

# Fighting for Fusion

## Why the U.S. Isn't Funding A Promising Energy Technology

By WILLIAM MATTHEWS,  
<bmatthews@defensenews.com>,  
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On Nov. 11, 2005, the day his small fusion reactor exploded in a shower of sparks and metal fragments, even physicist Robert Bussard didn't know what he had achieved.

For 11 years, the U.S. Navy quietly funded Bussard's research. It was a small project with a very large goal: deriving usable energy from controlled nuclear fusion.

Funding ran out at the end of 2005 and Bussard was supposed to spend the tail end of the year shutting down his lab. He kept postponing that in an effort to finish a final set of experiments.

He completed low-power tests in September and October and began high-power testing of the reactor in November.

After four tests Nov. 9 and 10, an electromagnetic coil short-circuited as electricity surged through it, "vaporizing" part of his reactor, Bussard said, and bringing his tests to an end.

"The following Monday, we started to tear the lab down. Nobody had time to reduce the data that was stored on the computer. It wasn't until early December that we reduced the data and looked at it and realized what we had done," he said.

Bussard said he and his small team of scientists had proven that nuclear fusion can be harnessed as a usable source of cheap, clean energy.

But for more than a year now, Bussard has been unable to move to the next step in his research. At 78, he is in ill health and his scientific allies fear that the long-sought breakthrough he appears to have achieved may fade into obscurity before it can be fully developed.

No small part of the problem is that the U.S. Energy Department has a competing project, and has spent five decades and \$18 billion on an as-yet-unsuccessful effort to solve the fusion puzzle.

"Who would believe that a tiny company based on one person could solve the riddle that has escaped literally thousands of researchers?" asked Don Gay, a former Navy electronics engineer and an early "technical point of contact" in the Office of Naval Research who helped keep Bussard's project alive.

But that, Gay and others insist, is what Robert Bussard has done.

## Science Fiction Fame

Bussard is not a household name, except possibly to "Star Trek" fans.

In 1960, he developed — on paper — the Bussard ramjet, an engine designed to power space vehicles by collecting hydrogen atoms from the near-vacuum of space and feeding them into a fusion reactor.

His idea was the basis for the "Bussard collectors" that powered the fictional space ships in the 1960s television series "Star Trek."

A decade later, Bussard served as assistant director of the Thermonuclear Reaction Division of the now defunct U.S. Atomic Energy Commission. He also worked for U.S. government nuclear laboratories at Los Alamos, N.M., and Oak Ridge, Tenn., and for TRW Systems.

Along the way, Bussard founded his own small company, Energy Matter Conversion Corp. — EMC2 — to pursue research into fusion.

Bussard aims to use fusion to produce cheap, inexhaustible, clean energy. Unlike other forms of nuclear energy, including other methods of fusion, Bussard's process does not produce radioactivity.

## How It Works

His fuel of choice is one of the earth's most common and least exotic elements: boron.

It can be scooped from the Mojave Desert in California, possibly even extracted from sea water. Boron is used in the production of hundreds of products as diverse as flame retardants, electronic flat panel displays and eye drops.

It's so common that no country, company or individual could corner the market on the fuel supply, Gay said.

The process Bussard hopes to perfect would use boron-11, the most common form of the element. Bussard says his experiments — which achieved fusion with deuterium, not boron — in November 2005 proved that the boron process will work.

The boron reactor would be similar to, but more powerful than, the reactor that blew up in 2005.

Bussard's reactor design is built upon six shiny metal rings joined to form a cube — one ring per side. Each ring, about a yard in diameter, contain copper wires wound into an electromagnet.

The reactor operates inside a vacuum chamber.

When energized, the cube of electromagnets creates a magnetic sphere into which electrons are injected. The magnetic field squeezes the electrons into a dense ball at the reactor's core, creating a highly negatively charged area.

