The end of my title says, "Here at last, and by golly, I hope this is one of the last of these sorts of talks that we'll have to give for a while." Historically, we go back to the date of my birth, when. NBS-Handbook 60 was published. Braestup and Wykoff, three years later published in their health physics text the basics of what we know and love today as NCRP Report Number 49. This was put out originally as an NCRP Report in 1972 in an English dimensioned, version and then metrfied in report 49, in 1976. And that's what we have been working with all these years. It was soon recognized that there were holes in NCRP Report 49 with regard to possible errors and lack of technology at the time. And so by the 1980's there were groups that were meeting to discuss problems with shielding and suggesting improvements in the methodologies and the procedures.

And this included task group 9 from the AAPM, formed in the late 80's and again it was more of a "get together and chat and let's pursue this alley or this highway, and see where we come out." Ted Villafona was the chair of the task group at that time. And then a few years later (problem with microphone, tape inaudible) a task group was formed to rewrite Report 49. It was initially again numbered Task Group 9. The group was renumbered a few years ago as lucky number 13 from the AAPM and Scientific Committee, No. 9 from the NCRP, formed (inaudible) lo these 13 years ago (back when I was young and eager and thin.) The co-chairs of the joint committee are Drs. Gray and Dr. Archer who we see smiling for camera when they weren't at each others throats or ours to get the bloody thing out. It's important to know that these folks are clinical

physicists, (or in one case he was clinical, now he's industrial. I'm not sure what an industrial-strength physicist is), but, we are active medical physicists. We are not in our little ivory towers; rather we are actually in the trenches fighting the good war, or the good battle of radiation safety every day. Other members include Bob Dixon, Bob Quillen from Colorado who is a retired state regulator. So we had him in on a few meetings to bounce things off of his regulatory brain. Bill Eide is an architect was at a few of the meetings to get his input and to remind us of the important concerns of the Americans with Disability Act. And of course Ray Rossi was an initial member and his common sense has been greatly missed. And here we see Dixon, both in his airplane and on one of his many jaunts. Link Hubbard is on the committee, Doug Shear and myself.

Eric Kiersely is named on the committee. He was an NCRP staff scientist who was really the first outsider, the first physicist coming from outside the group to look at what we had done by the late 90's and basically say, "what the heck did you do that for?" And so, he was the first one to independently review and criticize the document at that point. There are consultants named. One is a physician, whom I've never meet. Ken Case is a consultant and is participating and shepherding the report through it's final reviews. Wayne Thompson has been a very important name in the last few years. Wayne has basically reviewed the thing, redone the calculations, independent of the computer software that we used, developing his own and basically asking us "Why". So he has been checking with self consistency and again keeping us honest. Jack Krohmer was

initially a consultant and was at a few of the meetings early one. Jack did not suffer fools lightly. The first time we had such meeting I had just developed an early version of a shielding program and hurriedly slapped it on to the first lap top which I could get my hands on , which was a 286 IBM PC without a numeric coprocessor. And I loaded it without having tested it. wWe had a meeting in the afternoon, and went out for dinner, which of course included a couple of beers. When we came back I tried to demonstrate the thing, and the calculation took about 5.5 minutes on this laptop, during which time Jack gave me his unabashed opinion of the whole works. Basically he said "Simpkin why don't you pursue something worthwhile." And he may have been right. I don't know. Here we see some of the members vividly discussing the ins and outs of radiation

shielding at Bob's beach house, by the way, which you are all invited to this summer. We met on average twice a year to throw things at each other at the annual meetings of APPM, and the RSNA.,. And then we occasionally really did get together to try to do some work including a couple of sessions in Myrtle Beach. We decided early on to keep everybody up to speed as to what we were doing and the way things were going. And so we both published and hit the talk circuit. There were by Ben Archer's count 16 refereed publications that came out of this effort including five in Medical Physics and six in Health Physics. So basically, if you've had concerns, you have had, or you've had lots of time to complain about things. And on the talk circuit, Ben counted on the order of 31 refresher courses and invited lecturs and, again, hopefully this is the last one of that

