21st CENTURY SCIENCE & TECHNOLOGY

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Who Killed Fusion?

- Radioisotopes: The Lifesavers that Congress Is Suppressing
- Vietnam Moving Forward with Nuclear
- Fusion in Korea

21st CENTURY SCIENCE & TECHNOLOGY

Vol. 22, No. 4 Winter 2009-2010

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VAEC

Vietnam's Dalat Nuclear Research Institute. Vietnam plans to bring the first of four 1,000-MW nuclear plants online in 2020. See page 61.

ON THE COVER: The steel support columns for the Tokamak Fusion Test Reactor in construction, June 1981. Photo courtesy of Princeton Plasma Physics Laboratory/DOE; cover design by Alan Yue.

News

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White House on Nuclear: Words, Words, Words

Presidential Science Advisor John Holdren replied March 5 to a letter sent to him on Feb. 1, by more than 300 scientists and others, urging him to tell the President that the United States must get back to developing nuclear power. His reply consisted of "words, words, words"—pretty much what you would expect by a committed Malthusian who does not support any technology that would enable the world to support a growing population.* Holdren's reply is the clearest proof that the White House is not serious about going nuclear, despite feints in that direction.

The letter sent to Holdren states that the "world is leaving us behind," in developing and deploying nuclear energy. Of the 58 new plants under construction worldwide, it states, only one is in North America, which is a mothballed plant that the TVA is finally finishing. "Our nation needs to proceed quickly—not twenty or fifty years from now—while the people who pioneered this science and engineering can still provide guidance to a new generation of scientists and engineers. There is no political, economic, or technical justification for delaying the benefits that nuclear power will bring to the United States, while the rest of the world forges ahead," the letter states.

The signers make three "urgent recommendations." The first, is to "accelerate the licensing and building" of current-generation nuclear power reactors. The second, is to point out the urgent need for the United States to produce medical isotopes, the shortage of which has put thousands of lives in jeopardy. Third, is to develop the fourth-generation reactors. They specifically urge the reinstatement of the program to develop and demonstrate the technology for recycling used, or spent, reactor fuel (reprocessing), which has been cancelled by the Obama Administration.

The letter points out that Russia, China, India, Japan, and South Korea have expressed interest in contributing to a demonstration fast reactor.

The signers of the letter are predominantly from the United States, but include people from 21 other nations. Academician E.P. Velikhov, head of the Kurchatov Institute and a Russian policy advisor signed, as did Dr. Baldev Raj, director of the Indira Gandhi Centre for Atomic Research in India, and John Ritch, the director of the World Nuclear Association, based in London. Former U.S. Apollo astronaut and geologist, Harrison Schmitt also signed.

The letter was also sent to every Member of Congress and to Energy Secretary Steven Chu.

John Holdren's Reply

John Holdren's March 5 response* exemplifies why 321 scientists and others were motivated to send him the very letter to which he is replying: The Administration's nuclear policy is just a lot of words, with no intent behind them to change a policy that ensures that future generations of Americans will be living in deindustrialized poverty at best.

First: While the rest of the world is right now building dozens of new nuclear plants, and 50 non-nuclear countries are making plans to go nuclear, the Obama Administration is issuing words. There are promises of loan guarantees, but nothing substantially is changed to ensure that new conventional nuclear plants will be built, or that advanced nuclear plants will be built. Remember, we are the nation that pioneered civilian

nuclear technologies. Now we lag far behind.

Second: The shortage of medical isotopes has been a known problem (really a disgrace) for decades. Every single government study has recommended plans to domestically produce an isotope supply. Now we get more words. An Administration intent on solving this problem would reopen the FFTF to produce isotopes, and stop the burial of the so-called waste from Shippingport and the ORNL breeder, and use this material to make valuable isotopes. Instead, this Administration focusses on avoiding "proliferation"—a bogus issue to cover for anti-nuclear policies.

Third, it does not take a rocket scientist to figure out that setting up a committee, especially one without experienced nuclear scientists on it, to study something that has been studied for decades is simply a public relations effort to avoid taking action.

Words and promises are not what built the TVA or what got us to the Moon. Those programs were funded at the levels necessary to get the job done—even when the solutions were not yet known. There was a clear recognition that man has the creativity to solve any problem. The funds were allocated because these were national missions that required long-term support, science-drivers to move the entire economy forward.

In 1958, when South Korea was devastated by years of war and its people were literally starving in the dark and cold, American Walker Cisler, a nuclear pioneer, advised Korea's President to invest scarce funds in a science driver—nuclear power—that would not pay off for at least two decades. Dr. Syngman Rhee listened to Cisler, and 20 years later, Korea's first nuclear plant came on line. Now South Korea has 20 nuclear plants, a fast breeder in the works, and is a prosperous nuclear exporter. And Cisler's America? We are pouring billions into so-called "green" projects that will run our economy into the dust.

Cui bono? Not the American people.

What has to be done to achieve the kind of leap that South Korea made, and that this nation has made in the past, is not mysterious. We know what to do. It requires a political will that is entirely absent from John Holdren's letter of words.

—*Marjorie Mazel Hecht*

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* The full text and list of signers to the letter to John Holdren can be found here: see http://www.21stcentury sciencetech.com/Articles_2010/Nuclear_letter.pdf

The text of John Holdren's reply is here: http://www.21stcenturysciencetech. com/Articles_2010/John%20Holdren.pdf

Those interested in signing the nuclear letter, should contact the corresponding author, John Shanahan.

Letters

Can Machines Think?

To the Editor:

I was wondering if you could comment on Ray Kurzweil's view that the exponential progression in machine computing ability will, within 20 to 40 years, result in thinking-capable machines which will express their own desire to expand consciously, and physically, into the universe?

Such a situation would essentially mean the end of human civilization, and biological life generally, as the machines would consume the resources necessary to their survival, indiscriminately, including incorporating human consciousnesses (how many?) into its systems.

Without saying it (or likely knowing it), Kurzweil also argues that this would simply represent the next higher-level phase space in the anti-entropic behavior of the universe, à la the Vernadskian progression from the Lithosphere to Biosphere to Noösphere. The next level will be the Mechosphere, capable of transforming and otherwise utilizing the raw resources of the universe at many quantum leaps of efficiency and energy flux densities over biological capabilities, including the biological limitations on consciousness and information processing, and creativity.

If the historical anti-entropic behavior of the creative actions of the universe is a precedent, then this outcome is inevitable and humanity's existence will simply be a "cog in the wheel," so to speak, of this developmental process, just as how today, organisms which have lived over the eons in the past have provided for humanity's ability to develop; our function in this universal process may one day fulfill its purpose.

Something I think Kurzweil takes too for-granted is the human element required in mechanistic technology. Modern computers *do not* function with less

(Continued on p. 6)

OECD

French President Nicolas Sarkozy told the OECD conference that nuclear energy is the responsibility of states.

FRANCE BACKS THE UNIVERSAL RIGHT TO NUCLEAR POWER

Every country that complies with the current transparency rules has the right to civilian nuclear power, French President Nicolas Sarkozy announced at an international conference on access to civilian nuclear power, held in Paris, March 8-9. The French President attacked the Malthusian ideology of zero growth, and called nuclear energy the responsibility of states, not private concerns.

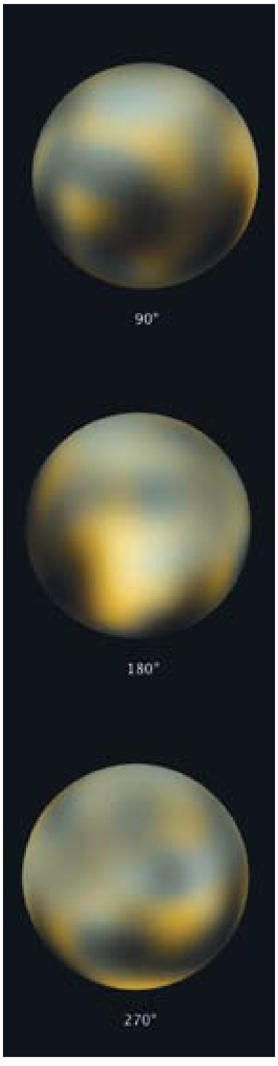
Although France, by itself, will not be able to break the British-led opposition to rapid economic development, Sarkozy's stance can help provide impetus to Lyndon LaRouche's call for a Four Powers agreement to relaunch scientific and technological progress on a global scale. Economist and statesmen LaRouche has called for unleashing nuclear power and the manned colonization of Mars to fuel world economic development, under a Four Power agreement among the United States, Russia, China, and India. There is no chance for a global recovery, without agreement among the world's four leading powers to replace the presently bankrupt world monetary system with a viable credit system modelled on Franklin Roosevelt's policies, LaRouche says. Failure to do so means a certain descent into a new Dark Age for all humanity.

Taking a direct swipe at the Malthusians, French President Sarkozy said: "World population is growing ... and the energy needs of our planet are growing as well.... The ideologies calling for reversing growth and progress offer no solutions. The solution lies in diversification ... rationalization, and scientific and technological progress."

Nuclear energy, Sarkozy said, is the responsibility of states, not of private concerns, because investments are very long-term and ponderous. He called for an "end to the ostracism against nuclear investments among international financial bodies." He also announced the creation of an International Nuclear Energy Institute to train nuclear cadre, and proposed that a "nuclear fuel bank" be created within the International Atomic Energy Agency (IAEA), to which new nuclear countries can have access should they lose their nuclear fuel suppliers. He also recommended recycling spent fuel.

"Let us put aside the stereotypes and suspicions of ulterior motives. The countries of the world are not divided between those with nuclear technology, jealously guarding their privileges, and those demanding a right that the others are denying them.... On the contrary, I think that nuclear power can be the cement that binds a new form of global solidarity."

21st Century's colleagues in France attended the conference, which was sponsored the OECD and the IAEA.



NASA, ESA, and M. Buie (Southwest Research Institute)

The most detailed view to date of the entire surface of Pluto, constructed from multiple photographs taken from 2002 to 2003. The center disk (180 degrees) has a puzzling bright spot, which is unusually rich in carbon monoxide frost.

INDIA: THORIUM WILL INCREASE ENERGY RESOURCES BY 155,000 YEARS

India's third phase of nuclear development is the building of advanced heavy water reactors using thorium as fuel, Srikumar Banerjee, chairman of India's Atomic Energy Commission, told the Paris conference on nuclear power. Because thorium is three times more abundant than uranium, he said, this process will extend the life of that resource to 155,000 years. Banerjee noted polemically that the 56 nuclear reactors now under construction worldwide represent only a 1-2 percent growth annually, while India and other developing sector nations need at minimum 10 percent annual growth to provide electricity to millions of poor. That resources are scarce is something that we've known for 40 years, he said, but we have done nothing to solve the problem. He called for international support of India's thorium project to deal with this scarcity.

SEASONS ON PLUTO CAPTURED IN NASA'S HUBBLE SPACE TELESCOPE

The latest images from the Hubble Space Telescope show the distant dwarf planet Pluto not as a simple ball of ice and rock, but an icy, mottled world, which undergoes seasonal surface color and brightness changes. Pluto has become significantly redder, while its illuminated northern hemisphere is getting brighter. These changes are most likely consequences of surface ice melting on the sunlit pole and then refreezing on the other pole, as the planet heads into the next phase of its 248-year-long seasonal cycle. The overall color is believed to result from ultraviolet radiation breaking up the methane on Pluto's surface, leaving behind a dark and red-carbon-rich residue.

JAMES LOVELOCK: CLIMATEGATE AND THE CORRUPTION OF SCIENCE

In a March 29 interview with Leo Hickman of *The Guardian,* British scientist James Lovelock said of the Climategate scandal: "I was utterly disgusted. My second thought was that it was inevitable. It was bound to happen. Science, not so very long ago, pre-1960s, was largely vocational. Back when I was young, I didn't want to do anything else other than be a scientist. They're not like that nowadays. They don't give a damn. They go to these massive, mass-produced universities and churn them out. They say: 'Science is a good career. You can get a job for life doing government work.' That's no way to do science.

"I have seen this happen before, of course. We should have been warned by the CFC/ozone affair because the corruption of science in that was so bad that something like 80 percent of the measurements being made during that time were either faked, or incompetently done."

Hickman has posted a partial transcript of the interview at www.guardian.co.uk/environment/blog/2010/mar/29/james-lovelock. *21st Century*'s Gregory Murphy's interview with Lovelock can be found here: http://www.21stcenturysciencetech.com/Articles_2009/Lovelock.pdf

NatureVideo

James Lovelock knows his CFC measurements. He is the inventor of the electron capture detector, which made possible the detection of CFCs and other atmospheric gases.

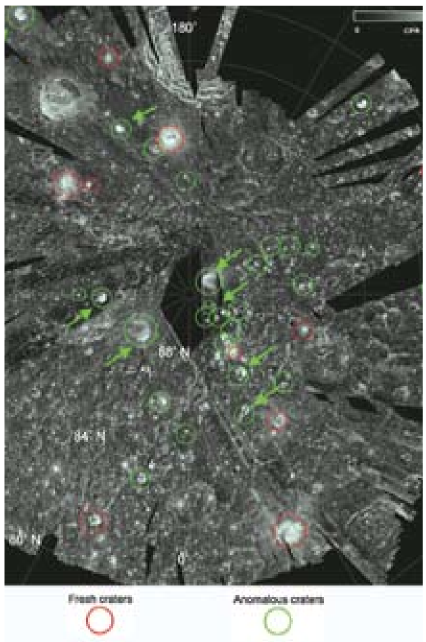
NEO-MALTHUSIANS PLAN ATTACK ON CLIMATE 'SKEPTICS'

Another group of private e-mails dealing with climate change has been made public, this time from scientists who promote anthropogenic global warming, among them the well known neo-Malthusian pair: Paul Ehrlich, author of *The Population Bomb*, and Stephen Schneider, a Stanford professor and lead author of all of the IPCC climate assessment reports. The two were key players in the 1975 Endangered Atmosphere conference where the global warming hoax was first proposed.

Their plan, according to a series of e mails on a private National Academy of Sciences exchange, is to set up a nonprofit organization that will raise money to take out attack ads in newspapers and set up conferences directed against scientists who dare question global warming. Despite several trillion dollars in funding for the zero growth movement, Ehrlich and Schneider complain that this nonprofit organization is needed because the climate skeptics are awash in money. In one e mail, Ehrlich wrote, "Most of our colleagues don't seem to grasp that we're not in a gentlepersons' debate, we're in a street fight against well-funded, merciless enemies who play by entirely different rules." Indeed!

MORE WATER ICE FOUND ON MOON—BUT WILL WE GO THERE TO USE IT?

More than 40 small craters near the north pole of the Moon contain water ice, scientists announced March 1, based on an analysis of data from the U.S. synthetic aperture radar instrument, Mini-SAR, which flew on India's Chandrayaan spacecraft last year. This is the latest in a series of discoveries by a fleet of lunar-orbiting craft, which have shown that "the Moon is an even more interesting and attractive scientific exploration and operational destination than people had previously thought," stated Paul Spudis, the instrument's principal investigator. Spudis has been outspoken in attacking the Administration's attempt to end NASA's manned lunar program.



NASA

The new Mini-SAR data indicate that in more than 40 small, permanently shadowed craters (green circles, north pole of the Moon) there could be at least 600 million tons of water ice. These craters are 1 to 9 miles in diameter and not visible from Earth.

Last September, data from the U.S. Moon Mineral Mapper on Chandrayaan revealed a previously unknown thin layer of water ice virtually all over the lunar surface, which waxed and waned with the lunar day and night. Two months later, results were announced from the October crash of a U.S. spent rocket stage into a region near the south pole of the Moon, providing indisputable evidence for water ice inside south polar craters. The new results are from the opposite side of the Moon, at the north pole.

From these multiple measurements, Mini-Sars principal investigator Spudis concluded that "water creation, migration, deposition, and retention are occurring on the Moon," which is a dynamic, not "dead" body.

Letters

(Continued from p. 3)

human involvement in their operation and production compared to computers of the past, as fundamentally required under Kurzweil's view. However, I suppose his response to that would simply be: "Not yet."

Of course the moral (and, the demoralization campaign of the Empire) aspects of this issue are of paramount importance to a view of humanity.

If you could, please comment.

Joseph Edwin Postma,
Astrophysicist

Lyndon H. LaRouche Replies: 'No Machine Will Ever Think'

Contrary to such fanatical followers of Bertrand Russell as the Norbert Wiener and John von Neumann who were thrown out of Göttingen by David Hilbert, no machine will ever actually think.

There are two approaches to the design of calculating machinery which could be considered under that subject-heading. Mechanical machines in the conventional sense, and, secondly, those in which a living biological process complements the mechanical, or mechanical-like. Under those conditions, we have defined the domain of "robotics," but not, for example, Classical poetry. A robot might be designed to function as a sex-machine, but would never be capable of love.

A debate of the sort to which you refer, arises when the noetic processes specific to the human mind, as illustrated by the work of V.I. Vernadsky on the "Noösphere" and also, so very neatly, by the concluding sentence of Bernhard Riemann's 1854 habilitation dissertation, are ignored.

"Machines" are specific to the domain of mathematics; the human design of machines, belongs to the domain of the practice of original discoveries of universal principles expressed as physical science, not by the Lithosphere, nor the Biosphere, but only by mankind—or, better said, by the natural potential of mankind.

In reply to questions of the type to which you refer, I refer to the case of Albert Einstein's cognitive kinship with his violin. Human creativity lodges within the domain associated with the powers of the Classical artistic imagination, as Johannes Kepler uses the inconsistency between the human senses of sight and harmonics, to discover what Einstein defines, respecting the universal principle of gravitation, as a finite, but unbounded universe.

The question you present arises in modern practice through, chiefly, that influence of Paolo Sarpi and his follower Abbé Antonio S. Conti, who defined the behaviorist principle of such as John Locke, Adam Smith, and Jeremy Bentham and their modern radically reductionist school. A valid discovery of a universal physical principle lies outside the bounds of the Lithosphere and Biosphere, in the domain of the Classical artistic imagination, whence the noetic powers of the developed human mind discovers the existence of principle as the means of escape from bestial-like ignorance. It has been, thus, the rise of existentialism in respect to Classical artistic insight, as in the Bertrand Russell version of the modern positivist school in modern mathematical practice, which has done so much to destroy scientific creativity, since 1945.

The Lies of Rachel Carson

To the Editor:

The author [Dr. J. Gordon Edwards in "The Lies of Rachel Carson, *21st Century,* Summer 1992, http://www.21stcenturyscience tech.com/ articles/summ02/Carson.html] makes a mathematical inconsistency in the argument below:

"Rudd and Genelly state in *The Condor* (March 1955): This value is equivalent to 15,000 parts per million DDT in the diet.

"This amount represents the highest dosage of DDT I have ever heard of in any experimental animal, and I cannot understand why they would use such an extreme concentration. This means that 15 percent of every bite of food was poison."

The transition of 15,000 ppm is 1.5 percent not 15 percent:

$1.5 \times 10^4 \times 100/(1 \times 10^6) =$ 1.5 percent.

15 percent equals 150,000 ppm.

Anthony Rajki

Marjorie Hecht Replies

You are quite right in the math; the amount should be 1.5 percent, not 15 percent. I suspect that this must have been an editorial error, rather than the author's, in misplacing the decimal point. Edwards (now deceased) was really meticulous in his work, and never to my knowledge made an error.

Now, for the amount itself: Even the 1.5 percent in an animal study would

have been very large. Here's what Dr. Alice Ottoboni, an experienced animal researcher, wrote when I sent her the Edwards article and Mr. Rajki's inquiry:

"Thank you for sending the link—great article. Like you, I have never found Gordon to even exaggerate, much less err. However, Mr. Rajki is correct, 15,000 ppm is equal to 1.5 percent.

"I can only assume that the "15 percent" was a typographical error in Gordon's draft that he did not catch. I know that he would have known better. He was correct, though, about it being the highest he had ever heard of in animal testing—even at 1.5 percent.

"In our four-generation study of reproduction in Beagle dogs, the highest level fed was 10 mg/kg which would equate to not quite 0.2 percent DDT in a human diet (70 kg man x 10mg/kg = 700 mg DDT: approximate daily food intake about 1 pound = 454 grams: 0.7 g/ 454 g = 0.00154 = 0.15 percent). We chose 10mg/kg as the highest level because we expected it to produce some overt toxicity. Instead of adverse effects, we found all of the dogs on the high level to be as healthy—or more so in some parameters—than the controls (Ottoboni, Bissell, Hexter. 'Effects of DDT in multiple generations of Beagle dogs.' *Arch Environ Contam Toxicol.* 1977, Vol. 6, pp. 83-101)."

LANCE ENDERSBEE (1925-2009)

Humanity Loses A Champion

by Robert Barwick

Endersbee addressing a Citizens Electoral Council conference, talking about Australian development projects.

CEC

Civil engineer Lance Endersbee, a long-time collaborator of the LaRouche movement in Australia and of *21st Century Science & Technology,* died of cancer Oct. 1, 2009.

Lance's career as a civil engineer spanned the wonderful Snowy Mountains Scheme, on which he worked under the great William Hudson while still an engineering student; Tasmania's brilliant hydroelectric system; dam construction in the Mekong Delta; and engineering projects in the United States. Also an educator, Lance was Dean of Engineering (1976-1988) and pro-Vice Chancellor at Melbourne's Monash University.

He was a world authority on rock behavior and tunnelling, a former president of the Institution of Engineers Australia, and a recipient its highest award, the Peter Nicol Russell Memorial Award.

Lance met the LaRouche movement in Australia, the Citizens Electoral Council or CEC, in 1997, when he was involved in the fight against electricity privatization. This led to a rewarding collaboration around great infrastructure projects, which was his true passion. Lance spent his active retirement self-funding surveying trips all over Australia and designing great infrastructure projects to see Australia into the future.

He told a CEC conference that his motivation for this work was witnessing young engineering students forced to expand their course to include business and commerce options, only because, unlike the hands-on opportunity the Snowy Scheme afforded him as a student, there were no equivalent nation-building projects to be tackled by his own students.

Lance's designs included a Melbourne-to-Darwin fast-freight railway, an Australian Ring Railway, and an economically viable Clarence River hydroelectric power and irrigation scheme.

LaRouche Youth Movement members and others would remember Lance from his work on underground water, which he showed is fossil water that is not being recharged, as was the common assumption. Further, he said, the extraction of this fossil water is causing land subsidence over the Ogalalla Aquifer, and other places.

His 2005 book, *A Voyage of Discovery,*[1] includes an examination of underground water worldwide. *21st Century* published a chapter from his book in Spring 2006, "The World's Water Wells Are Drying Up!"

Fighting Climate Superstition

In the final years of his life, Lance threw everything into the fight against the superstition of man-made global warming. He last addressed a CEC conference in February 2007, where he expressed his personal sense of outrage as a scientist at the Al Gore claim that "the debate is over." Through his many scientific contacts, Lance was instrumental in galvanizing honest scientists to not be intimidated and speak out against the global warming lie. This has helped to smash the consensus line, and throw the Australian debate about cap-and-trade into turmoil.

Earlier in 2009, Lance organized a Symposium on Global Warming at Monash University, where he said: "The purpose of the symposium is scientific, and directed to demonstrating that the global climate is determined by natural driving forces. We are of the firm opinion that the present claims about man-made global warming are wrong, and that the predictions from computer models of climate are seriously misleading. It will be shown that the immediate prospect for the global climate is not warming, but continued and deeper cooling."

Lance's son Philip recounted that his father fought to the end: Just 12 hours before he died, Lance said of the cap-and-trade bill to come before the Parliament, "Don't let them pass that emissions trading scheme."

Lance is survived by his wife, Margaret, three children, and 11 grandchildren.

Footnotes

1. Lance Endersbee's book, *A Voyage of Discovery: A History of Ideas About the Earth, With a New Understanding of the Global Resources of Water and Petroleum, and the Problems of Climate Change,* is available from the Monash University Bookstore website, http://bookshop.monash.edu.au.

We Need to Return to Thinking, and The Great Projects of the FDR Era

These are excerpts from a lengthy interview with the late Prof. Lance Endersbee, which appeared in the Executive Intelligence Review, *June 28, 2002. He was interviewed by* EIR *economics editor Marcia Merry Baker, while he was in Washington, D.C., to participate in a conference of the LaRouche political movement.*

* * *

Endersbee: One of the tragedies is, that we've tended to move away from the capacity to speculate, and to think about issues. And we're always trying to make things black and white, which is never the case. And this means, that we've got ourselves into the crazy situation, where, even in the universities, speculation is not on. And the idea that we can't speculate, is reinforced by this mad system of peer review, and all the rest of it.

I think there's an awful lot of young people in the universities, at the moment, that are being held in a system of thought-control, because all speculation is out of court. Unless you can prove things absolutely, it's not scientific. Well, all of the great scientific discoveries of the world began with speculation.


CEC
Endersbee as a young engineer. In 1952, he was sent by the Australian government to the Bureau of Reclamation in Denver, to learn the skills of designing big tunnels and dams.

EIR: Let's switch for a minute, to another area of control, where it's said, "It's not economical to build great projects. We do not have the money to develop our resources." First, you were in just the opposite position. After the Second World War, you were building things. Can you tell us something about that—the Snowy Mountain project. . . .

Endersbee: Well, let's begin a little bit earlier in America: When Franklin D. Roosevelt came to power—and it's worthwhile listening to his inaugural, because I think it's fantastic—Roosevelt got on with the job, with the TVA (Tennessee Valley Authority) and Grand Coulee. He had the Bureau of Reclamation already going well, and Hoover Dam. And they were absolutely wonderful projects. The important thing was that every one of them was big and challenging. Hoover Dam was, by far, the highest dam in the world. It was an arch dam. They had to develop new techniques for analysis, to work out the stresses in the dam. The mere matter of the diversion of the Colorado River, past the dam site, was a fantastic operation. And then, of course, they had the largest turbo generators in the world. There were *huge* steel pipelines. And they have to develop new ways of welding these great pipes, and so on. So, there was a great deal of activity in Hoover, which was exciting and interesting, and it challenged the Bureau.

The same thing was happening in the TVA. And the TVA was an absolutely incredible project, because it covered so much countryside in Kentucky and Tennessee. Hundreds of thousands of people were involved. And, in the case of the Tennessee Valley project, what was absolutely amazing, was that all of the people in the Valley, hundreds of thousands, were all captured by the idea, and they all worked together for a common purpose, and there was no sense anywhere, of people doing their own thing, or individual purposes: Everybody was united towards a common goal. It was an absolutely fabulous time.

Now, I was reading about these sort of things in the technical press, of course. I was watching it all like mad.

EIR: They had music evenings, to give briefings on why they should use electricity!

Endersbee: Yes! Well, it was all a wonderful time.

Now, this was also being monitored, around the world, because everybody was interested in these fantastic steps forward, that Roosevelt was making. And, one of the places where that was noted was, of course, Australia. We'd been thinking about the inland diversion of the Snowy River for some time. And so, after the war, we started getting on, developing plans for the building of the Snowy Mountains project [Figure 1, p. 12].

But, there are other people around the world, also, looking at all sorts of new plans for redevelopment. And we started

Along with the rest of the world, Endersbee was inspired by the Roosevelt-era great projects. Here, Hoover Dam, built by the Bureau of Reclamation, is a National Historic Landmark and has been rated by the American Society of Civil Engineers as one of America's Seven Modern Civil Engineering Wonders.

this project—the Act went through in 1949. We then had an immediate prob0lem, because we really didn't have the strength in depth, within our organization, to get on with the job. We started off with a commissioner, who was a hard-bitten, old hydro-electric construction engineer—he knew exactly what he was doing, and he was a wonderful leader—and a bunch of young engineers, like myself.

EIR: Tell us more now, how did the Snowy Mountain training come about, that you could go from one thing to another?

Endersbee: Okay. What happened was, that we just had two or three senior people with background and a bunch of young engineers. And the Snowy organization entered into a contract with the United States government, whereby we paid—this is Australian money; no aid or anything, right?—we paid the Bureau of Reclamation in Denver, Colorado, to help us with the design of the first major tunnels and the first two major dams, and in the process help us, by training some of the young engineers.

And so, in 1952, I was sent to Denver, Colorado, and I was told by the Snowy, that I had to learn to be an expert in tunnels and underground construction.

EIR: In how long?

Endersbee: Oh, as quick as possible!

And so, I was sent to Denver. And the Bureau engineers sat us down. And I sat down at an empty drawing board, and I started to draw up the first tunnel—the 14-mile-long Eucumbene-Tumut diversion tunnel. And so, I did that, and I was beavering away there for 12 months. And it was wonderful working with these Bureau engineers, because they were all 20 and 30 years older than me—they had all this experience.

And they would just saunter up to my desk and say, "Why don't you think about this?" or "Have a go at that." And, every now and again, they'd disappear and they'd come back with a book or a specification, with a few things marked in it for me. And there was this wonderful relationship between these older Bureau of Reclamation engineers and the team of 12 young Australians.

And, you can imagine, being Australians, there's lots of banter, and everybody had a good time. But, there was a wonderful human relationship there. And after 12 months, I was going back to Australia, with a bundle of drawings and specifications, so I was hoping I could answer all the questions, when I got home, and the details!

And so, we then got on with calling tenders, and getting on with the construction of the projects.

And then, there was another nice development: The Bureau of Reclamation had a number of older engineers, in their late 60s-70s, who had been construction engineers, resident engineers, on Glen Canyon, or Grand Coulee—you name it. Some of them had been on the Colorado—Big Thompson. And they had these construction engineers, who'd been there and done it, and so, we arranged for them to come and stay with us for periods of 12 months or so.

And they sat down with us, and they helped us with the administration of these *very* large contracts—you know, these were multimillion-dollar contracts; quite huge things, in those days. And once again, the relationships were rather wonderful. Because we'd get into a problem with a contract, and we were worrying about this and that, and they'd say, "Well, this is the way we did it, at Palisades"! And, off they'd go and they'd come back with some data for us.

Of course, there were absolutely wonderful relations there. By then, some of us were a bit older; we had children, and they were part of the grandfather circuit in the young Australian community, the relationships were absolutely fantastic.

So, the project was built on time and within the estimate, and it was a great, complex project, and it was this sort of harmonious relationship with the Bureau that helped it along.

▲ *Six generators at Tumut 3 power station. Two of them can provide enough electricity to power a city the size of Australia's capital, Canberra.*

The six pipes of the power station Tumut 3 are each 487 meters long, 5.6 meters in diameter, and collectively contain 10,260 tons of steel. ►

EIR: So, the examples of this, which I know have been recently published and available in Australia in the CEC periodical *The New Citizen,* are very appropriate to the Franklin Delano Roosevelt approach today. Because they're directly a spin-off, thanks to people like you.

And then, you built more underground power facilities and that kind of thing.

Endersbee: See, when you start off with a rocket behind you, which happened to me—this applied to most of the young Australians who were involved in this, because of the fact that they were expected to become experts, without trying to be experts—within about eight years or so, we were operating at a world frontier. And the interesting thing is, that we had already been working on the design and construction of two large underground power stations, and, at that time, the Bureau of Reclamation had not designed and built an underground power station.

. . . And now, the Bureau of Reclamation—they were watching us!

EIR: So, these were underground turbine stations.

Endersbee: Oh yes, absolutely: Large underground power stations. There are two in the Snowy scheme, and I worked on the first one of those. But, by then, as we were completing this first large underground power station, I was then invited to go to Tasmania, where the Hydro-Electric Commission in Tasmania was designing and building *their* first underground power station. So I went to Tasmania, and once again, we had a government instrumentality—a government utility—and we had an interesting charter from the Tasmanian government as a government utility.

Tasmania is a hydro-electric island, and, in effect, the orders from the government were, we were to generate the lowest-cost hydropower in the world, so that we would attract industries to Tasmania.

And so, in other words, as a government department, we were ordered by the government, to operate at the frontiers of technology, design, and construction, to keep the prices as low as possible. And you can only do that by technical excellence. And so, we were encouraged again.

We were the first in the world to use hard-rock tunnelling machines, boring tunnels. And that was an interesting exercise, in that we wanted to drill several miles of tunnels through hard rock, and hard sedimentary sandstones, and things like that. And, we found that, in America, there was a firm that had built a soft-shale cutting machine. . . . This was at the Missouri River diversion—on one of the Missouri projects. And this was [an Army] Corps of Engineers project, and they had used—for a fairly short distance—a soft-shale cutting machine.

But we saw that they had the electric

▲ *Endersbee was a world authority on rock behavior and tunnelling. Here drilling at the Tooma-Tutmut tunnel, part of the Snowy Mountain Scheme, in 1959.*

Construction at the Snowy Mountain Scheme's underground power station Tutmut 1, in 1958. ►

motor drive-system, which we wanted. So we got in touch with this firm in Seattle, and there were some financial problems there, with the firm. And, in essence, the Hydro-Electric Commission in Tasmania provided funds to re-float this company in Seattle. So here's a government department doing this sort of thing, to help us design and build this hard-rock tunnelling machine, which we were going to ship to Tasmania.

