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BEFORE THE

U. S. NUCLEAR REGULATORY COMMISSION

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Meeting: Advisory Committee :
on Nuclear Waste Working Group :
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Center for Nuclear Waste
Regulatory Analyses
Auditorium of the
Administration Building
Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

Thursday,
November 30, 1989

The above-entitled meeting was convened, pursuant to notice, at 8:40 a.m.

PRESENT:

DR. DADE W. MOELLER, Presiding
USNRC ACNW

DR. WILLIAM J. HINZE
USNRC ACNW

DR. EUGENE VOILAND
USNRC Consultant

DR. MELVIN CARTER
USNRC Consultant

MR. RICHARD K. MAJOR
USNRC ACNW Assistant

MS. CHARLOTTE ABRAMS
USNRC ACNW Assistant

PRESENT: [continuing]

DR. GUY A. ARIOTTO
USNRC

MR. MEL SILBERBERG
USNRC

MR. JESSE L. FUNCHES
USNRC

INDEX

PROCEEDINGS

DR. MOELLER: Good morning. The meeting will now come to order.

This is a meeting of the Working Group of the Advisory Committee on Nuclear Waste, which is advisory to the U.S. Nuclear Regulatory Commission.

I'm Dade Moeller, Chairman of the Advisory Committee on Nuclear Waste.

The other ACNW member present today is Bill Hinze, seated on my right. We have with us two consultants, Melvin Carter on the far right and Gene Voiland on my left.

During today's meeting, the Committee will review projects currently under way at the Center for Nuclear Waste Regulatory Analyses and projects planned for the near future.

Following the meeting this morning, we will be touring the Center.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act and the Government in the Sunshine Act.

Richard Major, seated two seats from me on my left is the designated federal official for this meeting.

Ms. Charlotte Abrams, seated on my far left, is also joining us. She is a staff scientist on the full-time support staff for the Advisory Committee.

The rules for participation in today's meeting have been announced as part of the Notice that was published in the Federal Register.

We have received no written statements or requests to make oral statements from members of the public regarding today's session.

A transcript of portions of the meeting will be kept and it is requested that each speaker first identify himself or herself and speak with sufficient clarity and volume so that he or she can be readily heard.

Before I turn the program over to Martin Goland, President of the Southwest Research Institute, for opening remarks, let me first say on behalf of the Committee, express our pleasure for the opportunity of coming here.

We have heard about you. We have met with Mr. Adler, your Washington representative, on several occasions, and we have had reports of the work of the new center.

This is our first opportunity to come down and visit with you. We had looked forward to it and we're looking forward to what we learn today.

There are many people here from different organizations. I have only introduced members of the Committee and its supporting staff.

I realize there's a full team of people here from the Center and, also, we have a full team of people from the

Nuclear Regulatory Commission.

Perhaps after the welcoming remarks, we should go around the table and have each person identify himself or herself.

With that, we'll have your remarks, Mr. Goland.

MR. GOLAND: Thank you very much.

First of all, I should apologize to our visitors for the weather. When I first came to San Antonio about 33 or 34 years ago, the motto of the Chamber of Commerce of San Antonio was, "Where the sunshine spends the winter," and it worked out for a while.

The first Christmas that I spent here with my family, we couldn't figure out why we were so warm. We had come from Kansas City and were wearing our winter clothes. It turned out that Christmas Day the sun was shining brightly, the birds were singing and the temperature was 94 degrees. So we are not always in this condition.

We are very pleased indeed to have this committee meeting here.

When the CNWRA was first announced, it just so happened that I was in on the announcement very early when it appeared in the _Federal Register_ and we made the decision that Southwest Research Institute was going to be the headquarters for NCWRA.

After that there was a long, arduous, competitive situation with questions that seemed to go on endlessly, but I'm happy to say that as a result of our effort, and I must say up to that point it was the greatest single effort to obtain a program that this institution had ever launched, after that we in fact did become the location for the Center.

Since that early award, or early in terms of the life of the Center, I must say that our enthusiasm and our dedication to the program has continually grown.

The appeal to us obviously was, first of all, it's an important national program. Southwest Research Institute is a not-for-profit organization whose purpose is to serve on national problems.

Secondly, it was not a management job as much as a technical assignment and our institution since its inception has been characterized by being an organization with a technical complexion.

I wish you had time to visit and meet some of our senior staff and visit some of our laboratories. We have about 2300-plus permanent staff members, incidentally, covering 12 different divisions, which embrace a very wide spectrum of research and development, industrial and governmental spectrum of research and development.

And we have approximately 1.3 million square feet of both laboratory and office space.

You can see that in the time you're going to spend here you're going to see a very small fraction of that, but we are in hopes that you will obtain some feel for the organization.

I mean a feel not only for the Center itself but for the rest of the organization that serves as the supporting base as needed for the Center.

I don't know precisely what was in the back of the minds of the folks that finally made the decision in our favor, but I believe and I hope that one of the factors was that in addition to the operation of the Center itself, we can bring to bear enormous talents on an as-needed basis from the rest of this organization, talents which range everywhere from basic research in magnetospherics.

We are one of the principal centers of NASA for magnetospherics research. I wish we had time to show you some of those facilities in which we are involved.

From very fundamental research of that kind to very practical research in some of the fields of engineering and science.

They've only give me five minutes and I see that I've used that.

Let me only say that having this Center come to the Institute involved us having certain new talents to our over-all spectrum of operation.

I think it is clear to all involved that this would be a necessary step, given the evolution of the Center and one that hasn't received primary attention.

In many areas, such as the areas of long-term fail-safe type design, we have extensive operations. In many areas of certain parts of geology, certain geological instrumentation, we have very strong programs.

But there are many areas which we need to strengthen and some areas where we even need to begin.

Since the history of the Center, I believe and I hope we can show you today that we have made extremely rapid strides and I do want to say that one of the things we have insisted on, or I should say one of the things that John Latz and Wes Patrick and his staff have insisted on was that as we brought new people into this operation, their quality had to be unimpeachable.

We recognized that this was to be a national center. That is what we are striving to create and to a large measure I think as the program schedules require, we have been able to do that.

So I am going to sit in with you this morning, of course. I just want to emphasize once again in closing, this program is of deep interest, deep concern and is a matter for complete dedication by our organization for building for the Nuclear Regulatory Commission the kind of center that they want.

There will certainly be nothing that we can do that we will not do to make that come to pass.

With that stirring speech...

DR. MOELLER: Thank you, sir. Those remarks are good to hear and certainly your presence here confirms to us your dedication to the importance of the Center.

So we'll move then to John Latz and I presume you will introduce the rest of your staff and so forth.

DR. LATZ: I'm John Latz, President of the Center and a division vice president of Southwest Research Institute.

Mr. Chairman, I would suggest that in the course of the morning that you will be introduced to most of the staff, so we will not take the time. The rest of the staff you can perhaps meet informally afterwards.

Again I wish to extend Mr. Goland's remarks of welcome. We not only welcome you; we are honored to have you.

We are honored to have your interest in the activities of the Center and we certainly encourage and invite and welcome your continuing interest in the months and years ahead.

The dedication to which Mr. Goland speaks permeates the Institute and is concentrated certainly in the Center.

I hope when you leave today that you will walk away with that very firm and strong impression.

My sincerest regret today is the relatively small amount of time that you have available so we'll try to make the best use of it.

I'm going to open by giving you a little overview of the Center's history and its status, but at the risk of being gratuitous and addressing that which I'm certain you've already been exposed to, I feel that the discussion of the Center has to be placed in the context of what we are. So I'd like to spend just a minute to relate what we are.

We are what our charter says. Our charter was signed on November 24th by then Chairman Zeck, and if I may, I would like to quote some phrases from the charter.

This alludes to the NRC's role and mission under the Nuclear Waste Policy Act of 1982: "In order to avoid conflict-of-interest situations while maintaining long-term continuity in technical assistance and research, NRC has chosen to establish and sponsor a federally funded research and development center for support of its high level waste under the NWPA.

"The mission of the Center for Nuclear Waste Regulatory Analyses is to provide sustained high-quality technical assistance and research in support of NRC's High

Level Waste Management Program under the NWPA.

"The Center shall provide an organization which possesses high technical competence and is characterized by permanence, stability and the capability of providing independent objective recommendations on complex technical issues."

You will notice that that charter alludes to an FFRDC, a federally funded research and development center.

I find it meritorious on our part to make occasional reference to what an FFRDC is in order that we may remain on course.

So if I may, please, I would read to you from an April 4th, 1984, letter from the Office of Management and Budget to all federal agencies delineating the nature and character definition of an FFRDC.

"An FFRDC performs, analyzes, integrates, supports and/or manages basic research, applied research and/or development. As a non-profit organization, a long-term relationship evidenced by specific agreement exists or is expected to exist between the operator, manager or administrator of the activity and its sponsor.

"When FFRDC's are established, long-term government relationships are encouraged in order to provide the continuity that will attract high quality personnel to the FFRDC. This relationship should be of a type to encourage the FFRDC to maintain currency in its fields of expertise, maintain its objectivity and independence, preserve its familiarity with the needs of its sponsor and provide a quick response capability."

The Center is just a little over two years old. We'll try to place in perspective a little bit of that history this morning and the status of where we stand and a little vision of our future directions.

This morning we will be giving you, as I will, an overview of the Center's operations, a summary status of our activities and then the several items that are involved in our current research program.

We will discuss a rather unique assessment tool, a fast probabilistic performance assessment methodology. We will address the transportation risk study currently under way, and we will speak briefly to the role and function of performance assessment program integration.

The RFP and the contract wisely understood what would be required in order to bring into being and functioning an FFRDC to serve the NRC and its purpose. It provided with keen insight an opportunity of growth and development of the Center.

We existed the first week as a core staff of ten people. We have very gradually, the contract provides for completion of full staffing by the end of the third year with core Center staff supplemented by use of professionals within the Institute and outside consultants providing the complete complement of disciplines necessary to address the program.

DR. MOELLER: Will we hear at any time how you search for new staff?

DR. LATZ: We will be happy to discuss that and we will quote a few figures.

May I please, Mr. Chairman, ask for your questions. Please feel free to interrupt, stop, ask questions as we proceed, any of us at any time.

DR. MOELLER: Thank you.

DR. LATZ: It's your meeting.

Our staffing is basically on target. At this stage we may be three or four people behind but we are closing in on attaining the point in staff acquisition and development where we should be.

We have completed planning and budget documents for FY '90 and '91 and submitted drafts and are submitting the final this week to the program management at White Flint.

We presently have five approved research projects, two pending approval and five planned starts. The transportation risk study to which I alluded earlier is under way.

During this period of time in these two years the

Institute has provided excellent office accommodations and developed and is in the process of equipping a laboratory facility that will be available for the Center's use, as well as the remainder of the Institute's laboratory facilities, all of which are available to the Center.

A characteristic of our relationship, I would wish to point out, a technicality, is that the NRC contractually requires that the Institute provide whatever facilities, capital facilities, that are required.

The contract expresses specifically that the NRC wishes not to fund or acquire any capital facilities.

DR. HINZE: Is there a specific building that is associated with the Center?

DR. LATZ: Yes, and perhaps you'll have an opportunity to see that this afternoon.

Again reviewing the reasons for the establishing of an FFRDC, it avoids conflict-of-interest situation, provides long-term continuity and technical assistance for research and provides a separate capability for performing an integrated technical assistance, research and independent review activities relating to all aspects of the licensing program.

On the NRC side of the Center's existence sits this organization, which gives guidance and direction and oversight of the Center.

Mr. Funches, under Mr. Bernero, is the Center's program manager, aided by his deputies and assistants. We are given technical oversight by three sponsors, Mr. Browning of the High Level Waste Division, Mr. Shao in the Office of Nuclear Regulatory Research and Mr. Burnett in the transportation.

The Center exists within the Institute in a very, very special relationship. It was by design and President Goland's construction that the Center exists reporting directly to the president of the Institute.

You will also note, we will not dwell on it at many other points, but the Institute possesses a very keen, strong, effective quality assurance culture.

This is reflected by the very fact that for all of the Institute's operations, there is a division vice president responsible for quality assurance within the entire Institute reporting directly to Mr. Goland.

MR. GOLAND: John, I think it would be interesting to just get a feel for some of the other aspects. We have our latest manual.

DR. LATZ: Please, Martin, did you wish to make some specific observations about the organization?

MR. GOLAND: No. I just thought if they just glanced at the titles, if they are legible enough.

DR. LATZ: All right. Mr. Goland didn't give you those statistics, but we occupy a 760-acre campus, the Institute does. We employ over 2300 people, and one of the hallmarks, I think, of the continuity and maintenance of long-term relationships is represented by the fact that the Institute wide for professionals and sub-professionals, the turnover rate within the Institute is something variously five or six percent, which I think will measure up very well to any comparable organization.

The Institute is organized in this fashion. I would call your attention to the fact that, again, the quality assurance relationship, but we are structured to reflect a programmatic organization within the Nuclear Regulatory Commission's staff.

You will see the first element being basically an administrative element; the rest of the elements being programmatic elements.

The people that are indicated are permanently in place now. We have filled out the organization in breadth. The last person to come to fill a role of an element manager is Dr. Sager, who will join us the first week in January.

You will notice that above the dotted line we have portrayed a line organization. Beneath that point we have indicated the functional activities that are conducted under each of the elements.

I would call your attention specifically to the fact that our element managers, we are quite confident that they possess all of the characteristics necessary to perform extremely high quality research, give guidance and direction to that research, as well as to function as managers of the administrative aspects of those elements and the regulatory aspects of each of the programmatic elements.

So we hold, then, the element managers responsible for all activities within their element, including research.

There's a crucial point involved here. We cannot mirror the NRC organization. We have one organization within the real world constraints of available resources. We have a body of people to do several functions.

We, therefore, are not able to have nor would we want to have a discrete entity, research entity, a discrete technical assistance entity.

We think it is crucial that the programmatic needs be clearly understood by the researchers so that even they in their day-to-day work are not wandering off on some unrelated activity, that their work remains focused to the need.

This reflects our staffing condition. We presently have 27 professionals and 8 support at the end of FY '90. We have since closed and, including Dr. Sager, who will come the first of January, 32 professionals and 8 support.

We are to be essentially at full support by the end of FY '90.

Alluding to the mix, Mr. Goland alluded to the utilization of talent within the Institute. Matching up the programmatic needs, for those of heavier need, we are placing in core Center staff.

Secondarily, we are reaching to those talents that appropriately are available within the Institute. And lastly, then, we reach to outside consultants and subcontractors.

This is listed in terms of FTE, and as you can see, we have -- I guess there's another import behind the construction of that chart.

We have come to understand with greater sophistication the role that we can and should play. We have understood at the outset that what the NRC was attempting to create in the Center was a programmatic center of excellence.

We have since come to a finer understanding that that center of programmatic excellence should contain within it centers of excellence in several disciplines.

In the first eight that you will see enumerated there, it is our objective, our goal to possess, obtain and possess and exercise the excellence in each of those disciplines.

DR. CARTER: Could I ask you a couple of questions related to that?

DR. LATZ: Yes, sir. If I may, clearly you will obtain copies of these slides afterwards.

DR. CARTER: You are short by roughly 50 percent of your total staff. It would seem to me that you would make more use of consultants and so forth during the current time and also the ensuing year

I notice in looking over the material that we received before our visit that there's page after page of consultants or areas that are identified, yet there are only two consultants that have been apparently contracted with.

Yet there are dozens of areas and dozens of people where there's been preliminary negotiations and that sort of thing.

I was curious why you don't use consultants more and I'm also not sure how you can use a consultant ten percent of the time. I would think there would be more problem in getting them on board and that sort of thing and trying to utilize them, if I read your numbers correctly.

DR. LATZ: I would first go back to my first premise that we operate in the real world of constraints. Ideally, if we needed a discipline, we would be able to have it on core Center staff.

But where we can only identify an allocation of available resources to provide one-tenth of an FTE, I know of no other way to acquire that other than as a consultant or subcontractor.

Speaking to material that we sent to you earlier, I'm afraid that it conveyed incorrectly the fact that we have considerably more than two consultants.

There are two principal subcontractors that are identified and were identified in our original proposal. The contract provides for our ability to use those subcontractors for the first three years of the contract.

We are presently having discussions with the program management about modifying the contract to permit an ongoing relationship with some of those.

But clearly, we have far more than two consultants.

DR. CARTER: The material we got identified two individuals that you have on a contract basis.

The other thing is some of the areas merely gives an organization like MTEL. That doesn't convey much information to me. It could be anything that exists, but they'll provide people in a given area, I suppose, and I'm sure those contractors, MTEL and some of the others, I would imagine they will cough up whatever you might want.

DR. LATZ: No. Very narrowly. We contract with those people for very narrow skills that they possess, disciplines that they possess.

DR. HINZE: If you could, please, could you in very brief terms give us the criteria that were used to decide whether you are going to have a core person or whether you're going to have a consultant and is there a breakdown in terms of research versus technical assistance?

DR. LATZ: The driving to placement of core -- Let me make one other comment.

We are contractually constrained from the filling or use of Center personnel on anything other than this program. So if we bring somebody on board, the full cost of that person has to be borne by the NRC.

To bring somebody on board for whom we have only a ten percent need of their available time would not be a wise use of that resource. That's the first driver.

We feel that when we get to the point of 80 to 90 percent of the use of that person's time being constructively used within the Center, that he should be brought on the core Center staff.

Wes, would you care to elaborate on any of that?

DR. PATRICK: I would include a third criterion and that is that in addition to essentially full-time utilization needing to be identified, there's a time element.

We from time to time have tasks which do use people full time but for perhaps six months or one year, and in those cases it is very effective to reach out to other divisions of the Institute or if the skills are not available there, to reach to our principal subcontractors or to a rather large group of consultants which we have contact with, and they would provide the skills that are needed on either a less-than-full-time basis or a short duration basis.

In trying to provide a Center which has long-term continuity of staff, we have to take the long view. We can't bring people on with six months of work in front of them or one year of work in front of them.

We are looking to the long scope of work, which incidentally, one of the most important guidance documents there is NRC's five-year plan.

We structure our plans and our staff bearing in mind the long-term view which our sponsoring agency has in terms of their needs on a discipline-by-discipline basis.

Does that help?

MR. GOLAND: If I may just amplify that very briefly, the fact that the Center has become an FFRDC, evidently and according to contract, as Dr. Latz has said, requires that a person whom we move onto the Center staff must be fully occupied as a Center person.

I think the philosophy that has guided us and the philosophy which has guided the folks at headquarters has been that we should have on the Center staff acknowledged experts in the prioritized principal areas of CNWR.

That has, therefore, guided the priorities with which full-time Center staff have been added.

Now, the use of consultants. Of course, there is the unique philosophy which the NRC wishes us to follow Institute wide. We have 700, 800 projects going.

We encourage the use of outside consultants and whenever one of our projects can be improved by capabilities and talents outside, we encourage their use and we do that in a very specific way.

As a consultant, we simply rebill consultants. If you use a staff member of the Institute, you have that onerous condition known as overhead, but when the Institute uses a consultant, it is a straight rebill.

That is a financial incentive to our program managers to reach out for the best talent. So I think that has been the broad philosophy.

DR. LATZ: The next viewgraph indicates the allocation of FTE to the various activities of our sponsor.

The breakdown, for example, under research of 13 Center FTE involved in research, that may actually be 18 or 20 separate individuals aggregated to 13 FTE. It also gives a breakdown of our use of consultants.

Quickly and lastly for the overview, this is our Center's core staff hiring profile. It gives you the various disciplines that we have and seek, have yet to attain, and the timing for the acquisition of those people.

At that point, then, I will turn the presentation over to Dr. Patrick. Wes.

DR. PATRICK: I think there was one question remaining unanswered. John asked me to address that.

I am Wes Patrick, also from the Center. I'm the technical director for the Center.

I believe the question was asked as to how do we attract staff, how do we go about the actual process of searching out and finding these high talented people. I believe that question was asked a little bit earlier in the presentation.

We use most of the normal ways of attracting. We advertise very heavily in the trade journals for the disciplines that would be most appropriately viewing those items.

We have found perhaps to be our two most effective means, though, are person-to-person interviews at technical meetings and the network.

Those are clearly the two most productive means which we have found for identifying people that we later find to be of the quality and of the inclination and temperament that we would want to bring on board the staff and become part of the core Center staff.

Those are by far our most effective techniques.

Does that sufficiently answer that question?

DR. MOELLER: For the moment.

DR. PATRICK: Okay, very good.

MR. GOLAND: I usually talk too much but may I say that one way in which we have been able to attract excellent staff is because of the nature of our mission.

A lot of these folks here come because they are challenged by this.

DR. MOELLER: Thank you.

DR. PATRICK: For the next portion of the presentation, what I would like to do is speak to each of the areas, programmatic areas which the Center is tasked to undertake, and by doing that, to speak to both the over-all methodology that we use as we undertake our work, and then for each of those specific areas, to identify the approach we use and some specific accomplishments that have been made in each one of those areas.

I'll personally speak to the first two portions. Then we have a number of briefers who will speak to each of the specific research projects that are under way and then we'd like to close out the agenda with a presentation on the transportation risk study, a particular study that is under way in that area.

The over-all approach that the Center is taking is one that can broadly be terms a systems engineering approach.

Generally, systems engineering has been applied to hardware type systems. The closest that the industry has gotten to using systems engineering in a soft system is its application to electronic systems and information systems.

We're trying to extend those same concepts and philosophies here to a regulatory system, a program for regulating or siting and licensing a high level nuclear waste repository.

The approach that we're using has five principal features to it. First, it's very clearly a mission-oriented program focusing on the Nuclear Waste Policy Act and its amendments.

It is requirements based in the sense that the foundation for all of the systems work that we do, for all of the research work that we do, for all of the technical assistance work that we do has its basis in 10 CFR 60 and, to the extent it's incorporated by reference, EPA's Regulation 40 CFR 191.

Another key feature is that it is proactive. Instead of taking the more traditional regulatory approach and waiting for the license application to come in, the systems engineering approach is trying to identify very early in the program the additional guidance that is needed to be given to the DOE, the license applicant in this case, and further, to be able to identify any uncertainties and to seek sufficient reduction of those uncertainties as early as possible.

That's a key part because of the very rigid statutorily required time schedule that we have with regard to making a decision regarding whether to allow receipt and possession of nuclear waste at a potential repository site.

Whereas nuclear reactors have historically perhaps a seven-year licensing period, Congress has mandated a three-year licensing period for this very first repository with the potential to extend that three-year period, as you are aware, to four years.

To meet that type of a schedule, it is essentially that the approach be very proactive as well as dealing with the more traditional reactive aspects of reviewing submittals of the license applicant.

The fourth feature is that the systems engineering approach provides a good basis for integration. Not integration on paper, but full organizational and functional integration, first of the parties that are working on the activities, NRC Research, NRC NMSS and the Center. That would be the organizational integration.

And then the functional organization of the regulations and the enforcement of those regulations themselves.

Finally, crucial to a program like that, and if you've had a chance to read yesterday's newspaper, it's a dynamic systems engineering approach.

It is very adaptable to change and that's crucial. Yesterday's change is really the second big one that's occurred in the very brief life of the Center.

We've been here for two years and one month. We were in existence about three months when Congress acted to amend the Nuclear Waste Policy Act and, of course, you can imagine the fundamental wide-reaching changes that occurred, both from NRC's perspective as they began to change their guidance to us as we went from three sites to one.

And, also, from our perspective, having just submitted a set of operations plans that were to a generic approach as to possible licensing evaluations.

DR. HINZE: Wes, just one quick question. You have 12 research project plans either under way or under consideration.

Following up on some of your previous comments here, how many of those were generated by the NRC and how many of those were generated by the ideas for them?

DR. PATRICK: That's a good question and one that I think is important to address up front, because you will be seeing a number of the research plans addressed this morning, six of them in total this morning.

We are young. We have come into a program which is quite mature at this point and it is only natural that NRC Research staff will have identified a number of research projects that need to be undertaken.

So if one were to say where specifically did that list come from, the answer has to be that it came from NRC staff and the mechanism for that is NRC's Division of High Level Waste issues a user need statement.

That user need statement is then passed to Research who negotiates with them and acts upon them accordingly, as some of you, I'm sure, are aware.

That is not to say, however, that we pick up those research projects without any input on the Center's part. In many cases those projects, as it were, are in existence in name only.

In other cases, even where a full-blown statement of work or a program element plan was in existence and was passed to the Center to act on, we've had very significant inputs and impacts on those.

I think a very good example is the thermohydrologics project, one we just began last spring to work on in earnest.

As originally posed, because of the timing, it was geared very much to a saturated zone repository. The Center was able to come in and bring to bear its understanding and its points of view and that project now has completely changed in flavor and is geared specifically to research of thermohydrological processes in the unsaturated zone.

That's an example of how the Center has been interacting with the NRC staff to modify, to embellish, to change in different ways the various plans that they have submitted to us in preliminary form.

DR. MOELLER: Gene has a question.

DR. PATRICK: Yes, sir.

DR. VOILAND: What is the Center's role in the prioritization of work, prioritization of research items and so on? Is that established fundamentally by the NRC and then massaged by the Center or how does that work?

DR. PATRICK: We have a responsibility to advise and recommend, to identify areas of uncertainties and the next few charts will look specifically at that process of identification.

There is a specific place in time where we provide a recommendation document. This year, in the spring, February-March time frame, will be the first time that we will make such an official submittal.

Aside from that, just in our collegial interactions with them, we recommend changes to existing projects and new projects that we feel would be appropriate.

That happens on a collegial, as-needed, as-identified point of view, but then there is a specific time in our over-all research responsibilities to come to NRC Research Group and provide them with specific recommendations.

One of the questions that fairly frequently arises is how do the various things fit together. Part of that question is why are you doing specifically what you're doing and why are you doing it in the order that you're doing it.

In the next three viewgraphs, which really are based on one fundamental viewgraph with some stipple screening involved, I'm going to try to address that and by addressing it, hopefully answer for all the research projects that will be presented how they fit, not to the specific project but to say broadly how they fit in the program, what their role is, what their purpose is.

These three viewgraphs will also show where the technical assistance work fits, as well, which is the other principal component of our work.

If you will just keep in your mind this but focus your mind that is not stippled over, we'll progress through the next three viewgraphs.

The starting point for the systems engineering analysis is to look at the regulations as they exist, to segment them to identify the particular regulatory requirements that are present in the regulations.

With regard to 10 CFR 60, a single regulation, there may be approximately 100 specifically identifiable requirements which the license applicant is required to meet.

Those individual requirements sometimes are quite complex, as they are stated within the regulation.

In those cases we would segment that regulatory requirement and say there are pieces of it, elements of it that must be proven, must be demonstrated by the license applicant before the NRC could make a determination that DOE was in fact in compliance with the specific regulatory requirements.

In some cases, in fact in most cases, the regulation does not go into great detail. This is not unique to 10 CFR 60, but it is fairly uncommon in regulation that one has a performance-based standard rather than a very detailed type of a design-based standard. That's the case with 10 CFR 60.

So the staff has found that in cases where the regulation is very broad, they would anticipate receiving from the DOE, the license applicant, additional information with regard to that broad requirement, that broad element of proof.

These things taken in total, the Reg requirement and the elements of proof that it is dissected into and any further details that the staff would wish to see present in the license application, taken together and structured together, those would form the body of the format and content of the Regulatory Guide, a Reg Guide which is prepared by the NRC staff and sent forward to DOE to guide their development of the license application.

DR. MOELLER: In taking this approach, though, you're assuming that you're dealing with a perfect regulation.

DR. PATRICK: No, sir. In fact, that introduces a very important component of our analysis, if I may.

There are really two tests and you've hit on the second one that I've not addressed here. One is you have to deal with the necessity of the regulation and you have to deal with the sufficiency of it.

The regulation as written and any analysis of that regulation as written, one can only address things like necessity and consistency. The sufficiency test can't be conducted on the Reg as written.

So in that case, what we do is we look at what's called functional analysis. We look at the broad functions down to, say, three or four levels of detail that a repository must fulfill.

By the repository, not only the surface and underground facilities, but the engineering barriers and the geological setting itself.

As we structure that functional analysis, we will see everything that the repository must do. We will then evaluate each one of those functions and find out, based on the statutes, which ones does NRC have regulatory authority for, because there will be ones that they don't have regulatory authority for, and then to come back and check the regulation and do the test for sufficiency.

That is how we deal with the likely false assumption that the regulation is perfect. We step back. We do a functional valuational of the entire repository site and engineering barriers systems so that we can do that test of sufficiency.

DR. MOELLER: Through this process, will you, if appropriate, challenge the thousand-year travel time for groundwater or challenge the three hundred to a thousand-year integrity of the waste container?

DR. PATRICK: Challenge is perhaps too strong of a term. If in our analyses, we find that any part of the regulation, not to take those specifically, but if any part of the regulation is inconsistent or we cannot find a statutory basis for it being in the regulation or if we find a gap in the regulation, we --

DR. MOELLER: Or inconsistency?

DR. PATRICK: Or inconsistency. We would

specifically bring those forward to the NRC.

We have already produced one deliverable on just that subject, dealing with the consistency and necessity question.

That document was delivered last December. It is an evaluation of regulatory and institutional uncertainties present in Subparts (b) and (e) of 10 CFR 60.

We will complete the analysis of the entire 10 CFR 60 and submit a list to the NRC of the regulatory and institutional uncertainties that we have found in that.

Technical uncertainties are another matter and they require another depth of analysis, as you can well imagine.

Any other questions about that?

[No response.]

In the next one, we've moved the shading over and now show a focus on what we call compliance determination methods.

These are NRC staff's guidance to themselves. I use "NRC staff" broadly because many of these compliance determination methods would be developed by staff here at the center as a result of our technical assistance work and our research activities.

Each of those compliance determination methods might itself require certain bits of information.

You'll note that there is a parallelism here, that for each technical review component there must be a method for determining compliance with that component.

Each element of proof the next level up, likewise, would have its own compliance determination method.

Finally, although not shown here for simplicity, at the highest level, the regulatory requirement itself would have its own individual compliance determination method.

Those compliance determination methods and information requirements taken in total form the second major licensing guidance document, the License Application Review Plan.

That, too, is a NUREG. It's a public document and it amounts to self-guidance primarily for the NRC staff. It is their guidance to themselves as to how they are going to review the license application when it comes in.

But of course, being a public document, it also alerts the license applicant, DOE, as to how NRC is going to conduct their review.

So they will be able to see, aha, when we try to prove compliance with this regulatory requirement, here is what NRC is going to do to check us. Here are the kinds of things they are looking for with regard to information. Here are the kinds of techniques, methods, models, confirmatory research, what have you, that they are going to conduct in order to prove that we, the DOE, are in compliance with that regulation.

The final chart, briefly, looks at this matter of identification of uncertainties. Not looking just at the Reg as written, but looking at the broad functions that the repository must fulfill, are there regulatory uncertainties, uncertainties in terms that we have discussed here already this morning.

If there are such high order regulatory uncertainties, then an uncertainty reduction method would be posed.

In the case of a regulatory uncertainty, in general, the Agency elects to go to rulemaking so you see that staff function.

So as you look at rulemakings that are being conducted by NRC now, their goal is to reduce particular regulatory uncertainties that have been identified by staff within that regulation

Down at the technical uncertainty level, we see similar things occurring. You might have a technical uncertainty which is best resolved not formally, but through the informal prelicensing consultation process, which is provided for under the NWPAA, meetings with DOE.

Other ones may be sufficiently complex that a formal technical position which is subject to review by the public and by the DOE would have to be prepared, issued for public comment and then finalized by the staff.

The same thing is being shown true here at some of the lower order of technical uncertainties which may exist with regard to how one would obtain particular pieces of information.

So this diagram is recognizing that certain uncertainties will arise directly from the regulation. Others will arise because we do not understand the methods for showing compliance with the regulation.

Yet others will arise because there are not techniques available to adequately obtain the specific information that is required to demonstrate compliance.

In all those cases there is some level of uncertainty reduction method which is most appropriate, given the time and resource constraints that are present and, also, the need to have the results of that uncertainty reduction stick, last, withstand the test of time.

And depending upon the outcome of those analyses, one might use rulemaking, technical positions, informal meetings and the SCP comment, the comment resolution period, to come to closure.

That bars dealing specifically with the process of proactively identifying uncertainties that exist and bringing those uncertainties to the proper level of reduction so that the licensing process can proceed.

The ultimate goal, I guess if there were an ultimate goal in that whole process, it is to ensure that when the license application comes in, it is complete.

Not that it automatically gets a, "Yes, the site is okay," but that it is complete so that the staff can review it.

So that the questions that arise at the hearing process are not questions of, "What does the Reg really mean?" but so that the questions can be narrowly focused on the technical merits of that site with regard to its ability to contain the radioactive materials.

Any questions on that? That is what I would say is speaking to the broad manner, the broad methodology which we use as we undertake all of our work here at the Center and it's true also on the NRC side as they undertake their activities.

We have spoken of the approach to systems engineering. There are a number of specific accomplishments.

I'd like to hit just a couple of those in honor of the time and how it is fleeting away on us.

As John Latz indicated, we will be providing a complete set of these for the record after this meeting, so you will be able to digest them further then.

One of the keys of the systems approach is it does give you basis for prioritization and we have gone through and identified all of the pertinent statutes and regulations and have prioritized those.

As of the end of next month we will have completed the delineation of specific regulatory requirements within 10 CFR 60, which is the primary regulation governing the management of high level nuclear waste and spent fuels.

One of the key mechanisms that we use to try to quantify to the extent appropriate a very qualitative decision-making process is through the use of attribute analysis.

There are a couple of specific reports that we have out on how we have applied that process to date.

The last bullet, I just note that the systems engineering approach, which we often refer to in shorthand as the program architecture, bears a program architecture support system, which is put in place.

It is, in simple terms, a computer database which allows us to guide and to capture the results of each of the analyses that we perform.

All of the material that I showed on the previous briefing charts then has a relationship within a relational database so that we are able to search and retrieve and find out exactly what the status of any particular issue is at any time and to bring to bear effort on those open items that exist at any particular time.

All of the process and procedures are in place in a version one of that program architecture support system, that computer database are in place at this time.

I'd like to move quickly, if we could, to the second area, the technical assistance work that the Center is undertaking and speak briefly to the approach that we use.

The guiding principles are to provide that technical support for regulatory guidance documents, TP's, rulemakings and so forth that that NRC needs, to provide them with the technical staff to support them in that area.

We have a rather substantial role in evaluating DOE's prelicensing documents, both the consultation draft of the Site Characterization Plan, the SCP, and also the final version of the SCP.

Our staff was engaged in very extensive reviews of those documents, both in providing initial input, point papers as they are called, and also to meet and dialogue with the NRC staff, our consultants and their consultants, to come to what is the final product, the appendices of the site characterization analysis.

We have a major activity in providing both technical people and quality assurance professionals to the process of conducting observation audits of DOE and its contractors, working directly with teams of NRC staff in this regard.

Development of compliance determination methods is also a key item and I'll speak to that as we look at some of the specific accomplishments that have been made in the last twelve months or so.

Finally, an activity that we have just begun on is to participate in a three-part team for the development of a performance assessment capability.

There's a Memorandum of Understanding between NRC NMSS and NRC Research. Those are the first two components of this performance assessment team and we will be augmenting as the third component of that performance assessment team.

As John indicated, we have just hired the manager for our performance assessment element and will be getting fully up to speed with that activity in the very near future.

Even while awaiting that full involvement in the performance assessment work, we have already undertaken several studies, gearing and looking specifically at the review strategy that NRC will elect to follow as they conduct their performance assessment, the so-called PAR's, or performance assessment review, strategy.

As I noted before, one of the specific areas that we've worked in was the review of the SCP, both in its consultation draft version and its final version, leading to the preparation of a site characterization plan.

The SCA itself is an NRC staff generated document. The Center did not generate the SCA. We provided the technical input, point papers and so forth that went into that document.

There are a number of technical positions and rulemakings which we have begun in recent months and several of these are enumerated here.

There are many others that will be brought on line during the next year. There are a total, I believe, of about seventeen technical positions and I believe four rulemakings that the Center staff will be directly participating in in a very substantive technical way.

DR. HINZE: Wes, if I may, do you decide which of the -- or does the Center decide which of the TP's to look at or is this done in consultation with the NRC staff or is this based upon the expertise that you have in-house?

DR. PATRICK: It's a combination of those. As with the case of your question on research, many of these TP's have begun. In fact, many are very close to closure and final publication.

In those cases, where they are near final, our role so far has been simply to review those documents.

In other cases, we will be playing a much more substantial role. We're just beginning one on natural resources, for instance, and we have helped to shape the conduct of the work, flow of the work, focusing in on specific technical areas where we felt there was additional information that was available or should be made available to address particular technical issues within that TP.

There is another area that ties in to this and it deals with the selection of what TP's would be done and which ones would not be.

The document I referred to earlier, looking at regulatory uncertainties in Subparts (b) and (e) in 10 CFR 60, in preparing that document we identified a couple of areas where it did not appear that a stand-alone TP made sense.

If I recall correctly, one of those dealt with trying to treat the disturbed zone and groundwater travel time separately and independently.

We found that as the regulation is structured, one really can't treat them separately and we recommended that those be merged.

I think you've probably seen a change or will shortly see a change in the document SECI 88-285, which originally would have had those to be separate technical positions. They are now being merged into one.

So we see those kinds of impacts that we've been able to bring very early in the program.

If I may try to perhaps address that question a little better, I see that look of incomplete satisfaction on your face.

DR. HINZE: That's right.

[Laughter.]

DR. PATRICK: What we see, again, coming into a program which is rather mature in the sense that it's been in existence for ten or twelve years, what we might find is this situation, and I present that non-critically.

This situation being there are in fact TP's, twenty-nine of them I think. There are in fact rulemakings, nine.

What is missing right now from public view, I think, is the ties that this viewgraph shows. So one of the first things that we do as we become engaged in the activities on a technical position is to ask first the question, "What is the uncertainty that is trying to be reduced here?"

Because if there's no uncertainty, there's very little point, other than professional satisfaction, to develop such a technical position.

Then coming back from that evaluation of the technical uncertainty, if we get the yes answer, there is a technical uncertainty, we then ask the question, why does it arise?

Is that a technical uncertainty because there are no mechanisms to obtain the data, because there are no codes and analysis methods to evaluate compliance?

What is the real source of that uncertainty, and eventually tracking it back until finally we have put in place the complete regulatory basis, the statement of the uncertainty, and have then the complete tie as to why that particular technical position is being undertaken.

People intuitively, through innate intelligence or whatever one would attribute it to have said, "Here's a problem that needs to be addressed," and they marked off and worked on that technical position.

In those cases, we're coming in and going behind that and saying just why does that exist. Is there really an uncertainty here or is this some other type of a matter which would be dealt with better otherwise.

[Transcript continues on Page 48.]

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DR. MOELLER: I'm glad to hear that because we have similar questions.

DR. PATRICK: I need to move along here rather quickly.

In the technical assistance area there are a number of other things, a number of other accomplishments which have been made.

We have done a good deal of work in an EBS, engineered barrier system performance assessment code, using a fast probabilistic performance assessment technique. I will not speak further to that because Dr. Prasad Nair will speak to that later this morning.

We were very heavily involved in the review of DOE's design acceptability analysis, the so-called DAA document. That work was conducted out of Asad Chowdhury's group.

Some additional significant accomplishments in the technical assistance area. I've noted the heavy schedule of quality assurance observation audits which we have conducted, to date providing only quality assurance professionals, but in the future anticipating providing technical experts to those audits as well.

We've done some strategic issues studies, had an involvement in development of the first draft of the outline of the format and content of regulatory guide for the license application.

I noted before some of the early performance assessment activities which we have under way. Looking at two things specifically: Backfilling operation of examining the regulatory and statutory basis for performance assessment and, second, to look at various options that might be available to the agency to conduct this performance assessment.

The transportation risk study is a very special study. It's one which is specifically tasked for us to do, but it is one which reaches beyond the narrow definition of dealing with high level waste.

Part of the materials, the radioactive materials to be transported, will be spent fuels and high level waste from both commercial and defense facilities.

But many of the wastes being transported on the highway are not in the high level waste category. Those are all included under the transportation risk study, which is aiming to provide a technical basis to support revision of a document that was published some years ago, NUREG 0170.

This study will not lead specifically to a new NUREG 0170. It will provide a technical basis, and then NRC staff and management will decide whether they're going to go forward specifically with an update of that document.

A number of other aspects of that program are outlined here. As time permits this morning, you will be hearing from Dr. Ruth Weiner, who will speak specifically to the transportation risk study.

I would note in summary form that there are some very significant accomplishments in that TRS area to date. We've completed our evaluation of the most recent version of RADTRAN, the primary code that is used to calculate effects of the transportation of radioactive materials, RADTRAN-3 it is referred to.

DR. MOELLER: Who did that originally?

DR. PATRICK: The original RADTRAN work? Ruth, would you --

DR. WEINER: That was done by Sandia National Laboratories. That's Jim McClure and Robert Luna's group at Sandia. And I believe Seiglunde Neuhauser at Sandia is the chief architect -- continuing architect of the RADTRAN updates.

We use RADTRAN through -- RADTRAN is available through a telephone hookup. They've designed a very user friendly method of using it.

We just use Sandia's RADTRAN. They are responsible for the maintenance of the code. They've worked very closely with a group of RADTRAN users, of which we are one of the larger users.

We all have input into maintaining that code. As we discover things in the code's application, they're incorporated into the RADTRAN updates.

DR. MOELLER: How significant was this error that was discovered?

DR. PATRICK: As I recall, approximately five percent of the --

DR. WEINER: Yeah.

DR. PATRICK: -- data in the data base was found to be in error. Ruth and her team are in the process of flagging those so that they're not used in any of the analysis.

DR. WEINER: I would like to make a brief point. There is a difference between the data base use and the RADTRAN code.

We haven't discovered anything you could call an error in the RADTRAN code. But in the data bases that were used, we went back to the original collection -- and I'm going to talk about this a little bit if I get the opportunity -- and found things like entry errors, which can't be corrected and can't be retraced.

These formed the RADTRAN inputs. They're not part of RADTRAN itself.

DR. MOELLER: Thank you.

DR. PATRICK: She will speak specifically to those points and also to the new projections that are in the process of being projected for radioactive materials shipments.

With those remarks, I've covered three of the four principal programmatic areas in which the Center is involved in providing support to the NRC.

We've spoken of the systems engineering area, technical assistance and the transportation risk study.

The next part, the fourth and final part of that, is the research area.