series. And, it's not just been in this country, but has been in some very exotic places. So while I was going to the exotic confines of Madison, Wisconsin, a couple of years ago to be thrown to the wolves at the CRCPD, Dixon was off gallivanting. Here we see him participating in some native culture with an anterior view and a posterior view. And at the same time, Archer was in the UK and again we get an anterior and posterior view of him. (Laughing) By 2001, a draft had been prepared and was sent to the NCRP council for their review. And this was pretty much their attitude of the whole thing. Approximately two-thirds of them responded. There were many positive and for the most part minor editorial comments, but there were eight members who said, "What's going on here. We want these issues changed." And one member voted for outright

disapproval. So that was of 2001 and it was all based on the quarter of a mSv per year, issue I'll mention in a moment. But I'll take a moment to also mention the scientist from the NCRP staff who were assigned to the committee. Jim Spawn was the very patient "older uncle" who sat in on the committee and basically let us do our own thing for the first eight or nine years, which was very important because we didn't know what we were doing. Literally, we were making it up as we went along. So his non-input was quite important at the time. Then Eric's input as an initial reviewer was important. And then I'll say unequivocally, that Marv Rosenstein, who's been on the committee since 2001 has been instrumental in getting us going again. Basically, knocking the chucks out from our wheels and getting us rolling so that this thing gets out. The input from him has been

overwhelming important especially in the issue of quarter mSv per year for uncontrolled areas. And also re-writing the thing for what he terms as technical accuracy, I would say ten years ago, he had something that was accurate enough, but not from an NCRP or

ICRP standpoint. So it should be as good as it possibly can be at this point. So, final approvals on the re-write have been received from NCRP, July 9th, AAPM July 7th. And it's been assigned a number, 147 and with that title. The price is unknown. I think it will probably be more than a couple bucks. I don't think it will be more than a couple hundred. So somewhere in that range. I don't know if it will be this color either. So what's in the new report? It is shielding for diagnostic x-ray imaging devices only. So there is no radionuclide stuff or PET/CT stuff. If you want to talk PET/CT, knock on my

friend Mark Madsen's door, who is heading up a task group. And that report is expected by the end of the year. There are no therapy, treatment, or simulator machines. Knock on Ray Wu and Jim Dye's door because there is an independent task group addressing those issues. And the dental units have already been addressed as of last year. Mark Edwards and NCRP Report 145 published the update to the dental report and that includes shielding information for dental units. The report begins with important things like, "Who can do this", and who can do this is a Qualified Expert. And I quote from the report, "This is somebody who can do shielding. And it is a person who is Board Certified by the ABR/ABMP, ABHP, or CCMP, or CCPM." I don't know that if, I know, I don't know that there are more than one or two regulators who meet that

definition. So this is a fairly restrictive definition. So even though we may the ones who are certified in doing the shielding, the shielding designs are still being sent to state regulators who don't meet the qualifications as experts. Alright. The big stumbling block in the last four years has been the permitted radiation level in uncontrolled areas. And at the time, initially, or when the initial draft came out, we were still thinking in terms of expressing the limit, or permitted radiation intensity in occupied areas as radiation doses, ideally dose equivalence, but of course dose equivalence can't be measured and the conclusion a year ago was that we would change from dose limits to some nebulous term called "design goals". So what we're going to shield our occupied areas to are design goals, which are kermas. And if you are of my generation, you still

think exposure and you think survey meter readings, which is basically what's in NCRP 49. So P is a designed goal. It is the accepted radiation level in kerma in the occupied area. These need to be consistent with Report 116, but of course, 116 is dose based and not kerma based. Here we see a table of the designed goals. The old fashion numbers from NCRP 49 to the new report and we're looking at a factor of 10 decrease in controlled areas and a factor of 5 in uncontrolled areas. In controlled areas the P-limit is set by a fraction of the 10 mGy per year limit for new operations that's in NCRP 116 written as millisevert per year. The fraction we chose was a half basically to allow pregnant radiation workers to continue to stand behind control booths and push buttons. In uncontrolled areas, we have gone to the number in mGy, which equals the dose limit in

