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UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

December 18, 2000

MEMORANDUM TO: ACRS Members
ACRS Staff

FROM: Medhat El-Zeftawy
Senior Staff Engineer, ACRS

SUBJECT: CERTIFIED MINUTES OF THE ACRS SUBCOMMITTEE MEETING ON SAFETY RESEARCH PROGRAMS, NOVEMBER 1, 2000

The proposed minutes of the subject meeting issued November 28, 2000, have been certified as the official record of the proceedings for that meeting.

Attachment:
Certified Minutes-Subcommittee Meeting on
Safety Research Programs, November 1, 2000

cc: J. Larkins, ACRS
J. Lyons, ACRS

MEMORANDUM TO: Medhat El-Zeftawy, Senior Staff Engineer
ACRS

FROM: Dana Powers, Chairman
Safety Research Programs Subcommittee

SUBJECT: CERTIFICATION OF THE MINUTES OF THE ACRS SUBCOMMITTEE MEETING ON SAFETY RESEARCH PROGRAMS, HELD ON NOVEMBER 1, 2000- ROCKVILLE, MARYLAND

I certify that, to the best of my knowledge and belief, that the minutes of the subject meeting issued on November 28, 2000, are accurate record of the proceedings for that meeting.

Dana A. Powers

Dana A. Powers, Chairman

15\Dec\2000

Date

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

November 28, 2000

MEMORANDUM TO: Dana Powers, Chairman
Safety Research Programs Subcommittee

FROM: Medhat El-Zeftawy, Senior Staff Engineer
ACRS

SUBJECT: WORKING COPY OF THE MINUTES OF THE ACRS SUBCOMMITTEE MEETING ON SAFETY RESEARCH PROGRAMS, NOVEMBER 1, 2000- ROCKVILLE, MARYLAND

A working copy of the Minutes for the subject meeting is attached for your review. I would appreciate your review and comment as soon as possible. Copies are being sent to the ACRS Members and Consultants, who attended the meeting for information and/or review.

Attachment: As stated

cc: G. Apostolakis
M Bonaca
G. Leitch
T. Kress
R. Seale
W. Shack
J. Sieber
J. Sorensen
J. Larkins
J. Lyons
ACRS Fellows

PREPARED FOR INTERNAL COMMITTEE USE

ISSUED: November 28, 2000
CERTIFIED: December 15, 2000

CERTIFIED

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SAFETY RESEARCH PROGRAMS SUBCOMMITTEE MINUTES
NOVEMBER 1, 2000
ROCKVILLE, MARYLAND

The Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on Safety Research Programs held a meeting on November 1, 2000 in Room T-2B3, 11545 Rockville Pike, Rockville, Maryland, with representatives of the NRC staff. The purpose of this meeting was to discuss the ongoing and proposed research activities, and gather information to formulate proposed positions and actions, as appropriate, for deliberation by the Full Committee regarding the 2001 ACRS report to the Commission on the NRC research programs and activities. Dr. Medhat El-Zeftawy was the cognizant ACRS staff engineer for this meeting. The meeting was convened at 8:30 a.m. and adjourned at 5:55 p.m.

ATTENDEES

ACRS

D. Powers, Chairman
G. Apostolakis, Member
M. Bonaca, Member
G. Leitch, Member
T. Kress, Member
R. Seale, Member
W. Shack, Member
J. Sieber, Member
J. Sorensen, Fellow
M. El-Zeftawy, Staff

NRC

A. Thadani, RES
V. Holahan, RES
J. Kramer, RES
E. Rodrick, RES
V. Perin, RES
J. Rosenthal, RES
M. Mayfield, RES
F. Eltawila, RES
J. Murphy, RES
I. Schoenfeld, EDO
J. Persensky, RES
J. Costello, RES
S. Mays, RES
T. King, RES
M. Federline, RES
J. Johnson, RES

OTHERS

J. Meyer, ISL,Inc.

No written comments or requests for time to make oral statements were received from members of the public. A list of attendees is available in the ACRS Office and will be made available upon request.

OPENING REMARKS BY THE SUBCOMMITTEE CHAIRMAN

Dr. Dana Powers, Chairman of the Subcommittee, convened the meeting at 8:30 a.m. and stated that the purpose is to discuss with the NRC staff the 2001 draft ACRS report to the Commission regarding the NRC's Safety Research Programs and related matters. The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Dr. Powers indicated that the objective of this meeting is to have a collegial discussion with the managers of the Office of Nuclear Regulatory Research (RES) regarding the future long-range (5 to 7 years time-frame) research programs that RES might be able to pursue to facilitate the agency meeting its obligation as nuclear industry progresses and evolves.

