June 18, 2012

Dr. J. Sam Armijo, Chairman
Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

SUBJECT: REVIEW AND EVALUATION OF THE NUCLEAR REGULATORY COMMISSION SAFETY RESEARCH PROGRAM

Dear Dr. Armijo:

On behalf of the U.S. Nuclear Regulatory Commission (NRC), I am responding to your letter dated April 3, 2012, enclosing Volume 10 of NUREG-1635, "Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program."

I want to express my appreciation for the Advisory Committee on Reactor Safeguards' (ACRS's) continued valuable review and evaluation of NRC's safety research program. Throughout the years, the ACRS's evaluations and suggestions have helped to improve the program.

The agency agrees with your observation that prioritizing the research needs through the "User Need" process has worked well and has allowed the agency to develop robust technical bases for its regulatory decisionmaking in a timely manner. The Office of Nuclear Regulatory Research (RES) will strive to ensure that this approach does not hamper the development of an in-depth understanding of issues that, as your letter suggested, may be needed in the future. I would also highlight that NRC's research program is not solely reactive. RES, in concert with the program offices, anticipates emerging issues and, as a result, a substantial portion of User Need requested research is performed to develop a regulatory position prior to a technology being submitted to the agency for licensing. The staff also prepares for licensing of technologies even further afield through the Long-Term Research Program.

The staff's responses to the ACRS's specific observations and recommendations are contained in the enclosure. We will consider your recommendations as we execute the research program and develop research plans and budgets for upcoming fiscal years.

I look forward to continued interactions with the ACRS and thank the Committee for its efforts.

Sincerely,

/RA/

Gregory B. Jaczko

Enclosure:
As stated

cc: Commissioner Svinicki
Commissioner Apostolakis
Commissioner Magwood
Commissioner Ostendorff
SECY

NRC STAFF RESPONSES TO RECOMMENDATIONS
ON SPECIFIC RESEARCH ACTIVITIES CONTAINED IN
NUREG-1635, VOL. 10, "REVIEW AND EVALUATION OF THE NUCLEAR
REGULATORY COMMISSION SAFETY RESEARCH PROGRAM"

On April 3, 2012, the Advisory Committee on Reactor Safeguards (ACRS) submitted a letter to Chairman Jaczko enclosing Volume 10 of NUREG-1635, "Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program." That report contains a number of observations and recommendations about the U.S. Nuclear Regulatory Commission's (NRC's) safety research program. The NRC staff responses follow below.

CHAPTER 3 – SAFETY RESEARCH IN THE AFTERMATH OF EVENTS IN FUKUSHIMA DAIICHI NUCLEAR COMPLEX IN JAPAN

The staff appreciates the Committee's feedback on the safety research activities related to the recent events in Fukushima, Japan and agrees with the ACRS that the agency needs to continue research when implementing lessons learned from this accident. As noted in the ACRS's review of the Severe Accidents and Source Term program, the staff is fully engaged in the Fukushima assessment that may identify some deficiencies in boiling-water reactor (BWR)-specific and ex-vessel modeling capabilities and plans on efforts to obtain the required data to address these modeling deficiencies.

The ACRS encouraged RES to develop a plan to address protection from external hazards in light of recent events at Fukushima. RES fully acknowledges the importance of moving toward a probabilistic approach for external hazards such as tsunami evaluation. Currently, RES has a tsunami research program focused on developing probabilistic hazard assessment techniques in cooperation with the National Oceanic and Atmospheric Administration and the United States Geological Survey. A draft regulatory guide on tsunami hazard assessment is currently planned for 2013, and we will continue to work closely with the Offices of Nuclear Reactor Regulation (NRR) and New Reactors (NRO) to ensure its timely completion.

The ACRS recommends that RES develop "a risk-informed approach for evaluating the protection against extreme natural phenomena whether acting singly or in combination" and that "development and application of such an approach for tsunamis or floods would be a real advancement in a full scope probabilistic risk assessment." RES has initiated work to develop risk-informed information for the consideration of extreme precipitation events for Standardized Plant Analysis Risk (SPAR) models and is in discussion with NRO to define a program to develop the basis for a systematic probabilistic assessment of flooding hazards.