uncontrolled areas in millisevert, 5 mGys per year, which is a 10th of mGy per week for 50 weeks per year; excuse me that was the NCRP-49 number. The new report drops that to 1 mGy per year, which is .02 mGys per week. So these are the P-values that we will be shielding to. Diagrammatically here we see an x-ray clinic with a tech imaging this patient on the table. This tech can receive again 5 mGys per year for a fully occupied area in this as a controlled worker. These folks are in uncontrolled areas in the waiting area, the receptionist, as well as the visitor, as well as the lawyer in the office beneath this department can receive 1 mGy per year. This would be a fully occupied area for this individual as well as the lawyer. This visitor, may be this visitor down here, would be partial occupancy. So what happened to the ¼ millisevert per year? This is the language

and I want you to all memorize that. In NCRP 116, there is this strangely worded paragraph that says that if you can't guarantee that the individual is not going to get their dose limit from any other place, then you need to drop your limit to a ¼ of a millisevert annually. And that was the hang up since 2001. In 2003, the main thing that happened, that got us rolling again was that NCRP had a change in leadership. The new president Tom Tenforti stated that the ¼ millisevert per year recommendation in Report 116 goes back to NCRP statement #6 from 1984 dealing with air emissions. And the original intent was to limit public exposure to airborne emissions and not specifically for other sources of external radiation exposure. So NCRP, given the hullabaloo that they faced with this shielding document, is looking at Report 116 in toto and will revise that as

necessary. Now in the committee in the new report we argue that the P-value of 1.0 mGys per year in uncontrolled areas will satisfy the ¼ millisevert per year for the following very conservative assumptions that are made in the calculation technique. [NOTE ERROR IN THE TITLE OF THESE SLIDES; THEY SHOULD READ P=1 mGy, not 0.1] And you can read them here and they go down. There are three pages of these things. We are of course ignoring the patient attenuation. We're always assuming perpendicular incidents of the beam. We ignore attenuating items in the room. We have unfortunately unpublished, measurement that were made about 15-20 years ago, where we put TLD's inside of x-ray rooms. And inside of the rooms we saw nothing above permitted levels. So basically we were wasting our time with shielding. That's what

those TLD measurements indicated. We're always assuming worse case leakage scenarios. We're assuming large beams for all of our exposures that will conservatively presume large scatter contributions. The occupancy factors are extremely conservative and then the fact is that when we require shielding we also throw up quantized thicknesses of lead, usually multiples of 1/32 inch. And using the next greater thickness will decrease the actual dose or kerma in an occupied area to a level much below P. We're assuming minimum distances from the source to people in occupied areas. And then finally the complication of converting kerma or exposure into effective dose equivalent raises it's ugly head. The fact is that at energies less than 50 kV photons contribute a small amount to the EDE for the same numeric value of the kerma. So there

is less than 10-30% conversion from kerma to EDE. That's what new in this talk. Is there anybody who hasn't heard Simpken, Archer, or Dixon talk in the last five years about diagnostic shielding. That's what I thought. I'm almost tempted at this point to just turn off the slides and ask if there are questions. But I think the folks in the continuing ed business would yell at me because they want you to experience a full hour of intellectual stimulation. And those who are looking at this recorded many months from now are supposed to put some time and effort into reviewing this, but otherwise what you're about to see is the "same old stuff". Then let's go. I'll wake you up when I'm done, if you do the same for me. One of the issues in the report is the occupancy factor. This is the fraction of the beam-on time that the area needs shielding because

somebody is in the area. The task then is to decrease the radiation dose in that area (excuse me I'm using old terminology) the radiation kerma in that area to a value of P/T. And frankly there have been some compromises made in the final report where T would be unacceptable to certain regulators and certain states east of Wisconsin given the assumptions we had initially made. These are the occupancy factors that are recommended in the final report. Most of them are based on common sense. The business of the corridors I've highlighted simply because this is different. Corridors used to be a ¼ under NCRP Report 49. Now we're recommending 1/5. Why that? Because it makes the regulators happy. But we simply could not argue that a person would be standing immediately outside of a door for every x-ray that was made a 1/5 of the time.

