

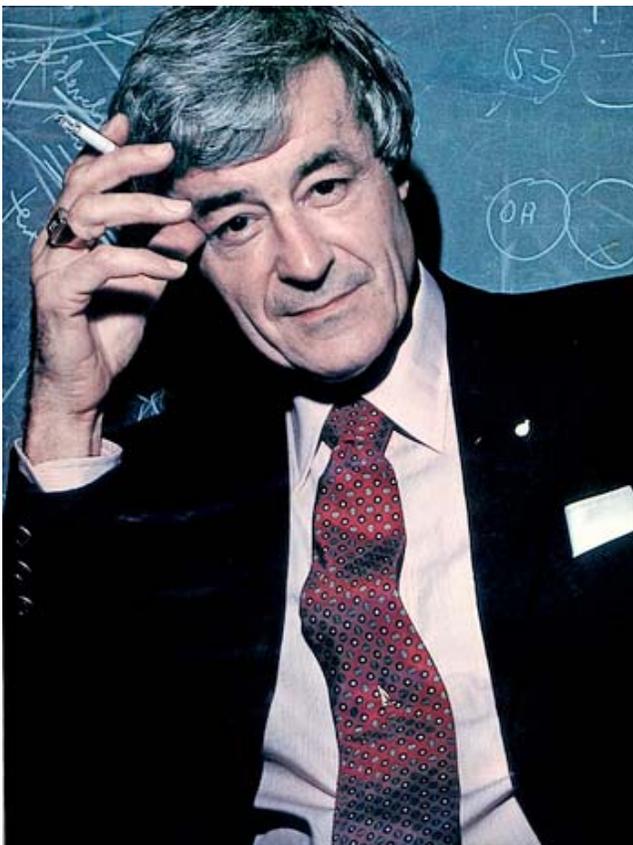
Physicist Known for Pursuits into Fusion Energy

By Anne Constable

<aconstable@sfnewmexican.com>, The Santa Fe New Mexican, November 4, 2007

Robert Bussard, a physicist known to his wife and even in some academic circles as “Doc,” died from cancer October 6, 2007 at his home in Santa Fe.

Until his death at age 79, Bussard was working on how to produce clean, cheap energy through nuclear fusion. Success would help end the world’s reliance on fossil fuels and halt global warming.



Photograph by Norman Seeff, January 1981

“I’ve met and worked with a lot of really smart people. Not many were real innovators, and that’s what he was,” said Rick Nebel, a physi-

cist on entrepreneurial leave from Los Alamos National Laboratory to continue developing Bussard’s concepts. “He would try to do things other people said you couldn’t.”

“He was a first-class guy, a super person, extremely innovative, a wonderful engineer,” confirmed Robert Hirsch, former director of the Atomic Energy Commission’s Controlled Thermonuclear Reaction Division.

Scientists have been trying for decades to harness nuclear fusion, the same process by which the sun produces energy. Bussard’s idea is to convert hydrogen and boron, a widely available material, directly into electricity, producing helium as the only waste product.

Two years ago, just as his federal funding was running out, Bussard believed he had achieved a “breakthrough.”

According to Bussard, data collected during experiments in the fall of 2005 by scientists from his company, Energy Matter Conversion Corp. (EMC₂), suggest they had developed a fusion process that was 100,000 times more efficient than previous designs.

The device they were using was the latest version of the Polywell, conceived in 1983 by Bussard and tested with funding from the U.S. Navy.

The WB-6, now resting in the company’s Santa Fe office, is shaped like a polyhedron with six tightly welded circular stainless steel cross sections about 1 square meter in size. The rings contain copper wires wound into an electromagnet. During tests, the reactor is placed inside a vacuum chamber.

In the final test, on November 11, 2005, the device shorted and blew up one leg of the machine. The following Monday, Bussard began shutting down the lab in San Diego. The scientists didn’t begin looking at the data until December.

Months later on the www.fusor.net forum Bussard declared, “We really have solved the last engineering physics problem that has plagued our work for 12 years or so.”

Ironically, the development occurred as the Navy energy program was being abolished in 2006 because of funding issues.

