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

September 10, 2004

MEMORANDUM TO: ACRS Members

FROM: Med El-Zeftawy, Senior Staff Engineer

SUBJECT: CERTIFICATION OF THE MINUTES OF THE ACRS SUBCOMMITTEE MEETING ON FUTURE PLANT DESIGNS, JUNE 24, 2004 -- ROCKVILLE, MARYLAND

The minutes of the subject meeting, issued on August 16, 2004, have been certified as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated

cc: J. Larkins
H. Larson
R. Caruso

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

FROM: Thomas S. Kress, Chairman
Future Plant Designs Subcommittee

SUBJECT: CERTIFICATION OF THE MINUTES FOR THE MEETING OF THE ACRS SUBCOMMITTEE ON FUTURE PLANT DESIGNS, JUNE 24, 2004–ROCKVILLE, MARYLAND

I do hereby certify that, to the best of my knowledge and belief, the minutes of the subject meeting on June 24, 2004, are an accurate record of the proceeding for that meeting.

T. S. Kress 9/9/04

Thomas S. Kress Date
Subcommittee Chairman

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

August 16, 2004

MEMORANDUM TO: Dr. Thomas Kress, Chairman
Future Plant Designs Subcommittee

FROM: Med El-Zeftawy, Senior Staff Engineer
ACRS

SUBJECT: WORKING COPY OF THE MINUTES FOR THE MEETING OF THE ACRS SUBCOMMITTEE ON FUTURE PLANT DESIGNS, JUNE 24, 2004–ROCKVILLE, MARYLAND

A working copy of the minutes of the subject meeting is attached for your review. Please review and comment on them at your earliest convenience. Copies are being provided to each ACRS Member who attended the meeting for information and/or review.

Attachment: Stated

cc: ACRS Members
J. Larkins
R. Caruso

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE SUBCOMMITTEE ON
FUTURE PLANT DESIGNS
ROOM T-2B1, 11545 ROCKVILLE PIKE
ROCKVILLE, MD
JUNE 24, 2004

PROPOSED AGENDA

TOPIC	PRESENTER	TIME
I. Introductory Remarks, ACRS	Dr. T. Kress	1:00- 1:05 pm
II. NRC Staff Presentation: - Background - Objectives - Technology-Neutral Framework	M. Drouin,RES T. King, RES J. Lehner, BNL	1:05- 3:00 pm
BREAK		3:00- 3:15 pm
III. NRC Staff Presentation: - Safety fundamentals - Risk objectives and design - treatment of uncertainties - Applications	M. Drouin, et. al	3:15- 4:45 pm
IV. General Discussion		4:45- 5:00 pm

ACRS Contact: Dr. Med El-Zeftawy (301) 415-6889
E-mail: mme@nrc.gov

NOTE:

- **Presentation time should not exceed 50 percent of the total time allocated for a specific item. The remaining 50 percent of the time is reserved for discussion.**
- **Thirty-Five (35) hard copies and (1) electronic copy of the presentation materials should be provided to the ACRS.**

INTRODUCTORY STATEMENT BY THE CHAIRMAN
OF THE ACRS SUBCOMMITTEE
ON FUTURE PLANT DESIGNS

11545 ROCKVILLE PIKE, ROOM T-2B3
ROCKVILLE, MARYLAND
JUNE 24, 2004

The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Future Plant Designs. I am Thomas Kress, Chairman of the Subcommittee.

Members in attendance are Peter Ford, Victor Ransom, Steve Rosen, William Shack, and Graham Wallis. The purpose of this meeting is to discuss the NRC staff's proposed draft technology-neutral framework document for new plant licensing. 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. Med El-Zeftawy is the Designated Federal Official for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on June 14, 2004.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register Notice. It is requested that speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

We have received no written comments, or requests for time to make oral statements from any members of the public regarding today's meeting.

(Chairman's Comments, if any)

We will now proceed with the meeting, and I call upon Ms. Mary Drouin of the NRC Office of Nuclear Regulatory Research to begin.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON FUTURE PLANT DESIGNS

June 24, 2004
Date

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NAME	AFFILIATION
John Lehner	BNL
DENNIS BLEY	BUTTONWOOD CONSULTING, INC
Vinod Mubayi	BNL
ADRIAN HEYMER	NEI
MIKE SCHOPPMAN	AREVA FRAMATOME ANP
CLIFTON FARRELL	NEI
Craig Matos	MIT

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON FUTURE PLANT DESIGNS

June 24, 2004
Date

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	NRC ORGANIZATION
AMARJIT SINGH	RES/PRAB
Mary Drouin	RES/PRAB
TOM KING	RES
JERRY WILSON	NRR/RNRP
Sherri Miotla	OIG/AIGA

Framework for a Regulatory Structure for Future Plant Licensing

Presented by
Mary Drouin, Amarjit Singh, Tom King, US Nuclear Regulatory Commission
John Lehner, Trevor Pratt, Vinod Mubayi, Brookhaven National Laboratory
Dennis Bley, Buttonwood Consulting, Inc.

June 24, 2004

PURPOSE OF MEETING

- Presentation today is to show the work in progress
- Solicit feedback (approval) on concept, scope, approach, and schedule
  - Start sharing details with public
  - Ready to start drafting proposed requirements
- Is the text detailed enough, is there enough explanation and discussion to clearly convey the concepts and approach?