NRC STAFF PRESENTATION

Mr. Ashok Thadani, RES Director, briefed the Subcommittee regarding the historical perspectives of RES. He stated that in 1974. Congress mandated the formation of RES to ensure "an independent capability for developing and analyzing technical information related to reactor safety, safeguards and environmental protection in support of the licensing and regulatory process." Since 1974, research has been performed to identify and resolve issues, evaluate uncertainties and to fill gaps in knowledge in the technical bases for regulatory requirements.

Mr. Thadani stated that the scope and emphasis of the NRC's research program have changed over the years as nuclear technology has changed and matured. During the 1970s and early 1980s, the research program was focused on postulated design basis accidents such as loss-of-coolant accidents. Prior to the TMI accident, the NRC and the industry were in a state of complacency and unprepared to deal with severe accidents.

Based on current understanding and knowledge of risk, many of the NRC requirements in response to the TMI accident could be characterized as overreaction. After the accident at TMI, with further impetus from the Chernobyl accident, the emphasis in the reactor research program shifted from design basis accidents to severe accidents. Exploratory research was also conducted to understand the aging of nuclear power plant components (e.g., reactor vessel, steam generator, mechanical and electrical components).

In the early 1990s, the emphasis shifted again, to support the NRC's review of newly emerging technologies such as digital instrumentation and control, and a group of new advanced reactor designs. Mr. Thadani noted that the 1990s showed a trend in improved plant performance, but aging of existing plants raised new challenges and questions. In the late 1990's economic pressures from deregulation of the industry emphasized the NRC's role in ensuring that industry does not overlook safety.

Currently, RES is facing a new century and is dedicated to give definition and meaning to a technically strong regulatory agency. The year 2000 and beyond will bring continuing challenges as well as increasing stakeholder interest. Generally, the RES program outputs are derived from: the technical experts both on the staff and at the contractors, the technical tools and techniques developed and maintained by those experts, and the experimental data to support the regulatory analysis and to validate the technical tools. The regulatory outputs derived from the experimental facilities include improvements to design basis and severe

accident modeling, validation of thermal-hydraulics codes, and improvements in modeling pressurized thermal shock phenomena.

Mr. Thadani noted that both the industry and the regulator are dynamic institutions as evidenced by the changes underway. This dynamic situation in the industry is illustrated by requests for power uprates, use of extended burnup fuel, license renewal, shortened outages, aging components and systems, and the introduction of new technology. Similarly, the NRC is experiencing dynamic change, including the transition to risk informed regulation, the new plant oversight process, and revisions to the accident source term.

Examples of research that provide short term benefits are steam generator tube and primary system integrity, improvements in inspection techniques to identify material flaws, aging of qualified cables, MOX fuel, and digital instrumentation and control. For the long-term research, RES is retaining its ability to transfer knowledge within the agency to improve the ability to regulate through realistic decisions. Another long term value of research is maintenance of the necessary experimental infrastructure. Mr. Thadani emphasized that as risk-informed regulations focus on the most significant aspects of plant operation, an understanding of the synergisms in the margins of safety and the phenomena that underlie these margins must be fully understood. Mr. Thadani stated that the dynamic nature provides a challenge for NRC staff to keep abreast of changes and RES not only provides the technical basis for conducting the required reviews, but also provides a body of expertise within the staff to independently analyze data and review licensee submittals, as appropriate, as evidenced by the design certification of AP600.

Generally, the RES program is funded through user fees which may result in a continued pressure to reduce spending. However, the NRC must be in a position to independently assess all major issues. For example, how confident the NRC in relying on data developed for the AP600 design to be used in the certification process for the AP1000 design?.

Mr. Mike Mayfield, RES, outlined some of the future challenges that faces the agency from currently operated facilities. These include the resources to plan and carry out longer term research, degree of cooperation with industry, need for independent analysis capability (particularly for new designs), and international cooperation and leadership. Some specific challenges are:

- Underlying assumptions such as deregulation, power uprates, extension of operating licenses, higher fuel burnup, economic pressures, expanded use of digital I&C, use of PRA, and changes in plant design and operation will be evolutionary rather than revolutionary.

- Plant aging will continue to result in challenges

- Radiation protection guidelines and recommendations are likely to change

- Decommissioning and waste management raise key fundamental issues that need to be resolved

- Managers will be less tuned to technical aspects of design and operation

- Quantification of human reliability for severe accidents

- Reducing the likelihood of operator misunderstanding that could lead to erroneous unsafe action

- Interim storage of spent fuel will present challenges in siting and cask/fuel aging.