I'll defer to you, Dr. Moeller, or, John, whoever is appropriate, as to whether we break now or proceed with that research portion. That would be the next block of time that we have set out, specifically to address each of the research programs that are currently under way at this time.

MR. LATZ: The next natural break, Mr. Chairman, to my mind would be after the item now scheduled on your agenda at 9:15.

I would suggest that you may either want to break now or wait until we complete the presentation that's noted at 9:15.

DR. MOELLER: Why don't we go ahead and break now. Let's keep it to ten minutes.

Also I think we ought to discuss at some point the agenda for the remainder of the day. I notice we're scheduled to adjourn at 3:30.

I think the most of our people are staying here tonight and not departing until in the morning. There are one or two exceptions.

If possible, maybe we should plan to go on until 4:00 or 4:30 to ensure we get in our questions and so forth. Is that --

DR. ARIOTTO: We encourage that.

DR. MOELLER: You encourage that. Is that going to be all right if we do that?

DR. PATRICK: Absolutely.

DR. MOELLER: Let's say we'll go a little longer. Let's take ten minutes then.

[Recess from 10:05 a.m. to 10:15 a.m.]

DR. MOELLER: Okay. Dr. Murphy, you will be talking about the geochemistry research project.

DR. RUSSELL: I'm John Russell --

[Laughter.]

DR. RUSSELL: I'll pass it along in just a moment to Dr. Pabalan and Dr. Murphy to talk specifically about some of the aspects of geochemistry.

Before we get to that point, I would like to start with some introductory material on the research project itself that the Center is conducting.

The first overhead shows the approach that the Center is using, some of the reasons why we're doing research.

To develop and enhance the technical basis for regulations. Certainly 10 CFR 60, groundwater travel time, has already been alluded to, and one of the research projects that Rachid Ababou will talk about later is involved with considerations of that technical aspect.

To provide confirmatory basis and calculations for use in the license review.

To confirm measurement analyses that DOE may perform.

To explore phenomena, processes and conditions not considered by DOE. An example of this would be within the geochemistry project, we are looking at cryoelectron microscopy coupled with energy-dispersive x-ray analysis to investigate the chemical composition of core water by quench-freezing samples containing core water, a technique that's not being used by DOE that may have some promise in determining the chemical composition of core water in the unsaturated state.

And, lastly, developing the capabilities of the Center staff and the NRC staff in reviewing license materials.

The Center is aware and strives to integrate all the research projects that they are responsible for. This particular overhead shows four of the research projects which are the most advanced at this time. It does not include two others that we will talk about today, but it shows on the race track on the outside the regulatory drives, the regulations which drive the research that is being conducted.

And it also shows that geochemistry affects, for instance, the integrated waste package experiments by the effects on the chemical environments of the engineered barrier systems, that corrosion of the waste package, for instance, will have an effect on localized geochemistry.

In fact, iron colloids could be created which would affect radionuclide transport.

Thermal hydrology certainly affects the geochemistry, and heat and fluid flow.

Geochemistry affects thermal hydrology with precipitation and dissolution of minerals, and you can see some of the other interrelations that are given, just as an example, among the projects listed on this particular overhead.

This certainly does not list all of them, but it illustrates some.

I am the manager of the geologic setting program element, which is responsible for all those activities that literally start with a "geo" within the Center. So geohydrology, geochemistry, geophysics, geology itself fall under my purview.

And then the research projects that are currently established at the Center, conducted under the geologic program element are given here, and these will be discussed individually.

We will begin with the geochemistry research project. The project manager is George Birchard. The principal investigators are Dr. William Murphy and Dr. Roberto Pabalan. Each of those two individuals will present their work after my brief introductory comments.

The general objectives of the geochemistry research project are listed on this overhead and some of them on the ones to follow.

But they are literally to understand the ambient conditions and processes at the reposed repository site, to understand those conditions and processes affecting transportation or transport of radionuclides and releases to the accessible environment, to under the geochemical conditions and processes which affect performance of the waste packages and the EBS.

And, in fact, in our project we have had significant interaction and input into Dr. Prasad Nair's project on integrating waste package by providing geochemical conditions that are important on degradation of waste canisters, for instance.

And, lastly, to -- not lastly -- but on this slide, to recognize and evaluate issues and uncertainties in predictive geochemical models which are used in performance assessment.

Certainly a major part of our geochemistry project is looking at predictive geochemical models.

In addition, our objectives include supporting the NRC activities, site characterization, establishment of design criteria, the identification/evaluation of favorable and adverse conditions as called out in 10 CFR 60, and evaluation of the license application.

The basis for the geochemistry research project are given here, the particular citations, so our project is firmly couched in what we need to do, based on regulatory requirements, and the work that is done in geochemistry will affect and has affected, in fact, the review of the SEP involved with the development of technical positions and has an impact on issued technical positions.

Proposed rulemakings, prelicensing guidance, license application evaluation and confirmatory experiments and exploratory experiments are all affected from materials in the geochemistry research project.

Performance assessment, particularly such things as source term modeling and overall systems performance, are aspects which are of concern in our project; and we're cognizant of the statement of research needs.

Geochemistry parameters that we are investigating in general include these four items: Groundwater chemistry, mineralogy, petrology and rock chemistry, the stability of minerals in glass (in this case glass meaning not a glasseous waste form, but glass within the rock itself), and radionuclide transport and retardation mechanisms.

Both Bill Murphy and Bobby Pabalan will talk in more detail about these aspects.

DR. HINZE: If I may, how do you integrate your investigations with work that's being performed by the U.S. Geological Survey for DOE and other groups as well for DOE?

DR. RUSSELL: I guess I would have to say that we do it not in so much integration as cognizance of their work. That cognizance comes from participation in technical exchange meetings or professional meetings.

We obtain a knowledge of what they are doing. In terms of integration of it, I guess I would use the word -- maybe not "integration with it," but just trying to mesh in.

We must be astute enough to realize what they are doing, what they are not doing, what we should do to fill in those gaps that they may not be doing so we can give them guidance and say, "Hey, look, I think that you're missing something," prelicensing guidance.

DR. HINZE: So your primary emphasis is to try to find the holes that would be pertinent to the licensing problem and fill those holes so that you can provide the adequate technical assistance?

DR. RUSSELL: I would say so, yes.

DR. MOELLER: Do you find or have you had placed upon you restrictions pertaining to conflicts of interest that are actually hampering you in talking to DOE or DOE contractors to really get first-hand knowledge of what they've done or accomplished? Do you feel that that hampers you in any way?

DR. RUSSELL: I'll have to express this as a personal opinion. I think that in my experience things are very much improving with the new openness that's taking place with technical exchange meetings.

But for us to directly interact with the DOE organization, such as Los Alamos who is doing geochemical research, certainly that must be done within the constraints of going through NRC, and NRC working the arrangement for any interchanges with the Department of Energy.

As a technical person, most of it feel it takes a lot longer than what we would like.

DR. LATZ: May I speak to that point, please, Mr. Chairman?

Without making comment on the institutional -- proper institutional concerns, the Center is following in the wake of, and greatly applauds and encourages, the initiatives of Mr. Silberberg at creating the technical interchanges that are taking place.

We think that's very useful. We felt a degree of frustration in that dialogue until such time as Mr. Silberberg, starting, I guess, last April or so got that kicked off.

We greatly applaud and encourage that mission.

DR. MOELLER: So the information that you need, you may be delayed perhaps or may have been delayed in the past, but through these formal technical interchanges, which I gather are open to the public --

MR. SILBERBERG: [Nods head.]

DR. MOELLER: Okay. They're open to the public.

You can do it and ask any question you want in an open forum and not be constrained. The way you are constrained is you can't -- or you should not or cannot go meet with them privately to exchange?

DR. RUSSELL: That's correct. And, of course, obviously those exchanges are on technical issues, not on policy.

MR. SILBERBERG: Dr. Moeller, I think a very good point has been made in the type of interaction that Dr. Russell is referring to is a traditional interaction of scientist to scientist, engineer to engineer, at a level understanding the details of what they're doing on the technical issues, without necessarily worrying about the encumberment of the regulatory process.

It's that dialogue and that interaction process that we're trying to improve, and have been working with Research and working with NMSS on the project and DOE to do that.

It has taken some time. Because we're in a licensing arena, there are procedures and care that has to be taken. So we're working within that system.

But I will say that there is a strong need in the development of our program and in the development of the Center for those dialogues and interactions to take place in however they can be done at the level of Dr. Russell.

DR. RUSSELL: It would be something that we would strongly encourage.

The geochemistry project, the basic approach is subdivided into two primary thrusts. One is geochemical modeling, and the other is experimental studies.

The individual who is responsible for the geochemical modeling on this project is Dr. Bill Murphy, and he will discuss that.

Dr. Roberto Pabalan will discuss the experimental studies that are being done as part of this project.

These are certainly interrelated, and one feeds the other.

Bobby, if you will please talk about the experimental studies, and then we'll go straight from there into Dr. Murphy discussing the modeling aspects and then into natural analog studies, which is a separate project from geochemistry, as presented here, but very closely related.

DR. PABALAN: My name is Bobby Pabalan. I'm a geochemist for the Center. I'm going to address the experimental studies being done as part of the geochemistry research project.

One of the key issues from a regulatory perspective is whether the geologic environment at Yucca Mountain will isolate the radioactive waste from the accessible environment after closure of the repository.

Therefore, in a broad sense the geochemistry program must evaluate how effective this geologic or geochemical barrier is.

This is a cross-section across Yucca Mountain showing a major distribution of zeolite minerals. The dark areas are stratographic horizons in Yucca Mountain, which are rich in zeolite minerals.

The position of the static groundwater level is shown by this line. The proposed repository horizon is located in this stratographic unit.

Because of the ion exchange properties of zeolite minerals, they can become potential barriers to radionuclide migration in case there is a leakage from the waste canisters.

The predominant zeolite mineral present at Yucca Mountain is shown by this scanning electron micrograph, determined during our characterization studies.

This is clinoptilolite. Its crystal structure is illustrated in this diagram showing the two major channels running through its crystal structure, where you have exchangeable cations and also exchange waters.

These channels with its exchangeable cations gives it its ability to exchange and track possibly radionuclides present in the groundwaters, which may eventually retard migration.

The research project -- experimental program for geochemistry will focus on the ion exchange and thermodynamic properties of the zeolites.

This basically consists of looking at its ion exchange properties, through ion exchange equilibrium experiments. We need to understand kinetics for how fast this ion exchange process takes place.

This has indication as inputs into any hydrologic or groundwater flow. We also need to study its ion exchange capacity and how much these minerals can uptake from the groundwater.

Understanding its selectivity we need to know whether these minerals will preferentially ion exchange radionuclides over that of naturally occurring groundwater carriers.

Recognizing that the geologic environment or the groundwater composition is very complex, we need to develop chemical models that will enable us to predict ion exchange equilibria and its complicated systems.

The second aspect of the experimental program is phase equilibrium and mineral stability experiments. What we are after basically are -- gives free energies and enthalpies of formation for these various minerals.

These data then can be used as input parameters in the geochemical modeling. This can be used to predict whether these minerals in the presence of a perturbed environment due to englassment of radionuclide -- of radioactive waste will change to another less sorptive mineral species.

In addition to the geochemical modeling, these basic equilibrium experiments will tie into the ion exchange experiments because we want to be able to develop solid solution models for a whole series of compositions of minerals.

DR. MOELLER: Where do you get your samples?

DR. PABALAN: The samples we have right now come from a variety of sources, a number of localities in California, some from Idaho and New Mexico.

We are looking -- trying to get pure -- in this case, clinoptilolite minerals on which we can do experiments.

We're looking at --

DR. MOELLER: Are you hampered now from obtaining samples from Yucca Mountain?

DR. PABALAN: Right now I guess -- Yeah, there is a problem getting samples from Yucca Mountain.

But at this point it is not the objective of the experimental program to work on samples from Yucca Mountain. We would like to be able to work on pure mineral samples, and there's a big reason for that.

Some of the initial experiments that have been published in the early sixties by Ames show that there's a complex dependence of ion exchange behavior on the composition of the aqueous solution shown on the X axis and also on the composition of the solid phase shown on the Y axis.

These are binary exchange isotopes for a number of reactions: sodium/potassium, sodium/calcium, sodium/strontium, calcium and strontium.

The problem is, how do we describe this complex type of behavior. And the approach that we need to take shown in this diagram for any exchange -- binary exchange reaction shown here, we have an equilibrium constant, which is a function of the composition of the solid phase and composition of the aqueous phase shown by the -- in terms of molalities of the aqueous species.

And then you have non-molality terms for both the aqueous solution species and non-molality terms, X, for the solids.

If we can -- basically using straight thermodynamic principles we can derive equations that will enable us to derive the activity coefficient for the solid phase.

From my previous work on aqueous solution thermodynamics, we have a pretty good handle now on the non-molality of the aqueous species in mixed solutions. So I think the only problem is getting experimental data over the whole concentration range of the solid shown by these integral terms, so that we can get the activity coefficient terms for the zeolites.

We need to use these models -- thermodynamic models because at Yucca Mountain itself, as shown -- the composition of the clinoptilolites show a variation. For example, on the western end of Yucca Mountain, the clinoptilolites tend to be alkali rich.

As you go down in depth, the compositions actually tend to become more sodium in composition.

If you go to the eastern end, you find more calcium and clinoptilolite.

In the northern end of Yucca Mountain, you have more potassium and clinoptilolites.

If we use the selectivity sequence for clinoptilolite determined by Ames, shown by this series, to a first approximation we can say that cesium may be effectively retarded over the whole area of Yucca Mountain. Cesium-137.

But strontium-90, which shows a lesser selectivity than potassium, may not be so effectively retarded at the northern end of Yucca Mountain.

But we have to recognize, of course, that the exchange in the geologic system is multi-component in behavior. This is only a first approximation.

The equation that I showed you here is only true for binary exchange. We would like to be able to develop -- These models can be expanded to more complicated systems, and that is basically the goal of the experimental program, is to develop those types of models.

I think I'm going to stop here for your questions and let Bill Murphy talk about the modeling aspect.

DR. MOELLER: Any questions?

DR. HINZE: Where is your research leading you at this time, in terms of your accomplishments; and do you think it's a fruitful area for continuation? How would you evaluate it?

DR. PABALAN: That's a good question. Bill Murphy and I have been back from Migration-89 conference about two weeks ago.

The bulk of the work that the Department of Energy has done on retardation are what are called sorption studies. There is a summary report that came out, I believe in '86, summarizing the results of Los Alamos sorption studies for 1977 and 1985.

There are accompanying documents which tried to statistically evaluate degradation shifts between sorption data: the mineralogy, temperature, pH, eH, groundwater chemistry.

What is interesting is that in the -- to paraphrase the Los Alamos report, they are saying that in retrospect we should have done a more systematic study of sorption because we need to look at the mechanisms.

There is a problem in the interpretation of any sorption study because there are several processes taking place. It could be adsorption, that is, physical or chemical adsorption through the ion exchange, or it could be precipitation.

If you're doing sorption studies on complex tuff samples with different mineralogies, then it's very difficult to make interpretations as to which variables are really affecting your experiments.

In the final report, Oak Ridge National Lab for the Nuclear Regulatory Commission came to basically the same conclusion.

To paraphrase again, in their '89 report they state that it makes little sense to do additional sorption studies which are not designed to look at the fundamental mechanics. They find again that it's very hard to make interpretations.

The approach that we have taken here is to zero in on the presence of zeolites, which we know will have the predominant mechanism of ion exchange. And from that if we can understand and use thermodynamic models to predict the ion exchange behavior in complex systems, then I think we have a better foothold on what needs to be done in the future.

DR. HINZE: What do you think, in terms of time, that it's going to take to arrive at some kind of conclusion, in terms of setting up your equations? Is this going to be -- Is it something you can accomplish in a year or two? What's your prediction on that?

DR. PABALAN: It depends on the resources that we have, I guess.

[Laughter.]

DR. HINZE: You owe me another cup of coffee.

[Laughter.]

DR. PABALAN: Certainly within a year we can get some preliminary conclusions as to how well this kind of modeling worked -- is successful.

There have been a number of experiments in zeolite chemistry, mostly done by chemical engineers for -- you know, physical chemists looking at -- or use thermodynamic models to look at binary exchange reactions.

It is only in the past ten years that -- a particular group in England, a group of physical chemists, have tried to extend the model to zeolite ion exchange equilibrium.

They have identified -- and based on their studies we have more or less designed experiments that we think will be able to eliminate some of the problems in looking at ion exchange in complex systems.

It's a tricky experiment to do. The basic -- The major requirement really is getting good data, because good data is required -- to use integral terms over the whole composition.

In fact, at Migration-89 there was a presentation of Los Alamos which tried to use this kind of model to evaluate and to correct their sorption experiments. That kind of evaluation is really totally meaningless because you can't use this kind of model.

DR. HINZE: Thank you.

MR. VOILAND: I take it that your work is primarily experimental; is that correct?

DR. PABALAN: Part of it is going to be experimental.

MR. VOILAND: You also follow the literature?

DR. PABALAN: Yeah. Obviously, that's part of the requirements in any experimental program, is to understand what has been done.

MR. VOILAND: What is the concentration range of these materials in the solutions that you use; for example, sodium substrate or potassium or whatever?

DR. PABALAN: In the experiment itself?

MR. VOILAND: Yes.

DR. PABALAN: We have designed it such that these integral terms require evaluation of the concentrate strength.

The experiments will be done initially at .05 molal, total ionic strength. There's a reason for that.

The zeolite literature indicates that if you have high concentrations of electrolytes in the aqueous solution, you may actually imbibe salt into the crystal structure itself. That invalidates -- Well, actually you can extend this model to incorporate the effects of imbibition of salt and changes in the water integrity within the crystal structure itself.

But we're going to try and stay away from those computations, stay below or at .05 molal ionic strength.

MR. VOILAND: That's a fairly high ionic strength, isn't it, in terms of --

DR. PABALAN: That's true. What you will find -- and this has been shown in one or two papers in the literature -- you can account for the ionic strength effect through the gamma terms shown in these equations. Those are the activity coefficient terms.

And what you find is if you correct properly for the activity coefficients in a mixed solution, then it doesn't matter what ionic strength you do the experiments in, as long as you don't have imbibition. So you can account for that.

In actuality, you need to only do experiments at one ionic strength. You can calculate the ion exchange behavior of other ionic strengths, if you have a good model for the activity coefficients of the aqueous species.

DR. MOELLER: Dr. Murphy.

DR. MURPHY: I'm Bill Murphy, and I want to discuss some aspects of the geochemistry research project, in particular some of the results that we have already obtained with regard to modeling.

I'm going to do that by giving a couple of brief examples, certainly not a comprehensive discussion.

One aspect of the modeling is certainly to support the experimental program. The two go hand in hand in experimental design and setting up experiments to get data that are meaningful and useful, and in interpreting the results from those experiments.

Another aspect, an important aspect of geochemical modeling is in making predictions of the conditions in the Yucca Mountain system at present and under perturbed conditions in the case of the repository. I'm going to focus primarily on that.

A lot of attention -- In particular to look first at the unsaturated zone groundwater chemistry and, secondly, at perturbations to that chemistry due to water/rock/gas interactions.

A lot of attention has been devoted to the J-13 well water because it's derived from the Topaphyte Springs tuff. That is, of course, derived from the saturated zone, and there are some good reasons to believe that there is substantial differences between J-13 well water and what one might find in the unsaturated zone.

Some of the modeling and calculations I have done to illustrate the kinds of effects one might find are shown here.

This column gives a calculated equilibrium aqueous speciation for full compositions measured for J-13 well water. These are not analytical compositions; these are calculated aqueous species concentration at 25 degrees.

Now, if we equilibrate this water with a typical mineralogical assemblage at Yucca Mountain involving smectites, fluorapatite, minerals characteristic of the alteration assemblage and observed -- at least generally similar minerals are observed in Yucca Mountain.

We see some differences. In particular, iron is changed quite a bit and manganese which might suggest analytical problems, or it might suggest the existence of some of the species as colloids.

I think a more important point, though, is to recognize the effects of the gas phase in the unsaturated zone on the groundwater chemistry.

If we equilibrate J-13 well water with air, which is a first approximation for the kinds of gases that are circulating in the mountain, we see a very dramatic effect in that the CO-2 is volatilized. The aqueous CO-2 content goes way up, and as a consequence, the pH goes up substantially.

These are calculated results, but they're very much substantiated by observations of J-13 well water, that if you let it sit in a glass overnight, the bubbles come out and the pH goes up.

So this is one major approach.

Now, another approach to interpreting the ambient system is through reaction path modeling; that is, doing theoretical calculations of the reactions of minerals, gases and water phases likely to occur based on fundamental thermodynamic and kinetic principles.

I show a few examples of those results.

Based on these kinds of principles -- First of all, there's a set of primary minerals there crystallized in volcanic processes, out of equilibrium with the earth's surface and likely to react with groundwaters and ground gases.

These minerals, such as albite, potassium feldspar and cristobalite, interact with the waters that migrate through the mountain, dissolve irreversibly by kinetic rate mechanisms and eventually lead to the formation of secondary minerals.

A conceptual model for the evolution of groundwater chemistry in the unsaturated zone is based on these principles.

So, here, for example, is a kinetic relation that might describe the dissolution of this primary mineral assemblage. This is theoretically based.

It involves some empirical parameters that can be determined, and to a large extent they have been determined in the lab, such as grade constants and reaction orders.

It depends itself on the aqueous solution chemistry in the sense that activity terms relating to the composition of the water and the chemical affinity term representing the degree of disequilibrium of these minerals.

Now, these rates, of course, are temperature dependent. And in the case of Yucca Mountain where there will be a thermal perturbation, one must know in addition the variation of the rate constant, the temperature; and once again there are empirical parameters that can be applied to expressing this relation, including the enthalpy for the various rate mechanisms.

Secondly, there's a secondary set of mineral phases, such as clays and zeolite and silica minerals in some cases, that precipitate from these waters.

These kinds of reactions are generally fast. One can do studies of these reactions in the laboratory, as we're proposing to do here and we're doing here.

The relations between these secondary minerals and the groundwaters can be constrained by equilibrium relations. So, in addition to the kinetic relations, we have thermodynamic equilibrium relations between some of these secondary bases.

In addition, one can expect, particularly in the perturbed system, that there will be gas volatilization processes. The water will be heated. Water, CO-2 out of the volatile species, will go into the gas phase; and we can model these various volatilization processes in a variety of ways.

One limiting approach that we've looked at in particular here is to look at an end member type of equilibrium Railey distillation process in which the rates of volatilization of various volatile species are related by a volatilization constant to their equilibrium gassities calculated for the waters.

So just to briefly show an example of the kind of modeling that's done making use of these principles, here's a calculation literally as a function of time. This is a true kinetic -- integrated kinetic relation showing the evolution -- prediction evolution of a system as a function of time.

And in this particular part I've plotted the logarithm of the rate of reaction of these primary minerals: albite, K-feldspar and cristobalite as a function of time. And I've plotted in the background the secondary phase assemblages that develop along this reaction path.

Now, an important aspect of this model is to look at the steady state generated at the end of this process. I think that it's steady state processes such as this, where there's a very slow dissolution of disequilibrium minerals and a system buffered by a secondary assemblage of likely minerals, such as smectites and clinoptilolites, that control the ambient groundwater chemistry in the unsaturated zone.

It's through calculations like this that we're making an effort to constrain the chemistry of the water in the unsaturated zone.

That's a big problem. People really don't know what it is, because it's so hard to sample primarily.

Now, to just show one example of how the system can be perturbed and how these perturbations can be represented and calculated, I've plotted here a variety of reaction paths analogous to the one shown in the previous slide for non-isothermal systems.

One can imagine a packet of fluid moving along a thermal gradient at a certain rate of movement. It will follow a given time/temperature path as it moves along that gradient.

I've plotted several reaction paths for different time/temperature gradients at .3 degrees increase in temperature per year, 1 degree, 3 degrees and so on.

Now, along each one of these paths for different scenarios, the evolution of the system will be different. I've plotted -- just to illustrate the kinds of calculations I'm doing here -- as a function of time, given there, and temperature along each one of these reaction paths, the sequence of secondary mineral phases that might be expected to form from -- in the unsaturated zone from reaction of the primary minerals creating a secondary phase assemblage.

Now, one of the key inputs to this kind of modeling are the thermodynamic properties of the various phases.

So our experimental program is devoted to deriving some of those fundamental properties. Many of the data used -- or thermodynamic data used in this set of calculations have been estimated, primarily by people involved in the DOE who openly state that they're not very confident in them.

Now, one question that arises in dealing with models like this and making long-term predictions that go well beyond laboratory time and space scales -- certainly we have to go beyond laboratory time and space scales in dealing with Yucca Mountain processes and problems.

One question that arises is how do we validate these models. Are they meaningful in the geologic context?

There are a variety of ways to gain confidence in these models. One is to stick to basic principles, such as thermodynamics and kinetics, that we can trust in our extrapolations rather than in pure empirical extrapolations.

But another very key approach to validation of large scale models is through the use of natural analog studies.

An additional research project at the Center that's just getting underway; the project plan has been written in its draft form and submitted to the NRC staff for review, and we're working collaboratively with the NRC staff to further develop this project, is the geochemical analog contaminant transport in unsaturated rock research project.

The NRC project manager is Linda Kovach, and I and Bobby and Ron Green are involved in the research with John Russell's direction.

As I said, this program has just been started. We've cut out a rather ambitious set of objectives for our natural analogs research program, as illustrated here.

Basically, these objectives are to become aware of the state of the art of the use of natural geochemical analogs, to establish criteria for selection of a site for successful use of these analogs, to do field work and laboratory work, to study a natural analog site; finally, to interpret those data, to develop models for a system of geologic and time and space scales, and ultimately with the desire to validate these kinds of models that in addition can be used to predict the evolution of the Yucca Mountain system.

I should state the regulatory basis for this. It's stated explicitly in 10 CFR 60 that predictive models should be supported by an appropriate use of natural analog studies.

The tasks for this project are summarized here. Basically they just approach those objectives that I just outlined: literature review, development of a work plan and identification of a site to do studies, the methodology for data acquisition at the site and collection of those data, and finally interpretation of the data.

DR. HINZE: Have you made any progress on a site?

DR. MURPHY: [illegible] that's actually a part of the plan. A part of our research plan is to get smart about the site and then to look at a variety of sites and ultimately to pick one.

We've certainly -- For our own study. There have been a number of sites already studied by various workers, and we want to look very closely at those.

So absolutely no determination of what site we might eventually look at has been made.

Nevertheless, I have a slide here --

[Laughter.]

DR. MURPHY: -- just pointing out a few sites that I find particularly interesting, just to give a flavor of what some natural analogs are.

The first one is the Oklo site in Gabon that most people are familiar with. It was natural fission reaction that occurred in an extremely rich uranium deposit about two billion years ago. And through careful study of this site, it has been determined that there has been a very limited migration of actinides in rivers and some transition metals in this site.

It's a good example of a case where a geologic environment can indeed isolate radionuclides for extremely long periods of time.

Now, there are other things that moved around here. Another important aspect of this site -- In fact, an important aspect of most natural analog studies is that they've focused on uranium ore deposits.

These deposits are generally in saturated hydrologic conditions, and they form under reducing conditions because those are conditions for which uranium solubilities are low.

So there are many processes that are of significance to Yucca Mountain, but in a very broad sense most analogs that have been considered to date really don't have very much relevance -- direct relevance to Yucca Mountain.

So our geochemical analog project is, among other things, designed to select an analog specifically relevant to unsaturated conditions. In fact, that's even in the title of the project.

Two potential sites -- these are very, very -- I offer them only as examples -- are the Pena Blanca site in Mexico where there's a rather unusual type of uranium deposit in unsaturated silicic tuffs.

These tuffs are in particular underlain by zeolitic tuffs. So this site gives us a remarkably close analogy to the Yucca Mountain site.

Another potential site is on the island of Santorini in Greece where about 3600 years ago there was a silicic ash fall that buried an archeological site.

Now, this site contains unique chemical characteristics, in particular, lead balance weights that were used by the Minoan culture and other artifacts.

It has been well studied. It's in the unsaturated zone. It's in a silicic tuff, and it provides the possibility of a natural analog -- or geochemical and analog site that unlike most purely geological systems offers very well constrained initial and value conditions for model validation.

So this is another thing that we're thinking about just generally at this point.

DR. PATRICK: Bill, you might comment on the workshop.

DR. MURPHY: Yes. Part of the natural analogs or geochemical analogs project will be to participate in a workshop that is being organized at this time to draw people from the DOE, from the academic community and from around the world who have involved themselves in the use of natural analogs in waste systems.

It's partially through this workshop that's being organized by the Center in collaboration with the NRC staff that we expect to develop the kinds of expertise we need to establish criteria for selection of a site to do our own.

So I'll draw that to a close now.

DR. HINZE: If I may, please, is there any significance of your work to the vein problem at Yucca Mountain, or to the definition of strengths that should be developed to ascertain their significance?

DR. MURPHY: Absolutely. I think those veins are a really fascinating key to the composition of the groundwaters in the unsaturated zones.

Because the waters are so hard to sample, a key to their composition is through the minerals that they've precipitated.

So I'm very curious about those vein deposits and their origin and the chemistries that led to their development.

I don't have the slides, but in some other calculations I've done, I've tried to mimic the evolution of deposits such as that, perhaps under a thermal perturbation or paths due to petrogenic processes.

DR. HINZE: Have you looked at any preliminary copies of the study plan regarding the veins?

DR. MURPHY: You mean the -- The study plans, no, I have not seen the study plans.

DR. HINZE: Thank you.

DR. RUSSELL: There's one question that was not completely answered, and I think that was the question about being hampered in getting samples from Yucca Mountain.

We've talked quite a little bit about J-13 well water. We have received approval -- and once we get the containers and make the arrangements, we will be going to Yucca Mountain to sample J-13 well water.

DR. MOELLER: Thank you.

DR. NAIR: I'm Prasad Nair with the Center. I'll be talking about the materials program.

Before I do that, I would request the Chairman, I'm supposed to be giving another little ten-minute presentation on the fast probabilistic performance assessment later.

That's under Item VIII. If it's okay with you, I'll go ahead and wrap it up at the same time.

DR. MOELLER: Fine. Do those both now.

DR. NAIR: Thank you.

Shifting gears now from the natural barrier to the engineered barrier area, and this is an area of interest in the waste canister business.

What I am presenting at this time is the integrated waste package experiment that's one of the research programs.

The project participants here are, besides myself, Dr. Narasi Sridhar, Dr. Gustavo Cragnolino is going to join our staff in a month or so; Dr. Hersh Manaktalno. All the first four are of the Center.

And then we have Mr. Fred Lyle from the Division VI at Southwest Research, and Professor Bryan Wilde, who's a subcontractor to us in developing some of the hydrogen procedures -- hydrogen-testing procedures.

What I want to do today is look at this program pretty critically and look at it from two parts: the programmatic aspects according to the regulatory framework, what is the implication of this to the waste package performance.

Then the integrated waste package experiment program approach, how we put this thing together, and then hit on the technical scope of the program as we have it right now, and then I'll talk about the specific objectives, the technical program as it's going, and finally give you a status of what has been done to date.

DR. MOELLER: You showed the staff what was involved.

DR. NAIR: Yes, sir.

DR. MOELLER: And yet when we were looking at this sometime ago we wondered why the performance assessment people were not included in it. To our point of view, there was no performance assessment input.

DR. NAIR: To me you could call me performance assessment because I model life extension, and that has been my background in this area.

To reflect, I've worked with the reactor side of the house, predicting life predictions for nuclear components and --

DR. MOELLER: So through you, you have performance assessment input?

DR. NAIR: Yes.

DR. MOELLER: You were fully aware, obviously, of the other performance assessment work underway?

DR. NAIR: Yes. In fact, the second presentation will speak to some of the aspects of the performance assessment.

In fact -- Let me go through the presentation and you will see the flavor of some of the things, why they are doing things the way they are doing.

DR. MOELLER: Okay. You've removed that question then.

DR. NAIR: Just briefly passing on this regulation, this is an important regulation. I want to take a minute or so on this one.

On the containment is the problem which is directed at the waste package. The regulations require it to contain between 300 and 1000 years.

We need to reflect on those years. It's not critical that it's 300 or 400 or 1000 years, but 300 is a large time frame.

We don't have a historical perspective of doing predictions to that extent. We don't have metals which we have documented, or historical information we can gather and use in this business.

We have typically done life prediction for reactor components like I was saying, 30, 40 years. 40 years is the lifetime; maybe 60.

Those are the kinds of dates we deal with. That's the kind of technology we're dealing with.

So it's important for us to recognize that the 300 to 1000 years is something beyond the realms of a lot of engineering predictions.

Given that, we figure that there is a big element of probability, uncertainty evaluation; and that's very key to this program.

And how does it manifest itself? And you talk about the performance assessment, and here's sort of our concept.

Now, typically what you see is here is a corrosion environment that might be -- it's probabilistic; you don't know what's exactly there, over time what it's going to do.

Now, on the other hand there's a material you can select that has got a certain resistance. In this case I chose -- the potential in terms of maybe a corrosion type of phenomenon. You may do a test like that.

So in this is an inherent uncertainty, inherent distribution of its performance.

The intersection of this is what we are really interested in, whether it is a phenomenon that can happen with time, or in some cases this may be moving away from each other. So it's a good situation.

The importance of knowing the outlier problems is very key in this area, meaning what are those extreme values that may create a material degradation process.

So our program is geared at looking at some of the specific areas, particularly the table of distributions, for instance, again from a regulatory sense. In the regulatory sense we are looking for what can get you.

DOE's program may most likely be in the center part of these activities. So our focus of research is looking at where we bound these evaluations.

To that extent it is a good thing for us for financial resource constraints where it will be focused at the program importance area from a regulatory perspective.

So the test matrix and test program is developed along those lines.

Then we're looking at controlled test environments. Now, Bill Murphy talked a little while back, for instance, on the chemistry. We are looking at species that are important to corrosion, important to degradation processes.

There is a variety of -- in the region of the Yucca Mountain, what are the species composition. I won't go through these.

These are EQ-3 computer values included right here, and Bill Murphy has done this. He has told you about the process of calculation, and it's important to recognize. This program does track with the geochemistry program; they feed on each other, to know what is out there in terms of the environment. Knowing the environment is important, and what are those species that really affect the degradation process. So it's interactive certainly.

Then the next key programmatic feature is the stepwise testing strategy, recognizing that you don't want to embark on a large, huge program without stepping through -- sorting out your key parameters and building on those parameters that are of importance.

So we will be looking at scoping tests initially, looking to see what the general literature says, what's the DOE/other programs and select certain tests and make sure you have scanned the waterfront in a short and very focused set of tests.

Then you get down to a short term test. Testing. This is directed at what are the uncertainties that still remain. Where can we make an impact on these certain areas of work and reduce the technical uncertainty in those, in our minds to understand if an application comes in with some data.

There needs some baseline testing. That means you need to review, compare materials. There are no absolutes in this business, so you need to find out how doing a certain test compares with other material tests.

So that's another key facet of this. Again, as Dr. Moeller pointed out, it has got to satisfy the performance requirements, performance assessment, and those tests better be statistically valid.

So all these things feed in developing test matrixes and coming up with conclusions.

The long-term tests have two aspects. One is to establish if you have a model, for instance, whether it is workable; it shows some long-term tests will feed back and say, "Yes, the model you developed did do that."

The second and very important facet of this long-term testing is the notion that the Center being here for a long arrangement with the NRC, we can put in certain tests that are maybe 20 years or longer, so that there is enough for confirmation testing. We can check those things.

So these are sort of the fundamental concepts of testing -- the testing process.

Now, I talked about another key aspect of it is when you look at performances, you look at materials. Now, several of the materials may behave like this; that is, here is an environment; here is the resistance to that environment.

Some materials can be demonstrated to fail with time or with exposure. Others are marginally so. And yet others are distinctly different; they never have a problem.

Now, the notion of using something like this as a baseline material test, you can compare certain others with respect to that.

So in our test program we've introduced a baseline testing material -- in this case it's C-22 material that was used -- for comparing some of the Hastellic materials just for the corrosion end of it, because we felt that it had a distinct -- distinct resistance to pitting corrosion and general corrosion, and you could compare materials of that same class.

The other opportunity is if you change the materials, we can relatively check how well something performs with something already done. So the expense of doing a lot of testing may go away.

So there are several motivations to doing some baseline testing.

So that's yet the other facet of this.

So what I talk to you about as far as programmatic -- how we structure the program.

Now, the technical project objectives, what are we doing, how we constructed the step. What we want to know is what's the state of knowledge, not only in general testing and engineering, but know the processes, how these things happen, the kinetics, what is out there in modeling, for instance, then conduct these experimental programs I've been talking about selectively and constructively, then select materials and the long-term testing.

All these objectives feed back to what I just spoke to you about. These are elements of the program as presented right now.

Now, the first task is of the state of knowledge, is evaluating the different kinds of activities here is the definition of the repository environments.

We've already done some work with Bill Murphy, feeding in some of the relevant environments.

Engineering models, we are starting to look and see which are the models. We would like to get these models based on kinetics, based on fundamental mechanisms, fundamental understanding rather than a lot of empiricalisms thrown in up in the front.

Then the corrosion in the repository environments. We would look to run these tests in comparable environments. We think that several species in its combination will have a more important effect from the licensing end of it than just looking at concentrated chlorides, for instance.

We need to understand the different synergisms of these different species that work in the waters. So we are looking at that.

Another aspect of the study is looking at -- we'll be looking at the metallurgical stability, long term, for instance, desensitization, if you have the stainless steels. If you keep them at low temperatures, the metal stability of the material is in question. We need to understand how it degrades with time on that, not just corrosion.

Or BL alloy, for instance, if you have the copper materials.

DR. MOELLER: Where are they going to use stainless steel?

DR. NAIR: Well, they may reduce it to one, from what I hear. 25 is one of the materials. Or they may -- It's still an open question.

DR. SILBERBERG: That decision we thought six months ago, a year ago we thought it would be made about now, but now that decision has been delayed.

DR. NAIR: The most recent information we have is they were going to make a decision in April of next year. That was the last we knew.

But as you recognize, there are problems in those materials still.

The other aspects to look at is hydrogen attack, maybe hydrogen generated by radialysis products and other aspects of it.

And then finally when you close these containers, what are the processes, what will they do to this life prediction of this.

So these are -- And the experimental programs may make all those aspects -- It also will develop eventually data for supporting the predictive models as we go along doing that.

Now, we talked about the materials. Let me throw up the materials that have been -- In the SEP as it stands, these are the six materials. These three are the Hastellics, and these are the copper materials.

We introduced the reference material for comparative purposes, but those are mostly for the Hastellics. Copper, when we get there, we will choose one of those to probably check on.

Now, in the scoping test, these are the kind of tests we've started and performed quite a few of those. I'll get back to what was done, is the electrochemical testing, characterization of materials, and we'll end up doing some testing looking at stress, corrosion and cracking problems, then other types of tests as necessary. It's more on a screening kind of thing.

Then the short-term tests, I just put up numbers to give you a feel for the time scale to do these tests. Some take a longer time, the so-called short-term test; others will take long term.

So a study of welding will be a later phenomenon until we understand better what the selected material is and what the procedure is going to be. There's no point in trying to go ahead and do a scoping.

Task 3 are the final tasks in this program. It's directly looking at the Yucca Mountain situation, so we look through all the same tests and gather support.

This is a key facet, and one of the things that we have done here is to be able to go over and sit across the table and talk with the NRC and other program people, exchange information, change if necessary. The flexibilities for it will be built in.

The program -- After you've seen some data and looked at something, that it's good, bad, indifferent.

Now, as part of this program, because it is a first of a kind and nature, meaning that we are trying to predict something in the 300-year region, there are a lot of things that no person has privy of or exclusive rights to intelligent arguments.

So we figured in this particular case it is prudent to get a few peers to evaluate and look at our plan.

One of the exercises we came up with, some very thoughtful look/see -- initial look/see at what people should look for in these cases. It is not just what we say should be done, but is there some understanding of what others will think.

And, interestingly, here are some of the highlights of those comments. And it's very important for us to recognize that.

The suitability of current testing, for instance in the STNP-4 test procedures, they are looking at electrochemical tests. There is wide variability. It's a gross test as you call it. You cannot use some of this testing in a predictive mode. They are more for material selection or material scanning, comparing materials and for short-term use and applications.

So when you talk about standard testing procedures, there are fallacies in those procedures itself. We are looking -- doing the wrong test for the right reason or right -- wrong reason, whichever way you want to look at it.

DR. MOELLER: Excuse me. I'm still not straight on who is doing the peer review.

DR. NAIR: Peer review was done by three outside individuals.

DR. MOELLER: Did you select?

DR. NAIR: We selected, and they are people with twenty or more years of experience: academic, industry and familiar with the nuclear business.

DR. MOELLER: Thank you.

DR. NAIR: So it was independent of our thinking. That was the key in this whole process.

Another thing is they said there are certain -- in certain areas you need to look at new methods to get this predictive methodology in place, and they have suggested a workshop. We will follow up.

The gaseous environment, and as you can see, heat to heat variations because the nuclear industry has other areas similar to those problems.

The internal corrosion of canisters, especially when you have spent fuel in it, if there is any gaseous or any entrapped liquids as a result, what would it do from the inside out, or galvanic corrosion problems.

We are in the process of preparing the review the recommendation on that.

What's done to date. Let's look at this.

We have evaluated and studied and reviewed the data that has been out from several of the DOE and NRC programs, and the questions do come back and say whether the test was the right kind of test for the right data.

Most of them fit the scheme of screening tests very good.

Now, we've done -- developed some synthetic J-13 procedures, and Bobby Pabalan has been involved in that activity, so that we can get some of these chemical species and run some of those tests.

We've run some tests, and you'll see in the lab today later some of that activity.

The preliminary screening tests have been done on the Hastellic materials, not only in the synthetic J-13 water, but in concentrations thereof, increased chlorides to a large degree, to look at pitting and the general corrosion aspect of it.

The hydrogen-related study which is being done by Professor Bryan Wilde -- He is essentially helping us develop the procedure where we can diffuse hydrogen into metals, and that is pretty much complete.

We will bring it over and Dr. Breedlove will pick it up from here on.

We have conducted a peer review, and we have participated in several technical exchange meetings.

And as was alluded earlier, we had some of these technical exchange meetings. Two of them have been extremely fruitful on this subject, and the second of the meetings, we had a free exchange on what DOE is doing. They presented some of their materials, and we do find the problems we are talking about -- they find themselves too, in relationship to test methods and some repeatability of data problems and other things.

