

RESEARCH

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In two articles, *The Chronicle* looks at how science has spawned two controversies at one university. In one case, a Purdue University physicist's career has been overshadowed by charges of fraud and a Congressional inquiry. In another, what some scientists regard as promising medical inventions have sat on the shelf while Purdue and its corporate partners, competitors, and a scientist have traded accusations, suits, and countersuits.

The Bursting of Bubble Fusion

Critics assail a Purdue scientist who said he had created the most exciting physics of the decade

BY ERIK VANCE

WEST LAFAYETTE, IND.

RUSI P. TALEYARKHAN'S LABORATORY IS buried deep within a squat, gray building a few miles from Purdue University. It sits on a wide parking lot, which melts into the flat expanse of northern Indiana, giving the building the sense of a solitary boat on a quiet sea. Inside, through a maze of hallways, Mr. Taleyarkhan's laboratory looks like many physics laboratories—a slightly messy spread of equipment, spare parts, and flasks. A few students bustle about in white laboratory coats, and there is a hum of running machinery.

From this ordinary scene, it is difficult to tell that the researcher was once said to have produced some of the most exciting physics of the decade—and one of the field's most acrid controversies, which to this day defies proper explanation.

Mr. Taleyarkhan has a round face and a strong accent from his native India. He has a piercing stare and a proud demeanor that can quickly turn to irritation, which has erupted often in the past year as he endured searing accusations from colleagues and the press.

Sitting in his office, he thumbs through a binder of photographs and documents. He pauses at a fuzzy black-and-white shot that looks like it is from a crime scene. The photo shows a wall at the laboratory where someone has scrawled a message above a series of signatures: "Here we created bubble fusion."

The photo marks a heady moment when a group of scientists, after months in a laboratory amid whisperings of a Nobel prize, felt compelled to mark a moment they thought was history in the making. But today, less than five years later, bubble fusion is a pariah in American physics, Mr. Taleyarkhan's reputation is in tatters, and he and his university face the possibility of a Congressional inquiry (See article on Page A20). Meanwhile two of the scientists who signed

the wall in the photo accuse him of sloppy work and even outright fraud.

A PROFESSIONAL MAGNET

Before arriving at Purdue in 2003, Mr. Taleyarkhan made his name when he published a paper in the prestigious journal *Science* in 2002. He worked at Oak Ridge National Laboratory at the time, and his paper detailed an experiment that created a cheap, small-scale form of fusion, using collapsing bubbles of ordinary acetone, the same solvent used in nail-polish remover.

If Mr. Taleyarkhan's analysis was correct, it would have huge implications for nuclear science. With just \$20,000 or so, any physics department could set up an experimental fusion laboratory, once the sole province of large facilities using vast amounts of power. (Lawrence Livermore National Laboratory, in California, for example, expects to spend more than \$4-billion by 2009 to build a brute-force form of fusion.) The paper made Mr. Taleyarkhan a professional magnet, attracting research partnerships and grants. Entrepreneurs started knocking on his door, and universities competed for the promising physicist.

Mr. Taleyarkhan's basic idea was to feed neutrons, the uncharged particles at the center of most atoms, into a sealed flask of acetone, making tiny bubbles rise in the liquid. He let those bubbles grow to the size of the smallest bubbles in a near-boiling pot of water, and then he bombarded them with high-frequency sound waves, which caused the bubbles to collapse violently.

The pressure of such a collapse creates heat, just as an engine piston does when it compresses gasoline, and Mr. Taleyarkhan said it was enough heat—10 million degrees or so—to actually fuse hydrogen atoms in the bubble. Unlike splitting an atom in a nuclear-fission power plant, though, nuclear fusion



LYNN FREENY, U.S. DEPARTMENT OF ENERGY

Rusi Taleyarkhan, now a professor of nuclear engineering at Purdue U., published a 2002 paper in *Science* about experiments on bubble fusion at a U.S. Department of Energy facility (pictured here) in Oak Ridge, Tenn.

theoretically creates a huge output of energy without the radioactive waste.

"It would basically solve every problem with nuclear energy known to man," says Richard T. Lahey Jr., a pioneer in nuclear-reactor safety and Mr. Taleyarkhan's former Ph.D. adviser at Rensselaer Polytechnic Institute.