And it worked. We sent our plant engineers over there. They worked with the firm in Seattle, and then, they came back to Australia with the machine. We put it up to the face, and it worked like a charm. We realized, we couldn't get the muck away quick enough, we were doing so well. So, we had to redesign the conveyor belt system, and everything else, to move the muck quickly—and we were breaking world's records.

EIR: This is the positive idea of building infrastructure. But we all know, wherever we live, almost, that the last 20 years, things lagged, there was a pause. And you are now saying, that, not just in power generation, but in railroads, you have a peculiarly dramatic situation in the railroad gauges in Australia. Can you tell us, in your expert opinion: If we were to start tomorrow to have that same spirit and technology commitment, what should we be doing there?

Endersbee: Well, the wonderful thing about Roosevelt is, that he identified not only problems in America—but helped to inspire a similar approach around the world. And you only have to look at the situation in Africa, in South America, parts of Asia, and so on: There is a need to match new infrastructure. And, the problem is, that the world is divided in various ways: In Africa, the sort of projects that should be built, involve several countries. In the Middle East, the problems of groundwater are sort of heading towards warfare, almost.

And so, it's really a matter of trying to overcome the political problems. If you can put the political structure together, the rest is easy.

EIR: You've developed maps to show Australia, in political-social terms—how it's part of a whole region of 4 billion people (if you count India and China and East Asia and Southeast Asia), so that it could be a positive location, not a strife location.

Endersbee: We have to look at that market. You see, we're just 20 million people, in Australia. And one of our problems today, is that our Constitution, which to a certain extent was based on the U.S. Constitution, preserved sovereign power at the state level.

EIR: Not Federal, but state.

Endersbee: At state level. That means that the various states of Australia agreed to the Constitution, on the basis that they preserved sovereign power. And the Federal government was only granted powers for defense and foreign affairs, and trade, and so on. That meant the states were responsible for water, electricity, and transport, and you name it. And so, that meant that the states—and for the last hundred years—have hung onto, not only the separate ports, but separate rail systems, *and of different gauges. . . .*

But, you see, at the time of the Con-

Figure 1
THE SNOWY MOUNTAIN SCHEME
The Snowy Mountain project covers an area of 7,780 square kilometers, with 16 dams and 7 power stations. Like the Hoover Dam, the American Society of Engineers rated it as "one of the seven engineering wonders" of the modern world.

Figure 2
ENDERSBEE'S PROPOSED ASIAN EXPRESS
Endersbee proposed a rail program that would link Australia to the entire East and Southeast Asia region, opening up a market of 4 billion people. His Asian Express plan is a high-speed train from Melbourne to Darwin, which would revolutionize Australia's export potential.

stitution, that was regarded as a plus, because the separate gauges leading to each port, meant that the other states wouldn't interfere.

EIR: Oh, wouldn't compete for the hinterland traffic!

Endersbee: No—and, if you like, this idea of separate state sovereignty still remains. I was in the Northern Territory, two or three years ago, and one of the local bureaucrats told me, very proudly, how the Chief Minister of the Northern Territory (which is probably about 200,000 or less people) had recently been in Beijing, and had signed a memorandum of understanding with the Premier of China! You know, I thought, "Ahhh! What madness this is!"

But, okay, if you look at the situation from the Australian point of view, there is still enormous potential in the north and south [see Figure 2]. And, if you look at the markets to our north: Darwin, for example, the distance from Darwin to Singapore is the same distance as the length of the Mediterranean Sea.

So, we can be communicating with all of that part of Asia, and entering into trade with Asia.

If you see the map, and you see the distances between Singapore and Japan; at any one time, half of the world's container ships are in the seas between Singapore and Japan. Half of the world's containers are there. So, it's a huge area, based on maritime trade, and that's easy to understand, when you think of all the islands of the Indonesian archipelago—so, we are in a good position to trade with that area, and also to be a source of food.

EIR: So, this would help define infrastructure, to build up ports.

Endersbee: Absolutely. This is what I'm getting at, is that the 4 billion market, and their needs, drives infrastructure development in Australia, because, in effect, we would be designing and building, to sell Australian produce and our goods, into that market.

EIR: Tell us something about the new railroad plans, or new irrigated farming plans—you have a terrific climate in Australia.

CEC

Lance Endersbee and other national water experts collaborated with the CEC in 2002, to outline 18 great water projects in Australia, shown on this map.

Endersbee: Well, I've been working on a new railway system, that goes up through the middle of Murray-Darling Basin—it's a great irrigation area, at the moment. The Murray-Darling Basin—we can double or triple the output, by getting a better access to market.

See, in Australia, we have what they call, a "tyranny of distance." And economic development depends on access to markets. If you change the access to markets, you improve the value of crops; you change the sort of crops you grow; it changes the value of water. So, if we have, if you like, rapid transport systems that connect Australian farms effectively to Asian markets, it changes what we grow, it changes the value of land, it changes everything.

And so, I've been looking at transport projects to bring Australian produce to these markets. Now, if we can do that successfully, we can easily support another 20 million people in Australia.

EIR: And also, besides the rail, then, you're thinking of inter-island and rapid marine travel. Have you been involved in that?

Endersbee: Well, down in Tasmania, they've been designing these twin-hull catamarans. And these are fairly rapid, in fact, a twin-hull catamaran, made in Hobart, holds the speed record across the Atlantic. Average speed of about 45 knots, I think. One guy, who was a student at the faculty, when I was dean, did some wonderful work with them, with the builders of this machine.

You can imagine, with a twin-hull catamaran; it's a devilish problem if you're running into a cross-sea. You're going like this, you see: One hull will hit the wave before the other hull. And so, this graduate student (he's 40-odd) was able to devise a sensing mechanism on a computer program, so the flaps at the stern of the catamaran, would go up and down, like this. And so, he had a sensing device to monitor the sea state, determine which hull was going to hit the water at which time, and the whole thing was adjusted—and it was just as steady as can be. And they used that on the Atlantic crossing.

Now, these fast catamarans—they're very good—and this chap's got designs for them with 500 or 1,000 containers, which are good for, if you like, inter-island travel, such as in the Indonesian archipelago. A bit of fun!

EIR: So, the technology is there.

Endersbee: Oh! It's the will. You see, with a lot of these things, every one of them requires a leap-frog in thinking. And we've been talking at this meeting over the last few days, about the railroad, which could go from China all the way through Kiev, into the heart of Europe; and you'd have Russia and China all connected up, as one common market—a fantastic rail project, which could go ahead.

And, the question is: Where is all the money going to come from, and everything else? And, the fact is, that the money is, in many cases, relatively easily found.

EIR: Well, in North America—you may have something to say, about the idea that that railroad should go from Kiev eastward through China, under the Bering Strait and into the Yukon and Canada. Do you have a tunnelling expert's opinion?

Endersbee: There are various technologies which are available, now, these days. You have to look at the costs; but, with a tunnel like that, you'd want to stay away from problems in the rock underneath. And you'd want to stay away from a floating bridge or bridge-tunnel arrangement.

But it is possible to have a tunnel made of pontoons, constructed in the dry. And then, taken out to the site, and in effect floating, submerged—above the seabed. They could be floating submerged, anchored to the seabed. And, so you could have a floating tunnel, and just join it up. So, you're independent of the rock conditions underneath, and you're independent of the sea state, and it's just a matter of paying for the box, and screwing it to the floor. And make sure there are no holes.

You see, that's an easy fix. You'd use longitudinal pre-stressing, all sorts of things to make sure it would work very nicely.

EIR: Is one of those in place?

Endersbee: No, not that I know of. They may be, but the Bering Strait is the sort of place, where that sort of thing could be done.

EIR: This could be the challenge that the projects of Franklin Delano Roosevelt were, in the 1930s.

Endersbee: He had the courage to have a go!

EIR: You said that after you retired—you're a civil engineer, actively retired—you're now in your most exciting thinking period in your life. So, your priority is setting straight the groundwater misconception?

Endersbee: No—primarily in national development: You see, when you're practicing, and, as I was working with the government, or when I was at the university, you are largely constrained by the system telling you what to do. Now, if you're an employee, you have to do what the boss says. If you work in the government, you have to do what the government says.

When you're in a university, and particularly these days, with privatization and all sorts of things, you're totally dependent on what money people give you for research. So, your research is totally determined outside, and the idea of free scholarship is totally lost.

So, since I retired, I've been a free scholar. For the first time in my life, I've been totally free, and I can think what I like, do what I like, travel where I want to—if I've got the money to do it. But, the important thing, is that, when you're as free as all that—all of a sudden, a great world of opportunity opens up, and there's *so* much to be done!

And, there are so many blockages: governments all around the world with problems.

EIR: One thing is, you're making available the levers and handles to reconceptualize, to push ahead. You mentioned Professor Gold, Professor Gregory, Professor Kerry, these other people. Do you think, among hydrologists and geochemists, you can force things through in the near future? What's your view?

Endersbee: I am hoping that there are young people out there, I'm hoping that there are young minds, who see these opportunities and grab them and run with them. And the more courage they have to think for themselves, and work things out, the better.

One of the things that worries me, is that our entire generation of young people are being conditioned. And they've lost this capacity to think independently. I could go on, and mention my concern about American teenagers. . . .

The problem here, is that there's a whole advertising and other industry, preying on the American teenager, because the American teenager's got money to spend. And, the money that American teenagers spend every year, themselves, is about $100 billion. The money that their parents spend on their behalf, is another $50 billion. So, the American teenage market is worth $150 billion every year: You could build an awful lot of things for $150 billion a year. You know, from my point of view, $150 billion on spiky hairdos and bare midriffs, is a total waste of money.

EIR: Whereas if you put it, you mean, in building projects and create natural resources?

Endersbee: Absolutely. But you see, the system is actually preying on these young people, and limiting their ability to think for themselves. They are being driven, so that, in effect, they worship the corporate sponsor. And they don't listen to their parents or their teachers, and that means that they're losing the capacity to work together. . . .

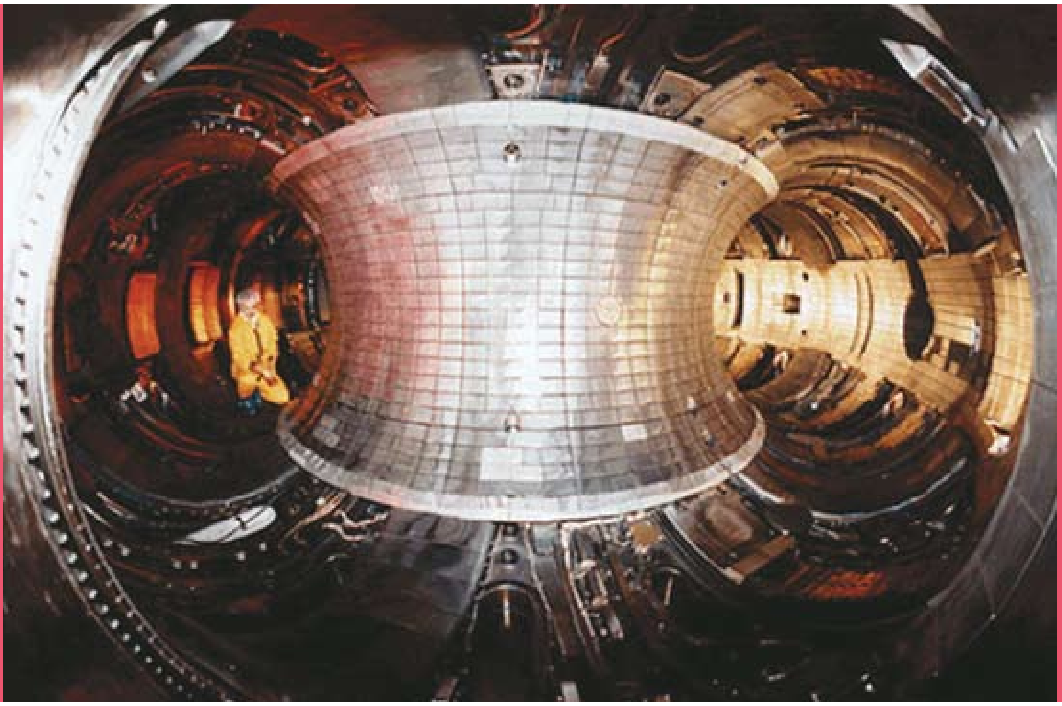
For Further Reading

"Ocean Temperature and CO_2: Global Climate Change Has Natural Causes," by Lance Endersbee, *EIR* March 7, 2008

"The World's Water Wells Are Drying Up!" by Lance Endersbee, *21st Century*, Spring 2006

"Australian FDR-Era Engineer: Let's Resume Great Projects. Interview of Lance Endersbee by Marcia Merry Baker, *EIR*, June 28, 2002

"TVA, Mekong, and China's 'Heroic Civil Engineering,'" Interview of Lance Endersbee by Gail and Michael Billington, *EIR*, Dec. 6, 2002.



PPPL

Inside the Tokamak Fusion Test Reactor at the Princeton Plasma Physics Laboratory, while it was in construction. The TFTR set world records for plasma temperature and fusion power produced in the late 1980s and early 1990s. But budget cuts closed it down before all its planned experiments were completed.

The True History of The U.S. Fusion Program —And Who Tried To Kill It

An inside analysis of how the U.S. fusion program was euthanized, dispels the myth that "fusion can't work."

by Marsha Freeman

There is no disputing that the world is facing an energy crisis of vast proportions. But this could have been avoided. For more than five decades, scientists, engineers, energy planners, policy-makers, and, at times, even the public at large, have known what the ultimate alternative is to our finite energy resources—nuclear fusion. This energy, which powers the Sun and all of the stars, and can use a virtually unlimited supply of isotopes of hydrogen, available from seawater, has been visible on the horizon for years, but seemingly never close at hand. Why?

Legend has it that there are more problems in attaining controlled nuclear fusion than scientists anticipated, and that little progress has been made. "Fusion is still 50 years away, and always has been" has become the common refrain of skeptics. But the reason that we do not have commercially available fusion energy is not what is commonly believed.

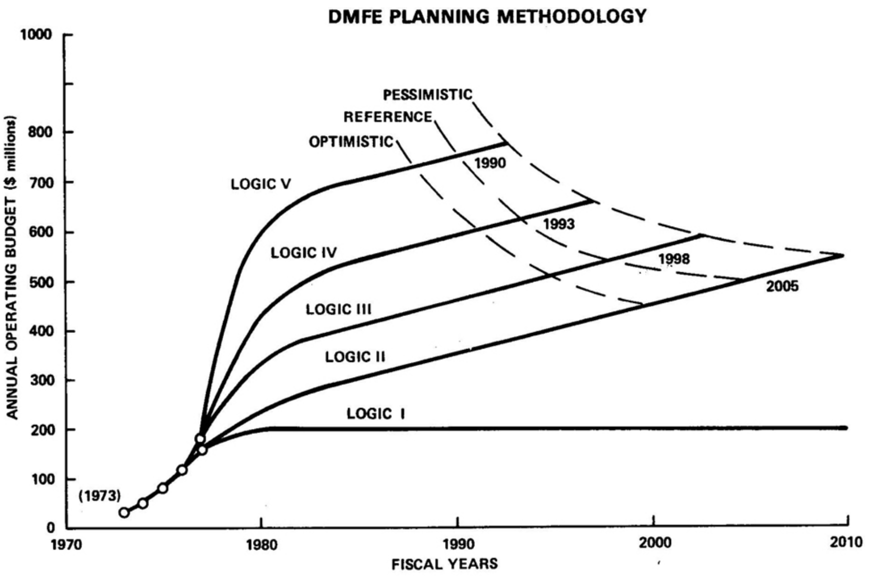


Figure 1(a)
WHAT IT TAKES TO REACH FUSION—ERDA'S LOGIC IN 1976
In 1976, the Energy Research and Development Administration (ERDA) published this chart showing the required fusion operating budgets to reach a working magnetic fusion reactor. Each option was called a "Logic," and each had three variations from optimistic to pessimistic. With $600 million a year, as shown in Logic V, the program would have been able to operate a demonstration reactor by 1990. Logic I, which represents the actual fusion budgets from 1976 to the present, produces "fusion never," as shown.

Source: ERDA, 1976

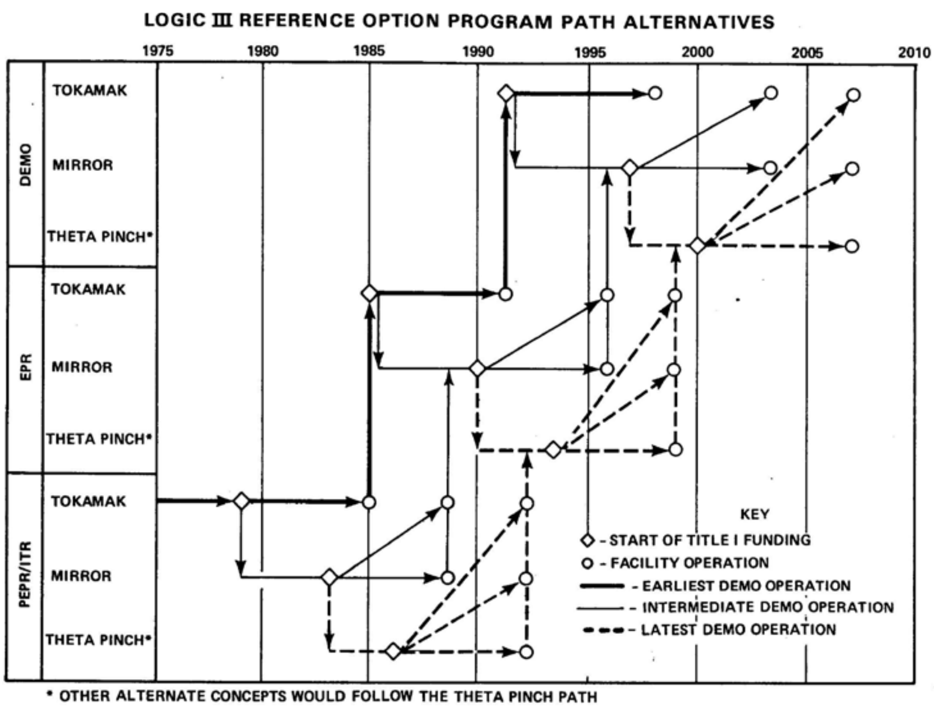
In 1976, the Energy Research and Development Administration, or ERDA—the predecessor to the Department of Energy—published a chart showing various policy and funding options for the magnetic fusion energy research program. Each option, called a "Logic," described how the level of funding for the research would determine when practical fusion power would become available. The most aggressive profile, Logic V, proposed that a budget of approximately $600 million per year would put the fusion program on a path to operate a demonstration reactor by 1990.

At the other end of the scale, Logic 1, set at a level of about $150 million per year, was the option colloquially described as "fusion never," because the funding never reached the level where the remaining challenges in fusion could be overcome. The U.S. fusion program has been at that fusion-never equivalent level, or *below,* for the past 30 years.

It is a specious argument to claim that there has not been the money available to aggressively

Figure 1(b)
ERDA'S OPTIONS FOR MAGNETIC FUSION IN 1976
These are the pathways planned for the tokamak, the tandem mirror, and the theta pinch (and other alternative concepts) if the reference option in Logic III (see a) were followed. Logics II and III would have put demonstration reactors online by now.

Source: ERDA, 1976



pursue fusion research, when one considers the multi-trillion-dollar cost to the U.S. economy of importing oil. In the 1970s, comprehensive studies had already been done, outlining the application of high-density fusion power, not only to produce electricity, but also to create synthetic fuels, such as hydrogen; to create fresh water from the sea, through desalination; to economically create new mineral resources with the fusion torch; to propel spacecraft to Mars and beyond; and myriad other applications.

The lack of progress in the U.S. fusion program is entirely a result of a lack of political will, a lack of vision, and the promotion of false and destructive economic and energy policies, which have now left us behind the rest of the world in developing practical fusion energy.

One might think that if the United States doesn't push ahead for fusion development, other nations will, leaving the United States in the lurch. In reality, the situation is far worse. At the present rate of world physical economic collapse, the ability to sustain the Earth's 6.7 billion population is already nearly lost. A crash program to develop the required physical infrastructure in agriculture, mining, water resource development, housing, health care, and, most of all, power production, must start now. Nuclear power now and fusion power within a generation is an absolute requirement. Without it, human civilization goes the other way—into a Dark Age, and the descent has already begun. We must reverse it now.

The United States in the Lead

At one time, it should be recalled, the United States was a world leader in fusion energy research. This was the result of the vision of policymakers, and the optimism and hard work of hundreds of scientists and engineers committed to fusion's development.

The dependence of the United States on imported energy supplies was dramatically demonstrated during the so-called energy crisis in the mid-1970s, following the 1973-1974 Middle East war, and oil embargo. The Nixon/Ford Administrations and energy policy planners responded with a broad-brush energy R&D initiative, which included increased funding for advanced nuclear fission, and for fusion research. In fiscal year 1974, the magnetic fusion energy R&D budget was $43.4 million. By fiscal year 1977, the funding had increased

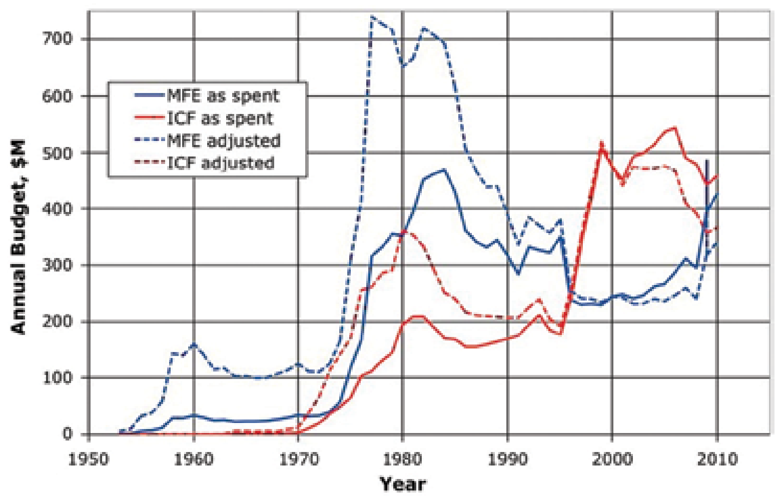


Figure 2
ANNUAL FUSION BUDGETS FOR INERTIAL AND MAGNETIC CONFINEMENT (1950-2010)

The annual budgets for magnetic fusion energy (MFE) and inertial confinement fusion (ICF) in millions of dollars. The magnetic fusion energy budget today, in real, inflation-adjusted dollars, is about one third what it was in the late 1970s. MFE is funded under the Department of Energy Office of Fusion Energy Sciences, and the ICF budet is funded under defense programs.

Source: U.S. Department of Energy, U.S. Energy Information Agency

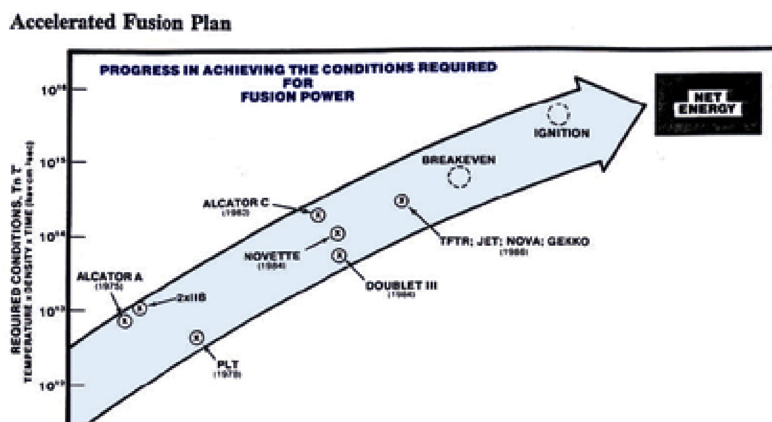
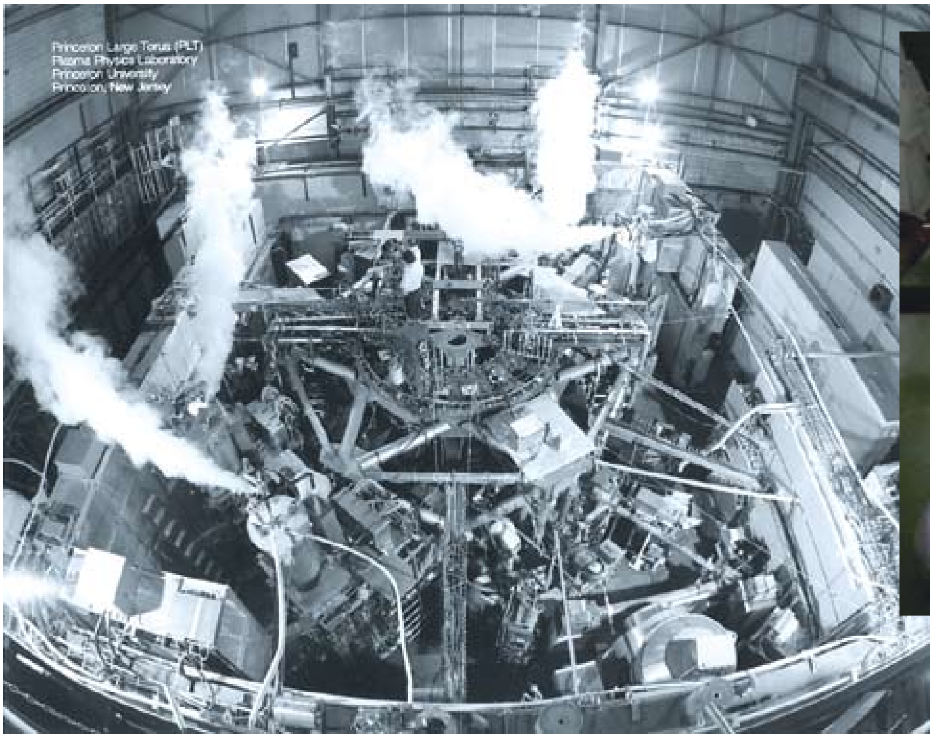


Figure 3
PROGRESS IN ACHIEVING THE CONDITIONS REQUIRED FOR FUSION POWER

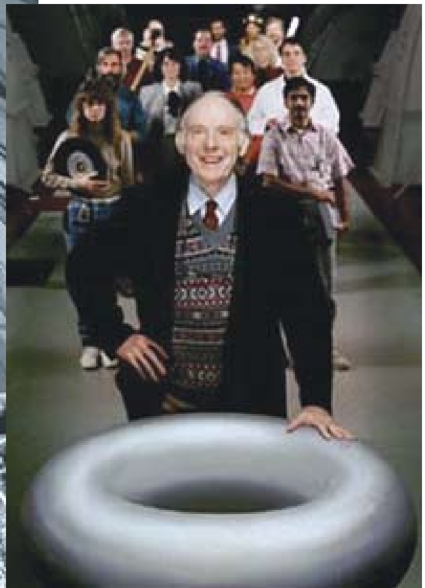
This 1991 assessment shows how the improvement in plasma parameters of ion temperature (T), density (n), and confinement time (t), often expressed as the product Tn, could be linked with the operation of new experimental facilities. The improvement required for a power plant compared with 1991 values was no greater than the improvement fusion had made in the 15 years preceding 1991.

Source: Stephen O. Dean et al., "An Accelerated Fusion Power Development Program," *Journal of Fusion Energy*, Vol. 10, No. 2, 1991



PPPL

In July 1978, the Princeton Large Torus (PLT) tokamak set a world record for ion temperatures of 60 million degrees C, using neutral-beam heating. For the first time, ion temperatures exceeded the theoretical threshold for ignition in a tokamak device.



Denise Applewhite/PPPL

Melvin B. Gottlieb was the director of the Princeton Plasma Physics Laboratory from 1961-1980. Although there were more than 100 tokamaks operating in 1978, the PLT results were unique, according to Gottlieb.

to $316.3 million.

This investment laid the basis, more than 30 years ago, for dramatic progress in the U.S. fusion program. That investment paid off. In August 1978, scientists at the Princeton Plasma Physics Laboratory reported that the previous month, the plasma in their Princeton Large Torus (PLT) tokamak had reached the record-setting temperature of 60 million degrees. This exceeded the ignition temperature of 44 million degrees which it had been determined was required for a sustained fusion reaction. One of the key barriers for fusion—the application of external power for heating the plasma—had been overcome.

At that time, the broad-based domestic magnetic fusion program wisely supported an array of, not just tokamaks, but a variety of machines with different geometric configurations, in which novel concepts for attaining fusion energy were being investigated. While advances using the tokamak design, created by the Soviet Union in the 1960s, showed great promise, the problems of plasma purity, superconducting magnet technology, new materials required for fusion reactors, methods for extracting energy from the fusion reaction, and other challenges, were being investigated in experimental facilities in national laboratories and universities around the country, and also internationally. But as Princeton laboratory Director, Dr. Melvin Gottlieb, proudly reported in 1978, although there

The Princeton PLT breakthrough in 1978 brought the energy policy war out into the open.

Rep. Charles Rangel: The solution of the world's energy problem is before us.

Stephen Dean: The biggest thing that ever happened in fusion research.

DOE Undersecretary John Deutch: Not a breakthough, just a significant result.

R.D. Ward/DOD

Energy Secretary James Schlesinger: We did not want to hype it up.

were then more than 100 research tokamaks around the world, all doing important research, the Princeton results were unique.

The reaction to the Princeton announcement was electric. In an interview with CBS News, Dr. Stephen Dean, director of the Magnetic Confinement Systems Division of the Department of Energy Fusion Office, stated: "The question of whether fusion is feasible from a scientific point of view has now been answered." The Princeton fusion breakthrough became front-page news in newspapers around the world.

Rep. Charles Rangel (D-N.Y.), counseled: "This breakthrough compels us to redirect our energy and funnel further funds and attention to highly promising and vitally important nuclear fusion research." The press hailed the achievement, recognizing the fundamental importance for the future prosperity of mankind of developing fusion energy.

But not everyone was excited by the breakthrough. In fact, a war that was being waged over energy policy somewhat behind the scenes, burst out in to the open.

For days, pressure was put on the Princeton scientists by the Department of Energy not to make a big deal over the results. A press conference that the Princeton team was to hold to make the announcement was almost cancelled. When it finally did take place, officials of the DOE, under James Rodney Schlesinger, spared no effort to try to downplay the importance of the Princeton achievement. As reported in an article appearing in the August 16 issue of the *Christian Science Monitor,* "Public affairs officers for the U.S. Department of Energy . . . say the DOE was both puzzled and embarrassed at what it considers an unauthorized and overblown announcement of the Princeton work." DOE public affairs director Jim Bishop emphasized that, "While the Princeton work is a major scientific achievement, it probably won't shorten the time scale or the cost of fusion power development"! Energy Secretary Schlesinger was incensed at the optimism that followed the Princeton fusion announcement.

Why?

The Administration of President Jimmy Carter came into office in 1977, just three years after the "Arab" oil embargo, which manipulation, it was shown, was created not by "Arabs," but by the international oil cartel. Gasoline lines, and the quadrupling of energy prices, were the result of these manufactured shortages, and it created the opportunity to implement a conservation, zero-growth energy and economic policy, which had been promoted by the British Malthusian interest through such institutions as Prince Philip's World Wildlife Fund, the Club of Rome, the Ford Foundation, and other think-tanks, since the 1960s.

For the first time in the history of the United States, the idea that "less is more," that "small is beautiful," that there are "limits to growth," that the world was running out of resources, became the policy of the Federal government. The possibility that there could be virtually unlimited fusion energy made an embarrassing mockery of the "conservation," and "turn-down-the-thermostat" belt-tightening policies being promoted by the Carter White House.

The most important, visible, and respected public advocacy organization for the full-scale development of fusion energy, at the time of the Princeton breakthrough, was the New York-based Fusion Energy Foundation. In its coverage of the Princeton results, in October 1978, the Foundation released a proposed budget for fusion development, in the form of a Memorandum to the Congress. The Memorandum proposed an acceleration of the fusion research program in both magnetic and inertial confinement, increased international collaboration, and a funding level comparable to that of the 1960s Apollo space program.

Library of Congress

Cartel manipulation of the oil market created gas lines like these—and their accompanying zero-growth energy and economic policies in the 1970s.

The Foundation proposal included funding for next-generation experimental machines across the range of tokamaks, plus magnetic mirror experiments, and scyllac, theta pinch, stellarators, and other magnetic geometries. Advanced laser, ion beam, electron beam, and other inertial confinement experimental facilities were included. Basic engineering, materials, component, and test facilities were part of the upgraded and accelerated program.