In addition, the ACRS made several recommendations for future research or activities in areas such as hydrogen control, operator response, material evaluations, severe accident phenomena, and others as a result of the Fukushima event. RES will consider these items during its evaluation of possible Long-Term Research Program (LTRP) projects in future years. RES also will provide the recommendations to the regulatory office for evaluation during the Fukushima lessons learned activities. In addition, if areas exist that would be better addressed through international collaborative projects, RES will consider raising these issues to the Nuclear Energy Agency's Committee for the Safety of Nuclear Installations for its review.

CHAPTER 4 – ADVANCED REACTOR DESIGNS

The staff appreciates the Committee's feedback on the advanced reactor research program. Research efforts for both Next Generation Nuclear Plant (NGNP) and integral pressurized-water reactor (iPWR) have focused on closing knowledge gaps to support potential NRC licensing reviews of specific reactor designs developed from the two broad concepts. However, DOE's decision in 2011 to not proceed in the near term to NGNP licensing has resulted in redirection of NRC resources. A few nearly complete NGNP-related research projects are being completed, with the remainder of NGNP research being terminated. Research work continues related to iPWR concepts but at a lower level than had been the case for NGNP because the regulatory knowledge gap is smaller.

CHAPTER 5 – DIGITAL INSTRUMENTATION AND CONTROL SYSTEMS

RES appreciates the Committee's support of the 2010-2014 Digital Instrumentation and Control (I&C) Research Plan that addresses critical attributes for digital and software-based technology used in nuclear power plants. The ACRS noted that activities in the Digital I&C Research Plan are technically challenging, such as the use of failure modes and effects analysis for digital systems and incorporating digital systems in PRAs. The staff will continue to focus on these particular challenges and will keep the ACRS abreast of its progress periodically.

The ACRS also highlighted that cyber security is a challenge for the agency—one specific issue being the need for licensees to update software to mitigate the vulnerabilities identified in the research vulnerability assessments. RES staff would like to clarify that the results of these research projects have been used to educate NRC staff and the digital I&C platform vendors about the different types of vulnerabilities that could exist in digital I&C systems; however, the specific results identified and the methods for how such identified vulnerabilities are addressed may differ from system-specific and site-specific systems.

The current NRC regulatory framework promotes the design, development, and operation of quality, secure digital I&C systems. Under 10 CFR 73.54, NRC established programmatic criteria that require licensees and applicants to take a life-cycle approach to cyber security in the design, development, installation, configuration, and operation of a safety system. Through the licensing review process, NRC performs a detailed review of the programmatic criteria provided in the licensees' and applicants' submitted Cyber Security Plans (CSPs). Once NRC approves the CSPs, they become part of the licensing bases. Given that cyber-based threats are constantly evolving, a review by NRC of cyber security design features early in the life cycle could generate a false sense of confidence regarding system protection throughout the life of that system. The current programmatic approach, such as the one outlined in Regulatory Guide (RG) 5.71, "Cyber Security Programs for Nuclear Facilities," provides flexibility for licensees to continually evaluate and manage cyber risks throughout the entire life cycle of the protected assets that include more than just the safety systems covered by digital I&C safety reviews. For digital I&C safety reviews, RG 1.152, "Criteria for Use of Computers in Safety Systems of Nuclear Power Plants," Rev. 3, addresses the development of reliable digital I&C safety systems. It is important to clarify that RG 1.152 Rev 3 does not explicitly exclude the review of digital I&C design features (including design features provided for cyber protection) but rather states that "the extent of the staff's review of these features is limited to ensuring that these features do not adversely affect or degrade the system's reliability or its capability to perform its safety function."

Consistent with NRC regulations governing similar operational programs, NRC will verify that licensees and applicants have complied with their CSPs through inspection. The ACRS expressed a concern that the inspectors associated with this program may not be experienced in the design of digital systems and in cyber security threats and solutions. In all cases, cyber security oversight activities will be conducted by highly trained and qualified headquarters and regional NRC inspectors specializing in digital I&C, cyber security, NRC regulations, and programmatic requirements set forth in licensees' NRC-approved cyber security plans.