Dr. Farouk Eltawila, RES, outlined some of the thermal-hydraulics related challenges in the time frame 2004-2010. He stated that the imperfect knowledge of two-phase flow and heat transfer processes are the main root causes of the limitations and deficiencies in reactor thermal-hydraulics (T/H) codes. In the past, these deficiencies and limitations were dealt with by imposing large safety margins to compensate for the lack of knowledge. One of the weakest points in the current generation of T/H codes is the modeling of interfacial transport processes. No progress has been made in this area over the past 15 years.

RES believes that no substantial improvement in code predictive capabilities can be made without the development of the database to formulate the constitutive relationship for interfacial area terms. Accordingly, NRC, in collaboration with other countries, will continue the development of interfacial area transport models to replace the flow regime in the current codes.

Dr. Eltawila noted that the one-dimensional models are dependent on correlations that require substantial code calibration. Significant flow and heat transfer phenomena occur at a local level and require a multidimensional modeling approach. The NRC is sponsoring research programs aimed at developing multiphase computational fluid dynamics (CFD) techniques into useful engineering tools.

The TRAC-M code will meet the NRC needs in the immediate future, however, it requires extensive noding of components. Coupling of the TRAC-M code to CFD code can enhance the NRC analysis capability.

Dr. Eltawila briefed the Subcommittee shortly regarding other issues such as fuel , severe accidents, materials, I&C, and human factors. For the fuel , issues such as the behavior of coated particle fuel at high burnup need to be investigated and different coating may be needed if higher temperature is needed. In addition, the use of different cladding materials need to be studied to improve accident response.

Materials issues could include a confirmation program for high-performance materials to reduce age degradation, high operating temperature, ceramic materials, and pre-stressed concrete vessel.

Advances in digital technology are likely to bring about evolutionary and revolutionary changes in plant control, monitoring, maintenance, and engineering. Digital I&C technology continues to evolve at a rapid rate. Control rooms will incorporate advanced technology, and "smart" devices will be embedded in many components, such as valves, transformers, and relays. Developments in digital technology will further support licensee initiatives to centralize maintenance and engineering activities.

RES representatives believe that the regulatory review process will need to be able to keep pace with the technology changes. In addition, the use of fiber optics and industrial

communication networks will decrease the physical space now needed for all the cables in the plant. Fiber optics are less susceptible to magnetic interference than cabling and the use of industrial communication networks means less penetrations into containment. RES representatives noted that the environmental and aging effects of smart sensors and wireless communications need to be studied.

Mr. Jack Rosenthal, RES, briefed the Subcommittee members regarding the human performance issues. He noted that the issues that face human performance in the nuclear industry include deregulation, consolidation, life extension, and decommissioning. The deregulation of the utility industry has forced many fundamental changes in both utility structure and operations. Reducing capital cost by almost 30% and downsizing to obtain better economic performance without adequate planning could result in the elimination of safety related positions and not allowing sufficient time and resources to perform the necessary functions. Such operating environment raises the level of regulatory concern to address practices that could reduce the safety culture.
Life extension can also present human performance issues such as the aging of I&C components and the aging of the workforce. Other human performance issues include the reduced preventive maintenance (e.g., more on-line maintenance) and even simplifying or eliminating the operator role for certain functions. The introduction of artificial intelligence methods such as neural networks and fuzzy logic techniques also need to be studied. RES believes that the means to measure, monitor and trend human performance need to analyzed.

Dr. Eltawila highlighted some of RES approach for maintaining readiness. This include the following:

- Integrated approach to advance NRC capabilities to include analysis tools, experimental data, and knowledgeable staff.
- Develop realistic mechanistic models.
- The need for experimental facilities to complement past results and to improve the quality of NRC codes
- Testing at properly scaled facilities to resolve complex technical issues and incorporate plant characteristics that influence phenomena
- Perform more in-house research to support the agency strategic goals and enhance public confidence
- Support risk-informed regulation
- Expand on the NRC's University research to foster independent thinking regarding scientific and engineering problems
- Increase the involvement in international leadership
- Ability to respond to unanticipated concerns.

