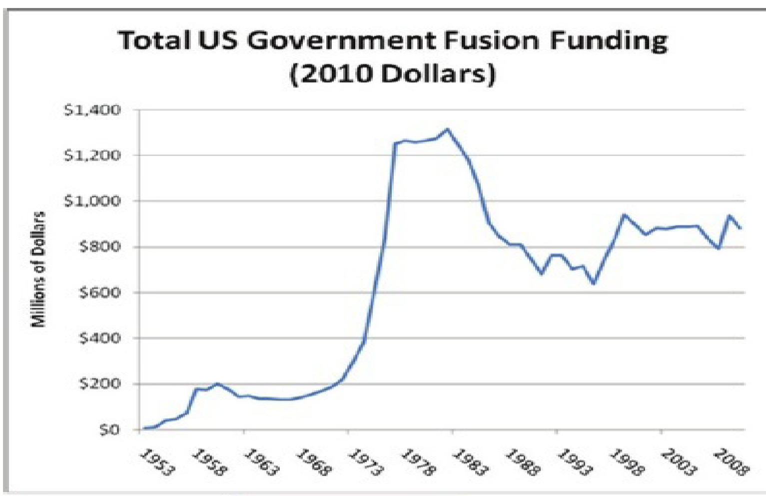
Fusion power can be the energy source of the future; it will be clean, safe, secure, and abundant. The international programs outlined in this paper demonstrate the level of commitment around the world to researching fusion.

The United States currently has a world-class workforce, but other countries already have facilities that are more advanced. These new facilities are luring America's best young talent and are training America's competitors of tomorrow.



A timeline of fusion projects (German). Note other countries ahead of the United States between 2000 and 2010.
Source: http://energy2050.se/uploads/files/f_wagner_primary.pdf

Funding for both magnetic and inertial fusion within the U.S. is threatened with budget cuts – including plans to close existing facilities.



If the U.S. fails to invest in fusion research, while the rest of the world makes rapid strides, America will fall behind. In a time of tight budgets, policymakers must focus on the bigger picture: fusion power holds great promise. It can provide clean baseload power, reduce greenhouse gas emissions, and provide an opportunity for American leadership in a new cutting-edge industry.

Further Reading

Fusion Power – A 10 Year Plan to Energy Security

Fusion Power in the 21st Century: Meeting the Challenge

What is Fusion Power?

Factsheet: Inertial Confinement Fusion at the National Ignition Facility

Map: Fusion's Reach Across America

The National Ignition Facility Shows What American Science Can Do

Through Innovation and Investment, the U.S. Can Lead on Next-Generation Energy, Nuclear Fusion

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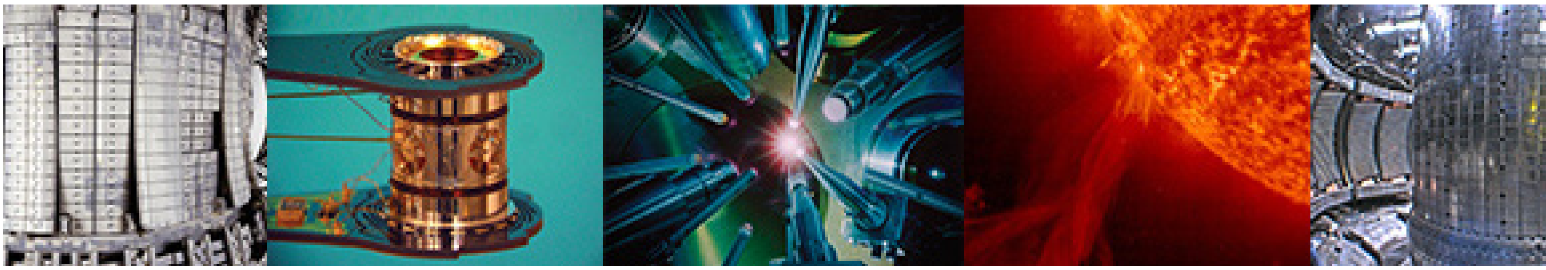

Glossary

- Deuterium – a hydrogen isotope used in a fusion reaction. It can be sourced from ocean water
- Fusion – when two hydrogen atoms fuse together they release enormous amounts of energy
- Ignition – the point at which more power is produced than is consumed. This is a key goal for inertial confinement fusion.
- Inertial confinement fusion (ICF) – one approach to producing fusion energy. Using lasers, hydrogen atoms can be crushed with extreme temperatures and pressure, forcing them to fuse together. The NIF is the leading ICF facility in the world.

- ITER – an experimental burning plasma facility under construction in the south of France. Led by the European Fusion Development Agreement (EFDA), but backed by six other nations including the U.S., ITER has the goal of achieving net energy gain.
- Magnetic confinement fusion (MCF) – one approach to producing fusion energy. With this approach, magnets are used to confine a plasma, which creates the conditions for fusion.
- Plasma – one of the four fundamental states of matter, plasma is a hot gas. It is needed to heat hydrogen atoms to the point that they fuse.
- Stellarator – an alternative design to the tokamak for magnetic fusion.
- Tokamak – a machine that uses magnets to confine plasma to achieve fusion. The tokamak confines plasma using a magnetic field.
- Tritium – a hydrogen isotope used in the fusion reaction. Can be sourced from lithium.

Endnotes

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Building a New American Arsenal

The American Security Project (ASP) is a nonpartisan initiative to educate the American public about the changing nature of national security in the 21st century.

Gone are the days when a nation's strength could be measured by bombers and battleships. Security in this new era requires a New American Arsenal harnessing all of America's strengths: the force of our diplomacy; the might of our military; the vigor of our economy; and the power of our ideals.

We believe that America must lead other nations in the pursuit of our common goals and shared security. We must confront international challenges with all the tools at our disposal. We must address emerging problems before they become security crises. And to do this, we must forge a new bipartisan consensus at home.

ASP brings together prominent American leaders, current and former members of Congress, retired military officers, and former government officials. Staff direct research on a broad range of issues and engages and empowers the American public by taking its findings directly to them.

We live in a time when the threats to our security are as complex and diverse as terrorism, the spread of weapons of mass destruction, climate change, failed and failing states, disease, and pandemics. The same-old solutions and partisan bickering won't do. America needs an honest dialogue about security that is as robust as it is realistic.

ASP exists to promote that dialogue, to forge consensus, and to spur constructive action so that America meets the challenges to its security while seizing the opportunities the new century offers.

ASP

American Security Project

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