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Undergraduate

Interview with Edward C. Morse

by Tiffany Horne, Mike Moses, Jennifer Yang, Felicia Linn, Stacy Hsueh, and Emily Fox



BSJ: Can you tell us a little about how you got started in your career?

Morse: Well I came to Berkeley as a professor when I was 22 years old. When I was in graduate school at the University of Illinois in Champaign, I would come out here and work at Livermore in the summers of '75 and '76. So then, in '78 my advisor contacted me and said that he had gotten a phone call from Berkeley, and they were looking for an assistant professor in my area and [I got the job].

BSJ: So what was the first project you were working on at Berkeley?

Morse: I did theoretical and computational work when I was a grad student, so my first project was a computational one I did with this brilliant, young Yugoslav student who was actually from Macedonia. I went from there and started a big project, which involved building a spheromak, which is a fusion confinement plasma system. That involved scrounging lots of microwave gear from the military. The military's been a great source of protein so there's about seven million dollars of hardware downstairs that I've scrounged, but that was what got me a trip to Kwajalein Atoll in the South Pacific where I brought back this huge collection of radar tubes called klystrons which are sixteen feet long and the largest tubes ever made.

And then up in Thule, Greenland, which is eight hundred miles from the North Pole, they were decommissioning a radar base up there and replacing it with something newer actually, and so I brought back about a quarter mile of this huge wave guide. Ultimately I scrounged what's called a rotating target neutron source, which is over there, and that's the largest source of 14 MeV neutrons in America. 14 MeV neutrons are the ones that you make with nuclear fusion. That actually led to some projects for Livermore, which were funded to study a lot of neutron detectors and things of that nature for a big project they led there called the National Ignition Facility, and we also got involved in making some isotopes for support for the community that's looking into third party nuclear detonations. In this case, India announced that they were testing nuclear weapons—even announced that one of its tests was thermonuclear, so then there are special things that happen with 14 MeV neutrons in rock and especially unique Argon-40, Argon-37 from a calcium n, alpha reaction.

That kind of fermented for a few years, while the rest of the scientific community changed a lot, and then I had a deal: there was an

infrastructure type funding program from the Department of Energy, and they wanted the universities that do nuclear

to get together and support each other because they're dwindling in number. And so this guy in Washington decided that what we ought to do is have some sort of consortiums of nuclear engineering departments, and we fell in with one from Oregon State. UC Davis doesn't have a nuclear engineering program, but they happen to have a reactor, which was perfect for us because we decommissioned our reactors, so we're able to send our students up on Saturday and use the nuclear reactor without having to pay for it.

BSJ: What happened with the programs at UCLA and UC Santa Barbara?

Morse: They collapsed, but the one thing about Berkeley is that we have a lot of inertia. Programs survive if the faculty want them to. But anyway, I thought we'd done the smart thing by getting rid of our reactor, and I put the RTNS where the old reactor was, so we convert our primary radiation source from fission to fusion, I'd say. So back to the infrastructure grant. My department chair forged my name to this grant as principal investigator because his chairs weren't allowed to do it and I wasn't around in the summer because we didn't have a reactor. The universities who had reactors got a most of the money. I was sitting around with a few of these guys and I

suggested that we throw a summer course on how to find plutonium in suitcases because that was getting to be an important subject. It wasn't really a big deal at the time, but I could see that this was coming. And so it came—it was *after 9-11*, but not yet to where we have gotten on this subject now, but you know that's what you really ought to do because for no other reason whether you believe in this threat or not, that's where a lot of jobs for our graduates will be.

So we did hold the summer course and it was taught at Idaho Falls during the first year. It was decided to be done at a national lab campus because they already have the infrastructure and the lab experiments and the people that can be reassigned to do that without having to pay for them. The course was reasonably successful and then Livermore heard about this, so I worked carefully with these guys to do it again, this time at Livermore. And so then that was the mother of all nonproliferation courses—and I attended that one myself because it was good. For example, there was a fundamental lecture on basics of nuclear weapons. You don't have to have a security clear-

ance so you can know everything, but you have to know all the basics. So they have a little course called Nuclear Weapons 101 that was taught by the former head of 'A' Division,

which was the nuclear weapon design unit at the lab, and we had a lot of good lab experiments. The lab really just bled financially to put this on because I think the support was like 45 thousand dollars. To do this 2 week course involving 20 people, the real cost if you were an accountant would probably be a million.