AGENDA

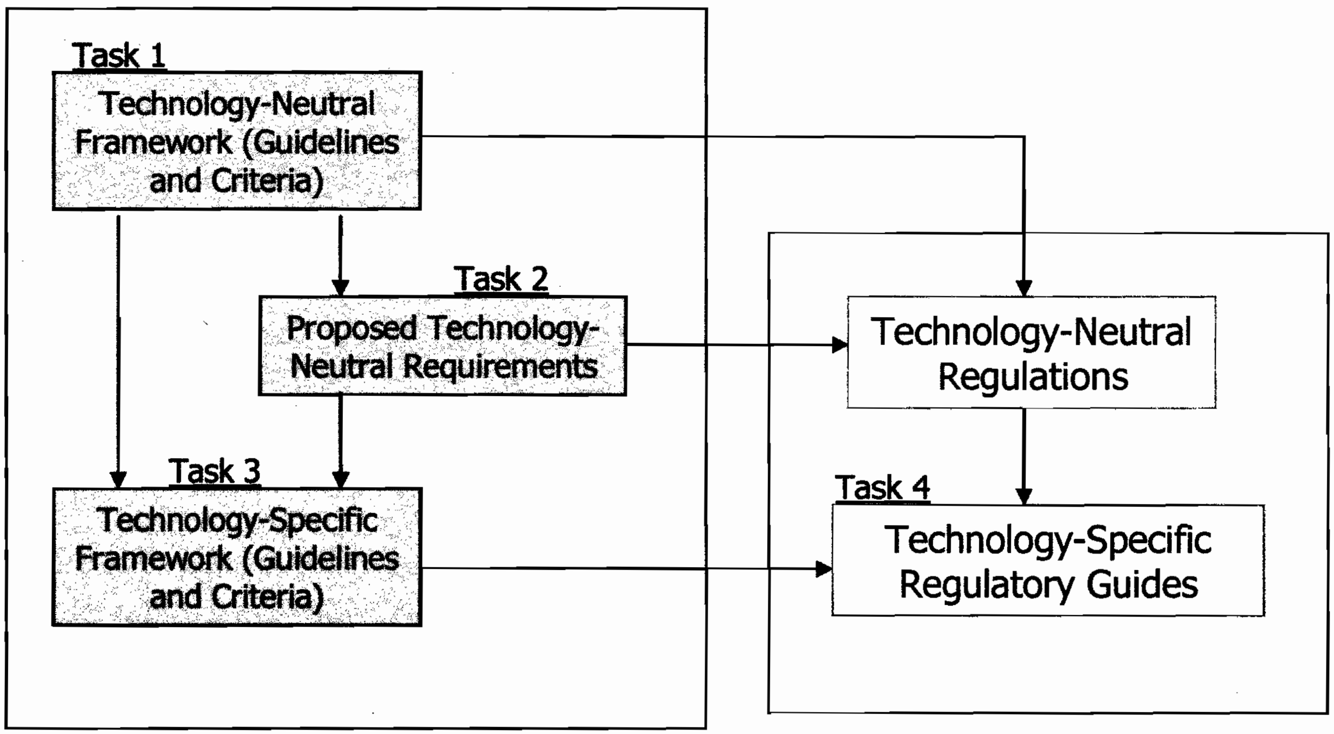
- *Chapter 1* *Overview*
- Chapter 2 Framework Roadmap
- Chapter 3 Safety Fundamentals
- Chapter 4 Risk Objectives
- Chapter 4 Design, Construction and Operation Objectives
- Chapter 5 Treatment of uncertainties
- Chapter 6 Development of Requirements
- Appendices
- Policy Issues

BACKGROUND

- Current regulations developed over 40 years
- SECY-03-59, dated 4/18/03, described the staff's plan to develop a technology neutral, risk-informed structure for new plant licensing
- Review and licensing of non-LWRs has been done case-by-case.
- SECY-03-0047, dated 3/28/03, identified key policy issues associated with licensing non-LWRs

OBJECTIVES

- Develop and implement a regulatory structure for the licensing of new reactors



FRAMEWORK OBJECTIVE

- Develop a technology-neutral framework that provides the necessary guidance and criteria, ***to the NRC staff***, to produce a set of technology-neutral requirements for rule-making consideration