At the time, and with the aid of the Fusion Energy Foundation's massive outreach through its widely read magazine, *Fusion*, an awareness was growing in the Congress that the high-technology path was the real way to energy independence. The Carter White House and financial interests who saw the development of unlimited sources of energy as a threat to their vested interests, mobilized to squelch the enthusiasm.

In July 1978, a group described as the Nuclear Club of Wall

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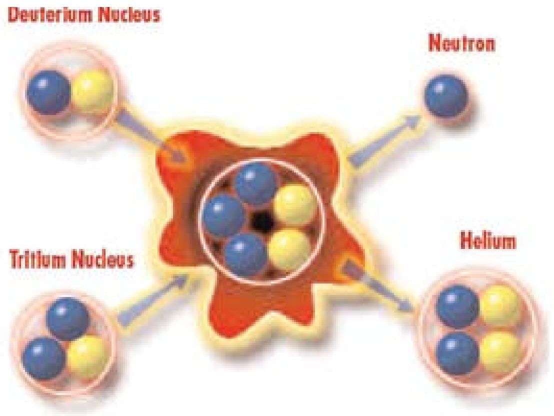


Figure 4
THE FUSION REACTION
A fusion reaction takes place when two small atoms combine to form a larger atom, releasing a large amount of energy in the process. Here, two isotopes of hydrogen, deuterium (1 neutron and 1 proton) and tritium (2 neutrons and 1 proton) combine, producing a helium nucleus (two neutrons and two protons) at 3.5 MeV, and a high-energy neutron (14.1 MeV).
Source: DOE

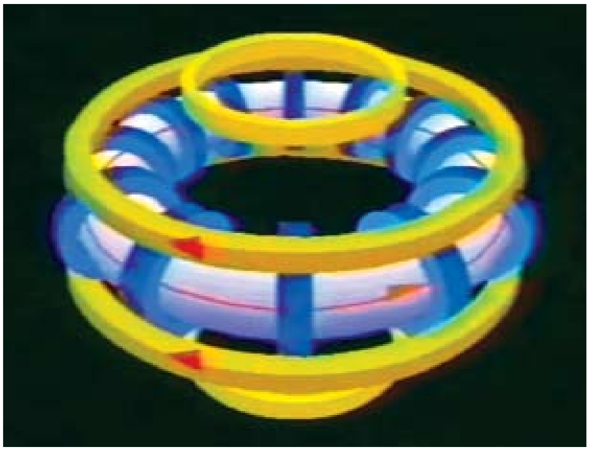


Figure 5
CONTAINING THE FUSION PLASMA IN A TOKAMAK
In magnetic confinement fusion, the combination of toroidal (long way around the tokamak) and poloidal (short way around the tokamak) magnetic fields contain the fusion plasma, preventing it from hitting the walls of the reactor.
Source: PPPL

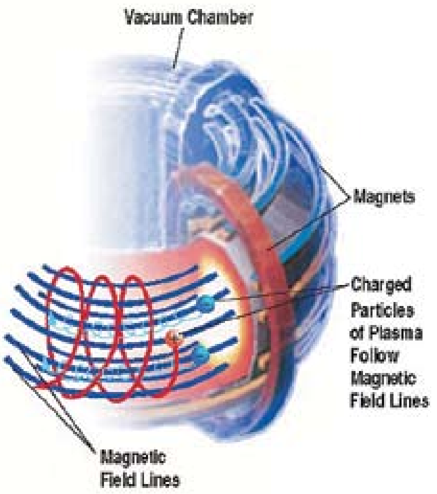
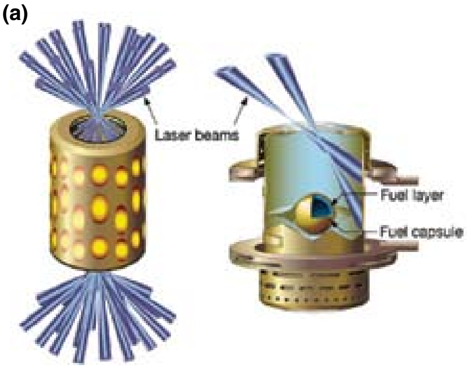
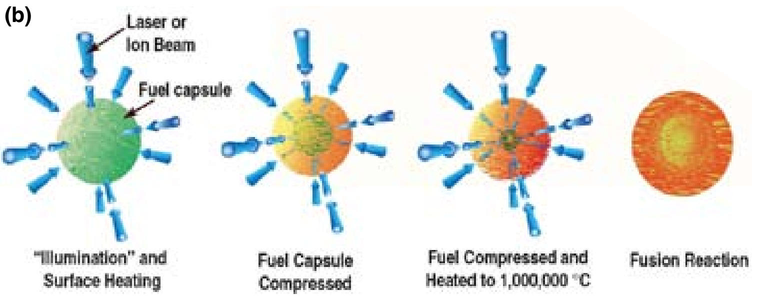


Figure 6
CUTAWAY VIEW OF MAGNETIC CONFINEMENT
This diagram of a tokamak shows the magnets, the magnetic field lines, and the charged particles of plasma that follow the magnetic field lines, spiralling around the tokamak.
Source: "The Surprising Benefits of Creating a Star," U.S. Department of Energy

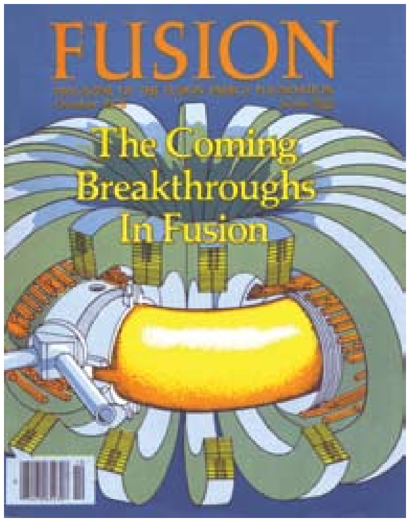
Figure 7
INERTIAL CONFINEMENT FUSION: THE NATIONAL IGNITION FACILITY
This schematic (a) of the National Ignition Facility shows the array of 192 laser beams focussed on a tiny pellet of deuterium and tritium fusion fuel, encapsulated in beryllium and carbide. The laser beams compress and heat the fuel pellet (b) in a billionth of a second, so that the deuterium and tritium fuse before the pellet flies apart. The term inertial refers to the fact that the atoms must have enough inertia to resist flying apart before they combine.





Source: Lawrence Livermore National Laboratory

The Fusion Energy Foundation was founded in November 1974 by Lyndon H. LaRouche and leading scientists, including Manhattan Project veteran Robert J. Moon. Here, LaRouche (center) at the reception following the founding meeting.



Fusion *magazine, published by the Fusion Energy Foundation, grew rapidly in circulation and influence in the 1970s, and was available on newsstands nationwide. This is the October 1978 issue that covered the PLT breakthrough.*

Princeton Plasma Physics Laboratory director Melvin Gottlieb (reading program) at a celebration in his honor given by the Fusion Energy Foundation in 1980. Speakers included both Gottlieb's teachers and students. At right is Dr. Robert J. Moon, one of Gottlieb's professors. At the podium is FEF director Morris Levitt.

Carlos de Hoyos

Carlos de Hoyos

e Kiyoshi Yazawa

Fusion Energy Foundation representatives visited and wrote about fusion reactors around the world. Above: Charles Stevens (second from left) on a tour of the TFTR at Princeton, and Tanu and Susan Maitra (at right) in 1984 with Dr. Miyoshi, the director of the Plasma Research Institute at Tsukuba University, which operated a tandem mirror experimental reactor.

Suzanne Klebe

EIRNS

The Fusion Energy Foundation worked closely with Rep. Mike McCormack (D-Wash.) and other members of Congress to organize and educate the public to support fusion and the "McCormack bill." Left: the author with Representative McCormack at fusion hearings on Capitol Hill. Right: McCormack addresses a Fusion Energy Foundation conference in Washington, D.C. in May 1981.

(Continued from p. 19)

Street helped stitch together the Society to Advance Fusion En ergy, or SAFE, funded primarily by the Slaner Foundation. While their stated goal was to promote fusion energy research, their attacks on nuclear energy, as "unSAFE," and on the then-leading tokamak program, revealed that SAFE's intention was not to advance support for fusion energy. In fact, as SAFE explained to inquiries, its sole purpose was to discredit and blunt the influence of the Fusion Energy Foundation! This attempt did not succeed.

Energized by the Princeton results, and the promise of the next critical breakthroughs in fusion, Rep. Mike McCormack, a Democrat elected to Congress in 1970 from the State of Washington after a 20-year scientific career, introduced a bill in January 1980 to accelerate the development of fusion energy. A scientific advisory panel, which McCormack had convened over the previous year, had concurred with his evaluation that the most significant barrier to the commercial development of fusion was the lack of a national commitment, and an inadequate level of funding. The bill soon garnered 140 cosponsors.

One week before introducing his bill, McCormack spoke at a conference in Washington, D.C., on nuclear safety. There, the anti-nuclear Carter Administration "energy" policy was laid bare. Department of Energy Undersecretary John Deutch, a Schlesinger appointee who had downplayed the Princeton results, stated that conventional nuclear power should be an energy source "of last resort." He continued that the DOE "would like to minimize the use of nuclear energy through conservation and the use of coal."

Representative McCormack also addressed the meeting. "We must take the offensive on nuclear energy," the Congressman stated. "Nuclear power as a 'last resort,' was never realistic and now is irresponsible," he continued. He stated that the United States "must have 500 gigawatts of nuclear energy by the year 2000, which is not overambitious," in order to ensure economic growth and a rising standard of living. Nuclear energy and coal would be the "bridge" energy sources to the future.

McCormack used the occasion to announce that he would be introducing legislation "to make it the policy of the U.S. government to bring the first electric-generating fusion power plant on line before the year 2000. We must move into the engineering phase with fusion," he said. "We must not wait for somebody else to do it."

McCormack called the decision to proceed with an Apollo-style fusion program, as promoted in his bill, "the single most important energy event in the history of mankind." He explained that, "once we develop fusion, we will be in a position to produce enough energy for all time, for all mankind. This is not hyperbole, but fact." In an interview with this writer after the bill's introduction, Rep. McCormack also added that fusion, which should be developed internationally, "for all mankind," could "be the most important deterrent to war in all of history."

The bill authorized the construction of a fusion Engineering Test Facility by 1987. The first experimental power reactor would be developed by the year 2000, to produce net power, and lay the basis for commercial development. The bill estimated that this program would require a $20 billion expenditure over the two decades from 1980 to the turn of the century; considerably less, in 1980 dollars, than what the United States spent to land a man on the Moon. The funding included the expansion and upgrading of the nation's science education programs.

The Fusion Energy Foundation mobilized its tens of thousands of supporters to tell their Representatives in Washington to support the McCormack bill. Statements of support were elicited from labor leaders, clergy, civil rights activists, state legislators, and other elected officials, industrial leaders, and the fusion research community.

On August 27, the House of Representatives passed the fusion bill by a vote of 365 to 7. Soon after, the Senate passed a companion bill by voice vote. President Carter signed the bill into law on

The passage of the McCormack bill set off a wave of optimism in the U.S. press.

October 7. The path to commercial fusion energy was clear.

But a month later, President Carter became a lame duck, as Ronald Reagan won the 1980 Presidential election. Regardless of the next Administration's policy toward fusion, the scientists warned, every new Administration wants to do its own review, which only delays progress. Worse still, because President Carter conceded the election before the voting polls were even closed on the West Coast, Democrats in key states, such as Washington, did not even bother to go to the polls to vote. Rep. Mike McCormack, and key collaborator, Governor Dixy Lee Ray, lost their bids for reelection.

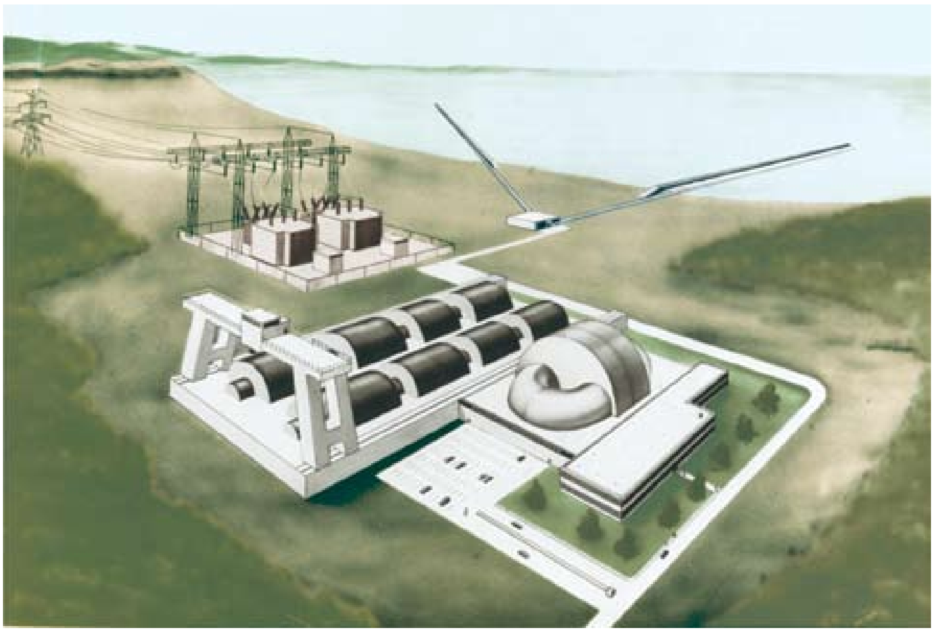
Recognizing that fulfilling the commitments of the fusion law would take a multi-generational commitment from the Congress, the Subcommittee on Energy Research and Production of the House Committee on Science and Technology, chaired by Rep. McCormack, issued a report in December 1980 providing an overview of the fusion energy program, for the incoming Reagan Administration. In the Preface, the report states that the signing of the bill into law "marked the end of the beginning" of "what may be the most historically important road mankind has ever taken." But, the report warns, "the hardest battles are yet to come. There must be continual annual authorizations and subsequent appropriations of funds." The report concluded: "It will take tremendous vigilance and determination on the part of the Nation to carry through the 20-year development plan which is necessary to make fusion a reality."

Even while the McCormack fusion bill was still being debated, conservative congressional representatives were responding to the Federal budget deficit, created through the Carter Administration's failed economic policies, by attempting to reduce Federal spending on energy R&D. Only an intervention on the floor of the House by Science and Technology Committee chairman Rep. Don Fuqua (Democrat from Florida), restored a proposed cut in Fiscal Year 81 funding that would have delayed construction of Princeton's next-step Tokamak Fusion Test Reactor (TFTR) for at least a year.

The handwriting was on the wall. It did not take long for the plan that had become law, to demonstrate commercially viable fusion energy by the turn of the century, to be derailed. In the incoming Reagan Administration, opposition to fusion would not come from radical "left" zero-growthers, but from an otherwise well-meaning President, who had been captured by the conservative free-market "right."

A Policy of Mediocrity

The Reagan White House's fusion budget request for fiscal year 1982, forwarded to Capitol Hill in early 1981, had, with breakneck speed, tossed aside the Congressional mandate for the McCormack law fusion engineering development program.

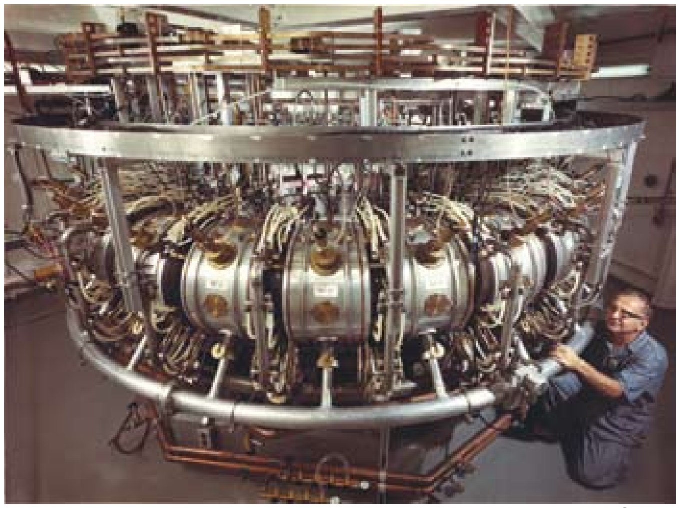


AEC

As early as 1972, research in magnetic fusion had shown so much promise that Westinghouse Nuclear Energy Systems created a concept of a fusion power plant for the U.S. government. The reactor shown here is an Atomic Energy Commission depiction of a commercial reactor that the AEC predicted would be in operation "about the year 2000."

Union Carbide

The dedication of the Elmo Bumpty Torus fusion site in Oak Ridge, Tenn. Rep. Marilyn Lloyd Bouquard, chairman of the House Energy Research and Production subcommittee, is third from left; Ed Kintner, head of the DOE Office of Fusion Energy is second from right. Kintner resigned his post in November 1981, in protest of the fusion budget cuts.



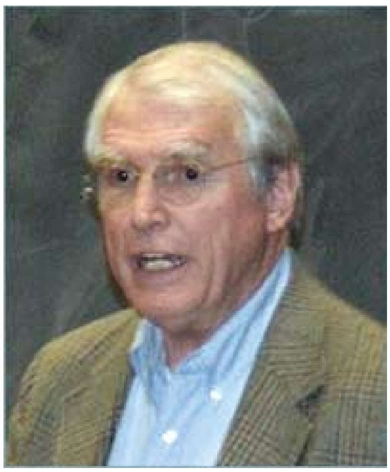
Union Carbide

The Elmo Bumpy Torus in 1978. The EBT concept used mirrors in a toroidal configuration with steady-state, high-power, electron cyclotron resonance heating to produce a steady-state plasma. Budget cuts shut it down in 1984.

At a briefing on Feb. 26, Energy Secretary James Edwards answered a reporter's question by stating that "we're going to fund fusion," adding, "but we're not going to throw money at it irresponsibly." At the same briefing, Treasury Secretary Don Regan said the Reagan Administration's economic objective was to "give the economy back to the people." Tax cuts and deregulation were on the agenda, not Federal investments in R&D.

On March 6, the Fusion Energy Foundation issued a press release, warning that the Reagan Administration's proposed budget cuts in funding for NASA's space programs and for fusion research, would implement the very Carter-era deindustrialization policies that President Reagan had been elected to reverse. Ten days later, the Foundation sent a letter to all of the co-sponsors of Representative McCormack's fusion bill, alerting them to the devastating blow the White House was proposing to the fusion development schedule, pointing out that it violated the law of the land.

On July 31, six months after President Reagan came in to office, Rep. Marilyn Lloyd Bouquard, Democrat from Tennessee, who had replaced Mike McCormack as chair of the Subcommittee on Energy Research and Production, wrote a scathing letter to Energy Secretary Edwards. The Department had proposed that rather than requesting funds to establish the industrially managed Center for Fusion Engineering, mandated in the fusion law, it would instead request for a Fusion Energy Engineering Feasibility Preparations Project, as a way of delaying the day when engineering challenges in fusion would be tackled. Rep. Bouquard described her response as "puzzled and dismayed," and wished to express her "dissatisfaction to you in the most emphatic terms."



Center for Science and Technology Policy, University of Colorado

George Keyworth, the fiscal austerity proponent who served as President Reagan's science advisor, saw no need for fusion development.

The betrayal of the promise of fusion led Edwin Kintner to resign from his post at the Department of Energy in November 1981, after having served since April 1976 as the Director of the Office of Fusion Energy. Kintner came to the Department following 22 years of service with the U.S. Navy, 14 of which were in the Naval Reactors Program, under Admiral Hyman Rickover. His resignation, he made public, was in protest over cuts in the fusion budget which indicated a change in policy, and a delay, or cancellation, of the program Congress had put into law.

Kintner reported, in an article in the May/June 1982 issue of MIT's *Technology Review,* that while the initial request from the Department's fusion office, for 1982-3 was for $596 million, the proposed $557 million, Kintner felt, would still, though barely, meet the Fusion Act commitments. But when David Stockman's Office of Management and Budget presented the 1983 budget to Congress, with a total of $444 million for fusion, or 25 percent less than the 1977 budget, in real terms, the fusion law was dead. The White House policy was that demonstration projects should not be funded by the government, but be left to private industry.

The following month, President Reagan's Science Advisor, George Keyworth, told the House Committee on Science and Technology that the United States "cannot expect to be preeminent in all scientific fields, nor is it necessarily desirable." Never before in its history did U.S. science have mediocrity as a goal.

"Science policy, made without considering economic policy, is irrelevant," Keyworth stated, advising that fiscal austerity dictated "limits" and that R&D must "compete" with other programs for Federal dollars. Members of the Committee wisely pointed out that this was exactly backwards: it is investments in science and technology that are the engine of economic growth; they are not a "drain" on the economy. In the same hearing, Keyworth defended his proposal that NASA discontinue its planetary exploration program, because "we couldn't afford it."

But despite the pull-back in funding in the 1980s, the investments in fusion research that had been made in the previous decade continued to bear fruit.

Princeton's Tokamak Fusion Test Reactor, or TFTR, which had been initiated in 1975, created its first plasma the day before Christmas, in 1982. In May the following year, President Reagan sent congratulations to the Princeton fusion team, looking toward the promise of unlimited fusion energy, which were presented at the official May 5 dedication of the tokamak. The TFTR would indeed prove itself a robust and highly productive research facility.

But in the Fall of 1983, at a fusion hearing, Dr. Dean warned Congress that "the U.S. is no longer the unquestioned world leader in fusion development. The fusion programs in the U.S., the U.S.S.R., Europe, and Japan have comparable accomplishments, facilities, and momentum." The present dramatic rate of progress, he stressed, "is based on the capital investment commitments made in the 1970s." But now, the United States was not making a commitment to move forward.

In July of 1986, the TFTR reached a record plasma temperature of 200 million degrees. Despite cutbacks in funding, and years of delays, in 1993, experiments were carried out which produced a peak fusion power of 10.7 megawatts, a world record, and 90 million times more than what could be generated in 1974, when the TFTR project was proposed. While not literally achieving energy "breakeven," where there is as much energy from fusion produced as is used to heat the plasma, the scientists reported that they "are very close." That year, the TFTR had switched from pure deuterium fuel to deuterium-tritium, similar to what would be used in a power reactor. Two years later, a record 510-million-degree plasma temperature was recorded.

It would have seemed only prudent, on the heels of these stunning results, that there would have been no hesitation to authorize the next-step experimental facility in the tokamak program, as the follow-on to the TFTR. Princeton proposed a Compact Ignition Tokamak (CIT), to create sustained fusion power. But in October 1989, President George H.W. Bush's DOE representative, Robert Hunter, told a Congressional hearing that the Administration proposed to cut another $50 million from the fusion budget, because the Compact Ignition Tokamak was too high risk, and probably would not succeed! Dr. Stephen Dean retorted that the reason you conduct experiments is to learn. "We've got to take some risks if we intend to develop a machine that makes electricity. If Columbus had waited for radar to be discovered before he set out, we wouldn't be there today."

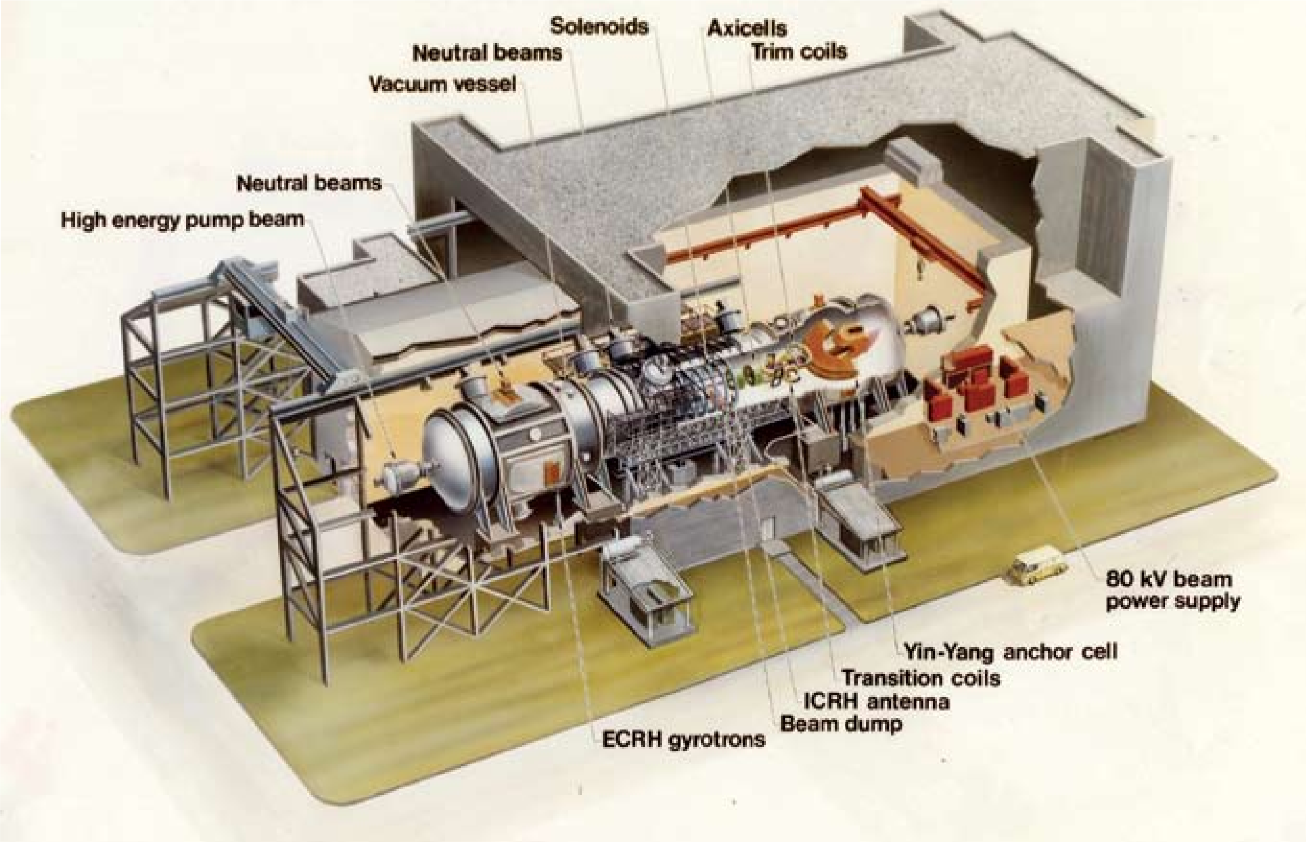
Meanwhile, the Princeton Plasma Physics Laboratory laid off 120 industrial contract personnel, who had expected to begin work on the CIT, as it became increasingly doubtful it would ever be built.

The mainline tokamak program was not the only approach to suffer, as the nation pulled back on research in magnetic fusion. From 1973 to 1984, Oak Ridge National Laboratory's Elmo Bumpy Torus produced promising results, as an alternate magnetic fusion concept to tokamaks. By 1981, the preliminary design for a 1,200-megawatt power plant had been created, and the next-step machine was selected for a scale-up to proof-of-principle. It was never built.

Incredibly, on the very day that Lawrence Livermore Laboratory's Tandem Mirror Fusion Test Reactor was to begin operation, in 1986, it was cancelled. The completed device was nev-

PPPL

Princeton's Tokamak Fusion Test Reactor (TFTR) was conceived as a link between its generation of tokamaks and the first experimental power reactor. It reached record plasma temperatures of 200 million degrees in July 1986 with deuterium fuel, and two years later reached 510 million degrees using deuterium-tritium fuel. But budget cuts precluded further breakthroughs, and the TFTR was decomissioned early, in 1995.



LLNL

Another casualty of the budget cutters was the Mirror Fusion Test Facility (MFTF) at Lawrence Livermore, shown here in an artist's drawing. The MFTF was forced to shut down just after it was fully completed because of budget cuts. It was sold for scrap. (For more on this story, see the Summer 2009 issue of 21st Century.*)*

er turned on, and was dismantled.

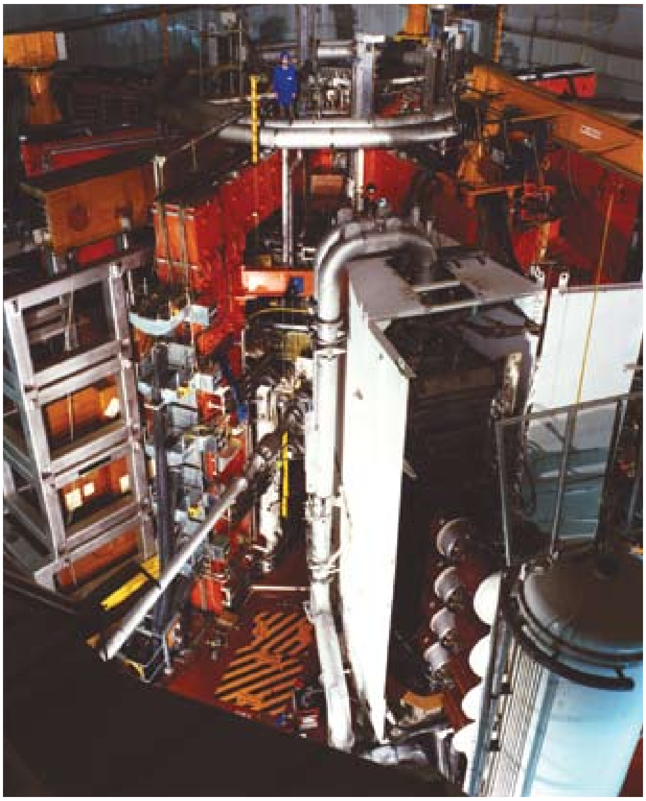
The fusion program did not fare any better during the years of the Clinton Administration, especially after the 1994 takeover of the Congress by the "conservative revolution" of Newt Gingrich. In December 1993, Secretary of Energy Hazel O'Leary sent her congratulations to the Princeton Plasma Physics Laboratory on the production of more than 3 million watts of fusion power, which set a world record. "This is a great day for science," she stated. "This world record is a great step in the development of fusion energy. It highlights the enormous progress being made in the field. This is the most significant achievement in fusion energy in the past two decades." The Princeton scientists proposed that the Tokamak Physics Experiment (TPX) be designed to replace the TFTR when its experiments were completed. This long-pulse machine, they explained, would use many of the existing TFTR facilities, and would develop the basis for a continuously operating tokamak fusion reactor.

Although O'Leary and other Administration officials continued to support the fusion effort, resistance from the Congress delayed fusion's next steps, both in participation in ITER, and in the domestic experimental program. The President himself, in a letter dated July 13, 1994, addressed to New Jersey Governor Christine Todd Whitman, supported "a strong balanced program for the development of fusion energy," endorsing both U.S. participation in ITER, and the construction of the TPX at Princeton.

Congressional wrangling over the fusion program budget led to the incredible decision for an early decommissioning of the TFTR in 1995, after it had achieved a record-setting 510-million-degree plasma temperature, even though more advanced experiments were still planned by the scientists.

All large-scale science and research projects were under attack through the 1990s. In 1988, the Congress had approved construction of the Superconducting Super Collider in Texas, to be the world's largest and most powerful particle accelerator. In addition to its research applications in fundamental physics, the advancement of superconducting magnet technology would have pushed forward the state of the art in medicine, energy storage, and fusion. In 1993, after 14.6 miles of tunnel had been built, the project was cancelled by the Congress.

In the first term of the Reagan Administration, the magnetic fusion research budget was in the $450 million range. By the time President Reagan left office, it stood at $331 million. When George H.W. Bush left office, in 1994, the magnetic fusion budget was stalled at a paltry $322 million. It faired worse during the eight years Bill Clinton was in the White House. The opposition from Congress was not helped by the fact that Vice President Al Gore had been given the responsibility for developing energy policy. Gore put billions of dollars into wasteful so-called "green" and "clean" technologies.



Joint European Torus

Europe moved its fusion program ahead with the Joint European Torus, the first tokamak to use tritium fuel. Meanwhile, the United States killed the Compact Ignition Tokamak at Princeton.

During the 1990s, the magnetic fusion energy budget collapsed in to the $200+ -million range. While there have been some ups and downs, using U.S. Energy Information Agency inflation-adjusted figures, in real dollars, the fusion budget of $286 million in 2008 was about *one third* what it was in 1977. Is it really any wonder that the United States has not achieved new breakthroughs in fusion?

The Rest of the World Moves Forward

While the Princeton TFTR was producing groundbreaking results in fusion research in the late 1980s and early 1990s, other nations were not standing still. In 1991, the Joint European Torus (JET) became the first tokamak to use tritium; the same year that the U.S. government officially nixed the Compact Ignition Tokamak at Princeton, Japan's JT-60 tokamak was on its way to setting its own records.

Today, world records in fusion are not held by the United States, but primarily by Europe and Japan, which provided steady support over the past two decades to upgrade experiments and build new facilities. Other advances have been made in newer fusion programs, such as those in China and South Korea. These countries have the only two tokamak experiments in operation now using advanced superconducting magnets, which will be needed for tomorrow's commercial fusion power plants.

