PERSPECTIVES

Technology from Fusion Research:
Benefits Today

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September 7, 2011

This is part of an ongoing series by the American Security Project on fusion power.

In Brief:

- Major technological advances have developed out of fusion research that have applications across American society.
- Key sectors that have benefitted from technological spin-offs from fusion research include: medicine, manufacturing, electricity transmission, environmental cleanup, and national security.
- We know fusion works. Fusion is taking place in laboratories all over the world, including in the United States. Commercial fusion energy plants would use relatively tiny amounts of fuel to generate millions of watts of electrical power.

Nuclear fusion is the power of the sun. When hydrogen is compressed and heated, its atoms will fuse together to form a heavier element, helium. This reaction releases the huge amount of energy stored in the nucleus.

If harnessed by humanity, fusion promises nearly unlimited energy, without pollution. One pound of hydrogen fusion fuel is capable of yielding as much energy as is contained in 10 million pounds of coal.

However, a fusion reaction will only take place at extremely high temperature and pressure: about 100 million degrees and 1000 times normal solid densities. In the sun, gravity is used to confine hydrogen at the density necessary for fusion. In a thermonuclear weapon, a nuclear fission explosion creates the temperatures and densities necessary for fusion. Unfortunately, neither the gravity of the sun nor the forces of a nuclear weapon are replicable on earth in the controlled manner necessary for energy generation. There are two practical ways being closely studied today to contain the pressure and temperature necessary to harvest energy from fusion; lasers

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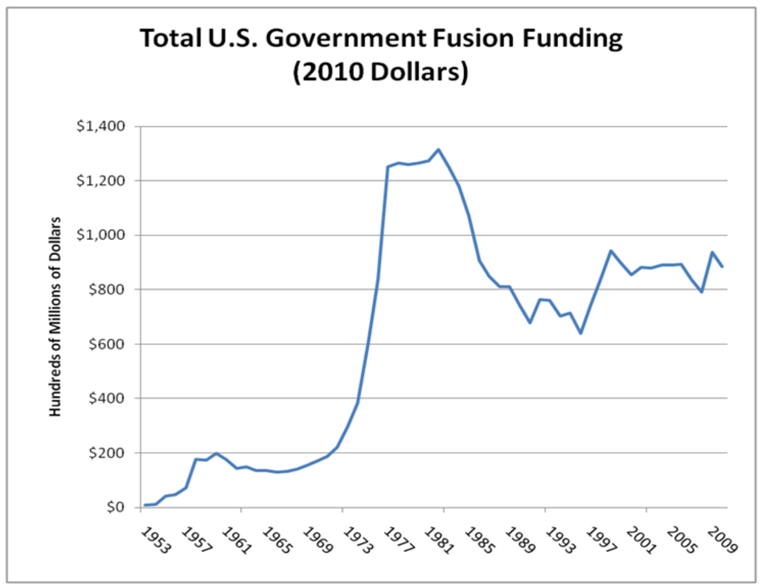
can be used to ignite and confine the fuel or magnets can be used to confine plasma that is heated by an electric current. The issue is that these magnets and lasers require more energy to contain the extreme heat and pressure of a fusion reaction than has yet been successfully gained from any experimental fusion reactions.

The first man-made nuclear fusion reactions happened on the Eniwetok Atoll in 1951 and 1952 during testing of the hydrogen bomb. Since this demonstration, the United States government has funded basic research into how to harness the power of fusion for peaceful energy production. Over these 57 years, the U.S. government has appropriated a total of approximately $36.4 billion in research funding (in inflation-adjusted 2010 dollars); an average of $639 million per year.[1] The funding is split into two tracks: the Magnetic Fusion Energy (MFE) program – which focuses on using superconducting magnets to contain the plasma – and the Inertial Confinement Fusion (ICF) program – which uses lasers. The peak year for fusion funding was 1982, when the U.S. spent $1.3 billion. In 2010, the U.S. government appropriated $884 million for fusion funding (all numbers are 2010 dollars).



The benefits of over 57 years of fusion research are not simply deferred to the future when fusion power will be commercially available. Other technologies have developed out of fusion research that have important applications across American society. Because of the very high requirements of confining fusion, many of the technological developments we enjoy because of the fusion program are in laser or magnet technology.

Sectors that have benefitted from technological spin-offs from fusion research include medicine, manufacturing, electricity transmission, environmental cleanup, and even national security. Some of the benefits we see every day, some are hidden, and still others have not yet achieved their promise. Even though fusion reactions have not yet powered so much as a light bulb, the impact of decades of fusion research is apparent across the American economy.

Impacts on Medicine

Modern medicine has benefitted from the advances in magnets and lasers that fusion research has generated. Advances in magnet technology have made identifying and treating tumors easier, and advances in laser technology have created a better way to cut through skin and tissue.

One of the most revolutionary tools in modern medicine is the magnetic resonance imaging (MRI) machine. MRIs utilize powerful magnets and harmless (non-ionizing) radiation to create an image of a targeted area within the body. From their first use in 1973, MRIs have become a common tool for doctors to identify tumors or injuries that earlier could have required invasive surgery. Fusion research drove the advances in large bore superconducting magnets that made the invention of MRIs possible.