BSJ: So this led to the formation of DoNuTS?

Morse: Yes. So I got it all in that, and I actually learned something about it, and saw what the real technical challenges people were facing firsthand. And also, in order to get the Berkeley students involved I had to qualify for credit course at campus. I put in my own set of follow-up lectures and laboratory experiments here. And I thought well this won't hold a candle to Livermore's but the students really liked it because I treated them like students. We started with the basics you know "what's a gamma ray? What's a gamma ray detector? What happens next?" It all worked out really well and so then that inspired me farther. Then there was a funding opportunity in Washington and it was called ARI, which stood for Academic Research Initiative. I think this was spawned because homeland security, in general, and this group called Domestic Nuclear Detection Office (DNDO) within that, had been called out on the carpet in congress, and

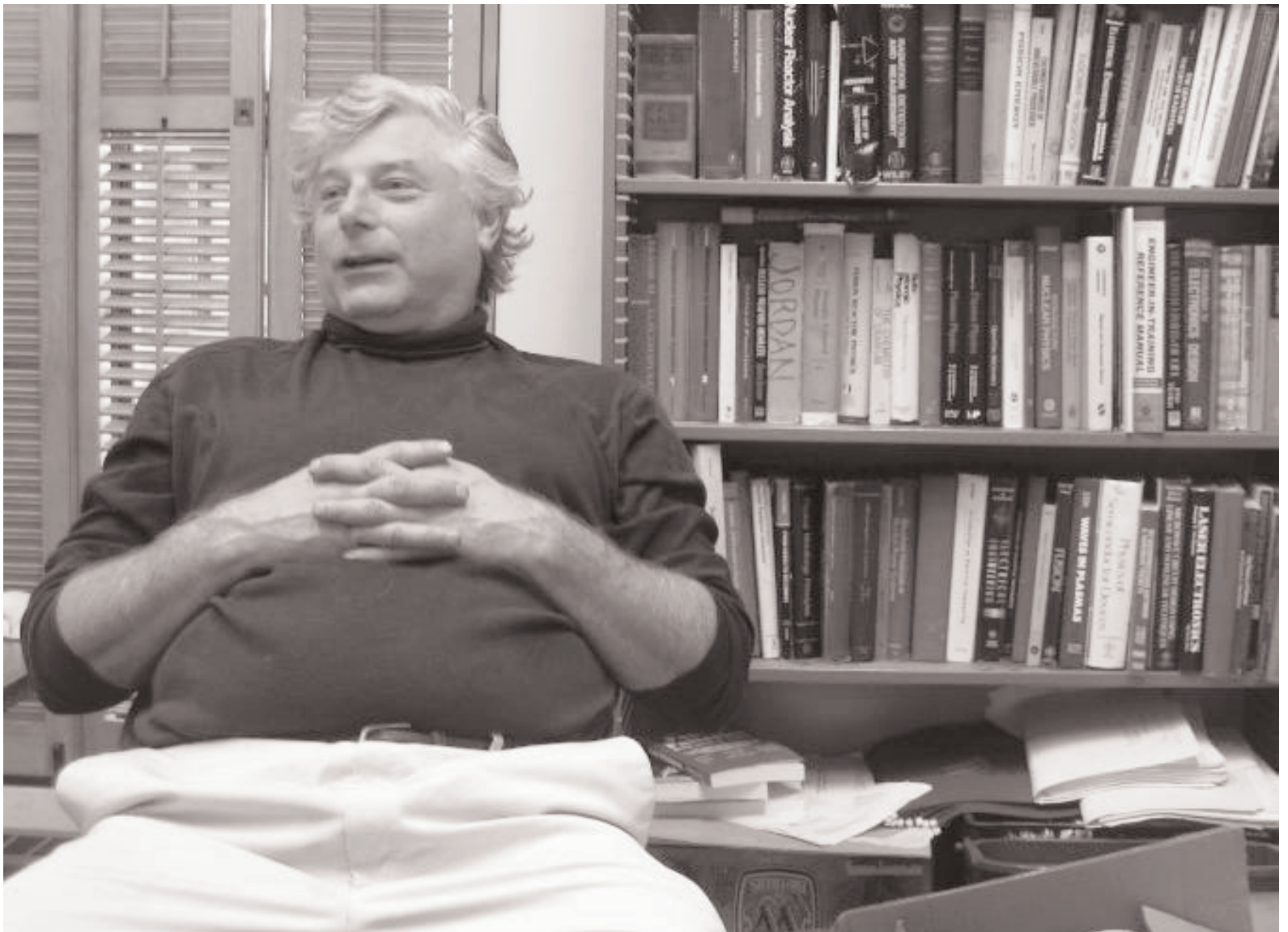
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basically I don't think because they did anything wrong but just by being maybe too honest for politics.