Last August, as Bussard was losing his battle with cancer, the funds were restored with the support of Alan Roberts, EMC2's longtime Navy contract monitor. The company now has \$1.8 million to pursue his work. If it is successful verifying the 2005 results, it would seek funding for a full-scale model, big enough to make net power, Nebel said. Bussard has estimated that such a demonstration model would cost about \$200 million to build.

"Unless somebody can repeat and show other people that it's operating, it's really not scientifically acceptable," Hirsch said. But "if the idea works the way he thinks it could, and there's a good chance he's right, it will not take a very big machine to show net energy."

The latest device, WB-7 (the WB refers to the children's toy Wiffle Ball), is currently under construction at a machine shop in San Diego and will be shipped to Santa Fe, where a small group of scientists is setting up a testing facility in an office park off Rufina Street. The device, like previous ones, was designed by engineer Mike Skillercorn.

"These are garage-scale experiments," said Nebel, pointing to the stock tank purchased at a local feed store.

"We shop at interesting places," he added, mentioning both Home Depot and the Black Hole in Los Alamos.

Although Europeans are building a huge device to demonstrate the scientific and technical feasibility of fusion power, the U.S. has spent relatively little — about \$300 million a year — on fusion research.

Much of that has been focused on a competing idea called Tokamak, a program that Bussard and Hirsch started at the Atomic Energy

Commission in the 1970s, which uses deuterium and tritium as fuel. Later both determined that the concept, which produces a lot of radioactivity, was impractical from an engineering standpoint.

With his own device, Hirsch said, Bussard was "swimming upstream as far as fusion community was concerned." Still, he was able to get about \$14 million in funding from the Navy for his work.

Bussard felt enormous pressure to solve the fusion problems. In a letter to an Internet forum on his 2005 results, Bussard wrote that he believed that "the survival of our high technology civilizations depends on getting off of fossil fuels ASAP, and — if we do not — we will descend into a growing series of 'oil wars' and energy confrontations that can lead only to a huge cataclysm. Which CAN be circumvented if only we build the clean fusion machines in our time."

But, he conceded, the political reality is that oil companies have no interest in supporting fusion research. "There is only one thing the oil companies want, and that is to sell oil, and more oil," he said.

"The only way to stop oil, from their view, is when it does run out. And then they'll go for deeper drilling, new fields, Gulf geopressure gas, LNG, etc. etc., and keep raising the price, until finally foolish solar and windmills become competitive," he wrote.

Nearly a year after shutting down the lab, Bussard presented his work — for the first time in more than a decade — to the International Astronautical Congress¹. He later discussed his results at Google, the online search engine company in a talk titled, "Should Google Go Nuclear?"² that is widely available on the Internet. Before his death, he also set up a nonprofit organization to solicit donations to

¹ "[The Advent of Clean Nuclear Fusion: Superperformance Space Power and Propulsion](#)," Robert W. Bussard, 57th International Astronautical Congress.

² <http://video.google.com/videoplay?docid=1996321846673788606>

restart the work. Information is at www.EMC2Fusion.org.

Bussard's wife, Dolly Gray, who co-founded EMC2 with him in 1985 and served as its president and CEO, has helped assemble the small team of scientists in Santa Fe. Besides Nebel, 54, the group includes Jaeyoung Park, a 37-year-old physicist who is also on leave from LANL; Mike Wray, the physicist who ran the key 2005 tests, and Wray's brother, Kevin, who is the computer guru for the operation.

"If this works, it's going to be a big deal. It could take the entire energy market," Nebel said. "And drag the oil companies into the 21st century," Gray added.

Someday, they said, if they're right, a machine just 20 times bigger than the one sitting in the corner on Parkway Drive could run the city of Santa Fe.

Dreams of the Stars

From early childhood, Bussard was interested in traveling to the stars. In 1960, he conceived the idea for the Bussard Ramjet³, a interstellar spacecraft that uses a magnetic scoop to collect fuel in interstellar gases as it moves through space. The conceptual device captured the imagination of scientists and science fiction writers. On the television series *Star Trek*, it was known as the Bussard Collector, and astronomer Carl Sagan described the Ramjet as a way humans might travel around the galaxy in his 1980 *Cosmos* series. "It's still the only known way to travel between galaxies," Park said.