And we're able to drop that down to an 1/8. So outside of corridors doors it's an 1/8. In corridors, it's a 1/5. Otherwise the rarely used areas or rarely occupied areas drops to 1/20, and a 1/40 is kind of the minimum occupancy factor in areas that can be inhabited by humans. We're going to calculate the kerma in occupied areas at the location of the closest important sensitive organ so if you look down at the floor from where you're sitting right now, you're about a half a meter off of the floor. Worse case would be for somebody just the other side of the wall. They'd be a foot away or 0.3 meters, which is the same number that was assumed in Report 49. And then if you're standing, so that we're concerned about shielding somebody beneath the x-ray room, we've gone to 1.7 meters, which will take care of the vast majority of the human population except Kareem

Abdul Jabar. The transmission data, of course, we know is the ratio of kermas as it's also been. That was one of issues with the shielding theory because we simply don't know what the transmission of the EDE values are. So we've stuck with the transmission of kerma values and the data sources for the kerma values are shown there. They're the ones that we have been talking about for the last 10 years. Archer and the folks at CDRH made measurements of transmission through lead, gypsum wallboard, steel, and plate glass that were published in 1994. Legare and Ray Rossi made measurements through concrete that are in very good agreement. And then, and this is supposed to be 1977 not 97, I apologize. And then I did calculations of the transmission of mammo x-rays through vari, various barriers and then took these things and interpolated them so that we

know the transmission every 5 kV through the five different barrier materials. Things were fit to the Archer equation, which is shown here. From the Archer equation you can investigate the transmission at high attenuation. At that level you can calculate a hard half value layer and the hard half value layer is related to one of the three fitting parameters in the Archer equation called alpha. The cool thing about the Archer equation is that it can be inverted. You can fit lots of different kinds of polynomials to this sort of curve, but it's a bear to try to invert them. This you can analytically invert, which is nice for spreadsheets and other calculators. The workload of an x-ray unit is of course is it's measure of use and it's simply the time integral of the tube current. The workload is distributed amongst the kVp' s and we are all aware that the output and therefore the

intensity of the radiation is a function of kV, and that's roughly kV^2. But probably more importantly the transmission through the barriers depends very strongly on the kV. And whereas you have a factor of 4 in output going to 60 to 120 kV, you get factors of hundreds in transmission in going from 60 to 120 kV. The point is it behooves us to know or think we know the workload as a function of kV. To try to determine this, about 10 years ago we performed a survey of workload information in clinical sites around the country and that was published as a task group report in 1996. The workload in various diagnostic settings was analyzed as a function of kV. From that we also came up with numbers for average, numbers of patients per week. And then as a by-product, the use factors in those radiographic rooms. We found that the numbers were far different from

the 1000 mA minutes per week that had been classically assumed based on Wykoff and Braestup's assumptions in the 1950's. And total workloads are shown here from the survey, about 300 mA minutes per week in a radiographic room, but only 45 mA minutes per week in a dedicated chest room. That number jumps up to 3000 mA minutes per week in a cath lab. The report accepts the shapes of these workload distributions and bases the calculations on these workloads distributions, but only the kV shape. You can modify the shielding based on the intensity of the workload, but the shapes I think are quite reasonable. Here's the cath lab workload distribution. And you see the standard sort of 60-90 kV distribution. Of course, in a cath lab if you get much above 90 kV the iodine contrast disappears. So this workload distribution is quite reasonable. And these

higher kV's come in, we think, when you come in at more oblique views through the heart. Twenty patients per week is what we observed for our cath lab. In a general radiographic room, we saw this bipolar distribution totalling 300 or so mA minutes per week for 112 patients per week. This is one of the sources of confusion in the report that everybody needs to understand. N here is the number of patients that are imaged in the room each week and not the number of exams. So an individual patient may come in and have a couple of different exams in the room. We're looking at the number of patients, not the number of exams. After this was acquired, Bob Dixon asked that I try to break this out based on where the beam was pointed. If the beam was directed at the chest bucky , we found that most all of the high kV distribution was directed at the chest bucky