For years, nations have recognized that a joint, international effort to solve the engineering problems in fusion and move toward a commercial demonstration would be the best approach. If you are creating an energy source that will be available to all mankind, why not have the collective brains and talent of all mankind working on it?

In April 1978, respected Russian scientist, vice president of the Soviet Academy of Sciences E.P. Velikhov, privately proposed to officials in Washington the creation of an international tokamak experiment. The proposal was made formally the following month, at the meeting of the U.S.-Soviet Joint Fusion Power Coordinating Committee in Moscow. Velikhov proposed that the project be under the auspices of the International Atomic Energy Agency (IAEA). At the same time, other nations had a similar response to the world energy crisis, and Japanese Prime Minister Takeo Fukuda proposed a $1 billion joint fusion development program during a May 1978 visit with President Carter. These proposals were pushed aside.

Two years later, on March 10, 1980, Academician Velikhov gave a lecture at the Swedish Adacemy of Engineering Sciences in Stockholm. Velikhov, who over the years has been a science advisor to Russian government leaders, outlined the nuclear power plans of the Soviet Union, and, again called for an international fusion project, which he called INTOR.

Finally, in November 1985, fusion was put on the international diplomatic agenda, when the Soviet-American statement issued after the summit between President Reagan and Soviet leader Mikhail Gorbachev stated that they "emphasized the potential importance of the work aimed at utilizing controlled thermonuclear fusion for peaceful purposes, and, in this connection, advocated the widest possible development of international cooperation in obtaining this source of energy, which is essentially inexhaustible, for the benefit of all mankind." Europe and Japan were invited to join the new project, the Inter-

ITER

Academician Evgeny Velikhov (with pen), President of the Kurchatov Institute and Vice-Chair of the ITER Council, signing a procurement arrangement for Russia's contribution to the ITER of its upper ports and divertor dome, June 2009. Velikhov had proposed an international tokamak experiment to the U.S. government back in April 1978. But the Carter Administration ignored this proposal, as well as a similar one by Japanese Prime Minister Takeo Fukuda.

NASA

Artist's illustration of a rocket returning from Mars to Earth. Without the development of fusion propulsion, we will not be able to travel back and forth to Mars in days—instead of years.

national Thermonuclear Experimental Reactor or ITER, and Canada also joined.

Design work for a reactor was carried out over the 1990s, with scientists from more than a dozen countries contributing to the effort. It is a very ambitious undertaking. The tokamak is being designed to generate 500 megawatts of fusion power for hundreds of seconds, as an important step towards the generation of steady-state power which will be required for a commercial power plant. As the design work proceeded, China and South Korea joined the ITER effort in 2003, and India joined two years later.

As is the case in nearly all international science and engineering projects, design of the reactor took more time than initially envisioned, and in the Summer of 1998, extensions for the work were required. Europe, Russia, and Japan signed the three-year extension agreement. Energy Secretary Bill Richardson tried to do an end-run around the opposition to the project in the Congress, and announced on September 22, 1998, that he had signed a unilateral agreement extending the United States support for ITER.

But the Congress, under the guidance of a Republican leadership intent upon cutting Federal spending, regardless of the consequences, eliminated the paltry $12 million for fiscal year 1999 that was to go toward U.S. work on ITER. "The project has failed," pontificated House Science Committee Chairman, Republican James Sensenbrenner, from Wisconsin. He continued: "It defies common sense that the United States should agree to continue to participate in a dead-end project that continues to waste the American taxpayer's dollars." The other international partners were stunned.

Engineering design work for ITER proceeded, without the participation of the United States. After the design completion, the partners began the process of choosing a site for the reactor. Then, in 2003, President George W. Bush announced that the United States would be rejoining the ongoing negotiations to choose a site for ITER. Perhaps the fact that China and South Korea had become ITER partners had caused the U.S. Administration to rethink fusion policy.

In June 2005, the nuclear research center site in Cadarache, France, was chosen for the construction of ITER Today, the site has been cleared, and preparatory work for the next phase of construction is well under way.

Now that ITER is proceeding, it has become urgent, once again, to return to a robust domestic U.S. fusion energy program, both in order for this country to fulfill its obligatory contributions to ITER, and so the U.S. is prepared to make use of the advancements that are made there.

Engineering Challenges

One of the major challenges of engineering a power-producing fusion reactor is the development of new materials that can withstand the severe fusion environment. At the annual meeting of Fusion Power Associates, Dec. 2-3, 2009, in Washington, D.C., leaders of the fusion programs at this nation's national laboratories, universities, and in industry stressed the need for a

ITER

Construction work at the ITER site in Cadarache, France.

shift from fusion as a purely scientific endeavor in the Department of Energy, toward solving the practical problems.

At the FPA conference, Ed Synakowski, who heads the Department's Office of Fusion Energy Sciences, stated that it was time that fusion broke out of its scientific and political isolation. He said that the nation needs a sensible program in materials research, and experiments to solve outstanding scientific questions.

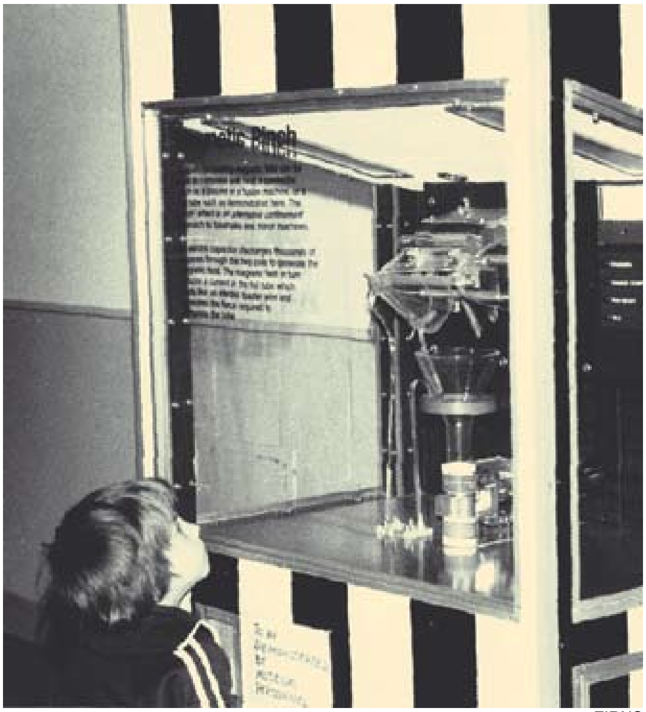
The presentations by U.S. fusion leaders at the conference stood in contrast to that of Dr. G.S. Lee, head of the South Korean National Fusion Research Institute. The Institute is currently carrying out experiments in its KSTAR advanced superconducting tokamak reactor [see article, page 51] and scientists from around the world have sent researchers to participate in KSTAR experiments. Dr. Lee explained that they will be well trained and experienced from their work on KSTAR, once ITER is ready for operation, about a decade from now.

The most exciting remarks by Dr. Lee concerned not Korea's technical progress, but its commitment to create a practical new energy technology. He explained that when the government approved the fusion program in the mid-1990s, it wanted to ensure that the research would not simply be an experiment, but would lead to a reactor. Understanding that this will be a long-term effort, which will have to survive numerous changes in ruling parties and five different presidents, Korea's Fusion Energy Development and Promotion Act was passed in 2007, which created a Federal Commission to oversee the fusion program. It ensures the continuity of the program, and is renewed every five years.

To meet the goal of developing a practical energy source, as stated in the law, Dr. Lee said, his Institute is already evaluating various sites where there are operating conventional nuclear plants, as potential sites for a demonstration fusion reactor. Design of the 700-megawatt Korean demonstration plant will be carried out while experiments are ongoing on ITER, with construction to start in 2027. In the following decade, Korea plans to be building fusion power plants.

There is little question that the U.S. fusion program must be rethought, lest the nation be left to do little but grouse, as other nations continue to leap ahead. One step to try to address this question was taken by Rep. Zoe Lofgren, (Democrat of California), who introduced the Fusion Engineering Science and Fusion Energy Planning Act of 2009 on July 10, 2009. The Act would require that within one year of passage, the Department of Energy present to the Congress a comprehensive plan to identify the range of research and development needed to achieve practical fusion energy. The bill stresses the engineering areas of materials science, in particular. One can question whether or not yet another study, delaying action for another year, is at all necessary. But the impetus of the bill does place the fusion question squarely in front of Congress, once again.

The most forward-looking great projects in science and engineering in the U.S. are barely marking time. The program for the manned exploration of the Moon and Mars, promulgated by the previous Bush Administration, has been so underfunded that layoffs have begun in the space program. If the Congress, which authorized the program, does not wish to see this country become a has-been in space, it must do more than complain. The resources required to maintain world leadership have to be forthcoming.



EIRNS

A young boy looks at a Franklin Institute display demonstrating the magnetic pinch concept for confining a plasma, an alternative to tokamaks and mirror machines. To make fusion a reality—instead of a museum display—will take a political commitment of the kind that put a man on the Moon in 1969.

Fusion Is Absolutely Necessary!

None of the arguments that have been marshaled against the fusion program hold any weight. That fusion is not here yet, and is still years away, is only the result of failed energy and economic policies, and the unwillingness to provide the resources to solve the outstanding problems. In the final analysis, it does not matter how much it costs to develop commercial fusion energy, because it is absolutely necessary to do so. It does not matter how much the first commercial demonstration fusion reactor will cost, or whether it will be competitive with coal, solar collectors, or windmills. Fusion energy will be available to all nations. For the first time in history, a country's finite natural resources will not be the limiting factor in its economic development. And with fusion to power space vehicles, man will be able to reach Mars and destinations beyond in days, thus fulfilling what has to be humanity's mission in this century.

Fusion will make available both a quantity and a quality of energy that is unattainable from any other known source. It is the technology on the horizon that not only can produce electricity, but also can economically create synthetic fuels, potable water, new materials through plasma processing, and employ applications that are still to be discovered The key ingredient for success is the will to do it.

In the 1970s, on the door to his fusion office, Ed Kintner displayed this biblical quote: "Where there is no vision, the people perish." There could be no time when this is more true, than today.

Doctors using cesium-131 radiochemical brachytherapy "seeds," to treat prostate and other cancers. Cesium-131 has a significantly shorter half-life than the two other isotopes commonly used for brachytherapy, allowing faster delivery of therapeutic radiation to the prostate gland, reduced incidence of common brachytherapy side effects, and lower probability of cancer cell survival.

Radioisotopes: The Medical Lifesavers That Congress Is Suppressing

by Christine Craig

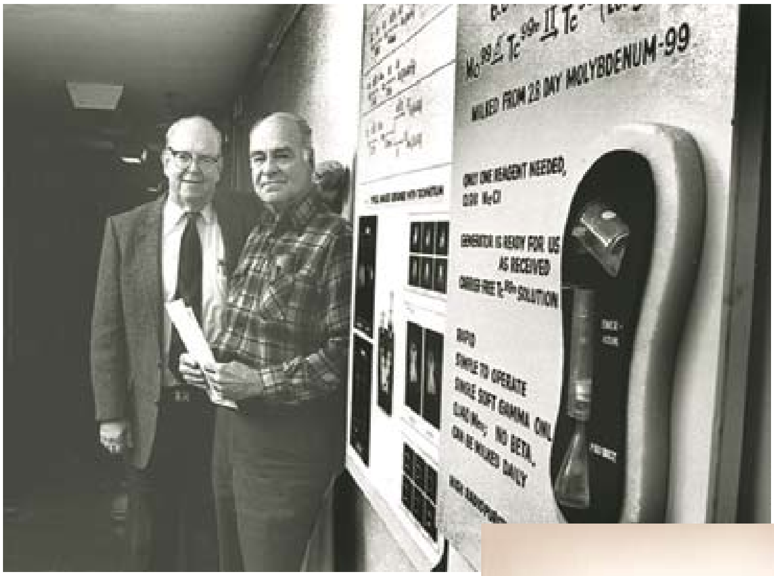
The cost of the U.S. policy restricting radioisotope production and use can be measured in human lives lost. Reviewed here is the history of radioisotope suppression, and the promise of new research with alpha emitters.

Part I
U.S. Radioisotope Production and Use

The use of radioisotopes for the diagnosis and treatment of disease is now a vital part of modern medical practice. Aside from a few simple treatments for mild infections, it is difficult to imagine a modern medical diagnosis and treatment strategy that does not involve the use of radioisotopes. The industry is huge, and becoming larger as new technologies are discovered and developed. But this growing industry rests on shaky foundations, leaving many areas of the industry susceptible to sudden collapse, and putting potentially millions of patients at risk worldwide.

The most vulnerable link is the production and supply lines of the medical radioisotope most in demand throughout the world, technetium-99m. This man-made isotope was created 50 years ago at the Atomic Energy Commission's Brookhaven National Laboratory in New York, by scientists Walter Tucker and Margaret Greene, while they were working on refining another radioisotope, iodine-232. Tucker and Greene developed the first molybdenum-99/technetium-99m generator, and Powell Richards, also of Brookhaven, fostered its development for medical purposes. But in 1966, the laboratory bowed out of production, leaving the playing field open to two private companies, Mallinckrodt and Union Carbide. At the time, Brookhaven could not keep up with demand for the versatile isotope!

Therein lies the tale. The U.S. Atomic Energy Commission, which ran the Brookhaven laboratory, left the technology to industry, and industry left the country with the technology, leaving the United States with no domestic source for an isotope that is used in more than 30 million diagnostic procedures each year worldwide, and almost 20 million procedures in the United States alone. Now the United States relies on other countries, and specifically Canada, for all of its technetium-99m needs, even though we are the major consumer of such diagnostic procedures worldwide. This folly of globalization has left our nation in an extremely precarious position regarding technetium-99m



Brookhaven National Laboratory

Walter Tucker and Powell Richards, radioisotope pioneers at Brookhaven National Laboratory. Tucker, working with Margaret Greene, created the first molybdenum-99/technetium-99m generator (right). Richards fostered its development for medicine.

In 1998, Mallinckrodt dedicated its new medical building in Petten, the Netherlands, to Richards, installing a bronze plaque with his prophetic words about the isotope: "Technetium-99m should be a useful research tool; it combines a short half-life and unique radiation characteristics. The absence of beta radiation reduces the amount of damage to biological systems usually associated with radioisotopes."

supply, as the last two years have dramatically shown.

Technetium-99m: An Unstable Supply

More than 80 percent of almost 23 million radiopharmaceutical injections given in the United States yearly use technetium-99m (Tc-99m), derived solely from foreign sources, mostly from the Chalk River reactor in Canada and the High Flux Reactor (HFR) in Petten, the Netherlands (see Table 1). Tc-99m is a daughter product of molybdenum-99 (Mo-99), a radioisotope produced as a fission product of highly enriched U-235 targets placed in the reactors.

Without warning, on Nov. 17, 2007, the Chalk River National Research Universal (NRU) reactor was shut down by Atomic Energy of Canada, Ltd., at the request of the Canadian Nuclear Safety Commission. At issue was not a malfunction or a dire safety problem threatening to harm the community, but a long-standing dysfunctional relationship between the operator, Atomic Energy of Canada, and the regulator, the Nuclear Safety Commission, regarding some mandated safety upgrades to the reactor. After the Parliament intervened with emergency legislation, the reactor went back on line in mid-December 2007. In the meanwhile, thousands of medical patients had been prevented from having imaging tests because of the shortage of Mo-99.

Chalk River is a small 1950s vintage research reactor, which has only 5 percent of the power of Canada's CANDU commercial power reactors. Yet it supplies more than 50 percent of the world's Mo-99, the raw material for Tc-99m, which is used for more than 85 percent of the world's medical nuclear imaging procedures.

The NRU is now at the end of its useful life, and MDS Nordion, the corporation with the monopoly on Canadian molybdenum production and distribution, at least had the foresight to plan ahead. The company worked for decades to get two new isotope reactors up and running at the Chalk River site. The two reactors, MAPLE 1 and 2, were to have replaced the aging NRU, allowing Canada and Nordion to continue to dominate the medical isotope market for decades to come. Unfortunately, after numerous setbacks in the design, construction, and financing of the two reactors, MDS Nordion and the Atomic Energy Commission

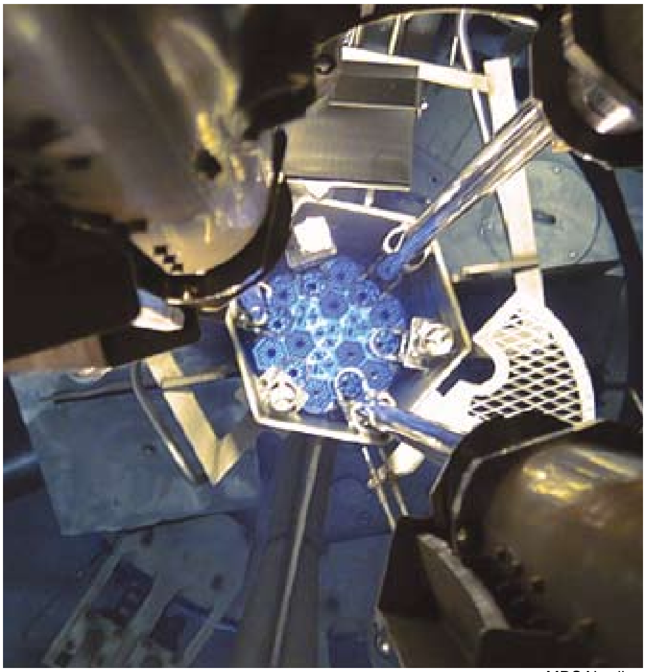
Table 1
MAJOR ISOTOPE PRODUCING REACTORS

Nuclear Reactor	Year Built	Product Country	Distributor	% World Present Mo-99	Status
National Research Universal (NRU)	1957	Chalk River, Canada	MDS-Nordion	40	Offline until May 2010
High Flux Reactor (HFR)	1961	Petten, Netherlands	Covidien IRE	20 10	Offline until August 2010
South African Fundamental Atomic Reactor Installation 1 (SAFARI-1)	1965	Pelindaba, South Africa	NTP	10	Online
Belgian Reactor 2 (BR2)	1961	Mol, Belgium	Covidien IRE	5 4	Online
OSIRIS	1964	Saclay, France	IRE	3	Online

Padraic Ryan

The Chalk River nuclear complex in Canada.

Inside the NRU Reactor at Chalk River, Canada, where MDS Nordion irradiates HEU targets to produce medical isotopes.



MDS Nordion

The Maple 1 reactor at low power.

announced in April 2008 that the already constructed reactors would be mothballed. The NRU has been approved to operate until 2015. After that, unless the MAPLE reactors are resuscitated, Canada will be without a Mo-99 nuclear reactor production facility.

Since that 2007 shutdown, the medical world has been hit with new shortages, as one or more of the five main Mo-99-producing reactors have gone off line for maintenance or repairs in the last year-and-a-half. In May 2009, the NRU was again taken off line for repairs after it leaked tritium from coolant pipes. It remains offline today, its start-up date now pushed back to at least May 2010. And now, the High Flux Reactor (HFR) in the Netherlands has just gone offline until at least August 2010 to repair its leaking pipes. This leaves the world without the two most productive Mo-99 producers for at least three months, and perhaps much longer.

A Sad History

Until 1989, the 5-megawatt Sterling Forest reactor run by Cintichem (Union Carbide, et al.) in Tuxedo Park, N.Y., was irradiating U-235 targets to generate Mo-99. The reactor sprang a leak, and instead of fixing it, the company sold its technology to the U.S. Department of Energy. In return, it was allowed to decommission the reactor, leaving the DOE to do the cleanup. That is how the United States came to be without a domestic source of Mo-99. It was cheaper for Union Carbide, Mallinckrodt, et al. to move to Europe and use willing government-subsidized reactors for their Mo-99 production.

The DOE sabotage did not stop there. Now the DOE, under a directive from Congress, is preparing to eliminate the supply of the uranium-233 feedstock, which decays to produce valuable alpha-emitting isotopes.

Uranium-233 (U-233) is not at present a naturally occurring isotope of uranium. It is purely a product of the ingenuity of mankind in the nuclear age, a product of the still-nascent *isotope economy*[1] that began a century ago with discoveries that led to the realization that elements were not fixed and unchanging primary substances, but were themselves composed of transmutable subspecies, differing in the number of neutrons within the nucleus.

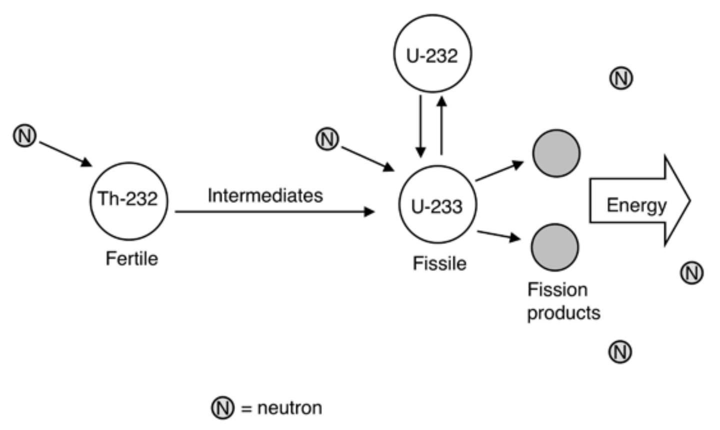


Figure 1
SIMPLIFIED DIAGRAM OF THE THORIUM FUEL CYCLE
The neutron trigger to start the thorium cycle can come from the fissioning of conventional nuclear fuels, or an accelerator. When neutrons hit the fertile thorium-232, it decays to the fissile U-233; a neutron striking the U-233 leads to fission products, more neutrons, and a lot of energy. (Not shown is the short-lived intermediate stage of protactinium-233.)

All of the U-233 now on our planet was created artificially by breeder reactors in nuclear weapons programs and in nuclear fuels research, by bombarding thorium-232 (Th-232) with neutrons (Figure 1). Neutron capture leads, through the short-lived intermediates thorium-233 and protactinium-233, to U-233, a fissile isotope with a half-life of 160,000 years.

Uranium-233 also decays naturally to thorium-229, a precious medical isotope. It takes 160,000 years to generate 1 kilogram of Th-229, the daughter product, from a 2-kg source of U-233. Since, to date, U-233 decay has been virtually the only source of Th-229 on our planet, and the oldest U-233 is less than 60 years old, it is obvious that Th-229 is a scarce commodity, indeed, a rare jewel of incalculable worth. And yet, the U.S. Department of Energy has set in motion plans to dispose of both the mother and daughter products.

The 45-megawatt High Flux Reactor at Petten.

The Idaho National Laboratory has already shipped a store of 300 kg of aged U-233, mixed within 30 metric tons of Th-232, which originally came from the decommissioned Shippingport light water breeder reactor[2] in Pennsylvania to the Nevada Test Site for burial. The inventory of U-233 at Oak Ridge National Laboratory is also set for burial.[3] The plan is to down-blend it with the non-fissionable U-238 and ship it to New Mexico for storage in the next few years.

These isotopes are being treated as dangerous garbage, which must be disposed of to remove a politically imagined nuclear weapons proliferation threat. The reality is that they are priceless resources. The U-233 bred from Th-232 is not only capable of powering a nuclear reactor to provide needed electricity for our power grid,[4] but its decay product, Th-229, with a half life of 7,340 years, is the source of two short-lived daughter nuclides—actinium-225 (Ac-225) and bismuth-213 (Bi-213)—which are highly prized in the medical field as next-generation treatments for cancer and even HIV and other infectious diseases (Figure 2).

The premature burial plan comes after both the Oak Ridge and Idaho labs had developed highly publicized plans to extract the Th-229 from the U-233 before disposal, for the express purpose of providing a steady supply of Ac-225 and Bi-213 for medical research and clinical trials. But, in the last three years, the DOE, at the behest of Congress, has very quietly pulled the plug on both programs, thus slaughtering the goose that laid the golden egg.

A May 2008 Special Report by the Office of the Inspector General of the Department of Energy,[5] made a strong case that the DOE plan, to dispose of its U-233 stocks without first extracting the accumulated Th-229, was foolish, for it would provide no assurance that sufficient quantities of uranium-233 and its valuable progeny

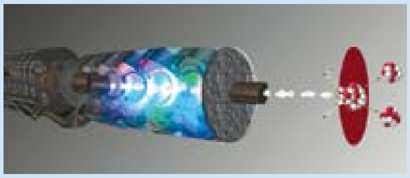
Alternative Ways To Produce Mo-99

There are at least four separate paths to Mo-99 production, with several possible technologies available for each path. Only the first method has a proven track record. The other methods are under development and investigational.

The linear accelerator (linac) at the Australian Synchrotron in Clayton, Victoria.

(1) U-235→Mo-99 (6%) + other fission products (94%)

This can be achieved through fission of high-enriched uranium targets or low-enriched uranium targets in nuclear reactors, or through accelerator-generated neutron fluxes to similar targets. Essentially all Mo-99 is made this way in nuclear reactors, followed by chemical processing of the targets and extraction and purification of the Mo-99 for use in Mo-99/Tc-99m generators.



TRIUMF Depicted here is the method of electron-accelerator-driven photofission to produce Mo-99.

Although the reactors now producing the bulk of Mo-99 are at the end of their lives, there are several existing reactors that could be brought into service for this task.

• The two new Canadian Maple reactors, built specifically to produce Mo-99, were completed but mothballed in 2008 because of design flaws. These could be resuscitated if experts put their heads together. The Maple reactors could probably supply the world's present needs and then some, even if converted from high-enriched to low-enriched fuel and targets.

AccSys Technology, Inc.

AMIC (Advanced Medical Isotopes Corp.) has selected this proton linear accelerator (PULSAR) manufactured by AccSys Technology, Inc. for the production of positron emitting isotopes.

• Another reactor capable of the high neutron fluxes required to produce Mo-99 is the Fast Flux Test Facility in Hanford, Washington. Although in perfect working order, the FFTF was killed by the Bush Administration in 2005, and is now in cold standby, awaiting a final DOE decision about what to do with it. It could be brought online to produce Mo-99 and many other medical isotopes.

• There are several other reactors at the national labs that could also be used. Further, university research reactors, such as the MURR at the University of Missouri, could be retrofitted to produce Mo-99 as well.

New Systems Under Development

Several novel systems are being developed to deliver the neutron flux necessary to fission uranium to Mo-99, including accelerator-driven systems and liquid reactor systems.

Babcock & Wilcox

The Babcock & Wilcox design for an aqueous homogenous reactor to produce Mo-99.

• Babcock & Wilcox of Lynchburg, Va. has received Federal funding to help it bring online several aqueous homogeneous reactors, each with a reactor vessel the size of a 50-gallon drum. The reactor has no fuel rods, but is a solution of low-enriched uranium nitrate or sulfate able to cycle from the reactor through tubing and back to the reactor. Some of this solution would be run through columns able to bind the Mo-99, leaving the rest of the liquid to return to the reactor. This Mo-99 would then be purified and made into Mo-99/Tc-99m generators.

• Several companies, including Advanced Medical Isotopes Corp. (AMIC) of Kennewick, Wash., are testing small linear accelerators capable of producing a particle beam (proton or electron) which can be run through various primary targets which will generate a neutron flux to a uranium target, fissioning the uranium to Mo-99 and other products as above. AMIC's machine is small and designed to be situated near a medical facility.

(2) U-238→Mo-99 (6%) + other fission products (94%)

• TRIUMF, a consortium of universities and other institutions in Vancouver, Canada, is pursuing a plan to use photo fission (fission produced by an electron particle accelerator bombarding mercury or tungsten targets to produce a neutron flux) of natural uranium targets to produce Mo-99.

(3) Mo-98→Mo-99

The naturally occurring, (~24%) long-lived isotope of molybdenum can be transmuted through neutron capture to produce Mo-99, using either neutrons from a nuclear reactor, or neutrons generated by particle accelerators. Small producers in several countries already use this method for indigenous use.

• CERN, the European Organization for Nuclear Research laboratory in Switzerland, has a plan to produce enough Mo-99 to supply present world needs. CERN would use a proton accelerator (1-megawatt beam) with Adiabatic Resonance Crossing to create a flux of neutrons equivalent to that of a research reactor, which would produce Mo-99 from Mo-98 targets by neutron capture.

(4) Mo-100→Mo-99

The naturally occurring (~10%) long-lived isotope of molybdenum can be transmuted into Mo-99 by an electron accelerator, which irradiates secondary targets that produce high-energy photons. These photons then bombard the secondary Mo-100 target, dislodging a neutron to produce Mo-99.

isotopes will be available to support U.S. medical and scientific research needs. The report noted:

- The Department is the only domestic producer of progeny isotopes from uranium-233 and current production is insufficient to meet medical and scientific research needs. Once the planned disposal of uranium-233 is complete, the Department will not have the means to increase isotope production to meet the dramatic projections of future needs for actinium and bismuth;
- At present, no viable alternative methods of production of actinium and bismuth have been demonstrated or proven; and,
- Uranium-233 also is used to support other Department missions such as the National Nuclear Security Administration's Test Readiness Program.

The report concluded:

Should the Department elect to proceed as planned, it may dispose of a national resource that is irreplaceable. The potential for isotopes produced from uranium-233 to help save the lives of thousands of American cancer patients is widely accepted, and one top Departmental official estimated that isotope production from ORNL stocks alone could be used to treat about 6,000 patients annually. While we are sensitive to the complex public policy implications associated with this matter, including significant budgetary issues, we believe that the Department should explore alternatives for ensuring a stable domestic supply of the important isotopes produced from uranium-233.

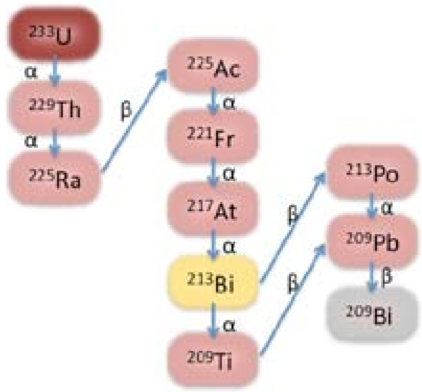


Figure 2
WHAT CONGRESS IS WASTING: THE URANIUM-233 DECAY CHAIN
Uranium-233 is fissionable and can be used to power reactors. Its decay product thorium-229, with a half life of 7,340 years, is the source of two particularly valuable short-lived daughter nuclides—actinium-225 (Ac-225) and bismuth-213 (Bi-213). These are prized in the medical field as next-generation treatments for cancer and even HIV and other infectious diseases.

DOE

The first Shippingport Spent Fuel Canister (SSFC) being welded for storage in underground vaults at the Canister Storage Building, where they will stay until permanent burial—instead of being used to produce radioisotopes.

Thorium Sabotage at Oak Ridge

Oak Ridge National Laboratory, which pioneered in the production of radioisotopes after World War II, has been a storage depot for U-233 supplies for more than 30 years. This includes U-233 produced in the ORNL molten salt breeder reactor, which was shut down in the mid 1970s. In 1995, funding was awarded to the Nuclear Science and Technology Division at ORNL to facilitate extracting the accumulated thorium-229 from the breeder reactor waste tanks in Building 3019A at the Radiochemical Development facility (Figure 3). Previously, the thorium extraction had been funded with internal laboratory funds only, including by selling one third of the waste sludge to a Dutch pharmaceuti-

DOE

The last shipment of Spent Nuclear Fuel From the Oak Ridge National Laboratory to the Idaho National Laboratory (INL) in 2003, where it was being stored until its "final disposal." Its valuable radionuclides are now lost to use.

Figure 3
WHERE THE TREASURE WAS STORED: BUILDING 3019A AT ORNL
Building 3019A at Oak Ridge National Laboratory stored the breeder reactor spent fuel tanks, from which thorium-229 could be extracted. To save maintenance costs, the DOE proposed closing the building and sending the contents to a burial ground, after extracting the Th-229. But Congress reversed this plan in 2006, cutting the funds to carry it out, committing all the material to burial without extracting the valuable Th-229.

cal company, PharmActinium, Inc., for its radioisotope production.[6]

Over the years, much of the thorium had precipitated out of solution onto neutron-absorbing boron-glass rings (Raschig rings) within the tanks, and was easily extracted, then purified. From these initial supplies came the first actinium-225 and bismuth-213 for medical research. In fact, Oak Ridge scientists from the Life Sciences Division, using these supplies, were part of the groundbreaking research demonstrating the potent cancer-killing potential of alpha-emitting isotopes when coupled with an effective targetting mechanism.

That initial thorium extracted from waste, plus additional small quantities of thorium extracted from samples which have been pulled out for examination from containers stored in Building 3019A throughout the years, amounts to 150 millicuries (mCi), or about three-quarters of a gram, from which can be extracted, or "milked," 100 mCi of Ac-225 every 60 days. Without additional sources of Th-229, or new technologies for creating the daughter isotopes Ac-225/Bi-213, research will be severely limited by the existing meager supplies of extracted thorium. The present Oak Ridge Th-229 supplies would yield quantities of daughter nuclides sufficient to treat only about 100 patients per year.