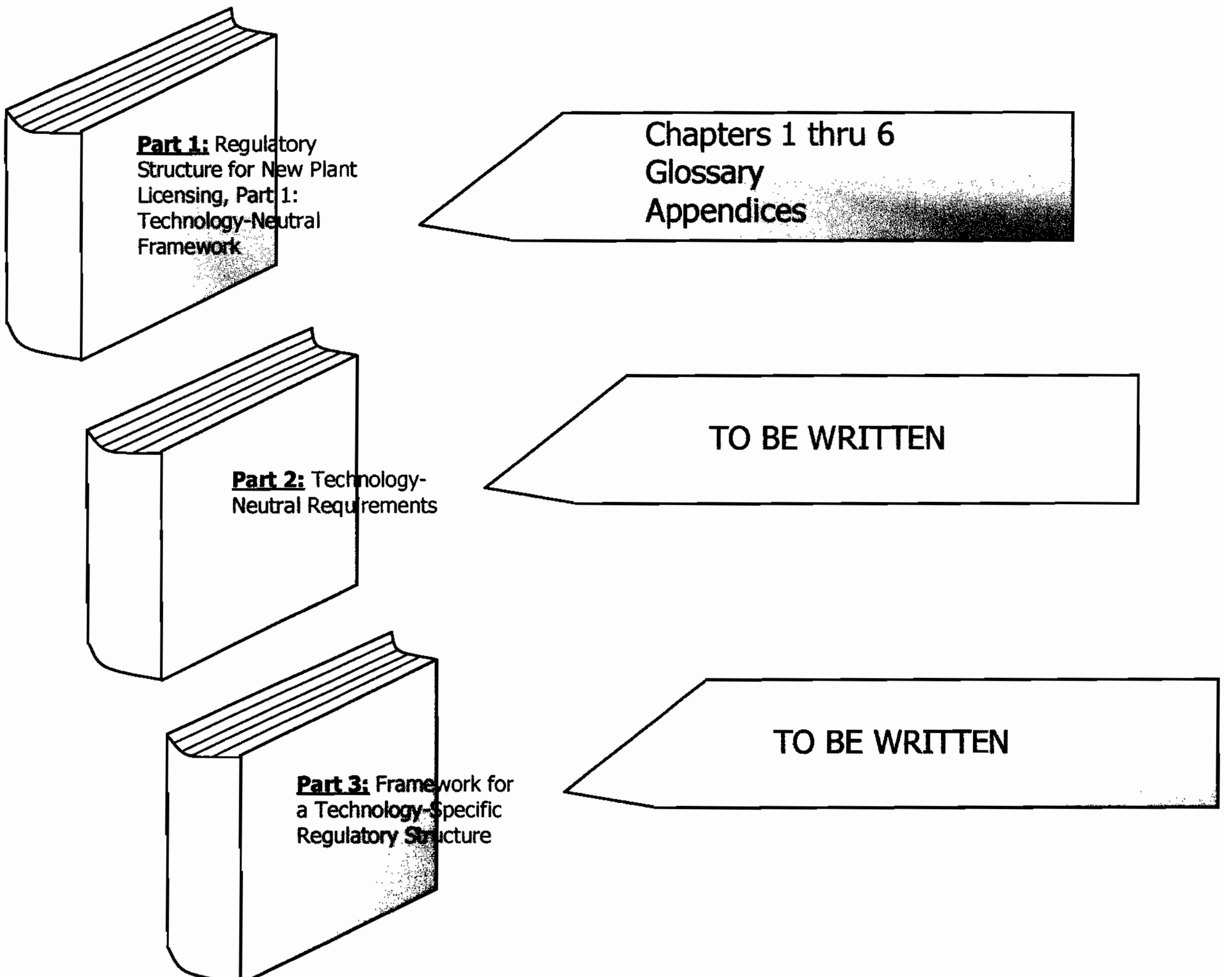
PROGRAM SCOPE

- Non-LWRs (e.g., HTGRs, liquid metal reactors, etc.)
- Advanced LWRs (e.g., IRIS)
- Public, worker, environmental protection

DESIRED CHARACTERISTICS

- Characteristics defined for an acceptable framework; how to measure that framework has accomplished its objective; examples
  - Traceable
  - Flexible
  - Risk-informed
  - Performance-based
- Are these right characteristics? Are there others, etc.?

REPORT ORGANIZATION



WORK IN PROGRESS

AGENDA

▪ **Chapter 1**	**Overview**
▪ ***Chapter 2***	***Framework Roadmap***
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FRAMEWORK

NRC's Overall Safety Mission

Atomic Energy Act and the Statutes that Amended It

Ensure Public Health, Safety and Security as a Result of Nuclear Reactor Operation and the Use of Nuclear Materials

Worker Risk ***Offsite Population*** ***Land/ Environment***

Complementary Approaches

Ch. 3

Protective Strategies

Safety fundamentals for safe NPP Design, Construction, Operation protect against unidentified uncertainties

Ch. 4

Risk Objectives & Design, Construction/Operation Objectives

Provide safety requirements, analysis for achieving safety goals

PRA shows how levels of defense support safety goals

Ch. 5

Defense-in-Depth

DID decisions are based on results of PRA and DBA calculations compared with safety/risk objectives and design expectations. PRA evaluates the specific protective strategies against risk objectives and calculates the effects of identified uncertainties.

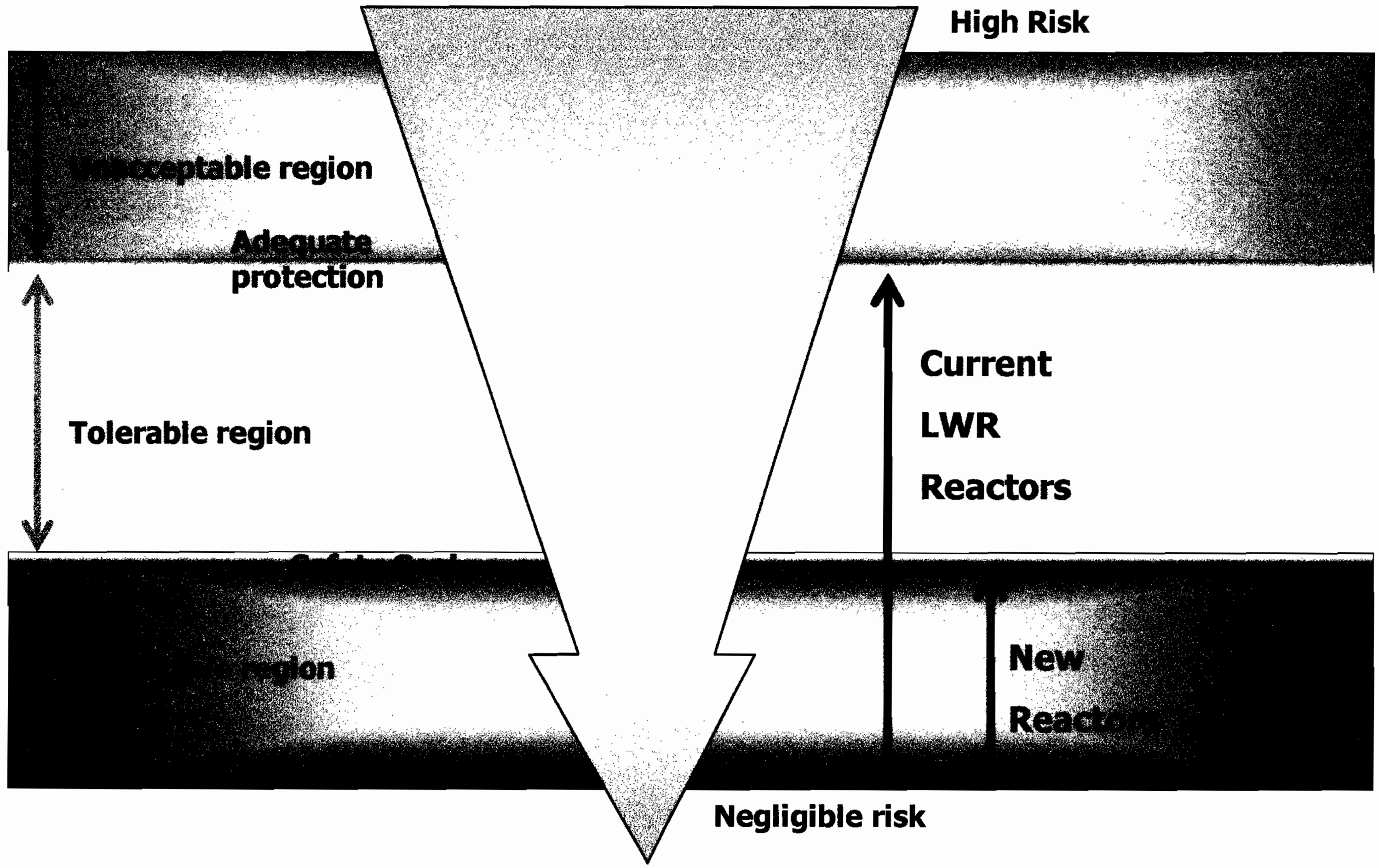
Logic confirming defense-in-depth focuses requirements