To begin the reaction, boron-11 nuclei and protons are injected into the cube. Because of their positive charge, they accelerate to the center of the electron ball. Most of them sail through the center of the core and on toward the opposite side of the reactor. But the negative charge of the electron ball pulls them back to the center. The process repeats, perhaps thousands of times, until the boron nucleus and a proton collide with enough force to fuse.

That fusion turns boron-11 into highly energetic carbon-12, which promptly splits into a

helium nucleus and a beryllium nucleus. The beryllium then splits into two more helium nuclei.

The result is "three helium nuclei, each having almost three million electron volts of energy," according to Gay, who has written a paper explaining Bussard's research in layman's terms.

The force of splitting flings the helium nuclei out from the center of the reactor toward an electrical grid, where their energy would force electrons to flow — electricity.

This direct conversion process is extraordinarily efficient. About 95 percent of the fission energy is turned into electricity, Gay said.

## Refining the Design

For years, Bussard had wrestled with a problem: too many electrons were somehow escaping from his reactor core. That meant too few fusion reactions to result in a net positive output of power.

"We never quite figured it out until the spring of 2005," Bussard said. Then, during tests of a reactor, he suddenly understood the problem.

The magnetic field used to create the electron ball at the core of Bussard's reactor core was directing some electrons into the metal walls of the electromagnetic coil containers and support structures.

It was an "obvious point that we had all missed for over a decade of working on this," Bussard said.

It meant he had to design and build a new reactor.

With funds running out, "we banged it together as quickly as we could," and began testing in September. Instantly, Bussard saw "impressive and startling results." Later analysis would show that the rate of fusion was 100,000 times higher than in previous tests.

"We got four tests out of it that showed conclusively that we had solved the electron loss problem," he said.

That ended on Nov. 11, when the short circuit “blew the machine apart,” Bussard said.

But Bussard is convinced he had built a reactor that could produce more power than it would consume, and had found a way, at long last, to harness fusion as an energy source.

That hasn’t persuaded the Navy to resume funding.

## Making the Case

The physics of Bussard’s process is daunting.

“There are only about five people in the United States who understand this well enough to comment on it,” Bussard said.

When the physicist and his allies asked the Navy to resume funding last August, top Navy scientists turned for advice to the Department of Energy, a senior Navy scientist recounted. “There were people in DoE labs who wrote papers that said this couldn’t possibly work.”

Bussard and his allies are convinced the Energy Department is intent on stifling any fusion projects that could rival its own.

Bussard provided the Navy a stack of papers explaining his work. Navy officials “looked at them — not very closely,” the scientist said, and then had a day-long meeting with Bussard. In the end, the Navy decided not to support him, the scientist said.

Weeks later, Bussard’s work won the 2006 outstanding technology of the year award from the International Academy of Science.

The academy called his fusion reactor “a revolutionary radiation-free fusion process that could change the world as we know it today.”

“Could” is a key word.

Bussard may have proven that his process can use controlled fusion to produce more energy than it consumes, but he did not achieve sustained fusion or non-radioactive fusion, nor did he actually produce usable electricity.

That will require more time and more money, he said.

“From the beginning, we were always funded at one-eighth or one-tenth of what we really needed,” Bussard said.

As a result, Bussard built tiny reactors. And because his reactors were small and his money was limited, Bussard had neither space nor funds to build cooling systems. Instead, to keep his equipment from overheating, he conducted his experiments using brief bursts of electricity to power the electromagnets at the heart of his reactors.

Tests lasted “fractions of milliseconds,” according to Gay. But actually, that’s “a long time from a nuclear perspective,” he said.

Also because of power constraints, Bussard conducted his experiments by fusing deuterium rather than his preferred boron-11.

Unlike boron, deuterium fusion produces neutron radiation.

Bussard explained his choice: “You need a lot of energy to cause fusion.” The requirement for “boron fusion is very large — 200,000 volts. Deuterium takes a tenth that much.”

