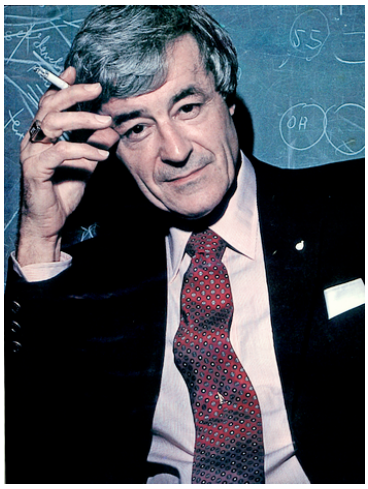

Robert Bussard Omni Interview

As the most vocal and visible advocate of the small-is-better school of fusion, a former rocket engineer recalls the frustrations in trying to persuade Uncle Sam not to think big.

Photograph by Norman Seeff

by K.C. Cole, Omni Magazine, January 1981

Background

Robert W. Bussard compares his bitter four-year battle with the federal fusion bureaucracy to a Robert Ludlum novel. It's more like the tale of David and Goliath. Bussard's small, independent company, Inesco (International Nuclear Energy Systems Company), wants to build cheap, modular, "midget" fusion reactors that could be used up and thrown away like so many light bulbs. To do it, he's had to buck a fusion "establishment" that would prefer to spend its money on large, expensive machines. Bussard compares the mammoth "Main Line" reactors — being developed at Princeton, MIT, and Oak Ridge to dirigibles — interesting research devices that are unlikely ever to produce economical net fusion power. But the Department of Energy (DOE) - has said that Bussard's three-foot-high Riggatron won't fly.

The "throwaway" reactor — if it does work — certainly offers a tantalizing alternative. Since it is small, it can be plugged in to existing fossil-fuel plants; its modular design can answer a wide variety of specific needs. The most important thing is it could produce commercial fusion power as much as 20 years sooner than its Main Line counterparts, saving billions in development dollars. A portable, flexible high-energy neutron source, the Riggatron is capable of producing fusion power, fission power, ethanol for cars, oil from tar sands, and nuclear fuel. In addition to all that, it could furnish estimated profits that boggle the mind: One "high growth" model shows Riggatron-based fuel production outstripping Exxon by the year 2000.

How has this miracle technology managed to earn the enmity of fusion experts at DOE? It all began in 1977, when the Energy Research and Development Administration (ERDA) funded a $637,000 conceptual study of Bussard's Riggatron. The results, according to a DOE review panel, were discouragingly negative. Inesco protested that the panel was blatantly biased and stacked with representatives from the Main Line labs who felt threatened by this new entry into the nuclear-fusion business. Indeed, lobbying by Main Line interests in Congress against a $7 million appropriations amendment to support Riggatron research was so "hysterical" that Representative Manuel Lujan, Jr., a New Mexico Republican, was moved to speculate that it was "very well orchestrated and most probably had an ulterior motive."

Pressure from Congress, the Office of Management and Budget, and such luminaries as Edward Teller eventually did win the Riggatron a second panel review. But the results are hardly conclusive: The DOE is sticking to its previous no-go position, while Inesco is insisting that the concept was vindicated. "We've won," says Bussard.

"As a former assistant director of the fusion program at the Atomic Energy Commission, Bussard knows his way around bureaucratic wrangling. He even holds a PhD in plasma physics from, of all places, Princeton University But he likes to think of himself primarily as an engineer. He was alternate division leader of the laser-fusion program at Los Alamos and head of R&D for a division of Xerox Corporation. Before that, he developed nuclear rocket propulsion systems for TRW, Los Alamos Scientific Laboratory, and Oak Ridge National Laboratory

This background, above all, has positioned him against what he perceives as the slow-poke approach of the Main Line program.

With an investment so huge and expensive, the Main Line fusion reactors can't afford to make mistakes. Bussard, however; believes in the kind of high-performance engineering that entails taking chances in pushing tech-

nology to its limits. “They’re learning a lot of interesting things in the Main Line program,” he says, “but they aren’t doing fusion. They’re just watching plasma particles dance around.”

Interview

Omni: Is there really a fusion “establishment” in the nation’s capital that excludes all but the Main Line magnetic-fusion programs from getting funded?