We have to rethink our whole methodology of operations and not just put more money out to "Go-Cos" (government contractors), but to try to bring in universities with their broader view. And so, they put 58 million dollars out on the street to do that, and they had NSF run it. Basically DNDO has a lot of smart PhD scientists from Livermore, Los Alamos and elsewhere taking 2 year and 3 year rotations in Washington. So they got a lot on their plate and the last thing they want to do is suddenly get embroiled in grantsmanship issues. So DNDO ran the offering through NSF.

Then I read about the 3 classes of proposals being a large award, a medium-sized award, and a small award. The large award said the project had to be multi-disciplinary, multiple people involved and they gave a laundry list of all the things they wanted done. So I looked at the list and the nice thing about Berkeley is that there is kind of a defense in depth; we don't have any weak sisters among all of the programs here. I looked at it and one of them was for example, using Bayesian inference modeling for informed decision analysis. Well that has nothing to do with physics, but it is

industrial operations and research, right down the hall from me. I asked Dorit Hochbaum in IEOR to represent that area as a co-PI. Also right down the hall here in nuclear engineering is Brian Wirth, who is a Presidential Young Investigator who was hired from Livermore with a background in materials and radiation interaction. And then another area was networking sensors and detectors together, so there was Jim Siegrist, who's in the physics department but also has the title of Head of Physics Division for the Lawrence Berkeley Lab. Then the other area was straight nuclear physics. Well we have a Professor In Residence from Livermore: Eric Norman who's actually been on the author list for the discovery of new elements, and he goes and looks for neutrinos in caves in Italy and all that sort of thing, He's the real article, a real nuclear physicist with as good a reputation as any in the field. So I looked at the list and I found the best person I could in each one of these four areas; I call it Manhattan Project-style management. You find the smartest people you can, doing the things in their field, and then you let them do it. I had designs on turning it into an academic program because the real currency is our future students; about 50 bright young Berkeley PhD's.



BSJ: And that's what the grant was looking for as well.

Morse: Absolutely! They're really tuned into the people side of this. You see if they wanted a technical solution to a technical problem, and they did it on competitive bid, they probably would have poured more money into companies like Halliburton or Passport Systems or, you know, some other company like that who has a long history of delivering hardware in this area. They are contracting work to many such companies now, but they need something else as well. They need a future workforce.

But you know, there is a practical side to Berkeley historically, and we may well design a better mousetrap. But we're not working in a vacuum either. We're trying to do some of the broadminded things and not trying to beat Livermore at their own game or trying to beat Passport Systems at their own game, which are clearly defined roles, but to cooperate with them and produce the students that go ahead and do the next thing. Even though this is a brand new field, I already have established a reputation in that area. Two of the students that are in Washington at Homeland Security are PhD graduates from this program.

One of them was one of my students.