So it has been a good exchange, technical folks to technical folks present.

So that's in a nutshell the program as it stands.

In this area, like you said, it has got to be driven by the performance evaluation, and it needs to tie with what are the key parameters and how you can estimate these parameters from a time base and time independent base.

Certain of these parameters can be treated as time independent, and you need to know which ones are those parameters.

So selectively we start building a case on that.

If there are no questions on the IWP, I would like to go into this performance assessment area which we talked about, and it's called the fast probabilistic performance assessment.

One of the things that intrigued us when we started a couple of years back looking at -- looking downstream, predicting, and from a regulatory stance and looking at the "what if" scenarios, is the methodology currently being used adequate? Is that good enough or is it cumbersome? What are the parameters?

We looked at a few of the things, and it so happened that at the institute we had some very special capability of some advanced methodology development in using fast probabilistic analysis.

It's one of those newer techniques that's being used.

So we tried to tailor make it to fit this to see if it worked. We explored the possibility of using this FPPA methodology in the waste package program, and bring it to -- at least to demonstrate if it is a feasible proposal.

So I'm going to speak to that part of the technique.

Now, to give you some of the high order aspect of what this program is about, typically when you look at probabilistic analysis, you need two things.

One, you need to simulate several behaviors, and then you've got to find out -- be able to do some sensitivity analysis, how good they are, one parameter versus something else, you know, several parameters.

So there are good simulation techniques using Monte Carlo, the Latin Hypercube and other methods. This method also is one of those that would help.

In this case -- This is based on some of the reliability methods that has been applied to structural systems. Most of it is NASA-derived type of work.

And it uses the sensitivity data, the relative merit of different things, and generates probability sensitivity factors. And it's important in our business. I'll show you some examples as we go along.

This is a new technology, like I just said; and it's more suitable for implicit functions. Again, these are things here.

The accuracies have been well demonstrated. It also happens to be an approximate method.

Now, to get an understanding of what these things mean, typically you look in terms of a property distribution function, you take a Monte Carlo approach, it's -- You get a good representation around the mean or the expected values, and the tails tend to be left out, meaning the accuracies are pretty poor in the tail region.

If you take a Latin Hypercube, it's equally disposed of. The points are chosen to equally spread out. And again the higher the number of points, the more accurate you get on a Latin Hypercube, even in the Monte Carlo.

What's different about the FPPA is you can focus on the area of interest, rather than worry about the area of non-interest.

Now, this just represents -- Since our concern is looking at the tail end of distributions, that's probably where we want to focus our attention and get accurate data there.

If you are inaccurate in the tail regions in your methodology, you immediately set up bad results all through your prediction methodology. So accuracy in the tail region is suspect in many of these cases.

This has an opportunity to focus it where it counts most. It doesn't mean to say that it only looks at the tails. If you wanted the whole distribution, you could do that, too. But it is the point of where you want to focus.

It's particularly relevant for the regulatory aspect of the problem.

Here's an example, just a concept, in the area of

3000 years -- 300 years to 1000 years history of -- if you want to predict.

The fast probabilistic analysis method works off a most probable value concept. It picks the most probable value area and draws -- tries to draw a locus. This is what we are seeing as a two-parameter joint probability assumption. We can handle in space and equal to in several ways.

It sets -- gives you an opportunity to set limit conditions. That means if I say what's the failure probability under those two conditions, those two-parameter situation at a 300 level, and you can draw the most probable locus on each one of these two parameters or N parameters.

This, incidentally -- You can talk about the probability of success versus probability of failure. It depends on how you couch it.

So this is sort of the concept in that. What you do in this program is a set of several approximations you enforce in this methodology. You look for the most probable value by some iteration and processes, and then you use Taylor series expansions around that point, around the point of selection.

Now, at these most probable values if you have a Taylor series expansion off the performance function, if I say Z is my performance function, Z is N parameters and different parameters interacting.

You have a Taylor series expansion that's supposed to -- You can compute at that point what the value is. If you wanted to include an error, you can add the error. So this is a stepwise process.

You can go more accurate by going into more number of steps.

This has the opportunity of -- Well, all it means in terms of going to more parameters on the Taylor series expansion is how fast you converge on your exact solution.

So there is a lot of numerical analysis that go into it and make that happens.

Now, take an example. How do you compare to something? We took a model and analyzed the cumulative distribution function.

What you see here is a hundred or 10,000 points on, say, a Monte Carlo type of evaluation, which is sort of the perfect fit. In this case we're using about ten variables in a corrosion model that says some corrosion rate, depending on chloride concentration times some other concentrations is the general model.

If you do that -- and in this case it took 70 minutes to run that, using a Monte Carlo approach.

Using this fast probabilistic analysis with the first order of your Taylor series, it just took one-tenth of a minute. And you see the little distributions on that.

And finally if you went to a first order -- advanced first order, you increased your severity, it took .2, but it obtained pretty good accuracy.

The point is, with very little time of computing you get very accurate at the points of interest. And that's the key in this whole methodology.

The other thing, I talked about the sensitivity analysis, how do you compare. At dose ten parameters, this is a plot of six of them. Yeah, that's right. Six of those parameters.

How do they change with time? And that's important to know.

If you take a parameter, it may be important at the start of the repository time, but a hundred years later it may not be important. How does it -- Relative to other parameters, how does it fit?

So these are -- For instance, in this case here's a parameter, talking about eight years corrosion in this case. It's high in the first -- early part of life. Afterwards some of the other parameters start.

It's an illustration. The values aren't the exact numbers.

But that's the key information that can come out very easily at no additional significant cost of computing.

Now, typically in Monte Carlo approaches, you really have to rerun the whole order again to run and get -- change your parameters and do this.

Here it works off of the input itself which is based on sensitivity parameters, the interaction of parameters.

So this is a technique that we have incorporated, and some of the plots you're seeing are runs done here on some of these test models.

As part of what Wes told you earlier on the EBS performance assessment, that's part of it.

And again all this integrates back -- feeds back into the research program. You say, "Which one of the parameters should we be spending time?"

And the feedback from the research to here is we've done these tests, and these are the parameters that show importance from actual tests.

So it's an interactive back-and-forth scheme, and eventually we'll optimize it to such an extent that it will be cost effective and, hopefully, it is very easily usable.

So that's my ....

DR. HINZE: The codes for this FPPA were done at the Institute?

DR. NAIR: Yes, that's right.

DR. HINZE: Have you modified these?

DR. NAIR: Oh, yes. This is the -- What I put out is directly for the waste package. So what it is is the FPPA, the way the model is structured, it's another tool that plugs into the -- we call it EBS pack -- E-B-S pack.

This is a module that fits into that thing, evaluates the probabilities of all those models that are stuck into this program and goes through -- inside it.

So the FPPA model is specifically geared for this one. We've converted it from what is used -- We have made some changes. We have modified it for this purpose.

See, the space station and other applications are a little different and the concentration of activity.

The thing is to focus on the area of importance. There the important areas are maybe startup times and coming down, reentry and those kind of situations.

Ours is a little different. We have the long term where we don't have any access to even check these things. So we have made modification.

DR. HINZE: Are you satisfied with where you are with that, or --

DR. NAIR: Yeah.

DR. HINZE: -- is there continued modification?

DR. NAIR: No, I think we have put it into a state that we can use it, and it is running right at this time. We only intend to change the FPPA, parts of it, but we are doing the rest of it, going on models generation, is to update.

As the technology changes or anything, we are working -- The Institute is fortunate to be working in other areas, and we just absorb the technology. That's about what we're doing.

DR. MOELLER: Is it being used in nuclear power plants?

DR. NAIR: No.

DR. MOELLER: You're the first to apply it to wastes?

DR. NAIR: That's right. We have a couple of papers -- In fact, FOCUS-89 had a paper on important sampling and using the FPPA methodology. It's out there, and people have looked at it and reviewed it. DOE is privy to this information.

MR. VOILAND: Has this been used with accelerated tests where you actually have a more reasonable time frame to deal with?

DR. NAIR: I hope we will end up doing that kind of thing. We want to use -- hopefully, it depends on what are those parameters we should be looking at.

Right now the statistical -- experimental statistical methods are like the 2N types, and it's a statistically-based development on most of the test parameters right now.

DR. MOELLER: This ties back into what Dr. Hinze was asking about. Maybe you answered it.

But what have you found out thus far? What's something really significant that has come out of this? You said it would help identify the important parameters.

DR. NAIR: Yeah.

DR. MOELLER: But have you identified an important parameter?

DR. NAIR: No, we haven't. The test hasn't proceeded --

DR. MOELLER: Far enough?

DR. NAIR: -- far enough to make those judgments.

DR. MOELLER: Okay. Any other questions?

[No response.]

DR. MOELLER: Well, this looks like a place we perhaps should break for lunch, if that's appropriate.

DR. LATZ: It would be as you wish, Mr. Chairman.

DR. MOELLER: And then would we go on a tour?

DR. LATZ: As you wish. We can either come back here and complete the formal portion of the meeting and then go on the tour, whatever your preference.

DR. MOELLER: All right. Well, we'll return here and complete the presentations and then go on the tour.

DR. LATZ: Very good, Mr. Chairman.

DR. MOELLER: Why don't you go ahead with the presentation? I'm sorry I was thinking it was --

DR. LATZ: I think we probably very well could do the seismic rock mechanics and then break, if that's all right.

DR. MOELLER: All right. Let's go on. I was still on Boston time.

DR. CHOWDHURY: I am Asad Chowdhury from the Center. I will be presenting the project on seismic rock mechanics.

Now, for this project, the principal investigator is Simon Hsiung from the Center; Barry Brady from the consulting group in Minneapolis; Daniel Kana from Southwest Research Institute; and myself from the Center.

There are also a few individuals who will be involved in different parts of this research project: Dr. Rachid Ababou from the Center; Dr. Roger Hart from ITASCA Consulting Group; and Mr. Mark Ward from ITASCA Consulting Group.

So these are the individuals who form a very effective group considering the various aspects of that research project.

This slide shows the regulatory basis of this project.

Now, let me explain in a simplified version the project. The typical rock medium, jointed rock medium similar to what we may face at Yucca Mountain, with an opening.

In a jointed medium there is a loosening around the joints. There would be continuous joints or intermittent joints. There would be detachment of the rock near the openings.

We are not talking about major force; we are talking about minor localized force.

Our knowledge to date shows that in a jointed medium like this, the most significant mode of deformation would be the deformation around those joints, instead of deformation of the rocks.

This is analogous to matrix flow versus fracture flow in underground hydrology.

Due to the seismic motion or other types of similar dynamic motion, the joints may open up or it may be in a permeable condition, a closed-up gap. There may be elongation of the opening of the joints.

As a result, we see that this problem would not only affect the stability of the openings, it would also affect the travel time of the nuclides. And if there is a large slippage of the joint, that may physically damage the waste package, or if there is any contact between the waste package and the sliding rock, there would be space erosion.

And also the opening of the joints or changing diameters of the joints would also provide input to the stability about which Dr. Ababou will be talking.

We can see various steps of integration between this research project and other research projects going on at the Center.

Here are the general objectives of the project. The first two objectives talk about understanding the different parameters that would affect the seismic response of -- understanding of joint dynamic response and parameters as to dose, and also the parameters which would affect the performance of other types of underground structures.

But the most important objective is here, to develop methodologies to evaluate, validate and reduce uncertainties in the prediction of models used in seismic assessment of the type medium.

So one of the most important objectives of this research project would be to validate the methodologies and goals which could be used by DOE for the prediction of the stability of the underground structures and its subsequent effects on travel time and other factors.

This slide shows the different tasks. Now, if we look at the task, it has got numerical analysis, experimental analysis and field studies.

Task one - focused literature research leads us to understand the state of the knowledge in this area, the state of the knowledge about the rock mechanics, how the joint would behave under different seismic loads and degradation of the joints.

I'll discuss a little bit of the details later on.

The laboratory characterization of jointed rock, this task has got two different aspects. One is to come up with the constitutional relationships of the rock joints, and the second component would be to test a single jointed rock specimen.

Later on, I will explain why we are doing this and how these results would be utilized for the end product of that.

DR. HINZE: Is that in any way focused on the tuffs at Yucca Mountain?

DR. CHOWDHURY: Here let me answer this question in two steps, if I could.

Since all validation is done, measured -- methodology, validation is a major part of the project. So it is not absolutely necessary we need Yucca Mountain site-specific information at this stage.

However, we are trying to get information which is as close to the Yucca Mountain situation as possible. For example, for the experimental part we are trying to get rock specimens from -- tuff rock specimens which have jointed characteristics similar to Yucca Mountain because at this moment we can't get the specimens from Yucca Mountain.

Okay. Does that satisfy your question?

DR. HINZE: Thank you.

DR. CHOWDHURY: Second would be assessment of analytical models and computer codes. We have selected all the possible numerical methods relevant at this time to validate that methodology and that computer code, so that whatever technique DOE comes up with, we can give them guidance.

So that would be the breadth and width of the scope, that whatever technique DOE uses we would be able to give the guidance to DOE.

Then we have rock dynamics, laboratory and field studies and code validation. Having characterized the rock specimen here would be doing the experiment on jointed rock blocks. That means a rock mass consisting of a large number of joints, as opposed to single joint specimen of this task.

And our field studies would include the response due to that. Also, we would be collecting instrumented data from some selected mine, if possible.

We will also be doing groundwork field studies. At Yucca Mountain the water table is some hundred meters below the repository horizon, but the effect of water table, the effect of seismic effect on water stability is not completely understood at this time. So we would be also doing some field studies to assess the effect of seismic effect on water table.

And, finally, we would be doing Yucca Mountain scoping analysis, which is the task where we would need site-specific information on Yucca Mountain.

DR. MOELLER: On Task 5 when you say you'll be doing field studies, will you plan to do those at Yucca Mountain?

DR. CHOWDHURY: No. Again, this would be trying to study is there any seismic effect on the water table and also validate the code. It is not absolutely necessary that we try to do it at Yucca Mountain.

But again we will try to do it at the site which approximates it as closely as possible, but it is not absolutely necessary.

Okay. On focused literature search, we have completed this task and already wrote a report and submitted it to NRC, which would be published as a NUREG.

Now, this literature search gave us much important information. One, which is generally known, is that at the surface these structures are affected by the surface wave of the seismic event.

But at the underground repository level, body waves, as opposed to surface waves -- But our knowledge of seismic effect on surface structures may not be directly applicable to the design of underground structures.

One reason is that in the case of surface structures, the primary mode of deformation is the deformation of the structure itself, whereas in the case of underground jointed rocks, the mode of deformation is due to grinding between the rock motions, and as a result, the design criteria we use for surface effects of design due to seismic motion is not applicable for the design of underground structures made of jointed rocks.

Okay. And also one paper has been presented, and this was in the SMiRT conference at Anaheim, California.

Next would be -- Here I only want to talk briefly about. Dr. Kana is sitting here and will be elaborating on that after my presentation is over.

As I mentioned, the experimental part -- One component would be develop the constituency relationships of the joints of the rocks.

At present in the partial programs several models are used: Mohr-Coulomb model, continuously yielding model and Barton-Bandis model.

We will be making a pseudo study test of the jointed rocks to find out experimentally the different parameters of these models so that we can get the experimental constituency relationships for the different types of models, which are at a level that are being used nowadays by different commercial computer codes.

So this would give us -- provide us the basic information regarding the constituency relationships.

The second part of the experimental work of Task 2 is testing the single jointed specimens under harmonic loads, shock load and earthquake load. So we'll get that experimental response.

Now, having known the constituency relationships of these jointed rocks, we will use the existing computer codes to analytically or numerically given in the response, and then we will compare that response with the experimental response to see how the various codes do against the experimental results of single jointed specimens.

Dr. Kana will talk more about it.

Now, the computer codes that have been selected for validation and verification are distinct element code: UDEC and 3DEC. UDEC is a two-dimensional version; 3DEC is a three-dimensional version.

The discrete element code, DECICE, is a three-dimensional code.

Finite element code: HONDO and SPECTROM-331, again HONDO is the two-dimensional version of SPECTROM-331.

And the boundary element code: BEST3D.

These will cover all the available numerical techniques in practice today. And so our validation of these codes could provide us the knowledge and expertise to give guidance to DOE without regard to whose model they use.

Previously I mentioned that we are also studying the three different types of joint models: Mohr-Coulomb model, continuously yielding model and Barton-Bandis model.

And again those are among the commonly used joint models. So this study will give a good breadth and depth of all the various modeling techniques of joints as a medium to give guidance to DOE.

Okay. Again I have shown here -- The validation process we have divided into two components: qualification of analytical model of computer code and validation.

For qualification we will be qualifying against the most strong solution and against the experimental results of single jointed rock specimen.

Now, because -- The analytical models which could qualify, based on these comparisons, would go for validation tests because we believe that if the analytical techniques or numerical techniques and the codes cannot predict a simple behavior of a single joint, we won't be able to simulate that behavior in a multi-jointed rock medium.

And the validation study would include experimental seismic response of jointed rock mass. That means we will conduct an experiment on the mass of rock consisting of a number of joints, and again Dr. Kana will expound on this.

And also we will be validating against the NTS shock response of underground structures, and also our validation study will include instrumented field studies for seismic response of underground structures.

We are in the process of negotiating with a mining company so that we can instrument the facility and get data from there.

Other validation studies will include studies for seismic response of groundwater. Again, we are negotiating with the same mining company so that we can instrument the site of the mine where the ground hydrology is well known.

And having received or obtained this data, we will be conducting the numerical analyses, using the computer codes which would qualify for validation studies.

This will complete our validation study. Having done this and we have a valid code or codes, we will be now in a position to do the scoping analysis for the Yucca Mountain site.

By that time, we hope we will have access to Yucca Mountain to get site-specific information.

If you have any questions, this is the end of my presentation, and then Dr. Kana will come.

DR. HINZE: I must congratulate you on a very interesting study, one that certainly will have a lot of implications in terms of Yucca Mountain.

I do have a couple of questions, though. You focused very much in your presentation here on the jointed aspect of the rock.

DR. CHOWDHURY: That's right.

DR. HINZE: In Dr. Pabalan's presentation, he showed us a cross-section of Yucca Mountain in which it was chopped up completely with near vertical faults.

Am I to understand that you feel that the joints are going to have a profound effect on the seismic response of the repository despite the fact that we have this intricate fault pattern?

DR. CHOWDHURY: Okay. As I mentioned at the beginning, we are not here predicting the behavior of the major fault. We are only predicting the behavior of the jointed rock, localized joints.

The objective is not to study the seismic effect on a major fault.

DR. HINZE: On any "measured fault"?

DR. CHOWDHURY: "Major fault."

DR. HINZE: Do you think that the response of the site to this jointing is going to be affected in a considerable manner in a highly specified manner in comparison to the fault response?

DR. CHOWDHURY: No. Let me answer this by giving an analogy.

Here we are not considering the effect of the fault. We are assuming that the fault does not exist, what the response of that jointed rock will be.

DR. HINZE: I have another question, and that is, in view of your literature search, I'm curious as to what your response is to the technical position on seismic hazards that has been prepared by the NRC staff and that is currently undergoing public review.

DR. CHOWDHURY: At this moment I am not prepared to answer that question, but will provide you that information for the record.

DR. KANA: Excuse me, Asad. I'm Dan Kana, by the way. I'll be following up with a presentation.

Perhaps I ought to make a bit of a clarification here. As I'll show in a moment we have two parts to the experimental program. The first deals with the individual joints between rock elements; that is, an upper and a lower block of rock and a joint interface in between.

The second phase of the experiments deals with an aggregate of such blocks. I'll show a diagram of that in a moment.

That aggregate of blocks will include a simulated fault in the segment of the rock mass. The modeling also does include the effects of geological faults in the rock mass, as well as the effects of the joint itself.

I'm not quite sure if that's what you said, Asad.

DR. CHOWDHURY: Again, we are not -- That fault may give rise to the seismic event, but we are not studying as a part of this project the effect of a major fault.

The presence of a fault will give rise to the seismic event, and we are studying the effect of the seismic event, not what would happen due to a major fault.

DR. HINZE: In view of your library search, do you have any feeling concerning the application of 10 CFR 100, Appendix A, to an underground repository?

DR. CHOWDHURY: Yes, it does have application.

DR. HINZE: Thank you.

DR. CHOWDHURY: Dan.

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DR. KANA: Thank you, Asad. My name is Dan Kana. I am a mechanical engineer with Southwest Research Institute.

I specialize in the studies of solid and fluid mechanic systems subject to dynamic environments. Typical applications are shock vibration and earthquake engineering type applications.

I'm involved with this project in the design of the experimental apparatus and the experimentation associated with it.

What I will do here very briefly is describe the apparatus and its purpose. I will not spend much time on the details because you will have an opportunity this afternoon to go into the laboratory and to view that apparatus and have an opportunity to ask questions at that time.

But certainly here it's appropriate to talk about two major facilities that we have for this program, one of which I show here, which is a jointed rock interface tester, which has been designed and recently installed for this project.

The second major facility is a biaxial seismic simulator, which I will describe here momentarily. It will be used to test a jointed rock segment, which in fact will be a scale model of a typical segment that would be considered in Yucca Mountain itself, a jointed model which would include tunnels, buildup of an aggregate of jointed rock and include a major fault in that segment.

As Asad has pointed out, our purpose here is to obtain experimental data at various levels so that we can use that data to develop parameters for the analytical model codes and in fact to validate those codes for the particular application that we're looking at here.

This facility, I will show a block diagram of it in a moment so that we can see the various parts of it a little better than on this photograph, but in the photograph in an angle view we have an opportunity to see the various parts of it a little better.

But basically, it is comprised of a jointed rock specimen, which is subjected to a static vertical compression through three electrohydraulic actuators.

Then part of the specimen, that is, the top part, is subject to a dynamic force, a horizontal dynamic force, a shearing force relative to the lower part of the specimen, which is fixed to a very rigid base, which supports this entire apparatus.

Now, let me show the block diagram of that and I can explain each part a little bit more readily.

In the upper part of the diagram, we show the primary item of interest, which is the tough sample. This full-scale sample would be obtained from a site as was pointed out earlier whose rock joint properties are judged to be as close as possible to the Yucca Mountain site.

The specimens are obtained so that we have a natural joint here that would be left intact when the specimen is extracted from the site.

That specimen is brought to Southwest Research Institute. It is then trimmed so that we have a smooth set of dimensions which will allow us to place it into the boxes that are part of the apparatus and, in fact, we grout it into those boxes with a material that will be stiff relative to the joint properties, the resistance forces of the joint itself.

Then it is subject to the horizontal force as well as the vertical forces and the apparatus is designed so that the shearing force is felt primarily at the joint itself.

The rollers at the top indicate that there is simply a small resistance to the compression part of the vertical actuation part of the apparatus.

There's a variety of instrumentation that we have to be installed on this apparatus. We will be measuring such things, of course, as the vertical loads, the horizontal dynamic load.

We will be measuring the vertical closure at several locations on the specimen, the top block relative to the bottom block.

These measurements will be made directly on the specimen itself so that we can eliminate the compliance effects of the grout, if there will be any significant there, as well as in the apparatus itself.

Likewise, in the measurement of the horizontal motion, those measurements will be made near the interface on the block itself.

DR. CARTER: Excuse me. Two questions. One, what are the approximate dimensions of the sample.

The other question is why is the horizontal extent of the top and the bottom part of the sample different?

DR. KANA: The dimensions on the sample are: The bottom block is eight inches by twelve inches. The upper block is eight by eight, such that it allows us a two-inch travel each direction, a four-inch total stroke in movement of the top of the sample over the bottom part of the sample.

What is your second part of the question?

DR. CARTER: That was it. You answered both.

DR. MOELLER: If you've collected the sample in the field and it's from under ground, how do you control humidity, temperature, anything that might influence that sample between collecting and testing?

DR. KANA: That, of course, is part of the sample acquisition procedure. It's, of course, realized that not only the humidity but the dynamic shipping environment, various handling procedures can influence the nature of the joint and particularly the character of the interface.

We have in mind, one, in the handling procedure which is being designed, to provide for a banding of the specimen together, the two parts of the blocks themselves.

Of course, we have to realize that a specimen of the dimensions that I mentioned here would weigh of the order of somewhere between one and two hundred pounds and so that it is somewhat difficult to handle.

Therefore, there will be a banding procedure of it to a support base, a pad if you will, a wooden pad such that it can be handled with a forklift and hoisting apparatus and in a manner such that we hope to minimize any disturbance to that surface.

Now, relative to the humidity aspects of it, it will have to be packaged during the shipping process in order to preserve the appropriate conditions and then once we have the specimens here in storage, then we can control that much more readily, of course.

We have in mind ultimately to test specimens that have varying degrees of humidity, basically dry specimens first or unsaturated, if you will, and ultimately saturated specimens, recognizing, of course, again, that that humidity will have a profound effect on the joint interface properties.

DR. VOILAND: Are there good methods for characterizing the joint?

DR. KANA: Are there good methods for characterizing the joint? I would say that that's part of what needs to be developed here.

There are methods at the present time. We have in mind to extend those to include the development of a profile type measurement that would be similar to what one uses in the machining process, for example, for describing the RMS roughness of a surface that has been machined.

We hope that we can use a process similar to that. In fact, the procedure for bringing the specimens here include, once the specimen arrives in the apparatus, opening up of the joint and a characterization of that using a process of this type. But the actual details yet have not been worked out.

MR. HSIUNG: May I add some point to that, if I may. My name is Sui Min Hsiung.

Currently, we think that we have three different types of characterization techniques. One is talking about modeling technique and another one is talking...and the third one is talking about continuous yielding model.

All those three conceptual relations are ideal to characterize a joint behavior. So right now, our experiment here is really geared to verify whether or not those three relationships are good enough for our purpose or we need to actually develop our own to serve our purpose here.

I hope that answers your question.

DR. KANA: Any other questions on that point?

[No response.]

Let me then quickly proceed with the other details of this and the additional apparatus.

I pointed out the instrumentation here. There will be at the moment some 13 or 14 channels of data that we have set up to acquire, which will ultimately be digitized and used to provide information into the computer programs we mentioned earlier.

Now, that apparatus, that is, the jointed rock interface testing apparatus, is designed to provide information about one pair of rocks that has a natural interface.

That's the building element of the entire computer code, if you will, which will be used to characterize the dynamics of the Yucca Mountain site.

Ultimately, we wish to develop a prediction of the response of a rock mass segment, which here is just shown as an aggregate of blocks, but which also has a natural fault through that rock mass segment.

We recognize that the joint properties of the individual rocks, the blocks themselves and the joint properties of the natural fault are different.

Those properties and the difference in those properties are part of what we hope to predict by the previous experiments which I described.

The supposition here s that as the joint, the natural joint between the blocks wears, ultimately a fault or the basic properties of a fault will be developed.

Whether or not that is true, of course, is quite conjecture at this point but it's part of what we hope to develop as part of this project.

I've mentioned that with the other apparatus, the full-scale specimens would be brought from the field and tested.

We ultimately must test a scale model of the segment of the mountain, because, of course, it's too big to test a segment itself.

This means that in addition to performing tests on jointed rock elements with the previous apparatus I described, we must also develop a scale model of that element and test the scale model, the physical scale model, and demonstrate that its properties conform scale-wise to the properties of the full-scale jointed element.

Then with that information in mind, we build this segment or rock mass segment and we place it on a seismic simulator, shake table, which is our second major facility that I mentioned, and subject it to a simulated seismic motion that would be anticipated at the Yucca Mountain site and measure the responses at the various locations and compare that with what we predict from the chosen computer model, computer code that we have for the project.

That's ultimately the process that we will use for the validation of the computer code.

Are there any questions now on the rest of the apparatus?

I haven't given you any details, of course, about the seismic simulator at all. I think I'll hold that until this afternoon when you visit the laboratories and if you have detail questions there, certainly we'd be happy to entertain them.

DR. MOELLER: I suppose obtaining a representative sample is another major headache?

DR. CHOWDHURY: That's right.

DR. KANA: Asad has pointed out earlier that in order to validate the code it is not necessary to have an exact sample from Yucca Mountain.

Of course, getting a so-called representative sample from Yucca Mountain would be quite a trick in itself as well, because you could vary the location in Yucca Mountain from where the sample comes and you would recognize there would be variations in properties.

All of that variation in expected results is what has to be accommodated by the program, of course, and that's why the thought of getting the samples from some other but quite similar location is acceptable in the philosophy.

MR. GOLAND: Is it necessary, Dan, for the benefit of the committee, to say anything about the dimensional analysis?

DR. KANA: Yes. I've indicated various parameters here that are part of the problem. I've mentioned that we would have a scale model that we would have to develop, both for the component itself, the individual pair of blocks, that component with its interface, and then ultimately putting an aggregate of that together for representing a rock mass segment.

In the process we use the usual type of dimensional analysis approach where all the various parameters that are considered important in the problem are collected and we develop non-dimensional ratios of those parameters.

The philosophy then follows such that those non-dimensional ratios are equal in both the model and in the prototype, that is, in the physical model.

Using that philosophy, then one is able to make measurements on the physical model and project that information to what that behavior would be in the prototype itself.

The scale that we are contemplating here at the present time would probably be a one-twenty-seventh scale. In other words, our scale model would be one-twenty-seventh the physical size of the actual segment that it would represent.

On the other hand, the various other parameters would also be scaled and their ratios would be some combinations, not necessarily just one-twenty-seventh.

In terms of gravity, for example, I show here that gravity would be scaled one to one. This means that we can test the system by not using a centrifuge which adds orders of magnitudes of cost to the experiment, needless to say.

So there's various schools of thoughts on that and its adequacy but I think you can find equal arguments for testing under one gravity as you can under increased gravity in the centrifuge, and so on.

But each one of these parameters requires such an equal consideration in the ultimate development of this one-twenty-seventh scale model.

Incidentally, one-twenty-seventh scale, because some work has already been done on experiments involving one-twenty-seventh scale of rock mass joints. This work, as I recall, includes basically static type loading.

There is no available experimental results, which include loadings of the type that we're describing here, particularly earthquake type loadings, and that's why this is so important in this part of the study.

DR. VOILAND: This is a new technology then?

DR. KANA: Yes, sir, it is a new technology in which each step of the experiment can lead to new information that can determine how ultimate steps need to proceed.

MR. GOLAND: Dan is a little bit modest but I should say that this dimensional scale for very complex dynamic effects has been one of the specializations of the Institute for -- How long have you been here, Dan, 25 years?

DR. KANA: I'm in my twenty-ninth year.

MR. GOLAND: We have had remarkable success in a wide variety of programs along those lines.

DR. MOELLER: Any other questions or comments?

[No response.]

Well, once again, I'll see if we can break for lunch.

DR. PATRICK: Mr. Chairman, if I may, I think there was a point of confusion that was probably grounded in semantics here on whether or not we are treating, quote, faults, unquote, in this model.

If I could, I'd like to make four clarifying points, two on what is and two on what is not included in this particular study.

The first point is that the geological features that are going to be studied here are those that will be anticipated to occur on the repository scale.

So when Dr. Chowdhury says, "We are not treating major faults," he is using the term "major fault" on what we might think of as being something outside the repository scale, the San Andreas, the Long Valley, some major fault of that sort.

That speaks to the second point, which is what we are not modeling here. We are not modeling regional scale geological features which are not anticipated to transect the repository itself.

The third point, then, is that the modeling and the laboratory studies will be looking at seismic effects on the repository and on the rock that comprises the repository environment.

The fourth point being what it is not, it is not looking at causative mechanisms of earthquakes, per se, that would occur on far field major faults, geological features that would be themselves the source of major seismic motion, the driving energy forces of those major seismic motions.

Does that help to clarify? Yes, there will be major through going geological faults we expect to occur at the repository scale.

Those are of the sort that Dr. Kana was showing to exist in his two-dimensional laboratory model, but not the driving force type faults.

DR. MOELLER: Thank you. Well, then, we will now break for lunch.

[Whereupon, at 12:30 p.m., a luncheon recess was had and the meeting reconvened at 1:30 p.m., the same day.]

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AFTERNOON SESSION

[2:00 p.m.]

DR. MOELLER: The meeting will resume.

The next item is Geohydrology/Stochastic Modeling; am I correct?

DR. RUSSELL: Surely. Rachid, will you please.

DR. MOELLER: I gather our approach will be to finish up all of the formal interactions, and then we will break and take the tour as the last thing.

DR. LATZ: We would suggest that, Mr. Chairman.

DR. ABABOU: All right. This is a project that we are just starting. We submitted the project plan, so I'm going to talk about future research, anything that has been accomplished.

The project manager is John Russell.

I am the principal investigator.

I want to say a few words about the title itself. There's a few key words here. "Stochastic" here means really the stochastic approach to a spatially distributed system. It means in a nutshell that at each point in space, we have random variables describing the material properties of the substrate formation.

We are going to look at the hydrology of that substrate formation.

As a real world realization of the stochastic versus large scale -- I'll explain that later -- we're going to focus on both flow and transport in the unsaturated zone.

We'll have to take into account the fact that the rock is no longer porous, but fractured.

These are the important key words here.

Let me mention quickly what the regulatory basis might be for this. I love colors, as you'll see.

First of all, I'm really focusing on one particular regulation that's mentioned here. It's the famous (I guess) 1000-year travel time rule.

I'm not so much interested in this number, but I'm much more interested in these qualifiers here, "fastest path" and "likely." What do they tell us?

I see questions. I will not say difficulties, but at least interesting questions to explore.

One is the qualifier "likely" is probabilistic, and it seems to invoke the need for a probabilistic distribution or characterization of the probability distribution of travel time, which is, of course, implicit when you read the rule here.

I'd say or I think that this probability distribution will have to be related, at least in part, to formation energy. In other words, if there's uncertainty, it is also because we don't know what's under our feet.

That is one of the motivations for the stochastic approach.

Another remarkable qualifier here is we're looking for fastest time. The problem might be that if you use this case of worst case terminology, in fact the fastest path might be the pathway to the accessible environment such that very, very little radionuclides will access the accessible environment in a very, very small amount of time.

The problem is that if you go to infinitesimal quantities, there is a possibility that they will access the environment very, very quickly.

But we might want to know how much of it also. So, in fact, perhaps we might be -- we might need to refine this concept by adding to it a few other things like we would like to know where the flux will lead to in the environment, the mass flux of radionuclides; and we might want to know spatially average wise.

And on what scale, if it's on the scale of a few square millimeters, we might have very large fluxes, but perhaps on the scale of a square few meters, they might be much smaller.

Do we want to accumulate that over time or not? The best approach would be to look at both.

DR. MOELLER: Well, now, will the results of your work provide the NRC with a way to more carefully word -- reword this regulatory requirement?

DR. ABABOU: That is the way I formulated the plan, that this was one of the possible implications of that.

DR. MOELLER: I see.

DR. ABABOU: These are the objectives of the plan. I want to go over this quickly and show you perhaps more quickly what that means.

But quickly the first step -- we're trying to follow a logical approach here. The first one is a modest approach, which is to look at what other people are doing, including in terms of collecting data.

And again this has come up already, not necessarily data at the site only, but for purposes of validation of the physical processes that we're going to look at.

Even data at other sites, such as the one in Arizona, which is a fractured tuff, but not exactly the same type of fractured tuff that you have at Yucca Mountain.

That might be data of interest. There might be data of interest there, and they are being collected by a group in Arizona.

Another aspect that I want to review is models. And in most of the cases, these won't be stochastic models, but there are a lot of things to be gained from other people did with other approaches.

The second part will be to -- This is a little bit like a systems approach. Wes likes to think of it that way.

Submodels and then examples -- I think an important case where it will be very useful to simplify the problem and to look at one part of the problem is the case of a single fracture embedded in a porous matrix.

I think research is -- There is a very short history on research on this problem, and I think I want to specify that I'm interested here in the hydrodynamic characterization of the behavior of a single fracture embedded in a porous matrix.

We don't know much about it. We don't know what are the effective properties and how the -- for instance, the conductivity of the whole fracture plus porous rock varies as the ambient moisture varies.

That's one thing that we want to look at. One effect of interest is, for instance, is that the effective conductivity will be much different along the fracture than across the fracture and will depend also on the state -- the moisture conditions in the rock, in the porous matrix surrounding it.

Of course, I have ideas on that, and other people have developed models. But I would want to elaborate on this.

The second aspect that is recorded here is that the stochastic approach that we are advocating will be conditioned on data. I'll show you in a few moments an example of generation of such specific data that might be conditioned.

Other important things that might be studied in isolation from the global model are extreme events, like today, for instance. It's an extreme event for San Antonio.

[Laughter.]

And then technical issues, in particular the kind of thing that we're envisioning will need supercomputers to be sold numerically.

This leads me to the third task, which is really the climax of this kind of research. It's large scale simulations using the stochastic concepts, but we end up solving the problem on a computer.

Okay. So it's a stochastic numerical approach. The computer is a tool. The stochastic approach is the scientific basis for the investigation.

And here's an example, to be more concrete, of a synthetic -- in this case not very realistic, because I haven't conditioned it on data -- but it's an example of a synthetic random shield in space.

What we're looking at here are regions of high conductivity in a hypothetical formation. And to give an example here, we might be interested in how continuous regions of high conductivities are.

Are we going to have a continuous path of high conductivity from one end of the domain to the other end?

These are the kind of questions that we might want to ask.

So this is a code that already exists and that I developed at MIT and then at Princeton for the conditioning part, which is now shown here.

Once this is done, an example of the flow, an unsaturated flow is shown here. This is mimicking an experiment in Las Cruces, New Mexico, called the strip source experiment.

What we're looking at here is given the random heterogeneity of the porous formations, we're looking at the moisture plume, given that we had a strip source infiltration above here.

It's the same moisture plume viewed from two different angles. The important thing to see here is that it's very heterogeneous. We have been able to link the kind of heterogeneity of the plume to the heterogeneity of the formation through its constitutive relations.

I guess I want to stick this one here and end up with another kind of example. All of this is past research, of course. I'm not talking about any results that are directly a part of this project.

This is another example of a flow in the formation that might very well have been in this case a little like Yucca Mountain but without the fracture network.

What we're looking at here is a simulation with 300,000 grid points. At each grid point there's a different constitutive relationship that characterizes the conductivity of the porous matrix.

And, of course, as I mentioned before, this was generated using a random field generator. We solved that on the supercomputer or the CRA-2 at NASA. This was done at MIT.

We're looking here at the vertical cross-section and here at the horizontal cross-section. We're looking at the moisture field.

Unfortunately, I don't have a 3-D view of this one. But I should explain one thing.

Here we have wet regions. If we look only at this vertical cross-section, we might think that this is a vertical conduit for flow. The first impression might be that this is a vertical conduit for flow here, so that there is vertical flow.

But if you go back to the vertical cross-section -- that's too high for me, up there -- what you see is that there is a moisture plume or moisture zone, a wet zone, that is hanging over the drier one and is actually spreading laterally rather than going downwards.

The reason for this is very interesting, the fact of unsaturated soil or unsaturated porous region, and it doesn't happen in the saturated state.

This might be, for instance, a more sandy layer, in the case of a soil; and this a clay. And given the ambient moisture condition, the sand is more permeable than the clay, and water cannot go through.

However, if the moisture conditions are different, if we had the very, very dry medium here, it might have been the opposite; that is, the wet part here could have clay, and the very dry part is sand.

What happens is that indeed as you decrease the ambient moisture conditions, the sand, which is usually perceived as more permeable, becomes less permeable than the clay.

There's a turning point, a threshold. So we have an interesting kind of behavior.

And in both cases, the effect is lateral spreading instead of downward.

So the interesting thing that we're going to look at now is what happens if you superimpose on this a fracture network and possible preferential flow downwards.

This is one of the few aspects.

I am finished.

MR. VOILAND: What sort of distances are represented by that?

DR. ABABOU: This is a good question. I forgot to address that.

The distances in this case were about 15 meters by 6 meters by 15 meters. In other words, the square is 15 meters by 15 meters, and the vertical scale is about 6 meters.

But these units are in fact units of correlation scales, and there could have been other units that we use.

In other words, you could make the model coarser by saying -- by claiming that what we want to do now is to have a larger distance between the nodes, the grid points that we used in the examination.

Then you could make these distances much larger. But what you do by doing this is to -- how to explain this.

The details of the flow will not be modeled if you do that. And if you do so, you do not model the details of the flow, then you will probably be in error when you look at solid transports.

The reason for that solid transport is a dispersive mechanism. If you do not take into account even the small scale heterogeneities, you will not get the correct kind of dispersion that one gets in a realistic formation.

So I don't want to say that this could be 300 meters by 300 meters by 15 meters or 100 meters. But one could look at it that way, too, as a first approach.

MR. VOILAND: Is it reasonable to look at that as essentially measuring the heterogeneity of the system?

DR. ABABOU: Well, what we're doing is we plug in the heterogeneity through the conditional random field generator. In this case it was not conditioned on data.

What I want to do is to condition it on data. The remaining randomness is our uncertainty about what is going on underground.

There are interesting things that quantify heterogeneity. One of them is variance of quantities. But the other one is correlation scale.

I want to take the opportunity of your question to point out, the reason for the kind of imperfect stratification that you see here in this flow pattern is that I had used a much larger correlation scale horizontally than vertically.

The equivalent effect of doing this is something like putting imperfect layers or imperfect glances that have a land scale horizontally that is much larger than their vertical land scale.

So, in other words, we're putting a stratified type of heterogeneities, using this technique of having different correlation scales along different dimensions.

What I wanted to say was to answer your question by saying not only can we quantify heterogeneity, but we can also quantify its spatial structure. It does have a definite spatial structure, in this case the stratification nature of it.

DR. MOELLER: Any other questions?

[No response.]

DR. MOELLER: Thank you.

We're doing Thermohydrologic Research.

DR. RUSSELL: Yes. Dr. Ronald Green will make the presentation on our thermohydrologic research project.

DR. GREEN: I'm Ron Green. I'm a hydro geologist with the Center. I'm going to be speaking on the thermohydrology research project that's undergoing at the Center.

The NRC project manager is Linda Kovach. The project manager is John Russell. The investigators are Frank Dodge, Chris Freitas, Mike Lewis, Steve Svedman, Institute employees.

I'm a Center employee, as I mentioned.

The phrase "thermohydrology" is used in this project to refer to the complex physical processes that result from the placement of heat-generating wastes in a geologically -- Replacement of heat-generating wastes in a medium will causes changes in the pre-emplacement thermal environment and the pre-emplacement hydrogeologic regime.