Bussard was born in Washington, D.C. in 1928. His mother was one of the first architecture graduates at Carnegie Technology. At age 7, he moved to California where his father, a civil engineer, had a company, and he grew up in Westwood.

Though clearly blessed with a fine mind, Bussard flunked out of CalTech, then entered the University of California at Los Angeles after a road trip to Chicago with friends. He graduated with a bachelor's degree in engineering in 1950 and a master's two years later.

After working on the FALCON missile program at Hughes Aircraft Company and on solid rocket propellants for the Whirljet Corp., he joined the Oak Ridge National Laboratory in Tennessee, where he did design work on the Aircraft Reactor Experiment. In June 1955, he moved to Los Alamos National Laboratory, where he helped develop the Rover nuclear rocket program.

In the fall of 1957, with support from the lab, Bussard began graduate school at Princeton University, earning a master's degree in physics in 1959 and a doctorate in 1961. His was one of the first doctorates in the college's new plasma physics program. He returned to the lab, working there until 1962, when he left to re-enter private industry. He worked on concepts such as nuclear space propulsion for a variety of companies including Space Technology Labs, a division of Xerox and CSI Corp. He came back to the lab briefly before becoming assistant director for development and technology at the U.S. Atomic Energy Commission in 1973. There he worked with Hirsch on the development of the controlled fusion energy program, reorienting the agency from physics research to engineering objectives and helping to build the fusion budget.

In 1976, Bussard founded the company Inesco to build small Tokamak fusion reactors called Riggatrons. He holds numerous patents and has published widely in leading journals.

Bussard is survived by his wife, four children (Elise Bright, William Bussard, Robert Bussard, and Virginia Barausky) and five grandchildren.

³ "Galactic Matter and Interstellar Spaceflight," Robert W. Bussard, *Acta Astronautica* 6 (1960), pp. 179-94

Robert William Bussard

Physicist; born Washington, August 11, 1928.

Siblings

- Marcel Julian
- Elsa Mathilda (Griesser) B.

Married Dolly H. Gray, 1981. Their children included:

- Elise Marie Bussard Chisholm
- William Julian
- Robert Lee
- Virginia Lesley Bussard Barausky

Education

BS Engineering, UCLA, 1950

MS Engineering, UCLA, 1952

MS Physics, Princeton University, 1959

PhD Physics, Princeton University, 1961

Work

1949-1951 Design engineer, Falcon program Hughes Aircraft Company

1952-1955 Mechanical engineer, aircraft nuclear propulsion project, Oak Ridge National Laboratory

1955-1962 Alternate group leader nuclear rocket program, Los Alamos Science Laboratories

1962-1964 Director nuclear systems staff, Assistant director mechanics division, Space Technology Laboratories, TRW, Redondo Beach, CA

1964-69 Associate research research and engineering., corporate chief scientist Electro-Optical Systems division Xerox Corp., Pasadena, CA

1969-1970 with CSI Corp., Los Angeles, CA

1970-1972 Manager Cherokee Associates, Pasadena, CA

1971-1973 Alternate leader laser division, Los Alamos Science Laboratories

1973-1974 Assistant director division controlled thermonuclear research, U.S. Atomic Energy Commission, Washington

1974-1986 Founder, president, chairman, Energy Resources Group (ERG), Arlington, VA

1976-1984 International Nuclear Energy Systems Company (INESCO), La Jolla, CA and McLean, VA

1985-1989 Senior scientist PSR Corp., Arlington, VA

1984-2007 Founder, technical director, Energy/Matter Conversion Corp. (EMC₂), San Diego, CA

Consultant

1960-1964 NATO

1974-1978 U.S. Department of Energy

1973-1988 Los Alamos Science Laboratory

1971-1978 director ctrl. intelligence

1960-1969 lecturer UCLA

1962-1964 lecturer University of Florida

Publications and Awards

Author: (with R.D. DeLauer) Nuclear Rocket Propulsion, 1958, and Fundamentals of Nuclear Flight, 1965;

Editor: Nuclear Thermal and Electric Rocket Propulsion, 1967;

Contributed articles to professional journals.

Fellow AIAA; member American Physics Society, International Academy Astronautics.

Clubs: Princeton (N.Y.C.); Cosmos (Washington), Capitol Hill (Washington).