Bussard: If you ask people in the government, they would categorically deny it, obviously, because to admit it would be to agree that they are perpetrators of evil. So they say, “Oh, of course not. Anyone with a good idea is welcome to come, and we will to glad to support them.”

Omni: But in reality?

Bussard: In reality things are quite complicated. Everything is funded by the Department of Energy establishment through Germantown, Maryland, which is the old AEC (Atomic Energy Commission). Combine this with a small number of people who wander around the country, contending that they should be given government research money to fund new and novel research solutions for fusion. In fact, one can show by known physics that most of these solutions don’t work, which is why the DOE in its reasonable wisdom has chosen not to fund them. But we did not invent a new magical confinement scheme. All we did was to take the world standard confinement mechanism, the Tokamak, and shrink it in size by an engineering approach, not a physics approach. The physics is perfectly sound. We don’t want to fight unproven physics. We never did.

Omni: Then how do you explain the reaction you got from DOE and the Main Line fusion people?

Bussard: The reaction is simple. Suppose we’re right. Suppose our machines do run as all nature tells me they will. By 1984, we will have five machines that run at power outputs of two hundred million watts for a couple of seconds. Our first commercial plant will be running in 1987, twenty years sooner and at one fortieth the cost of the Main Line program Now who in the national program can be enthusiastic about that? The Riggatron’s swift development could, in their view, put careers on the line. Long-term personal futures are involved in this program. The bureaucracy in Washington, which has planned the main national program, is now faced with a curiosity of a twenty-year-sooner solution that it didn’t invent. That doesn’t make people feel good. It’s human nature.

Omni: But the Riggatron is designed differently from a standard Tokamak. It’s disposable, or, more accurately, recyclable. Which is it?

Bussard: You can do either. You can either rebuild light bulbs or buy new ones. It’s all a matter of cost. Do you recycle your light bulbs back to the GE light-bulb factory? No. You buy new light bulbs, don’t you? In this case, it is cheaper to throw the light bulb away and buy a new one. We made a study that shows the cost is just about the same to make a new Riggatron from scratch as it is to recycle an old one.

Omni: That sounds pretty expensive, to have to plug in a new fusion reactor every fifteen or thirty days

Bussard: Is it too expensive to plug in light bulbs?”

Omni: But we are not talking about light bulbs. We are talking about fusion reactors.

Bussard: It’s all a matter of looking at power levels and the costs of the power. The total energy output of Riggatron is so large and the cost of the machine so small that when you replace it, even if you threw the old one away and buried it in a mine shaft, it would cost you only 1.3 mills per kilowatt hour of electricity that would have been produced by that machine.

Omni: And is that substantially cheaper than what the big Tokamaks could produce?

Bussard: Yes. You can’t throwaway the big machines. They are long-term, thirty-year lifetime machines, multibillion-dollar investments. They are so big that the down times are nine months or thereabouts when you have to take one of these big turkeys apart and rewind it.

Omni: The Riggatron is so much cheaper because you avoid two very expensive and complicated technologies - superconducting magnets and neutral beams. Right?

Bussard: In part, but that is not the main advantage Use of superconducting magnets forces the overall design of the machine to be fundamentally different, to be very large and very expensive. You cannot put a superconductor next to the fusion plasma, because the neutrons will overheat the superconductor and it will cease to be a superconductor. So you must move the superconductor behind shielding - heavy metals, stainless steel But if you do that, you still have to breed tritium for the deuterium-fusion process This is accomplished by capturing neutrons in lithium But you can’t put the lithium “blanket” outside, because the shield keeps the neutrons from getting outside. You have to put it inside. So the choice of superconductors requires a design in which you have a huge superconducting magnet filling a tremendous volume of space in order to have a little bit of fusion plasma continued inside two meters of shielding and a meter of lithium blanket.

It also makes the blanket an integral part of the plasma machine, which is a nightmare to maintain. We have taken that whole geometry and inverted it, put the

blankets outside where they are cheap to build and maintain, use water-cooled copper alloys for magnets, and end up with a Riggatron a thousand times smaller and four thousand times cheaper than a superconducting machine.

Omni: If they cause so many problems, why do all the Main Line Tokamaks use superconductors?