Mr. Thomas King, RES, briefed the Subcommittee members regarding "Future Reactors". He noted that the current regulatory framework and requirements are, for the most part, based

upon LWR technology and current plant designs. There appears to be renewed interest in future plants worldwide (i.e., Generation IV initiative by DOE, AP-1000, PBMR). Many of these future designs will propose features different from the traditional LWR designs, including the fuel type, coolant type, containment type, and accident response. RES has a role to prepare the agency for the future. This role includes preparation for future plant licensing activities. Therefore, RES plans for future work should consider early interactions with reactor designers to identify key safety issues and plans for their resolution, and to establish a framework for licensing that recognizes the unique features of these designs.

Subcommittee Discussion and Follow-up

- How strong the technical bases should be to enable the NRC to make regulatory decisions?
- How well should the NRC keep trying to understand severe accidents and perform additional research?
- The reliance on the IPEs for risk insights on specific plants need to be examined further.
- The original function of AEOD and its event analysis reports should be made more useful.
- Some members noted that research is a benefit to the public and would be more appropriate if it is funded with public revenues.
- Communication with the public is an essential element to focus on the needed research areas.
- The agency still does not have a well coordinated, well-founded human performance program.
- Research with cask storage to assess the effectiveness of regulations needs to be examined.
- Phenomena Identification and Ranking Table (PIRT) approach is successful for high burnup fuel issues and could be useful in other areas (e.g., digital I&C).
- New thermal hydraulics issues are rising such as blowdown, and vibrations during load-following.

CONCLUSION

The Subcommittee Chairman will discuss this matter during the November 2-4, 2000 ACRS meeting to develop a plan of action regarding the 2001 ACRS report to the Commission on the NRC Safety Research Program.

Presentation Slides and Handouts Provided during the Subcommittee Meeting

The presentation slides and handouts used during the meeting are available in the ACRS Office files or as attachments to the meeting transcripts.

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NOTE: ACRS Subcommittee meeting agenda and transcripts are available for downloading or reviewing on the Internet at http://www.nrc.gov/ACRSACNW.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON SAFETY RESEARCH PROGRAM

NOVEMBER 1, 2000

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	BADGE #	NRC ORGANIZATION
Bonnie Schoenfeld	6983	OEDO
J. MURPHY	A6556	RES
V. HOLAHAN	A-7561	RES
Joel Kramer	B-8401	RES
J PERSENSKY	B-8413	RES
E. RODRICK	B-7439	RES
JF Costello	B-8355	RES
V.A. Peiu	A-7361	RES
S.E. MAYS	B-8405	RES
JE Rosenthal	A6661	RES

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON SAFETY RESEARCH PROGRAM

NOVEMBER 1, 2000

ATTENDEES - PLEASE SIGN BELOW

PLEASE PRINT

NAME	AFFILIATION
Jim Meyer	ISL, Inc.

MMC

United States Nuclear Regulatory Commission

Value of Research to the NRC, the Industry and the Public and a Future Vision ACRS Discussions

Ashok Thadani, Director
Office of Nuclear Regulatory Research

November 1, 2000

Historical Perspectives

- In 1974, Congress mandated the formation of the Office of Nuclear Regulatory Research to ensure "an independent capability for developing and analyzing technical information related to reactor safety, safeguards and environmental protection in support of the licensing and regulatory process."
- Since 1974, research has been performed to identify and resolve issues, evaluate uncertainties and to fill gaps in knowledge in the technical bases for regulatory requirements.

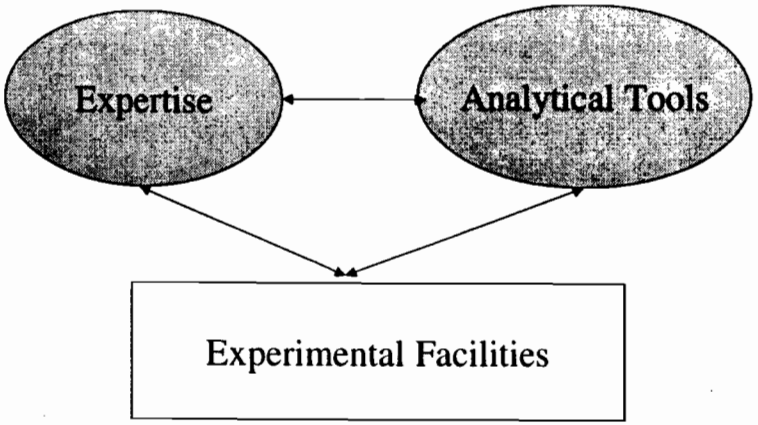
Historical Perspective of Research Emphasis