Some of the complex processes that are affected by this would be things like two-phase flow, thermal gradients, conductant cells, and an important thing that has been discussed in the literature, called a heat pipe.

In order to pursue this area, this project is designed to use laboratory experiments and analytical methods to provide NRC with an understanding of thermohydrologic phenomena in unsaturated media on both the repository and the waste package scales.

This type of investigation is not without precedence in NRC. There were two projects, one at the University of Delaware and one at Colorado State University, that investigated thermohydrology in saturated media.

There was an earlier investigation at Lawrence/Berkeley that investigated thermohydrology as it relates to hydrothermal and geothermal systems.

There's an ongoing project at the University of Arizona, which I was previously a member of, that's investigating flow and transport in unsaturated fractured rock.

We are -- At Arizona they're doing a number of -- and have done a number of experiments in this field. The lab experiments were directly mostly towards core studies and rock sample studies, and there was one field scale study that put a -- entailed putting a heater in a series of bore holes in a road tunnel.

There is one planned field scale heater experiment that should start in approximately one year. And as recently as two weeks ago, Rachid and I participated in discussions with the personnel at Stafford, Arizona, to help them formulate the concepts of just the actual conducting of that experiment.

Those discussions were held at INTRA-VAL up in Berkeley.

The thermohydrology project, as similar to the other research projects, has regulatory basis within subparts of 10 CFR Part 60.

There are several regulatory products that are affected by the thermohydrology research project. There are several technical positions that are associated with it. There are several draft technical positions out currently, and there are a couple of potential rulemakings.

Important of these -- or maybe more prominent are the disturbed zone and the groundwater travel time that will be affected by the thermohydrology nature of this project.

The objectives of this research project are summarized in these four bullet items. The first and probably the very most important is to improve our understanding of the thermohydrologic phenomena. It will affect many of these different issues, although it is not a comprehensive listing.

It's not possible to conduct a research experiment without understanding the basic processes involved.

Likewise, many of the other research projects will be affected by thermohydrology. So an understanding of these processes will also be important to those projects.

Secondly, it's an objective of this project to determine the limits to which laboratory simulations will be used to validate computational algorithms.

It will be an objective to assess the predictive capabilities of the computational algorithms used to model thermohydrologic phenomena.

And, finally, as I implied earlier, the information gained in this project will be used in many of the other research projects.

These objectives will be accomplished by performing these five tasks. The first task is essentially a literature review and assessment of the research that has been performed to date throughout the scientific community.

We have prepared, or under preparation there is a letter report summarizing work done to date on Task 1. However, Task 1 will be pursued throughout the duration of the project as other groups published information and data on thermohydrology.

The second task I'd like to expand on, this is a task that's currently being pursued; and that is the design and execution of preliminary separate effects experiments.

This task sort of embodies the essence of our approach to this problem.

The transport in unsaturated media is a difficult and complex process. Not to trivialize similar investigations of the saturated zones, but their results will be essentially an end point for this type of investigation.

We feel that in order to understand these processes, that we should investigate them separately and investigate them for a simplified media.

After we understand some of the separate and individual processes, then we can look at more complex media; and we can perhaps in the future start combining the separate processes, learn how they act in concert with each other.

DR. HINZE: Do you take into account the movement of heat source in this type of analysis, the radioactivity?

DR. GREEN: The movement?

DR. HINZE: Do you assume a point source, like --

DR. GREEN: That's correct.

DR. HINZE: And do you assume that the radioactivity is carrying the heat; it's also producing heat as it moves outward?

DR. SILBERBERG: Dr. Hinze, my perception of your question, I think -- I'm not sure -- is that the principal heat source is at the waste package, and that the heat that might be carried by those radio isotopes that are transported would represent a small heat load, I think. I don't know.

DR. PATRICK: I would say that you can address that by the converse problem. If so much radioactive material was moving, that it was significant, then you don't have a site.

If we look at one point in 10 to the 5th, which is the specified release rate beyond a thousand years, that becomes a very, very small percentage of the heat generating waste.

That is one part in 10 to the 5th of the inventory that remains at 1000 years, which is some 33 half-lives into the decay of the principal heat-generating elements which are strontium-90 and cesium-137.

So there would be little heat-generating material remaining when the release begins.

DR. HINZE: That's an interesting perturbation problem.

DR. PATRICK: Yeah, it would be.

DR. SILBERBERG: I tend to look at those things in a heat capacity sense. What's the heat capacity of the waste package in terms of its environment and heat loss in terms of heat balance.

And then you actually look at the individual species moving out and the heat capacity of the surroundings, I would find that the heat capacity of the surroundings would overwhelm the transport of the species being transported.

DR. HINZE: It would be interesting to see calculations on that.

DR. GREEN: A major portion of this project has been geared towards -- of this task has been geared towards evaluating and determining methodologies to accomplish flow visualization and flow measurement.

Flow visualization, two of the methods we have evaluated are dye tracers, and the other would be thermochromatic liquid crystals.

For the flow measurement we've looked at such things as x-ray attenuation, gamma ray attenuation, neutron moisture meters, reflectometry, thermoconductivity probes, electro resistance probes, cychrometers and tensionics, among some others.

It should be interesting -- It should be important to note that an instrument such as gamma ray attenuation denscometer will be used exclusively on laboratory scale measurements, whereas a neutron probe is by its nature a field instrument.

These methods and methodologies and techniques have been used on the preliminary separate effects experiments.

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DR. GREEN: The results of Task 1 and Task 2 will be used to perform Task 3 which will be designing additional experiments in order to accomplish Tasks 4 and 5.

Task 4 will be looking at one waste package unit, whereas Task 5 will be looking at multiple packages.

As we move into the project, accomplish some of these earlier goals, you'll note that some of these goals will more parallel projects like Rachid's and geochemistry.

So the goals of some of these projects will become closer as time goes on.

That's the conclusion of my presentation.

DR. MOELLER: Any other questions or comments on this?

[No response.]

I hear none. We'll move on then to the Transportation Risk Study and Dr. Ruth Weiner.

DR. WEINER: I'm Ruth Weiner and I'm the principal investigator for the Transportation Risk Study and I'm going to borrow Wes's slide just to give you an overview.

The NRC program manager for this is John Cook and the study has a relatively small budget. Unlike the rest of this project, we are concerned not with the transportation of radioactive wastes but with the transportation of all radioactive materials.

In 1977 NUREG 0170 was published, which was entitled, "Environmental Statement for the Transportation of Radioactive Materials."

The document has since then been used to support a great many things and recognizing that a document published in 1977 was really completed in 1975 and used data from 1972, the staff felt that an update was in order.

There is no federal action contemplated, so that the update is not an Environmental Impact Statement, and in any case you don't update Environmental Impact Statements.

So what we are doing is a Transportation Risk Study which is basically an update of what was done in 0170 and which will be able to support any future Environmental Impact Statements if it's desired to do one on the transportation of radioactive materials.

The purpose of the Transportation Risk Study is to evaluate and assess the adequacy of the data that is available on transportation of radioactive materials and update it with new data.

To look at the regulations governing radioactive materials transport and to basically calculate the risks of radioactive materials transport, projecting those risks for some scenarios and looking at alternatives, if you transport all radioactive materials by truck, if you do it all by rail, if you do it all by barge and so on, and look at these under both normal conditions of normal transport and accident conditions.

We've divided the project into two and I'm going to give you some results actually. This project is well into its last year.

We intend to finish the project and have the draft risk assessment finished by September of 1990, so we are in the last year of the project.

There has been a thorough literature search done on the literature of radioactive materials transport and associated risk and we have investigated the databases that are available on radioactive materials transport.

I'd like to talk just for a moment about this question of adequacy of data.

NUREG 0170 depended on a survey. There was a shippers survey that was done and the data from that survey was extrapolated to cover the universe of shippers of radioactive materials.

The survey was repeated by Sandia in -- actually, it was a subcontractor to Sandia and there was a report on this, SAND 74-8184. It was basically repeated in 1982.

That database is the only one that is really comparable to the initial shippers survey.

The Department of Transportation keeps a database, SARAN RT database. The Department of Energy has a spent fuel database, the integrated database, but that's not a transportation database.

There are a number of other sources of transportation data but what we found in looking into these was that you couldn't add one to another. There was overlap.

Some of these databases include the same shipments and you never know when they do.

Some of them base shipments on different things. RAM RT uses only one radionuclide as representative of an entire shipment, for example.

So we have had to go with the SAND 84-7174 database and extrapolate from that.

This is one of the problems that is occurring with transportation data and we've discussed this with John Cook.

If we're going to keep a continuing assessment of risks of radioactive materials transport, it really is necessary to have a consistent database formed on a continuing basis.

NRC is one agency that could possibly do that. There are others. Department of Transportation is a possible agency that could do that, but to try and correct this kind of data in surveys once every ten years, once every fifteen years, doesn't give you very good data from which to make any kind of projections at all.

So we are hampered in that because that's all basically that there is.

DR. CARTER: I wanted to ask you a question about are you going to use sort of generic values or are you going to use any route-specifics as far as, say, population distribution and so on?

DR. WEINER: We're going to use route-specific. We're taking a slightly different approach from NUREG 0170. NUREG 0170 had a standard shipment model and used kind of generic values.

We are using our database of shipments to pick out what we see as representative shipments of different kinds of materials and construct these scenarios, low level waste from Boston to Hanford, that kind of thing.

We have an idea from the database as to how big these shipments are and, of course, there are various ones and you have exclusive use vehicles, Type A packages, Type B packages, and so on.

But our purpose is to look at what we can best identify as the riskiest or worst case shipment in each category and to look, also, at representative shipments so that we get an overview of the risks of transporting different types of radioactive materials through different population distributions and over different distances.

The code that we're using, which I'll talk about in a moment, is RADTRAN. RADTRAN is now in its fourth generation. It's now a RADTRAN 4.0 and allows you in the latest version to put in all of the data for a given shipment.

That is, you can completely characterize, the user can completely characterize the transportation link. The population density, the route, is it urban, is it suburban, what kind of highway, and so on.

The longer the distance the more the results of this tend to correspond to what you get using the RADTRAN averages, but we can completely characterize it.

DR. CARTER: Let me ask you a couple of questions since you brought up the RADTRAN.

DR. WEINER: Sure.

DR. CARTER: This is one of the areas where there seems to be very few codes actually in practice, except reactors and you have multiple codes for just about everything.

But in the transportation area there's little. The question is, what are you going to compare this with or are you?

DR. WEINER: Code comparison, there really isn't much and you are quite right.

This is a little diagram we drew up of the codes that feed into RADTRAN and RADTRAN really is nothing but a collection of algorithms for calculating these various factors that go into risk.

If you look at what RADTRAN does as it calculates the dose for normal transport using the Transport Index for accidents using very standard galcian dispersion equation and then fractionates the dose between deposition and what is in the soil, what is taken out by the plants and so on.

There are other codes in use but they are all variations of RADTRAN and there really is not in the literature any different approach than this one.

DR. CARTER: That's what bothers me. Everybody depends on this same old code, whether it's NRC, DOE, DOT or what.

The question is, how good it is. I've got [illegible]ther question.

Have you considered a project to actually validate RADTRAN? As far as I know it's never been done in the U.S., and I dare say that there's some sites where there's sufficient exposures, even low admittedly, where it could actually be measured.

So I think this is one of these codes that could be validated, if somebody would spend the effort to do it.

DR. WEINER: We haven't done validation of RADTRAN because really this project was not big enough to do that at the present time, but we have done what turned out to be verification exercises.

That is, we tried a little series. We said, according to RADTRAN, twenty packages of one millicurie each should give you the same results as one package of twenty, and so on; and twenty shipments of one package each would give you the same results as one shipment twenty times that great.

We discovered that RADTRAN contains internal switches. It does not, for example, permit you to ship anything that is in violation of the regulations, of either 10 CFR 71 or 49 CFR 173.

Even though there are exemptions to these regulations all the time, the biggest shipment, the Cobalt 60 shipment, but the biggest shipment that's recorded in our database is one that we cannot calculate the risks for using RADTRAN because RADTRAN has a switch that shuts it off.

It's a shipment that got an exemption, a regulatory exemption, and you can't run a regulatory exempt shipment through RADTRAN, at least not externally.

We are in the process of working that out right now with Sandia.

We also found that the initial scenarios that were used to calculate the risks in NUREG 0170, that input deck still existed in RADTRAN 3. It existed up until last week.

That was run with RADTRAN 1, which was used for NUREG 0170.

We took that data and ran it through RADTRAN 3, taking the initial input deck, which was completely untouched by human hands. It was running Sandia's input deck through Sandia's code, basically, and we got extremely strange results.

We got some very high doses. We got some unrealistically high doses. We just did normal transportation.

We found that one number was read, which was truck stop times, was in the input deck as hours per trip and was read by RADTRAN 3 as hours per kilometer.

So you get very, very screwy results.

In doing this, there are a number of users of RADTRAN and all of us, since RADTRAN has gone on the TRANSNET system, TRANSNET is not on this slide, but TRANSNET is the communications interface system and allows you to use RADTRAN through ordinary communication software.

We happened to use CrossTalk because you can then transfer files into current.

Since they put that on, a lot of people who use RADTRAN are discovering the same things that we are. So I think the answer to your concern is a very positive one, which is that as the use of RADTRAN is more widespread, these verification and eventually validation exercises are done by the users.

The Sandia people are very happy to have the information and they are very cooperative.

DR. CARTER: Well, I'm not too sure we're speaking the same maybe we are. This is one of the few cases where I think we've got some sites, whether they are DOE sites or low level waste disposal sites, where there's actually enough shipments that you can actually physically measure exposures nearby.

This is a case where you can get actual validation, not computer validation.

DR. WEINER: This would be a wonderful project to do. I hate to sit here and ask for money, but I think that this would be a very good thing to do, because you're quite right.

There has never been a physical validation.

DR. CARTER: I'd like to see one of these codes actually validated. This might be a first.

DR. WEINER: It is, though, basically the only game in town, for whatever that's worth, and it's certainly the one that there has been the most continuing work on.

DR. MOELLER: The NRC, of course, is considering now revision and a requirement of the manifest system. Will that give you the data you're seeking in terms of shipments and where they go and how much is in them and so on?

DR. WEINER: In conversations that we've had with

John Cook and Chuck McDonald, we've talked about structuring these revisions so that we can get the information that we need and to date it's inconclusive.

They haven't said, "Yes, we will, but what questions do you want to ask," and we haven't handed them a list of questions.

It seemed to us that this was the logical place to get this information. As long as NRC has to collect manifest information anyway, why not ask whatever it is we want to know.

That would answer the database problem very well.

One of the questions that arose, NUREG 0170 projected shipment data. These are the major categories of packages per year of various types of waste, curies per year and TI. TI is Transport Index.

They had 1975 data, which was actually 1972 data, and using one point, basically, projected to 1985.

The first thing that we did was to compare the 1982 actual data with the 1985 predictions, giving us two data points instead of just one.

We found --

DR. MOELLER: But again, why didn't you use '85 data and compare it to '85.

DR. WEINER: We had '82 data.

DR. MOELLER: Oh, okay. You used what you had.

DR. WEINER: We used what we had. The SAND 84-7174 database, which is the most complete one, is actually '82 data, even though it was published in 1984.

We couldn't get all of this on one slide but just comparing the curies per year, the actual 1982 data is much, much lower. The numbers are much lower than what was projected.

So you really cannot draw any conclusions from the 1975 data alone.

The difference is that these numbers are anywhere from five percent for fuel cycle waste to a high of twenty percent of what the 1985 projections were.

So the first thing that we can say is that the 1985 projections are far off.

One of the purposes of our project is to try to project, using what we now have. We now have two sets of data, 1975 and 1982.

Using these two to make some projections to 1995 and initially 2005, because everyone thought 2005 was the year that waste would begin to be shipped to the repository.

I think that's probably not a valid assumption any longer.

Clearly, even the fuel cycle data and the waste projections don't begin to project what the waste shipment, high level waste shipments would be to a repository or to an

MRS.

But we can at least use these two sets as a base line from which to make such projections.

My own feeling is that we had one point to begin with and now we have two. So from this you can say it goes in a straight line or something, but you can't really say anything very much by way of accurate projection.

I would point out that in calculating the risks, the risks from normal transportation depend on Transport Index, which is the external dose from packaging.

The accidental risks depend on the curies transported, because we're looking at releases.

By the way, I'd like to point out that another problem with RADTRAN, which one hopes we'll never have a situation validated, is that the worst case accident modeled by RADTRAN releases something less than ten percent of the contents of the package, so that you never have...

RADTRAN gives you the peculiar case that an exclusive use shipment of a Type B package which has had an exemption from the Department of Transportation is going to give you bigger population dose as it travels through an urban area than the worst case accident will that's modeled by RADTRAN because they're not postulating big enough releases.

We're in the process right now of drawing up some full shipment scenarios and these are real shipments that are in the SAND 74-8184 database.

These are some of the shipments which we will use to calculate the dose and ultimately the risks from RADTRAN.

I'd like to make a point at this point about the calculation of dose and risk.

RADTRAN 4.0 still uses for risk factors the risk factors in WASH-1400. So we are using RADTRAN 4.0 to calculate doses at this point, rather than calculating risks.

We are assembling risk factors from the literature. The most prominent in the literature is Dr. Moeller's Harvard Health Study, which are among the risk factors that have been suggested that we use.

RADTRAN 4.1, which is expected to be out in about a year will incorporate the Harvard Health Study. NUREG CR 4214 will incorporate those risk factors instead of WASH-1400.

They quite readily admit that the current set of risk factors are very much out of date and probably should not be used in any final publication.

The last few slides that I have just cover what you can do with RADTRAN. There are predefined data sets that exist in RADTRAN and the present way to put data into structure and input deck is to take a predefined data set and change it.

That does not change with RADTRAN 4. RADTRAN 4 operates that way, too.

RADTRAN outputs, calculates doses to passengers and everyone else who is exposed. For the incident free analysis, you calculate dose from the Transport Index.

Actually, this is incorrect. You don't calculate ground level concentrations for incident free analysis but you just calculate the dose at ground level.

You do have figures for expected population densities, identified as urban, suburban or rural.

One of the problems that they've run into with RADTRAN is that the current population densities that are in the RADTRAN decks themselves are only good in the United States.

The modification allowed for doing population density is very valuable for international applications.

The accident analysis. The way that RADTRAN 4 is structured, the accident analysis gives you expected values of risk, which you can then, knowing the risk factors used, back calculate the doses from.

You can calculate, the code will calculate early fatalities, latent cancer fatalities, latent fatalities, early morbidities.

We are not presently planning to use those calculations. We are going to limit our calculations at the present time to dose calculations.

This is a summary of what we have been doing with the RADTRAN to verify RADTRAN. We used the predefined data set.

We altered inputs to try to see if there was internal consistency and then we tried to duplicate the baseline model and found out what the problem was with it.

I think that these next few slides give a little menu system for RADTRAN, which is really only of interest to users.

I think that I will close on that note and simply say that right now there is an attempt to broaden the use of RADTRAN.

I think the broadening of the use will improve the model, because as more people use it, they see more things to put into it.

It would be a wonderful project to do some actual validations.

We expect the risk analysis to be finished and in draft form by next summer. We are due to submit it to NRC in September 1990.

DR. MOELLER: Does the code calculate -- Of course, it calculates the dose to population but does it include the dose to like the truck driver?

DR. WEINER: Yes. Right now the code calculates doses for truck transport for little trucks and big trucks, rail transport, barges and air transport and it in every case calculates doses to the crew and to handlers.

In trucks and rail there is also the calculation to populations along the route and during stop times.

Air transport there is no population dose, general population dose assumed between the beginning and the end of the trip. When the airplane is at 35,000 feet, you assume no one is exposed.

DR. CARTER: Pretty good assumption.

DR. WEINER: It's a very good assumption.

DR. MOELLER: The NRC and EPA are both working on trying to develop a below regulatory concern level of low level radioactive waste which can be sent to a municipal sanitary landfill within a local town.

As I understand it, if NRC and EPA should agree on a limited dose, one of the key factors will be the truck driver or the people along the route, that that may even overshadow the doses from the waste in place, given this sanitary landfill.

If that be true, the first thing the public is going to say when they attempt to implement whatever below regulatory concern value they choose, the public is going to say this code has never been validated, it's not accurate, no one knows, et cetera.

So this could help in the low level as well as the high level doses.

DR. WEINER: Yes. By the way, that's a very good point. A lot of the shipments, particularly of the shipments of low specific activity materials, are very large shipments.

Just to load these things on trains and you have unit trains of material from the Hughes sites and the UMTRAK sites. The dose along the route of a shipment like that is small but it's not insignificant.

DR. MOELLER: The collective dose?

DR. WEINER: The collective, the population dose, because you are running these trains through populated areas. Most of the United States is populated at the level that they've used is suburban.

I think you're quite right. There will be a fair amount of public concern about these shipments.

One of the classes of shipments that few people know about and nobody seems to be concerned about, and I think they should be, radiopharmaceutical manufacturers ship very large quantities, very high specific activity from the factory to the distribution center.

Then they are shipped in small packages all over the place. Those are high curie high TI shipments and those are frequently shipments for which an exemption is given to the Transport Index

DR. MOELLER: Thank you, Dr. Weiner.

Are we ready for the performance assessment and program integration wrap up by Wes Patrick?

DR. PATRICK: I'd like to spend just a very little amount of time on the subject of performance assessment for at least one reason.

One, we are ourselves just beginning to work in the area and I think it's really premature at this point for us to try to express any global comments about how we feel performance assessment ought to progress, the strength and weaknesses of the program, and so forth.

What I'd like to do is just to speak very briefly to the approach to performance assessment, which we feel is appropriate and as part of that approach, to also speak to the role that we feel performance assessment should play, needs to play in the program.

Those items break down into the three general areas that are highlighted by the bullets here: The uncertainty and sensitivity identification, the integration and the compliance determination aspects of the program, the latter being primarily what I think we think about when we think in terms of performance assessment.

That first bullet is one that Dr. Nair spoke at some length this morning about with regard to a subsystem, the engineer barrier system as we've referred to it.

But early performance assessments, we feel, have a very important role to play in terms of identifying the key parameters and key features of the geological setting, the repository and the engineer barrier subsystems that will be operative at the site.

After identifying them as key in a global sense, early performance assessments can be used to evaluate the relative importance of those parameters and features.

That is a portion of analysis that we usually use the term sensitivity analysis when we discuss that, as opposed to saying uncertainty analysis.

The final part of that program would be to identify any targets, any areas of perhaps high risk, areas of great sensitivity in terms of parameters and the features that are present, where either confirmatory research or exploratory research would be appropriate.

I speak here to research where we would go in and for certain key parameters we would confirm the results the Department of Energy had obtained in their own much broader, much larger research program.

Or those cases where even after continued dialogue, perhaps, DOE wasn't moving forward in a manner that the staff felt appropriate, then we would step back, do certain exploratory research in these key areas so that we would have a technical basis from which to argue that, "Yes, DOE, this is a bona fide area of concern that needs to have some attention."

So we see performance assessment playing a very important role in the area of uncertainty and sensitivity analysis.

We also view it as the key technical integrator of all the activities that are taking place. That starts as early in the program as when one begins to examine what ought to be investigated during the site characterization process, and continues all the way through the design of the testing of the various components and features of the repository site and the engineered systems as well.

We feel it gives you a very good basis for that technical integration across the program.

One of the key concerns that comes up and in fact we discussed it this morning in a little bit difference context, and that's the consistency of the various methodologies and the step below that or above it, whichever direction you care to go, the consistency within the regulation itself.

If one has a broad performance assessment strategy in place, then each of the research activities, each of the compliance determination methods that will be developed, each analytical technique, each model and so forth, will be consistent with the major full system performance assessment that needs to be conducted.

So that those analyses that will be done to look, say specifically at groundwater travel time or at the engineered barrier release rate or at the substantially complete containment during the first three hundred and one thousand years, the results of all of those would be consistent technically, as well as on a regulatory basis with the global or system performance assessment that is ultimately required to be performed.

The final concept here deals with the area of compliance determination. That is a term which we use a little more broadly perhaps than the way EPA defines performance assessment.

We're speaking here not strictly to the calculation of a CCDF, complementary cumulative distribution function, but any tests, measurements, audits, what have you, modeling, that would be used to determine whether DOE was in fact in compliance with each particular regulatory requirement.

That would be done first at a subsystem level and then finally at the over-all system level, the 40 CFR 191 type of a performance assessment.

Those are our early thoughts, our early concepts. I think unless there are any questions, I've spoken enough earlier about the kinds of things that we are engaged in right now in the performance assessment area.

It is an element which falls under our technical assistance work as well as under our research work.

It's not unique in that nature, as you noted the people who spoke for geological setting and technical assistance also had the research in that area.

The same is true of performance assessment. So as we come as a third member of this team that I described earlier, NMSS and Research from the NRC side, we actually have separate channels through funding and specific tasks that we do to support each of those sides.

Both of those tasks are fulfilled by the same principal staff here at the Center with regard to our contribution to that program.

DR. MOELLER: Let me ask a couple of questions. This came up earlier today and I didn't ask it, but why do you separate your technical assistance from your research?

DR. PATRICK: We treat them separately in the discussion only because they are separate entities, organizationally through the NRC.

Here we have the same individuals working on both things and we don't separate them in-house at all.

DR. MOELLER: If you don't separate them here, then you remove my...

DR. PATRICK: I could go around the room and point to Sui Min, did an SCP review; Bill, Bobby, each person that is on the staff at the time who you saw speaking to research today, they also have very important and fairly substantial levels of their effort on the TA side as well.

DR. MOELLER: What is your schedule for performance assessment work?

DR. PATRICK: Our involvement in that performance assessment work?

DR. MOELLER: In other words, your involvement, your target dates to have completed certain portions of it. Indeed, what percent role do you see it occupying of your total activities over the next five years?

Let me clue you. I don't want to give you the answer I want to hear, but the NRC established internal -- it's not internal, it's external -- but it's to advise them on research.

They have an Internal NRC Research Advisory Committee to the Office of Nuclear Regulatory Research.

I don't know if you see their reports but we do. In one of their recent reports they made the following statements.

They were looking at you as the Center and they were saying, where could you best serve the NRC.

It was their conclusion that one of the best places you could provide service would be in performance assessment.

To add to that, we as a committee, and I think I can speak for our committee, have been very concerned about the lack of emphasis on performance assessment within the NRC high level waste repository activities.

We saw it as doing all the things you have here on this slide, but they were talking about -- and I'll probably misquote him and I'm probably giving him the short end of the deal, but they were talking about, "Oh, yes, in five years or so we'll get on with it."

Well, we think it's one of the most important activities you or anyone else could be pursuing.

DR. PATRICK: We would echo that, that we also, as you can tell, we feel it is extremely important to try to answer your specific question, how much of our time, how much of our activity would be devoted to performance assessment.

The simple answer, the one that you would get if you were to read the first three pages of our six-inch thick operations plan for the Center, is one that probably wouldn't be terribly satisfying to either you or to us.

It says that approximately, if you add the numbers up that are associated with performance assessment, it's something like one-eighth to one-tenth of the program.

But that's not a fair comparison, because within the EBS element there is performance assessment being done; subsystem model development for the engineered barrier system, performance assessment codes.

Many of the research projects that you've heard described this morning have clear performance assessment implications and clear performance assessment contributions.

When Rachid speaks to the stochastic modeling of groundwater flow, he's addressing groundwater travel time, one of the subsystem requirements for the repository.

When Bill and Bobby speak to the geochemical aspects, they are looking at sorption, one of the key mechanisms which will be counted upon to retard the movement of radionuclides. And so on across the programs in each of the projects.

I don't know what the number would be if we were to collect up in toto all of the things that are -- not grasping at straws but just taking each of those things which we know is going to feed principally into performance assessment, it's much, much larger than that one-tenth figure that one would have as an initial impression.

The key has got to be, though, that the people who carry the title "performance assessment" are listening to, are integrated with each of those who are doing the subsystem's work out in the element.

If we think that that is a key area where as much as anything because of our small size, we are in a better position to fully integrate all of that than what a much larger or a more dispersed organization would be able to do.

DR. MOELLER: Your first bullet and the first item under it, it has the potentiality of providing early identification of the key parameters of the features.

What's more important than that? There's very little that I can think of that's more important than that.

So I'm glad to hear what you say. It's a very key important activity for the Center.

DR. PATRICK: I think I will end with that unless there are any specific questions that we wanted to go back to. I feel that our earlier discussion this morning fully explored the matter of integration; that coupled with the technical integration aspect of performance assessment.

I've concluded my remarks unless there are questions.

DR. MOELLER: While you're there, since we are at the end of formal presentations, the Committee has discussed the Center from time to time on numerous occasions and I tried to summarize some of the questions and comments that they have raised.

I'd like at this time, because we promised them faithfully we would raise these issues while we are down here, I'd like to go over them.

A number of them you've already answered, but let me just run through the list. It will take a little bit of time.

Even before I do that, any time you have put up a project today or described a project, you have begun with what I'd call the regulatory base for that project.

Why is that so overwhelming to you? Why don't you just say, "This is important and we're going to do it"?

But you'll say 10 CFR 60.122 or 121 or 113. Why is that?

DR. LATZ: I'll ask if Dr. Arloto would like to address that one.

DR. ARLOTO: I'll address it. The issue is always very clear regarding what our rule is. We are a Nuclear Regulatory Commission. We have an Office of Nuclear Regulatory Research and, therefore, we always start with the purpose of addressing regulatory issues.

In this case it was decided and I think principally through the program architecture involved at the Center, that we would start with the regulatory base to identify programs and the issues we're going to address.

Since that issue has come up, it was one of the items that I had identified earlier and I thought was a very important issue, and that is what I will call the necessary sufficiency of regulations or regulatory base.

I'd like to start out immediately by saying that the NRC, as we evolved 10 CFR 60, we recognized the frailty of that particular regulation and recognized that it was a great jeopardy in publishing and codifying at that time.

Historically, as some people may know, my base comes from development of regulations and standards. That's what I've been doing for a good part of the 27 years I've been at the AEC and NRC.

I've been in that process both from the regulatory viewpoint and from the national voluntary viewpoint with the ASME and those kinds of activities.

One of the things you learn about a good standard is it evolves from documented successes. It evolves from experience. I can give you many examples where the ACRS had made initiatives.

We recognized that when we were developing this particular regulation we had, in essence, zero or a very little base of experience in which to do this.

However, it was decided at the time that we had to put out a base of regulation of what we thought was the best we could do.

That's why we actually put out this particular regulation.

Look at historically the NRC regulations. We have amended our regulations over the years in many areas and we've had a much, much better technological base.

So needless to say, I would expect this particular area to be one which will be amended over the years.

I would like to continue to say that some of the issues talked about today and questions to the Center regarding if you find something that's not quite right, do you feel that you will bring it to the NRC's attention.

I think I'll be fair when I say I've been down here before and it isn't a matter of "will they." That's part of their specific charter.

It is a demand that as they evolve this program architecture, identify the research that must be done, develop technical positions, that that could feed in either direction. Going up, it might amend our regulations.

In other words, they are very conscious of areas of commission as well as omission, holes in regulatory bases as we go forward.

So I think that, to answer your question explicitly, it was a starting point. Being a regulatory organization, why not start with the only base that the Commission has specifically endorsed, which is the basic regulation, rather than start with, "It's good," because when we start with the attitude of "it's good," particularly with researchers, they usually will tend toward increasing the knowledge of the universe rather than address the very specific problems we have.

We have a very, very limited budget, which I think Dr. Latz made very clear earlier.

That's the best I can do.

[Transcript continues on Page 188.]

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DR. MOELLER: That's very good. Your last part was excellent. You are a regulatory agency, and this is the regulation, Part 60, that you're trying to see that you can determine compliance with that, or to give the NRC the ability to determine compliance.

DR. ARIOTTO: May I make one more point, Mr. Chairman? That is, I'd like to turn to the people on my left and say, I will feel very much more comfortable when we get to a point where various advisory committees, whether they be the TARDRES Committee or your committee, feel comfortable in feeding back to us in an advisory capacity where they see we may have gone wrong in the past, not just where we may go wrong in the future.

DR. MOELLER: Well, let me also say -- and I've said it before -- that the NRC staff deserves a tremendous amount of commendation or credit for writing 10 CFR Part 60 when they did and having the foresight that they did.

I mean, it's a marvelous document to have withstood the test of time as well as it has.

I know when I look at it, I'm just very much impressed by how many things they anticipated and covered within the document.

Wes, you had hinted just a speck on determining compliance with -- using the CCDF in determining compliance with the probabilistic EPA standard.

Our committee has had a running battle -- and it's a very friendly battle -- with the NRC staff. I mean, we both understand the difficulties, and we're trying to be constructive.

But a running battle on whether it will be possible to determine compliance with the EPA standard, you know, through the CCDF and so forth.

Are you working on that, or will you be working on it and providing help to them?

DR. PATRICK: We will be working in that area. We have not done any substantive technical work in that area to date, but that is a specific part of our operations plans (as we call them) for the performance assessment element.

DR. MOELLER: Okay. Let me now go through my list, and I'll go through a whole -- one broad topic and many little subparts.

You've already answered some of them, but make some notes and come back and try to help us.

The first one is the selection of research topics. We've already talked about who determines the research topics.

Questions that have come up within the committee are: What assurance do we have that you're addressing the topics of highest priority? And is there a list somewhere of topics you've considered but rejected, you know, as not being of high enough priority to fit -- or to be addressed at the present time?

And if, indeed, you have a system for determining the topics of highest priority, what is that system? What is your rationale for establishing your research priorities?

Then you or someone has told us you have a performance evaluation board that oversees the Center or something?

DR. PATRICK: Well, that term applies to an NRC board, which is a fee-determining board. We have an advisory board to the Center.

DR. MOELLER: Okay. You have an advisory board, and this performance evaluation board is an NRC board?

DR. PATRICK: That's correct.

MR. FUNCHES: There's an NRC board that evaluates the performance of this Center and makes award recommendations.

DR. MOELLER: Okay. And then the last one in this group is: If you do well you get an 8 percent or something bonus, and then you decide how that money is to be spent. Could you tell us a little bit about that?

So that's one category. I'll hush and listen.

DR. LATZ: I would take exception to your word "bonus." There is no bonus.

The nature of the contract is cost plus award fee.

I can say to you historically, with the many government contracts that the Institute has done, that whatever that fee might be, the net is always less than that perceived fee. The first point.

The performance range on that fee is from 0 to 8 percent.

We can, at the discretion of the performance evaluation board and the federal deciding official who happens to be the Director of the Office of NMSS -- can range from 0 to 8 percent.

Our first four performance -- These evaluation periods span six months. In our two years of existence, we have been through four such evaluations.

In order, we received an 8 percent award, a 7 percent award, an 8 percent award and a 7½ percent award, which leaves me an opening to address another thing.

Perhaps part of your question, Mr. Chairman, what do we do with that money? That money, among other things, provides the building that we're sitting in, the laboratories that we build.

But there is commitment -- contractual commitment, which Martin Goland made in this creation of this FFRDC that what amounts to approximately one-third of those fees would go into the Institute's internal research and development program.

The Institute has a very well-developed, highly respected internal research and development center program to which it allocates a great deal of its bottom line revenues.

In this instance, we anticipate that the sum will be roughly one-third of the awarded fee. Unlike most of the rest of the Institute's IR&D program, the commitment here is that it will be programmatically focused.

Now, it is not intended to supplant, replace or otherwise do NRC's work for them. But where some of the creativity of the people, both in the Center and the Institute, perceive opportunities of investigation and research that are not provided for by programmatic funds from the NRC, this will provide a means or avenue for the expression of that creative thought.

So that's something of which we're very proud.

I've answered more questions than you've asked, but ....

MR. FUNCHES: I would just one thing to make it clear. That one-third is a contractual and it has to be applied to high-level waste related research.

DR. ARIOTTO: May I, Mr. Chairman? I think the first question, Mr. Chairman, may not have been quite fair for the Center to try to answer at this time, the question regarding prioritization and research.

I am now putting on a hat I no longer have, because when I was in the Office of Research I had some responsibilities for this area.

The Center has been really up to now in a reactive mode regarding research. So it's sort of unfair for us to ask them, are they the people who have identified the needs and priorities.

Recognizing that we had a program ongoing in a normal sense of an NRC program, we contracted for the most part with national laboratories to do our work.

The Center is now in a position of trying to do -- with the NRC staff obviously -- trying to phase out many of those contracts because one of the key reasons, as you know, that the Commission decided to add a center is we were concerned about the potential for bias or conflict involved with some of these contracts, as well as having a center of excellence, as you already have discussed early this morning.

The second thing they're trying very hard to do is a technology transfer. We have invested a considerable amount of money over the years, particularly in an area like performance assessment.

Sandia has been working on this area for many years. And we would like the Center to take as much advantage of that as possible in an orderly close out --

phase out/close out of many of these programs.

So, therefore, the fact of the matter is that the Center really at this time is not in a strong position to say, "We, the Center, have identified what the needs and priorities of research are."

However, on the other hand, Dr. Ross, who is the Deputy Director of Research, was down here a couple of months ago. I think that it's fair to say he laid a particular obligation on the Center, that he specifically requested Center input on the research for high-level waste.

That is forthcoming. In approximately the spring he expects feedback from the Center exactly on the program.

Recognizing that, the Office of Research has developed a research program for high-level waste.

DR. PATRICK: If I may, Guy, in that same meeting we presented to Dr. Ross a short list, unprioritized at this time because we have not gotten that far -- a short list of potential research topics which will be evaluated further and incorporated in this spring time deliverable.

DR. ARIOTTO: Up to now -- regarding your very direct question on how we could be sure that the right research is being done and the right schedule, I guess the answer to that question is never.

DR. MOELLER: Right.

DR. ARIOTTO: I don't think we will ever be sure.

I think you didn't even ask what I consider to be the question that will plague us a great deal, which is who should do it.

At what point do we lay on the fact that this is strictly something that should be done by DOE. They have this literally a billion dollars probably available to them, and we have a few million dollars available.

The DOE budget for high-level waste is more than half the whole NRC budget, including all the pay of the people.

So we have that difficult issue also is where are we going to draw the partition, the partition of when DOE should do something versus when we should do it.

So the bottom line is I would see that we would start evolving a system of developing needs and priorities for research as well as other issues, including rulemaking, based on what I would call the normal cooperative effort that seems to have worked reasonably well for many years in the reactor area.

We will get guidance -- overall guidance from the Commission regarding what is needed.

We will work with the NRC staff internally, and in this case probably mostly between NMSS and Research in this area.

We will get input and interact directly with the

Center -- and I want to come back to that one -- and we'll get advice from our advisory committees, in this case both you and the TARDRES Committee, at least as long it's in existence.

And from that, combined with feedback we get from published documents, we will evolve something that will look like what this consensus of knowledgeable, interested groups believes is the right combination.

Obviously, you will have a major part in that.

My hope is, regarding the Center and the staff -- I am very optimistic because the management within the NRC staff and the management within the Center are of one mind, and that is, when we answered your question by saying, "We don't know who in the Center or on the staff identified the needs or priority." We will be on the right track when it becomes a blur.

When the technical people are talking to each other so clearly and so often, that it is difficult to discern, "Was that a thought that came out of the NRC staff or the Center staff," we will be close.

So when we get a letter from the staff that will be -- from the Center saying, "Based on agreement with your staff, we have decided that," we will be close to an optimum situation.

DR. MOELLER: Okay. Thank you.

Yes.

DR. LATZ: Mr. Chairman, if I may.

I recognize your commitment to the other members of your committee to ask certain questions for clarification.

Be that as it may, I feel that somehow or another I may have failed this morning in my overview to convey to you or to make it clear the development and evolution of the Center.

The Center is a very deliberate, thorough, act-taking -- taking place over a period of time.

We do not wish to be involved in something premature, premature to the acquisition of the competence.

I think many of these -- some of the questions that you have raised today at any rate, are frustrated by an awareness of that growth process: deliberate, planned growth involving a maturation not only of the Center itself, but an evolution and a maturation of our relationship with NRC staff.

One of the questions earlier today had a nuance of the Center having independence of thought and expression of that independence of thought.

I think there are probably those in the NRC staff who say that the Center has probably exercised that independence prematurely, perhaps with some merit.

But we are indeed exercising our independence. And as Dr. Ariotto and Mr. Silberberg just articulated, we feel we are evolving and maturing to a calicea' cooperation that will be both -- preserve our independent expression and input, but yet arrive at the right consensus.

So I hope that helps.

DR. MOELLER: That's helpful, and I think those are key items that we should all keep in mind.

Yes, Mel.

MR. SILBERBERG: If I may, Dr. Moeller, I wanted to add something about performance assessment that, in fact, is sort of a corollary to what Dr. Ariotto just talked about in terms of the research process.

When it came up, I failed to make a note of the point that in fact -- and I'm speaking for myself as well as Mr. Browning and his people -- that together as we move out on the performance assessment methodology as a team that it's very clear that in Mr. Browning's planning and our planning and reflected in, in fact, in the '90-'91 budget process is in effect the replacement and performance assessment of Sandia by the Center.

You remember that came up during our discussions. People on the committee had raised that point.

So it's very clear that the Center will now move out and fill that role -- respecting then the fact they will fill that role that had been played for NMSS by Sandia.

DR. MOELLER: I keep watching the clock so we'll have to move along.

The second item was on activities and staffing. I think you've answered most of these already.

The questions were: Is the funding -- Are the funding and staffing levels high enough to attract outstanding people? I think you've already answered that.

Is the funding long range enough to assure career opportunities versus, you know, coming in and out? You've already, I believe, answered that.

A couple of other questions: What do you do to keep your staff at the cutting edge? You might comment on that.

The last one in this group, which I don't think we need to discuss, but the committee was very much interested in favor of a program where you would have exchanges of personnel between the NRC and the Center.

We like the idea of post-doctoral fellowships here at the Center, and we like the idea of some sort of an intern program.

So I don't think we need to comment on that. Perhaps of this group, how do you keep your staff on the cutting edge would be of interest.

DR. PATRICK: Okay. I think there are -- Well, there are three areas.

One for myself personally, and I think for most of us, there is a fourth area; and it's really the first one.

There aren't too many places where -- I'll say young scientists or engineers -- but a scientist or engineer of any age can go and work on a program of this importance on a national and international scale.

That's an excitement factor that enables us to compete for initially, and I hope the test of time will show it enables us to keep on staff and keep at the cutting edge the very best.

I think the people you've seen today are a tribute to that.