Ch. 6

Technology-Neutral Requirements

Technical requirements flow from the Framework; Administrative requirements provide assurance that analyses and plant conditions are maintained as assumed. Both can be performance-based.

FRAMEWORK SAFETY PHILOSOPHY



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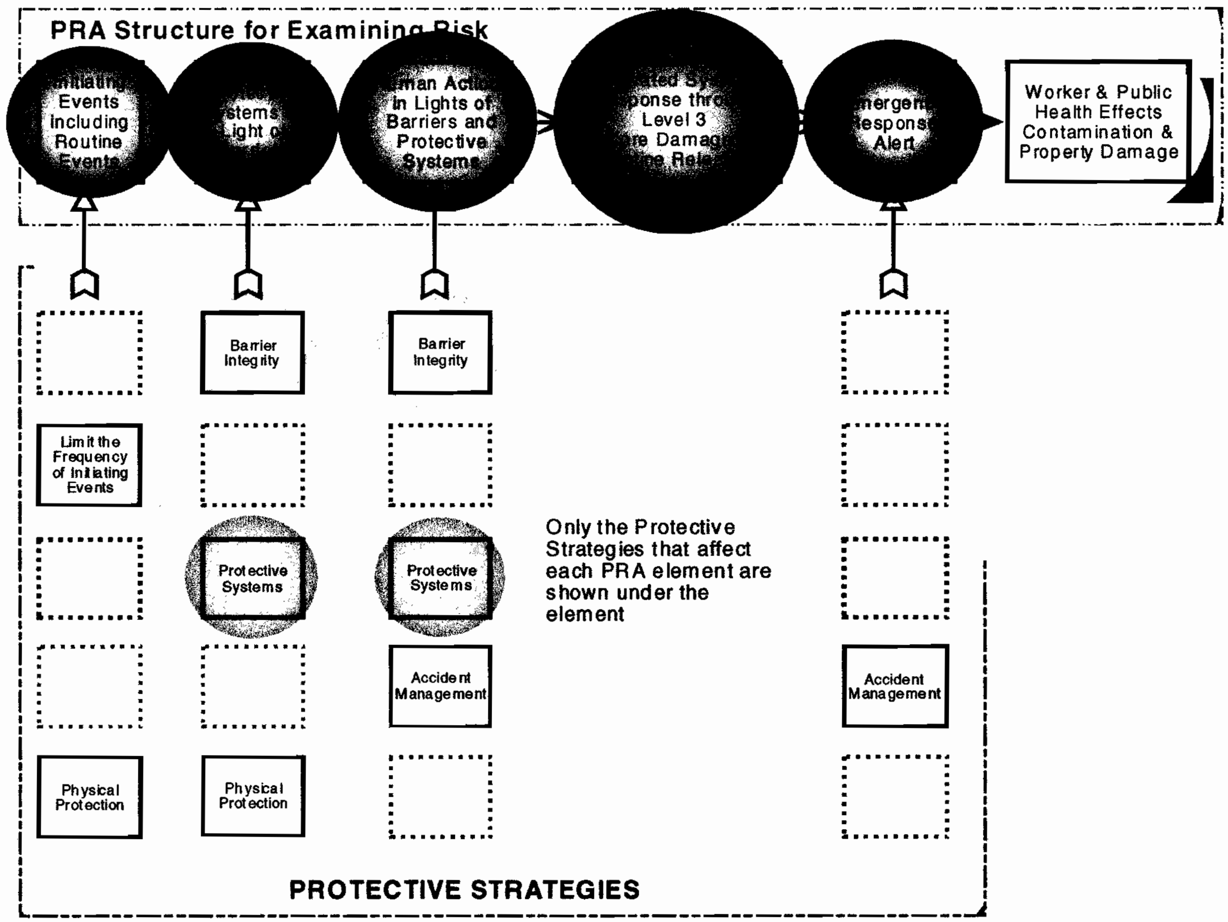
Safety Fundamentals: Protective Strategies

- What are the Protective Strategies?
  - Barrier integrity
  - Limit IE frequency
  - Protective Systems
- Design, construction and operation (shutdown, refueling, power operation, spent fuel storage)
  - Accident Management
  - (Physical Protection)
- Why are they sufficient?
  - Engineering judgment (defense-in-depth to protect against completeness & modeling uncertainties)
  - Mapping to elements of PRA
- How do we infer technology-neutral requirements?
  - Top-down analysis