- Pre-TMI
- Post –TMI
  - LOCAs
  - Severe Accidents
  - Aging
  - Risk Analysis
- Early '90s
  - Newly emerging technologies
    - Digital I&C
    - High Burnup Fuel
  - Advanced reactor designs
    - ABWR
    - CE80+
    - AP600
  - Aging
    - Operating experience

Current Perspectives

- In the new century, complacency regarding safety could become a concern
  - Perceptions of a Mature industry, but
    - ✯ Significant economic pressures
    - ✯ Many changes being made.
  - Declining infrastructure

Inter-relationships



WHY FUTURE RESEARCH IS NEEDED

- Dynamic Nature of Nuclear Power Industry
  - Power uprates
  - High burnup fuel
  - License renewal
  - Shortened outages
  - Aging components
  - Introduction of new technology
  - Introduction of new designs

Examples of Research That Provide Short Term Benefits

- Steam generator tube and primary system integrity
- Improvements in inspection techniques to identify material flaws
- Aging of qualified cabling
- Digital instrumentation and control

FOCUS OF LONGER TERM RESEARCH

Examples:

- Improved understanding of phenomena
- New Technologies
- New Designs
- Risk Informed Regulation
  - LWR
  - Non-LWR

Some Challenges

- Resources to plan and carry out longer term research.
- Degree of Co-operation with Industry (degree of independence)
- Need for Independent Analysis Capability (also people, and facilities) particularly for new designs.
- International Co-operation/Leadership

Common Themes Emerging from Expert Panel

- A strong viable RES Organization is essential.
- RES must expand inhouse expertise where appropriate.
- Technical expertise has been steadily eroded in some technical areas.
- RES should increase its cooperative research efforts.
- Current working agreements with DOE and EPRI should be re-examined and strengthened.
- A single strong center conducting all research for the agency should be considered.
- The current mix of anticipatory and confirmatory research is reasonable.

Common Themes Emerging from Expert Panel (Contd)

- The costs for anticipatory research should not be recovered through fees but the general funds.
- The definition of NRC research needs to be more specifically defined.
- The physical facilities available to RES are decreasing.
- NRC must work with industry and other government agencies on maintaining facilities.
- RES must improve the communication of its products internally and externally.
- The funding for RES is at a dangerously low level.
- The NRC should increase its dialogue with Congress.

FUTURE CHALLENGES FROM CURRENTLY OPERATING FACILITIES

- Underlying Assumptions
  - Deregulation has led to economic pressures on licensees -- need to 'get more' from existing plants
  - Licensees will seek power uprates
  - Many plants will extend the operating licenses
  - Licensees will seek to use higher fuel burnup limits -- longer operating cycles
  - Responding to economic pressures will bring about human performance issues -- e.g., expanded use of overtime

FUTURE CHALLENGES FROM CURRENTLY OPERATING FACILITIES

- Underlying Assumptions (cont.)
  - Changes in plant design and operation will be evolutionary rather than revolutionary
  - Fact-of-life changes will be made in all plants
    - ✯ Expanded use of digital technology
    - ✯ System/material/operational changes to mitigate aging
  - Use of PRA will become more routine
    - ✯ Models will have to be more robust
    - ✯ More staff will be trained in use of PRA
  - Analytical and experimental support for regulatory decisions will be needed

FUTURE CHALLENGES FROM CURRENTLY OPERATING FACILITIES

- Plant aging will continue to result in challenges
  - Identify new and evaluate emerging degradation
  - Evaluate monitoring, inspection, and testing techniques
  - Characterize current condition and performance of degraded structural components
  - Expanded application of advanced computational techniques
- Radiation protection guidelines and recommendations are likely to change
- Decommissioning and waste management raise key fundamental issues that need to be resolved

FUTURE CHALLENGES FROM CURRENTLY OPERATING FACILITIES

- Deregulation of electricity supply and economic pressure
  - Downsizing and outsourcing
  - Eliminating apparently non-productive functions without proper recognition of their long-term contribution to safety
  - Hollowing of competency
    - ✯ Overloading of key persons -- affect long-term overview of crucial safety activities
- Managers will be less tuned to technical aspects of design and operation
  - Spend more time to manage changes
  - Planning how to do more work with less resources

FUTURE CHALLENGES FROM CURRENTLY OPERATING FACILITIES

- Quantification of human reliability for severe accidents
- Develop methods to support succession planning and maintenance of corporate knowledge
- Reducing the likelihood of operator misunderstandings that could lead to erroneous "unsafe action being initiated"
  - Improved human systems interface; simplifying, not eliminating, operator role
- Improving information to the operator post accident, thus improving the decision making process
  - Increased automation
  - Use computer-based equipment having wider industrial applications