as you'd expect, and this distribution for abdominal work, but for all other barriers there is very little high kV workload. Notice for that for both of these cases we have 112 patients per week up against the chest board and all other barriers. And again, that has to do with the definition of how many patients per week are imaged. I scratched out a theory for shielding for the primary and secondary radiations for multiple sources and came up with the computer program that Jack Krohmer had such a good belly laugh over. Later versions of that (on much faster computers) are what the output in the report are based on. That theory begins with the radiation output of the x-ray tube. The output data for standard radiographic tungsten anode , aluminum filtered beams comes from the measurements of Archer and the CDRH. The output for moly mammo systems come out of my mammography notebook. The primary beam unshielded kerma model is basically the same as what is in NCRP Report 49 where we have a kerma per workload times a use factor times the total workload, again now distributed over kV divided by inverse distance squared. The use factor is now actual numbers and we believe that they are reasonable numbers when compared to the wild guesses that were in NCRP 49. Of the total workload in the radiographic room, 22% was directed at the chest bucky wall, 7% at the cross table lateral wall, 2% at another unspecified wall, and everything else was down at the floor. If you only look at that part of the workload that was not directed at the chest bucky, about 90% is directed at the floor, about 10% at the cross table lateral wall, and a few percent is directed at another unspecified wall. These are much different than

the use factors of 1 at the floor versus a quarter at the walls that are in NCRP 49. We also define modalities where we don't have a use factor and that includes all image intensified modalities as well as mammography. Indeed there is a narrow strip of radiation that is typically escaping the image receptor in mammos, but I've done measurements in my institution to show that the patient absorbs basically all of that uncaptured radiation and the intensity that you actually measure where you should see that primary transmission is actually less than what you predict from just secondary radiation. Here's the model for the kerma behind the primary barrier. Basically it's the same as what's in NCRP 49 with the explicit introduction of a kV distribution for all of these values. In NCRP 49 this was the geometry of their model. They assumed

absolutely nothing between the source and the person being shielded except the primary barrier. In reality we know we have a patient, image receptor and other structural supports for the image receptor. This is the model that the reports suggests. We will ignore the patient who we know for the most part attenuates on the order of 99% of the beam, and we will allow for inclusion of the shielding afforded by the image receptor and it's support. The effect of the image receptor and it's supporting structures is summarized in something called X-pre, for pre-shiedling. This is the shielding barrier equivalent of the stuff that is presently in the beam before the beam even gets to the primary barrier. The X-pre values are based on data from Bob Dixon, published 10 years ago for simply a grid and a cassette. And then chest buckus as well as tables. These

things all fit on the same curves as a function of kVp. You see that just the image receptor by itself gives us on the order of a tenth value layer, whereas if you're directed against the chest bucky and/or the table, you're down by a couple of TVL' s. Here are the values of X-pre that come out of that, and you see that there's relatively little kV dependence so that we can, then,come up with these conclusions that for the radiographic room workload distribution. If you simply have the image receptor in the way, that will allow you on the order of 1/3 of a millimeter of lead, 3 cm of concrete, or 9 cm of gypsum wallboard. Whereas, if you're shooting down at a table or up against a full chest bucky, you're talking 0.85 mm of lead, or 7 cm of concrete, or 23 cm of gypsum wallboard. This whole issue was contentious with the regulators because when you do

calculations like this you end up not requiring shielding in many cases. And that simply goes against the grain of many regulators who believe that their job is to save lives by throwing tons of lead on radiographic rooms. That's the final model for the primary beam with the X-pre explicitly stated. Scattered radiation we know comes from the patient. The scattered data is based on the same source as what's in NCRP 49, namely numbers from Trout and Kelley, published the year I graduated from high school. We realize these data on a per square centimeter basis. So what you do is look at what you see for a scattered kerma at a meter compared to what you see for it for a primary kerma at a meter and these numbers turn out to be quite small. So we provide the ratios scaled by a million. Here are the numbers scaled by a million. These smiley face curves are for