Another one is a science advisor to the House Committee on Homeland Security. He was my PhD student from only two years ago

and that's kind of a meteoric rise for him. And that's the best you can hope for being a professor around here. One of my students is now Chief Engineer for General Electric Nuclear. Got them under every rock now, you know, and every kind of academic position and industrial and government, and hopefully they'll keep me out of trouble someday.

BSJ: To move on to more technical things, can you talk about the major applications of your research in nuclear detection?

Morse: The grand challenge problem has to do with terrorists or some organization trying to conceal weapons grade materials, U-235 in particular, in cargo containers. That is hard because a cargo container is usually 8 feet by 8 feet by either 20 or 40 feet. A basic concept of the interaction of radiation with matter is the mean free path. That's the distance particles travel before they interact, and the best you can hope for for fast neutrons or energetic gamma rays is maybe a foot. The number of particles drops a factor of e for every mean free path. So if you have a pit (a nuclear weapon component) in a container, that's emanating a signal, you have 4 feet to the edge. So that's a pretty good

attenuation. And Uranium 235 in particular does not cooperate because it only has a 185 kilovolt gamma ray which is very low energy, a little bit above dental x-rays. The mean free path for this gamma is extremely short.

BSJ: What would be a high-energy gamma ray?

Morse: A high energy gamma ray, for example, would be Cobalt 60 has 2: one at 1.17 MeV and one at 1.33 MeV. Or when you're looking for oil you use 14 MeV neutrons in these little tubes that can go down holes and then there's a 4.4 MeV gamma ray that comes back for carbon which makes it a unique fingerprint. That's an example of a case where now you've got a source here, and the oil is maybe a foot away from the source and you've got the detector collocated with that thing, so that the interaction distance is this much (uses one hand) and you're using radiation identification that works. In the case of the cargo container you've got distances that are many feet and you have to allow all angles to come in and out. And you got radiation coming out from U235, particularly this 185 keV gamma that won't travel very far. So it's a very hard problem. And not only that, the natural background radio activity is one

thing, like noise, but, what you call "clutter" is usually a more important thing.

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once. What happens here there is that there are a lot of radio-activities in cargo for various reasons. For example toilets are made out of porcelain, which is made out of clay. Clay has thorium in it, and thorium is radioactive. Bananas have a lot of Potassium 40; any kind of vegetable material has a lot of Potassium 40 which also includes fertilizers. There's Uranium that is in the form of dirt; every cubic yard of soil at Berkeley has 3 grams of uranium. You get a lot of uranium signal, whether it's from a nuclear device or not. That's an example of the problem. And potential solutions include things like Nuclear Resonance Fluorescence, uscendas which requires highly tuned gamma ray signals. You might have, for example, a 1 MeV gamma ray resonance that is off-resonance at 1.00001 MeV... That kind of micro-tuning is needed. Some line in millions of electron volts plus or minus, say, seven eV.

BSJ: You send in the rays, and then what is it that you're measuring? What's coming back out?

Morse: In this case what you can do is you can send in 2 signals nearby in energy. One is directly at the resonance, and the other is not. So the absorption has this big spike at the resonance. You see the problem is, if you have two dif-

ferent gamma rays, like one at 500 keV, and one at 1 MeV, the attenuation characteristics are very different in the material. In the case of uranium, it attenuates its own radiation on the way out, so sometimes you're only measuring stuff from the very surface of the material. It's hard, but if you have 2 gamma ray energies that very close to each other, the attenuation curves in most materials will slowly changing with energy so that don't change much from one electron volt to the next at one million. If there is a particular resonance for one nucleus, for example U-235, by doing that, you can get a specific fingerprint that detects U-235. If it works at all, it will be a very accurate method.

You can't take a long time to test every container in a port. The thing is, disrupting commerce is also real terrorism. In this case, the terrorists have it made, because they don't even have to do anything! They don't have to send threatening e-mails, or phone calls, or anything. They can sit back and let Congress decide we're under threat and let them make rules, like we want all cargo to be inspected. That just has a tremendous impact on the economy. When you get a false positive, it generally causes bad things to happen. For example, there were cases where they pulled out the container at Long Beach, and every longshoreman decided to take the rest of the day off, because *it's not safe here*. Of course, the false negative will ruin your whole day. That means something gets through and becomes a bomb and takes out a whole city. So you can't have that happen either. So it's a very difficult problem to deal with and we're hoping to find solutions everybody can live with.