Bussard: Because they have a nice scientific property. Once you have current flowing through them, it flows forever. Scientifically, that is appealing. It is like believing in motherhood and believing that sunshine is good for you. It is nice if you have no losses, but it doesn't pay.

Omni: The other major difference between how the big Tokamaks work and ...

Bussard: How they work? Do they work?

Omni: Well, how they are designed to work.

Bussard: There is no machine that makes fusion on this planet. None. To this day, no one has built a machine that sustains a controlled fusion reaction. The only proof that we can truly make fusion power has already been demonstrated by five nations, and those are the superpowers, which have exploded thermonuclear bombs.

Omni: Do you think this surprises a lot of people?

Bussard: I think a lot of people think fusion is further along than it is because of the way the public-relations campaigns have been waged, at least by the government, implying that fusion is sort of here.

Omni: You've said that essentially what is being done in the Main Line program is not fusion, but watching plasma particles dance around. What did you mean by that?

Bussard: Generally, the national fusion program is dominated by considerations of understanding plasma physics, not to be confused with building devices to control fusion. The national fusion program, which is now running at 1.8 million dollars a day and would like to spend more, is doing beautiful research on the nature of plasmas, their confinement, their instability, and their transport across magnetic fields. We need that. We rely on some of that for basic information, But the national program is really not an R and D program. There is no D (development).

Omni: You mean they want to know all of the physics thoroughly before they try anything?

Bussard: You hit it right on the head. And that is almost the only thing they can do, because the large machines they're evaluating as future power systems are gigantic and cost several billion dollars each. Before you are willing to commit several billion dollars on one machine, you had better know everything in the world about it, absolutely everything. Our machines are handmade versions, built in small machine shops. At most they will cost about a million to a million and a half dollars each. Not billions, millions. We plan to build five of them simultaneously - of slightly different configurations, shapes, fields, materials and find out which ones work best, why and how, and which ones fail

Omni: That seems ironic. The national pro- . gram is trying to save money by being cautious, when in truth ...

Bussard: They are saving, in respect to the program they are doing. If you went and built five two-billion-dollar machines and ran three of them to destruction, you would have blown away six billion dollars, which isn't wise.

With our approach:; we shall be able to test whether Tokamaks work or not in a fusion mode before anyone else can, at very low cost. If for some reason:, unknown to all, a new physics problem appears, we will learn it sooner than anyone else at modest cost. We may even find that Tokamaks don't work - in which case all Tokamaks don't work. In that case most of the world fusion programs are going to be in deep trouble.

Omni: Let's go back to how Riggatrons are different. Another expensive technology that you avoid is neutral-beam injection. How can you get to high enough temperatures with ohmic heating alone?

Bussard: It is like heating a toaster wire. Fusion will begin to occur if a current is simply passed through the plasma. It requires a certain set of conditions for the plasma density. If the plasma density is too low, putting the current through it will not work successfully. If the plasma density is too high, it is going to require much too much current. There is a range in between those two in which the density is just right To find out what those conditions were, that was the burden of our calculations in 1977 And that was the basic thing that my colleague, Dr. Bruno Coppi, at MIT, who is the co-inventor of this concept, learned that it was possible to reach ignition by ohmic heating alone, without any neutral beams, without any microwaves, just through resistance in heating the plasma.

Omni: Why didn't anyone else think of that?

Bussard: Well, they did a long time ago, furnishing the basis of the world fusion program Then they abandoned it all and went back to studying basic physics. But physicists don't think about, nor do they understand, power engineering and are not abreast of current developments and materials that come from other fields They seized on superconductors as wonders of science, and the whole program has gone off in that direction We took a different approach and said, "Let's look at what the aerospace world brings to us," because I am an aerospace engineer by background. That's where I began.

"With our approach, we will be able to test whether fusion actually works or not before anyone else can. If we find it doesn't work, the world's fusion programs will be in deep, deep trouble."

Omni: In other words, when the DOE review panel said you were pushing technology beyond the state of the art, it didn't know what the state of the art was?

Bussard: The panelists didn't have any idea what the state of the art was. If you look at their backgrounds, almost without exception, they have never built anything, of any kind, at any time

Omni: Didn't they say, for example, that the first wall in your Tokamak would melt?