tungsten anode, aluminum filtered radiographic and fluoroscopic beams and molybdenum mammographic data is shown at the bottom. The theory then for the scatter is identical to what's in NCRP 49, again with the reanalysis of the scatter factor data with the recognition that Trout and Kelley phrased their data (as well as NCRP 49) in terms of what therapy physicists know. Diagnostic physicists know things like SIDs and beam sizes or image receptor sizes. And that's now what we have here; a beam size at the image receptor and DF as an SID. DS is the distance from the patient to the scatter area in the transmission shown here as B. So basically the same model as what' s in NCRP 49. The leakage model is different. Leakage of course emanates from the x-ray tube and penetrates through the housing of the tube. This intensity is limited by

regulations. As of today it's still in mR units. You can listen to Tom Schoops talk tomorrow. They'll change that number a bit, but 100 mR per hour at a meter is the limit on the leakage when the tube is operated at it's leakage technique factors. The leakage technique factors are the maximum kV that the x-ray tube can operate at continuously. And then Imax is the maximum continuous tube current that is permitted. It's the I value that has provided a lot of confusion. And NCRP 49 because the I in the BLX equation in NCRP 49 is the leakage technique current, and not the clinical tube current. The values suggested by NCRP 49 remain fairly typical for tungsten anode tubes today. It turns out that for the higher use graphite anode tubes all this does is drive up the thickness of lead that's necessary in the housing, and the leakage factors do not change particularly. Of

course, because of the heavy filtering, only the highest energy photons exit as leakage. You've also got an inverse squared distance from the tube to the occupied area because only the highest energy x-rays leave that we are shielding through the leakage barrier with the hard half value layer. The model for leakage presumes that the leakage rate is proportional to the kV^2, the tube current that we're operating at, and the transmission through the housing. And we assume a worst case scenario that the leakage is the maximum value. This we know to be conservative by at least factors of 3, sometimes factors of infinity. We've got data from the FDA where in many cases the manufacturer's can't measure the leakage because it's so low. The new leakage model then uses the primary beam as the unfiltered beam, and then figures out what thickness of

housing needs to be around the tube in order to decrease that value to 100 mR per hour, given these leakage technique factors. Then it looks at the rate of the leakage at clinical techniques compared to maximum techniques, integrates over time to give you the workload, (which is simply the integral of the tube current). This is the resulting model after you throw in an inverse square and exponential attenuation, which leads to this picture. This is how far off the NCRP 49 leakage model is. They presume the clinical techniques all occur at the leakage technique factors. You see that if indeed your system operates at 60 kV instead of 150 kV, you're only off by factors of millions. Even in diagnostic radiology factors of millions are probably important. So given those models, we come up with shielding solutions. The first one is to numerically or graphically sum

these things up and iteratively find a thickness X, which satisfies the P over T requirement. You can download software for that purpose from that website. That turns the whole thing into rocket science, which a lot of people don't like, including Ben Archer. So he told me about six years ago to keep it simple. Let's figure out how to do this with pen and paper and calculator and not a computer. We came up with a method where by we can calculate ahead of time the kerma per patient as well as the transmission of the radiation for a defined workload. The kerma per patient is based on what we call W-norm, the workload per patient as seen in the workload distribution. This number you can modify. So here's the model for a total workload WT. W-norm is the workload seen by the survey. Here's the kerma per patient. And so you can scale these things and

include an inverse square distance and it makes things fairly simple. But you then have to make sure that you use the correct transmission value. The transmission is now a function of not just the barrier material and thickness, but also the workload distribution and whether we're looking at a primary or secondary barrier. Here's an example of a cath lab, where we are going to an uncontrolled fully occupied area for a 12" diameter image intensifier. It's side scatter, in other words 90 degrees scatter. We will assume 25 patients per week. We go to a table in the book that gives us a value of 2.7 mGy per patient at one meter, that's what we call the K1 value. Stick that into our previous equation; That per patient times a number of patients per week divided by the inverse distance squared and you get then 4.22 mGy per week. And that is the unshielded kerma.