Protective Strategies

- Barrier Integrity
  - Adequate to protect public from ~~accidental~~ radionuclide releases
  - Adequate functional barriers to limit the effects of reactor accidents
  - Physical barriers & physico-chemical barriers
- Limit Initiating Event Frequency
  - Events that upset plant stability & challenge critical safety functions
  - All plant operating states
  - Any source of radioactive material on-site in any form
- Protective Systems
  - Adequate design and performance (reliability and capability) to satisfy the design assumptions regarding accident prevention and mitigation during all states of reactor operation
- Accident Management
  - Include emergency evacuation plans, drills and training

Relationship between Protective Strategies and Elements of PRA



Conclusion

- Protective strategies provide a key element of defense-in-depth to protect against state-of-knowledge (epistemic) uncertainties in completeness and modeling
- Top-down analysis leads to requirements during design, construction and operation
- Analysis and development of requirements are in Chapter 6 (still in progress)

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Public Health and Safety Objectives

- Protection during normal operation
- Limited risk of accidental exposure, as defined by frequency–consequence plot
- Consistent with Commission Safety Goals

Protection During Normal Operation

- Provided by system of dose limits in Part 20
- Public dose limit of 100 mrem/year from licensed operation plus ALARA
- Consistent with recommendations of ICRP and NCRP

Risk Limits of Accidental Exposure

- Based on ICRP-64 recommendations:

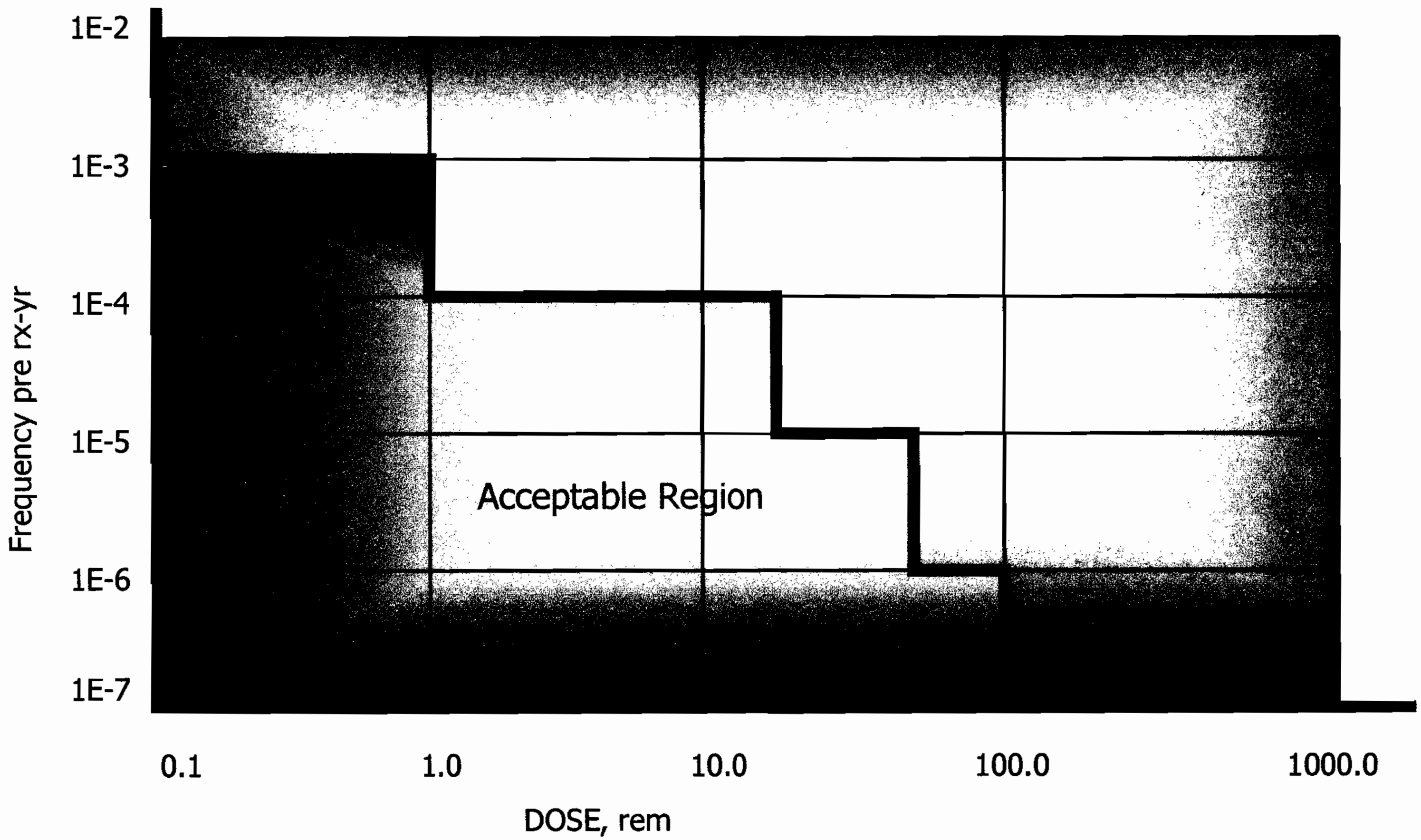
Dose ranges	Frequency ranges
▪ Doses treated as part of normal exposures	1E-1 - 1E-2 per year
▪ Stochastic effects only but above dose limits:	1E-2 - 1E-5 per year
▪ Doses where some radiation effects are deterministic:	1E-5 - 1E-6 per year
▪ Doses where death is the likely result:	< 1E-6 per year

Risk Limits of Accidental Exposure (continued)

- **Proposed dose/frequency ranges for public accidental exposures**

Dose Range	Frequency (per year)	Comment
100 mrem - 1 rem	1E-3	1 rem offsite triggers EPA PAGs
1 rem - 25 rem	1E-4	25 rem triggers AO reporting
25 rem - 50 rem	1E-5	50 rem is a trigger for deterministic effects, i.e., some early health effects are possible
50 rem - 100 rem	1E-6	In this range some early radiation health effect is likely
> 100 rem	5E-7	Above 100 rem, early health effects are quite likely and the frequency is based on the early fatality QHO of the reactor safety goal policy