The other problem is that there are things that you can do where you just flood the containers with neutrons, let's say. And if there's any fissile material inside, it will fission and you can find it no problem. But then what happens is, you're irradiating cargo. If it's food, you're making radioactive contamination in the food. And what if they're stowaways? One of the primary ways we get illegal immigrants from certain countries here is inside containers.

We are also interested in taking detection methods and turning them into imaging methods. Anything that you can do to detect something will ultimately turn into something you can image.

In fact, that's another thing common in engineering called



Bayesian methods, where you try to make an image recognition system that works something like the human brain. As a human being, you don't scan an object at night that you can't see very well and do an FFT of it and reconstruct an image. Most engineered imaging is based on this process. As a human being, you have a short list of things that go through your head of things you don't like. That's the kind of system that we'd like to maybe ultimately go with for cargo inspection. And the scheme could be learning-based, you see. If you do have a container you pull over for detailed analysis, then the next time you'll be that much smarter from having the data somewhere to do that. It all pulls together, but there are a lot of facets, so it's good for a multidisciplinary approach to this. And it's going to be a long haul to do this. It's not going to get that much better overnight. We've been incredibly lucky, or clever, depending on your outlook, with simple law enforcement methods. There haven't been any detected movements (of clandestine weapons grade nuclear materials) in the U.S. But in Europe, there must be 10, 15 documented cases.

BSJ: Are there teams in other countries that are working on this type of thing?

Morse: This is becoming one of the oldest games of town, really; there are different facets to it. The problem I just described is an example of what is called forensics. And that's the area which is suddenly the hot subject because they realized that there are only about eight people in this country that are good at that. And they mostly work at Livermore.

After you find something, what do you determine about its provenance: where did it come from? For example, you could figure out what mine the lead came from for the shielded container. You can tell where the uranium came from. In the case of uranium and plutonium, you can actually date when it was separated or manufactured, within a couple of weeks, sometimes. And with the basic detection thing, everybody has their own systems that they're working on.

We've had good cooperation with the Russians, and a lot of the material that has turned up we think has been of Russian extraction. Working really simple things, like introducing bar-code technology. We want to have at least that good of a system of detecting a stolen plutonium pits as we have at, say, for detecting shoplifted batteries or razor blades at Wal-Mart.

BSJ: How would you mark plutonium or uranium that you're manufacturing so that it can be identified?

Morse: You put a sticker on it.

BSJ: Just like that?

Morse: Yea, just like I said. Or you put an RFID tag, that's the new technology. It only works for a quarter-mile radius. It gives you back a signal and tells you it's still in inventory and what the serial number is... conventional techniques.

BSJ: Do you want detection? Do you want technology to be available to everyone, or just for the government?

Morse: Well, there are different answers to that question. But in general, the things is, science never works out well to have it classified,

because it comes out anyways. You can go on the Internet and find out a lot of stuff about nuclear

weapons and their characteristics. Furthermore, everything we do at Berkeley is unclassified. If it was a reason to have a classified component, it wouldn't happen here. That has been the situation for a long time now. But I would say,

I had designs on turning it into an academic program because the real currency is our future students.

most of the things we're doing aren't going to be of value to terrorists to try to find some countermeasures. If we go off and measure NRF cross-section of uranium, that's not the sort of things Osama's guys would sit around at night-time reading. One school of thought says, well, maybe you're just moving the dirt around. If you have this airtight security system for cargo containers at major ports of entry aren't you shifting the problems to smaller crafts coming in from Canada or Mexico?