Almost immediately, however, people began comparing the claim with another energy panacea that fizzled out, so-called cold fusion. In 1989 two researchers from the University of Utah held a news conference to announce a form of fusion that worked at room temperature. It turned out to be an explosive case of jumping the gun. Their experiment did seem to give off a little unexplained heat, but other researchers around the world could not reproduce the results. Cold fusion eventually became the laughingstock of physics.

With that scientific history in mind, skeptics of bubble fusion began criticizing the 2002 paper even before it was published. Later, in an unusual move, several reviewers of the *Science* paper shed their traditional anonymity and openly criticized the work after publication.

One such critic was Seth J. Putterman, a professor of physics and astronomy at the University of California at Los Angeles. Mr. Putterman quickly became the loudest in the anti-bubble-fusion camp and was awarded a Department of Defense contract to try to repeat the experiment, but he and his team never produced more than a few weak flashes of light. They concluded the process was a bust.

At first, Mr. Putterman and his colleagues simply said Mr. Taleyarkhan's work in detect-

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had been Ms. Kuutila's predecessor and was later invited to help find her replacement.

Mr. Hornett said that Cook Biotech "does not play a role" in personnel decisions and declined to comment further on Ms. Kuutila's dismissal. Mr. Bleyer says Cook Biotech "had nothing to do" with her dismissal.

Having settled their differences, Cook Biotech and the Purdue Research Foundation turned their sights on Dr. Badylak, ACell, and Dr. Spievack, suing them in June 2003 in federal court for patent infringement. The lawsuit is also where Cook and Purdue accused Dr. Badylak of secretly helping Dr. Spievack obtain a patent based on Purdue research.

Although a jury in July 2005 initially found ACell guilty of infringement, that verdict was overturned last August by a three-judge panel of the U.S. Court of Appeals for the Federal Circuit. The full appeals court declined to consider Purdue and Cook's appeal, and the ruling now stands.

The charges against Dr. Badylak never even got before a jury. Early in the federal trial, the judge found no basis for the allegations. But Purdue and Cook Biotech still contend that Dr. Badylak played a role in the ACell patent, and Purdue officials have raised many of those allegations again as a defense against his state-court lawsuit. No date has been set for that trial.

'THIS IS BUSINESS'

Dr. Badylak calls himself a reluctant plaintiff against a university with which he had a long history. He received his undergraduate, Ph.D., and veterinary degrees from Purdue, and three of his children attended the institution. "I would have never sued my university" if things hadn't gone so far, he says. He finds Purdue's conduct harder to understand than Cook's. "To Cook this is business. They sue everybody," he says. "But it's a different story for a state-run, not-for-profit institution."

Purdue's willingness to let Cook sit on the inventions is troublesome, he says, particularly as time is ticking down on the patents. He says the liver ECM's, in particular, show strong promise for treatment of liver damage. "It's not good for the field because nobody is developing that particular ECM for the thing that it is good for," he says.

Cook's license for the liver ECM is not exclusive, and Purdue says it is upholding its obligations under the Bayh-Dole Act by making the patents available to other companies that show interest. Mr. Hornett says none have.

Dr. Badylak and others say it is unlikely any ever will: A broad, nonexclusive license makes it impractical for any other biomedical company to invest in developing a product because it would know that Cook or others could come in at any time to compete.

Cook Biotech itself faces some competition. Cleared of the infringement charges, ACell has begun delivering versions of its product to the U.S. Army for a clinical trial and is gearing up to begin commercial production on its ECM's by mid-2008. The company expects to develop products that compete with Cook Biotech and with those made by DePuy.

Richard R. Tarr, a former DePuy executive who once oversaw the company's relationship with Purdue, says it has been sad to see the Purdue-Badylak story unfold. "Frankly, I think Purdue lost," he says. "They really had a technology that they could have used as a basis for growth, and they let it go."



STEVE KAGAN FOR THE CHRONICLE

Lefteri H. Tsoukalas, former head of Purdue U.'s School of Nuclear Engineering, raised questions about Rusi Taleyarkhan's bubble-fusion

How a Scientific Bubble Burst

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ing fusion was sloppy. But as time went on, the accusations escalated.