Frequency-Consequence Curve



Risk Objectives

- Surrogate Risk Objectives
  - Use of surrogate risk objectives to implement the frequency-consequence curve (i.e., do not have to do a Level 3 PRA)
  - Surrogates based upon the safety goal QHOs
  - Technology neutral
  - Addresses - accident prevention and mitigation
  - Also provides for protection of the environment (i.e., same level of protection of the environment as is provided to the public)

Risk Objectives (cont'd)

- Accident Prevention Criterion
  - Serves as a surrogate for the latent fatality QHO
  - Derived from latent fatality QHO ($2X10^{-6}$/yr) considering only the effects of atmospheric dispersion:
    - No dependence upon reactor size, timing of release, form of source term
    - No dependence upon EP
  - Proposed criterion is – $1X10^{-5}$/ry (mean value)
  - Definition of what constitutes accident prevention will be technology specific
  - Applicant can propose an alternative criterion, taking credit for plant specific characteristics and/or EP

Risk Objectives (cont'd)

- Accident Mitigation Criterion
  - Serves as a surrogate for the early fatality QHO
  - Derived from early fatality QHO ($5x10^{-7}$/ry) considering only the effects of atmospheric dispersion:
    - No dependence upon reactor size, timing of release, form of source term
    - No dependence upon EP
  - Proposed criterion is – $1x10^{-6}$/ry large release frequency (mean value)
  - Large release is that associated with one or more early fatalities offsite
  - Applicant can propose an alternative criterion, taking credit for plant characteristics and/or EP

INTEGRATED RISK

- Staff assessing options for the treatment of integrated risk from multiple reactors on a site:
  - Modular designs
  - Any design
- Principles:
  - Accident prevention goals are important regardless of reactor power level (mw thermal size)
  - Accident mitigation goals may be dependent on reactor power level
- Assessing issues raised by ACRS

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Design Objectives

- Event Selection:
  - Ensures risk assessments consider a sufficient range of events to adequately assess risk consistent with the Safety Goals
  - Provides for categorization of initiating events and event sequences for deterministic treatment
  - Proposed criteria:
    - frequent events $>10^{-2}$/ry (mean value)
    - infrequent events $<10^{-2}$/ry but $>10^{-5}$/ry (mean value)
    - rare events $<10^{-5}$/ry but $>10^{-7}$/ry (mean value)
  - Initiating events and event sequences less than 10^{-7}/ry (mean value) do not have to be considered for licensing purposes

Design Objectives (cont'd)

- Selection and Treatment of AOOs/DBAs
  - Based on probabilistic event categorization criteria presented earlier
  - Select event sequences with highest consequences and/or conditionally closest to core damage as AOOs/DBAs
  - Helps ensure risk-informed (not risk-based) approach
  - Helps ensure low consequences for more frequent events
  - Provides for linkage to 10 CFR 100

Design Objectives (cont'd)

- Proposed deterministic acceptance criteria:
  - Frequent events= AOOs which must
    - not exceed 100 mrem at EAB
    - not result in loss of core cooling or fuel damage
    - maintain at least 2 barriers to the uncontrolled release of radioactive material
  - Infrequent events= DBAs which must
    - meet current siting criteria (or a fraction thereof consistent with F-C curve)
    - not result in sustained loss of core cooling or fuel melting
    - maintain at least one barrier to the uncontrolled release of radioactive material
  - External event DBA selection – use current guidance

Design Objectives (cont'd)

- Probabilistic Safety Classification Criteria
  - Criteria to be applied to all plant SSCs, not just those used in DBA analysis
  - Use risk importance measures and defense-in-depth considerations to determine safety classification
  - Build upon work done in developing 50.69 rulemaking:
    - Risk importance measures
    - System vs. component
  - Open items
    - Treatment of common cause failures
    - Treatment of cumulative effect

Design Objectives (Cont'd)

- Analysis Guidelines
  - Best estimate analysis with quantification of uncertainties
  - Risk criteria – use mean values
  - AOO/DBA criteria – 95% confidence level
  - Scenario specific equipment failures/human errors (no SFC)* criteria
  - Scenario specific source terms

Single Failure

*will also affect design

Construction Objectives

- Field fabrication – traditional NRC role (assessing NUREG-1789 for implications)
- Factory fabrication – modular construction – role of NRC?
- Non- U.S. fabrication – how to ensure applicant controls/ensures quality?
- Fuel quality (e.g., HTGR fuel) – how to ensure licensee controls/ensures quality over the life of the plant?
- Role of PRA in identifying key areas for inspection/control?

Operational Objectives

- Normal Operation
  - Training, procedures, technical specifications, etc.

- Accident Management
  - Applicant/licensee must have process to address beyond design basis accidents
  - Applicant/licensee must have an EP program (discussed further under defense-in-depth)

- Protection of Operating Staff
  - Control room must be designed to remain habitable for events external to the control room (build upon GDC-19)
  - Personnel protection and access must be considered when developing AM program
    - 10 CFR 20.1206 dose criteria for operating staff outside the control room

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Treatment of Uncertainties

- Approach
- Types of uncertainties
- Defense-in-depth
  - Principles
  - Model
  - Application

Approach

- Concept of Defense-in-Depth a fundamental part of NRC safety philosophy to treat uncertainties
  - Regulatory Guide 1.174
  - Commission White Paper
  - ACRS papers
- Consists of multiple successive layers of barriers and lines of defense against undesirable consequences
- Builds on past practice, but will result in more consistent and traceable implementation

Types of Uncertainties

- Random or stochastic (aleatory)
- State of knowledge (epistemic)
  - Parameter uncertainty – applies to basic data used in analyses (partially random)
  - Model uncertainty – applies to data limitations, analytical physical models, acceptance criteria
  - Completeness uncertainty – applies to
    - risk contributors not thought of
    - Considerations for which adequate analysis methods do not exist
    - Risk contributors deliberately excluded from analysis