Somebody once joked, that if you really want to smuggle plutonium or uranium what you do is put it in a brick of marijuana because we know that works. There's a lot of what you call *law* enforcement aspects to the problem in addition to the big science. And the other thing is, I don't want to get into the situation where we solve the problem completely we just need to isolate the container, put it in a low activity counting area for about 30 days and scan it. When you consider there is are about 200 million container shipments a year it's just not going to work too well. It's not a feasible solution. You're talking about one-minute inspections. You drive a truck real slow and pass the portal. We have systems like that now, they're just sensitive to clutter. If we set up a system that has a zero rate of false negatives and an acceptably low rate of false positives and works within the confines of cargo without leaving to some behavior modification to the particle shipping industry that could prove to be costly, then that would be good.

BSJ: Do you have any ways of improving detection?

Morse: We're picking up on a thread. We didn't invent it, but it seems to be the way to go now. A great deal of gamma ray detectors are uses semiconductors. And, if you've had some chemistry, you know you have to have something from row IV for a semiconductor, like silicon and germanium, or you have to have III-V compounds like gallium arsenide. There's a whole bunch of these out there and one of those that's becoming quite popular now is called CZT, which is cadmium zinc telluride, but it's hard to grow and fabricate this. The big buzz word now is called "combinatorial chemistry" and that's really a chemist version of: with enough typewriters and enough monkeys, you get Shakespeare. But you can do it in kind of an industrial setting where basically you can make wafers with gradients

in concentration of several different compounds, and you can make 10,000 new compounds in a day and have sort of have automated testing of

their physical properties.

People have designed semiconductors have worked on hunches. Well (working at 78 degrees Kelvin) has to do with the band gap in the material. If you have materials

with a low band gap they can detect radiation but there can be too much promotion of the carriers into the conduction band at room temperature-as we teach in E45. But anyway, the detectors are too noisy at room temperature so you cool them. Liquid nitrogen temperature actually happens to be 78K, so that's usually our benchmark.

What's even harder is 4 degree Kelvin technology which is liquid helium, You see the trucks go up and down Hearst Avenue with liquid nitrogen: LN technology is common. When you go into laboratories, you see LN-cooled detectors. But those weighs about 400lbs. In the field the chilled detectors might have an external Stirling engine to do the refrigeration that get down to LN temperature. Or thermoelectric chillers to do that. But that's still a lot of technology to carry around. What you'd really like is some ultra high quality room temperature detector, which for example, could be built into every cell phone issued to a government employee with a back channel. That kind of a thing would be a dream and there's a preliminary version right now called RadNet that we're fooling around with but the detection technology still leaves a lot to be desired.

Then the other thing is, you have Coast Guard people as the primary defense against a lot of this stuff, but they've already got to carry around all the stuff they have to have for the job, a flashlight, life vest and all that stuff they don't want to give up. And so if you're going to make them carry a 12-pound radiation detector because there's a probability of one in a million in their career that they're going to encounter a nuclear device, they're not going to be too happy about that. So we like to find better detection technology for that reason.

We also have investigated inexpensive, maybe throw away technology where detectors could be packed with containers and then processed at the other end. You could have something that goes clipped to a container that you could pull off at the port and read those. Containers are never opened at sea both for legal reasons and for practical reasons. So it's a pretty safe bet that the container has to remain sealed from one end to the other. When the container is at sea, it's usually there several weeks, and you can have a detector that takes a long time to get a signal - but you have a long time.

There's another line of thought that sounds really out there but it's kind of fascinating is using muons. Years ago physicist at UCB and LBL who got the Nobel Prize, Louis Alvarez proposed a scheme to find hidden chambers in pyramids using cosmic ray muons and this is the case where you don't have active interrogation in the sense of coming in but they'll be coming in whether you like it or not. The

muons can interact in a strange way, like high atomic number materials, they scatter into a narrow cone so maybe you can have some imaging equipment below the containers, depends on how much cooperation you have with the

shippers and, again, with long downtimes. My exposure to shippers is they want to help. The world now is organized into better-experience corporations

that actually want higher standards of safety and security than the government.