Proton radiotherapy is a type of radiation therapy for cancerous tumors that allows doctors to target only the tumor. Traditional radiation therapy uses X-ray radiation that can damage the surrounding, healthy tissue. Proton therapy can more specifically target the tumor. However, proton therapy requires a large cyclotron to isolate and accelerate protons into a beam. Due to their size – about 1000 tons – and capital cost – roughly $100 to $150 million – there are only 37 proton therapy centers in the world.[2] However, advances in superconducting coils for magnetic fusion experiments at MIT's Plasma Science and Fusion Center may allow for the creation of a smaller, less expensive "compact synchrocyclotron" that will allow many more hospitals to offer proton therapy.[3]

Lasers are also useful in modern medicine. The 'Ultra-Short Pulse Laser' was developed in the 1990s as part of the Inertial Confinement Fusion program at Lawrence Livermore National Laboratory. It utilizes pulses of energy that last for just 50 to 1,000 femtoseconds (quadrillionths of a second). These pulses of energy are not long enough to do lasting damage to surrounding tissue. These lasers have been very effective in delicate surgeries, such as laser eye surgery or tonsillectomies.

Impacts on Manufacturing

The high pressure and heat resulting from the plasma necessary for a fusion reaction have placed a demanding requirement for materials capable of withstanding such extremes. Some areas of a fusion reactor that face plasma will have withstand heat of more than 2000°C. Very few materials can withstand this heat and maintain their structural integrity.

However, the combination of two materials—carbon fiber composite coated with tungsten—has proved to be able to withstand the heat. The development of new materials like this has important spin-off effects on other manufacturing processes that need to withstand high heat.

Carbon fiber composite is increasingly being used as a material in airline engines. Carbon fiber technology originally developed for the plasma-facing tiles inside a reactor is now being used for high performance brakes in most airplanes.

In addition to alternative uses for the materials used to build a reactor, technology that was developed to heat plasma, called "ion source technology," has been adapted to harden materials or to microscopically sculpt surfaces. Ion beams sculpt the surface of a material at the molecular level. This technology is now used to improve titanium hip implants, to improve the lenses of lasers, and even to manufacture consumer eyewear.

Impacts on Electricity Transmission

The "smart grid" is a term for how to move and integrate fluctuating renewable energy generation into an existing electricity grid. A smart grid adapts to fluctuations in electricity generation by moving electricity over long distances and storing excess capacity. Many of the applications that will make a smart grid possible come from advances generated by fusion research.

High-temperature superconducting (HTS) wires are being developed jointly by Oak Ridge National Laboratory and private industry out of technology originally developed by the Applied Superconductivity Group, a part of the Department of Energy's Fusion Energy division. HTS wires can conduct five times the electricity with half the transmission loss compared to traditional copper cable. These wires will allow power companies to create the "electricity superhighways" along which the smart grid will distribute electricity to where it is most needed.

Energy storage is a problem for fusion reactors. A reactor can require a pulse of energy upwards of 50 megawatts for less than one second of plasma discharge. This is often too much for a local power grid to handle. That means that the reactor has to develop a way to store energy in preparation for that pulse of electricity. Massive new flywheel machines are being developed to supply fusion reactors, some with a rotating mass exceeding 30 tons. They can store energy over time, to be released when needed.

Energy storage is a key part of making any electricity grid "smart" as well. If wind and solar power are going to be a large part of electricity generation, it will be important to build up reserves for when it is neither sunny nor windy. By addressing the problem of how to power fusion reactors, emerging flywheel technology will help with a smart grid.

Nuclear Security

In the 1990s, scientists at the Princeton Plasma Physics Laboratory (PPPL) needed a way to determine the amount and type of residual radioactive elements that remained inside a decommissioned fusion reactor. They developed a device that could be lowered into the reactor and could identify each of the types of radiation on the inside of the reactor.

In late 2001, after the September 11 attacks, the United States government issued a call for proposals for a portable device that would be able to detect radioactive materials. It is important to be able to detect radiation because terrorists could try to detonate either a nuclear weapon or a 'dirty bomb' (a conventional bomb that spreads radioactive material) inside the United States. The scientists at PPPL have since adapted their device so that it can be used around the country. It is now called the "Miniature Integrated Nuclear Detection System" (MINDS). MINDS units have been deployed to ports and areas of critical infrastructure around the United States.

Conclusion

Over fifty-seven years ago, scientists working for the American military completed their mission to harness the power of nuclear fusion for nuclear weapons. Since then, the American government, along with governments around the world, has been funding research to utilize the almost unlimited potential energy that fusion could provide for civilian energy generation. This is a vast technological and engineering challenge and it remains incomplete. However, history has shown that large scientific endeavors can lead to new and unexpected advances.

Although the funding for fusion over the last 57 years does not match the funding that the American government spent on the Manhattan Project or the Apollo Program - $4.5 billion per year and $7 billion per year (2011 dollars), respectively – the scientific and engineering challenges of generating fusion power are similar.4

The laser and superconductor industries have been the main beneficiaries of fusion research, but it is increasingly reaching across all sectors. In addition to these contributions, fusion research funding has supported and developed the skills of generations of scientists and engineers. The "human capital" developed in their research on fusion energy is transferable across many other scientific fields.

(Endnotes)

1 Fusion Power Associates http://aries.ucsd.edu/FPA/OFESbudget.shtml (accessed on June 23, 2011).

2 Whelan, David and Langreth, Robert "The $150 Million Zapper" *Forbes Magazine,* March 16, 2009 http://www.forbes.com/forbes/2009/0316/062_150mil_zapper.html (accessed on June 23, 2011).

3 Fusion Communications Group "Fusion Spinoffs: Making a Difference Today" http://www.iter.org/doc/www/edit/Lists/Stories/Attachments/624/spinoffs.pdf (accessed on September 1, 2011).

4 Stine, Deborah D. "The Manhattan Project, the Apollo Program, and Federal Energy Technology R&D Programs: A Comparative Analysis" *Congressional Research Service*, June 30, 2009. Report available at http://www.fas.org/sgp/crs/misc/RL34645.pdf.

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Learn more about our fusion energy initiatives by visiting:

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Building a New American Arsenal

The American Security Project (ASP) is a bipartisan 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.

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