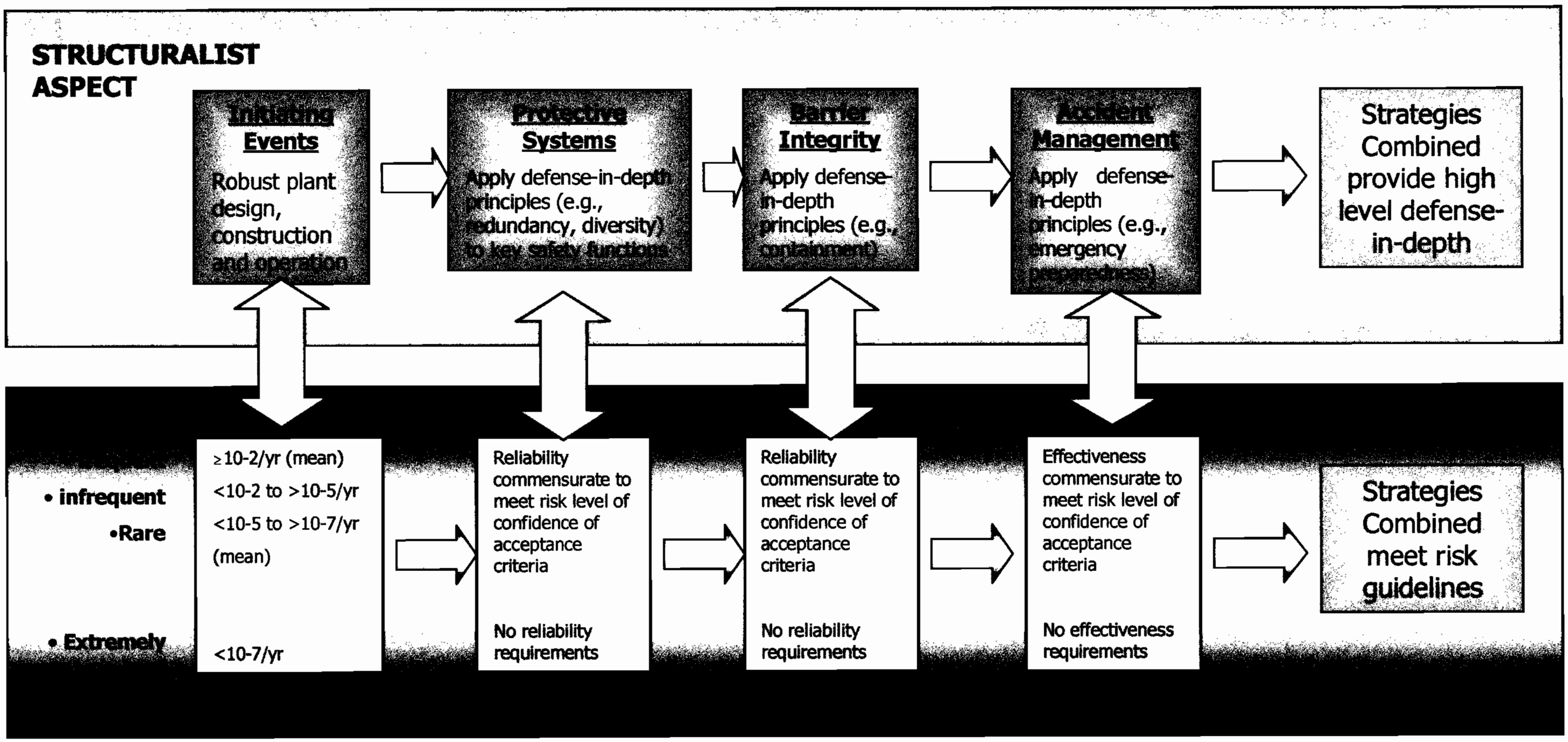
Defense-in-Depth Principles

- Balance between accident prevention and mitigation
- Key safety functions not dependent on a single element of design, construction, or operation
- Uncertainties in SSCs and human performance accounted for
- Siting consistent with intent of Part 100 and Regulatory Guide 4.7