The stored remaining stock of U-233 at ORNL—some 450 kg within some 1,400 kg of uranium-containing materials—presently contains about 37 remaining grams of Th-229 as a decay product. An additional amount (perhaps 69 grams) of Th-229, as mentioned above, was stored until recently within the Shippingport fuel rods at the Idaho National Laboratory. This has since been carted off to the dump at the Nevada Test Site, leaving ORNL as the sole domestic supplier of daughter nuclides from U-233.

If the 37-grams of Th-229 accumulated in the U-233 in Building 3019A were extracted, the number of patients who could be treated would be 50-fold greater than at present, and no new technology would even be necessary. This would give the medical research community enough ammunition to proceed expeditiously with its alpha immunotherapy research, backed by the security of a greater-than-7,000-year baseline supply of Th-229, continuously generating the Ac-225 and Bi-213 needed for cancer therapies.

One Step Forward —and Two Steps Back

In 1996, the DOE held a workshop on Alpha-Emitters for Medical Therapy, in Denver. According to the report on the workshop:

> A major consensus was the need for focussing research and development on two promising alpha-emitters: astatine-211 (^{211}At) and bismuth-213 (^{213}Bi). The latter is being currently supplied from abroad and has been linked to a specific monoclonal antibody against tumor cells being prepared for the first clinical trial, phase I, at the Memorial Sloan Kettering Cancer Center in New York, N.Y.[7]

From where abroad was the Bi-213 coming? The former Soviet Union was the only other generator of enough cold-war U-233 to possibly extract significant amounts of Th-229 for medical treatment. However, it was the Institute of Transuranium Elements in Karlsruhe, Germany, that was providing the Bi-213 for the U.S. cancer trials, using thorium-229 received from ORNL!

According to the report: "Preclinical studies with ^{213}Bi have been completed using a 20 mCi actinium-bismuth generator from Karlsruhe, Germany produced from ^{229}Th recovered at a DOE facility." This thorium-229 stock was received from Pharmactinium, Inc., the same company that had purchased some of the breeder reactor waste sludge from ORNL in 1994. The irony of a foreign institute providing a U.S.-derived isotope to the U.S. researchers was not lost on the workshop participants, who concluded:

> A more rapid development of α-emitters should be a national effort by the DOE. This demands *short-term actions for immediate development*, and longer term commitments over the next few years. DOE could provide absolutely essential support for the necessary basic research. This should include radionuclide availability for these projects, and the studies in radiobiology, radiochemistry, dosimetry and toxicity required for designing clinical trial protocols.

In January 2001, the DOE finally got moving on the project to extract the thorium-229 from the U-233 stored at ORNL, as a DOE report states:

> On January 8, 2001, former Under Secretary of Energy Moniz signed Excess Material Deposition Decision Memorandum No. 2, which established the path forward for managing the U-233 stored at ORNL. Specifically, this memorandum determined that there is no programmic use for the U-233 currently in storage at ORNL other than as a possible source of medical isotopes. The memorandum directed that a Request for Proposals (RFP) be issued that will require a contractor to:
>
> • Process the U-233 to extract Th-229 for use as a source of medical isotopes;
>
> • Further process the U-233 to eliminate current concerns regarding criticality, stability in storage, and provision of safeguards and security; and
>
> • Remove the U-233 material from Building 3019A, allowing the building to be deactivated.[8]

The DOE had decided to kill two birds with one stone. Eager to get rid of the expensive security burden of continuing to store the U-233 in Building 3019A, the Department determined that the uranium was not necessary for any DOE programs, and that millions of dollars in security and radiation protection services could be saved each year if the U-233 were down-blended with the non-fissionable U-238—to remove any danger of criticality accidents or theft by nuclear terrorists—and carted off to a suitable storage repository in New Mexico. Building 3019A was to be shut down.

To put a positive spin on this trashing of a national treasure and to gain proponents for the project, the DOE incorporated into its U-233 disposal plans a concomitant thorium-229 extraction phase, which would salvage the valuable isotope before down-blending the uranium. The DOE put out a proposal, conducted an environmental impact study, and hired a consortium of companies called Isotek[9] to design, manage, and carry out the project. The consortium carried out the design phase of their task in good faith, and its extensive and interesting work was outlined in a paper detailing its efforts and planned future activities (Figure 4).[10]

But by 2006, the DOE was forced to change its plan to extract the Th-229 from the U-233 before processing for disposal (Figure 5). Congress had decided against the isotope extraction, and had provided no funding for the project. A DOE report states:

> In the November 2005, Conference Report for the Energy and Water Development and Related Agencies Appropriations Act for Fiscal Year (FY) 2006, the conferees provided no funding for the Medical Isotope Production and Building 3019 Complex Shutdown project. The conferees' action directed DOE to terminate promptly the Medical Isotope Production and Building 3019 Complex Shutdown project. Per DOE's recommendation, the responsibility for the disposition of the ^{233}U was transferred to the Environmental Management (EM) program. The conferees provided FY 2006 funds in the Defense EM appropriation for the disposition of the material stored in the Building 3019 Complex and directed the Department to provide a report within 60 days detailing a path forward for managing the material.[11,12]

The new directive, needless to say, had dropped all plans to extract the valuable Th-229 from the "waste" U-233.

Nuclear scientists and medical researchers were outraged by Congress and the DOE's double-cross on Th-229 extraction. In the public comment section of the DOE's 2007 Environmental Impact Report on the revised plan, Dr. Rose Boll of the Department of Chemistry at the University of Tennessee, who had worked with ORNL for years on Ac-225/Bi-213 isotope development for medicine, made the following statement:

> Please include in the actions of this process, the separation of the Th-229 from the ^{233}U. The increased cost in the overall process for the recovery of the Th-229 from the ^{233}U is minimal (1-5%).
>
> The Th-229 isotope is being used for medical treatment and research with very promising results. Th-229 exists in limited quantities in our world. The

Congress Throws Away $100 Billion Per Gram

The magnitude of waste of resources demanded by Congress in the name of saving money, by cutting out "1-5%" of the cost, can be calculated in dollar terms. The present value of Ac-225, the daughter isotope of Th-229, is roughly $2.5 million per Ci. The yield of Ac-225 from present stocks (~.75 g) of Th-229, based on a 60-day campaign cycle of extracting the Ac-225 from the Th-229 by present ORNL techniques, is about 100 mCi per campaign. That comes to 600 mCi per year, with a value of $1.5 million.

The estimated additional Th-229 available from processing the U-233 (now considered waste and slated for burial) is 37 g—50 times the present stock. This 50-fold greater quantity of Th-229 would yield 30 Ci of Ac-225 every year, rain or shine, for many thousands of years.* That comes to around $75 million per year, in perpetuity, from slightly over an ounce of parent Th-229.

The quantity of Ac-225 required to produce this $75 million, given a specific activity for Ac-225 of 58,000 Ci per gram, can be calculated to be about 0.0005 g, which comes to a "specific value" for Ac-225 of almost $150 billion per gram!

Here's the catch: Use it or lose it; with a half-life of just 10 days, and daughter products very short-lived, though valuable as well, if you put that Ac-225 in a bank vault instead of to immediate use, you soon end up with nothing but a tiny pile of Bi-209 worth just pennies per gram.

* R.A. Boll, D. Malkemus, S. Mirzadeh, "Production of actinium-225 for alpha particle mediated radioimmunotherapy," *Applied Radiation and Isotopes*, Vol. 62 (2005), pp. 667-679.

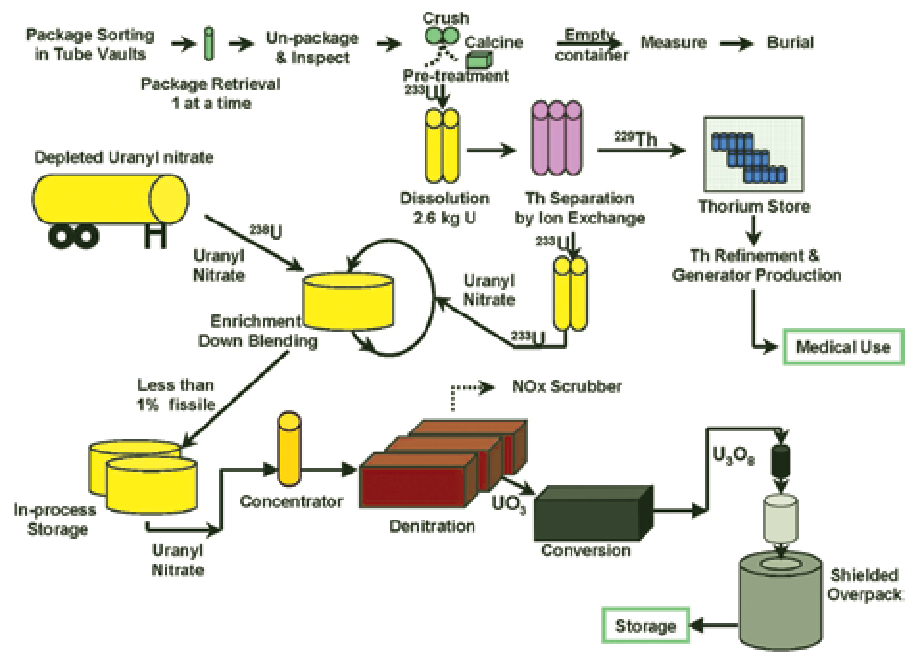


Figure 4

DOE PLAN FOR SHUTTING DOWN BUILDING 3019A—2004

In this plan, the thorium-229 was scheduled to be separated out from the U-233 before the U-233 was treated and sent for burial.

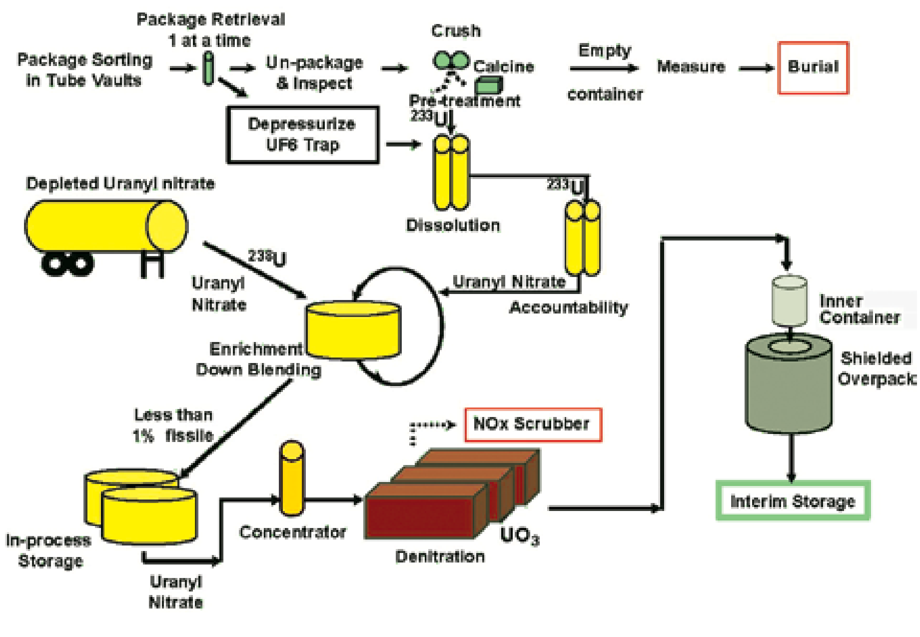


Figure 5

DOE PLAN FOR SHUTTING DOWN BUILDING 3019A—2007

In the revised plan, Congress mandated the shutdown of the U-233 storage facility with no extraction of thorium-229, sending this valuable resource to the dump.

Th-229 that is contained in the ^{233}U at ORNL is high quality material, unmatched in purity and quantity anywhere in the world. For the United States to dispose of the ^{233}U without recovery of the Th-229 would be irresponsible and a major waste of our country's resources.[12]

Since 1990, Congress has mandated that the U.S. isotope program must pay for its isotope production costs through sales of its products and services[13] (a short-sighted "market" approach, the effect of which is to kill technologies and kill people). But even on these terms, an annuity of $75 million from selling the Th-229 would be a tidy nest egg for its projects. The catch is, there has to be a market for the 50-fold greater quantity of Ac-225 that would flood the market if the DOE proceeded with Th-229 extraction. Right now, according to the DOE's own admission, there is not enough Ac-225 available to provide for present medical research, let alone future projects. But in order for the Ac-225 to retain its market value, there must be a large demand for it in the medical field. This requires that the therapeutic value and safety of it and its daughter products for cancer and infectious disease treatment be proven in many clinical trials in order to eventually get Food and Drug Administration approval of the isotopes for human treatment of specific diseases—an expensive and lengthy procedure.

To date, only two radioimmunotherapeutic treatments have been approved by the FDA, and both use beta-emitting isotopes (see box, page 41). Requiring the DOE's Isotope Program to "pay to play" by recouping all costs of production through isotope sales and related services is a very short-sighted policy that has failed in the past, is failing, and will fail in the future.

Part II
Targetted Alpha Radioimmunotherapy

Following the trail blazed by targetted immunotherapy in the last quarter of the 20th Century, a new clinical sub-field has grown and begun to mature: targetted radioimmunotherapy (RIT), which not only holds the potential to add to the effectiveness of cancer treatment, but which also has great potential as a treatment against infectious disease. The only thing standing in the way of this development is the failure of governments, especially the U.S. government, to nurture this promising technology.

Cancer is the second-leading killer of people in the United States (led only by heart disease), killing about 560,000 people per year. The five-year survival rate for all cancers has risen steadily since 1975, from about 50 percent to more than 67 percent today, due largely to earlier diagnosis and better treatments, with radioactive isotopes playing a prominent part in these advances.

Because cancer cells are human cells, almost all treatments to kill cancer cells, including chemotherapeutics and radiation therapy, kill many healthy cells as well. The challenge of cancer treatment is to maximize damage to cancer cells while minimizing damage to healthy tissues; the goal is to cure the disease without killing or maiming the patient. This goal is remarkably hard to achieve, which is why success is measured in five-year survival rates rather than cure rates. Even when no cancer is detectable in the body after treatment, cancer has a tendency to eventually "come back."

In order to surmount these obstacles to successful outcomes in cancer therapy, researchers have increasingly turned their efforts towards highly targetted therapies, capable of seeking out and killing even single cancer cells that are undetectable by present-day diagnostics, while sparing surrounding cells and tissues.

Monoclonal Antibodies Target Cancer Cells

Ever since it became feasible to produce monoclonal antibodies (mAbs) for therapeutic uses more than three decades ago,[14] cancer researchers and clinicians familiar with targetted nuclear medicine have envisioned a time when the power within the nucleus could be harnessed for targetted radioimmunotherapies against cancer cells within the human body—and especially against occult cancers, micrometastases, and minimal residual disease remaining after completion of surgery, chemotherapy, and other treatments (Figure 6).

Even in the early years, researchers in the field considered that short-lived alpha-emitting radioisotopes should, theoretically, be the premier magic bullet to link to specific antibodies targetted to specific antigens, expressed predominantly or solely by target cells such as tumor cells or infectious agents.

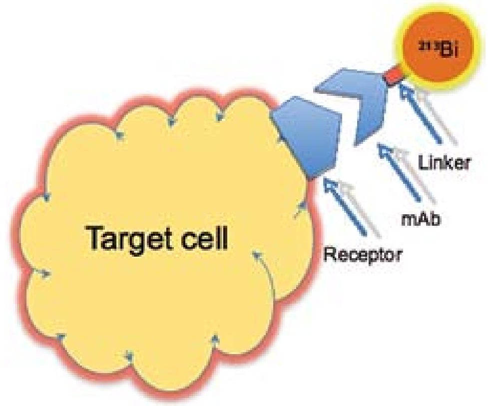


Figure 6(a)
USING RADIOIMMUNOTHERAPY TO TARGET A CELL
Short-lived alpha-emitting radioisotopes like bismuth-213 are linked to specific antibodies (mAb) which are targetted to specific antigens. The linking agent, a chelator, has to attach both to the mAb and the radioisotope. This package is injected into the patient, and the antigen carries the payload to recognized cell receptors, where the radioisotope kills the diseased cells.

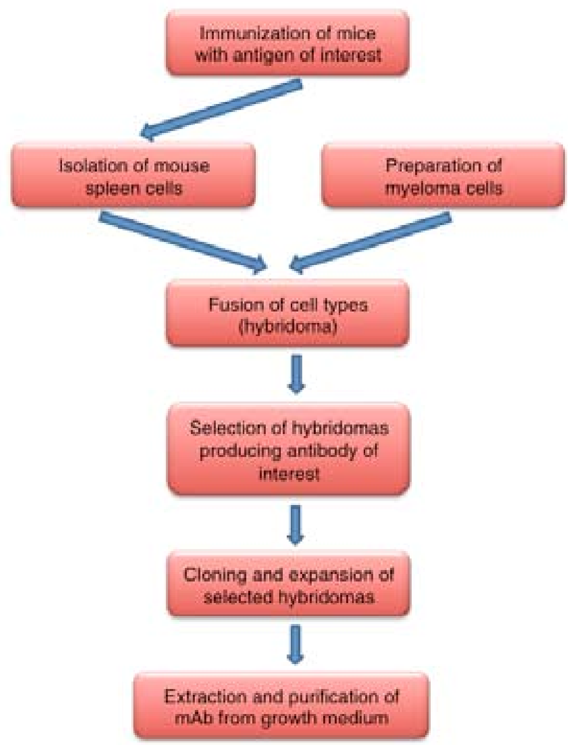


Figure 6(b)
MONOCLONAL ANTIBODY PRODUCTION
Over the past 40 years, researchers have developed a variety of monoclonal antibodies, which now can be used as carriers to target radioisotope receptors specific to particular cells or tissues.

INL

The Idaho National Laboratory's Advanced Test Reactor during its installation. The ATR is a pressurized water test reactor that operates at low pressure and low temperature. New equipment is being installed that will allow the ATR to produce medical isotopes.

U.S. Reactors That Could Produce Radioisotopes

DOE

Looking into the Annular Core Research Reactor (ACRR), a water-moderated pool-type research reactor capable of pulse and steady-state operations, which is currently used for defense purposes. The reactor was modified in the 1990s to allow for the production of Mo-99, but the DOE dropped the project. To use the reactor for Mo-99 production would require the DOE to reassign its mission from Defense Program uses to medical isotope production, at an estimated cost of $10 to $50 million.

DOE

The 400-megawatt Fast Flux Test Facility (FFTF) began full-power operation in 1982, under the management of Westinghouse Hanford. For 10 years it operated flawlessly. It tested materials and fuel components for fast breeder and fusion reactors under actual operating conditions, it transmuted high-level nuclear waste, it tested space nuclear fuel systems, and it produced 60 special isotopes for life-saving medical use and for industry. The DOE shut it down in 1993, stating that there was no "long-term mission" to justify its operating costs (about $100 million per year).

Successful development of such a weapon required, however, the development and maturation of several prerequisite medical technologies, which have been largely perfected in the intervening years. The most important technologies enabling the advancement of targetted radioimmunotherapy were of course those making possible a library of monoclonal antibodies (mAb) and mAb protein fragments in the commercial quantities and purity necessary to be utilized as vectors to target receptors specific to certain cells or tissues in an organism. These technologies, after 40 years, are now beginning to mature.[15]

Once the vector technologies were in place, the problem became one of weaponizing the mAbs to make them more potent killers of the target cells. Initially it was thought that mAbs alone could cause the destruction of cancer cells by binding to spe-

Memorial Sloan Kettering Cancer Center

David A. Scheinberg (left), a pioneer in research with monoclonal antibodies in the 1980s and in using alpha-emitting radioisotopes to target cancer cells. With him (from left) are Andrew Zelenetz and Joseph Jurcic.

cific surface receptors expressed on the cells to signal the body's own immune system to attack and destroy the target cells. The results of that approach often proved disappointing for various reasons, one of which was that the monoclonal antibody—produced from a hybridoma of a mouse antibody-secreting cell and an immortalized myeloma cell—was itself soon targetted for destruction by the body's immune system.

Researchers soon began to develop methods of attaching "payloads" to the mAb vectors using linking molecules. These linking agents had to be bifunctional, with one moiety able to attach to the mAb, and the other capable of binding the payload. The linking agents had to be as diverse as the payloads, which included drugs, toxins, fluorescent molecules, and radioactive isotopes. The molecules developed to attach such payloads to the mAb vectors were chelators modified by linkers of various sorts to be bifunctional.

Chelators (from the Greek word for claw) are molecules able to chemically bind one or several small molecules or atoms such as metal ions. The most well-known chelator to the layman is EDTA (ethylenediaminetetraacetic acid), used to bind metal cations such as Ca^{2+} and Fe^{3+}. EDTA has been around since the 1930s, and is ubiquitous in our society. Since its characterization, however, many other chelators with useful binding qualities have been discovered. Two of the most common of these used to bind radionuclide payloads to mAbs are known as DOTA (1,4,7,10-tetraazacyclododecane-1,4,7,10-tetraacetic acid), and DTPA (diethylenetriaminepenta-acetic acid).

Once the payload could be bound tightly to the mAb by chelation or other techniques, the formulation could be injected into the patient's blood stream or into a localized compartment of the body, where the antibody could freely bind to recognized cell receptors, carrying the payload to its destination.

An Early Proof of Principle Study

In 1982, David A. Scheinberg, Mette Strand, and Otto A. Gansow,[16] used a bifunctional metal chelator, 1-(p-carboxymethoxybenzyl) EDTA, conjugated to the monoclonal antibody (mAb) 103A, targetting the Rauscher leukemia virus (RLV) envelope glycoprotein (gp70), which is copiously expressed in mouse leukemic spleen cells 12 days after infection by the virus. Being bifunctional, the unconjugated side of the chelator is designed to carry a radioisotope payload piggyback on the antibody straight to the diseased cell, where the antibody will attach strongly to the antigen.

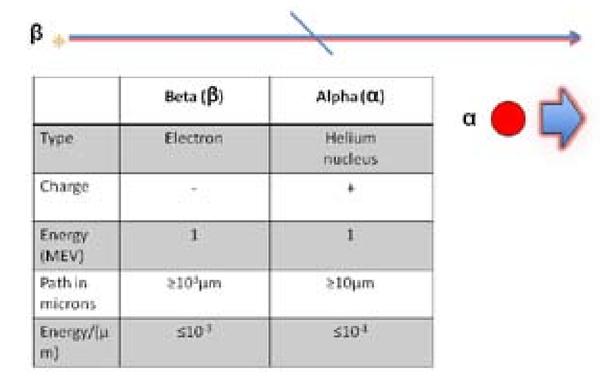
In the Scheinberg et al. research, the isotope targetting the cell was the radiometal indium-111 (In-111), a gamma-emitting radionuclide with a half-life of 67.9 hours. The purpose of the targetting was to explore the specificity and quality of imaging of the leukemic cells in the mouse spleen, using an external gamma camera to record the gamma photons released from the targetted celles as the isotope decayed by electron

BEXXAR® and Zevalin®: Prolonging Life

At present, there are only two targetted radioimmunotherapy drugs approved for treating human disease, and neither of them is an alpha emitter. The two drugs are Zevalin® and BEXXAR®, which were approved by the FDA in 2002 and 2003 respectively. Both are approved for the same limited indications of the same disease: CD20-positive (that is, bearing the CD20 targetting antigen) follicular non-Hodgkin's lymphoma which is refractory to chemotherapy. Zevalin® consists of a monoclonal antibody linked to the radioactive beta-emitting isotope yttrium-90 and targetting the antigen CD20 expressed on both malignant and normal B cells. BEXXAR® binds iodine-131, a beta- and gamma-emitter, to a mouse-derived antibody targetting the same antigen.

These drugs have shown promise in treating non-Hodgkin's lymphoma and prolonging life, often with less toxicity than traditional chemotherapeutic modalities. The main drawback to the drugs is the dose-limiting bone marrow suppression, which results from the target antigen CD20 being expressed on both diseased and non-diseased B cells. Since the beta particles emitted from the antigen/antibody complex are both energetically weak, and have a long path length in comparison to alpha particles, it takes a large number of them to ensure a kill. The bone marrow suppression factor thus limits the effectiveness of the drugs.

Furthermore, the I-131 also emits a gamma ray, which makes the patient a radioactive source, although it does allow easy imaging of the I-131 uptake by the patient. Lastly, any I-131 that is freed from its complex targets the thyroid, making it imperative to saturate the thyroid before, during, and for some time after the procedure, to limit thyroid damage.



	Beta (β)	Alpha (α)
Type	Electron	Helium nucleus
Charge	-	+
Energy (MEV)	1	1
Path in microns	$\geq 10^3$µm	≥ 10µm
Energy/(µm)	$\leq 10^{-3}$	$\leq 10^{-1}$

Figure 7
COMPARISON OF ALPHA AND BETA EMISSIONS IN SOFT TISSUE
Beta emitters can penetrate into solid tumors, and have a cross-fire effect, but have weaker energies than alpha emitters and longer path lenghts. This means that more disintegrations are required to kill a targetted cell. Alpha-emitters, by contrast, can often kill the target cell with one or just a few hits, and the short path-length of the alpha particle spares surrounding tissues from destruction.

capture to stable cadmium-111. (In-111 is produced from another stable cadmium isotope, Cd-112, by proton bombardment in a cyclotron.)

Their procedure functioned splendidly, producing easily visualized images of the infected spleen area when the 103A mAb was used. Infected spleen cells bound 60 times more radioactivity than non-infected cells. Control infected mice given non-relevant mAbs showed no cell-binding capabilities.

In the discussion section of the 1982 article, the authors speculated that in the future it should be possible to use similar techniques to deliver cytotoxic (lethal) doses of radionuclides to leukemic cells—and that particularly useful might be certain alpha-emitting radionuclides.

This paper not only illustrated an extremely useful technique of using short-lived gamma emitters bound to mAbs to locate and image cancer cells within the body, but also pointed the way forward for techniques to target and kill cancer cells with appropriate particle-emitting radioisotopes. Furthermore, it illustrated the usefulness of mAbs targetting unique receptors (caused by the infection of the transforming virus) expressed on the cancer cells. Variations on these themes have been ubiquitous in subsequent medical literature dealing with cancer treatment.

Targetting Cancer with Radioisotopes

It was not long before researchers in nuclear medicine (including those who authored the paper referenced above) turned their attention to finding and exploiting radioisotopes capable of delivering a therapeutic dose of ionizing radiation specifically to target cells.[17]

Using radionuclides for targetted therapy requires a different sort of radionuclide from those gamma emitters used for targetted imaging. With imaging, the point is to have the emitted high-energy photons travel right through the body to the imaging device. But to treat cancer using targetted radioimmunotherapy, the radionuclide must have a short half-life and a short path length capable of delivering a powerful dose to cells at short range, but sparing nearby non-targetted cells (Figure 7).

Some of the radioisotopes used for early imaging studies, such as lutetium-177, and I-131 were also capable of giving a therapeutic dose of ionizing radiation through electrons emitted during decay. These and other beta emitters, including yttrium-90 (Y-90) were some of the first radionuclides successfully exploited for targetted radioimmunotherapy purposes. Even today, the two beta emitters I-131 and Y-90 are the only radionuclides approved by the FDA (Federal Drug Administration) for use in targetted radioimmunotherapy in the United States (See box, p. 41).

Although beta emitters have some great qualities for targetted therapy, including a cross-fire effect, and the ability to penetrate into solid tumors, their weaker energies and the longer path lengths over which their energies are expended mean that sometimes hundreds or more disintegrations are required to kill one targetted cell, thus requiring more of the radioactive isotope at the target area. Alpha-emitting isotopes, by contrast, can often kill the target cell with one or just a few hits. And the short path-length of the alpha particle spares surrounding tissues from destruction.

These qualities make short-half-life alpha-emitting radioisotopes ideal for going after single cells, micrometastases, and the residual disease remaining after other cancer therapies have been applied.

Problems and Promise of Alpha Isotopes

Alpha radioimmunotherapy has been long envisioned but slow to arrive in clinical usage, to a great degree because many of the most useful radionuclides are so rare and of such short half lives.

However, since the early 1980s, long before the daughter products of U-233 became available through ORNL in the 1990s, a very few short-lived alpha-emitting radioisotopes were already being shown to have therapeutic properties in treating certain cancers in animals. The early researchers working with these isotopes had to pave the way, overcoming numerous hurdles in evaluating the usefulness and safety of these isotopes for medical use. Not only were monoclonal antibody and radioisotope-linker technologies in their infancies, but the dosimetry and fates of the daughter isotopes within animals had not been worked out for the relevant isotopes. Furthermore, the isotopes were in extremely short supply because they were products of military research carried out during the Manhattan Project.

The alpha emitter astatine-211, for example, was first produced at the cyclotron at the University of California at Berkeley in 1940, and only in the 1950s was there the leisure to begin to study its bio-characteristics. As late as 2001, Zalutzky et al. commented regarding still-unsolved problems impeding the medical use of At-211:

Although there is a compelling rationale for initiating human trials with some of these ^{211}At-labeled compounds, patient studies have been impeded by the lack of methodologies for producing clinically relevant levels of ^{211}At labeled radiopharmaceuticals. There are 2 aspects to this problem. First, cyclotron targetry and ^{211}At purification systems are needed to provide large quantities ... in chemical form appropriate for chemical manipulation. Second, labeling and purification procedures are required that are appropriate for high-level syntheses under conditions where radiolytic decomposition may play a role.[18]

These problems are not unique to At-211, but have hampered the development of all the useful alpha-emitting isotopes. Part of the reason that the beta emitters BEXXAR® and Zevalin® are the only two FDA-approved targetted radioimmunotherapy drugs for cancer treatment is that the isotopes I-131 and Y-90 are relatively cheap and plentiful, not because they are necessarily the best isotopes for the job. In order for such treatments to be approved by the FDA for use in human medicine, the safety and effectiveness of the treatments must be proved to a high degree. Such proofs require *in vitro* studies, and large-scale animal studies followed by phase 1, 2, and 3 clinical trials in humans to prove the safety and effectiveness of the therapies. Such lengthy and expensive studies require a large and steady supply of the isotopes in usable form at a reasonable cost.

No private company can be relied upon to provide for such needs because there is no short-term profit in the early days of research and development, and no guarantees of any profit in the medium or long term. Providing adequate medically useful isotopes for research and clinical development is the proper task of governmental institutions funded by governments.[19]

In fact, many of the current research and clinical projects involving alpha-targetted radioimmunotherapy are collaborations between research groups and major government-subsidized alpha-isotope producers. such as the Institute for Transuranium Elements (ITU) in Karlsruhe, Germany, and Oak Ridge National Laboratory in the United States. These are two of the few institutions able to extract from "aged" uranium-233 the minuscule amounts of thorium-229 (Th-229) from which actinium-225 (Ac-225) can be "milked" at intervals for use directly, or as a bismuth-213 (Bi-213) generator. The Karlsruhe ITU got its original stash of aged U-233 from ORNL long ago, and since then has benefitted from producing the Ac-225/Bi-213 generator for medical research efforts throughout the world.

The ITU decided to devote a significant portion of its work to the development of alpha-emitting isotopes for medicine. Specifically, it decided to concentrate on the daughters of U-233 generated from Th-229: Ac-225 and Bi-213. Over the years its researchers have methodically developed the basic science and technologies necessary to provide a reliable, well-characterized delivery system for these alpha-emitting isotopes. They have also collaborated with medical researchers in many countries, providing both the means and know-how to utilize isotopes to study the effects of alpha targetted radioimmunotherapy on cancers and infectious disease.

Some of their collaborations using Bi-213 are listed in Table 2. These studies have allowed researchers to test the effectiveness of this on solid tumors such as malignant melanoma and brain tumors, and also on blood cancers such as leukemia, which form no tumors. The isotopes have even been tested on HIV and the fungal pathogen *Cryptococcus neoformans* in mouse models. Some of these early studies with animals and human volunteers have been very promising, especially those targetting single cells or small clumps of cells. The results with larger solid tumors have been more disappointing, as would be predicted given the short half-lives and short path-length of the alpha-emitters used.

Radioisotopic 'Nano-generator' with a Powerful Punch

One collaborator with both ITU and ORNL, is the laboratory of David A. Scheinberg, the early pioneer who targetted cancer cells with radioisotopes (see above). He has devoted a good portion of his professional career to trying to develop alpha-targetted radioimmunotherapy for cancer treatments at Memorial Sloan Kettering Cancer Center, using Bi-213 alone, and using the parent Ac-225 (half-life 10 days) as a nano-generator able to produce four targetted alpha emissions as it decays to stable Bi-209 (see Table 3).