"If a scientist feels they've made a great discovery, it's their obligation and joy to convene other scientists from other schools to come to their lab to observe it," Mr. Putterman says. "As soon as that doesn't happen, that scientist has to be prepared for the backlash of the scientific community."

When Mr. Taleyarkhan joined Purdue as a professor of nuclear engineering in 2003, his graduate students and colleagues worked feverishly to confirm his work, believing they were in a race with laboratories all over the world to confirm bubble fusion. But those other laboratories never reached the finish line. None of the world's 60 or so bubble experts and fusion scientists trying to duplicate the experiments had managed to make them work. There were grumblings that Mr. Taleyarkhan provided poor details of his design and withheld his raw data. And in his own school, scientists were growing skeptical.

"Initially we thought, 'Well, maybe he did it once and couldn't do it again,'" says Lefteri H. Tsoukalas, who was head of the School of Nuclear Engineering when Mr. Taleyarkhan worked there. "But he was very adamant. 'We do it all the time. We just press the button and do it.' Then we thought maybe it was just sloppy work. He got carried away; you know, sometimes people talk themselves into something."

Eventually, Mr. Tsoukalas says, he had to act on his doubts. After stepping down last year as head of the school, he began talking to the news media, taking the critics' side and demanding that the university investigate Mr. Taleyarkhan for research misconduct.

In response Mr. Taleyarkhan says that Mr. Tsoukalas was happy enough to take credit for promising early results, and his was the first signature on the wall in the laboratory. The current controversy has more to do with personal differences than with

science, says Mr. Taleyarkhan. "I can defend the science and the technology of what we did. But when you get to human issues, they are far, far more complex," he says.

Mr. Tsoukalas says he wanted the experiments to work. "I would be the happiest person in the world if this was true because I worked very hard to bring this guy here," he says. "I cannot tell you how much time I spent trying to accommodate and make Rusi succeed. But I wouldn't go as far as covering up fraud."

DOUBTS ABOUT DATA

As always in science, the heart of the debate is whether or not anyone has independently repeated the bubble-fusion experiment. For several years after the initial *Science* paper, nobody reported any success, even though Mr. Taleyarkhan claimed to successfully do the experiment regularly.

Then, in 2005, two Purdue graduate students published a paper saying they had duplicated the results. Mr. Taleyarkhan called for a press release announcing independent confirmation, seemingly unconcerned that the lead author, Yiban Xu, was his own student. Mr. Taleyarkhan considers the experiment independent because he had not yet joined Purdue when Mr. Xu conducted the test. But to critics like Mr. Putterman and his former student, Brian B. Naranjo, at the University of California at Los Angeles, the report seemed suspect.

Mr. Naranjo, now a postdoctoral fellow in Mr. Putterman's laboratory, says it all comes down to a single graph. Scientists can detect fusion reactions by measuring newly freed neutrons, similar to those fed into the experiment, pouring out from the glass jar of acetone. Mr. Naranjo's graph shows the energy spectrum of the neutrons he expects from a fusion reaction, next to the energy curve taken from one of Mr. Taleyarkhan's papers. One is a graceful sweep, like a curving ramp, while the other is a bulbous arc. "If it were fusion happening, it would have

been a statistical impossibility" to get the curve that Mr. Taleyarkhan reported, says Mr. Naranjo. The graph, however, was created with limited data he took off a journal Web site because Mr. Taleyarkhan refused to share raw data with his detractors.

To settle the matter, the Department of Defense group that was providing financial support to both Mr. Putterman and Mr. Taleyarkhan came to Purdue to investigate for themselves. It was here, after the demonstration, Mr. Taleyarkhan says, that his critics dropped their biggest bomb: an alternative explanation for the neutrons.

They said the sweeping arc on Mr. Naranjo's graph did not look like fusion but like californium 252. Californium 252, a radioactive metal commonly found in physics laboratories, constantly sheds neutrons that can pass through just about anything. It was those neutrons, Mr. Putterman's team says, that were fooling Mr. Taleyarkhan's sensors into showing a fusion output.