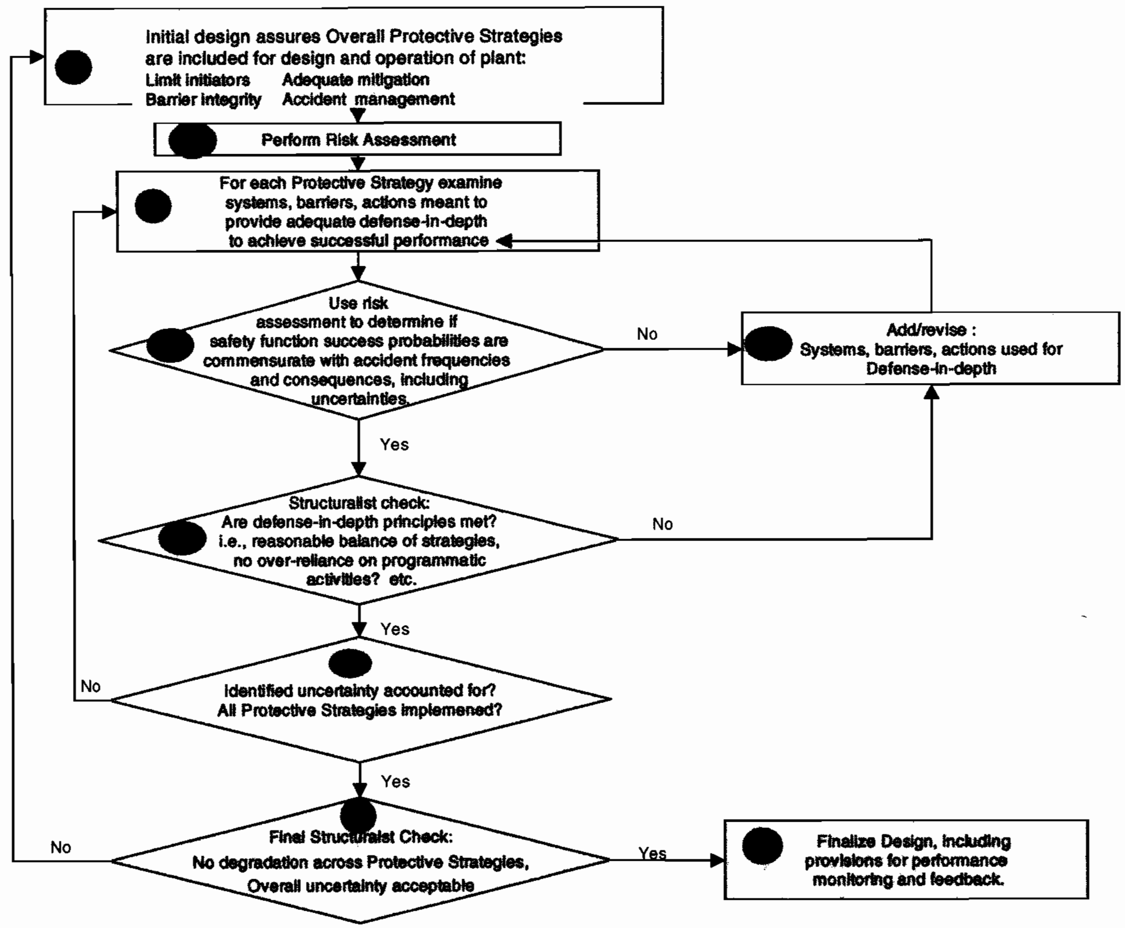
Defense-in-Depth Model

- Combination of structuralist and rationalist
  - Structuralist at high level
    - Qualitative (deterministic) requirements to assure accomplishment of protective strategies and their key safety functions
    - Addresses primarily completeness uncertainty
  - Rationalist at lower levels
    - Quantitative (probabilistic) performance goals to assure achievement of each protective strategy at required confidence
    - Specific requirements to ensure uncertainties are accounted for (safety margins, level of confidence, monitoring and feedback)
    - Addresses primarily modeling and parameter uncertainties

Defense-in-Depth Model



Defense-in-Depth Application



How DID addresses uncertainties

- Completeness uncertainty addressed by structuralist elements: barrier integrity, limit initiating events, reliable mitigating systems, accident management
- Parameter uncertainties remaining after research and testing programs addressed mainly by rationalist elements
- Model uncertainties addressed by both rationalist and structuralist elements
- Monitoring and feedback important for ensuring all uncertainties were adequately met (embodies concepts of living PRA)

How DID addresses uncertainties (cont'd)

- Structuralist Elements:
  - Redundancy and diversity for key safety functions (Reactor shutdown, decay heat removal, barriers to release of large quantities of radioactive material)
  - Containment versus confinement (policy decision)
  - Accident management and emergency preparedness (extent of EP dependent upon plant characteristics)
- Rationalist Element:
  - Reliability goals
  - Overall risk goals
  - Monitoring and feedback

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Development of Technology Neutral Requirements

- The framework describes the overall objectives, scope, criteria and technical basis to support the development of a set of technology neutral, risk-informed and performance-based requirements for future plant licensing.

- The final step in the framework is to define the scope and content of the requirements using a systematic process based upon the approach and criteria in the framework.
  - Technical and administrative requirements
  - Requirements for design, construction and operation
  - Full power, shutdown, refueling

- This step will identify topics only – writing the requirements is Task 2

Development of Technology Neutral Requirements (cont'd)

- The process to define the scope and content of the requirements consists of the following steps:
  - Identify what needs to be done to ensure the 4 protective strategies discussed in Chapter 3 are accomplished (key questions)
  - Use the criteria and processes developed in Chapters 4 and 5 to help define how to accomplish what needs to be done.
  - Identify topics for administrative requirements to ensure structure for future plant licensing is self contained. Example topics include:
    - PRA scope and quality
    - Analysis methods
    - Research and development
    - License-by-test

Development of Technology Neutral Requirements (cont'd)

- Conduct a final check for completeness, practicality, implications
  - Completeness
    - check against Commission Policy Statements, 10 CFR 50, IAEA Safety documents, etc.
  - Practicality
    - check against future plant designs (VHTR via DOE; ACR-700)
  - Implications
    - check to see if problem areas of the past are prevented (e.g., DCH, MK-I containment shell melt thru)
    - Check against current LWR

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Glossary and Appendices

- Glossary: Provide a consistent and common understanding of key terms

Appendices:

- A – Current Quantitative Guidelines
- B – Safety Characteristics of the Generation IV Future Reactors
- C – PRA Quality Needs for Future Reactors
- D – Applicable International Codes and Standards for Future Reactors
- E – Assessment of Part 50 for Future Reactors
- F -- Guidance for the Formulation of Performance-Based Requirements

Potential Policy Issues

- Other potential policy issues have resulted from work to date to develop the framework (other than those in the SECY).

- Plans are to include discussion and recommendations on the issues as part of providing the framework to the Commission in late 2004

Potential Policy Issues (cont.)

- Should the requirements have as their objective achieving the level of safety expressed in the Commission's Safety Goal Policy?
- Treatment of integrated risk?
- Should security issues be included in the scope of plant risk assessments?
- License-by-Test Approach?
- Selective implementation?

Next Steps -- Schedule

- June, 2004, brief ACRS subcommittee
- July 27/28, 2004, public workshop
- October, 2004, brief ACRS full Committee
  - Policy issues
- December, 2004, brief ACRS full committee
  - Staff will be requesting letter
- December, SECY paper to Commission and release NUREG (Part 1) for public review and comment
- Part 2: 2005
- Part 3: 2006