The rationale for using Ac-225 as an alternative to Bi-213 is to capitalize on the potential of delivering over a period of days rather than minutes, four alpha blows to a cancer cell for each atom of Ac-225 delivered to the target—more bang for the buck. Scheinberg's experience with this isotopic nano-generator amply illustrates the potential and problems with alpha targetted radioimmunotherapy.[20]

With a 10-day half-life and four alpha emissions, Ac-225 potentially packs a punch 1,000 times greater than Bi-213 alone, allowing a much lower total radiation dose to the non-targetted tissues and the potential to penetrate solid tumors more effectively. The problems involve the complexity of dealing with the daughter products of Ac-225, which are all different elements with different binding properties to linkers, and different tissue affinities and excretion rates. The fates of these daughters when not bound in the cells, and their effects on non-targetted tissues such as kidney, thyroid, and bone marrow, must be fully ac-

Table 2
SELECTED COLLABORATIONS BETWEEN ITU AND MEDICAL RESEARCHERS

Country	Location	Disease
Australia	Sydney	Malignant melanoma
Belgium	Gent	Chronic leukemia
France	Nantes	Multiple myeloma
Germany	Heidelberg	Lymphoma
	Düsseldorf	Lymphoma
	Munich	Gastric cancer
	Ulm	Acute leukemia
Switzerland	Basel	Brain tumors
United States	New York MSKCC	Acute leukemia
	New York AECM	Infectious diseases

Table 3
Ac-225 AND ITS DAUGHTERS

Tl-207	Pb-208	Bi-209	Po-210	At-211	Rn-212	Fr-213	Ra-214	Ac-215
Tl-208	Pb-209	Bi-210	Po-211	At-212	Rn-213	Fr-214	Ra-215	Ac-216
Tl-209	Pb-210	Bi-211	Po-212	At-213	Rn-214	Fr-215	Ra-216	Ac-217
Tl-210	Pb-211	Bi-212	Po-213	At-214	Rn-215	Fr-216	Ra-217	Ac-218
Tl-211	Pb-212	Bi-213	Po-214	At-215	Rn-216	Fr-217	Ra-218	Ac-219
Tl-212	Pb-213	Bi-214	Po-215	At-216	Rn-217	Fr-218	Ra-219	Ac-220
Tl-213	Pb-214	Bi-215	Po-216	At-217	Rn-218	Fr-219	Ra-220	Ac-221
Tl-214	Pb-215	Bi-216	Po-217	At-218	Rn-219	Fr-220	Ra-221	Ac-222
Tl-215	Pb-216	Bi-217	Po-218	At-219	Rn-220	Fr-221	Ra-222	Ac-223
Tl-216	Pb-217	Bi-218	Po-219	At-220	Rn-221	Fr-222	Ra-223	Ac-224
Tl-217	Pb-218	Bi-219	Po-220	At-221	Rn-222	Fr-223	Ra-224	Ac-225

A

Z

The parent Ac-225, with a half-life of 10 days, can deliver four alpha blows to a cancer cell for each atom of Ac-225 delivered to the target, as it decays to the stable element bismuth-209.

counted for, even though all the daughters except the stable and relatively benign Bi-209 have short half-lives. The longest-lived of the daughters, Bi-213, becomes the problem child in this system.[21]

For targetting cancer cells with Ac-225 using the Scheinberg, et al. protocol (where the Ac-225 is internalized into the cancer cell after binding), the limiting factor in achieving the maximum therapeutic dose is the accumulation of Bi-213 in the kidneys. Too high a dose can lead to eventual kidney failure. Because the cancer-killing benefits are dose dependent, techniques to lower kidney damage at higher doses must be developed, including using metal chelators in the blood (DMSA, DMSP), or adding molecules which compete with bismuth for kidney binding sites, or using diuretics and forced hydration to increase the patient's excretion rates.

All of these problems are solvable, but to solve the problems and realize the benefits, requires scientific manpower focussed on the research. And that takes plenty of available isotopes, and plenty of funding, without which, these technologies will never make it into clinical usage.

Where Do We Go from Here?

The problem with cancer is that, after all the standard treatments, in almost every case, some cells or colonies are left behind. Not only did the patient's immune system not deal successfully with the original disease, but, after the ravages of chemotherapy and many non-targetted radiation treatments, the patient's body is often left totally unable to mount an immune attack on the remaining cells. From wherever they were sequestered, these cancer cells start to grow and spread. And often these surviving cells are more resistant to repeats of the same treatments. The patient's options narrow and the outlook darkens. In the conventional cancer therapy, more toxic treatments are then tried to knock down the new growth.

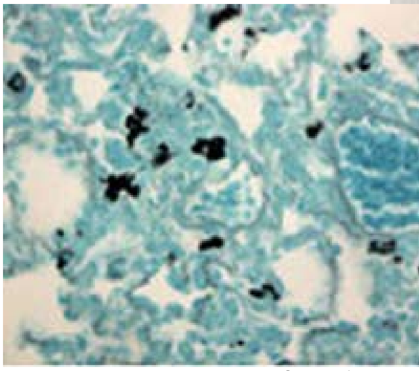
If this sounds somewhat like a scenario one might find with highly drug resistant tuberculosis or with HIV/AIDS, that is not coincidence. In many respects, cancer acts like an infectious disease once it has successfully gained entrance to the body. Monoclonal antibody treatments, and the weaponized versions of mAb treatments follow this model, targetting somewhat unique receptors on the cancer cell. The best treatment would be one which successfully flags only cancer cells for destruction by recruiting the body's existing immune system—the original dream of mAb development.

Lacking such recruitment, radioisotopes and other toxins or drugs attached to the mAbs can be used for the destruction. In this scheme, radioimmunotherapy, and especially alpha RIT would be the mop-up crew in the armamentarium of the war on cancer, spreading out locally to heave grenades into remaining enemy enclaves after the carpet bombers have finished. It is for just this purpose that highly targetted immunotherapies are at the leading edge of cancer research.

But, why stop there? Why not use radioimmunotherapy to target diseases like HIV/AIDS? At least one medical research lab is doing just that. Dr. Ekaterina Dadachova and her team at the Albert Einstein School of Medicine have, in collaboration with ITU and others, been testing RIT against the bacterium *Pneumococcus,* HIV/AIDS, and a fungal pathogen, *Cryptococcus neoformans,* in a mouse model. Her lab has also been focussing on the potential for RIT to target the many cancers that are actually the result of infectious disease, such as hepatitis-induced liver cancer and human papilloma-virus-induced cervical cancer. Worldwide, those cancers account for a significant portion of cancer morbidity and mortality.

Using the beta emitter rhenium-188 and the alpha emitter Bi-213, Dadachova's lab has gotten promising results using mAbs targetting the foreign proteins expressed on cells infected with HIV—the very approach used by David Scheinberg way back in 1982 when he targetted the Rauscher leukemia virus receptors in infected mouse spleen cells with mAb-linked In-111, to visualize the infected spleen. The spiral has come full circle at a higher level. But these are still very preliminary studies—promises, but nothing delivered.[22,23]

To actually get some of these therapies into clinical use, especially in the United States, would require a mandate by Congress, backed by adequate funds, to put medical isotopes on the front burner. The United States has to get back into the isotope business. We have seen the harm to the nation from choosing not to have a domestic source of Tc-99m. When foreign sources shut down, patients in the United States are harmed. But a much greater harm is sustained by the millions of cancer patients treated with old-school methods because we are too cheap, shortsighted, and in some cases deliberately Malthusian, to build the infrastructure to foster new technologies that might prolong the lives of our citizens or cure them outright.



Albert Einstein School of Medicine

Cyryptococcus neoformans in mouse lung.

For too long, Congress has hidden behind a "free-market" ideological façade, proclaiming that government should not compete with private industry. President Obama even wants to leave space exploration to private industry! We never would have reached the Moon with private funding. And without generous public investment, we will never realize the massive potential benefit waiting to be harvested from the many dozens of short-lived isotopes with useful medical properties. Meanwhile, those with potentially treatable diseases will go on dying.

Albert Einstein School of Medicine

Ekaterina Dadachova (center) and her laboratory at Albert Einstein School of Medicine are using radioisotope immunotherapy to target HIV/AIDS, the bacterium Pneumococcus*, and the fungal pathogen Cryptococcus neoformans (inset). Dadachova's lab members are (from left) Ekaterina Revskaya, Ruth Bryan, Zewei Jiang, Robertha Howell, and Andrew Schweitzer.*

Footnotes

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INTERVIEW: DR. GUY TURQUET DE BEAUREGARD

We Need to Expand Medical Isotope Production!

Dr. Turquet de Beauregard, a nuclear physicist with 15 years experience in nuclear medicine, is the vice president of AIPES, the Association of Imaging Producers & Equipment Suppliers, based in Brussels. AIPES serves the different regulators as a coordinating body for all disciplines in nuclear medicine, from radiopharmaceutical companies to camera suppliers. It also conducts public education, providing an overview of the current crisis of medical isotope shortages.

Dr. Turquet de Beauregard spoke with 21st Century *correspondent Vyron Lymberopoulos on Feb. 1, about the shortages that have delayed medical diagnoses and treatments for hundreds of thousands of patients worldwide.*

*   *   *

Question: There are a limited number of reactors and processing facilities worldwide. Why is that? Why are we so far behind in the use of medical isotopes?

Nuclear medicine emerged as a result of many programs of the Manhattan Project during the Second World War. Many reactors were built by government agencies at great expense. At that time there was little concern for industrial or medical applications; most were built for power generation.

Nuclear medicine began as a small partner of these power reactors, taking just a small percentage of the time of the reactor. Not one single reactor was designed dedicated to nuclear medicine. The industry piggybacked along nuclear power, which made things easy.

There are basically three methods to produce a medical isotope:

(1) *Cyclotrons.* These are a kind of particle accelerator, and you need many of them.

(2) *Irradiation for activation* in a power reactor, which can be done in many reactors.

(3) *The fission process.* This is most important method today, extremely productive. Fission of uranium creates the byproducts of molybdenum-99 and other isotopes. It is a very

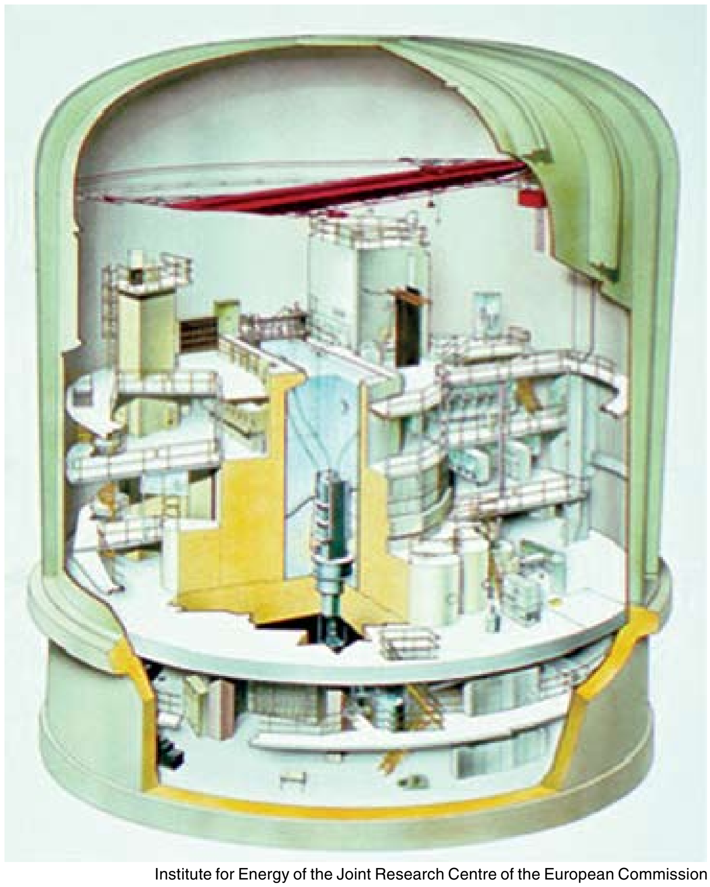
Medical Isotope Sources and Use

At present, six reactors provide more than 95 percent of the molybdenum-99/technetium-99m supply worldwide. These are: NRU (Canada), HFR (the Netherlands), BR2 (Belgium), OSIRIS (France), SAFARI (South Africa), and OPAL (Australia). The remaining 5 percent is produced by CNEA (Argentina), BATAN (Indonesia), and KARPOV Institute (Russia).

Eighty percent of all nuclear medicine procedures worldwide are used for diagnosing disease. This includes:

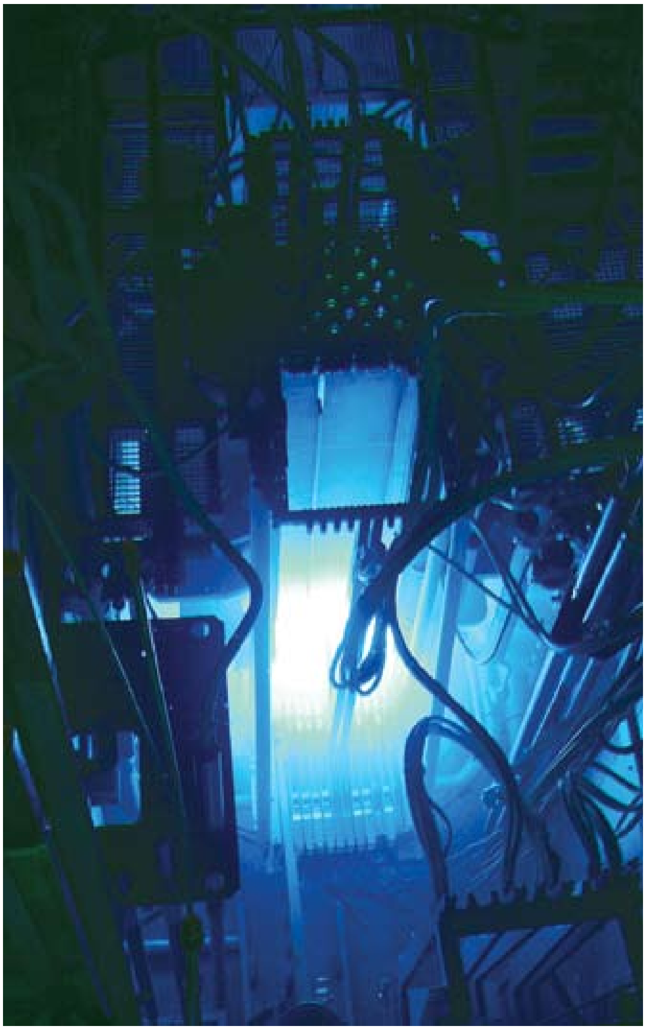
Heart pathology	12 million procedures
Bone pathology	10 million
Lung pathology	5 million
Thyroid pathology	5 million

Source: AIPES



Institute for Energy of the Joint Research Centre of the European Commission

The High Flux Reactor at Petten, now shut down for maintenance, supplies 70 percent of Europe's molybdenum-99. The HFR is a 45-megawatt tank-in-pool-type reactor which is cooled and moderated by light water. It has 20 in-core and 12 poolside irradiation positions, in addition to 12 horizontal beam tubes.



Institute for Energy of the Joint Research Centre of the European Commission

Looking down the core of the Petten reactor. The High Flux Reactor also conducts research on fission fuel and materials. The HFR has used low-enriched uranium fuel since 2006.

complex process. Few reactors in the world have the license to do it, and most of them were built in the 1960s. They are now near the end of their lifetime, and there are safety issues, and security issues of proliferation involved.

Only recently have reactors been built that are dedicated to the production of medical isotopes. Canada was very active in the medical isotope production, and 15 years ago they planned to address the medical isotope shortage by building two reactors dedicated to nuclear medicine. Both these Maple reactors failed, because of design problems. There are many lessons to be learned from this.

Question: What is the difference between Europe and the United States in medical isotope production?

Everything for North America is based in Canada. The equivalent of AIPES in the United States is called CORAR, the Council on Radionuclides and Radiopharmaceuticals.

Question: When the High Flux Reactor (HFR) in Petten, the Netherlands, is closed for maintenance, what impact will this have on worldwide supply?

In Europe, we will lose 70 percent of molybdenum-99 production; worldwide we will lose 30 percent. So not having the HFR will cause major problems. Nuclear medicine doctors will be obliged to switch to other isotopes, like thallium for SPECT (single photon emission computer tomography scans), which is produced by cyclotrons.

Doctors will have to make good use of the isotopes that are delivered to hospitals. They will have to be extremely conservative in their use of technetium-99m solutions, and be much more efficient than before.

There will be an even bigger problem when both the HFR and the Canadian Chalk River facility are closed at the same time. In order to assure a minimum availability of medical isotopes, AIPES tries to organize coordination between the reactors in the Netherlands, Belgium, France, and South Africa. Some urgent procedures can use alternative isotopes, but many procedures will have to be delayed by a couple of weeks.

As for alternatives, the problem is that imaging with nuclear medicine in some specific cases is far superior to the results of MRI and X-ray imaging.

Question: What are the bottlenecks in regulating medical isotopes?

Nuclear medicine is a very regulated world both on the national and international level. Regulation in the nuclear world is separated into the manufacturing of isotopes, which is highly regulated, and transport, which is also highly regulated. There are also security regulations as a result of the threat of terrorism after 9/11.

Question: What must we do to expand the production of medical isotopes?

We need, as a capacity, two and a half times the current consumption in Europe to secure steady molybdenum-99 availability because of nuclear cycles and reactor maintenance. Now we are far below that. We must organize the world to do this, and there are ways to do it. This is a top priority, to expand production of medical isotopes.

Several solutions exist. First, present-day research reactors could be used for medical isotope production using fission. In addition, in the future, we could use the reactors that are now under construction. We can turn the crisis into an opportunity.

Second, we can expand the use of cyclotrons to produce isotopes, that is, positron emitters like fluorine-18 and gamma emitters like thallium-201. The production of isotopes with cyclotrons for PET (positron emission tomography) applications is a way to expand production. The drawback is that cyclotron isotope production is very expensive compared to fission in a reactor, but clearly it is a solution for the future.

Also, for the emerging nations, this technology is easier to transfer. The cyclotron isotopes have a short half-life measured in hours. So they have to be produced close to where the camera and the patient are located.

Now, note that the progress in nuclear medicine is as fast as the microprocessor industry. Thanks to camera efficiency and

ATOMKI

The MGC-20E cyclotron of of Hungary's ATOMKI. Particle accelerators like this one are used to produce the radioisotopes for PET and SPECT imaging.

the increased speed in calculations, where we once needed two hours to treat one patient, we now need only 10 minutes for one patient, thanks to the new cameras using the same isotopes!

Question: Can molybdenum-99 be produced without using uranium-235?

The answer is yes, you can activate molybdenum-98 by the irradiation method, but the efficiency is extremely poor, compared to the fission method.

Molybdenum-98 is a stable isotope found in nature. When you irradiate it in a reactor, it gains a neutron and becomes molybdenum-99. The problem is, the costs of this process are high, and it is not yet approved by the regulating agencies.

Question: Recently, a small research reactor at Delft University in the Netherlands has offered to take over part of the production of molybdenum when the HFR shuts down for maintenance.... Can a research reactor, which is used to train nuclear engineers, be used to produce molybdenum-99?

Let me talk about how the reactor must be designed for this process. To use it for isotope production, you place a target near the reactor core and "cook" it for a week. Then the target is sent to a processing facility to extract the molybdenum-99.

There are different regulatory issues that come up, when you add fission into the core or near the core. You must show that there is no critical safety issue hiding with this fission product near the core. From a nuclear physics safety point of view, you must produce a safety dossier for the authorities, and you must show that you can extract the target and store it safely in containers. If the design of the reactor is already set up for this, that is good. But if it isn't—take for example in Munich: It took three years to build the required mechanism to transfer targets from the core to the containers to be shipped to the processing facilities. You need a safety dossier to check all the different steps.

I'm just mentioning what is needed in general, because I don't know this particular Delft reactor.

Question: How long would it take to license a reactor to start producing medical isotopes?

I don't know, because I'm not the authority. But as industry spokesmen, we welcome any good initiative that is appropriate for safe production.

Question: What are the bottlenecks in transporting medical isotopes?

First you need a license for transportation. It's a just-in-time product, and has to move quickly. For road transport of nuclear products there are certain regulations but no major bottlenecks. Air transportation is different because of security issues. People don't want to keep things in a plane, which they think (erroneously) could be used as a bomb. People working with radioactive parcels need a security clearance. The process needs to be carefully monitored from manufacturing, processing, and shipping, until delivery at the medical facility for use. A major bottleneck is the security clearance of the operatives handling the isotopes at any stage of the process. A second bottleneck is the denial of shipment by captains or drivers who do not wish

LeRoy N. Sanchez/LANL

A technician using hot-cell remote manipulators in the Isotope Production Facility at the Los Alamos Neutron Science Center.

to carry radioactive material.

Most of the time this is a communication issue, and we have to work on this. People easily mistake medical isotopes for "nuclear waste," which has an extremely long half-life. The medical isotopes shipped all have short half-lives. They are injected in patients for medical procedures, for diagnosis of disease and to cure people or save or prolong life.

Question: Would nuclear medicine benefit from the lifting of a transport ban on medical isotopes by certain transport companies?

Definitely yes, especially if companies located close to an isotope-producing facility would resume the transport of medical isotopes; that would be very good news. If they could look at the problem and see it is not as dangerous as they thought, that would be a very positive thing to show to the world. It could be dangerous, but it is so regulated, monitored, and controlled, that people should be much more confident with these products. There have been extremely few incidents. We have to report any problem, even the smallest problem, and there are very few.

So, communication could be improved to inform the people involved what they are transporting—and what it is not! Also by pointing out the beneficial side of nuclear medicine to the general health of the population around the world.

Question: What is the situation in the emerging nations?

Outside Europe there is good information from a limited number of countries, primarily North America and Japan. I have no information on China or India; the government there is working with local manufacturers—it's purely a local market. Russia has many reactors and very good knowledge of nuclear physics. AIPES is focussed on Europe, so probably the IAEA is better equipped to answer this question.

Question: How do you rate the prospect of future isotope production by means of thermonuclear fusion?

Well, I'm surprised by this question; I haven't a single idea

The Moly/Technetium Cow

The most efficient way to create molybdenum-99 is by the fissioning of the fissile isotope of uranium, U-235. When uranium nuclei fission, several fission products are created, and about 6 percent of them are molybdenum-99.

To produce Mo-99 in a reactor, uranium targets are placed on flat plates and inserted into target holders on a rack, which is positioned at the outer lining of the reactor vessel. For one week, the neutrons from the reactor core bombard the targets, splitting the uranium nuclei. This is called "cooking" the target.

The targets are then removed from the core, placed in containers, and transported to the processing facility. There, technicians working remotely in hot cells (see photo, p. 48) chemically separate the molybdenum from the uranium targets. The molybdenum is first produced as a salt, sodium molybdate, which is then diluted in water. Then it is stored in a stainless steel flask (the cow).

Molybdenum-99 has a half-life of 66 hours, and decays to produce technetium-99m, a gamma emitter (140 keV) which has a half-life of only 6 hours. Each batch of molybdenum fills more than 500 cows, and each cow can serve between 100 and 200 patients. Quick transport is required, because the moly cow loses 22 percent of its product every 24 hours.

To milk the moly cow, the technetium-99m is washed from the molybdenum/technetium solution by an aqueous solution. The technetium is then coupled to a specific carrier, a protein, for administering it to a patient.

—*Vyron Lymberopoulos*

MDS Nordion

A shipping box for canisters of Mo-99.


MDS Nordion

A moly "cow," which is milked to supply the short-lived isotope technetium-99m for medical diagnostic procedures.

on that. I'm a nuclear physicist and know very well what nuclear fusion is. I was at the Los Alamos and Lawrence Livermore labs, but I'm not up to date on the latest progress. Maybe my great-great-grand-children will see it? Right now, we don't know how to create continued fusion reaction. The ITER project in France is a worldwide project to build a fusion reactor. The fusion reaction produces high-energy neutrons, which would have to be slowed down. But to be honest, I have no idea of any prospect of isotope production by means of fusion. . . . If you can manage fusion, many questions are answered.

Question: What is the most important isotope produced today to save lives of people?

Clearly it is molybdenum and technetium; next to that is fluorine-18, which is produced in cyclotrons for PET. Worldwide, approximately 40 million molybdenum/technetium procedures are performed each year, and about 2 million procedures with fluoride-18. The number of moly/tech procedures increases between 2 and 5 percent each year. I don't know the numbers, but fluoride-18 procedures are progressing much faster than that.


D. Calma/IAEA

"We are living in a revolution of imaging. . . ."

Fluoride-18 has to be produced close to the hospital because of its short half-life of 110 minutes.

Question: Is it possible to quantify medical isotope treatment of patients in life years?

AIPES is not an expert in this, but other organizations, like the EANM, the European Association of Nuclear Medicine, might have an answer.

If you have a heart problem and you have so-called perfusion imaging diagnostics, you will have five procedures during your lifetime, compared to a drug you take every day. Another well-known application in nuclear medicine, is using the fission product iodine-131 to treat thyroid cancer.

Question: What can you say about the future of nuclear medicine?

The main issue in nuclear medicine—treatment of disease—by far is the radioactivity toxicology, but the active ingredient we use to target the malignant organ is almost like homeopathy, an extremely low concentration of active ingredient. . . .

It is clear that we are living in a revolution of imaging throughout the whole world. Imaging is becoming more and more important in diagnostics and medicine, and nuclear medicine is part of it.

Perhaps you have heard of personalized medicine. It is clear that each patient is different, even if they have the same disease, because of their specific DNA. Nuclear medicine allows you to create drugs that will target very specific molecules, personalizing the treatment with the help of molybdenum, technetium, or fluoride. These new radioisotope drugs are first tested on animals but will be available for human use soon. This is definitely a new world for nuclear medicine. Maybe in some cases you will be able to take a personalized drug after having had only a nuclear medicine imaging procedure. It could happen!

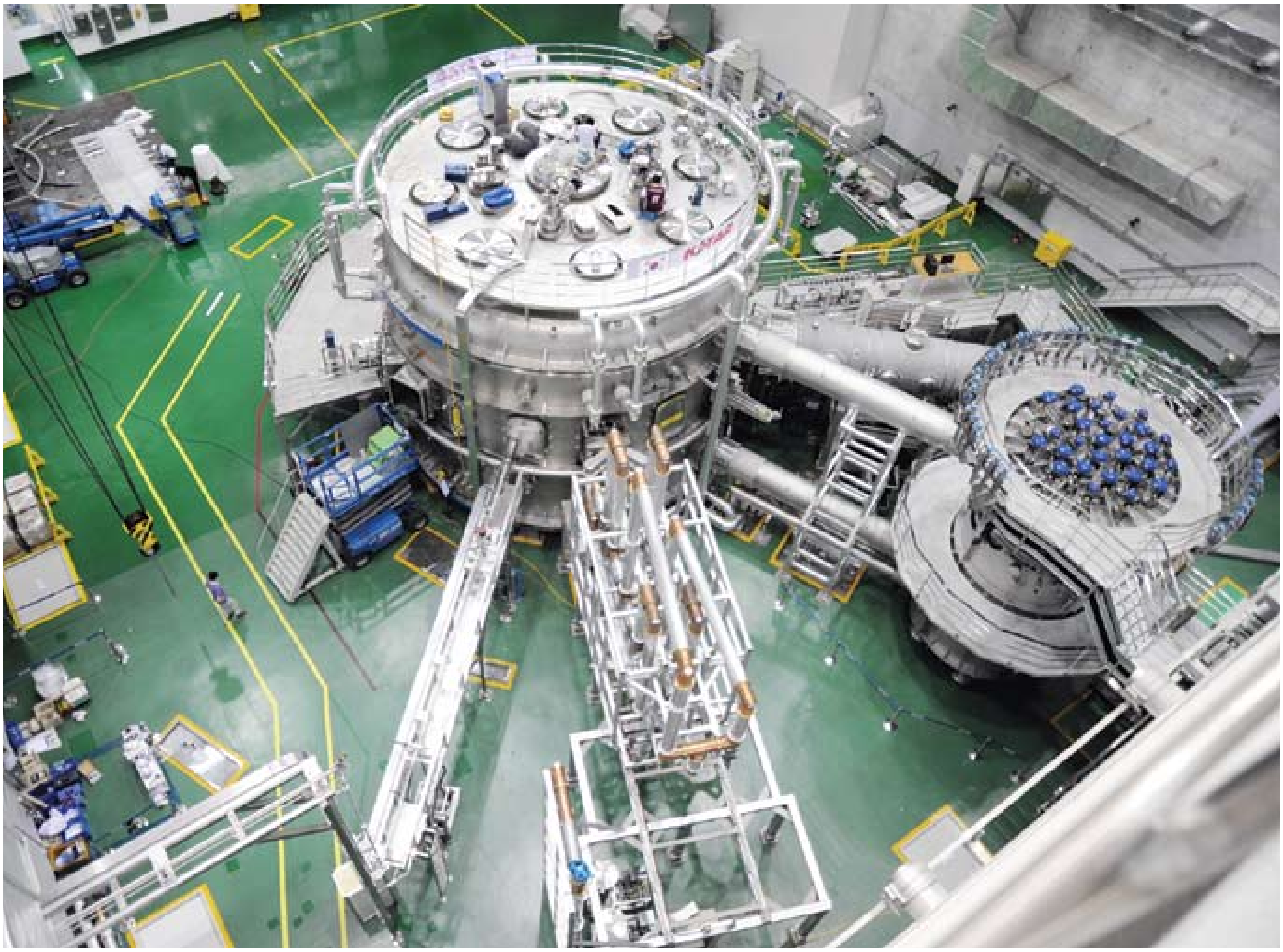
INTERVIEW: DR. GYUNG-SU LEE

Fusion in Korea: Energy For the Next Generation

Dr. Gyung-Su Lee

Dr. Gyung-Su Lee is president of Korea's National Fusion Research Institute (NFRI) and chairman of the International Fusion Research Council of the International Atomic Energy Agency. Here he discusses his bold vision for the future with Associate Editor Marsha Freeman and EIR *Washinton Bureau Chief William Jones, who interviewed Dr. Lee in Daejeon on Oct. 9, 2009.*[1]

In 2007, the Republic of Korea completed construction of a tokamak fusion experimental reactor, the Korea Superconducting Tokamak Advanced Research (KSTAR), the newest in its class. It is one of only two such machines in the world using advanced superconducting magnets to confine the fusion plasma. KSTAR created its first plasma in 2008, and it is now preparing for next Spring's campaign to, step-by-step, move toward the requirements of a future commercial



NFRI

A top-down view of Korea's KSTAR tokamak.

fusion power plant.

Dr. Myeun Kwon, the director of the KSTAR Research Center, explained to Freeman and Jones during their tour of the center, that one purpose of the facility is to train Korean specialists, who will contribute to the larger International Thermonuclear Experimental Reactor (ITER), now under construction in France. KSTAR has allowed Korean industry to manufacture high-technology components, such as those needed for fusion, and Korea will be supplying hardware for ITER, including 20 percent of the superconductor for ITER's toroidal field magnets.

KSTAR will function as a satellite experimental fusion research facility, once ITER is operational. In addition to trainees from the ITER partner nations (United States, Russia, Europe, Japan, China, and India), young professionals from Taiwan and Australia work on KSTAR, and Mexico and Brazil have expressed interest in participating.

In October 2010, NFRI will host the 23rd Fusion Energy Conference, organized by the IAEA.

* * *

NFRI

The KSTAR cryogenics system used to cool down the superconducting magnets.

Question: Today, you are going to be powering up the superconducting magnets of KSTAR. Can you review the history of the project, and its major goals?

Lee: KSTAR started construction at a greenfield site in January 1996. We planned to design, construct, and operate almost an ITER-like machine—smaller, but with most of the same features as ITER. At that time, Korea was not a part of the ITER family, because we didn't have anything to show in fusion.... Fusion is needed due to the energy crisis, and now climate change trouble to come. Whether you believe it or not, it doesn't matter, because climate change is threatening, politically or technically. We started the design of KSTAR in collaboration with many experienced partners, such as the United States, Japan, Europe, and so on.

But then, in late 1997, the famous IMF economic crisis in Asia exploded. We never knew it was going to happen. When we started to build KSTAR, one U.S. dollar was worth 750 won. At the peak of the crisis, at the end of 1997, it was about 2,000 Korean won to the dollar—[a drop in value] almost three-fold in just a few months. So the situation was chaotic. There was a Presidential election, and the government changed from one party to the other....

The government did not have much money, and they almost cancelled the KSTAR project, because many people talked about how many years you need to complete research on fusion, and the government of the Republic of Korea was on the brink of bankruptcy. Fortunately, they decided not to cancel it, but to put it on hold. That meant that the budget was just sustainable; people were paid, but there was not really any progress.