In order for this new claim to be true, Mr. Taleyarkhan would have to be going to considerable effort to hide a piece of the metal near or in his experiment, along with some kind of device that shielded it and unshielded it as adjustments were made with equipment. Without such a shielding mechanism, any californium 252 in the laboratory would have registered even when the experiment wasn't running.

In science, calling a researcher reckless is a forceful claim. Explicitly calling him an outright fraud is something even the strongest rivals avoid. Not long after the pivotal visit by the Defense Department group to Mr. Taleyarkhan's laboratory, the journal *Nature* published a series of articles online on March 8, 2006, exposing inconsistencies in his work and suggesting fraud. Scientists who had signed the wall in the laboratory now accused him of practicing questionable science and even, on one occasion,

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of removing laboratory equipment that was not his.

After the *Nature* articles, Sally Mason, provost of Purdue, hurriedly organized an inquiry committee in March 2006 and said it would have a decision by June. The focus of the inquiry was not whether Mr. Taleyarkhan had created bubble fusion, but whether he had interfered with the subsequent supporting demonstration by his student, Mr. Xu.

During this time, Mr. Taleyarkhan says, two more scientists came into his laboratory and independently verified bubble fusion. Mr. Taleyarkhan contends that both were experts and did their work independently of him. But in interviews, both researchers contradict aspects of that account. One of those scientists, Edward R. Forringer, a professor of physics at LeTourneau University, in Texas, says he is certainly not an expert. Nonetheless, he says he is confident that his results do support the reality of bubble fusion.

The other scientist mentioned by Mr. Taleyarkhan is William Bugg, a retired particle-detection specialist from the University of Tennessee. He says he checked for californium, but at a certain point he had to trust Mr. Taleyarkhan and his laboratory. However, he freely admits that he did not actually conduct the experiment. He watched Mr. Taleyarkhan do the work.

After conducting its inquiry, Purdue sided with Mr. Taleyarkhan, saying in a brief February 2007 news release that there was no evidence of misconduct. But the questions have not subsided. Two weeks ago, the House Committee on Science and Technology started an investigation, saying that it had concerns both about the research itself and about the way Purdue conducted its inquiry.

POST-MORTEM

Researchers have not totally given up on Mr. Taleyarkhan's idea. Many who criticize his methods, and even those who accuse him of fraud, reluctantly say bubble fusion may work someday. However, that day will probably not be soon and may not be in the United States. Mr. Lahey, Mr. Taleyarkhan's former adviser, still has hope for bubble fusion and is an avid supporter of Purdue's work, but he says that federal money for the technology has all but dried up in this country. He looks to Europe, where he says laboratories are still working on the problem.

"For any of us who've been involved with

it, there's no doubt that it is real," he says, adding "I've learned in this business it ain't over 'til it's over."

The problem, says Mr. Lahey, is not with Mr. Taleyarkhan's science, but with the way he described to others how to build the cell. "It was like a chef who knows how to make a great meal, but he doesn't know what's in there," he says. Mr. Lahey says the first cells were built "to taste," moving a piece here, shaving down a piston there, leaving other researchers to more or less do the same.

Mr. Putterman rejects that assessment and says the problems were more basic than a few tweaks to the system. He adds that he had more to gain than lose if Mr. Taleyarkhan had succeeded. "I would be thrilled if he was right and he had fusion," he says.

Another person hoping to gain from bubble fusion was Ross Tessien, president and founder of Impulse Devices Inc., in Grass Valley, Calif. He has spent \$4-million trying to get bubble fusion to work, even hiring Mr. Taleyarkhan as a consultant.

Mr. Tessien says he still thinks of Mr. Taleyarkhan as a friend but "walks the fence" as to whether Mr. Taleyarkhan ever created bubble fusion. He says Mr. Taleyarkhan's designs were impossible to follow, and the machine was prone to problems.