Achievements include patentee space nuclear propulsion, power generation, fusion and fission power, solar power systems.

Remembering Robert Bussard

2007-10 Admiral Cohen, Under Secretary for Science and Technology, Department of Homeland Security

Cancer

Dr. Bussard was a cancer victim of two kinds who was in the last weeks enduring radiation and chemotherapy for the disease.

It was lung cancer. I spent a morning with him this past spring as he was about to undergo some specialized radiation therapy. He was weak but in good spirits and raring to go on Polywell fusion if funds could be found.

First Degree was in Engineering

Something you may not realize about Robert W. Bussard, is he actually IS an engineer! His first degree was thermal engineering. He specifically studied that field in order to figure out how to utilize the heat from a nuclear reactor to make a rocket engine. The Rover program, and hence NERVA, was the result. If there is one thing he knows on an engineer's level, it is how to extract heat from a nuclear reactor on an industrial scale.

Only after getting that running did he go to Princeton for his PhD in Physics.

Bussard Ramjet

A note from James Benford, soon to be followed by e-mail from other interstellar advocates, tells me of the death of Robert Bussard. The creator of the Bussard ramjet concept, Bussard (1928-2007) died of cancer in Santa Fe just a few days ago. Benford, who knew Bussard for forty years, recalls his open attitudes and deep technical insight, adding "He was still sharp as a pin into old age." We should all be so lucky.

Recently we've seen a lot of discussion about Bussard's fusion ideas, but it's the ramjet that I return to as I think about him. If you collect classic papers, as I do, here's one for you: Bussard's "Galactic Matter and Interstellar Spaceflight" in *Acta Astronautica* 6 (1960), pp. 179-94. Imagine a scoop created by a magnetic field that sucks in interstellar hydrogen ionized by a forward-firing laser. The result is fed into a fusion reactor. Get the vehicle up to about six percent of light speed and you could light that engine, with presumably amazing results.

I think Bussard must have taken great pleasure from reading *Tau Zero*, as well as knowing that his stunning starship concept would galvanize theoretical research into interstellar propulsion for decades to come. He's been part of my thinking on interstellar matters for the last forty years, a loss everyone involved in our deep space future will take to heart. Our thoughts and condolences go out to his family.

- *Tau Zero*, by Poul Anderson,
- *Orbitsville* by Bob Shaw
- *A Deepness In The Sky*, by Vernor Vinge

The Bussard ramjet method of spacecraft propulsion was proposed in 1960 by the physicist Robert W. Bussard and popularized by Carl Sagan in the television series and subsequent book *Cosmos* as a variant of a fusion rocket capable of fast interstellar spaceflight. It would use a large ram scoop (on the order of kilometers to many thousands of kilometers in diameter) to compress hydrogen from the interstellar medium and fuse it. This mass would then form the exhaust of a rocket to accelerate the ramjet.

Haste Makes Waste

As for haste-makes-waste, maybe one day I'll be able to write the whole long, sad story. In retrospect, there are several key spots where asking and answering the right questions might mean we'd now be picking destinations for the resulting spacecraft. The earliest of these is circa 1968 when a bunch of AEC guys attended a meeting with Hirsch and Farnsworth. Hirsch

and Farnsworth rigged up a fusor on a borrowed meal cart from their hotel, and rolled a working fusion reactor into the meeting, where they irradiated the attendees with a fairly substantial flux of neutrons, to their amazement and delight. That little machine was making more controlled fusion than had ever been achieved at that time by any other means. Everyone present thought IEC was worth pursuing. However, nobody wanted it taken out of their budget! So AEC and later DOE never pursued it (even after Hirsch wound up in charge of the henhouse at the DOE fusion program a few years later). By the 1970's, the system was so hidebound there was no way to squeeze in an electrostatic approach in competition with lasers and tokamaks.

In the 1980's, the HEPS experiment used the closed-box Polywell configuration instead of a MaGrid, and was run pulsed (against Dr. Bussard's objections). Had the MaGrid concept's advantages been fully appreciated at that point, that machine had sufficient resources behind it that the effort probably would have put us in the 1980's where WB6 is now.