That you need to decrease that to P/T. Take that ratio and that defines the transmission that is necessary. Then you look at the transmission curve to find what thickness we're talking about. And we end up requiring 1.2 mm of lead. Doing the same calculations with the same assumptions by NCRP 49, we would have required 1.88 mm, which would have not been satisfied by a standard thickness of lead sheet. Here's the transmission curve. The transmission curve as I mentioned is a function of material, in this case lead, whether we have primary or secondary radiation, and the different workload distributions. So you look up your transmission value and then read off your thickness. That wasn't simple enough for Ben. And it wasn't simple enough because when you look at the simplest room, an x-ray room, a radiographic room, you have x-rays shooting

against the chest board. You have x-rays shooting down at the table, x-rays shooting across the table. And things are surprisingly, complicated for the simplest of installations. And so what we did there was to decide to calculate the shielding requirements for such a room, which we call a representative room. We crammed it into the smallest possible room so that the radiation contributions from each of the sources would be maximized. And then assumed the kinds of distributions of exposures that the different tube locations would make. So here's the different kinds of exposures you can get off such a representative radiographic room. And we did the calculation for this whole thing as well as a representative R and F room, which is the same as the radiographic room except we throw in an image intensifier in there and assume that 25%

of our patient's are imaged by the fluoroscopic tube. There we see the representative R and F room. Now what we have is a solution that is based on the factor NT over Pd^2, where the NT over Pd^2 looks at the patients, T the occupancy factor, P the thedesign goal, and d^2 the inverse distance squared, and that turns it into this problem. And what you see in the final report are graphs of these values. NT over PD^2 , (this is an old graph. It needs to be changed to per mGy per square meter.) And then the thickness of the barrier is shown there. And then there are I think eight of these in the document for different lead and concrete radiographic, R and F, and primary with and without preshielding, and secondary barriers. And then if you really want to keep everybody but the physicist out we could have put this on a semi log graph, which I actually like, but

nobody else did. The graphs give you values in terms of lead and concrete. If you want to go to other materials, we conservatively determined that steel has the same thickness for these representative rooms as lead multiplied by eight. Gypsum is concrete multiplied by 3.2 and glass is concrete multiplied by 1.2. Right now the very last bit of this report is an argument over how we should shield CT scanners simply because the technology has moved on so rapidly past where we thought we were five years ago. The idea is quite simple. Guesstimate the unshielded weekly kerma, and we know what P/T is. Take that ratio, that gives us a transmission and then get the barrier thickness and the values will be obtained from transmission calculations I made 14 years ago. The workloads in CT will not be in mA minutes per week. Rather we're going to be looking

at thickness of patient covered and the number of patients per week as well as the mA and frankly with the auto mA systems that everybody is buying now, I'm not sure what the numbers are. We need a survey of CT scanner workload. So if anybody has a graduate student sitting around not doing anything, who's semi-computer proficient, put that person on that problem, please. We believe at this point that it's reasonable to assume that head patients will get not less than 20 cm of thickness coverage and body patient's 40-60 cm of coverage. You can then scale the kerma distribution that is shown by the manufacture, but make sure that you have the, a distribution that was performed with a reasonable phantom. The worst I ever saw was a Toshiba pattern like this where they hadn't included any phantom and the numbers were only of by factors of 10,000. Or

you can take the CTDI values and attempt to convert them into kerma in the environs using measurements from Doug Shear from about eight years ago that still seem to be quite reasonable. He looked at the kerma at a meter and that was measured for a 10 mm slice and then compared that to the peripheral CTDI. These are the CT scatter fractions that he measured. You can then shove that into an equation that simply looks at the CTDI, and this is the mAs that the CTDI was acquired at. And then look at the clinical mAs, and the number of, rotations and the slice thickness, and this was reasonable for axial scanners. For helical and multi-slice scanners, we then need to look at the thickness of patient covered and look at the pitch and presume some sort of mAs per rotation. And that itself can be modified by looking at the product of the CTDI and the thickness of