Three more specific things, though, aside from that more global one: The IR&D program, we anticipate -- the internal research and development program which John spoke to -- we anticipate that that is going to be a very good mechanism to keep people fresh, to allow them, even within what is a rather structured, regulatory research environment, to be able to go out and probe those things that are relevant to the high-level problem, but may not be the sort of thing which NRC is able to step up and fund at this point.

I think those will be very important aspects of keeping people up near the edge.

The second item: Our staff is free and very actively engaged in professional meetings, not just programmatically relevant meetings, but professional meetings as well.

We have a number of our staff who are heavily involved in professional committee activities. That's true not only in the technical staff, but in the quality assurance staff and in the administrative staff as well.

Up and down the line we have people who are engaged in those sorts of activities.

A related item: Many of you aren't aware, but here in this community we have a number of colleges and universities. It has been an Institute tradition that people who work here teach also at those universities.

That opportunity is available for our staff members, to keep them interacting with the new, young minds and with the faculties of some of these universities.

That, too, is an important area.

The last area I would mention is involvement in international working groups. You've heard today some of the work that our staff just in the last few months has been involved in, in INTER VAL, which is an international code validation exercise, the Migration series of meetings which are held -- What, Bill, every two years?

DR. MURPHY: Every two years.

DR. PATRICK: Those of us on the rock end are involved in national and international committees on rock mechanics and so forth.

DR. MOELLER: You didn't mention, there are international cooperative efforts on natural analogs. You didn't mention that. Are you involved?

DR. RUSSELL: There's a meeting scheduled of the working group for natural analogs, which is a CEC organization. There's a meeting scheduled for June, and we're anticipating to participate in that.

DR. MOELLER: Good.

DR. PATRICK: If I may, one last item, which is really not so much of how you keep people at the cutting edge, but how you do the acid test of are they at the cutting edge, we, in addition to our programmatic reports and NUREG's, we strongly encourage the publication in the open peer reviewed literature. That's the test.

DR. MOELLER: Right. I was going to mention that.

DR. PATRICK: -- you know, are you at the cutting edge or not, that's the test.

DR. MOELLER: Right. Very good.

The next area -- you've answered most of these; let me just put them on the record. They all dealt with performance assessment.

The question was: Who directs the performance assessment program, the staffing of it, the number of people. I think you've covered most of that.

They did raise a question of will you be able to keep abreast of all that DOE is doing in performance assessment modeling, or how are you going to do that.

And the last one was: Have you developed a performance assessment model, and have you applied it at Yucca Mountain?

Well, you've already told us you're in the early stages and so forth.

How do you keep up with what DOE is doing in performance assessment modeling?

DR. PATRICK: Well, this -- There is a simple answer to it. Having just hired Bhudi Sager, who has been a principal developer of DOE models over the years, that's certainly a first step.

But that does open up and gives us an opportunity to come back and touch on something that we probably didn't say strongly enough earlier.

We really need to have a much more open dialogue with the DOE, not with DOE as an agency, but with DOE's contractors, the national labs, who are really the active doers of the work and performance assessment and other areas.

Part of that help will come through these technical exchanges. And the recent ones, we think, have been very good.

But those are -- For any one topic, those are infrequent and rather structured. There needs to be in our opinion a much more scientist to scientist/engineer to engineer level of discussion going on.

I don't know how you do that within a regulatory environment. I just express it, you know, as a sense -- as an engineer, as a scientist where we would feel that it would be much easier to stay abreast if one didn't have to wait for the next international meeting on performance assessment before you found out what the performance assessment people were doing, or the next meeting or technical exchange on performance assessment, or geochemistry or what have you.

A more collegial kind of an interaction, we feel would be very helpful in that area.

DR. LATZ: There should be no Berlin Wall between good science.

DR. MOELLER: There were other things on my list which I won't list because you have covered them, one pertaining to QA. You've certainly shown us that that's one of your brightest areas.

Let me just close out by mentioning the reports. I know we're supposed to have an arrangement whereby the NRC staff routinely feeds to us all of your technical reports, but I don't think it's working or something, because we're -- Of course, what we've heard about today, perhaps they're on their way or something.

We certainly -- I think we need to set up a mechanism so you could almost send the reports directly to Richard Major so we would see them.

I say that because six months or so ago -- six, nine months ago, when we were first getting into a review of your activities, in fact when Chairman Zeck told us specifically he wanted this committee to do that -- we asked for your reports, and we received two or three early ones.

They were all essentially reviews of the literature, and we thought -- to us. We said, "Well, if that's all they're doing, you know, it's not very much." And it was a misrepresentation of what you're doing.

So I think we need to get your reports -- to receive them; and we need also to continue these types of meetings because this has been very beneficial.

Let me -- believing we're near the close of the formal meeting here, let me say that it was quite obvious that you have put a lot of work into the presentations that were made today. Technically they're as good as I have personally heard on the various subjects discussed.

I think you deserve credit on that.

It has been a pleasure for us to be down here and to interact. I say that I hope that we can continue these types of interchanges, so long as we don't disrupt your important work too much.

Are there any comments from members of the committee or consultants? Is there anything?

[No response.]

DR. MOELLER: Do you have any comments, John?

DR. LATZ: Mr. Chairman, only to reiterate our earnest desire of frequent visitations with you. The welcome mat is out.

Indeed, you do not disrupt our activities; you aid and abet our activities.

We certainly look forward to your continuing interest and tracking of the Center's work. We're very grateful to you for coming.

DR. MOELLER: Thank you, and thank you for your hospitality.

We will adjourn the formal meeting and undertake the tour.

Thank you again.

[Meeting adjourned at 3:55 p.m.]

C E R T I F I C A T E

CASE TITLE: MEETING: ADVISORY COMMITTEE ON NUCLEAR WASTE WORKING GROUP

DATE: November 30, 1989

I hereby certify that the transcript contained herein is a full and accurate transcript of the notes taken by me at the meeting described above, to the best of my knowledge and belief.

Dated this 2nd day of December, 1989.

Betty Morgan

Betty Morgan, Reporter
ANN RILEY & ASSOCIATES

BRIEFING TOPICS

- OVERVIEW OF CNWRA OPERATIONS
- SUMMARY STATUS OF CNWRA ACTIVITIES
- RESEARCH PROGRAM
  - Geochemistry Project
  - Integrated Waste Package Experiments
  - Seismic Rock Mechanics Project
  - Geohydrology/Stochastic Modeling Project
  - Thermohydrologics Project
- FAST PROBABILISTIC PERFORMANCE ASSESSMENT
- TRANSPORTATION RISK STUDY
- PERFORMANCE ASSESSMENT AND PROGRAM INTEGRATION

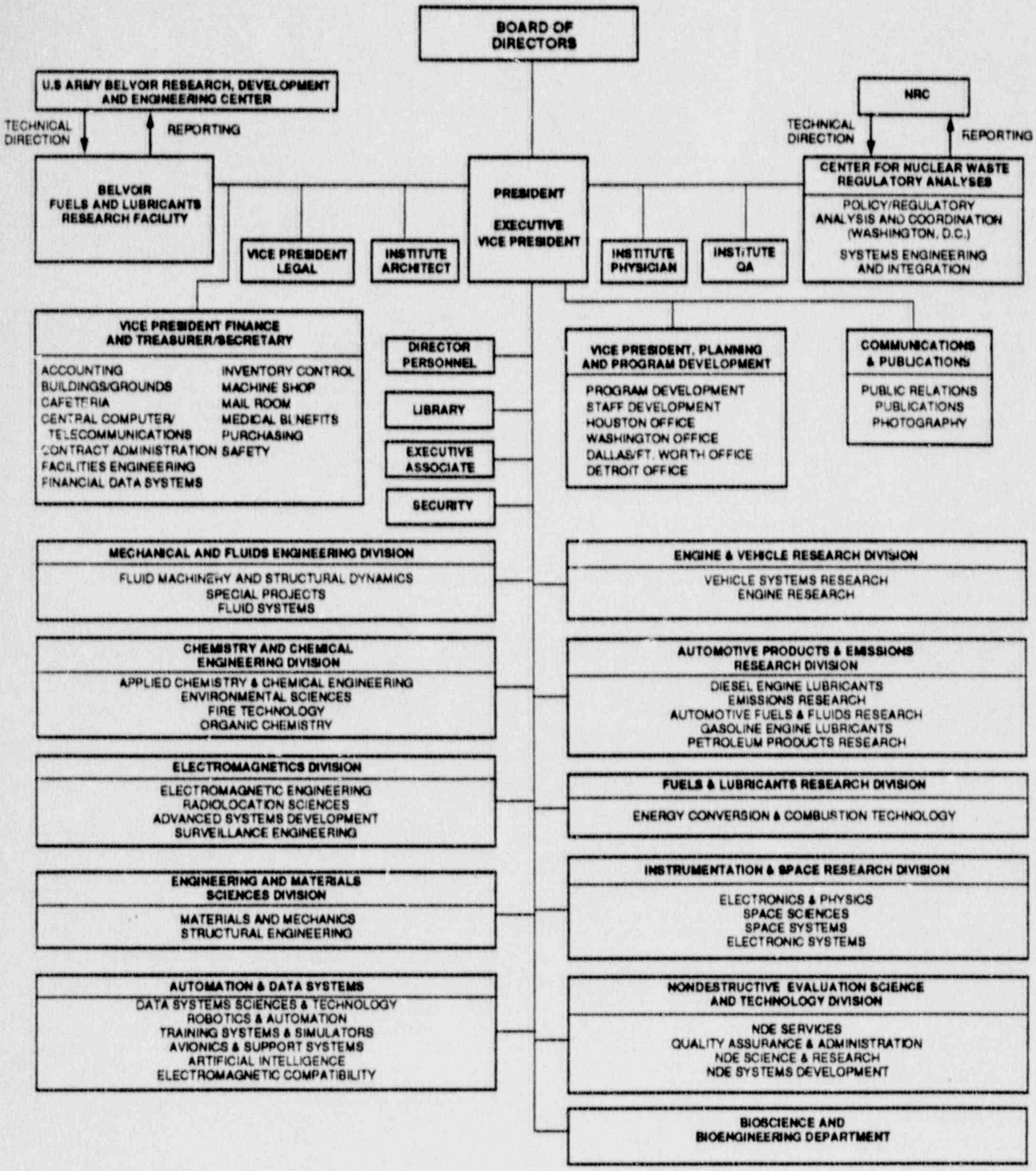
OVERVIEW OF CNWRA OPERATIONS

- COMPLETED START UP OF CENTER
- STAFFING ON TARGET
- COMPLETED PLANNING/BUDGETING DOCUMENTS FOR FY1990-1991
  - Division of HLW Operations Plans
  - Research Project Plans (5 Approved, 2 Pending Approval, 5 Planned Starts)
  - Transportation Risk Study Plan
- OCCUPIED ON-CAMPUS OFFICES AND RESEARCH LABORATORY

ESTABLISHMENT OF A FFRDC BY THE NRC FULFILLS THREE PURPOSES

- AVOIDS CONFLICT-OF-INTEREST SITUATIONS
- PROVIDES LONG-TERM CONTINUITY IN TECHNICAL ASSISTANCE AND RESEARCH
- PROVIDES A CENTRAL CAPABILITY FOR PERFORMING AND INTEGRATING TECHNICAL ASSISTANCE, RESEARCH, AND INDEPENDENT REVIEW ACTIVITIES RELATED TO ALL ASPECTS OF HLW LICENSING

SOUTHWEST RESEARCH INSTITUTE
ORGANIZATION CHART



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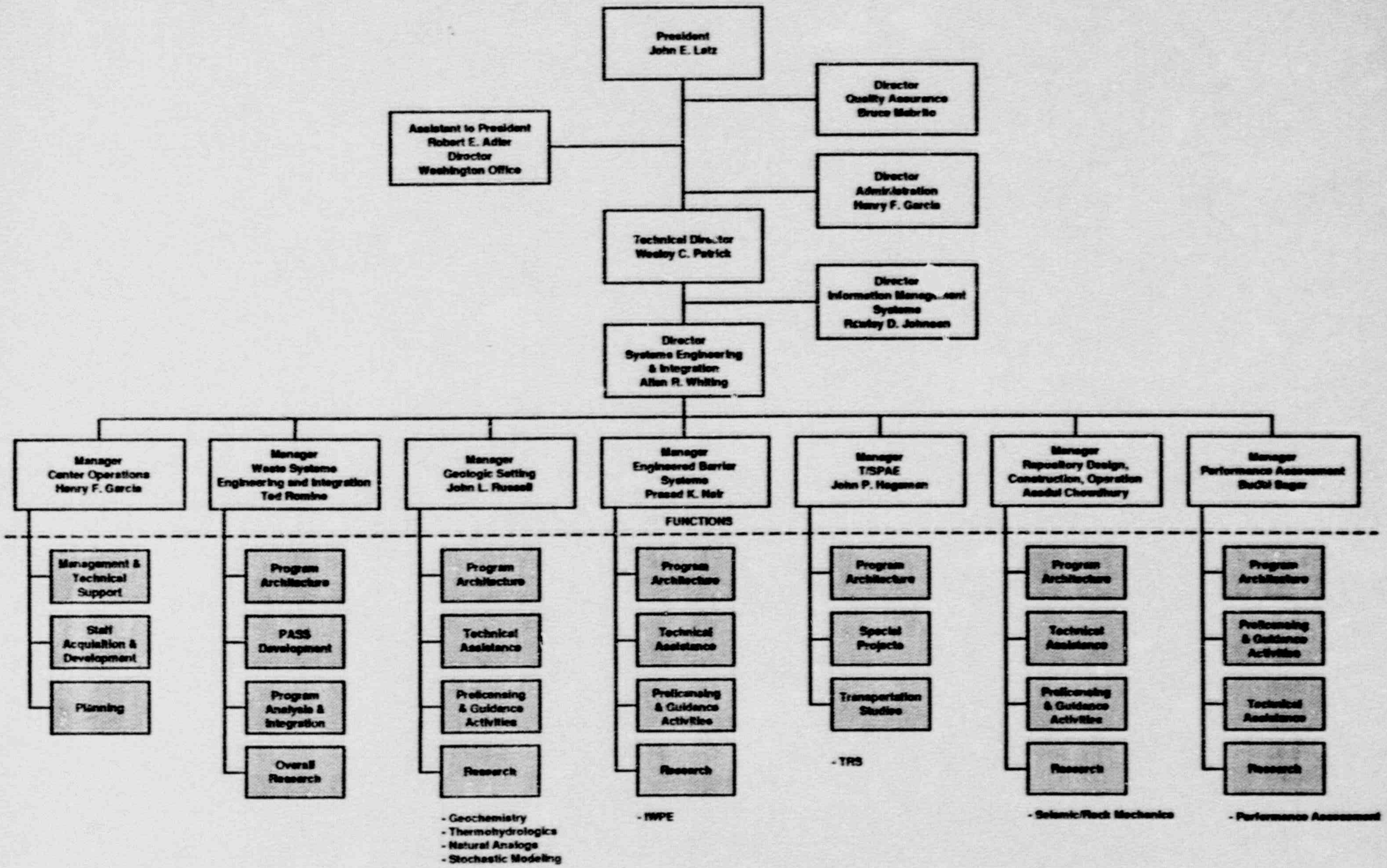
- SERVICES COMMITTEE

SEPTEMBER 1989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11/9/89

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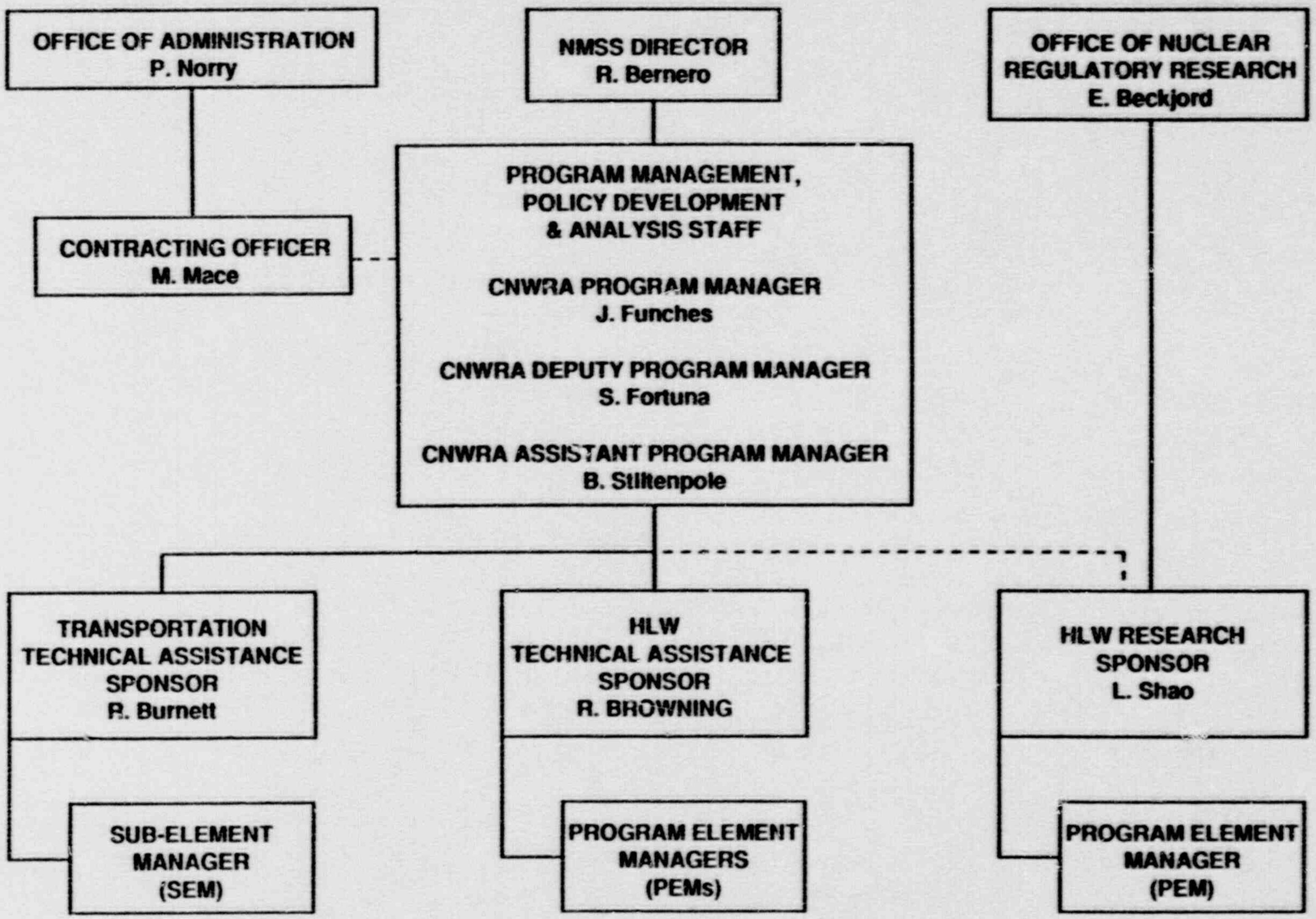

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PROGRAM ELEMENT MANAGERS (PEMs)

PROGRAM ELEMENT MANAGER (PEM)

SUMMARY CENTER STAFFING PLAN

	Professional	Support	Total
END OF FY89	27	8	35
CURRENT	32	8	40
PLANNED END OF FY90	51	9	60

ESTIMATE OF EXPERTISE NEEDS – SUMMARY

ESTIMATE OF EXPERTISE NEEDS--SUMMARY

EXPERTISE/EXPERIENCE	CNWRA	SWRI	CON./SUB.	TOTAL
GEOCHEMISTRY	6.00	0.00	0.20	6.20
HYDROLOGY/CLIMATOLOGY	4.00	0.50	0.30	4.80
ROCK MECHANICS/MINING	5.00	0.50	0.45	5.95
MATERIAL SCIENCES	4.00	1.50	1.10	6.60
STRUCTURAL/TECTONICS	6.00	0.25	0.30	6.55
PERFORMANCE ASSESSMENT	6.00	0.70	0.10	6.80
MECHANICAL & FACILITIES ENGINEERING	2.00	0.20	0.80	3.00
SYSTEMS ENGINEERING	8.00	0.00	0.60	8.60
ADMINISTRATION & SUPPORT SERVICES	7.00	0.00	0.00	7.00
ALL OTHER AREAS	2.00	1.70	0.80	4.50
TOTAL	50.00	5.35	4.65	60.00

ESTIMATED AVAILABILITY AND UTILIZATION OF PERSONNEL – SUMMARY

ESTIMATED AVAILABILITY AND UTILIZATION OF PERSONNEL--SUMMARY

FISCAL YEAR

SOURCE	FY 90			FY 91		
	TOTAL	NMSS	RES	TOTAL	NMSS	RES
CNWRA	45	32	13	50	36	14
SWRI	6	2	4	4	1	3
SUB/CONSULT.	7	4	3	6	4	2
TOTALS	58	38	20	60	41	19

CENTER CORE STAFF – HIRING PROFILE

CENTER CORE STAFF -- HIRING PROFILE

EXPERTISE/EXPERIENCE	FY 88	FY 89	FY 90				FY 91	FY 92
			1Q	2Q	3Q	4Q		
ADMINISTRATION	5	5	5	5	5	5	5	5
DATA BASE MANAGEMENT AND DATA PROCESSING	1	2	2	2	2	2	2	2
ELECTROCHEMISTRY			1	1	1	1	1	1
ENGINEERING GEOLOGY/GEOLOGICAL ENGINEERING				1	1	1	1	1
GEOCHEMISTRY	2	2	3	5	5	5	5	5
GEOHYDROLOGY		2	2	4	4	4	4	4
GEOLOGY	1	1	1	1	2	2	2	2
GEOMORPHOLOGY				1	1	1	1	1
GEOSTATISTICS				1	1	1	1	1
HEALTH PHYSICS	1	1	1	1	1	1	1	1
INFORMATION MANAGEMENT SYSTEMS	2	2	2	2	2	2	2	2
MATERIAL SCIENCES	2	2	3	3	3	3	3	3
MECHANICAL, INCLUDING DESIGN & FABRICATION			1	1	1	1	1	1
METEOR/CLIMATOLOGY				1	1	1	1	1
MINING ENGINEERING	1	1	1	1	1	1	1	1
NUMERICAL MODELING			1	1	1	1	1	1
PERFORMANCE ASSESSMENT		1	2	4	4	4	4	4
QUALITY ASSURANCE	1	2	2	2	2	2	2	2
RADIOCHEMISTRY				1	1	1	1	1
REGULATORY AND POLICY ANALYSIS	2	3	3	3	3	3	3	3
RELIABILITY	1	1	1	1	1	1	1	1
ROCK MECHANICS		1	2	3	3	3	3	3
STRUCTURAL GEOLOGY				1	1	1	1	1
SYSTEMS ENGINEERING	1	1	2	2	2	2	2	2
TRANSPORTATION	1	1	1	1	1	1	1	1
VOLCANOLOGY/IGNEOUS GEOLOGY				1	1	1	1	1
TOTAL REQUIRED	21	28	36	50	51	51	51	51

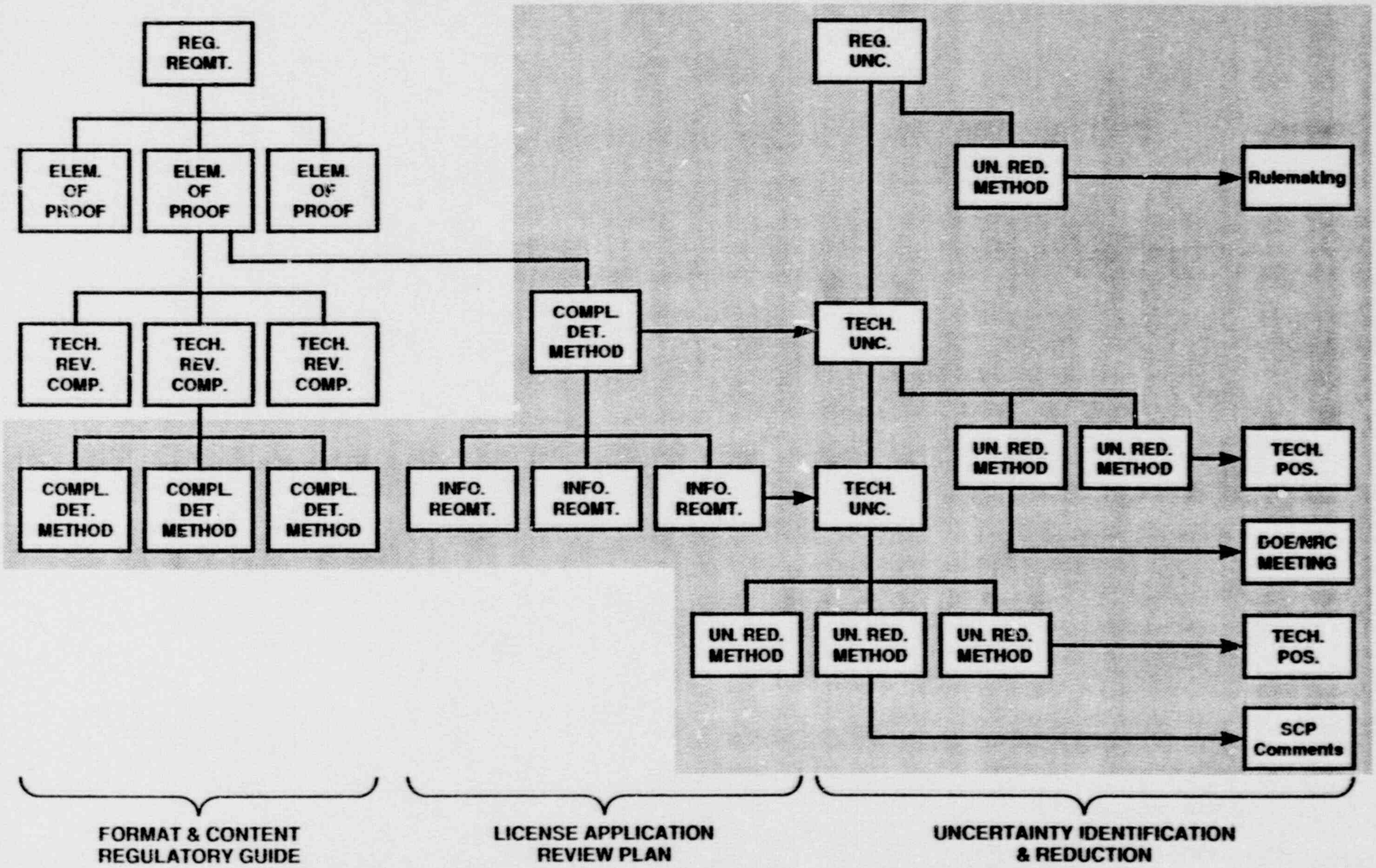
CNWRA PRINCIPAL PROGRAMMATIC AREAS

- SYSTEMS APPROACH TO LICENSING
- TECHNICAL ASSISTANCE
- RESEARCH
- TRANSPORTATION RISK STUDY

SYSTEM ENGINEERING: APPROACH

- MISSION ORIENTED – NWPAA FOCUS
- REQUIREMENTS-BASED – 10CFR60 AND 40CFR191 PRIMARY FOR REPOSITORY
- PROACTIVE – SUFFICIENT AND TIMELY GUIDANCE TO DOE
- BASIS FOR INTEGRATION – ORGANIZATIONAL AND FUNCTIONAL
- DYNAMIC – ADAPTS TO CHANGES

RELATIONSHIPS AMONG COMPONENTS OF NRC PROGRAM AND SYSTEMATIC REGULATORY ANALYSIS



REG. REQMT.

ELEM. OF PROOF
ELEM. OF PROOF
ELEM. OF PROOF

TECH. REV. COMP.
TECH. REV. COMP.
TECH. REV. COMP.

COMPL. DET. METHOD
COMPL. DET. METHOD
COMPL. DET. METHOD

COMPL. DET. METHOD

INFO. REQMT.
INFO. REQMT.
INFO. REQMT.

REG. UNC.

UN. RED. METHOD

Rulemaking

TECH. UNC.

TECH. UNC.

UN. RED. METHOD
UN. RED. METHOD

TECH. POS.

DOE/NRC MEETING

UN. RED. METHOD
UN. RED. METHOD
UN. RED. METHOD

TECH. POS.

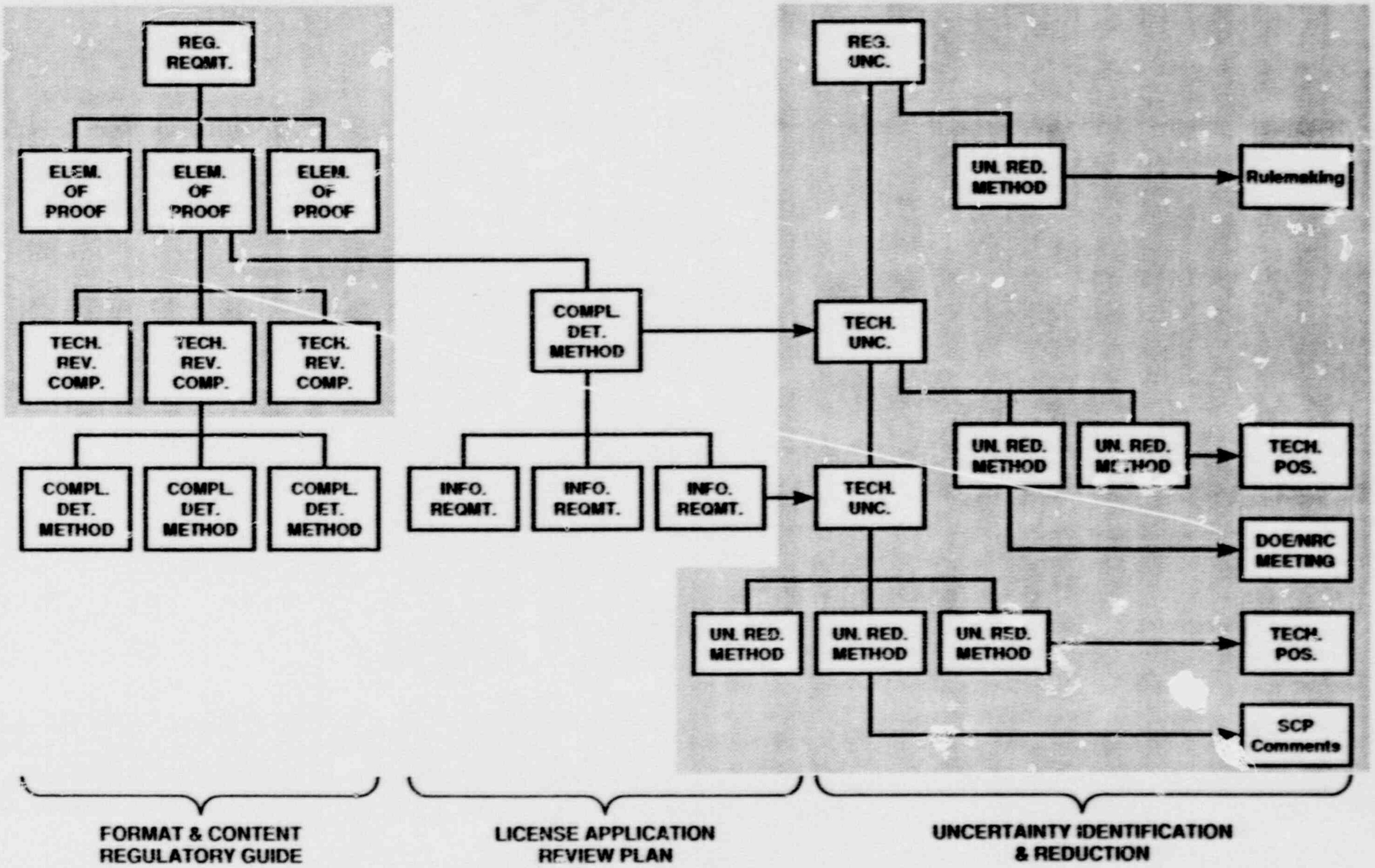
SCP Comments

FORMAT & CONTENT REGULATORY GUIDE

LICENSE APPLICATION REVIEW PLAN

UNCERTAINTY IDENTIFICATION & REDUCTION

RELATIONSHIPS AMONG COMPONENTS OF NRC PROGRAM AND SYSTEMATIC REGULATORY ANALYSIS



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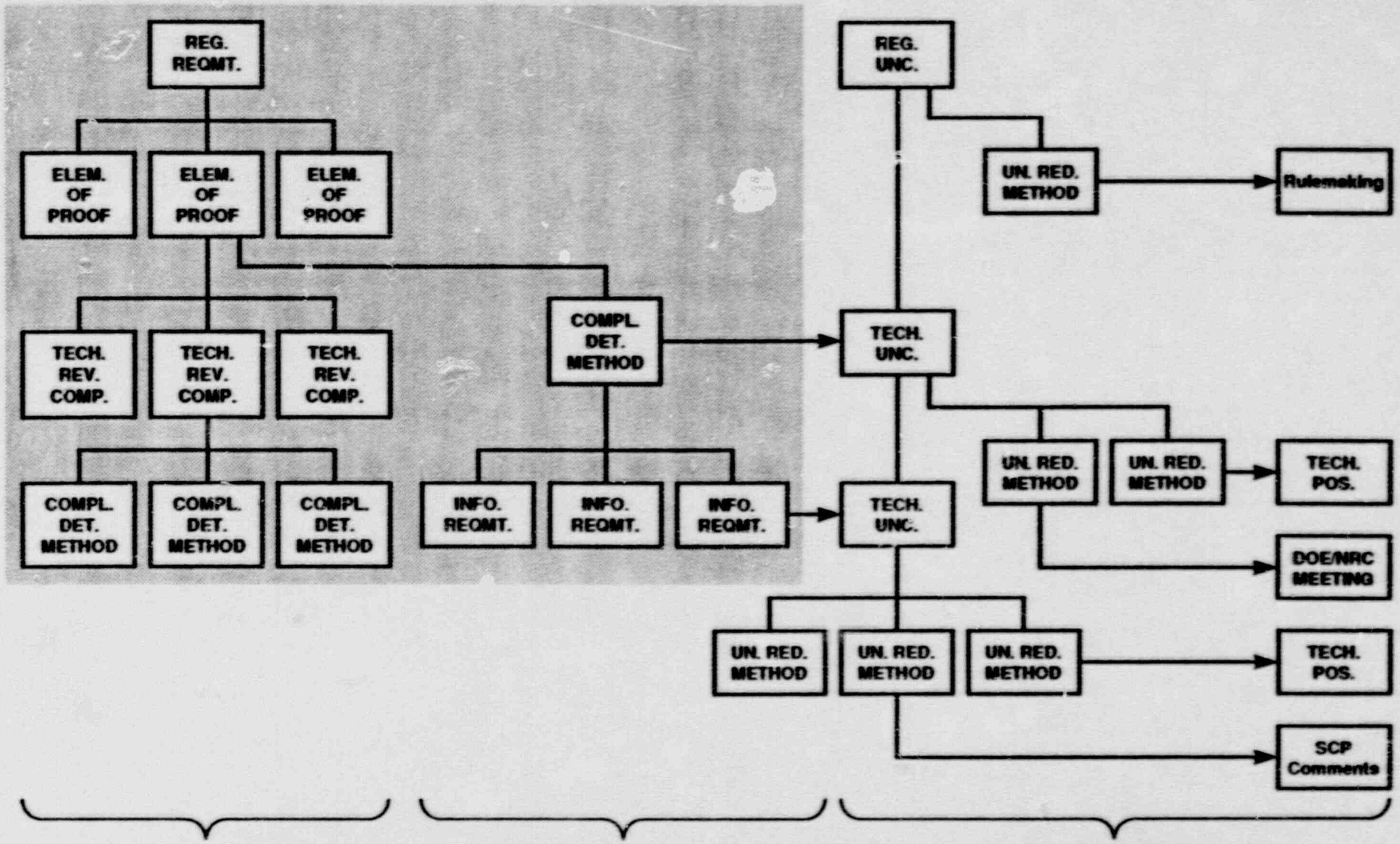

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TECH. POS.

SCP Comments

FORMAT & CONTENT REGULATORY GUIDE

LICENSE APPLICATION REVIEW PLAN

UNCERTAINTY IDENTIFICATION & REDUCTION

SIGNIFICANT ACCOMPLISHMENTS – SYSTEMS ENGINEERING

- PRIORITIZED STATUTES AND REGULATIONS FOR ANALYSIS
- DELINEATED REGULATORY REQUIREMENTS IN 10 CFR PART 60
- CONDUCTED SYSTEMATIC REVIEW OF ASSIGNED PORTIONS OF SCP
- COMPLETED ATTRIBUTE ANALYSES
  - Uncertainties Related to the SCP and ESF
  - Regulatory/Institutional Uncertainties in Subparts B and E
- BASELINED THE PROGRAM ARCHITECTURE PROCESS AND PROCEDURES

TECHNICAL ASSISTANCE: APPROACH

- PROVIDE TECHNICAL SUPPORT TO REGULATORY GUIDANCE DOCUMENTS
- EVALUATE DOE PRE-LICENSING AND LICENSING SUBMITTALS
- PROVIDE QA AND TECHNICAL SUPPORT TO AUDITS OF DOE AND ITS CONTRACTORS
- DEVELOP COMPLIANCE DETERMINATION METHODS
- PARTICIPATE IN DEVELOPMENT OF NRC PERFORMANCE ASSESSMENT CAPABILITY

SIGNIFICANT ACCOMPLISHMENTS – TECHNICAL ASSISTANCE

- **PREPARED INPUTS TO THE SITE CHARACTERIZATION ANALYSIS**
- **COMMENCED WORK ON TECHNICAL POSITIONS AND RULEMAKINGS**
  - **Natural Resources Assessment**
  - **Retrievability**
  - **Thermal Loads**
  - **Design Basis Accident**
  - **Substantially Complete Containment**

SIGNIFICANT ACCOMPLISHMENTS – TECHNICAL ASSISTANCE (CONT'D)

- COMPLETED CODE STRUCTURE FOR EBS PERFORMANCE ASSESSMENT CODE

- ADVANCED EBSPAC CAPABILITIES
  - Selected Fast Probabilistic Performance Assessment
  - Introduced Importance Sampling Scheme
  - Implemented Advanced Mean Value Procedure

- COMPLETED REPOSITORY DESIGN ACCEPTABILITY ANALYSIS

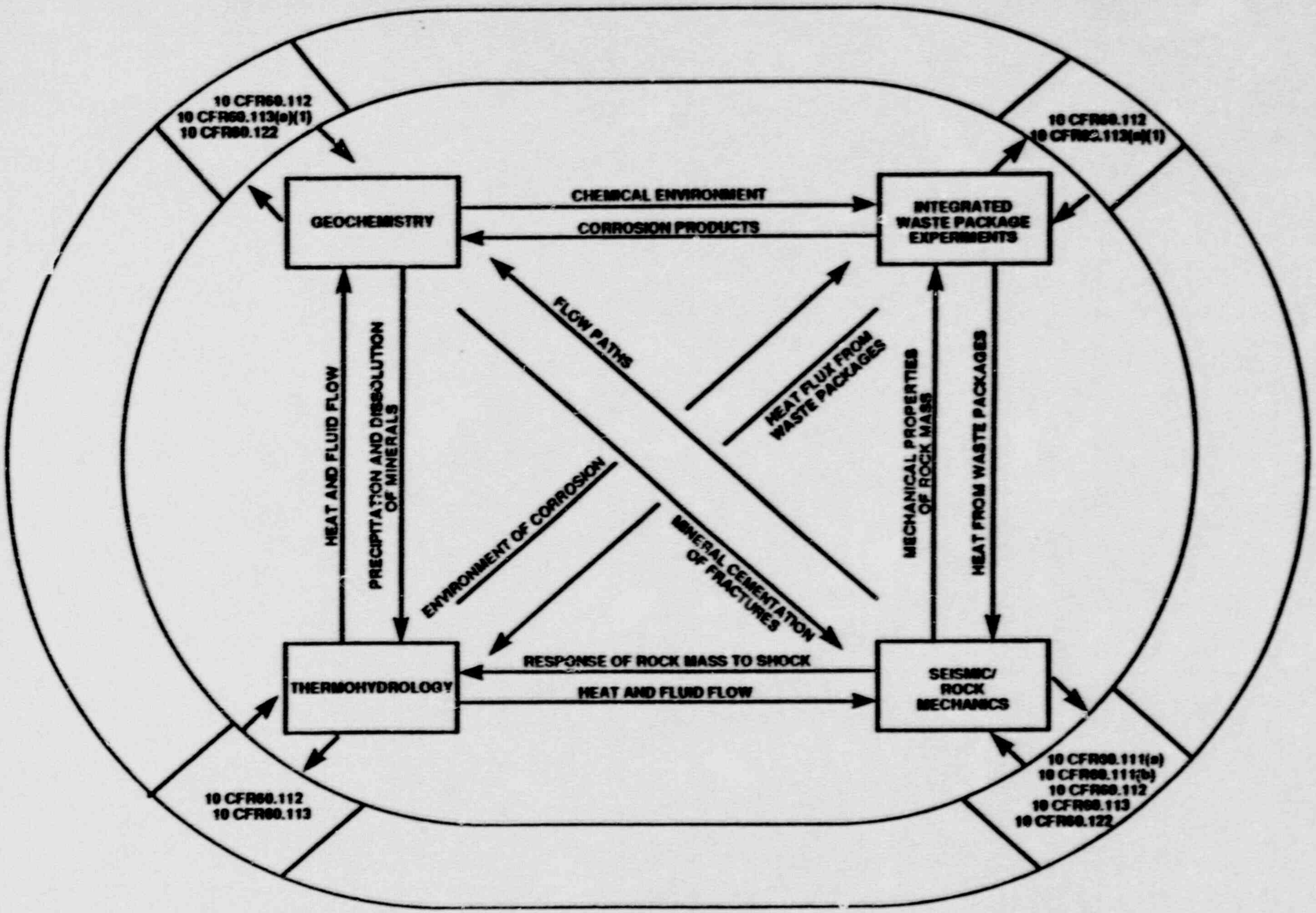
SIGNIFICANT ACCOMPLISHMENTS – TECHNICAL ASSISTANCE (CONT'D)

- SUPPORTED QA OBSERVATION AUDITS
- COMPLETED COMPREHENSIVE SURVEY OF STRATEGIC PROGRAMMATIC ISSUES AND RISKS
- ASSISTED DEVELOPMENT OF FORMAT AND CONTENT GUIDE FOR LA
- DEVELOPED STATUTORY AND REGULATORY BASIS FOR PERFORMANCE ASSESSMENT
- DEVELOPED AND EVALUATED PERFORMANCE ASSESSMENT REVIEW OPTIONS