That lasted through 1998, 1999, and 2000. So for three years, we had just the design and the paperwork and things to talk about.... But then the economy rebounded and was booming again, and we started machine construction with the final design in 2001. We completed the hardware in 2007.

The most critical part is that we constructed the machine. But then, whether it will operate as you expect, is a different thing. Not many people trusted or believed that we could do it, because it is so complicated, very high technology, and the risk is very big. We started the commissioning of the machine at the end of 2007, and in 2008 we started checking everything. The main event started in March of 2008.

Creation of a Plasma

We cooled down the superconducting magnets in a vacuum, using liquid helium, which is 10^{-8} millibar, or 10^{-11} atmospheres, because 1,000 millibars is one atmospheric pressure. The vacuum evacuation was successful. The superconducting magnet cooled down from room temperature to 4.5° Kelvin, or –269°C. Even the Large Hadron Collider at CERN in Europe failed last year, with a helium [coolant] leak. When things are cooling down, they get squeezed. And lots of things are squeezing in different directions, although at normal room temperature, it is okay.

Question: When you say the superconducting magnet material gets "squeezed," do you mean it shrinks, or that it twists?

Lee: Both—It shrinks and twists. Because it has to be anchored somewhere, as it shrinks, there is a force, so it twists. Even though we did all the analysis of the design, you cannot be sure this is completely safe, even though inside the vacuum vessel cryostat [which maintains cryogenic temperature], each component is tested. But *in situ* welding is used for assembly, and there are 8,600 points of welding inside. These all have to pass quality assurance. But helium is famous for leaks. It is the worst leaking material.

We did all the welding and tested it at room temperature, but you never know about leaks until you cool down [the magnets]. Because, let's suppose this tube is at room temperature, and it has no leak. You check and there is nothing.

But another tube can have very, very minor leakage, which is undetectable. The machine can operate like that, at room temperature, with no problem, with a small leak. But when you cool down, the small leak becomes big, and helium comes out, and you cannot operate. You have to detect this and correct it.

NFRI

Marsha Freeman and William Jones with Dr. Myeun Kwon (left), director of the KSTAR Research Center. Dr. Kwon described the role of the facility in training Korean specialists who will contribute to ITER.

But in order to do that, you have to warm it up so people can get at it, and then the leak closes, so you cannot detect it! Then you operate it again, and it happens again! This is a famous problem of a superconducting machine. No machine yet has proven that this did not initially happen—Japan, Europe—they all had the same problem. The helium leak in the Large Hadron Collider generated an arc which had to be repaired before operation.

So, a leak was the expectation, because Korea was not experienced. I don't know why, but at some point, around 70°K, the shrinkage of normal material stops. This is physics. If you pass through 70, and go below that, it is easy, because there is no more shrinkage. The temperature of the magnet is going down from 300K all the way to 70K, a little more every day; it is slowly going down.

The first time you run the machine, you are slowly going down. Every time you do this, you watch the gas analyzer, looking for helium inside the cryostat, because, normally, there is no helium in this environment. But, if there is a helium leak, you'll see it. Every night, I call up the laboratory, and ask someone to tell me what the reading is of the helium. And he says, "not visible yet." We check every day; 24 hours a day. Then, when we passed through the 70° level, nothing happened.

Question: So you had no helium leak?

Lee: No helium leak. Zero. And it operated without a leak the first time, after a four-month countdown. That was last year. That's why BBC television and *Science* magazine came and did a story about KSTAR.

The reason why we are so proud of it, is not just because it is the Fusion Research Institute's achievement; rather, this is an achievement of the Institute together with Korean industry, in quality assurance of the hardware and manufacture. So this was a demonstration last year of the machine's construction, and it was commissioned.

Now, we have to produce something, right? With this beautiful facility that we built, we started research on machine performance and plasma confinement, to see if we can really push this research to better and better plasma confinement, to meet the requirement of fusion energy, so fusion becomes commercially demonstrated. So that was the next phase.

This year, we are cooling down the magnets again with no problem. Next, we will put more current in so the magnetic field strength will meet the design requirement. Within this week or next week, we will finish all the design checks. The performance requirements of the magnets and of all the active components will be checked. Then the plasma formation and heating starts. That is the issue for this year's campaign.

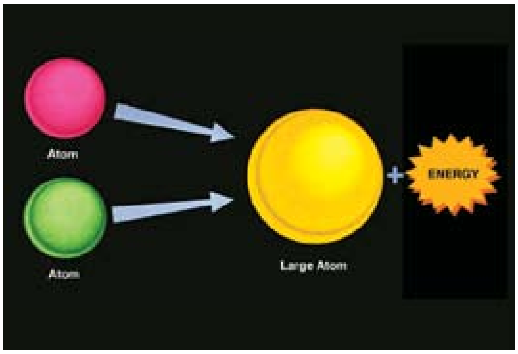


Figure 1
DEUTERIUM-DEUTERIUM FUSION
A fusion reaction takes place when two isotopes of hydrogen, such as deuterium, or deuterium and tritium combine to form a larger atom, releasing energy in the process. The products in the deuterium-deuterium reaction are an atom of helium-3 and a neutron, which carries a tremendous amount of energy. With a deuterium-tritium reaction, the products are helium-4 and a neutron. The helium nucleus carries one-fifth of the total energy released, and the neutron carries the remaining four-fifths.
Source: General Atomics

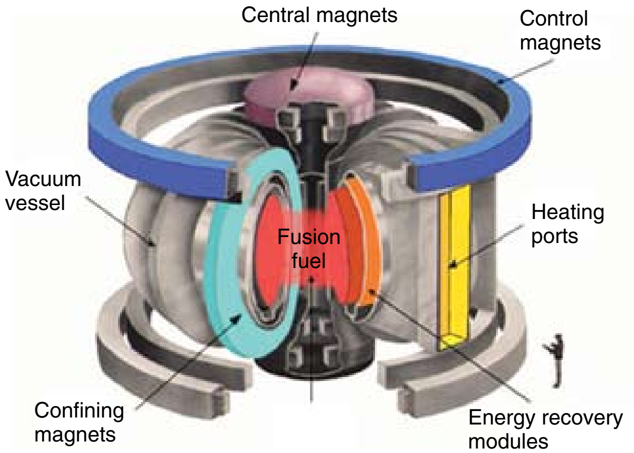


Figure 2
MAGNETIC CONFINEMENT IN A TOKAMAK
The tokamak contains the fusion plasma with a strong magnetic field, created by the combination of toroidal (the long way around the torus) and poloidal (the short way around the torus) fields. The resulting magnetic field forces the fusion particles to take spiral paths around the field lines. This prevents them from hitting the walls of the reactor vessel, which would cool the plasma and inhibit the reaction.

Question: What do you plan for next year?

Lee: Next year, in early Spring, we will put in lots of heating so the plasma gets very hot. We will then supply deuterium fuel. At the present time, we are using hydrogen, because it has no activity, no fusion. It can be fused in the Sun, but rarely, so we are not producing any fusion energy, just a plasma. We are still using the machine for configuration and studying control, so we don't need to have real fusion happening. But early next year, we will supply deuterium, a heavy isotope of hydrogen, and this will fuse. Deuterium-deuterium fusion is easier to handle than fusion with tritium, so we will start with deuterium-deuterium fusion.

This reaction generates neutrons. Nuclear fusion happens, and we measure the neutrons coming out and how much power is produced. So we are trying to put lots of heat into the plasma, and keep it very high for a long time. Because of the superconducting magnet, we can hold the plasma much longer than normal magnets, such are used in the TFTR [Tokamak Fusion Test Reactor] and JET [Joint European Torus]. This one is basically the same as the magnet for ITER—a niobium-tin magnet—so we will carry out experiments on how long we can keep this fusion beam controllable and producing neutrons. This will continue until ITER is on line. This is what we are doing.

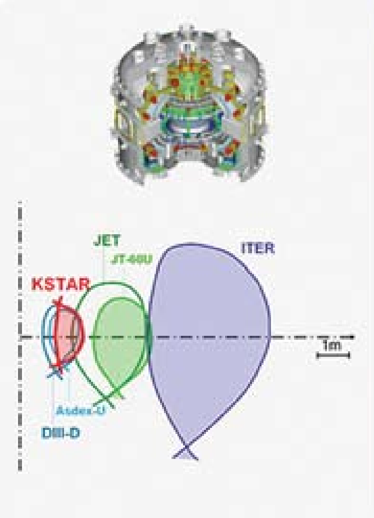
Moving to Commercial Fusion

Question: What were your reasons for building KSTAR?

Lee: When we started KSTAR, the United States, Europe, Japan, and Russia had been doing fusion research for a long time, and had spent a lot of money and used a lot of people, and were trying to build ITER. In 1991, when I came back to Korea from the United States, this whole place was rice paddies. Can you believe that? Rice paddies. Nothing here. So we started. When we started, many people could not believe us. They were skeptical, at first: "This guy is crazy." It is very understandable. We aimed very high, to do what ITER is supposed to do, but on a smaller scale. Then we trained our engineers, and trained with our industry and factory, together.

So, when ITER expanded its family, and accepted us, in 2003-2004, Korea jumped in, with a *real* capacity to help build ITER. ITER is now under construction, and you need 10 years to construct it. During those 10 years, engineers and construction workers have lots of headaches, and lots of work to do. But during these 10 years, scientists who want to do experiments and research, have no machine. Machines that you want to play with, you have already played with for 20 or 30 years. But new machines—there are none.

So, we built KSTAR. First, we proved that we can be a worthwhile partner for ITER. Then, during the 10 years of construction of ITER, we would provide this machine to the ITER family. Young scientists can prepare for 10 years with this machine. So for 10 years you play, work, do research. Then, once ITER operates, these people move to ITER, and ITER is no longer a "new" machine, because they have all this experience. You don't need to repeat using trial and error, so they can do much better, and exploit the machine very easily, in a short time. This is the reason why we built KSTAR.



PARAMETERS	KSTAR	ITER
Major radius, R_0	1.8 m	6.2 m
Minor radius, a	0.5 m	2.0 m
Elongation, κ	2.0	1.7
Triangularity, δ	0.8	0.33
Plasma volume	17.8 m^3	830 m^3
Plasma surface area	56 m^2	680 m^2
Plasma cross section	1.6 m^2	22 m^2
Plasma shape	DN, SN	SN
Plasma current, I_P	> 2.0 MA	15 (17) MA
Toroidal field, B_0	> 3.5 T	5.3 T
Pulse length	> 300 s	400 s
β_N	~ 5.0	1.8 (2.5)
Plasma fuel	H, D-D	H, D-T
Superconductor	Nb_3Sn, NbTi	Nb_3Sn, NbTi
Auxiliary heating /CD	~ 28 MW	73 (110) MW
Cryogenic	9 kW @4.5K	

Figure 3
KSTAR AND ITER PARAMETERS COMPARED
The table compares the parameters for KSTAR to those of the much larger ITER. The lower image depicts the size of the KSTAR plasma compared with other fusion tokamaks, including the General Atomics Doublet III and the Joint European Torus.
Source: KSTAR

Question: And you see this as one step on the path to one day having a commercial fusion reactor?

Lee: Sure. They need to put in the money to develop it commercially. With government money alone, we are not going to make it. Because the government decides very poorly; sometimes it says, "Bye, bye," and sometimes it comes in again. And today we have lots of trouble in the economy so, people may say, "How about delaying it five more years?" In this way, fusion progress will be slow. This is how it has happened for 45-50 years.

If they knew this energy crisis was coming, they would have given money, spent it wisely; probably we would have already had fusion. ITER was negotiated in 1988. For 30 years, they hung around. Then, suddenly, people said, "20 years, I have waited for fusion and nothing happened." Yes, of course. We never built anything.

Question: I have a quote from you that was in the *Korea Times* two years ago, in which you said: "Should the world accelerate spending on nuclear fusion, its commercial launch will be possible in about 15 years."

Lee: If you look at the quote from BBC, which was broadcast five or six months ago, during their visited here, they taped what I said. I knew it was going to be broadcast all over the world, so my credentials were on the line, right? After taking all the pictures, this guy from BBC came with a big blackboard with white chalk and asked me to write, in front of a video recorder. He said, "You write when fusion power will be possible, in your perspective. Write it here."

Then he said, "This BBC Horizon TV program is famous, and has already had a very long lifetime. It will go on. So when you write this date, we will come back to you then to see if your prediction matches what you said some time ago." He said it jokingly, but this is interesting. So I wrote, after thinking a long time. . . . Can you quess what time I wrote? "2036.6." So this was a challenge: June 2036. This is what I predicted. . . .

Fusion, if you don't need it, never comes. If you need it, you just need the willingness of human beings working together, and resources and leadership, I believe, not for the commercialization of fusion in the whole world, but the initial demonstration of fusion power on the grid, which is possible within the years 2030-2040. But in order to do this, the necessity is very important. If you are happy with fossil fuels, not even mentioning global warming, or with nuclear power with uranium, then it's OK, and fusion may come very late. But if this is not sufficient and human civilization requires another source of energy to sustain it, then each major country needs to look at reality and put the resources together. Then we can pull it off.

This can be seen in Korea. It is a resource-poor country. And on green grass, and with just a few people, we built KSTAR. So why not Japan, why not the U.S., why not Europe, with science and an economy hundreds-fold bigger, and so many people—why not? We rocketed to the Moon in 10 years. With this kind of resolution and passion we can do that. But without it, just pushing poor scientists, with no power; criticizing; giving them just a few dollars, forget it. We have technology and we have people. If we put them together, we can do that. Of course, it's not easy, but it's possible, for sure. We demonstrated it.

So I believe, as you quoted me, that *definitely* I can do that. Seriously. You can quote me.

Question: The question is, how quickly can we convince the governments of the world to do it? Today, many of them are foolishly building solar panels, and not funding fusion.

Lee: We have to do all of this. But this is not sufficient. When you have cancer in your stomach, you drink medicine every day to make you feel better. We are facing a big problem, but what they do is drink some pain killer. We have to do it because until we really solve the problem, we have to take a pain killer, of course. But a painkiller alone cannot remove this cancer.

All of these ideas, I give to my students in my lectures, and even go to the young students in kindergarten through grade 12, and I tell them: Jesus Christ came 2,000 years ago, and look at the changes in 2,000 years. The history of the human race is short, but look forward to 2,000 years more. We know this is a short time,

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The KSTAR control room. The KSTAR project is producing a continuing stream of fusion scientists with the experience necessary to operate ITER in 10 years' time, and to teach succeeding generations of young scientists.

but if you try to extend our lifestyle 2,000 years more, what solutions do you have? What imagination do you have to sustain human behavior and the quality of life we are enjoying? How will this problem be solved? This is very important. I am not negative on nuclear; I am very positive on nuclear, because without it we will have to cut out everything, now.

Question: In Korea, nuclear is 40 percent.

Lee: We should extend nuclear, and this "green" energy is possible and important. But what do we do with the 40-50 percent that is still carbon-based, that we are burning? The human race, will continue not just 2,000, but at least 10,000 or 20,000 years. In order to do that, we have to control our appetite for energy. . . . At the same time, we have to have some other sources of energy that need to be tapped. Whether the tokamak is the best configuration for fusion or not, I don't know. But you want to replicate a small portion of the Sun so we sustain the human race. We have enough captial to complete it.

Question: It is a question of priority. What is so impressive about Korea is how quickly the country moved from where it was 50 years ago, to where you can now export nuclear reactors. Also, in space and in fusion, you took advantage of what had been developed around the world, and now your country is at the frontier of nuclear, fusion, and space.

Lee: I think it is an important lesson of a small country. I remember vividly the situation when I was young. In 1945, when Korea was liberated from Imperial Japan, per capita income was 67 U.S. dollars. When I was born, in 1956, per capita income was below $100. In less than 50 years, we hit $20,000, so it is a 200-fold increase. It is remarkable. Along the way, we also made all of our land green.

When I was young, a small kid, I believed that the Earth was red, because I never saw anything else. Green was here and there sporadically, with a tree, but I didn't know anything else. There were no trees, because people were so poor, they cut the trees to burn them for light. On this whole mountain, over a period of 40 years, we completely made this a forest.

We also had dictators for a long time, and then we had democratization. So it was a very chaotic and hectic time. But we put it together somehow. We still have lots of complaints, and we still have lots of challenges. I appreciate what you said, that is so complimentary.

The Challenges Ahead

Question: What are some of the challenges you see?

Lee: All of our energy, besides a small amount of hydro or biomass, we import. So this is a risk, with the fluctuation of the oil price, from $100 to $30, and all the politics. In this environment, we

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The National Fusion Research Institute in Daejon.

have to exploit our human capital. It is the only way, intensively thinking and working, and that's how we did it in the past 40 years. If we keep this intensity, then, even as a small country, we can prolong our growth and be a better country. But we are still at a crossroads.

Question: Korea is becoming an important factor in new technology and economic growth in Asia. You have a lot of very big neighbors, who are also very active in fusion, and in space. . . .

Lee: Also, army! Our neighbors are—Japan is a good friend; Russia, China, Mongolia, a very good friend in America. They are strong and we are small. . . .

ITER/European Fusion Development Agreement

An aerial view of the Cadarache site where ITER is beginning construction.

Question: But many countries are larger than Korea, but did not have the commitment and passion, and have not gotten where you are.

Lee: This is leadership. Look at Temujin, or Genghis Kahn. If you look at history, before him, Mongolia was feudal. People were scattered around, nomads. If you visit it today, it is still nomads. But we know about the greatness of Genghis Kahn, who took small people, put together power, and swept Asia and Europe. Human leadership can resonate with the people. Also, America did the same thing—Washington, Lincoln, resonated with the peole, and established greatness for the United States.

In fusion, or any science, it is human beings doing it. But this simple fact is overlooked most of the time. Money, time, building hardware—this all can become garbage one day. But if you put it together with this passion and intensity, then vision will be cast with the people, and suddenly you go to the Moon. This happened. Many people search for answers in the wrong place.

Question: We know that you studied in the United States. It has been a long, hard battle, to make progress in fusion research in the U.S.

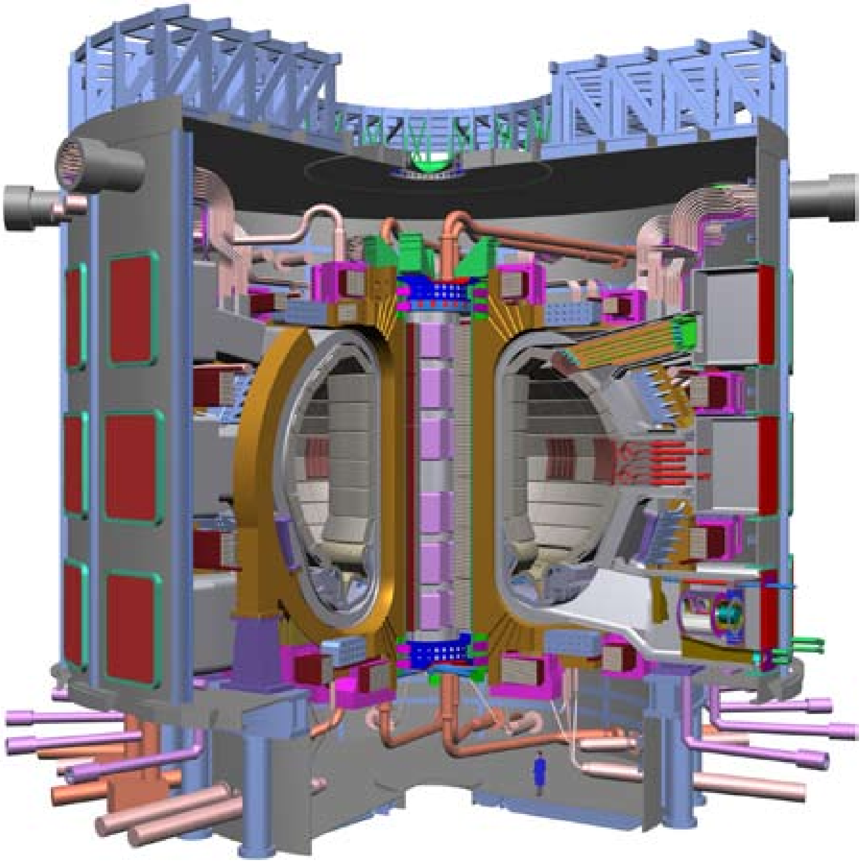
Lee: Initially I studied at the University of Chicago. I worked for Marshall Rosenbluth, at the Institute of Advanced Study [in Princeton]. Then, I worked with him at the University of Texas, when he moved there, doing theoretical work. Then I moved to Oak Ridge National Laboratory in machine design. At the time, Oak Ridge built the Advanced Toroidal Facility, the stellarator, a very complicated machine. Then I relocated to MIT, and I worked at the fusion center. I spent 12 years in the United States.

Question: That was when we had a fusion program!

Lee: Yes, they had boosted the fusion program. But suddenly the oil price went down, and willpower went down.

Question: And stupidity goes up. It's an inverse relationship.

We began publishing *Fusion* magazine in the 1970s, and helped Congressman Mike McCormack get a bill through Congress in 1980 for a Manhattan-style crash



ITER

Cutaway view of the ITER tokamak design. Korea will supply 20 percent of the superconduction for ITER's toroidal fuel mangets, a portion of the main vacuum vessel, part of the tritium storage and delivery system, and other hardware.

fusion program. But this was never implemented, which led to drastic cuts in funding, and stagnation in much of the U.S. fusion program.

Lee: That was because of a miscalculation. The solution is the human being. That is key. The United States invested billions of dollars in fusion and built the PLT [Princeton Large Torus experiment], and so on. Look at that investment now. What is the value of this? It has minus value now. This is hardware, and when you finish the experiments, you have to remove it. You spent several hundred million dollars to build it. At the time, this was the price tag, and that was it's value. Now it has minus value. Where did this value go? Into people.

Machines can stay around for 30, 40, 50, 60 years, but a human being goes 60-something years; he can continue, but he decays physiologically. This is not something you can avoid. And some day, you go. But if the human time created by this machine has value, it is much bigger than the investment of the hundred million dollars in hardware. That's how science wins. You invest one hundred million here, but people's knowledge has a value of 500 million, or a billion.

But this guy disappears; he dies. Then this knowledge in the brain and the heart disappears. Then, how do you continue it? You transfer knowledge. This is how you teach. But to do this, you have to build continuously, for people to be able to teach.

The Importance of Human Capital

Question: And you lose this transfer of knowledge, when the programs start and stop?

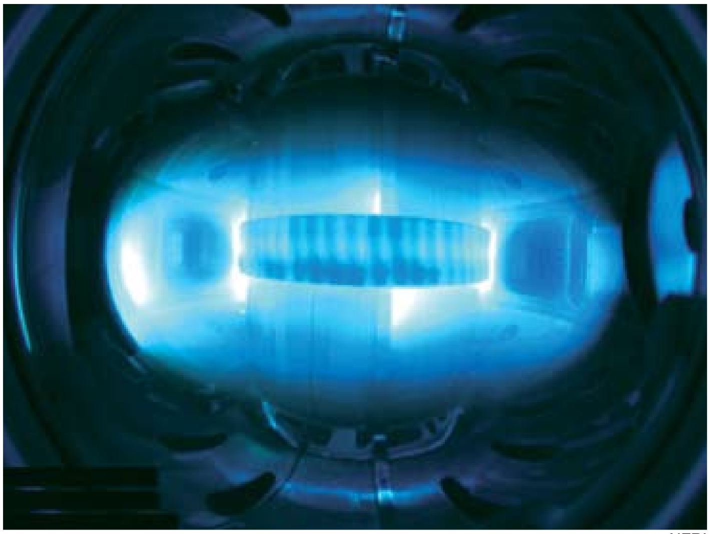
Lee: You are not attracting new people. They look at it, and say, "it's unstable." Good people come in, but there are lots of other good job opportunities. So this is the normal sequence of destroying this program. This was my "lesson learned," because I was watching, just as an interested party, all this history, and not just in the United States. So, in order to build KSTAR, we had to have a very compact scenario of people teaching. That's why we start with young people.

At the time I started fusion research in Korea, when I was hired, I was 35 years old—and I was the oldest member. I was very realistic: I have only 30 years to go, I recognized. Even though I would survive longer, my scientific education tells me the mean value of your effectiveness is, at best, 30. So you have 30 years.

We needed engineers to build KSTAR over 10 years. I had students who finished PhDs and Masters degrees. I had all young people in their early 20s. We worked together to build KSTAR. Now, they are in their early 40s and late 30s, and they already have full experience in machine building, with KSTAR.

They will have to work harder with ITER; literally, harder. So here they are learning ITER construction. And along the way you are hiring scientists, in their late 20s and early 30s, to operate the machine.

There are two tiers: one is engineers now in their late 30s, who did the KSTAR construction, and the younger people come along as their disciples. When the construction of ITER is finished, the first tier will be in their late 40s, early 50s, and the younger guys will be in their late 30s. The first group were the leaders. This system can generate successive



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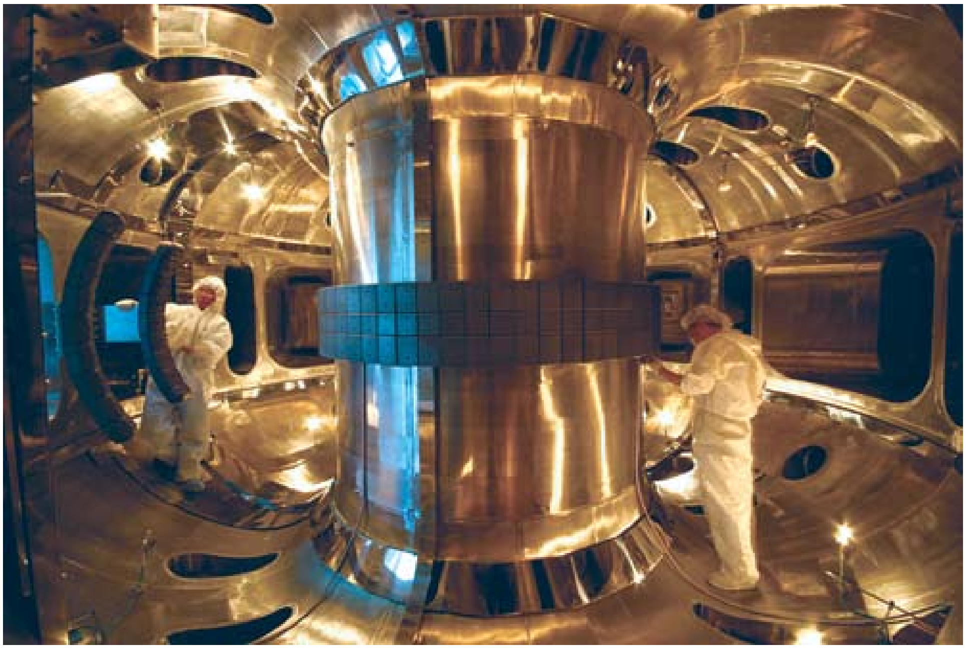
A magnetically confined plasma in KSTAR. The ultra-hot plasma radiates in a spectrum that cannot be seen by the human eye. Visible in this image are the colder regions on the outer edge of the plasma.

NFRI

The ceremony celebrating KSTAR's first plasma, July 15, 2008.



NFRI

Inside the KSTAR tokamak, during its construction in 2007.

generations, and history tells me it's possible. We may not be so successful, but this is why we built this kind of tiered scheme: recognizing the importance of the human capital, not the money. If it is successful, then what we want to have is a gathering of people, disciples, and followers, and with people, together with industry, you can solve any problem.

Question: That was the lesson of the space program in the United States. What we built was not a rocket, but a capability, and we could have done anything after Apollo. But we destroyed that.

Lee: And also, this happened in the fusion program. Smarter people always have high mobility, and can be successful in anything. The ultimate solution is giving this person resources to do something, not giving him just money; not millions and billions of dollars to people who are mediocre. Smart people hate it when the leader is so mediocre. This current system is unstable, so it is just wasting money.

Question: Then people complain that nothing is being accomplished. They say, "all of this money was spent on fusion research, but we still don't have it."

Lee: Money is always being spent, because you hire people, but they do nothing, just maintain the facility. Spending $100 million per year is easy, just to pay them. Multiply that over 20 years. Now there is $2 billion gone, and then they claim, that after $2 billion, nothing happens. This is a dishonest, political statement.

But if you had built the machine, and put it together in a package, and had done exciting research, giving people the money, in less time, you would have already met all of the requirements for fusion. If you look at the energy produced from fusion experiments over 30 years, it is an exponential curve. But certainly, after TFTR, nothing happened.

They say, over 30 years, nothing happened. But what they intentionally overlook is that they put nothing in over 30 years; they just waited. This is unfair. So if you want to kill it, kill it, so people can do something better with their lives. But if somebody wants to do it, do it with intensity. I hate the delay approach, not because money is spent, and wasted, and the total costs rise, but most importantly, because of the human waste.

Let's say that ITER is built over 20 years, rather than 10 years. Then the people you hired are working and are paid an enormous amount, but this is a relatively small price, since they each waste 10 years of their lives. They could complete it in 10 years but it is extended to 20 years, so half the total human capital involved is lost.

What's at Stake

Question: In the space program, you lost a whole generation of people, because there were 20 years without bringing in new people or building new vehicles. So today you have people in their 20s and 30s, and then in their late 50s and 60s in the space program.

Lee: And the new people never build anything; they just play with the automatic CAD [Computer Assisted Design] program, and create beautiful pictures.

Question: There was also a cultural degeneration in the U.S. from the mid-1960s. The shift was away from the belief in progress, with the hippie phenomena and the Baby Boomers. Instead of advancement in science and technology, and increases in productivity and infrastructure, we became a consumer society.

Lee: In Korea, it was the same thing. We are now more or less prosperous, compared to the old days. These people want to be safe, easy-going, and make money; the same behavior. We have to tell them, not just lecture them, but they have to figure out what they want to commit their lives to. If you ask about fusion, why am I, myself, here? Because I can do other things, too. But I do this, which so many people criticize, so many people don't understand.

What kind of incentive do you have in daily life to work with this intensity, for so many long years? You have to understand what is at stake, and what you're committing to. Otherwise, this will never happen.

People with vision and intensity always try to see something that normal people don't see. Sometimes if you see it, and you believe, people believe you are crazy, because they don't see it. Then one day, there is a storm gathering, and they all see it, and they complain: "Why didn't you tell me? You are a scientist. You must have known this many years ago!"

So we have to tell them the choices.

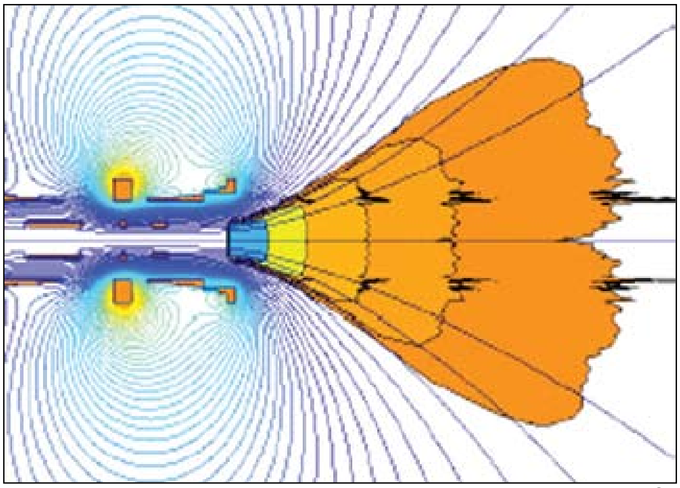
This is how we make progress. As human beings, we all have different interests and different ideas, and they are honest; and all of them believe they are correct. So we cannot lecture, but communicate, and steer in the right direction, so they see the storm.

ITER, KSTAR—this is just very small. In the big picture, this is just one step. But in order to go all the way, you have to walk in small steps, every step consistently, continuously, with the belief that you will reach there.

Many people glorify KSTAR. This is not the story. What we are doing humbly is trying to communicate that even this greenfield facility, with small humble people with very small resources, with no experience, can take one step. This is what we've tried to prove. And to tell people and all the leaders of the big nations, they need to put their power behind it, and we can move on—step, step, step, finished. The tokamak might not be the answer, but eventually we will find the solution. If you find something you cannot overcome, you come back and you overcome it. If you just worry, you don't move and you never face anything. But eventually, there are big storms boiling, and everybody is screaming, but then, what? Turn off the electricity? Or beg for it, or pray?

NASA

Astronaut Franklin Chang-Diaz, who has flown on seven shuttle missions, is working on a plasma-based propulsion system. He is the founder of AdAstra Rocket in Houston.



NASA

VASIMR, the Variable Specific Impulse Magnetoplasma Rocket, is the space propulsion system designed by Chang-Diaz. Radiowaves are used to ionize fuel into a plasma. Electric fields heat and accelerate the plasma, while magnetic fields direct the plasma as it is ejected from the engine, creating thrust for the spacecraft. The VASIMR engine can use nuclear or fusion power to create the plasma.