FUTURE CHALLENGES FROM CURRENTLY OPERATING FACILITIES

- Interim storage of spent fuel will present challenges in siting and cask/fuel aging
- Pressure will increase for burnup credit for storage and transportation of spent fuel
- Licensees will seek ultrahigh burnup and use of MOX fuel (moderate & high burnup)
- Evaluation of operating experience

FUTURE CHALLENGES FROM CURRENTLY OPERATING FACILITIES

- Expanded use of digital I&C technology
  - Rapidly evolving technology
  - Human performance issues
  - Need for review and evaluation criteria that can keep pace with applications
  - Need for underlying technical basis
- Expanded use of PRA
  - Further changes to regulations
  - Need for training staff
  - Reduced and quantified uncertainties
  - 'Best estimate' analytical techniques

United States Nuclear Regulatory Commission

RES 2010

Presented to
Advisory Committee on Reactor Safeguards
By Farouk Eltawila
Division of Systems Analysis and
Regulatory Effectiveness
Office of Nuclear Regulatory Research

Licensing Issues

- Public Concern--Low Probability Accidents, Will Require New Concepts to Achieve an Acceptable of Safety
  - Compatibility Between Increasing Safety Requirements and Need for Competitiveness
  - Decommissioning by Design Measures
- In Addition to Producing Electricity, Future Nuclear Energy
  - Efficient Burning of Stockpile of Civilian and Military Plutonium
  - Transmutation of Long-lived High Activity Nuclides
  - Minimization of Waste Productions
- Defense-in-Depth
  - Fission Product Retention, Reactivity Control, Decay Heat Removal, Debris Confining and Cooling, Long Term Containment Heat Removal, Combustible Gas & Containment Pressure Control

Licensing Issues

- Use of PRA Technique Throughout the Design Process
- No Experience of Licensing Procedure for Innovative Technology
  - Safety Codes and Guides for Licensing New Reactors Should Be Made at an Early Stage
    - ✯ Classification of Accident Sequences Will Not Be a Direct Transposition of the Existing Classifications for LWRs
    - ✯ Gaps in the Qualification of Existing System Codes Must Be Fixed
      - – Codes Should Be Able to Model Accident Management
  - A Step by Step Approach Is Recommended
    - ✯ Assess Existing Data, Codes and Make Use of Them
    - ✯ Identify Gap in Knowledge With Significant Consequences
    - ✯ R & D Pursued, If No Other Cost Effective Alternatives Are Available

Fuel Issues

- Use of Cladding Materials to Improved Accident Response
- Ultra High Burnup--UO_2 ; And Higher Burnup for MOX
- Burnable Poisons/ Low Boron Core
- Minimizing High Level Wastes
  - High Efficiency, Ultra High Fuel Burnup
  - Flexibility for Using Different Fuel Cycles (Thorium Cycle With a Reduced Production of Actinides)
- Plutonium Burning Potential -- Control Excessive Reactivity
- Non of the Above Represent an Innovative Approach, but Cannot Be Considered As Automatically Available, and If Available, Is Fragmented
- Confirm the Behavior of Coated Particle Fuel at High Burnup
  - Different Coating May Be Needed If Higher Temperature Is Needed (Increase the Operating Temperature, Margin for High Burnup)

Thermal-Hydraulic & Severe Accident Issues

- Improved Physical Modeling of 2-φ Flow With Interfacial Area Transport (Dynamic Flow Regime)
- Develop 2-φ Thermal-Hydraulic Models for Computational Fluid Dynamics (CFD) Code
- Modeling of Turbulence (K-ε)
- Improved Numerical Methods (Efficient Time-Stepping Strategies, Unstructured Mesh Formulation)
- 3D CFD Code/Module Coupled to TRAC-M Systems Code
- Develop Expertise to Review Innovative Passive Thermal-hydraulic Components, E.G., Thermal-Valve Design
- Better Understanding of Safety Margins and Consequences of Changes—actual Margins Rather Than Qualitative or Perspective
- Retention and Cooling of Molten Reactor Materials

Material Issues

- New Safety Requirements, Consideration of Severe Accidents, Use of Passive Devices Will Require Knowledge of Material Behavior Under Harsh Environmental Condition
- Improved Materials to Reduce Aging Degradation, Corrosion, and Embrittlement
- New Reactor Designs May Rely on Materials That Have Industrial Experience, but No Nuclear Experience
- Confirmation Program Will Be Needed For
  - High-Performance Materials
  - High Operating Temperature
  - Ceramic Materials That Could be Used--Guide Tube, Cladding, Core Catcher
  - Pre-Stressed Concrete Vessel