So that's where the nuclear detectors come in. You want to make a lot of them, make them cheaper, make them larger area. For example, in some ports, they don't have it in Oakland, but in some ports they do shipping direct to rail. Now the rail piggybacks one container on top of another. I think in some cases even three. Then suddenly you have this technology where the portal monitor is for one-high containers on a truck going by and suddenly it doesn't work for doubled-up containers. It may sound kind of dumb, but that's the kind of thing that really trips things up. So someone figured out that since they have a crane that comes down and picks up the containers, like one of those amusement park things where you put a quarter in and try to scoop, you could put a detector on the spreader bars of that: it has the same view of every container that comes in no matter where it's headed to. That's why we call it "intermodal traffic", because it's the same for a truck or for the rail or whatever, big ship, little ship, it doesn't matter. And so that's another opportunity where they can have an extended array of detectors - it takes a few minutes for that thing to go from one place to another, so you have enough time to get a better signal.

So everyone is investigating all the combinations and permutations. The really rigorous part of this development path is that Homeland Security have these red teams and blue teams, so when they have trials of new technology, they put other smart physicists from the other laboratory and then they scheme to try to pack the container so that you can't see the signal. Which is great, better that you embarrass Los Alamos than that you lose New York City. There are a lot of things that I think will be developed. But, again, what you're trying to do is take examples where other disciplines have had similar problems and have had some semblance of success. Like Jim Seigrist had his successes with his multi-element detector work in high-energy physics. They learned to detect rare events. Seeing one gamma ray that was absolutely, positively from U235 would mean something. The other thing is neutrons. Neutrons are really an important thing because there's seldom an in example in an ordinary environment to see very many neutrons. If you see neutrons, it means something is really odd in the container. Maybe something could make

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you get three radio stations playing at once.

one neutron for a reason that's totally innocuous, but it would be really rare to see, say, a hundred neutrons in a detector. Maybe that detector had a false trip, but it would be very unusual. False positives are difficult to deal with, though. Even if you're diverting 0.1 percent of containers, well that's still a whole lot of containers. That's an area that's ripe for growth.

The other thing I keep thinking about is that I had some experience in the oil industry and their methods of detection and using active methods to find oil underground are extremely sophisticated. They have customized electronics that don't work anything like the conventional stuff you see physics labs because it all has to handle 200 degrees centigrade and 40 G's and vibration. And why are they so good at it? Because they make a lot of money. If you made 2 billion dollars a year working in high energy physics instrumentation you probably wouldn't just have people running around with flashlights and black tape to build detectors. You'd do it in the way that they do it in the oil services industry: all facets of the problem get looked at in a holistic way because they take the detector out in the field, and you can't tell the oil company that you're working for, "could you please drill a little slower, because our detector isn't keeping up." That's not the way that business works.

So I'm trying to entice the oil services companies into sharing some of their signal processing technology. One of the things we're good at Berkeley is called ASICS, which stands for Application Specific Integrated Circuits. Your cell phone is full of ASICS chips at a medium scale. Not like in the sixties when we made the first logic gate equipped with 7 transistors on a chip and it had to be something everybody needed. Like function "A AND B" is the output when A and B are the input or some other really earthshaking thing. Now they have these customized chips. I want to develop some ASICS chips that could do some of the Bayesian pattern recognition on a chip, and maybe we could integrate the chips with detector elements. That relates back to advanced materials. So that's an area where three of my co-PI's can share some of their genius to do something that solves the problem. Those are some of our dreams right now.

Meanwhile I'm trying to scrounge a container to put downstairs so that I can fill it with publications from some of our emeritus faculty that's just sitting around in file cabinets anyway. And then I'm going to make a dummy simulated bomb that doesn't use Uranium-235 to make 185 keV, but uses some other relatively benign element that makes 186 keV gammas, maybe, so that it's a surrogate. And then I'll give the students some labs like:

Lab 1: Find the pit.

Lab 2: Play with this kitty litter for a while (Kitty litter makes a lot of gamma rays from the thorium in the clay.)

Just to show how hard it is and give people the basic hands on with this, because this is not charmed quarks or anything out there. This is a very practical problem, you've got to get your hands on a container, you've got to get your hands on a detector and you've got to get your hands on data that comes in from real world data situations and learn how to make something of that. We're not going to put out any impractical people to work on this problem.