patient covered, which is the dose length product. These numbers, physicists in the community are slowly recognizing as being published on the prescription page of all CT scanners. It's something that the techs and the physicians aren't aware of, but it's one of those things off in the corner that nobody looks at. But those numbers are out there. And I think for shielding, if we get used to reading them, we can simply take those dose length product numbers and multiple them by the appropriate scatter factor and that will give us a feel for the unshielded kerma at a meter from these patients. Even if you don't have these numbers for individual patients, there are guidelines out there now. 1200 mGy cm for bodies and 1000 mGy cm, excuse me for bodies and this is the head number. So these are numbers are out there. This is the last bit in the report that is getting hammered out

this week and next. Here's an example of the CT scanner shielding where we're going down to an area that's fully occupied uncontrolled. Three meters from our scanner isocenter, we'll assume 150 patients per week, 50 bodies, 100 heads, and we'll assume 600 mm of coverage of the body, 200 mm of the head. These are typical CTDI numbers in the head and in the body and we'll assume worse case 140 kV operation. We'll assume the mAs is the same as what was used for the CTDI calculation, for simplicity. And we'll assume a pitch of one. Shove that into the calculation to get the kerma at a meter, and you predict .072 mGy for heads and .45 mGy per bodies. Add those together to get the total unshielded weekly kerma at a meter. Take that out to three meters and you get this value as the predicted unshielded weekly kerma. The transmission

requirement then is obtained by taking the ratio of that into the .02 P/T value and you get this as the transmission. You then go to the curve for lead or if this was a floor or ceiling, concrete, and this turns out to be something that is typically not available for most modern construction sites. We simply don't have that thickness of concrete in the floor and the ceilings for modern buildings, so watch out above and below. Especially above where you get lots of angular scattering. And in order to fully shield that ceiling, you typically have to go up 30-40 feet from isocenter, which is completely impractical because then you're outside the room extent, so it simply makes sense to me to take your lead shielding in the walls all the way up to the floor above and then shield the whole ceiling above the CT scanner suite. Those are the transmission figures that are in the

report. The last chapter has to do with surveys. The point of surveys is to look for both holes in your shielding as well as whether or not the thickness of your shielding is adequate. We are allowing visual inspections during construction and then hope nobody puts a nice big gash into the shielding before the walls are covered up or puts a screw to hold a towel dispenser through your shielding. Or you can do a radiation survey with very sensitive meter such as a simulation survey meter. This is best done with a gamma source, but you better check your license before you walk into an x-ray room with Tc-99m, because most specific licenses do not allow such use. In terms of checking for the barrier thickness, again we can do a visual inspect during construction or a survey afterwards to estimate the transmission through the barrier and therefore the thickness of

that barrier. And from that we can do an inverse calculation to see how many patients can be imaged in that room based on the transmission measurement that we have. So in conclusion, we've got these design goals as we have been arguing about all along, 0.1 mGy per week, 0.02 mGy per week for controlled and uncontrolled areas. The suggested occupancy factors are reasonable and yet conservative. Transmission is a kerma ratio and they're based on the workloads. The workloads are based on what has been clinically evaluated. We have models for shielding and three different solutions for shielding determination. One, involving a computer or graphs. The other involving presumptions based on the Task Group 9 workload surveys. And our findings are that the standard 1/16 inch lead in the walls today remains acceptable. If the cassette, grid, and table

preshielding is assumed, then most standard density concrete floors will suffice, and in mammography standard construction gypsum wallboard suffices in the wall and solid core wood doors suffice. In CT again, there are methods either based on the manufactures iso exposures curves or Doug Shears scatter fractions. The workload here is high and make sure that you look up and look down when you upgrade a unit. And then finally, the report will be out shortly. Paraphrasing Martin Luther King, "here at last, here at last, thank God almighty it's here at last." Thank you very much.