Bussard: That was nonsense. Total nonsense. It was said by people who have no experience in building heat-transfer systems that conduct high-heat flows. The kindest thing that you can say about those on the first panel is that they were woefully ignorant of the engineering technology of high-power machinery. That is the kindest thing.

For the second review, we had an honest, unbiased, and non-bought-and paid-for reviewer in the form of a gentleman from NASA Ames This man has built a high-temperature, water-cooled, constricted arc with the Ames Jupiter arc reentry heating test facility for the shuttle It's a tremendous machine. It has run three years without a failure The heat fluxes that he can take on that arc on the first wall are three times the highest heat fluxes that we have ever seen required for any version of Riggatron reactors. And he sat on the panel and said that heat transfer is no problem.

Omni: Then can we review basically what happened? You received more than six hundred thirty-seven thousand dollars from ERDA for a conceptual study, after which it was downhill all the way

Bussard: No, it was uphill. It was progress as far as we were concerned. For the first time we had money to explore the engineering parameters that bounded the physics requirements. As a result of that study, I was a hundred percent confident it would work.

Omni: But something happened.

Bussard: Yes, it did. The scientific community aligned itself against us. In the spring of 1978, a board was convened to evaluate Riggatron's feasibility The panel met and produced a report. The report was so asinine that Inesco wrote a twenty-page rebuttal. The rebuttal got the panel to reconvene and consider it again. They came out with essentially the same kind of idiotic statements. Then they went downtown to higher levels of DOE and made presentations condemning the Riggatron concept.

The Office of Management and Budget was brought in to hear those presentations, ostensibly to get them to say this was a bad idea. The OMB got so troubled and unhappy it called me right away and said, "What the hell's going on? We hear this thing won't work, that the machine will break" It was the first I'd heard of such a meeting.

Eventually OMB called its own meeting of OER [Office of Energy Research), OFE [Office of Fusion Energy], and the OMB went away completely with a mind that the entire DOE review report was discredited. Totally and fairly discredited.

Omni: Was this the meeting that someone described as a shootout?

Bussard: Yes. We utterly destroyed them, technically. We were right and they were wrong. Congressman Mike McCormack [of Washington] asked the people at DOE to arrange another review committee from outside of the system. The second group was headed by honest guys with track records of some stature. Their report showed conclusively by all known physics that the machine will ignite.

Omni: What was DOE's reaction to this second panel review?

Bussard: They wanted devoutly to ignore it. The Office of Energy Research finally came out with a report around the end of November 1979. If you read the body of the report and the technical analysis, you will find that it says what I said earlier. But it has a one page executive summary dictated largely as a cautionary note to upper management at DOE. It says, in effect;"'Well, it's high-risk, and it may work and it may not, but in any event it should be viewed in the context of the larger program. Meaningless. So now they can ignore it. The report was never distributed. You don't want to distribute a report like that, right? You want to distribute only the executive summary. So they did.

Omni: Could one problem with acceptance of the Riggatron fusion reactor be that it goes totally against the long-life thinking that goes on in the utilities industry?

Bussard: It doesn't go against. It's as if we took a ninety-degree turn in the road and said there's another way around a certain mountain You don't have to climb straight over it; you can go around the other side.

Omni: You've said that the utilities don't like the large Tokamak approach, either, because they are too complex and too expensive. The Riggatron is appealing because it's modular and replaceable, How does that work?

Bussard: Think of a string of light bulbs, You want to have five lights burning at all times, You build a string seven bulbs long, and you light five of them, When one burns out, you turn on the sixth and you have no down time and replace the burned-out bulb.

Omni: So you can make power for utilities. What else can Riggatron do?

Bussard: That all has to do with producing cheap steam. The Riggatron is really nothing but a steam generator. When you compare the cost of steam from natural gas-fired plants or coal-fired plants, this thing produces steam at one third the cost. So we make such steam, and with a gadget that's so small it can be shipped in an airplane to the tar sands region. Then we pipe steam at three hundred fifteen degrees centigrade down one hundred eighty-three meters to tar sand formation and steam-distill the tar sand and get oil.

Omni: All this and you make ethanol, too.

Bussard: That's a different use of the same cheap steam. It's just the fact that the steam is so cheap and comes from an inexhaustible source.