RESEARCH PROJECTS: APPROACH

- DEVELOP AND/OR ENHANCE TECHNICAL BASIS OF REGULATIONS
- PROVIDE CONFIRMATORY DATA AND CALCULATIONS FOR USE IN LICENSE REVIEW
- EXPLORE PHENOMENA, PROCESSES, AND CONDITIONS NOT CONSIDERED BY DOE
- DEVELOP NRC AND CNWRA STAFF CAPABILITIES FOR TIMELY HIGH-QUALITY REVIEW OF LICENSING MATERIALS

INTEGRATION AMONG RESEARCH PROJECTS



10 CFR60.112
10 CFR60.113(a)(1)
10 CFR60.122

10 CFR60.112
10 CFR60.113(a)(1)

GEOCHEMISTRY

CHEMICAL ENVIRONMENT

CORROSION PRODUCTS

INTEGRATED WASTE PACKAGE EXPERIMENTS

FLOW PATHS

HEAT FLUX FROM WASTE PACKAGES

HEAT AND FLUID FLOW

PRECIPITATION AND DISSOLUTION OF MINERALS

ENVIRONMENT OF CORROSION

MINERAL CEMENTATION OF FRACTURES

MECHANICAL PROPERTIES OF ROCK MASS

HEAT FROM WASTE PACKAGES

THERMOHYDROLOGY

RESPONSE OF ROCK MASS TO SHOCK

HEAT AND FLUID FLOW

SEISMIC/ ROCK MECHANICS

10 CFR60.112
10 CFR60.113

10 CFR60.111(a)
10 CFR60.111(b)
10 CFR60.112
10 CFR60.113
10 CFR60.122

GEOCHEMISTRY RESEARCH PROJECT
FIN B6644
NRC Project Manager: G.T. Birchard

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

SOUTHWEST RESEARCH INSTITUTE
San Antonio, Texas

Project Manager: John L. Russell

Principal Investigators:
William M. Murphy and Roberto T. Pabalan

November 30, 1989

GEOCHEMISTRY RESEARCH PROJECT
GENERAL OBJECTIVES

- To Understand the Ambient Geochemiocal Conditions and Processes at the Proposed HLW Repository Site
- To Understand the Geochemical Conditions and Processes Affecting the Transport of Radionuclides and Releases to the Accessible Environment
- To Understand the Geochemical Conditions and Processes Which will Affect Performance of the Waste Packages and EBS
- To Recognize and Evaluate Issues and Uncertainties in Predictive Geochemical Models Used in Performance Assessment in Regard to Isolation of the Waste

GENERAL OBJECTIVES (CONT'D)

- To support NRC activities associated with:
    a. Site characterization

    b. Establishment of design criteria

    c. Identification and evaluation of potentially favorable and adverse conditions

    d. Evaluation of licensing application of DOE for the candidate HLW repository

GEOCHEMISTRY RESEARCH PROJECT

- **REGULATORY BASES IN 10 CFR PART 60**

60.112	Overall System Performance Objective for the Geologic Repository after Permanent Closure
60.113	Performance of Particular Barriers after Permanent Closure
60.122(b)(3),(4)	Siting Criteria – Favorable Conditions
60.122(c)(7),(8),(9),(20),(24)	Siting Criteria – Potentially Adverse Conditions

GEOCHEMISTRY RESEARCH PROJECT
REGULATORY PRODUCTS AFFECTED

- REVIEW OF SCP/PREPARATION OF SCA
- DEVELOPMENT OF TECHNICAL POSITIONS
  - Environment of EBS Package
  - Radionuclide Transport
  - Rock/Water Chemical Interactions
- ISSUED TECHNICAL POSITIONS
  - Determination of Radionuclide Solubility in Groundwater for Assessment of High-Level Radionuclide Waste Isolation
  - Determination of Radionuclide Sorption of HLW Repositories
  - Guidance for Determination of Anticipated and Unanticipated Processes and Events (Draft)
  - Interpretation and Identification of the Disturbed Zone (Draft)

GEOCHEMISTRY RESEARCH PROJECT
REGULATORY PRODUCTS AFFECTED (CONT'D)

- POTENTIAL RULEMAKINGS
  - Further Amplification of the Meaning of the Phrase "Disturbed Zone" used in 10 CFR Part 60
  - Further Amplification of the Meaning of the Phrase "Anticipated Processes and Events and Unanticipated Processes and Events" used in 10 CFR Part 60
- PRE-LICENSING GUIDANCE
- LICENSE APPLICATION EVALUATION
- CONFIRMATORY AND EXPLORATORY EXPERIMENTS

GEOCHEMISTRY RESEARCH PROJECT

REGULATORY PRODUCTS AFFECTED (CONT'D)

- PERFORMANCE ASSESSMENT
  - Source Term Modeling (MOU Task 2)
  - Overall System Performance Assessment (MOU Task 3)
- HLWM STATEMENT OF RESEARCH NEEDS
  - Groundwater Chemistry
  - Radionuclide Transport
  - Rock/Backfill/EBS Mineralogy

GEOCHEMICAL PARAMETERS:

- Groundwater chemistry
- Mineralogy, petrology, and rock chemistry
- Stability of minerals and glass
- Radionuclide transport and retardation mechanisms (e.g., complexes, colloids, sorption, precipitation)

GEOCHEMISTRY RESEARCH PROJECT

BASIC APPROACH

- Geochemical Modeling
  - allows integration of results from various types of studies
  - enables prediction of the performance of geochemical systems under physical and chemical conditions not studied experimentally
  - permits predictions of the performance of geochemical systems on scales of time and space that exceed those accessible by laboratory study
  - enables design and interpretation of experiments
- Experimental Studies
  - required to provide accurate parameters for the geochemical model
  - necessary to validate geochemical modeling
  - needed to independently judge the geochemical work by DOE on HLW isolation

AQUEOUS SPECIES	EQUILIBRIUM CONCENTRATION (MOLALITY)*			
	J-13	J-13 and MINERALS	J-13 and AIR	Simplified Model Water
HCO_3^-	2.1E-3	2.1E-3	1.9E-3	2.6E-3
Na^+	2.1E-3	2.1E-3	2.1E-3	2.5E-3
SiO_2	1.1E-3	3.6E-4	1.0E-3	3.6E-4
$CO_2(aq)$	5.8E-4	5.8E-4	1.1E-5	5.6E-4
Ca^{2+}	2.7E-4	2.7E-4	2.7E-4	2.7E-4
SO_4^{2-}	1.8E-4	1.8E-4	1.8E-4	1.8E-4
Cl^-	1.8E-4	1.8E-4	1.8E-4	1.8E-4
NO_3^-	1.6E-4	1.6E-4	1.6E-4	
K^+	1.4E-4	1.4E-4	1.4E-4	3.3E-5
F^-	1.1E-4	1.1E-4	1.1E-4	1.1E-3
Mg^{2+}	6.8E-5	6.8E-5	6.7E-5	6.8E-3
$Fe(OH)_3$	6.1E-7	1.6E-14	7.2E-7	
$Al(OH)_4^-$	5.5E-7	1.9E-9	9.6E-7	9.1E-9
Mn^{2+}	1.9E-8	5.6E-14	2.5E-9	
pH	6.9	6.9	8.6	7.0
$\log(f_{O_2}/\text{bar})$	-0.85	-0.85	-0.7	-0.7

↑

SMECTITE (Na,K,Mg,Ca,Fe,Al,Si)
CRISTOBALITE
FLUORAPATITE
PYROLUSITE

*Calculated for 25°C using the EQ3/6 software package.

RATE EQUATIONS

IRREVERSIBLE MINERAL DISSOLUTION:

ALBITE, K-FELDSPAR, CRISTOBALITE:
pH-INDEPENDENT RATES AT INTERMEDIATE pH,
AND pH-DEPENDENT RATES AT HIGH pH.

$$\frac{d\xi}{dt} = \sum_r k_r \, s \prod a_i^{-n_{i,r}} \left(1 - \exp\left(\frac{-A}{\sigma R T}\right)\right)$$

$$k_r = \frac{T \, k^\circ_r}{T^\circ} \exp\left[\frac{-\Delta H^\dagger_r}{R}\left(\frac{1}{T} - \frac{1}{T^\circ}\right)\right]$$

MINERAL PRECIPITATION/GROWTH

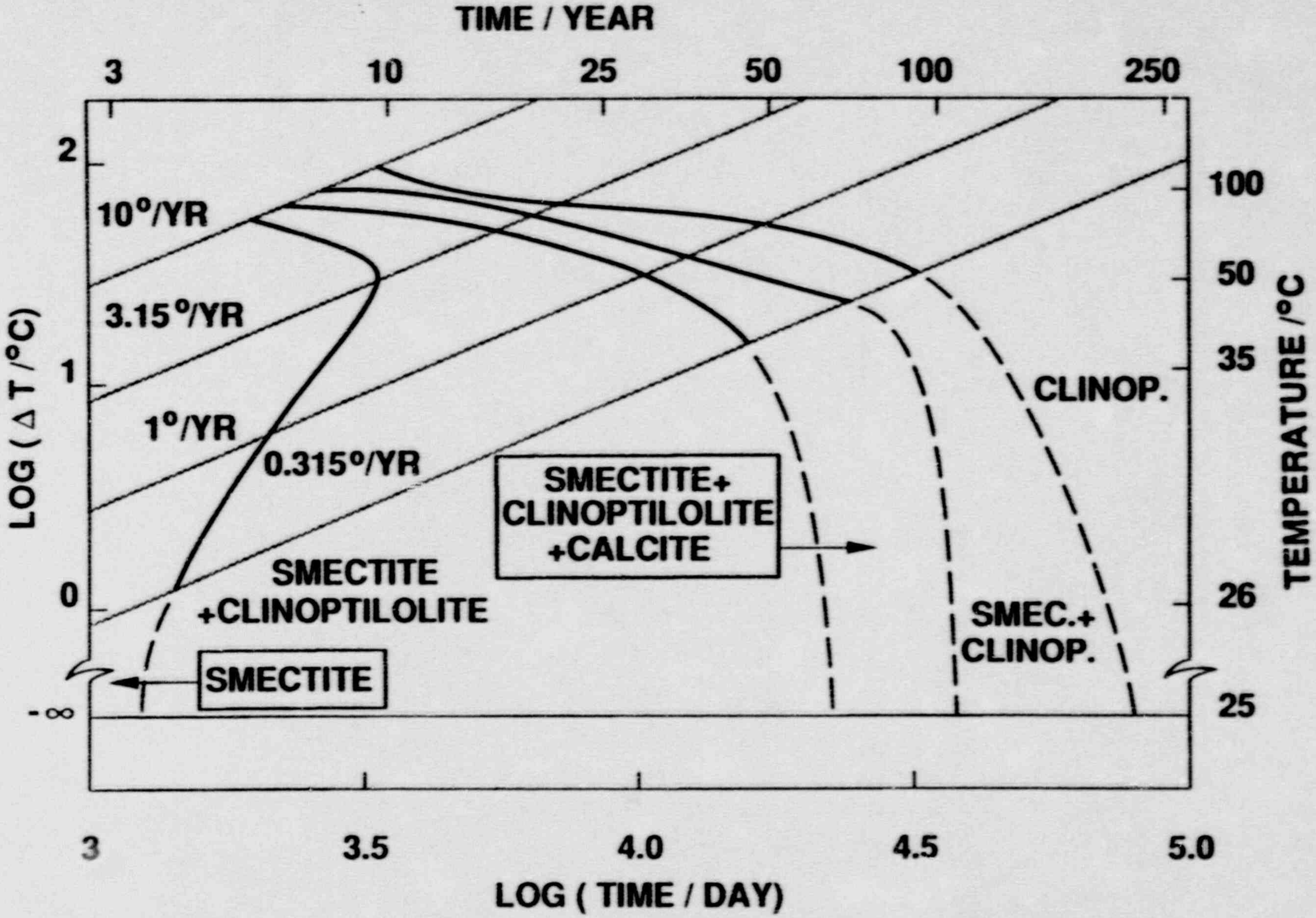
LOCAL EQUILIBRIUM:
SMECTITE, ZEOLITES, CALCITE

SUPPRESSION:
SILICA POLYMORPHS

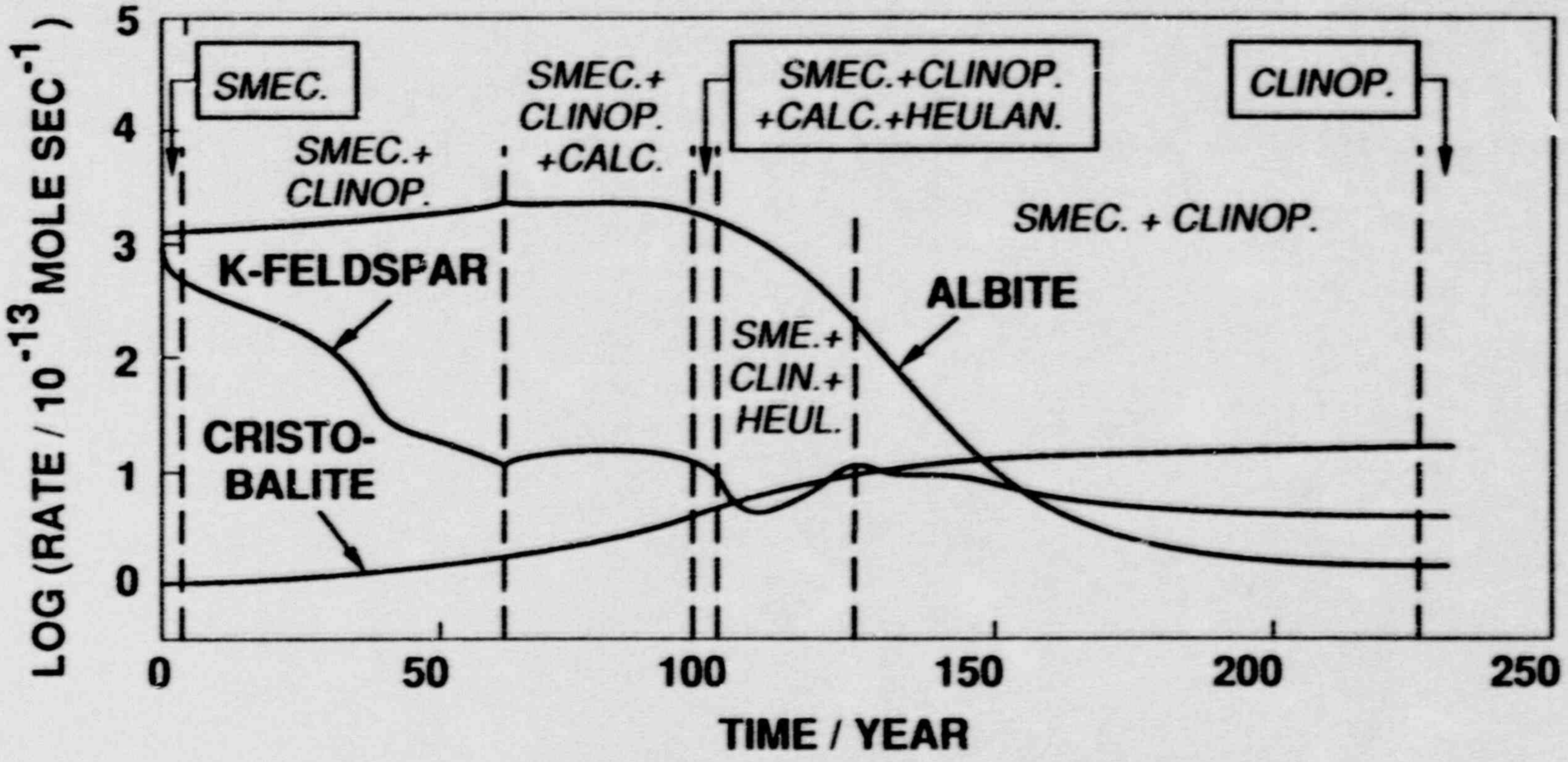
GAS VOLATILIZATION

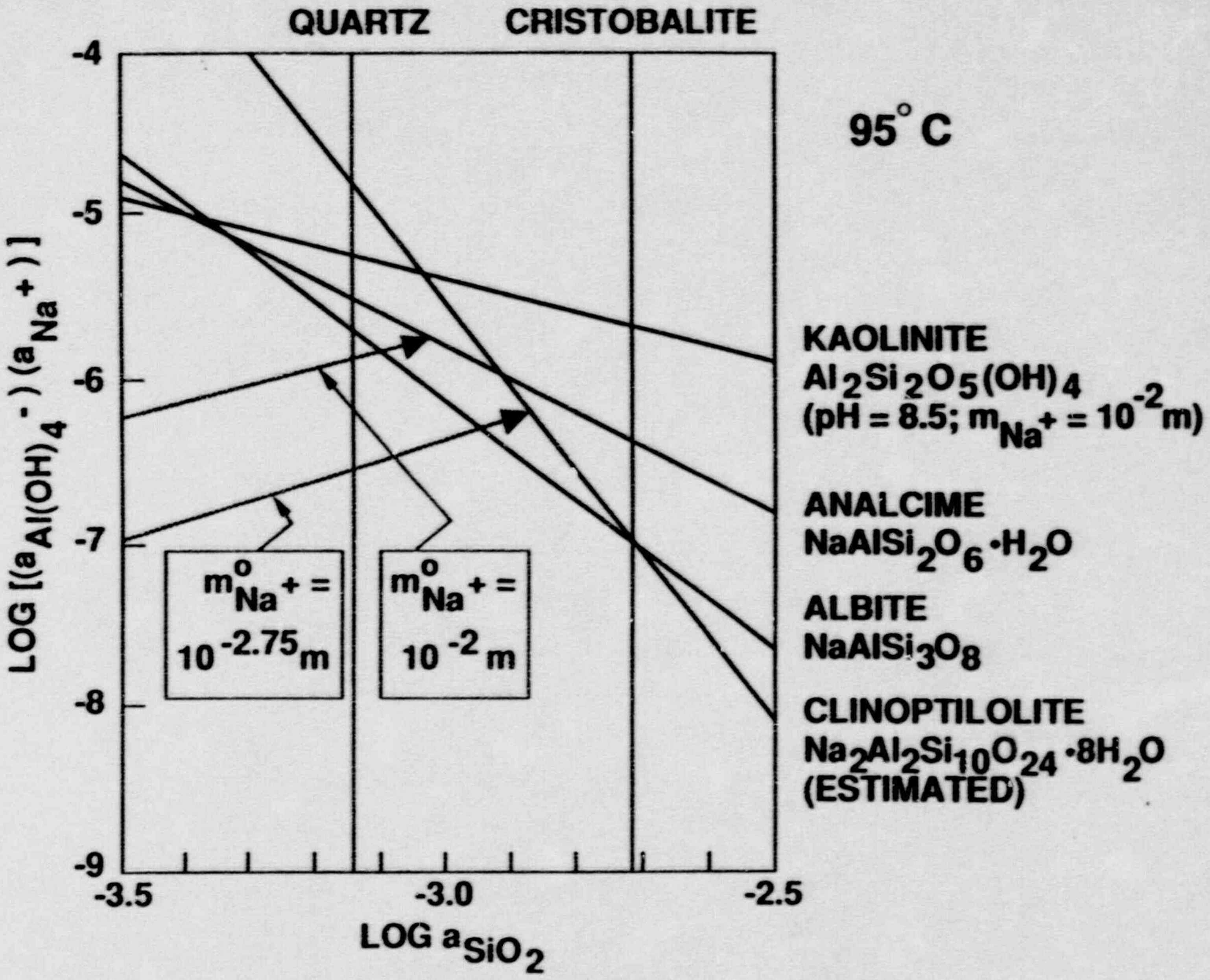
$$\frac{d\xi_{CO_2}}{dt} = k_v f_{CO_2} \qquad \frac{d\xi_{H_2O}}{dt} = k_v f_{H_2O}$$

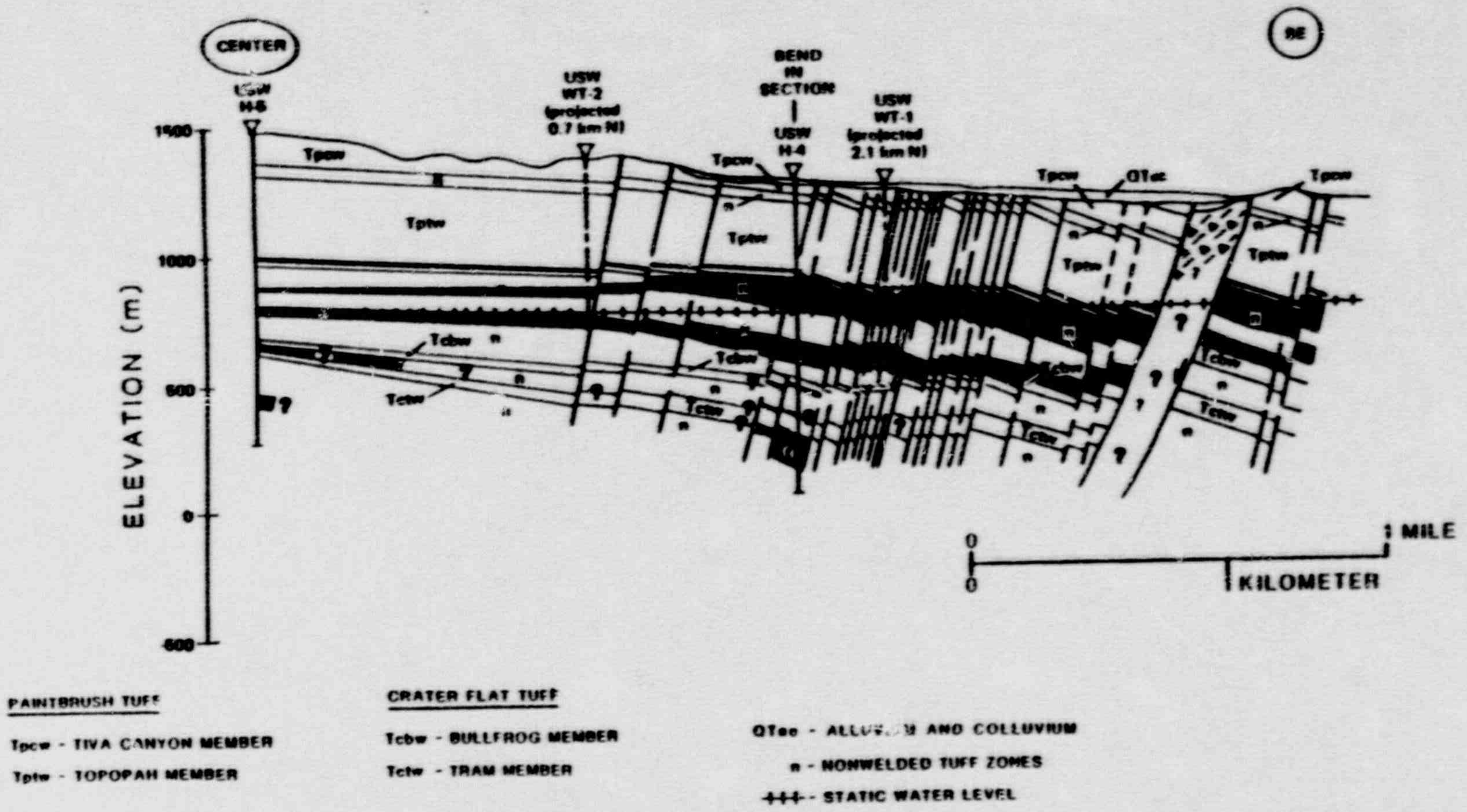
NONISOTHERMAL OPEN (FLOW THROUGH) SYSTEM REACTION PATHS



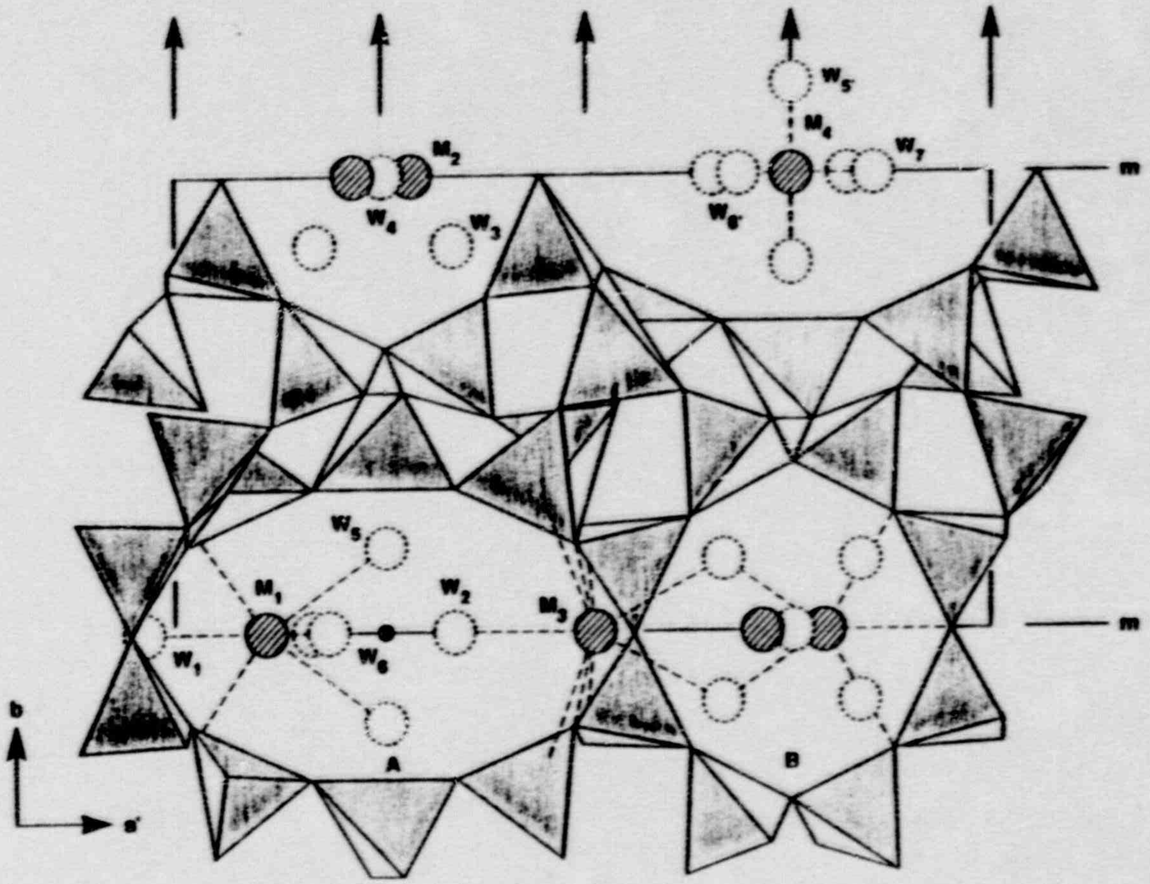
OPEN (FLOW THROUGH) SYSTEM REACTION PATH MODEL, 25°C




QUARTZ
CRISTOBALITE
95° C
LOG [(a_Al(OH)4^-) (a_Na+)]
-4
-5
-6
-7
-8
-9
-3.5
-3.0
-2.5
LOG a_SiO2
m°Na+ = 10^-2.75 m
m°Na+ = 10^-2 m
KAOLINITE
Al2Si2O5(OH)4
(pH = 8.5; mNa+ = 10^-2 m)
ANALCIME
NaAlSi2O6·H2O
ALBITE
NaAlSi3O8
CLINOPTILOLITE
Na2Al2Si10O24·8H2O
(ESTIMATED)



Major zeolite distributions (Bish and Vaniman. 1985). center to southeast cross section



W5'
M4
M2
W7
m
W4
W3
W6'
W5
M1
W2
M3
m
W1
W6
b
A
B
a'

EXPERIMENTAL STUDIES ON ZEOLITES

---

1. ION EXCHANGE EQUILIBRIA

a. Ion Exchange Kinetics
b. Ion Exchange Capacity
c. Ion Exchange Selectivity

Development of chemical models for predicting zeolite ion exchange equilibria in complex systems.

2. PHASE EQUILIBRIA AND MINERAL STABILITIES

a. Gibbs Free Energies
b. Enthalpies
c. Heat Capacities

To be used as input parameters in geochemical modeling. Development of solid solution thermodynamic properties using ion exchange data.

EXCHANGE REACTION:

$$z_B A^{z_A+} + z_A \overline{B}^{z_B+} \Leftrightarrow z_B \overline{A}^{z_A+} + z_A B^{z_B+}$$

EQUILIBRIUM CONSTANT:

$$K_a = A_c^{z_B} f_A^{z_B} m_B^{z_A} \gamma_B^{z_A} / B_c^{z_A} f_B^{z_A} m_A^{z_B} \gamma_A^{z_B}$$

Using the Gibbs-Duhem relation, the zeolite phase activity coefficients are derived as:

$$\ln f_A^{z_B} = (z_B - z_A)B_c - \ln K_{c(A_c)} + A_c \ln K_{c(A_c)} + \int_{A_c}^{1} \ln K_c \, d\, A_c$$

$$\ln f_B^{z_A} = -(z_B - z_A)A_c + A_c \ln K_{c(A_c)} - \int_{0}^{A_c} \ln K_c \, d\, A_c$$

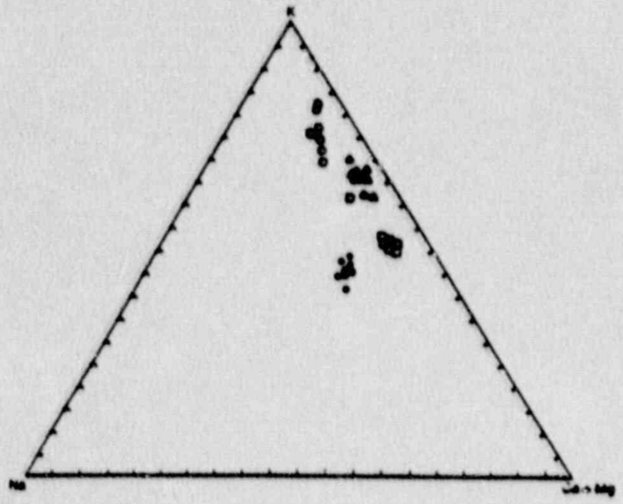
VARIABLES

---

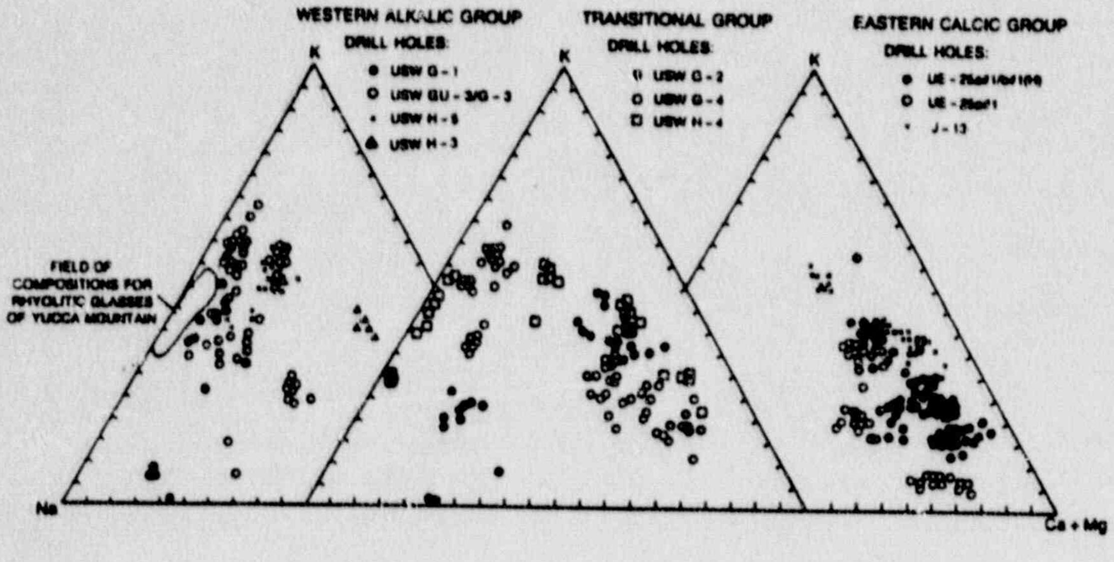
1. TEMPERATURE
2. MINERAL COMPOSITION
3. GROUNDWATER CHEMISTRY
    - a. pH
    - b. Eh
    - c. Composition
    - d. Ionic Strength

SORPTION PROCESSES:

1. ADSORPTION
    a. Physisorption
    b. Chemisorption
2. ION EXCHANGE
3. PRECIPITATION



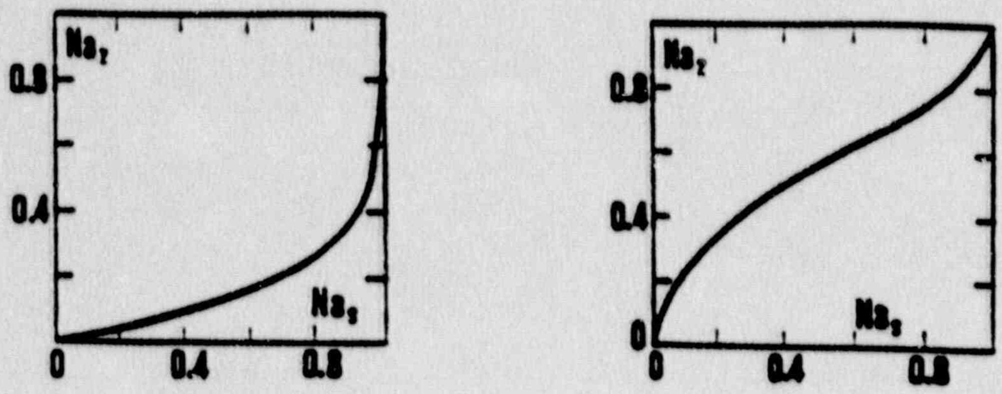
Triangular diagram showing relative alkali and alkaline-earth contents for clinoptilolites in the tuff of Calico Hills at Prow Pass, northern Yucca Mountain.



Triangular diagrams showing relative alkali and alkaline-earth contents for clinoptilolites of diagenetic Zones II and III, Yucca Mountain, Nevada. Broxton et al. (1986)

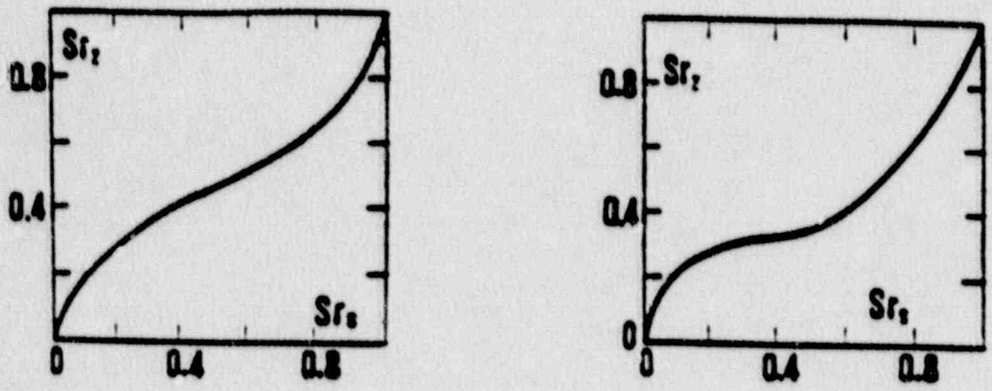
Selectivity sequence for clinoptilolite (Ames, 1960):

Cs > K > Sr > Na > Ca > Mg



Na ⇔ K

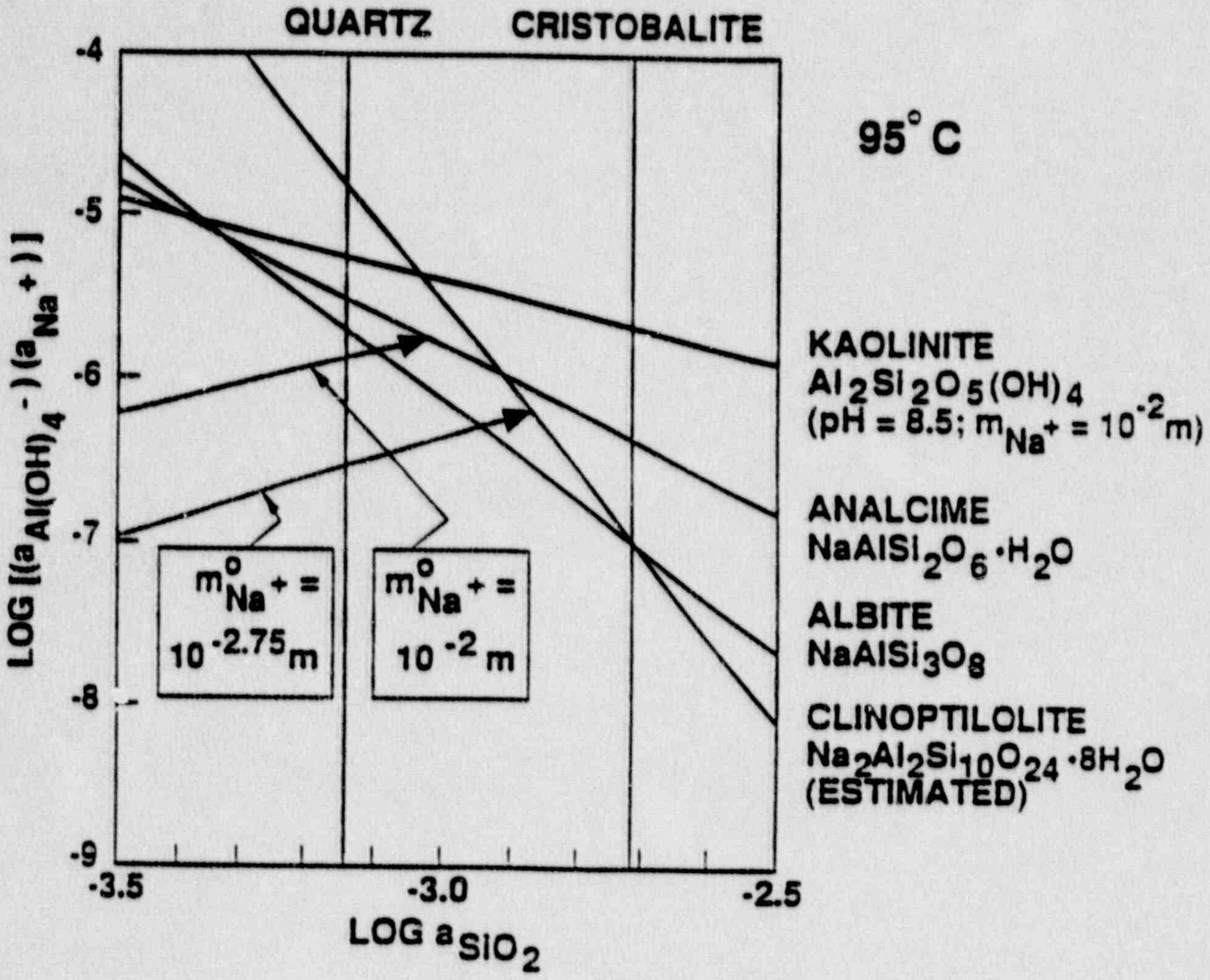
Na ⇔ Ca



Na ⇔ Sr

Ca ⇔ Sr

Ion exchange isotherms of clinoptilolite (Ames, 1964 a,b)



$$Na_2Al_2Si_{10}O_{24} \cdot 8H_2O \Leftrightarrow 2\,NaAlSi_2O_6 \cdot H_2O + 6\,SiO_2 + 6\,H_2O$$

Na-clinoptilolite analcime aqueous silica

GEOCHEMICAL ANALOG OF CONTAMINANT TRANSPORT IN UNSATURATED ROCK RESEARCH PROJECT, FIN B6673

NRC Project Manager: Linda A. Kovach

CENTER FOR NUCLEAR WASTE
REGULATORY ANALYSES

SOUTHWEST RESEARCH INSTITUTE
San Antonio, Texas

Project Manager: John L. Russell

Investigators:
William Murphy, Roberto Pabalan, Ron Green

November 30, 1989

GEOCHEMICAL ANALOGS RESEARCH PROJECT

OBJECTIVES

- Review the state of the art in natural analog studies applied to contaminant transport

- Participate in a workshop on the use of natural analogs

- Establish criteria for selection of a natural analog study site and select a site

- Develop research and data collection techniques and collect site data

- Discover key contaminant transport processes in the analog site

- Identify and/or develop contaminant transport modeling capabilities and model the site system to simulate transport processes

- Apply the results of field and modeling research to understand and predict the processes and evolution at Yucca Mountain

- Validate unsaturated transport modeling

GEOCHEMICAL ANALOGS RESEARCH PROJECT

TASKS

- LITERATURE REVIEW AND WORKSHOP
- IDENTIFICATION OF SITE AND DEVELOPMENT OF WORK PLAN
- DEVELOPMENT OF METHODOLOGY AND DATA ACQUISITION
- INTERPRETATION OF DATA AND MODELING

GEOCHEMICAL ANALOGS

OKLO, GABON

Natural fission reactor 2 billion years old

Limited migration of actinides, rare earths, and transition metals

Hydrologically saturated, chemically reducing

PENA BLANCA, MEXICO

Uranium mineralized area in fractured welded tuff

Unsaturated environment

Underlain by zeolitized tuff

SANTORINI, GREECE

Archeological horizon buried by silicic ash fall, 3600 years old

Unsaturated environment, semi-arid climate, initial thermal pulse

Well constrained initial and boundary conditions for contaminant transport

INTEGRATED WASTE PACKAGE EXPERIMENTS

NOVEMBER 30, 1989

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

Project Staff:
- Dr. Prasad K. Nair
- Dr. Narasi Sridhar
- Dr. Gustavo Cragnolino*
- Dr. Hersh K. Manaktala
- Mr. Fred F. Lyle, Jr.
- Dr. Bryan E. Wilde

*To join staff shortly

IWPE PROJECT OVERVIEW

PROGRAMMATIC BACKGROUND

- Regulatory Framework
- Implications of Regulations to Waste Package Performance
- Integrated Waste Package Experiment Project Approach
  - Uncertainty Reduction Concepts
  - Controlled Test Environments
  - Stepwise Testing Strategy
  - Baseline Evaluations
  - Reference Material – Hastelloy C-22