Instrumentation and Control Issues

- Technology Evolving Very Rapidly -- Difficult to Anticipate Where We Will Be in 5-10 Years.
- Control Rooms Will Incorporate Advanced Technology -- Look and Feel Will Be Different
- "Smart" Devices Will Be Embedded in Many Components, Such As Valves, MCC, Tap Change Transformers, Relays -- Provide Significantly More Functionality, Diagnostics and Self-testing
- Regulatory Review Process Will Need to Be Able to Keep Pace With the Technology Changes
- Improved Computing Technology Will Permit Simulation of New Digital Systems Before They Are Installed in the Plants
  - ✯ Raises Issues of System Design Analysis, Architecture, and Modeling Simulation
- Expanded Use of Internet for Data Communication
  - ✯ Raises Issues for Monitoring, Control and "Cyber Terrorism"
- On-line Analysis System Status -- Predictive Maintenance
- Evolution of Standards

Human Factor Issues

- Reducing Capital Cost by 30%
  - Modular Designs With Fewer Operating Personnel
    - ✯ Managing Several Plant From a Remote Location
  - Reduced Preventive Maintenance--More On-Line Maintenance
  - Outsourcing
  - More Automated Systems
  - Improved Human Systems Interface; Simplifying, Even Eliminating, Operator Role
    - ✯ Improving Information Available to the Operator Post Accident
    - ✯ Knowledge of the Status of the Barriers to the Release of Fission Products
      - – Signal Validation and Condition Monitoring for Severe Accidents
- Artificial Intelligence Methods—neural Networks and Fuzzy Logic Techniques

Critical Facilities

Facility Type/Boundary	Issue	National	International
Fuel Cladding	LOCA	ANL Hot Cell B	France, Japan, Russia, Halden Blue
Fuel Cladding	RIA	TREAT	Cabri, NSRR, IGR B
Reactor Coolant	Thermal-Hydraulics	APEX, PUMA B O UMD-B&W	ROSA, SPES, PANDA, PKL Orange
Fuel Degradation	Cooling Degraded Core	None	Quench
Fuel Degradation	Fission Product Release	ORNL HI& VI Hot Cell	Phebus, VEGA VERCORS, B

Critical Facilities

Facility Type/Boundary	Issue	National	International
Steam Generator	Aerosol Deposition	None R	ARTIST B
SG Tube	Thermal-Loading, Corrosion	ANL-SG Tube Mock-up B	
RPV& Internals Material	Irradiation, EAC	ORNL, FNR, ANL B	Halden,NRG, PSI, etc B
RPV Lower Head	Mode of Vessel Failure	SNL-OECDLHF O	MASCA
Containment	Debris Coolability	MACE O	MACE, COMET O

FNR ≡ Foreign Nuclear Reactor

Critical Facilities

Facility Type/Boundary	Issue	National	International
Containment	Ex-Vessel FCI	None	FARO
Containment	Hydrogen	Surtsey, HTCF	MISTRA, RUT, LSVCTF
Cables	Aging of Cables	SNL, BNL/Wyle	
Subcritical	Reactivity Worth of Spent Fuels	LACE, SFSX, ZPPR	VALDUC, MINERVE, NUCEF, VENUS

Critical Facilities

Facility Type/Boundary	Issue	National	International
Decommissioning	Radionuclide Transport	Apache Leap Site Naturita Site NIST—Concrete ARC—Infiltration Lysimeters (ARC, INEEL)	Alligator Rivers

RES Approach for Maintaining Readiness

- Integrated Approach to Advance NRC Capabilities--Analysis Tools, Experimental Data, and Knowledgeable Staff
  - Why Independent Analysis Codes
    - ☆ Vendor Codes Are Proprietary
    - ☆ Answers Obtained by System Analysis Codes Can Vary Dramatically
    - ☆ Implementation of Risk-informed Regulation Will Require Best-Estimate Analysis Tools
- Why Do We Need Experimental Facilities
  - Complement Past Results
  - Current Models Are Unrealistically Conservative
    - ☆ Current Data Are Not Suitable for Developing Mechanistic Models
  - Plants' Design Basis Envelopes Are Being Changed
    - ☆ New Fuel and Cladding Designs, longer Fuel Cycles, Increased Core Power Levels, Higher Peaking Factors, Etc