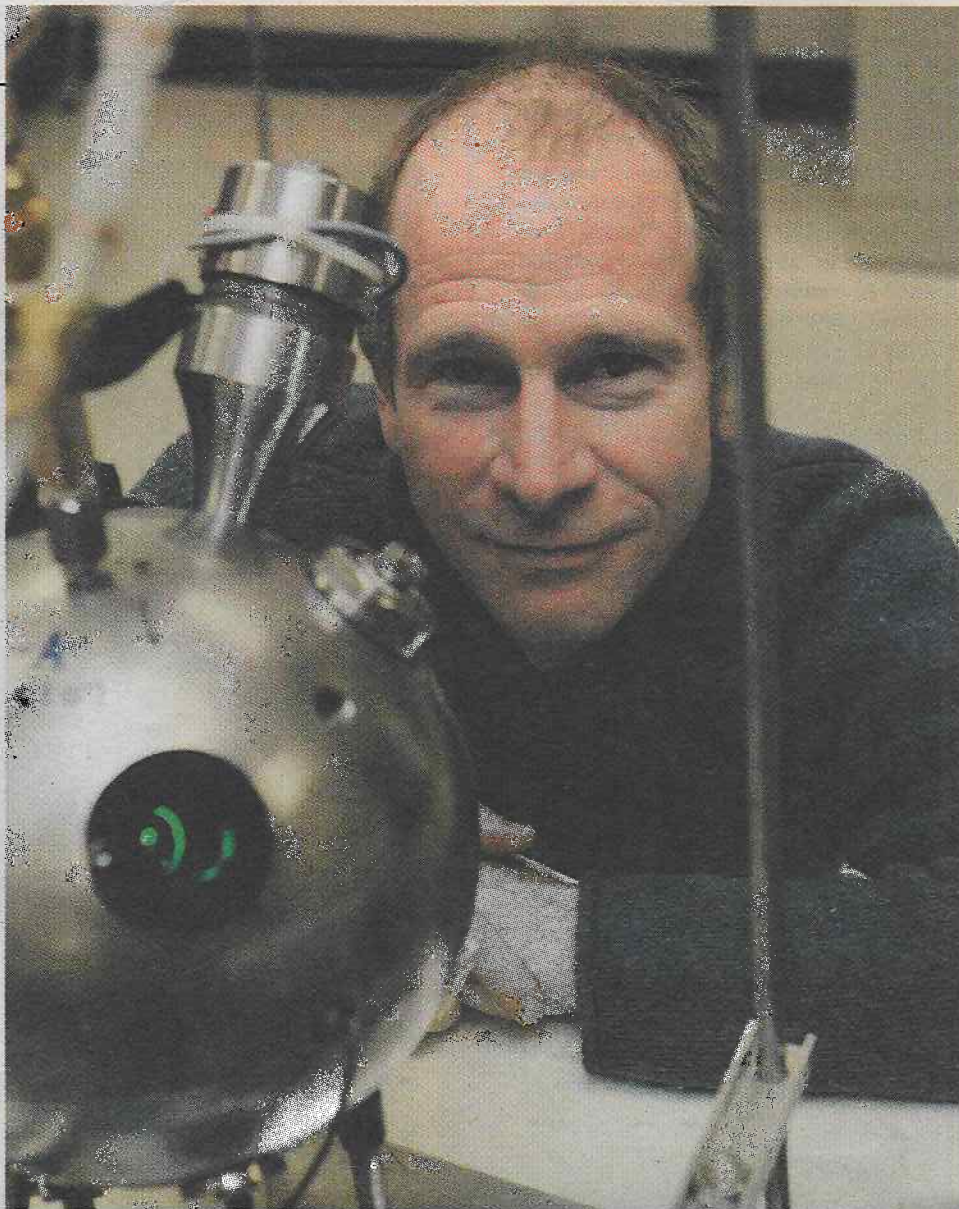
"It's a nightmare to run it, and it breaks," he says. "The only reason we got it to run as close as we did was because it was our sole purpose in life."

However, the California engineer says he had some success with Mr. Taleyarkhan's design. After years of tinkering, Mr. Tessien claims to have achieved temperatures up to almost one million degrees in the collapsing bubbles. But bubble fusion would require the bubbles to collapse hard enough to reach 10 million degrees, a vital factor of 10 times more that is difficult to achieve.

THE COST OF CONFLICT

Today, Mr. Taleyarkhan has little regret for how he presented bubble fusion to the world. Rather than spending more time helping scientists like Mr. Putterman, he says he wishes he had ignored them altogether.