TECHNICAL SCOPE

- Specific Objectives
- Technical Program
- Technical Approach

REGULATORY FRAMEWORK

10CFR60.113(a)(ii)

Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 60.113(b), provided that such period shall be not less than 300 years nor more than 1000 years after permanent closure of the geologic repository;

10CFR60.21(c)(1)(ii)(D)

. . . The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to waste isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

STEPWISE TESTING STRATEGY

- Scoping Tests
  - Literature Assessment
  - Other NRC/DOE Programs
  - Select Tests

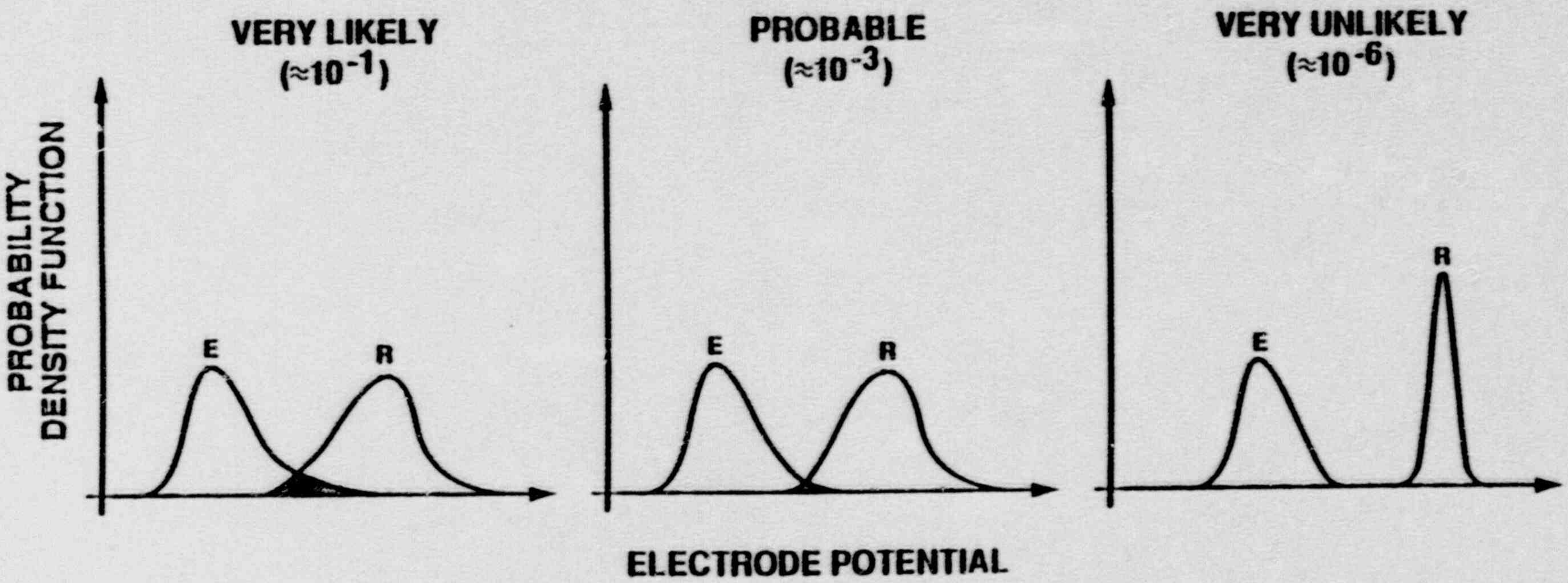
- Short Term
  - Uncertainty Reduction Need Based
  - Baseline Tests
  - Performance Assessment and Statistically Valid Tests

- Long Term
  - Performance Confirmatory Tests

CONTROLLED TEST ENVIRONMENTS

Constituents (Molal)	Field		EQ3/EQ6 Calculated				
	Yucca Mountain Vicinity	J_{13}	EQ3 25°C	EQ3 70°C	EQ3 95°C	EQ3 25°C Magnetite	EQ6 25°C Fe
Na^+	6.1×10^{-4} to 1.4×10^{-2}	2.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
Cl^-	2.0×10^{-5} to 3.2×10^{-3}	1.8×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}
HCO_3^-		2.7×10^{-3}	1.7×10^{-3}	1.5×10^{-3}	1.3×10^{-3}	1.7×10^{-3}	1.7×10^{-3}
fCO_2	$10^{-3.5}$ – $10^{-0.8}$	$10^{-1.8}$	$10^{-3.5}$	$10^{-3.5}$	$10^{-3.5}$	$10^{-3.5}$	$10^{-3.5}$
fO_2		Oxidizing	0.2 (bar)	0.2 (bar)	0.2 (bar)	0.2 (bar)	0.2 (bar)
pH	6.6 to 9.1	6.9	8.5	8.8	8.9	8.5	8.5

EXAMPLES OF PROBABILISTIC PERFORMANCE ASSESSMENT



PROJECT OBJECTIVES

- TO ASSESS THE STATE OF KNOWLEDE FOR CORROSION AND OTHER POTENTIAL WASTE PACKAGE MATERIALS DEGRADATION PROCESSES IN THE YUCCA MOUNTAIN PROJECT (YMP) TUFF ENVIRONMENT AND THE METHODOLOGIES USED TO PREDICT LONG-TERM MATERIALS PERFORMANCE

- TO CONDUCT EXPERIMENTAL PROGRAMS TO IDENTIFY AND UNDERSTAND KEY FACTORS AFFECTING LONG-TERM MATERIALS PERFORMANCE

- TO ASSESS EXPERIMENTALLY YMP SELECTED MATERIALS AND DESIGNS AND PROVIDE INDEPENDENT EVALUATION TO ASSURE LONG-TERM PERFORMANCE

- TO FACILITATE TECHNICAL INTEGRATION SUPPORT IN THE AREA OF WASTE PACKAGE PERFORMANCE

TECHNICAL PROJECT PLAN

TASK 1: ASSESS STATE OF KNOWLEDGE

- DEVELOP INFORMATION/DATA BASE – YMP REPORTS; NRC REPORTS AND ONGOING WORK OF OTHER NRC CONTRACTORS; OPEN LITERATURE; OTHER COUNTRIES; AND CNWRA EXPERIENCE
- EVALUATE TECHNOLOGY WITH RESPECT TO YMP CURRENT WASTE PACKAGE PLANS

MAJOR TOPICAL AREAS

- DEFINITION OF REPOSITORY ENVIRONMENTS
- ENGINEERING MODELS FOR PERFORMANCE PREDICTION
- CORROSION OF CONTAINER MATERIALS IN REPOSITORY ENVIRONMENTS
- METALLURGICAL STABILITY
- OTHER FAILURE MODES – e.g., HYDROGEN ATTACK, MICROBIOLOGICAL ACTION, AND FAILURE OF CONTAINER CLOSURES

TECHNICAL APPROACH

TASK 2: EXPERIMENTAL PROGRAMS

OBJECTIVES

- DETERMINE FORMS OF CORROSION AND OTHER TYPES OF MATERIALS DEGRADATION
- DEVELOP KINETICS DATA FOR CORROSION AND OTHER DEGRADATION MECHANISMS
- IDENTIFY AND EVALUATE EFFECTS OF METALLURGICAL CHANGES THAT CAN OCCUR AS A RESULT OF FABRICATION HISTORY, THERMAL HISTORY, STRESS AND STRAIN, EXPOSURE TIME, AND ENVIRONMENTAL EXPOSURE
- DEVELOP DATA FOR PREDICTIVE MODELS

TEST MATERIALS

METALLIC ALLOYS PROPOSED IN YMP SITE CHARACTERIZATION PLAN (SCP)

- TYPE 304L STAINLESS STEEL (REFERENCE ALLOY)
- TYPE 316L STAINLESS STEEL
- INCOLOY 825
- COPPER ALLOY CDA 102 (OXYGEN-FREE, HIGH-CONDUCTIVITY COPPER)
- COPPER ALLOY CDA 613 (7-8% ALUMINUM BRONZE)
- COPPER ALLOY 715 (70% COPPER-30% NICKEL)

ADDITIONAL CNWRA REFERENCE MATERIAL

- HASTELLOY C-22

EXPERIMENTAL PROGRAMS

PROGRAM STRUCTURE

- *SCOPING AND SCREENING TESTS*
  - *ELECTROCHEMICAL CHARACTERIZATION* OF MATERIALS IN REPOSITORY ENVIRONMENTS, INCLUDING EFFECTS OF GAMMA RADIATION
  - *SLOW-STRAIN-RATE SCC TESTS*
  - OTHER TYPES OF TESTS, AS NECESSARY
- SHORT-TERM TESTS (3 TO 12 MONTHS)
- LONG-TERM TESTS (12 MONTHS TO 3 YEARS OR LONGER)
- DEVELOP PREDICTIVE MODELS THROUGH DATA ANALYSES
- *STUDY HYDROGEN EFFECT*
- STUDY WELDING (OR OTHER CLOSURE) EFFECTS
- EVALUATE METALLURGICAL STABILITY OF MATERIALS

TASK 3: ASSESS YMP RECOMMENDED WASTE PACKAGE

- EVALUATE ADEQUACY OF CORROSION AND METALLURGICAL STABILITY MODELING
- PERFORM SMALL-SCALE CONFIRMATORY TESTING
- EVALUATE NEED FOR LARGE-SCALE TESTS AND DEFINE TESTS, IF NEEDED

PROVIDE GENERAL SUPPORT AND COORDINATION

- COORDINATE CNWRA PROGRAM WITH OTHER ONGOING NRC-SPONSORED WASTE PACKAGE RESEARCH PROGRAMS
- PREPARE TECHNICAL REPORTS AND PUBLICATIONS

PEER REVIEW

- STAFF PRESENTATIONS HELD ON JULY 27, 1989
- SIGNIFICANT REVIEW COMMENTS
  - DETERMINE LIMITATIONS AND SUITABILITY OF CURRENT TEST METHODS
  - DEVELOP NEW METHODS – WORKSHOP
  - INVESTIGATE EFFECTS OF GASEOUS ENVIRONMENTS
  - CHECK FOR HEAT-TO-HEAT VARIATIONS IN MATERIALS
  - DEVELOP PREDICTION METHODOLOGY, i.e., USE OF SHORT-TERM DATA FOR LONG-TERM PREDICTION
  - INVESTIGATE INTERNAL CANISTER CORROSION
  - STUDY EFFECTS OF CORROSION PRODUCTS
- SUMMARY AND ANALYSIS OF REVIEW COMMENTS UNDER PREPARATION

ACTIVITIES AND ACCOMPLISHMENTS

- PERFORMED REVIEWS OF TECHNICAL DATA FROM NRC AND DOE PROGRAMS
- CONDUCTED EXPERIMENTAL STUDIES ON THE PREPARATION OF SYNTHETIC J-13 WATER
- CONDUCTED PRELIMINARY SCREENING ELECTROCHEMICAL TESTS
  - 304L
  - 316L
  - 825

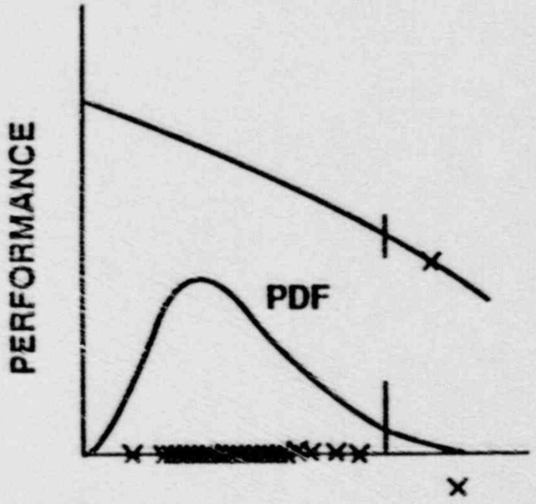
  SYNTHETIC J-13
  &
  CONCENTRATIONS
- COMPLETED TEST METHOD DEVELOPMENT FOR HYDROGEN RELATED STUDIES
- CONDUCTED A PEER REVIEW OF THE IWPE PLAN
- PARTICIPATED IN TECHNICAL EXCHANGE MEETINGS WITH DOE

FAST PROBABILISTIC PERFORMANCE ASSESSMENT (FPPA)

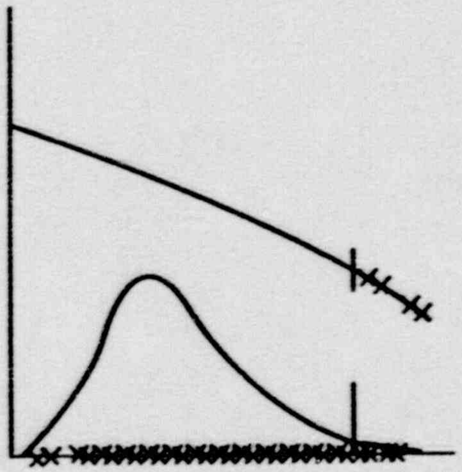
- BASED ON RELIABILITY ANALYSIS METHODS CURRENTLY APPLIED TO STRUCTURAL SYSTEMS
  - USES SENSITIVITY DATA AND GENERATES PROBABILITY SENSITIVITY FACTORS
  - NEW TECHNOLOGY FINDING WIDE ACCEPTANCE IN DIVERSE INDUSTRIES (OFFSHORE, CIVIL, AEROSPACE)
- MOST SUITABLE FOR IMPLICIT FUNCTIONS
  - STATE-OF-THE-ART TECHNOLOGY
  - ACCURACY DEMONSTRATED
  - SEVERAL ORDERS OF MAGNITUDE FASTER THAN THE CONVENTIONAL MONTE CARLO APPROACH
  - APPLICABLE TO WASTE PACKAGE PERFORMANCE ASSESSMENT

ILLUSTRATIONS OF PROBABILISTIC METHODOLOGIES

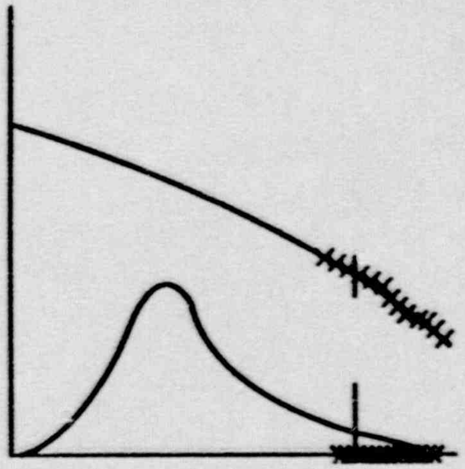
STANDARD MONTE CARLO
(Fewer Samples In Tails)



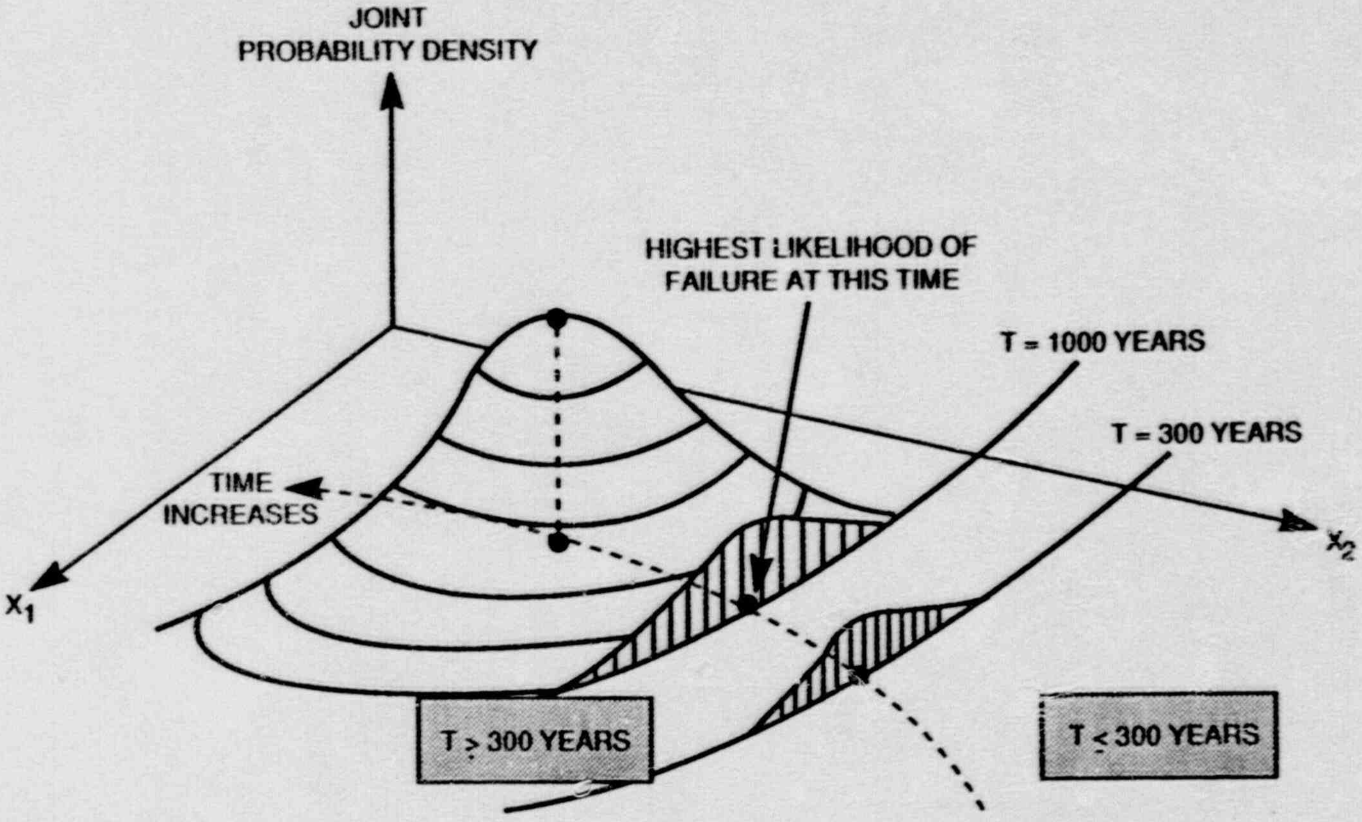
LATIN HYPERCUBE SAMPLING
(Samples More Evenly Spaced)



FPPA
(Samples In Tail Regions Only)



FPPA CONCEPT



FPPA
ADVANCED MEAN VALUE METHOD

- CONVENTIONAL MEAN VALUE FIRST-ORDER (MVFO) METHOD
  - First-Order Taylor's series expansion at mean values:

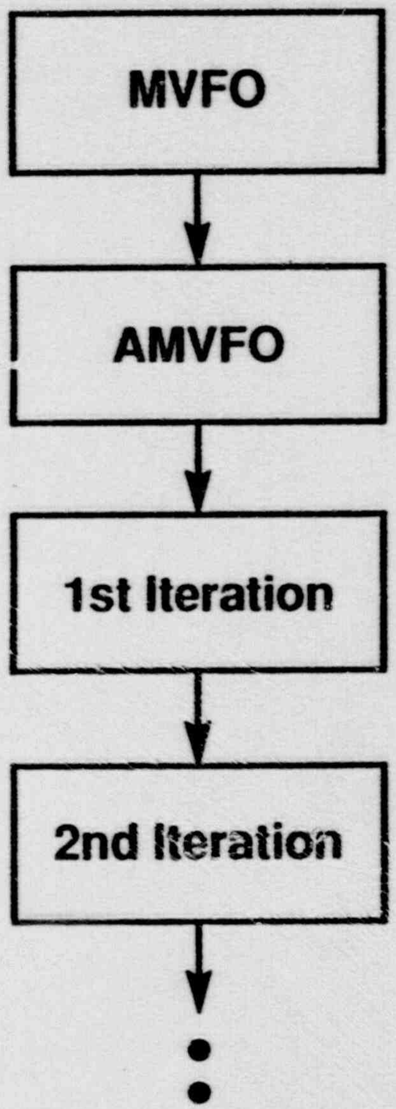
$$Z = a_o + \sum a_i X_i (\equiv Z_1)$$

- ADVANCED MEAN VALUE FIRST-ORDER METHOD
- Basis: Most-Probable-Point-Locus concept (1987)

$$Z = Z_1 + H(Z_1)$$

- Features:
  - H (Z_1) defined to miniize truncation error.
  - No iterations.
- Limitation: One dominant Most-Probable-Point for each Z_1.

AMV-BASED ITERATION PROCEDURE


MVFO

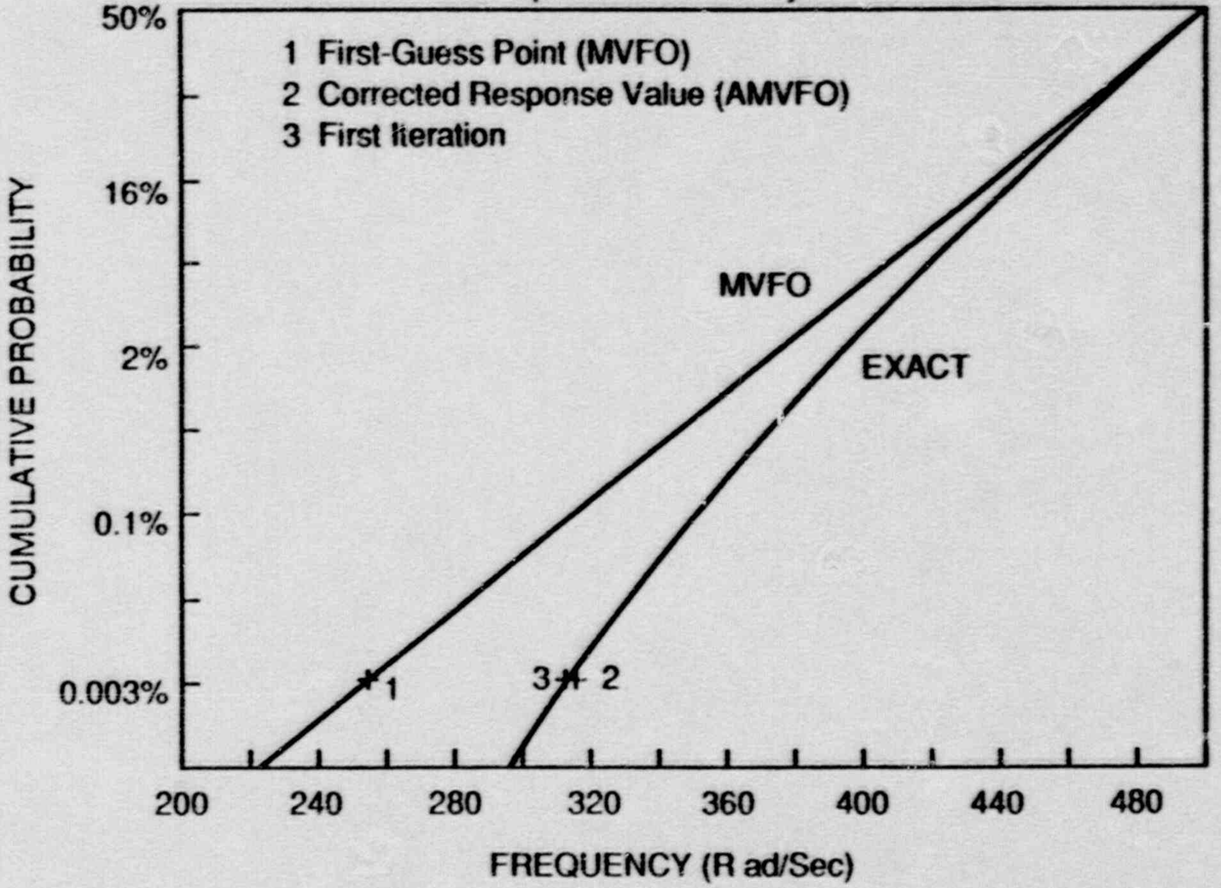
AMVFO

1st Iteration

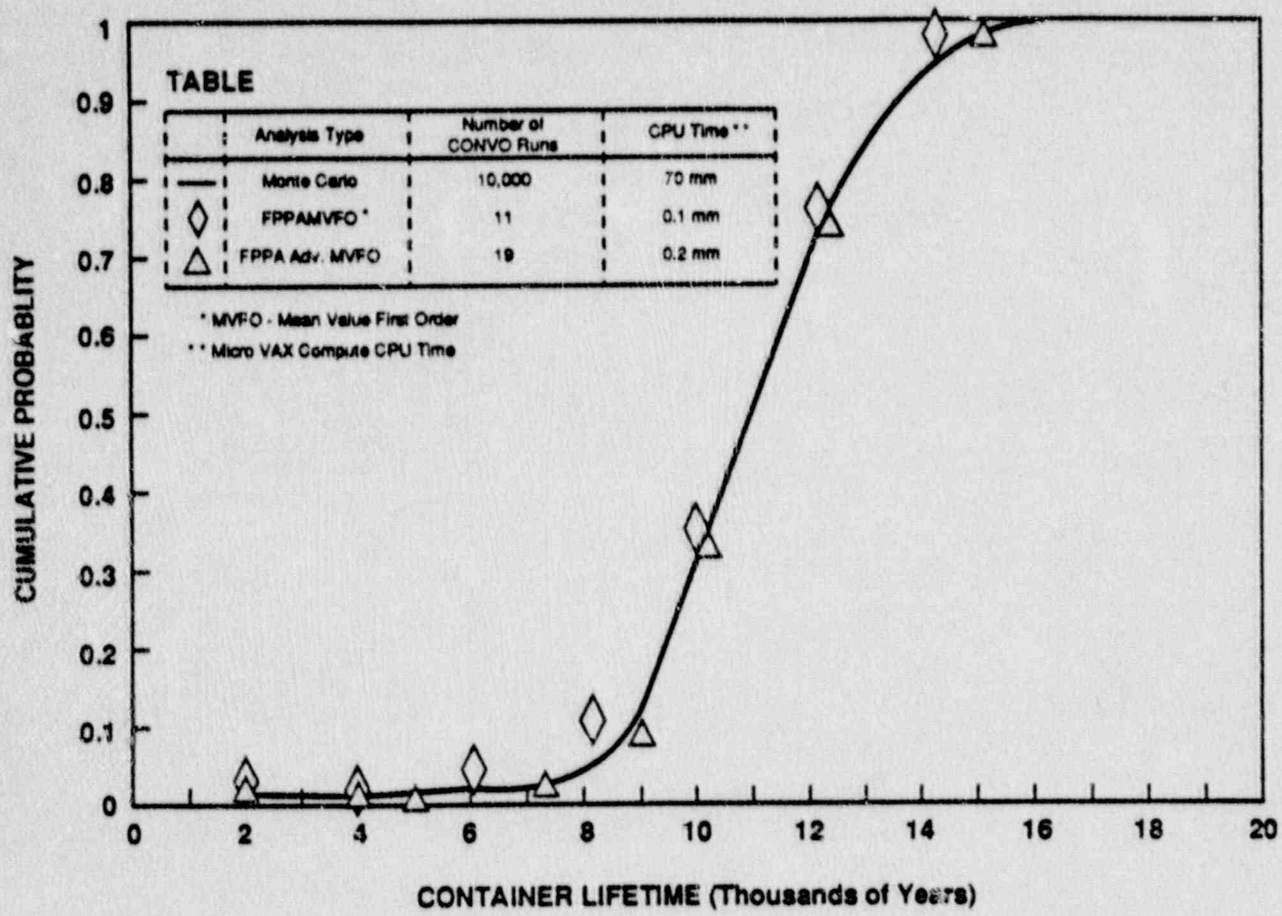
2nd Iteration

ITERATION ALGORITHM I

For Specified Probability Level



THE COMPARISONS OF THE FAST PROBABILISTIC PERFORMANCE ASSESSMENT (FPPA) METHOD WITH THE MONTE CARLO SIMULATION METHOD



TABLE

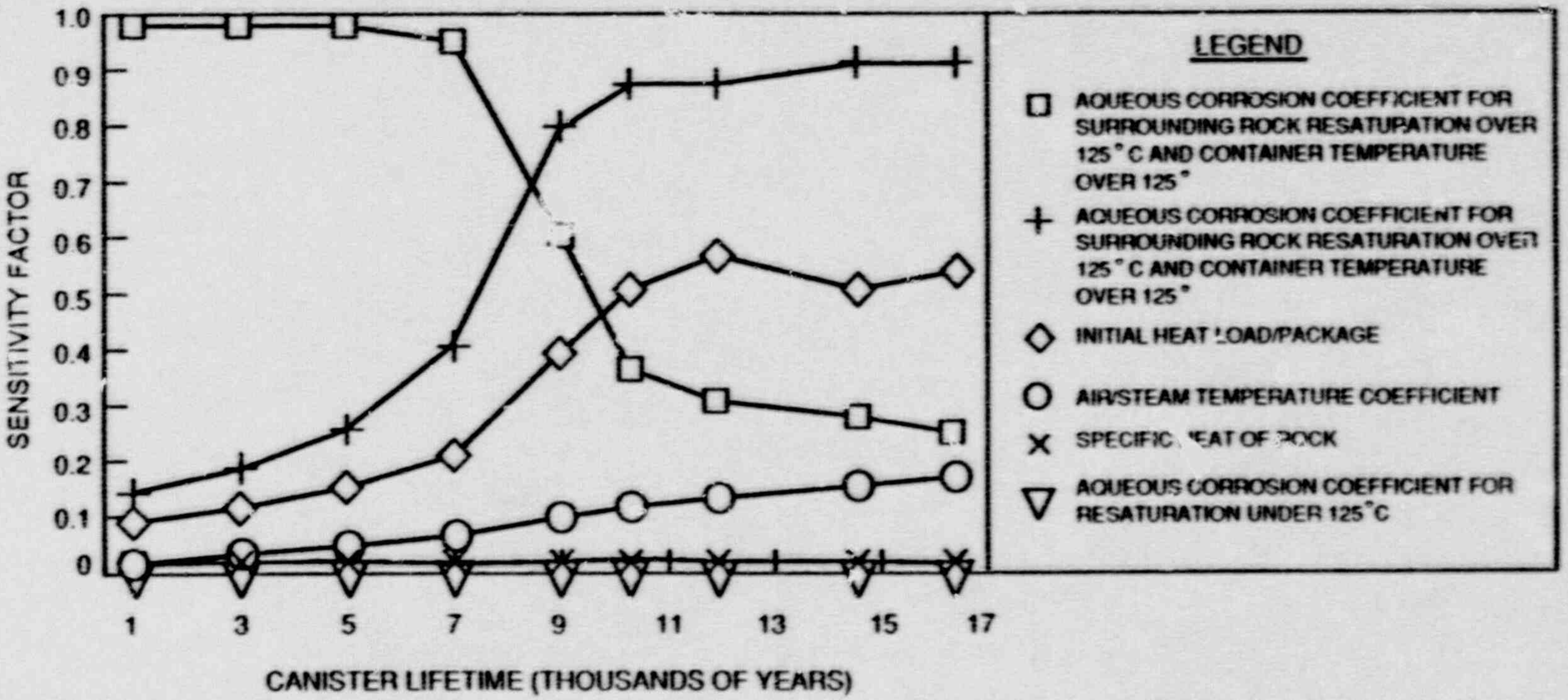
	Analysis Type	Number of CONVO Runs	CPU Time **
—	Monte Carlo	10,000	70 mm
◇	FPPAMVFO *	11	0.1 mm
△	FPPA Adv. MVFO	19	0.2 mm

* MVFO - Mean Value First Order

** Micro VAX Compute CPU Time

VARIABLE	MEAN	STD DEV.	DISTRIBUTION
Thermal conductivity (W/m-°C)	1.51	0.152	Normal
Density of Rock (kg/m3)	2800.	100.	Normal
Specific Heat (J/kg-°C)	929.0	14.49	Normal
Initial heat load package (W)	1448^{d}	2276^{d}	Uniform
Air/stream corrosion coef. (mm/yr)	2.33	1.35	Lognormal
Air/stream time exponent	0.25	0.05	Normal
Air/stream temp. coef. (°K)	1778.	290.0	Normal
$A_{q1}{}^{a}$ (mm/yr)	0.00306	0.00504	Lognormal
$A_{q2}{}^{b}$ (mm/yr)	0.00738	0.00122	Lognormal
$A_{q3}{}^{c}$ (mm/yr)	0.02842	0.00468	Lognormal

FPPA SENSITIVITY EVALUATION



SEISMIC ROCK MECHANICS RESEARCH PROJECT

CENTER FOR NUCLEAR WASTE
REGULATORY ANALYSES

SOUTHWEST RESEARCH INSTITUTE
San Antonio, Texas

Project Manager: Asadul H. Chowdhury

Principal Investigators

Simon M. Hsiung
Barry H. G. Brady
Daniel D. Kana
Asadul H. Chowdhury

SEISMIC ROCK MECHANICS RESEARCH PROJECT

REGULATORY BASIS

(1) 10CFR60.111(b)(1) – Retrievability of Waste

(2) 10CFR60.112 – Overall System Performance Objective for the Geologic Repository after Permanent Closure

(3) 10CFR60.113(a)(1)(ii)(A) – Containment of HLW within the Waste Packages for a Period Between 300 and 1000 Years after Permanent Closure

(4) 10CFR60.131(b)(1) – Protection Against Natural Phenomena and Environmental Conditions

(5) 10CFR60.133(c) – Retrieval of Waste

(1) 10CFR60.133(e)* – Underground Openings

PURPOSE, GOALS, AND GENERAL OBJECTIVES

(1) To obtain an understanding of the important parameters associated with the response of the shaft liners and the underground repository structures in tuff due to seismic motion. This objective supports the requirements in 10CFR60 for repository design, safe operations, waste retrievability and integrity of the engineered barriers.

(2) To obtain an understanding of joint dynamic responses and important parameters associated with the responses due to seismic motion. This objective supports the postclosure performance requirements in 10CFR60 under seismic loading.

(3) To develop methodologies to evaluate, validate, and reduce uncertainties in the prediction models used in seismic assessment of tuff media. This objective is directed toward decreasing the uncertainties in repository design input conditions.

SEISMIC ROCK MECHANICS RESEARCH PROJECT

- Task 1 – Focused Literature Search
- Task 2 – Laboratory Characterization of Jointed Rock
- Task 3 – Assessment of Analytical Models/ Computer Codes
- Task 4 – Rock Dynamics Laboratory and Field Studies and Code Validation
- Task 5 – Groundwater Hydrology Field Studies and Code Validation
- Task 6 – Yucca Mountain Scoping Analysis
- Task 7 – Technical Report

PROJECT ACCOMPLISHMENT/STATUS

- FOCUSED LITERATURE SEARCH Complete
  - Submission of Task Report to NRC, for Publication as NUREG, June 29, 1989
  - Presentation of a paper "An Assessment of Dynamic Response Prediction for a High-Level Nuclear Waste Underground Repository" at 10th SMIRT Conference, Anaheim, CA, August 1989

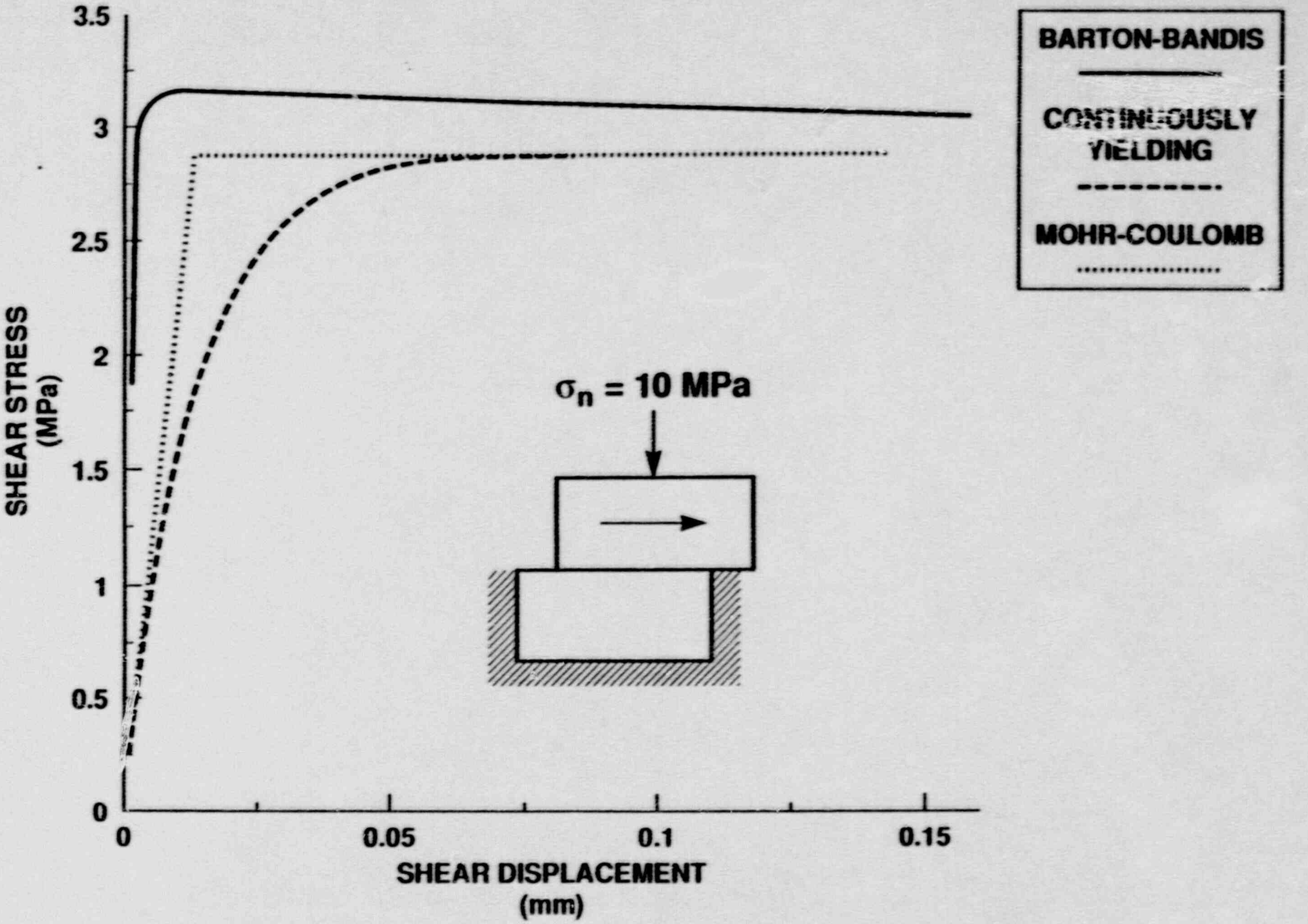
- QUALIFICATION OF ANALYTICAL MODELS/ COMPUTER CODES
- VALIDATION OF ANALYTICAL MODELS/ COMPUTER CODES

Distinct Element: UDEC, 3DEC

Discrete Element: DECICE

Finite Element: HONDO, SPECTROM-331

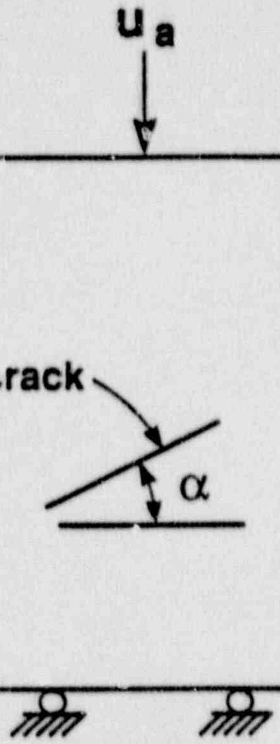
Boundary Element: BEST3D


SHEAR STRESS (MPa)
3.5
3
2.5
2
1.5
1
0.5
0
0
0.05
0.1
0.15
SHEAR DISPLACEMENT (mm)
BARTON-BANDIS
CONTINUOUSLY YIELDING
MOHR-COULOMB
σ_n = 10 MPa

- **VALIDATION**
  - Experimental Seismic Response of Jointed Rock Mass
  - NTS Shock Response of Underground Structures
  - Instrumented Field Studies for Seismic Response of Underground Structures
  - Instrumented Field Studies for Seismic Response of Groundwater

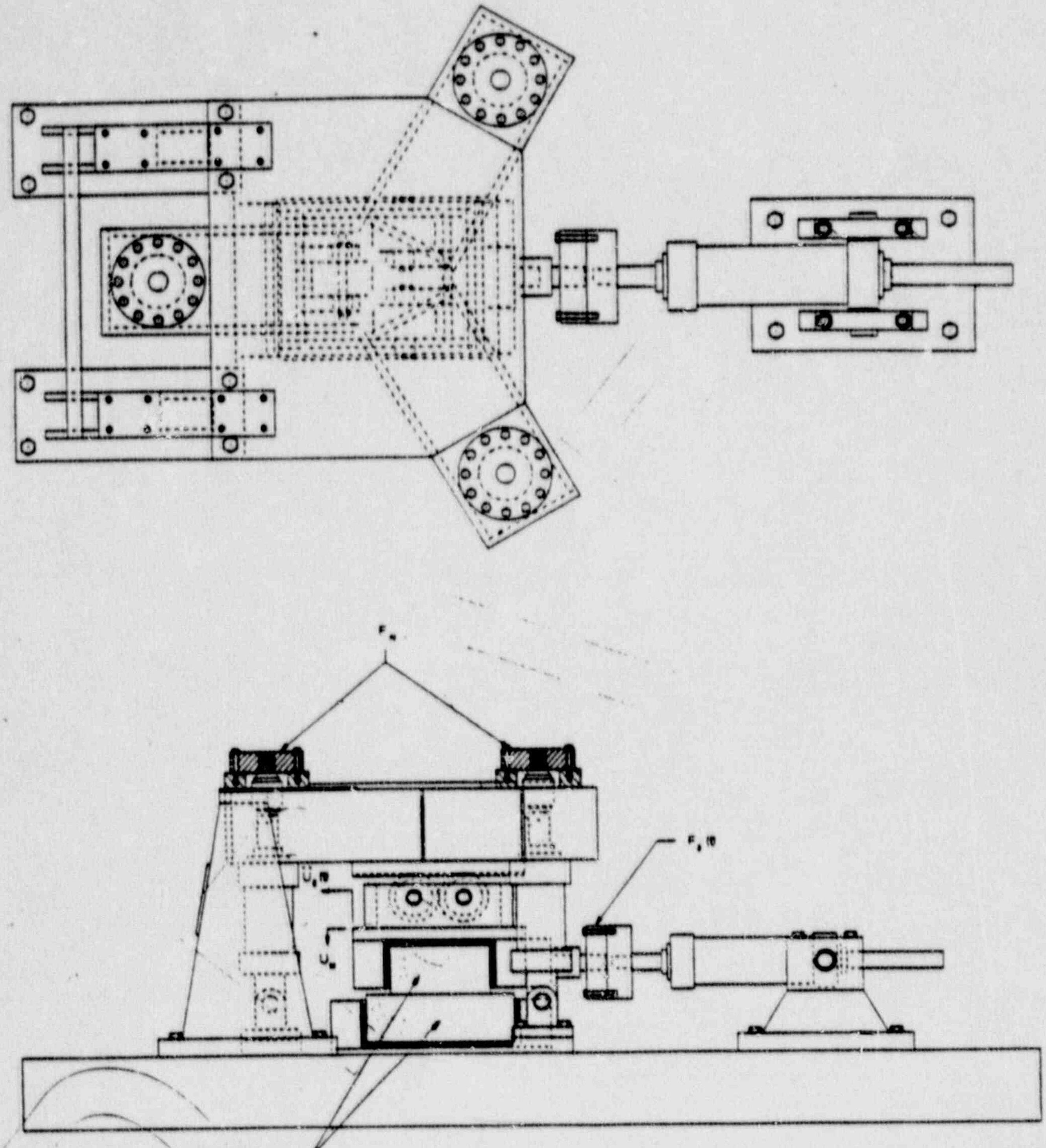
- **QUALIFICATION**
  - Closed-Form Solutions
  - Experimental Dynamic Response of Single Joint Tuff Specimens
    - Harmonic
    - Shock
    - Earthquake