RES Approach for Maintaining Readiness

- Experimental Facilities (Continued)
  - Introducing Provisions to Make Part 50 Risk--Informed Might Lead Into a Change in the Design Basis of Plants
    - ☆ New Models Must Be Able to Address Various Accident Conditions
  - Improve the Quality of Specific Capabilities in NRC Codes
  - Testing at Properly Scaled Facilities Is Important to Resolving Complex Difficult Issues
    - ☆ Incorporate Plant Characteristics That Influence Phenomena
- Knowledgeable Staff
  - Perform More In-House Research
  - Technically Direct Contractors' Research

Maintain Readiness

- Agency Strategic Goals (Continued)
  - Public Confidence—NRC Research
    - ✯ To a Large Extent Independent (Not Isolated) of Research Carried Out by the Industry
    - ✯ Peer Reviewed By Renowned Experts in the Filed
    - ✯ Publicly Available
    - ✯ Discussed in Open Meetings, E.G., ACRS Meetings
    - ✯ Benchmark, and Compared With Other International Research Products
    - ✯ Public Confidence Will Erode
      - – If NRC Does Not Provide Visible Examples That It Is a Technically Strong Regulatory Agency Able to Independently Assess Applicants and Licensees Proposals
- Support Risk Informed Regulation
  - Use Best-Estimate System Code As a 'Sanity Check' for Evaluation of PRA Success Criteria

Maintain Readiness

- The NRC's University Research
  - Engages Some of the Country's Best Theoretical & Experimental Scientists and Engineers
  - Provides Training for Future Government and Industry Engineers
  - Fosters and Encourage Independent Thinking About Scientific and Engineering Problems
  - Acquire Knowledge to Identify and Anticipate the Unexpected
- International Leadership
- Intangibles--Ability to Respond to Unanticipated Concerns
  - Data From International Research May Alter Present Understanding
  - RES Independent Assessment
  - An Infrastructure that is easily accessible to NRR and NMSS

RES-2010—General Issues

- Use of Fiber Optics Instead of Cables in NPP As Well As Smart Sensors, and Wireless Communications
- Extend the Capability of the TRAC-M Thermal-hydraulic Code
  - To Respond in Real Time to Events to Support the Incident Response Center
  - Analyze Thermal-Fatigue , Flow-Induced Corrosion, Steam Generator Tube Integrity
  - Asses Accident Management Strategies (Depressurization)
  - Linkage to CFD-Generated Look-up Tables to Address Mixing Issues
- Develop Containment Design Requirements to Replace Large Break LOCA
- Support for NMSS--Criticality Safety for Yucca Mountain, Medical Use of Radioactive Materials, High Enriched Fuel Transportation

RES-2010—General Issues

- Human Factor Issues—Management Organization
  - Consolidation of Industry May Lead Into Consolidation of Incident Response Centers and Technical Support Centers Into Single Center With Remote Communications
  - Roving Maintenance (Knowledge and Familiarity of the Design)
  - ATWS Emergency Procedure to Control Level Is Not Practical Due to Oscillation, Flashing, and Instrumentation Inaccuracy

Future Reactors

- The current regulatory framework and requirements are, for the most part, based upon LWR technology and current plant designs.
- There appears to be renewed interest in future plants worldwide:
  - Generation IV
  - AP-1000
  - PBMR
- RES has a role to prepare the agency for the future. This role includes preparation for future plant licensing activities
- Therefore, RES plans for future work should consider early interactions with reactor designers to:
  - Identify key safety issues
  - Identify research necessary to resolve these issues
  - Identify possible licensing framework that accounts for innovative designs and non-traditional approaches to safety

Future Reactors (cont.)

- Identify and begin development of agency infrastructure needs to support licensing
- Perform preapplication reviews

■ Consistent with NRC's Policy Statement on Advanced Reactors

■ Potential Key Safety Issues:
- Use of inherent/passive safety systems
- Greater application of new technology
- Less reliance on human actions, including reduced staffing
- Non-LWR technology (fuel, coolant, temperature, materials)
- Non-traditional approaches to defense-in-depth. E.g.,
  - ☆ Containment
  - ☆ EP
- Non-traditional missions (e.g., enhanced proliferation resistance)

Future Reactors (cont.)

- Modular design and construction
- Seismic isolation
- What accidents should the plants be designed for?
- What startup testing should be required?

■ Licensing Framework issues:

- Use of risk assessment
- Criteria for resolution of key issues

■ Infrastructure Issues:

- Analytical tools and data
- Risk methods and data
- Experimental facilities
- Plant oversight