Science never works out well to have it classified, because it comes out anyway.

BSJ: What part do you think undergraduates can play in this research?

Morse: There is this program called URO, which is Undergraduate Research Opportunity, through which we can hire undergrads and make them trainees and they can work 10 hours per week maximum. It works out to be \$2500 a semester. We have already hired some undergrads. We already had undergrads working on this project before the grant they can be pretty useful at times.

BSJ: Is it difficult to recruit or is there a lot of interest?

Morse: We've got some grad students on the payroll already. If this does get renewed, this is a five year program, so we have 7.1 million. That's plenty of money and we hold a couple of national conferences in Berkeley and we pay for some of the noteworthy people to come here and talk and get some exposure to our students. A condition of the grant is that the co-PIs, some of the students and I have to meet with the Homeland Security people supporting this grant several times a year, as do all of the other grantees. That will give us some additional exposure for recruiting. This effort in Homeland Security is bustling. They're busy expanding by another factor.

I suppose there's a political issue. To me it looks quite possible that we're going to have a change of political parties in the White House and I don't know what their take on all this is. There are certain things I've heard that kind of disturbed me a little from some of the candidates, and other things are kind of too reassuring. I don't really know but hopefully we'll stay in there and do this, because again, this is a long term thing and we're involved in making the bodies and doing some of the fundamental science. We're not really out there in Coast Guard uniforms at the Port of Oakland at 7 o'clock in the morning. Somebody else gets to do that. We should have continuity, because you know, getting a PhD is at least as long as the gestation period for an elephant, for the same reason... it's quite a beast. You

know it takes at least three years to get a PhD, if not six or twelve or whatever, and so I'm hoping we have the continuity to put out some pretty sharp people over time. And my new course has now been approved by the College of Engineering and it's called Nuclear Engineering 230 and that's taking the old Livermore course except it's going to be entirely taught at Berkeley. No citizenship requirements or anything to participate and open to anyone that's a graduate student in science or engineering to take. I'm looking forward to teaching this – that's one of my roles in this project. I think that will probably be a good recruiting element as well.

I don't know if it's just the luck of the draw that I have three women here, but you should also know that at least one of our post-docs is female, and one of the co-PI's is a woman, and it seems to me that this field will probably end up being more diverse than most in the world of nuclear engineering. It's my conjecture that women probably don't like to make bombs as much as men do, but it seems to me they like to find them. But anyway, the interest has been relatively diverse, so far.

Of the nuclear forensics people working in the field, many of them are from Berkeley in Chemistry and Chemical Engineering, and they came from this really famous enclave, which was where Glen Seaborg was from. They use chemical methods for radioactivity analysis and things like that. This area is closely aligned with this project. I would like to see more cross-fertilization on campus with that group. And I think that in the long run we're going to have the reputation that, these guys from Berkeley have not just learned nuclear physics, but they also had to learn some electronics and decision making analysis routines and image processing and they had to learn about material science chemistry as well. So then you have created the kind of people that cannot get buffaloed in their career later on because they suddenly had to shift divisions or departments somewhere and they know nothing about how they have to do the job.

BSJ: Any final thoughts or comments?

Morse: It's nice that suddenly you can hold you head up and be a Nuke. That's a big change. I started at Berkeley in January of '79 and March of '79 was the reactor accident at Three Mile Island. We've endured about 20 years of students coming out of California schools which had a mandatory segment called "Environmental and Consumer Education." We've heard horror stories where these teachers, which sometimes would have no background in any of this stuff, and would say, "Okay, put your head down on your desk and close your eyes and try to imagine a nuclear power plant accident." But now the numbers are returning to nuclear, and the interest is way up.. I don't personally do much in directly in connection to nuclear power but I'm glad that my interests in fusion and nonproliferation benefit

from the upsurge of interest in nuclear power. My feelings on that are kind of like Woody Allen's joke: "My brother's crazy, he thinks he's a chicken, I'd turn him in for therapy, but I need the eggs."