Mr. Taleyarkhan's unwillingness to help anyone he sees as having "vested interests" seems to breed mistrust in critics, who call him over-secretive. Mr. Lahey says Mr. Taleyarkhan was one of the best students he ever had, but he also says the man can be a "bulldog" who sometimes irritates the egos of other scientists.



THOR SWIFT FOR THE CHRONICLE

Ross Tessien, president and founder of Impulse Devices, has spent more than \$4-million in pursuit of workable bubble fusion.

Sitting in his laboratory on the day Congress announced its investigation, Mr. Taleyarkhan conceded that the controversy has taken its toll on him. He has become an outcast at conferences, bubble fusion grants have dried up, and most of his research financing is dwindling. Since March of 2006, he has had a pervasive ringing in his ears.

"The doctors say it's stress related," he says.

He walks around the laboratory and points out the work his students are doing using bubbles to detect radioactive material. Many of those students are undergraduates, and he admits he has had to turn graduate students away because of "internal problems" in the school.

Neither he nor his students are now doing any work in bubble fusion.

Several students gather around one apparatus, and Mr. Taleyarkhan explains that by spinning a water-filled glass tube, they can "stretch" the water and create pressure on a cork at the top of the device. Then, using a laser to release that energy, they can fire the cork at the ceiling at "near-lethal speeds."

The students start the device, and the tubes begin to spin. Finally, Mr. Xu, who still works in the laboratory, turns on the laser. The cork pops out anemically and bounces to the ground. There is a brief disappointed silence. Science can be hard to do when everybody is watching. ■

U.S. House Panel Reviews Research-Misconduct Investigation at Purdue

IN AN OFFICIAL REQUEST for documents from Purdue University, a U.S. House of Representatives committee has questioned the credibility of the university's investigation into research misconduct by one of its scientists.

In March 2006, Purdue's administration hastily put together a committee to look into the research of Rusi P. Taleyarkhan, a professor of nuclear engineering. The thrust of the inquiry was not to determine whether Mr. Taleyarkhan had achieved bubble fusion, which he claimed to have done, but whether he had ghost-written a paper by two students, Yiban Xu and Adam Butt, confirming his own work.

Under federal guidelines, reviews of research misconduct should be based on written allegations and come in two phases: an

open-ended inquiry and, should the inquiry find cause, an investigation. In July, after four months of inquiry, Purdue announced it would convene a more formal investigation. Including a fact-finding committee formed by the head of the School of Nuclear Engineering, this would be the third Purdue committee to look into the matter.

In an interview, Sally Mason, provost of Purdue, said the first formal written allegations of misconduct against Mr. Taleyarkhan came in September 2006 from Lefteri Tsoukalas, head of the School of Nuclear Engineering. However, Mr. Tsoukalas points to e-mail messages sent to the provost's office as early as October 2005 in which he questions the authorship of Mr. Xu and Mr. Butt's paper. He also points to a June letter to the provost's of-

fice written by Kenneth Suslick, a chemist at the University of Illinois at Urbana-Champaign and a critic of bubble fusion, that made serious accusations.

Though Mr. Tsoukalas says he spoke to the inquiry committee, neither he nor Mr. Suslick were contacted by the investigation committee, nor were two other scientists who had made detailed accusations. Ms. Mason declined to comment on who was contacted by the committee, but said she felt the work of the committee was thorough.

The Congressional letter cited a lack of meticulous inquiry as well as a report by the original fact-finding committee. In that report, Mr. Butt said he did not write one of the confirmation papers listing him as an author and never even read the other before it was published. In the letter, Mr.

Xu told the Purdue committee that he could not "state who had written the final article, saying it would jeopardize the 'confirmatory' nature of the research."

Ms. Mason stands behind the second Purdue committee's eventual finding that there was insufficient evidence of research misconduct. Instead, she says the charges are related to internal strife in the department.

"What you've got are really some individuals here who, for whatever reason, are pretty unhappy with each other and are going at it tooth and nail," she says. "And they really like to use whoever they can as a scapegoat to make a point."

In December, Mr. Tsoukalas stepped down as head of the school in protest, he says, of the administration's dragging its feet. —ERIK VANCE