As a new regulatory program, the staff recognizes the value of insights gained through additional operating experience. As a result, cyber security has been added to the agency's existing operating experience program. After the cyber security oversight program is implemented, the staff will analyze lessons learned and, if necessary, adjust the program. This approach is consistent with the ACRS letter of November 12, 2009, (ML0931301110) to the Chairman that stated, "After the initial implementation of the cyber security plans, RG 5.71 should be revised to include the resulting insights and provide guidance regarding the adequacy of cyber security plans and policies." Based upon a previous ACRS suggestion and in an effort to best conduct an integrated agency review of safety and security for digital safety systems modifications both during the licensing process and throughout all phases of a system's life cycle, the staff is developing an interoffice instruction that will document and formalize the existing interactions between the Regions, NRR, NRO, and the Office of Nuclear Security and Incident Response (NSIR) to provide more clarity regarding the integrated approach between cyber security and digital I&C reviews.

The ACRS also expressed interest in wireless technology research. The ACRS noted that providing licensing offices with more prescriptive research products and guidance may be required because of the cyber security risks and reliability challenges posed by wireless technology. The staff would like to highlight the point that no wireless application with a nexus to safety has been identified by the industry or NRC. Currently, no further wireless research is planned. However, we will work with NRR, NRO, and NSIR to address any future user needs in this area.

The ACRS noted the need for improved, hardened instrumentation in light of recent events at Fukushima. The staff is currently engaged in scoping activities and will work with NRC's Japan Lessons Learned Project Directorate to address the long-term task for evaluating hardened instrumentation for use during severe accidents.

CHAPTER 6 – FIRE SAFETY

Although the majority of fire research projects are driven by NRR and the Office of Nuclear Materials Safety and Safeguards (NMSS) user need requests, RES also anticipates emerging applications. Two examples are the development of a one-dimensional heat transfer cable functionality fire model as a byproduct of the CAROLFIRE test program and the publication of NUREG/CR-7123 on the effects of smoke on electrical equipment. The fire human reliability analysis (HRA) activities are being closely coordinated with the larger integrated HRA methodology project. Completing NUREG/CR-7114 on low-power/shutdown fire probabilistic risk assessment (PRA) will form a starting point for other low-power/shutdown risk activities. Technical evolution should be expected with use of the report. Fire effects on new digital I&C systems remains a future research activity. This work can be expected to start assuming resources become available in the future.

RES appreciates the comment and agrees that integration of fire risk into a full-scope PRA framework is a very important research activity. As the ACRS identified, the requirements of NFPA-805 and the guidance in NUREG/CR-6850 provide cornerstones for the development of risk-informed, performance-based fire protection programs and a comprehensive assessment of fire risk.

CHAPTER 7 – REACTOR FUEL

The staff appreciates the Advisory Committee's review of the reactor fuel program and, in particular, the feedback on research to develop a technical basis for regulatory qualification of zirconium-based cladding.

The ACRS noted that "the pellet clad interaction (PCI) stress corrosion failure mechanism, which is… capable of causing large numbers of fuel failures during AOOs, is not addressed in the regulations." This issue was raised to the ACRS Full Committee in June 2009, where the NRC staff stated that PCI failures are of low safety significance. Industry representatives presented various views opposing new regulatory criteria on PCI failures, and the Committee decided that this is not an immediate safety concern.

The staff believes that the assessment of risk associated with PCI is qualitatively addressed by reviewing fuel-operating limits established by each plant in accordance with NRC requirements. These limits are based on test reactor data and are considered in reviews of licensee safety analyses, thereby ensuring safety. In addition, the NRC staff continues to participate in international programs, to communicate with the international research community, and to monitor new developments concerning PCI.

The ACRS noted "the limited NRC experience with MOX fuels" and recommended "that there be a research program to follow closely the post-irradiation examination of the lead-test assemblies planned by DOE." NRC will remain abreast of these DOE post-irradiation examination results throughout the project. Sufficient information from this or similar DOE- or industry-sponsored test programs (e.g., Halden) would normally be needed to support a license amendment allowing the use of MOX fuel, and NRC will ensure that a sufficient technical basis has been established by the applicants before its use is approved.