WB2, 3, and 4 were all built with square cross-section coils, touching each other. These two subtle form factor problems caused much larger electron losses than had been realized. They were economy measures (made the coils much easier to build) that wound up keeping the devices from working, so they were false economy. Had WB2 been built in the form factor of WB6, and with somewhat more robust magnets, I suspect it might have been able to burn DT at detectable levels. WB3 likely could have made decent fusion on DD, and would have done so for 10 seconds at a time.

Quotes

Jim Benford writes: "I knew Bob for about 40 years. We collaborated on several fusion matters and talked often about space propulsion. I always liked him for his open attitudes and deep technical insight."

"He was an interesting, friendly man, who seemed to be attempting to accomplish great things for humanity."

"He was a classic, and I'm very sad to see such an innovator go. Like Max Hunter, he came from a different age, and we won't see his like again."

"... always bright, friendly, generous, and open. Never was too busy to answer one of my questions, and very apologetic if he didn't get back in a timely manner.

Here was a guy who was quietly revolutionizing industrial civilization, and I never heard of him giving attitude to anyone. Very stark contrast to other folks I've dealt with who had far greater reason for modesty. This is a really great loss of a great man."

Kelly Starks, October 9, 2007

"I knew Bob for about 40 years. We collaborated on several fusion matters and talked often about space propulsion. I always liked him for his open attitudes and deep technical insight. He was still as sharp a pin into old age. He was a real charmer too! He had a big impact and will be missed."

James Benford, October 9, 2007

"I am Dr. Bussard's daughter. I want to thank everyone for their comments here. I have one to add myself, as to why he did not publish: your guess is correct, the gag order prohibited him from publishing for 11 years! By then he was terminally ill, and put every ounce of strength he had left into getting funding so his work could go on. He did manage to write (with great effort) the Valencia paper, which was reviewed and accepted for presentation at a conference, and I believe he planned to publish as soon as time and health allowed. I'm not a physicist so cannot comment on the other debates, but I hope this clears up at least one controversy here!"

— Elsie Bright, October 10, 2007

"Mars is Bussard's first love. He'd like a place 'a

little south of Syrtis Major.”

Tom Ligon, January 1, 2007

“Back in 1995, I learned from my old company that somebody named Bussard needed some vacuum leak testing done. So when I quit to set up my own consulting service, I dropped by the address and slipped my propaganda under the door. When I got a call from “R.W. Bussard” a couple of weeks later, I asked “I gotta know, is this The R.W. Bussard, as in interstellar ramjets?”

He replied, “I guess I’ll never live that down.”

Tom Ligon, February 16, 2007

“I like to compare this to the development of the internal combustion engine. Imagine someone like Otto cranking an early prototype, and getting it to fire a few times when he dropped some alcohol into the intake. On the fifth run, imagine the piston cracked. A skeptic would scoff and ask why anyone should be interested in a noise-maker that wastes perfectly good booze. But Otto knew he had proved that the concept that would power the future basically worked.”

Tom Ligon, April 10, 2007

“What a great dream Robert Bussard had. He started something that could literally change the world. His family and friends can take great comfort in that.”

John Papiewski, October 9, 2007

“I met Bussard and did an experiment with Tom Ligon while Bussard did the math on the white board. He was gratified with the result enough to finance a steak dinner for us when we were done. Bussard was a real power house, even in old age. I do hope his ideas on the Polywell are followed up by others.”

Richard Hull, October 9, 2007

“I never met the man and I am poorer for that, but he sure did inspire me. He helped fire my imagination and get me thinking about trying to do things I never thought possible. He will be sorely missed.”

Mike Beauford

“I too mark Dr Bussards passing with a deep respect and sadness that he did not see his dream fulfilled. His contribution to this science will endure - his name remembered.”

John Hendron

“Bob Hirsch who was always careful with what he said, laughingly noted with some awe that Doc Bussard could get money where there was none to be had. Tom Ligon used to say it would look grim about an upcoming paycheck. Doc would go into town and come back with just enough to keep going. ... Funds can be yanked or cutoff in mid-stream for any number of reasons none of which bear on the science. Bussard knew when to lay low and who to lay low from.”

Richard Hull, October 15, 2007

“Dr. Bussard was a hard charger always giving his best. Even if I didn’t always agree with him I held him in the highest esteem for his integrity and honesty.”

Michael Thomas, October 12, 2007