Given the physical limitations of his small reactors and the fiscal limitations of his budget, “It’s much easier to work with deuterium,” Bussard said.

Now that he has shown that controlled deuterium fusion is possible, it is simply a matter of building bigger reactors with bigger power supplies and cooling systems to demonstrate sustained boron fusion, he said.

Bussard said his next step is to build a new reactor to replace the one destroyed in 2005. Ideally, he’d like to build two and use them to demonstrate to other scientists beyond doubt that his process works. For that, he says he needs about \$2 million.

To build a full-size reactor, Bussard said he needs about \$200 million.

“We’ve solved the physics; now it’s time for engineering development,” Bussard said.

That means developing special reactor hardware, such as high-voltage power supplies, spe-

cial transformers and switches that work in timeframes of sub-milliseconds. Some of that work may be challenging, “but you don’t have to discover new things,” Bussard said.

## No Bucks, No Bussard Reactors

For now, a source of money seems to be the hardest thing to find.

Despite repeated appeals by Bussard, Gay and others, the Navy has declined to continue funding Bussard’s research.

“We tried going to ONR [the Office of Naval Research], but we ran into a brick wall,” said Larry Triola, a former deputy chief scientist in the Navy program executive’s office for surface combatants.

During the 1990s, Triola and his bosses hoped that Bussard’s fusion process could be turned into a revolutionary ship-propulsion system.

“I believe he has demonstrated that it will work,” Triola said. But, he stressed, that is his personal opinion, not the Navy’s.

Convincing others has not been easy.

“There’s a giggle factor” about Bussard’s process “because of all the decades the Department of Energy has pushed billions of dollars” into building fusion reactors the size of small factories that consume vast amounts of energy, but have yet to produce any, he said.

“They’re never going to make a useful power device for the Navy,” Triola said. “We need something that will fit on an aircraft carrier. We would like to put them in submarines and on destroyers. Everything says we should be able to do that with Bussard’s.”

But the money people aren’t convinced.

“People either don’t believe you or they say, ‘It’s not my mission,’” Triola said. “The money we’re talking about is spent in an hour or two in Iraq.”

The Navy spent a total of \$14 million during the years it supported Bussard’s work, said Navy spokesman Jim Boyle.

The decision to stop funding came after careful evaluation, he said. But Boyle said he did not know what the “evaluation criteria” were or why the Navy reached the decision it did.

Bussard’s work should be funded, agreed Frank Shoup, director of the systems engineering institute at the Naval Postgraduate School.

“I’m not an expert” in fusion physics, Shoup conceded, but he has followed Bussard’s work.

“It relies on a new principle in developing fusion energy,” he said. “The fuel is totally abundant and cheap, there are no noxious byproducts like radioactive waste, it doesn’t produce carbon and it doesn’t pollute.

“The quick answer is, if it works, the payoff is so large it is worth funding to find out if it works,” he said.

Bussard is getting discouraged.

“The [U.S.] government, I don’t think, is going to do anything,” he said.

So he has begun to look elsewhere. Last October he published a paper detailing his work for the 57th International Aeronautical Congress in Valencia, Spain. In it he named eight countries, including China, India, Russia and Venezuela, that “could logically develop interest” in his research.

In November, Bussard presented his work in a 90-minute lecture at the headquarters of the Internet search engine Google.

The lecture is archived at <http://video.google.com/videoplay?docid=1996321846673788606> and had been viewed 87,700 times by early March.

The lecture generated a lot of e-mail, but so far, no funding, Bussard said. His next effort may be a book-length publication detailing his fusion work.

Much as supporters Gay and Triola want to see Bussard’s fusion work resume, they worry about the broadening appeal for funding.

“My concern is China,” Gay said. “If they have more vision than we do, they could jump on it.”

Triola shares the worry. “I think it’s a matter of engineering now, not physics any more. Once Bussard gets enough publicity, one of our not-so-friendly allies, probably the Chinese, will go do it.”