Question: We are working intensively on a vision for the next 50 years. The centerpiece is a Moon/Mars program, in which we are proposing using fusion power for propulsion to Mars. We have a lot of young people working on the problem of going from the Moon to Mars using constant acceleration and deceleration, with fusion-generated power. We're circulating this proposal throughout the country, to create an interest in the development of fusion among a generation of young people do not know very much about it, and who are just coming on line now.

I understand that the developer of the VASIMR plasma rocket, former astronaut Franklin Chang-Diaz, visited your Institute.

Lee: We believed what he said, and we are interested. I know his vision, and why he wants to do it that way. It's very good. We invited him and gave him a chance to lecture to the young people at the Institute. A vision sometimes looks like a crazy idea, but if you are consistent, eventually, it is clearer and clearer and you see it.

Vision is important, and also continuous execution. That is one reason why we invited Franklin Chang-Diaz. He lectured and showed a beautiful animation of how to go to Mars. We showed it to the young people, not because it uses a plasma, but because this kind of thing is possible, and I believe it is important. Also because, like fusion, it has obstacles, and that is why scientists exist.

We are providers of solutions. We like problems. We are paid because problems exist. We don't complain, but we want to realistically solve the problem. To do that, you need support from the public and the resources, with trust. Without it, if you say that the execution is zero, then the vision is non-achievable, and all I can do is complain. This is non-constructive. The most important thing, with leadership, is communication with people, so they can support it using correct scientific reasoning.

This is the reason why KSTAR was built; not for the scientific correctness, but to move big industry—Samsung, Hyundai—and the government, to support it. Because believing in putting hundreds of millions of dollars into this, committing responsible public money, is not easy. With the IMF and this near-bankruptcy—still putting money in? Why? This is not scientific preference. This is *vision*, and communication that resonates.

Footnote

1. A shorter version of this interview appeared in EIR, Dec. 4, 2009.

Vietnam Is Ready to Go Nuclear!

by Marjorie Mazel Hecht

Vietnam, a nation of 85 million, has set an ambitious goal of supplying 15-20 percent of its electricity needs from nuclear by the year 2030. The first step will be the construction of four 1,000-megawatt nuclear plants to start in 2014, with the first unit coming online in 2020, and the others to follow in the next four years. At this point, Vietnam leads the way for the rest of the Southeast Asian nations—Thailand, Indonesia, and Malaysia in particular—which have discussed building nuclear plants for many years, but which have not instituted the laws and infrastructure necessary, nor mustered the necessary political will.

At present, most of Vietnam's power (about 60 percent) is supplied by hydropower, and the remainder from gas-fired plants in the south, coal-fired plants in the north, and imports of electricity from neighboring states. Government studies expect that electricity production can continue to meet demand, until the year 2015, at which point there will be a shortfall of from 11 to 65 terawatt hours, depending on whether there is low economic growth (6.3 percent), baseline

The Vietnam Atomic Energy Commission economic studies determined that the nation will need 2,000 to 4,000 megawatts of nuclear power in its electricity grid by 2020, to meet the needs of its growing population.

VAEC

The Dalat Nuclear Research Institute, which houses Vietnam's nuclear research reactor, began operating in 1963 to produce radioisotopes for medical uses and for food preservation. Dalat is in the highlands of Vietnam, with a temperate climate. A new research reactor is now under study.

economic growth (7.1 percent), or high growth (7.5 percent).

Atoms for Peace

Vietnam's impressive development plan for nuclear dates back to 1958, when Vietnam was one of the first nations under the Atoms for Peace program to order a small research reactor, the General Atomics-built Triga-Mark II, used for training of scientists and engineers and producing medical isotopes. The reactor began operations in 1963.

Lothar Wedekind/IAEA

Luong Van Chinh, a farmer in Dong Tien in Southeast Vietnam's Binh Phuoc province, explains how he cultivated his hardy crop of rice. He used seeds developed by plant breeders at the South Vietnam Institute of Agricultural Science in an IAEA-supported technical cooperation project.

The Second Indochina War (the first having been fought against the French colonialists in the 1950s) interrupted Vietnam's development plans. Vietnam was at war again until 1975, and during that war, the United States dismantled the U.S.-supplied Triga reactor. Immediately after the war, the reunified nation began to rebuild its infrastructure and governmental agencies, establishing the Vietnam Atomic Energy Commission early in 1976, under the management of the Ministry of Science and Technology.

In 1980, the Russians reconstructed the research reactor on the Triga site in Dalat, making it a unique combination of a Russian reactor core and Triga infrastructure. Since that time, the Dalat research reactor has been used to conduct basic research and development in reactor physics and engineering, train scientists and engineers, and produce medical isotopes. Many of Vietnam's senior nuclear scientists and engineers were trained in former Soviet countries.

***Doi Moi*—Innovation**

Guiding the nuclear program has been Vietnam's overall policy for uplifting the nation's socio-economic level from its postwar poverty and chaos: *Doi Moi* or innovation, in which the "science driver" approach to development is a priority.

In the last two decades, Vietnam began to put in place the regulatory and other groundwork required for a nuclear economy, setting up a Radiation Protection and Nuclear Safety Authority, and working with the Ministry of Industry to survey potential nuclear sites, environmental impacts, the nuclear fuel cycle, waste management, economics, and other issues. As part of the National Research and Development program, the Vietnam Atomic Energy Agency carried out an analysis of a future role for nuclear in the economy and the infrastructure required.

Vietnam has worked with the International Atomic Energy Agency on many joint projects to train personnel and to study nuclear technologies and safety. For example, Vietnam has worked with the IAEA to use radiation mutation techniques to create new varieties of high yield rice.

To explore the different reactor possibilities, Vietnam has collaborated on many bilateral projects with nuclear suppliers, including with Toshiba and JCI, Mitsubishi, the Atomic Energy Commission of Canada, and Korea's utility KEPCO. An international exhibition on nuclear in 2008 was attended by many nuclear companies and national representatives—all of which are contenders for contracts to build Vietnam's nuclear plants and supply other required technology.

Lothar Wedekind/IAEA

Education is a top priority for a nuclear economy. Here a school boy dressed in his school colors, in Thanh Gia, a small rice farming village outside Hanoi.

Education Key

Key in all this is education. Vietnam not only needs to train significant numbers of engineers, technicians, and scientists to support new nuclear plants by the year 2020, but it also requires an educated public. To carry out this education, the Atomic Energy Commission and the Ministry of Industry, with the support of Japan's nuclear industry, organized three public exhibitions on the "use of atomic energy for peace" in the cities near the selected nuclear sites and in Ho Chi Minh City. The enthusiastic local attendance at these exhibitions has the character of optimism that typified the Atoms for Peace era, during which Vietnam began its nuclear program.

Vietnam's Atomic Energy Law went into effect at the beginning of 2009, and the National Assembly gave its go-ahead to the proposed nuclear construction plans in November 2009. Vietnam will be the first Southeast Asian country to build *and operate* a nuclear plant. The Philippines completed its Bataan nuclear plant in 1984, but it was shut down by the Kissinger faction before the plant could operate. (Now plans are under way to revive the mothballed Bataan plant, but they are not on a fast track.)

Vietnam thus leads the way in Southeast Asia as part of the booming nuclear renaissance centered in the Pacific. We need a rapid change in the United States to join this renaissance, and infrastructure building, to ensure that we move mankind forward.

INTERVIEW: TRAN HUU PHAT

Vietnam Is Moving Ahead with Nuclear

Dr. Tran Huu Phat

Dr. Phat is the Former Chairman of the Vietnam Atomic Energy Commission (VAEC) and is now the Chairman of its Council of Science, Technology, and Training. This interview was conducted recently via e-mail between Dr. Phat and Marjorie Mazel Hecht.

* * *

Question: Vietnam has a very impressive nuclear program, and I think the progress you have made in planning for two to four 1,000-megawatt nuclear reactors by 2020 should be very encouraging for other developing countries. What stage are you in now, and when do you expect to start construction?

Phat: The Investment Project of Ninh Thuan Nuclear Power Plants was approved by the Vietnam National Assembly at the 6th Session Meeting held in Hanoi from 20 Oct.20-Nov. 26, 2009. According to a schedule proposed by the utility owner, Vietnam Electricity (EVN), the construction of the first unit among four units could be started by 2014-2015.

Question: Your nuclear program has proceeded very systematically, looking at projected growth and electricity supply for the entire country, and seeing that a shortage could arise by about 2015.

As I understand it, the plan is to meet this by importing electricity, coal, and gas, and by developing nuclear as an indigenous energy resource, to reduce energy dependence on other countries. How did you arrive at the balance of your power supply choices?

Phat: In order to meet the national electricity demand in the future, Vietnam has to choose a harmonious solution, which consists of energy saving, optimal exploitation of indigenous primary energy resources (including small hydro power and renewables) coal, electricity imports, and nuclear power.

Question: What percentage of your power do you plan to be produced by nuclear by the year 2050?

Phat: It is expected that by the year 2030, about 15-20 percent of Vietnam's electricity needs will be supplied by nuclear power.

Question: How will you meet the manpower requirements for building and operating nuclear reactors? Are you recruiting and training engineers and technicians?

Phat: Manpower is currently a big problem of Vietnam while starting the nuclear project. The Ministry of Education and Training has completed the National Long-Term Program for training manpower to meet the demand of the first nuclear project. In addition, we also are considering policies and measures to attract and recruit overseas Vietnamese and foreign

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Headquarters of the Vietnam Atomic Energy Commission in Hanoi. ►

WONUC

▼*The site of the planned first nuclear power plant in Ninh Thuan province, where construction is expected to start in 2014. The reactor type will be a "third or third-plus generation" conventional reactor, according to Dr. Phat. The first two plants in the project are expected to cost 200 trillion dong (about $11.2 billion).*

VAEC

Vietnam has a long-term manpower training program to meet the needs for staffing its ambitious nuclear program. Here, the opening ceremony of the second nuclear power training course for engineers in Hanoi, May 2007.

experts in the fields concerned.

Question: What about the regulatory and safety infrastructure?

Phat: Our regulatory and safety infrastructure is in a state of being improved step by step in order to fulfill the requirements of the nuclear program. Namely, in coming years we will pay great attention to the development and improvement of the state management system and national legal framework. All of these works are implemented within the Atomic Energy Law, which was adopted on June 3, 2008, by the National Assembly and came into force on January 1, 2009.

Question: Can you say something about the international nuclear collaboration that you are engaging in?

Phat: International cooperation plays a very significant role and is considered as an important resource for ensuring safe and effective operation of the first nuclear power plants in Vietnam. At present, Vietnam is a Member State of the IAEA (International Atomic Energy Agency), Regional Cooperation Agreement (RCA) and the Forum for Nuclear Cooperation in Asia (FNCA), and has signed intergovernmental agreements on the peaceful use of nuclear energy with India, Korea, China, Russia, and Argentina.

In the meanwhile, we also have close relations with Japan, France, Korea, and Russia in the field of nuclear power. Recently, nuclear cooperation between Vietnam and the U.S.A. has been established. Vietnam joined many important international conventions and agreements such as the NPT (Non-Proliferation Treaty), CTBT (Comprehensive Test Ban Treaty), the Nuclear Safeguards Agreement, and so on.

Question: Have you selected a reactor type?

Phat: The Investment Project for the Ninh Thuan Nuclear Power Plant recommended that the reactor types which we should choose are those belonging to the third and third-plus generation. However, the final decision will be confirmed either by the Finance Secretary or bid.

Question: What about the IAEA cooperation you've received in nuclear. I know that the IAEA's program has been helpful in using radioisotopes to breed new rice strains.

Phat: As a Member State, Vietnam has been receiving the assistance of the IAEA in various areas, fruitfully contributing to the research and development of atomic energy in the country. Medicine and agriculture are two domains that have benefited very much from this assistance.

For the cycle 2009-2011, the IAEA has provided us with three technical assistance projects related to nuclear power, namely VIE/4/015, Developing Nuclear Power Infrastructure; VIE/9/011, Improving the Capacity for the Site Characterization and Evaluation of New Nuclear Installation; and VIE/9/013, Strengthening the Technical Capacity of the Radiation and Nuclear Safety Regulatory Body. These proved to be very significant to setting up the nuclear power program in Vietnam.

Question: Vietnam's population is now about 85 million, heading toward 98 million by 2020. From what I've read, 90 percent of the population supports nuclear power, which is very good! What kind of educational programs has the Atomic Energy Commission carried out?

Phat: I am not able to determine the exact percentage of those Vietnamese who support nuclear power, because so far we have not conducted any national level survey on this issue. But I can confirm that most Vietnamese people agree with the approval of the National Assembly on nuclear project.


VAEC

Bilateral cooperation is a central part of Vietnam's nuclear program. Here, a Japanese delegation at a 2009 seminar of the Vietnam Agency for Radiation and Nuclear Safety.

VAEC

The opening ceremony of Vietnam's International Exhibition on Nuclear Power in 2008.

In order to attain the present success, since early 1996 with the aid of various foreign companies from Japan (Toshiba, Hitachi, Mitsubishi), Korea (Kepco), Canada (AECL), France (EDF, Areva) Russia (Rosatom), and China (CGNPC), a great number of international seminars on nuclear power have been held in Hanoi. There, hundreds of nuclear scientists gathered from all the countries.

In parallel, we organized many nuclear power exhibitions around the country, in particular, in Ninh Thuan province where the first nuclear power plants are to be sited. The participation at these exhibitions of the well-known companies from Japan, Korea, France, Russia, China, and India were very significant and highly appreciated.

The public education activities are continuously conducted under many other forms such as mass media, publication of documents and booklets on nuclear power, organizing the visits of high-ranking officials to nuclear power plants in Japan, Korea, France, and the U.S.A., etc.

In close cooperation with our Japanese partners (JAIF, Toshiba) and the Technology University in Hanoi, the VAEC organized many training courses for those key people from the electricity utility, EVN, who will directly join the Ninh Thuan Nuclear Project. Inside VAEC we also have established a training center focussing on radiation protection and other topics related to nuclear safety.

Question: Nuclear research began in Vietnam in the Atoms for Peace days, and you had one of the first Triga research reactors, built by General Atomics in Dalat, which began operating in 1963 at 250 kW. But then the war came. In 1980, the Russians restored the Dalat research reactor, and uprated it to 500 kW. The 1960s were a time of great optimism, especially for nuclear. It is good to see that that optimism has survived in Vietnam. Did some of your nuclear staff get their start on the Triga reactor?

Phat: Yes, several of our staff, who got their start at the Triga reactor, have stayed in Dalat and worked for that reactor until their retirement. However, most of our staff, who participated in the restoration and successful restart of the uprated Dalat reactor, have graduated from universities of Vietnam and former socialist countries.

Question: When was the Vietnam Atomic Energy Commission established?

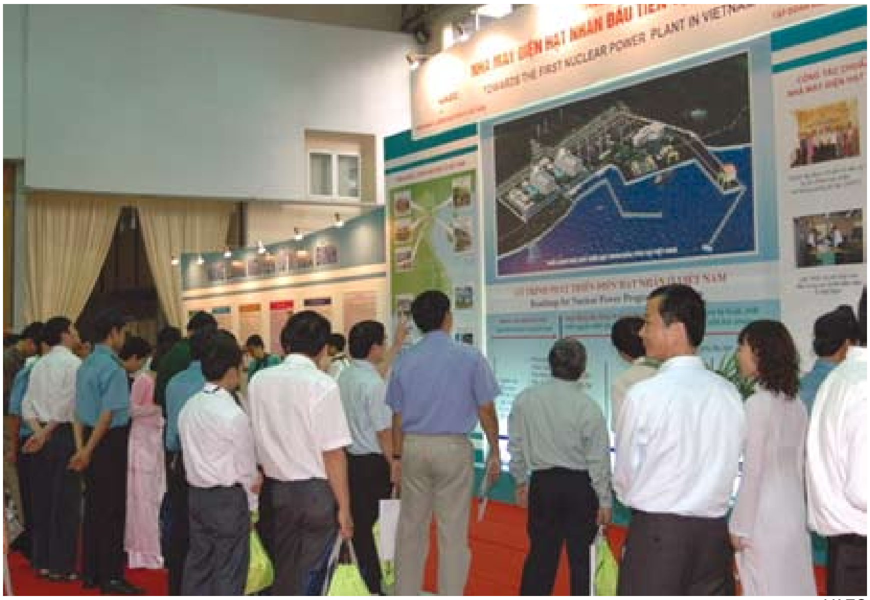
Phat: The Vietnam Atomic Energy Commission (VAEC) was established by the Government on April 26, 1976. This is a research and development institute, which at present belongs to the Ministry of Science and Technology (MOST). Its functions are determined as conducting fundamental and applied research, technology development in the field of atomic energy; assisting the state management of atomic energy; and also providing technical support on nuclear safety and radiation protection.

Question: What kind of activities now go on at the Dalat reactor?

Phat: The Dalat reactor with 500 kilowatts of power is now used for limited purposes: nuclear research, development of some techniques, training scientific personnel, radioisotope production, and technical services.

VAEC

Poster for the Vietnam Nuclear Power 2008 exhibit.



VAEC

The 2008 nuclear exhibit attracted international suppliers and crowds of Vietnamese.

cated a Eurasian Land-Bridge, using advanced rail technologies, from the east coast of China to Rotterdam, with many side links, water projects, and industrial development centers, including nuclear, along the way. . . .

Nuclear power is essential if we are to develop the entire world population, and raise living standards. So I think that what Vietnam is doing will be a real inspiration to those countries that aspire to go nuclear, but are not as advanced as Vietnam, and I would like to get news of your nuclear program to other countries.

Phat: Thank you for your encouraging comments. I would like to mention that the Ninh Thuan Nuclear Power Project is only the first one of the National Long-Term Nuclear Program. However, it plays the crucial role for the whole nuclear program. In this respect we must do the best for its success.

Question: Will you build another research reactor to keep up with the development of the nuclear program?

Phat: At present the New Research Reactor Project has been studied by VAEC and will be submitted to the Government as soon as possible.

Question: The spirit of your "Doi Moi Policy"—innovation—is a very optimistic view, looking ahead to provide for the advancement of the entire country using the most advanced technologies. Are there other projects besides nuclear that come under the Doi Moi Policy?

Phat: The Doi Moi Policy has opened up a new period for Vietnam since 1986 with rapid economy development. Today Vietnam has become an equal member of many international and regional organizations, and as well has close relations with most nations in the world.

The nuclear power project is only one among many other national programs that the Government deals with in the process of industrializing and modernizing the country.

Question: The political organization I am a part of, the Lyndon LaRouche movement, has campaigned for many years for development programs and a just economic order. LaRouche and his wife, Helga Zepp-LaRouche, have advo-

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◄ *The Second International Nuclear Power Exhibition in 2006 in Hanoi drew 6,600 Vietnamese visitors, including 200 Parliament members, with exhibits from five countries.*

▼ *Attendees at the 2007 nuclear power training course for the Electricity Corporation of Vietnam, which took place in Hanoi at the Electric Power University, in cooperation with Japan.*

VAEC

Wilhelm Weber's Works Translated into English

A bibliography compiled by A.K.T. Assis

Wilhelm Eduard Weber (1804-1891)

Wilhelm Eduard Weber (1804-1891) was one of the main scientists of the 19th Century. His complete works were published in six volumes between 1892 and 1894 [1, 2, 3, 4, 5, 6]. Here we cite all of his works and letters known to us which have been translated into English.

The joint book of Wilhelm Weber and his brother, the anatomist Eduard Friedrich Weber (1806-1871), originally published in 1836, has recently been translated [7].

Weber wrote eight major Memoirs between 1846 and 1878 under the general title *Electrodynamic Measurements,* or *Determination of Electrodynamic Measures*: [8, 9, 10, 11, 12, 13, 14, 15]. The eighth Memoir was published only posthumously in his collected papers.

Three of these eight Memoirs have already been translated, namely, the first [16], the sixth [17], and the last one [18]. In 1848, an abridged version of the First Memoir was published [19]. This work is extremely important as it introduces for the first time Weber's potential energy, which is a function not only of the distance between the interacting charges, but also of their relative radial velocity. This paper has also been translated [20].

A joint paper by Weber and Kohlrausch of 1856 [21], has recently been translated [22].

Three of his works related specifically to diamagnetism have already been translated. One is a paper of 1848 [23], translated into [24]. The second one is a paper of 1852 [25], translated into [26]. It is an abridged version of Weber's third major Memoir, [10]. The last one is a letter from Weber to John Tyndall (1820-1893) related to the theory of diagmagnetism [27].

A paper of 1851 on the measurement of electric resistance according to an absolute standard [28] was been translated in 1861 [29].

There is a translation of the results of the observations made by the Magnetic Association in the year 1836 [30].

There is a translation of a paper of 1837 with observations on the arrangment and use of the bifilar magnetometer [31], namely, [32].

Likewise, there is a translation of a paper of 1838 on a transportable magnetometer [33], namely, [34].

There is a translation of an extract from remarks on the term-observations for 1839, of the German Magnetic Association [35]. An extremely rich exchange of letters between C.F. Gauss (1777-1855) and Weber has been recently translated [36].

Weber's aphorisms, published only posthmously [37], have recently been translated [38].

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The Sky's Not the Limit

by Oyang Teng, LaRouche Youth Movement

"Hubble 3D"
An IMAX® Space Team and Warner Brothers film, in cooperation with NASA
Producer/director Toni Myers
March 2010, at IMAX theaters

Last year's Shuttle mission to repair the Hubble Space Telescope was a classic lesson in the calculus of risk-versus-reward decision-making. Defying his predecessor's decision to scrap the mission for budgetary and safety reasons, NASA's previous Administrator, Mike Griffin, revived the daring mission to save the Hubble, which required five extended spacewalks in a higher-than-normal, debris-strewn orbit, and with the unprecedented contingency of a standby Shuttle ready to launch a rescue operation if needed.

The high-profile mission was a resounding success, and the rewards have been streaming down to Earth from the telescope's 350-mile orbital perch ever since, in the form of spectacular new imagery and data revealing ever more of the beauty and complexity of our universe.

The new IMAX film "Hubble 3D" presents both the highlights of the dramatic mission to repair one of history's most venerable scientific instruments, as well as images from the Hubble itself, some of them animated and newly visualized in breathtaking sequences that transport the viewer into the heart of star-forming nebulae and staggeringly distant galaxies.

The Extraterrestrial Imperative

The film premieres at a poignant moment in history, as the Obama Administration's stated intent to shut down NASA's Constellation Program throws America's future in space into doubt. Although the filmmakers don't explicitly say it, the Hubble repair mission is a clear example of a mission in the service of science that could only be accomplished with a manned space program.

They do, however, clearly strike the risk vs. reward theme, largely through the voice of the astronauts, who we see during their intensive two-year training, and then through all phases of their delicate mission to install a new camera and other equipment on the 20-year-old Hubble. Despite a couple of tense moments during the spacewalks, the end result is a more powerful telescope, capable of looking to the edge of the observable universe. The resulting Hubble imagery, translated onto the massive IMAX screen and in 3D, is a fitting testament to the scope and grandeur which confront our curiosity in searching out the skies—and, by itself, is worth the price of admission.

Unfortunately, the underlying message of such awesome beauty, that mankind must fulfill his extraterrestrial imperative by staking out new frontiers in the exploration and settlement of the cosmos—which director/producer Toni Myers delivered admirably in her 2002 IMAX film "Space Station 3D"—is instead somewhat clouded by the message that the farther we look, the more we must focus on the perfect utopia we enjoy on Earth. This is no doubt due to the influence of narrator Leonardo DiCaprio, who has made an ass of himself as a leading Hollywood propagandist for global warming hysteria.

Nevertheless, "Hubble 3D" is a must see. It may well be the last time audiences will have the opportunity for the as-good-as-it-gets-without-being-there

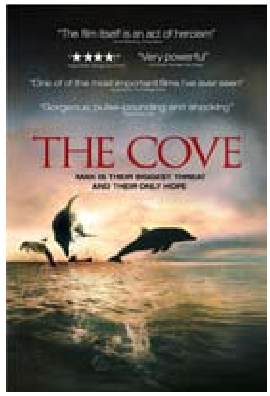
NASA, ESA, HEIC, and The Hubble Heritage Team (STScI/AURA)

The Cat's Eye planetary nebula (NGC 6543), captured by the Hubble Space Telescope. The eye is more than half a light-year across.

experience of an IMAX Space Shuttle launch, because the Shuttle fleet is slated for retirement by the end of this year. Long before that, a decision will have to be made on the next phase—if there is to be one—of America's manned space program. Hopefully, those leaving the theater after watching "Hubble3D" will have a renewed sense that this decision is not only one of national policy, but of mankind's place in the universe itself.

The Slaughter of the Truth

by Gregory Murphy



"The Cove"
Directed by Louie Psihoyos
Documentary, 1 hour, 30 min.,
$27.98 (PG-13)

"The Cove" is an Academy Award-winning documentary directed by former National Geographic photographer Louie Psihoyos, which plays fast and loose with the facts about dolphins, and heavy with the emotions—in much the same way as Al Gore's comedy science fiction horror film "An Inconvenient Truth." The film also has a Hollywood action thriller edge to it, which is meant to draw the audience in for the real message, which is not the purported slaughter of dolphins, but a rant against eating fish because of its alleged mercury content. As the reader will see, the mercury argument is a red herring and is based on a fraudulent study.

Flipper's trainer Richard O'Barry.

The real laugh of the documentary is that its chief expert is Richard O'Barry, a dolphin trainer on the 1960s "Flipper" television show. The other expert in the film is eco-terrorist Paul Watson, who was thrown out of Greenpeace in 1977 for being too radical. Watson currently operates Sea Shephard Conservation, which has a mission of shutting down whaling. A few months ago, one of Watson's million-dollar boats was sunk trying to ram a Japanese whaling ship.

In "The Cove," Louie Psihoyos and Ric O'Barry claim that 23,000 dolphins are killed each year in the bay near the Japanese fishing town of Taiji. In reality, there are only 800 to 1,000 dolphins killed, and the reader should keep in mind that part of the Japanese diet is eating whale and dolphin meat, much the same way that most people in the United States eat beef and chicken. This intentional misstating of the numbers of dolphins killed is based on using the number of yearly permits the Japanese government issues for hunting dolphin and whales. It is a big leap from the number of permits issued to the actual number of animals killed.

The film gives the impression that bottlenose dolphins (like Flipper) are being killed, which is the emotional hook for the film. To make the hook catch, the film's director keeps repeating the same footage of beautiful dolphins playing in the ocean and performing at ocean parks like Sea World. The truth is the Japanese fishermen have stopped hunting bottlenose dolphins.

Mercury Scare

The film spends much time talking about mercury in the dolphin meat, but here the dolphin is only a surrogate for all fish. The film cites a 1956 incident in Minamata, Japan, as an example of mercury poisoning. This documented poisoning at Minamata was caused by a factory blindly dumping chemical waste into the nearby bay, but this waste also contained PCBs and other chemicals in addition to mercury.

The mercury scare is based on a study of sea life near the Farne Islands, off the northeast coast of England. The methodology of the Farne Island study is full of intentional misrepresentations, so as to make it more of a political document than a scientific study. But based on these data of mercury in sea animals, the U.S. Environmental Protection Agency and the Food and Drug Administration set the U.S. mercury limit to 5.8 parts per billion, which is extremely low. In comparison, the World Health Organization's limit on mercury is 80 ppb.

In discussions with people in the fishing industry and others with extensive knowledge of marine life, one thing becomes clear: The real intention of the mercury scare is to stop people from eating fish and making use of its much needed protein. The people I talked with have said that so far, not one fish brought into the United States has even been close to

Ecoterrorist Paul Watson, the expert advisor to "The Cove," along with O'Barry.

A typical "Cove" scene with its spy thriller approach to propaganda.

this excessively low mercury limit.

The point is that the Malthusian greens are using this issue for two reasons; one is the shutdown of coal power plants (which emit mercury) and the other is the removal of fish from the human diet. The green propaganda on mercury would have you believe the fairy tale that mercury levels in fish have steadily increased since the start of the industrial revolution. It's not true.

A study done in 1998, for example, compared mercury levels from yellowfin tuna caught in 1998 with yellowfin tuna caught in 1971. The interesting result was that there has not been a discernable increase in mercury. Another study a year later, using similar methodology but comparing striped bass, again found no discernable increase in mercury.

Coal power plants are blamed by the greens as the main source of the mercury. But this is simply not true. The mercury that accumulates in fish and animals is acquired in a different biological pathway; this bioactive mercury is different from the inorganic mercury that is expelled from power plants and factories.

More Fish Stories

"The Cove" also makes the claim that because of overfishing, the oceans will run out of fish. The director uses as his proof for this outlandish claim a thoroughly debunked 2003 *Nature* magazine article written by Ransom Myers, (now deceased) professor of biology at Dalhousie University, and Boris Worm, then biodiversity professor at the University of Kiel, which claims that the oceans will be devoid of fish by 2048.

One marine biologist told this author that the *Nature* magazine article was debunked "about five minutes after it was published," and both *Science* (which published a similar article in 2005) and *Nature* have had to print rebuttal comments and papers over the past few years. The main problem with the *Science* article, he said, is that it was based on a computer model. Apparently the authors believe that fish live in computers and not in the oceans!

A Scientific Perspective

If the reader is looking for a better assessment of the state of the ocean's fisheries, without falling prey to genocidal pipedreams of poisonous fish and magically disappearing fish, I would suggest reading *Climate Changes and Fish Productivity*, written by Alexey Lyubushin (Institute of the Physics of the Earth, Moscow) and Leonid Klyashtorin (Federal Institute for Fisheries and Oceanography, Moscow). Both authors have worked with the Food and Agriculture Organization, and their 2007 book deals with the relationship of climate cyles and the changes in fish populations. The authors also propose a method by which to forecast major changes in the oceans fisheries.

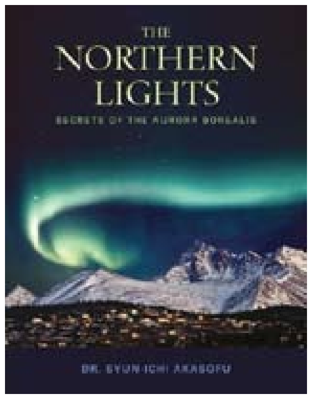
(The book is available at the following link: http://alexeylyubushin. narod.ru/Climate_Changes_and_Fish_Productivity.pdf)

In summary, viewers of "The Cove" should not be drawn in by the Hollywood-style spy thriller, which is designed to keep you interested so that you will be scared by the mercury-in-fish message and stop eating fish. This is a deadly trap.

I encourage readers to avoid genocidal propaganda like "The Cove," and instead to campaign for a truly science-driven economy with a real space program.

Exploring the Secrets of the Northern Lights

by Gregory Murphy



The Northern Lights: Secrets of the Aurora Borealis
by Syun-Ichi Akasofu (with Jackie Finch and Jan Curtis)
Portland, Oregon: Alaska Northwest Books, 2009
Paperback, 192 pp., $18.95

Dr. Akasofu is the founding director of the International Arctic Research Center, located at the University of Alaska, Fairbanks, and through his research has become one of the world's foremost authorities on the aurora borealis. With this in mind, I was excited to read his book and I was not disappointed in the least.

The book takes the reader on a short journey of what is known about the Northern Lights, punctuated by amazing photographs. In fact, the photographs alone are reason enough to buy the book.

The journey begins with the early myths about the aurora borealis, and quickly moves to the different theories that were proposed to explain this natural phenomenon. It concludes with a brief discussion of the role that the Sun plays in the Northern Lights.

The section on the Sun could have been longer, but it did highlight the recent NASA discovery that the Earth and the Sun seem to be connected by magnetic ropes, which solar scientists at NASA have theorized is one of the major factors in the production of Northern Lights. Akasofu tends to believe that this idea can explain some of the phenomenon, but he doubts it can explain the whole.

Akasofu's book points to the past theories and his recent research into the Sun and other geophysical components of the Northern Lights, and concludes that several unanswered questions remain about their nature. One of the most interesting theories was put forward by Benjamin Franklin: that the Northern Lights are produced by an electric current. Askasofu notes that a large portion of the Northern Lights is produced by the interaction of the Earth's magnetosphere and the Sun's highly magnetic solar wind. With this in mind, it seems that Benjamin Franklin's idea was not far from being right.

The Aurora Borealis, or Northern Lights, above Bear Lake in Alaska.

Akasofu writes that as his research progresses, and as we gain a further understanding of the interaction between the Sun and Earth, it will become possible to better forecast aurora activity and to determine when the Sun's activity will become harmful to satellites. It will also further our knowledge of the Sun-Earth climate connection as well.

I highly recommend this book. Apart from the breathtaking photographs, the book can be used as a guidebook for serious Northern Light watchers and casual sky gazers alike.