CYCLIC LOADING OF A SPECIMEN WITH A SLIPPING CRACK



Specimen with Embedded Crack

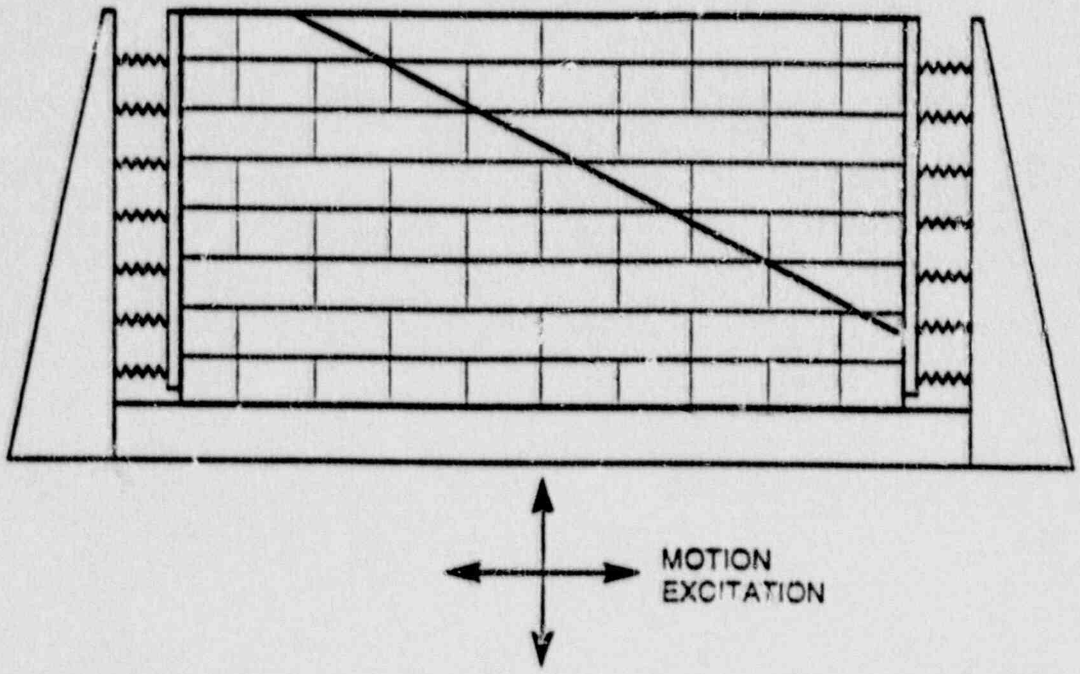
	Conceptual Model	Coulomb Model		Continuously-Yielding Model		Barton-Bandis Model	
Loading Segment	Stiffness (GPa/m)	Stiffness (GPa/m)	Error (%)	Stiffness (GPa/m)	Error (%)	Stiffness (GPa/m)	Error (%)
Load (OA)	36.34	36.04	0.82	36.11	0.65	35.31	2.8
Unload (AB)	38.89	38.91	-0.05	38.77	0.31	38.77	0.31
Unload (BO)	34.52	34.14	1.1	34.18	0.98	33.8	2.1



Loading Apparatus for Dynamic Joint Normal and Shear Tests

SAMPLE SIMILITUDE REQUIREMENTS

Variable Identification	Variable Ratio	Numerical Ratio
Gravity	g_m/g_p	1.0
Block Geometry	D_m/D_p	$1/\lambda$
Rock Density	ρ_m/ρ_p	$1/\alpha$
Structure Stiffness	$(EI)_m/(EI)_p$	$1/\alpha\lambda^5$
Position Coordinate	y_m/y_p	$1/\lambda$
Response Deflection	x_m/x_p	$1/\lambda$
Structure Mass/Length	M_{pm}/M_{pp}	$1/\alpha\lambda^2$
Rock Elastic Modulus	E_{rm}/E_{rp}	$1/\alpha\lambda$
Rock Loss Modulus	$E_{\ell m}/E_{\ell p}$	$1/\alpha\lambda$
Frequency	ω_m^2/ω_p^2	λ
Time Duration	$T_o{}^2{}_m/T_o{}^2{}_p$	$1/\lambda$
Lateral Force Amplitude	F_m/F_p	$1/\alpha\lambda^3$
Ground Acceleration	A_m/A_p	1.0
Ground Velocity	$\upsilon_m^2/\upsilon_p^2$	$1/\lambda$
Ground Displacement	X_{gm}/X_{gp}	$1/\lambda$
Fluid Properties	*(To be determined)*	



Experiments with Scale-Model Faulted Rock Mass Segment

STOCHASTIC ANALYSIS OF LARGE SCALE FLOW AND TRANSPORT IN UNSATURATED FRACTURED ROCK

RESEARCH PROJECT
FIN B6664

NRC Project Manager: T.J. Nicholson

CENTER FOR NUCLEAR WASTE
REGULATORY ANALYSES

SOUTHWEST RESEARCH INSTITUTE
San Antonio, Texas

Project Manager: John L. Russell

Principal Investigator: Rachid Ababou

November 30, 1989

STOCHASTIC RESEARCH PROJECT

REGULATORY ISSUES

- **REGULATORY BASIS:**

10 CFR 60.113.a.2

"The geologic repository shall be located so that the pre-waste-emplacement groundwater travel time along the **fastest path** of **likely** radionuclide travel from the distributed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved of specified by the Commission."

- **QUESTIONS:**

  - Probabilistic Terminology (how "**likely**"?):
    Needs Probability Distribution of Travel Times in Relation to Formation Heterogeneity

  - Worst Case Terminology ("**fastest path**"):
    Needs Refinements and Comparison with Alternative Probabilistic Criteria (Permissible Radionuclide Flux to Environment, Spatially Averaged Flux, Cumulated Flux).

STOCHASTIC RESEARCH PROJECT

OBJECTIVES

- DATA REVIEW AND MODELING APPROACHES
- INVESTIGATION OF SUBMODELS AND SEPARATE EFFECTS
- LARGE SCALE SIMULATION AND ANALYSIS

STOCHASTIC RESEARCH PROJECT

OBJECTIVES

- DATA REVIEW AND MODELING APPROACHES
  - Literature Review of Hydrodynamic Data and Flow/Transport Models
  - Development of Alternative Stochastic Approach
- SUBMODELS AND SEPARATE EFFECTS
  - Single Fracture Submodel
  - Conditional Generation of Randomly Heterogeneous Properties
  - Separate Effects: Climatic Fluctuations and Extreme Events in Unsaturated Formations
  - Numerical Issues and Supercomputer Applications
- LARGE SCALE SIMULATION AND ANALYSIS
  - Assembly of Submodels
  - Supercomputer Simulations of Unsaturated Flow and Transport over Large Space-Time Scales with Detailed Heterogeneity Conditioned on Data.
  - Spatial and Statistical Analysis of Flow Field and Contaminant Plume, 3D Graphics and Interpretation.

3D INFILTRATION IN RANDOM STRATIFIED SOIL :

T = 10 days

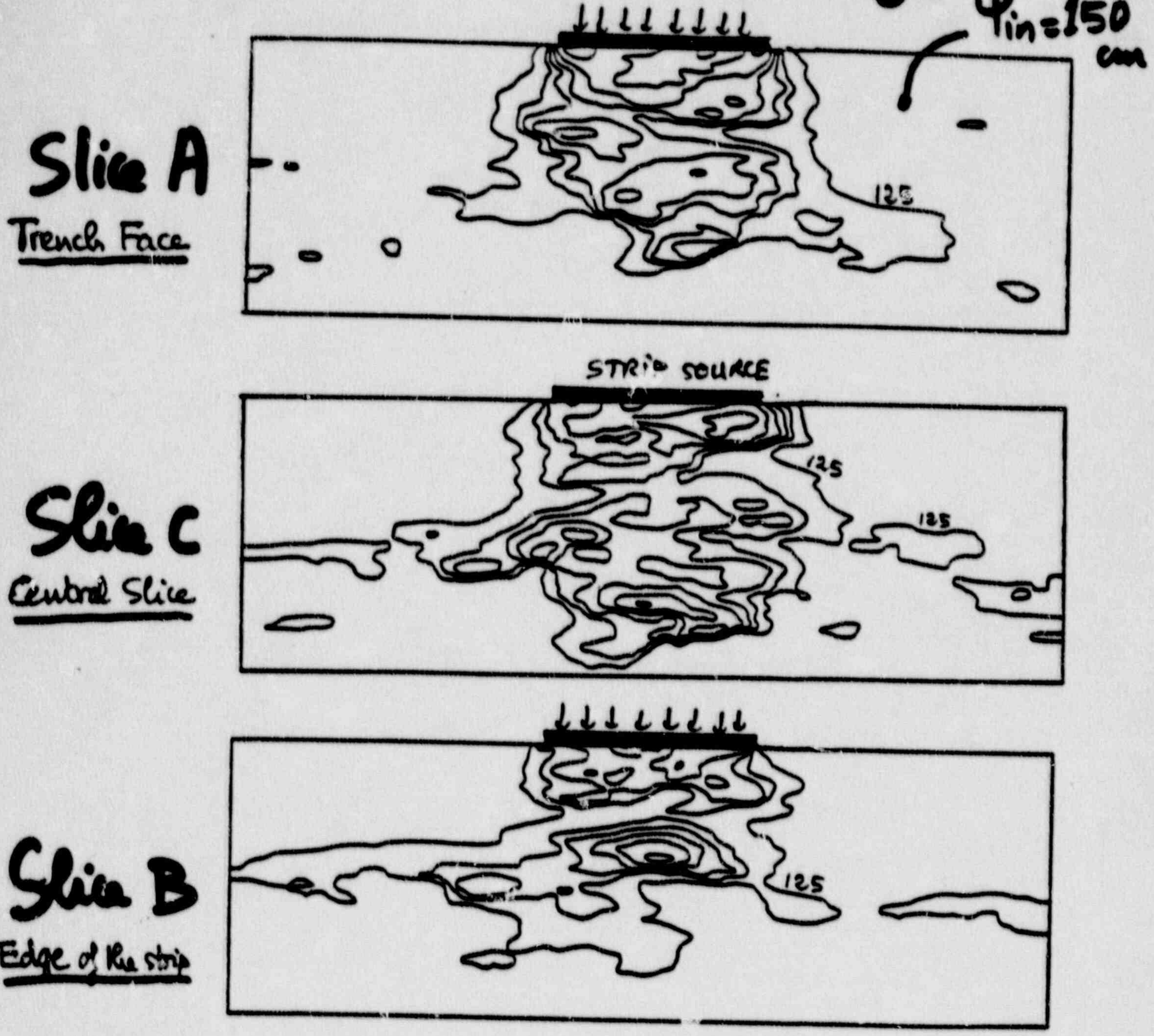


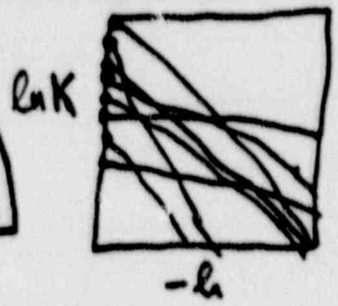
Figure 7.12 Contour lines of pressure head in three vertical-transverse slices during the simulated strip-source experiment after 10 days of infiltration (t = 10 days). From top to bottom: slices Y = 2m, Y = 4.8m, Y = 9.8m.

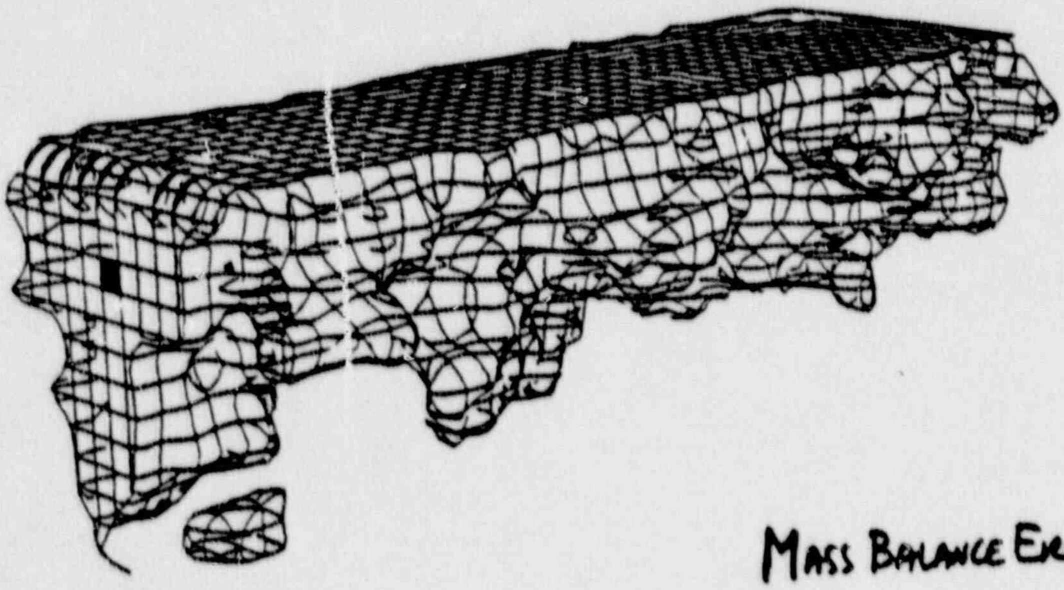
THREE VERTICAL-TRANSVERSE SLICES AT FIXED TIME

3D VIEW OF PRESSURE HEAD SURFACE CONTOUR

③ K_s RANDOM, α RANDOM, (K_s, α) UNCORRELATED

INFILTRATION FROM A SURFACE STRIP SOURCE: 3D random soil without stratification





Mass Balance Error ≤ 1%

Unsaturated flow equation (NONLINEAR):

$$\frac{\partial}{\partial t}\theta(h,\underline{x}) = \frac{\partial}{\partial x_i}\left[K(h,\underline{x})\cdot\left(\frac{\partial h}{\partial x_i}+g_i\right)\right]$$

NONLINEAR

NONLINEAR

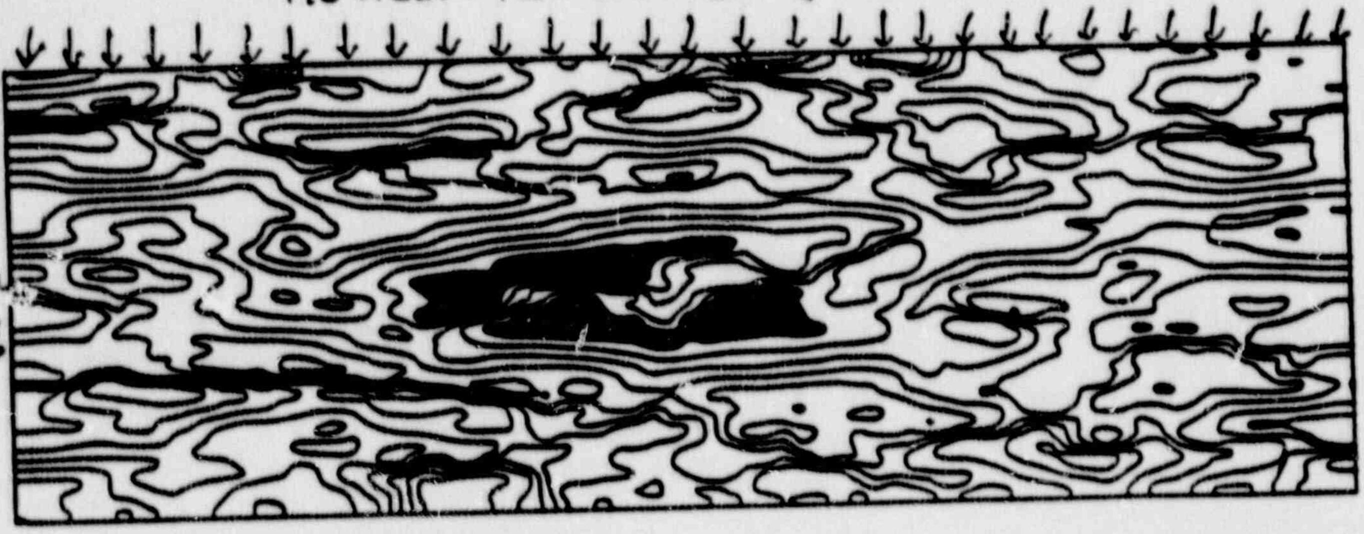
GRAVITY

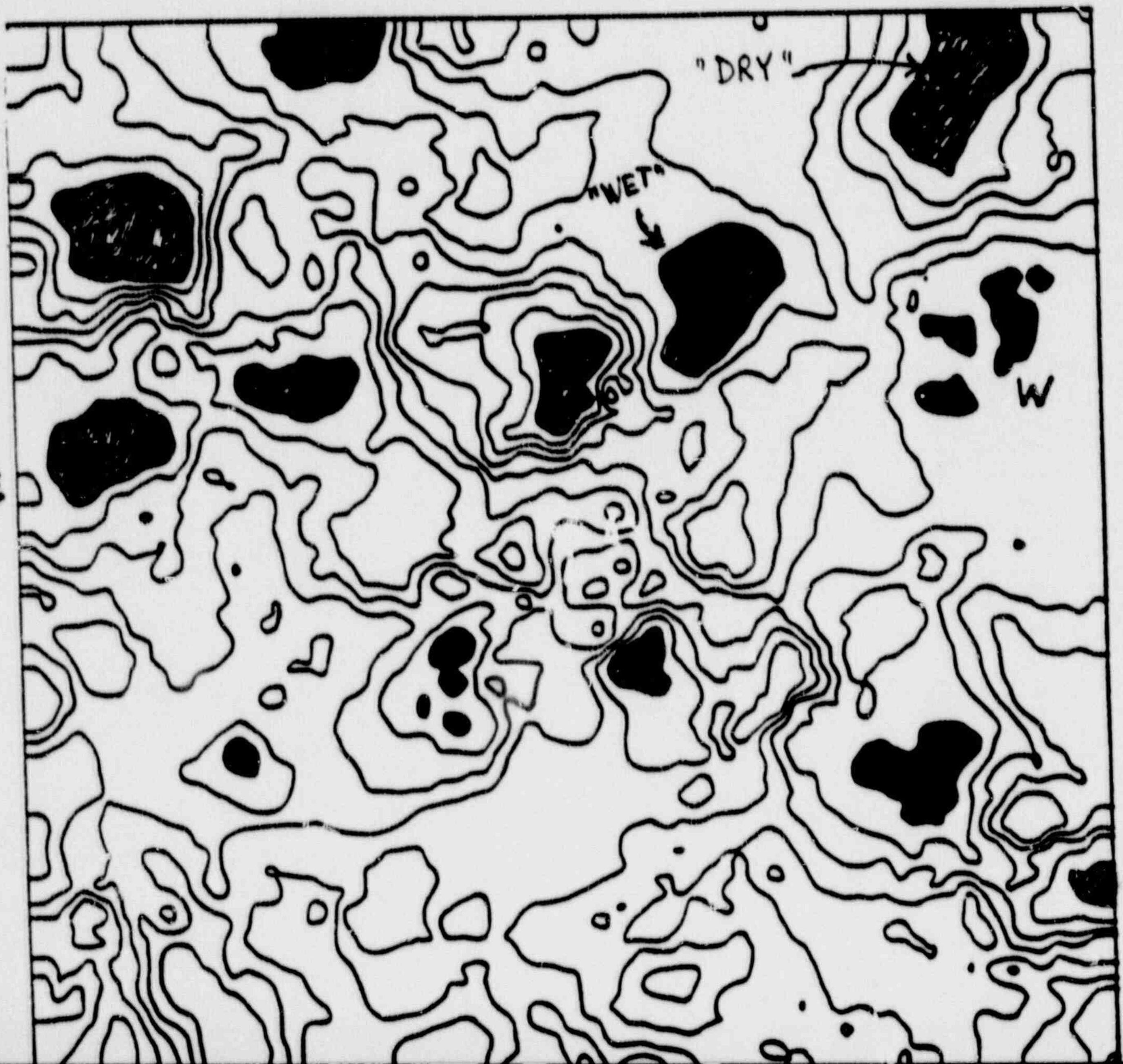
Three-dimensional excursion regions of the 3D random conductivity field in a cubic domain with 130,000 grid points (problem B with $\sigma_f = 2.3025$).

The regions correspond to high values of the conductivity such that $K/K_G \geq 10$.

VERTICAL SLICE (TOP)
HORIZONTAL SLICE (BOTTOM)

STEADY FLUX
INFILTRATION





THERMOHYDROLOGY RESEARCH PROJECT
TASKS

1. TECHNOLOGY TRANSFER FROM OTHER NRC PROJECTS AND ASSESSMENTS OF OTHER RESEARCH
2. DESIGN AND EXECUTION OF PRELIMINARY SEPARATE EFFECTS EXPERIMENTS
3. DESIGN OF UNSATURATED-ZONE THERMOHYDROLOGICAL EXPERIMENTS
4. THERMOHYDROLOGICAL PHENOMENA INDUCED BY THE AGGREGATE OF EMPLACED HLW IN UNSATURATED GEOLOGIC MEDIA
5. UNSATURATED-ZONE THERMOHYDROLOGIC PHENOMENA INDUCED BY MULTIPLE PACKAGES OF HLW

THERMOHYDROLOGY RESEARCH PROJECT

TASK 2: DESIGN AND EXECUTION OF PRELIMINARY SEPARATE EFFECTS EXPERIMENTS.

PURPOSE: TO STUDY PHENOMENA THAT AFFECT THERMOHYDROLOGICAL FLOW AT VARIOUS AMOUNTS OF SATURATION.

- Surface Tension Effects
- Fracture vs Matrix Flow
- Natural Convection
- Media Effects
- Forced vs Natural Convection
- Transient Heat Effects
- Flux of Fluids

BASIC TYPES OF SEPARATE EFFECTS EXPERIMENTS

- Flow Visualization
- Flow Measurement
- Combinations of Visualization and Measurements

THERMOHYDROLOGY RESEARCH PROJECT
GENERAL OBJECTIVE

- **To Use Laboratory Experiments and Analytical Methods to Provide NRC with an Understanding of Thermohydrologic Phenomena in Unsaturated Media on Both the Repository and Waste-Package Scales.**

THERMOHYDROLOGY RESEARCH PROJECT
FIN B6667
NRC Project Manager: Linda A. Kovach

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

SOUTHWEST RESEARCH INSTITUTE
San Antonio, Texas

Project Manager: John L. Russell

Investigators:
Frank Dodge, Chris Freitas, Ron Green,
Mike Lewis, Steve Svedman

November 30, 1989

THERMOHYDROLOGY RESEARCH PROJECT OBJECTIVES

- TO IMPROVE UNDERSTANDING OF THERMOHYDROLOGIC PHENOMENA IN UNSATURATED MEDIA TO SUPPORT EVALUATIONS OF:
    - --- Containment of Radionuclides in Waste Packages
    - --- Release of Radionuclides from the Engineered Barrier System
    - --- Extent of Disturbed Zone (Required to Determine Ground Water Travel Time)
    - --- Effects on Transport of Radionuclides to the Accessible Environment
- TO DETERMINE THE LIMITS TO WHICH LABORATORY SIMULATIONS CAN BE USED TO VALIDATE COMPUTATIONAL ALGORITHMS
- TO ASSESS THE PREDICTIVE CAPABILITIES OF COMPUTATIONAL ALGORITHMS USED TO MODEL THERMOHYDROLOGIC PHENOMENA
- TO PROVIDE NECESSARY INPUT FROM THE THERMOHYDROLOGIC RESEARCH PROJECT TO OTHER CENTER PROGRAMS

TRANSPORTATION RISK STUDY: APPROACH

- PROVIDE TECHNICAL BASIS TO SUPPORT REVISION OF ENVIRONMENTAL IMPACT STATEMENT ON TRANSPORTATION OF RADIOACTIVE MATERIALS
- EVALUATE AND ASSESS ADEQUACY OF DATA, MODELS, AND CODES
- ANALYZE REGULATIONS GOVERNING RADIOACTIVE MATERIALS TRANSPORT
- DISCUSS AND ANALYZE TRANSPORTATION ALTERNATIVES
- ANALYZE RADIOLOGICAL AND NON-RADIOLOGICAL EFFECTS OF RADIOACTIVE MATERIALS TRANSPORT

COMPARISON OF RADIOACTIVE MATERIAL SHIPPING DATA

1975 DATA FROM NUREG-0170

Shipment Type	Packages Per Year	Curies Per Year	TI per Year
Limited	7.03×10^5	2.11×10^3	7.74×10^3
Medical	9.10×10^5	5.78×10^6	6.43×10^5
Industrial	2.15×10^5	9.39×10^6	3.43×10^5
Fuel Cycle	2.04×10^5	5.32×10^8	5.69×10^5
Waste	1.52×10^5	2.68×10^5	2.98×10^6
TOTAL	2.19×10^6	5.48×10^8	4.54×10^6

1985 PREDICTIONS FROM NUREG-0170

Shipment Type	Packages Per Year	Curies Per Year	TI per Year
Limited	1.83×10^6	5.50×10^3	2.02×10^4
Medical	1.71×10^6	1.50×10^7	1.20×10^6
Industrial	5.63×10^5	2.47×10^7	8.79×10^5
Fuel Cycle	8.36×10^6	8.41×10^9	2.46×10^6
Waste	6.27×10^5	1.11×10^6	1.23×10^7
TOTAL	1.31×10^7	8.45×10^9	1.68×10^7

COMPARISON OF RADIOACTIVE MATERIAL SHIPPING DATA (CONT'D)

1975 DATA FROM NUREG-0170

Shipment Type	Packages Per Year	Curies Per Year	TI per Year
Limited	7.03×10^5	2.11×10^3	7.74×10^3
Medical	9.10×10^5	5.78×10^6	6.43×10^5
Industrial	2.15×10^5	9.39×10^6	3.43×10^5
Fuel Cycle	2.04×10^5	5.32×10^8	5.69×10^5
Waste	1.52×10^5	2.68×10^5	2.98×10^6
TOTAL	2.19×10^6	5.48×10^8	4.54×10^6

1982 DATA FROM SAND84-7174

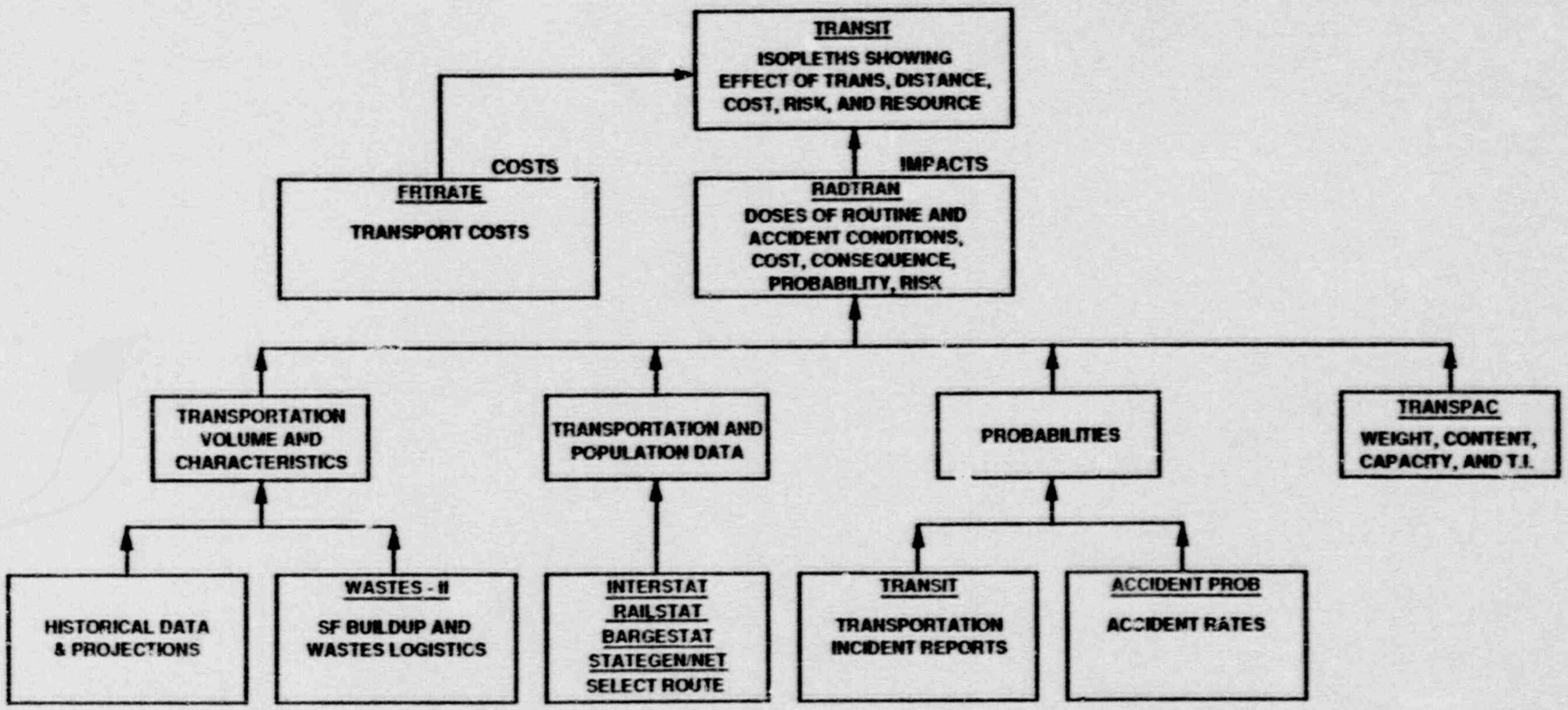
Shipment Type	Packages Per Year	Curies Per Year	TI per Year
Limited	4.17×10^5	1.05×10^3	7.25×10^4
Medical	1.73×10^6	3.08×10^6	9.43×10^5
Industrial	2.13×10^5	5.70×10^6	1.54×10^5
Fuel Cycle	1.34×10^5	3.47×10^7	$7.61 \times 10^{4*}$
Waste	1.81×10^5	1.37×10^5	2.37×10^5
TOTAL	2.67×10^6	4.36×10^7	$1.48 \times 10^{6*}$

*Does not include TI from Spent Fuel shipments (information not provided in SAND84-7174 document)

TYPICAL SHIPMENT SCENARIOS

Material Type	Nuclide	Curies/Pkg	TI/Pkg	Pkgs/Shpmt	Mode	Origin	Destination
Spent Fuel	Various	2450000	14	1 PWR 5y	Truck	West Valley, NY	Hanford, WA
	Various	2450000	14	3 PWR 5y	Rail	West Valley, NY	Hanford, WA
Industrial	Cs-137	222.30	14	1	Truck	Oak Ridge, TN	Hanford, WA
	Cs-134	92.170					
	Sr-89	0.020					
	Sr-90	0.001					
	H-3	0.116					
	Co-60	3.917					
Medical	Co-60	3103.700	2	1	Truck	Oak Ridge, TN	Berkeley, CA
	Mo-99	218.750	2	1	Air	Boston, MA	Phoenix, AZ
Transuranic	Cm-243	0.020	200	1	Truck	Idaho Falls, ID	Carlsbad, NM
	Cm-244	0.020					
	Pu-238	0.070					
	Pu-234	0.0001					

THE TRANSNET TRANSPORTATION RISK AND SYSTEMS MODELS



TRANSIT
ISOPLETHS SHOWING EFFECT OF TRANS, DISTANCE, COST, RISK, AND RESOURCE

COSTS

IMPACTS

FRTRATE
TRANSPORT COSTS

RADTRAN
DOSES OF ROUTINE AND ACCIDENT CONDITIONS, COST, CONSEQUENCE, PROBABILITY, RISK

TRANSPORTATION VOLUME AND CHARACTERISTICS

TRANSPORTATION AND POPULATION DATA

PROBABILITIES

TRANSPAC
WEIGHT, CONTENT, CAPACITY, AND T.I.

HISTORICAL DATA & PROJECTIONS

WASTES - II
SF BUILDUP AND WASTES LOGISTICS

INTERSTAT
RAILSTAT
BARGESTAT
STATEGEN/NET
SELECT ROUTE

TRANSIT
TRANSPORTATION INCIDENT REPORTS

ACCIDENT PROB
ACCIDENT RATES

RADTRAN VERIFICATION PROCESS

- Used pre-defined data set "LSALMT" for first runs, and as a baseline for future test runs
- Altered several inputs to run a customized scenario
- Identified default values used by program and verified their validity
- Identified all relevant input variables
- Modified a different data set, attempted to duplicate the baseline case
- Could not duplicate the baseline model, but using the new data set as a second baseline which was wholly self-created, found that this new baseline case could be recreated by modifying any other data set
- Periodically consulted with C. Peterson and S. Neuhauser (SANDIA) to answer various questions

RADTRAN MENU SYSTEM

SELECT INPUT DECK

1 TITLE
2 PARAMETERS
3 TRANSPORT MODES (NEGATIVE FOR EXCLUSIVE USE)
4 POPULATION DENSITIES
5 PACKAGE

RADTRAN MENU SYSTEM (CON'T.)

- 11 ACCIDENT RATES & FRACTIONS OF TRAVEL
  - ACCIDENT RATE
  - FRACTION OF TRAVEL
    - PRE-DEFINED
    - OWN INPUT
  - BASE ACCIDENT RATE
- 12 ACCIDENT SEVERITY (RURAL, SUBURBAL AND URBAN FOR EACH TRANS. MODE)
- 13 RELEASE
  - FRACTION RELEASED
  - FRACTION AEROSOLIZED
  - FRACTION RESPIRABLE
  - USER DEFINED AREAS AND CONCENTRATIONS
    OR
    PASQUILL AREA PROBABILITIES
- 14 OTHER
  (RADII THAT DEFINE EXPOSURE FOR RURAL, SUBURBAN AND URBAN)

RADTRAN MENU SYSTEM (CON'T.)

(FOR A NEW MATERIAL ONLY)

- 6 SHIPMENT MATERIAL - MATERIAL PARAMETERS
  - [illegible]/Ci CONVERSION FACTORS FOR INHALATION
  - [illegible] CONVERSION FACTORS [illegible]TION
- 7 SHIPMENT MATERIAL (CON'T.)
- 8 SHIPMENT DISTANCE
- 9 NORMAL OPERATIONAL DETAILS
- 10 NORMAL PARAMETERS (POPULATION ZONES)

DNORM INPUT

RADTRAN INPUTS

- METHODS FOR DATA INPUT
  - 11 pre-defined data sets
  - Data sets can be modified to customize data
  - Menu-driven input

RADTRAN OUTPUT

- INCIDENT FREE ANALYSIS
  - Doses to passengers, crew, handlers, and surrounding population
  - Ground level concentration calculations
  - Expected population (Population density x area)

RADTRAN OUTPUT (CONT'D)

- ACCIDENT ANALYSIS
  - Dose tables
  - Expected accidents
  - Expected values of risk (can be converted to doses with proper conversion factors)
  - Early fatalities
  - Early morbidities
  - Latent cancer fatalities (for groundshine, cloudshine, inhalation, etc.)

MAJOR REVISIONS SINCE RADTRAN I

- ACCIDENT MODEL
  - Cloudshine dose evaluation
  - Revised economic impacts
  - Addition of Pasquill stability category option
  - Inclusion of Building Dose Factor in urban groundshine model
  - Addition of shielding factors to exposure source accident model
  - Inclusion of inhalation dose to pedestrians in urban areas
  - Redefinition of material categories
  - Inclusion of accident sensitivity analysis
  - Inclusion of food ingestion dose for accidents in rural areas
- GENERAL
  - Redesign of input and output

MAJOR REVISIONS SINCE RADTRAN I (CONT'D)

- INCIDENT-FREE MODEL
  - Checks for regulatory consistency
  - Addition of rail and water crew doses
  - Sensitivity analysis
  - Addition of urban rail model
  - Revision of dose to persons in vehicles sharing the transport link
  - Modifications to rail stop and crew models

REVISIONS SINCE RADTRAN II

- Ability to change output for accident model from health effects to population dose
- Units on the normal default parameter for stop time changed from hours per trip to hours per kilometer.
- Ability to specify a dedicated train
- Automatic package dimension is invoked for packages > 4 meters
- Ingestion dose conversion (rem/Ci) factor, food, and soil transfer fraction input parameters were added

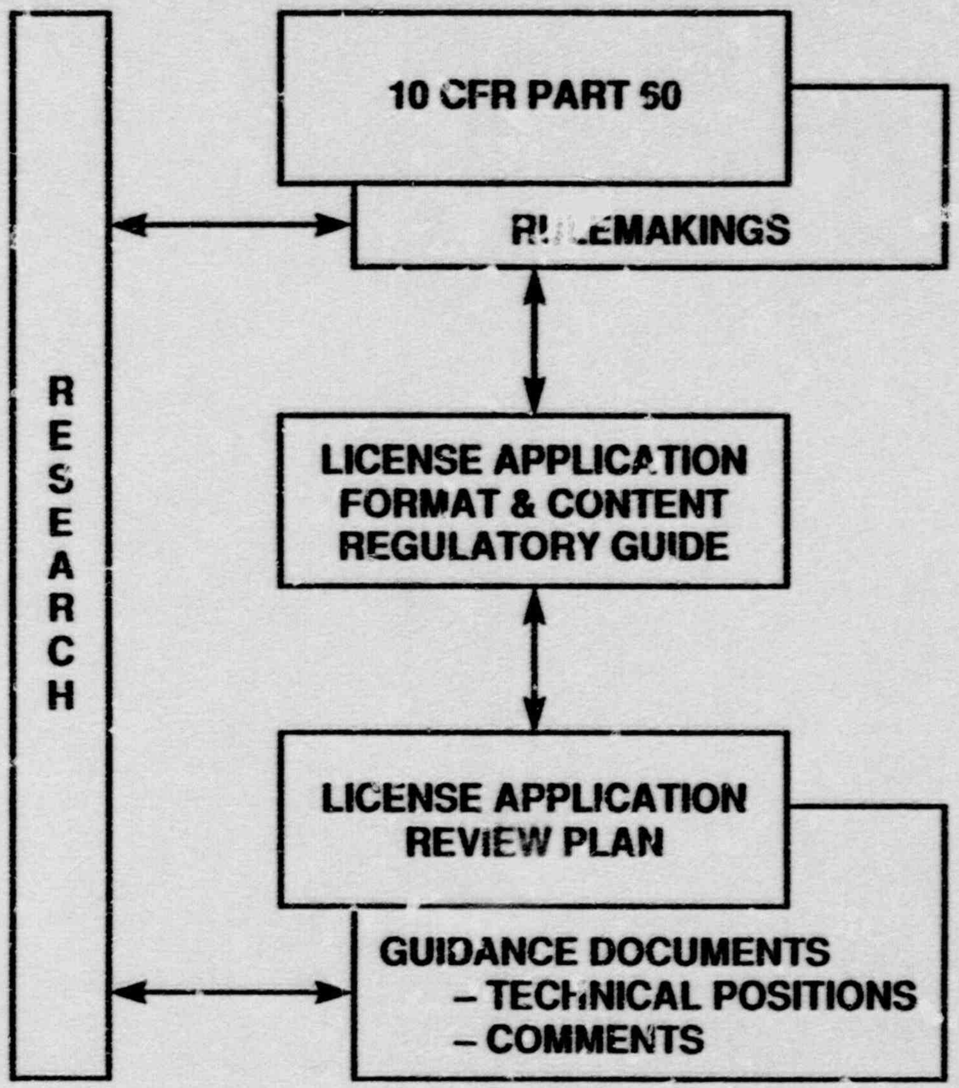
SIGNIFICANT ACCOMPLISHMENTS – TRANSPORTATION RISK STUDY

- COMPLETED EVALUATION OF RADTRAN III
- DISCOVERED ERROR IN PRIMARY RADIOACTIVE MATERIALS SHIPMENT DATABASE
- DEVELOPED NEW PROJECTIONS OF RAM SHIPMENTS

PERFORMANCE ASSESSMENT: APPROACH AND ROLE

- UNCERTAINTY AND SENSITIVITY IDENTIFICATION
  - Early Identification of Key Parameters and Features
  - Evaluation of Relative Importance of Parameters and Features by Means of Sensitivity Analyses
  - Identify Targets for Confirmatory and Exploratory Research
- INTEGRATION
  - Provide Basis for Technical Integration Across the Program
  - Ensure Consistency of Subsystem Evaluation Methodologies with the Overall System Performance Assessment Methodology
- COMPLIANCE DETERMINATION
  - Provide for Determination of Compliance with Subsystem Regulatory Requirements
  - Assess Performance of Overall System in Context of 10CFR60 and 40CFR191

GENERAL RELATIONSHIP OF MAJOR REGULATORY DOCUMENTS



RESEARCH

10 CFR PART 50

RULEMAKINGS

LICENSE APPLICATION FORMAT & CONTENT REGULATORY GUIDE

LICENSE APPLICATION REVIEW PLAN

GUIDANCE DOCUMENTS
- TECHNICAL POSITIONS
- COMMENTS