I can also tell you about breeding nuclear fuel. The world is building reactors whether we are or not. There are hundreds of them overseas; they are being built in France like potato chips, All will need nuclear fuel. Riggatrons are probably the world's best breeders of commercial-grade fuel. It is completely proliferation-proof fuel. You can't make a bomb out of it because it is isotopically all mixed up. And there's an infinite supply so long as you have thorium and there is twice as much thorium as there is uranium 238.

And last, but not least, because it is such a copious neutron producer, Riggatron light bulbs can take fission waste products from reactors or from hybrid blankets and put fission-waste-product blankets around the machine. Then, by neutron transmutation, you can burn up the wastes so that they no longer constitute a nuclear-wastes storage problem.

Omni: Is this how you come up with these incredible profit projections?

Bussard: The profit figures come from almost anything this machine can be applied to. It turns out to be the same incredible profit margin, because the energy cost for any of them is so small.

Omni: And what exactly are those projected profits?

Bussard: It depends on how you capitalize it If you use thirty percent equity capital investment and seventy percent borrowed capital, you can generally show a case for an eighty to one hundred twenty percent return on investment. Only if you're in a totally free economy, of course.

Omni: That's certainly a very profitable business. So why did you need government involvement in the first place?

Bussard: I simply wanted to get one government contract, which has one very great virtue associated with it. It means that our Tokamak was at least of sufficient interest that the government would look at it and say, "Hey, that's interesting Let's put our USDA prime beef stamp on it because we'll fund a study"

Omni: Then why did you go through this big battle if government approval wasn't all that important?

Bussard: Because the government produced a report that was technically false, which was made available as a public document. I went to some government officials to make them do an honest assessment, on paper, admitting what they had done. That's all, I don't like being lied about.

Omni: Since you're in this for profit, why should the government be supporting your research?

Bussard: I'm in this for a lot of reasons other than profit. Its a damned shame that the United States is not solving the energy problem. The US government alleges that its interests lie in solving the energy problem. As far as I can see, those are empty words. The government's interest is in doing research on long-term solutions, not in grappling with real solutions for today. The technologies that could be brought to bear now, such as the Riggatron and other things in energy development are not being promoted by the government.

Omni: Had you stayed at the AEC, would you have been able to convert the federal fusion program to Riggatrons?

Bussard: I've no doubt that the AEC would have picked it up and run with it. I believe that sooner or later the government will be driven to it. Let me add that it is being done now. Independent of us and the Energy Department. The Soviet Union is busily constructing a Riggatron-like device,

Omni: What is their name for it?

Bussard: It's called the T-200. The Russians are certainly going to build these machines as the best vehicles for fusion They're also going to build them in order to produce massive quantities of plutonium for the Soviet plutonium-reactor economy, and they have said they will do so by the early 1990s.

If our current program is successful, we should beat them to it by five to seven years, recapture the world energy market from the OPEC cartel, and provide cheap energy - across the board, for the next several centuries, at least.

2007 Postscript by Tom Ligon

The perception that the Riggatron "didn't work" caused Dr. Bussard some credibility issues. In fact, the funding history of the Riggatron was rather like the Polywell. Bob Guccione originally intended to fund the Riggatron with $150M, using projected revenues from an Atlantic City casino. In fact, he was unable to get the permits for that enterprise, and so had to cut the project off at about the $17M level. It was never built, so nobody knows if it would have worked. Dr. Bussard still believes it was the one tokamak design that had any chance of making break-even.

A key advantage of the Riggatron was that it supposedly had better magnetic field stability due to its magnets being immediately adjacent to the plasma torus. In contrast, the ITER design must project its superconducting magnetic fields through 5 meters of lithium, resulting in serious stability issues with its magnetic field wriggling around like a slinky.

In any event, the Riggatron experience left Dr. Bussard down on tokamaks. Even if he thought that the Riggatron would have worked, it is evident that he felt that it was not practical for the funds he had available.

If the Riggatron have been successfully developed, it was a nasty little neutron-maker with a very short live expectancy. Bussard's Polywell concept grew out of frustration over the difficulties in confining ions with magnetic fields, which was the big cost item in the Riggatron, as it is in all tokamaks.