The ACRS also noted that "there will be a continuing need for the agency to independently evaluate the safety of proposed changes in the nature and burnup limits of reactor fuel." The staff will continue to monitor domestic and international efforts to increase burnup, including data obtained from high-burnup lead-test rod and lead-test assembly programs. The staff will continue to collect and evaluate available high burnup fuel and cladding data for use in NRC regulatory decisionmaking and in updating fuel behavior codes.

CHAPTER 8 – HUMAN FACTORS AND HUMAN RELIABILITY

The staff appreciates the Committee's assessment that NRC's Human Factors (HF) and Human Reliability Assessment (HRA) research program has evolved into a carefully coordinated series of projects that are extending human factors and HRA knowledge and are providing useful products to regulators. In alignment with the Committee's recommendation and the Commission's direction as part of its Benchmarking and Model Differences projects, the staff is investigating and evaluating the validity of the assumptions behind current HRA models, developing a new HRA method (IDHEAS) to capture best practices in HRA. In addition, the

staff is developing a scientific basis for the IDHEAS method founded upon sound human factors principles. The staff will continue to keep the ACRS informed of progress in this area.

The staff also continues to improve HF and HRA methods to reduce uncertainty and promote the state of the art. These activities include the collection of licensed operator simulator training data through our collaboration with industry partners, the development of the NRC's Human Performance Test Facility for HF data collection, and the continued collaboration with the Halden Reactor Project on state-of-the-art HF and HRA issues. The staff plans to use these data sources and others to further develop and refine its HF and HRA methods.

CHAPTER 9 – MATERIALS AND METALLURGY

The Committee's assessment of the staff's efforts in environmentally assisted cracking (EAC) is factual and accurate. RES is pursuing irradiation-assisted stress corrosion cracking (IASCC) research to confirm industry data. Moreover, the staff is engaged in research in the area of void swelling using ex-vessel materials and high-flux irradiations. The staff is collaborating with domestic and international partners to leverage resources to the greatest extent possible in this very costly research area. With regard to primary water stress corrosion cracking (PWSCC), the staff has developed the robust research program needed to assess replacement materials and the effectiveness of weld overlays. The successful confirmatory testing and analyses conducted on a North Anna nozzle and the Davis Besse replacement vessel head demonstrated the excellent capabilities developed by the staff in PWSCC. The staff remains cognizant of the need to maintain the requisite technical expertise in EAC to be able to deal with uncertainties and continually evolving knowledge in the field.

The staff fully agrees with the ACRS on the need to address known and emerging materials degradation phenomena in aging light-water reactors and to monitor the effectiveness of licensees' aging management programs. We are glad to see that the Committee recognizes the value of the Expanded Proactive Materials Degradation Assessment (EPMDA) Program that will include concrete and cable insulation. The EPMDA and the voluntary ageing management program (AMP) audits conducted recently at Ginna and Nine Mile Point are significant contributors to bolstering the technical bases for subsequent license renewal. We also appreciate the ACRS's recognition of the staff's efforts to leverage research resources internationally through the International Forum for Aging Management (IFRAM) and other cooperation vehicles.

As noted by the Committee, steam generator tube integrity research continues to be an important area of research. Substantial progress has been made on understanding the initiation and progression of degradation mechanisms. The staff also has worked toward an improved knowledge of steam generator response under severe accident conditions. Confirmatory research continues to be necessary as surveillance methods evolve and new techniques are employed by the industry. The staff's efforts are enhanced by the sharing of operational experience and research results made possible by the International Steam Generator Tube Integrity Program.

The ACRS recommends that RES should expand the assessment of materials degradation to include concrete. In fact, RES already has ongoing research on the mechanisms of concrete degradation and planned projects in the Long-Term Research Program to look at nondestructive examination for concrete degradation. This work was initiated in response to concerns about the long-term performance of concrete in disposal facilities and focused on the development of an understanding of degradation mechanisms and the development of models to simulate

degradation processes. A Memorandum of Understanding with the National Institute of Standards and Technology and the U.S. Department of Energy, and a multinational cooperative research program, "The Cement Barriers Partnership," also were initiated to look into concrete performance (including issues about aging concrete in nuclear power plants). RES also participates in the multinational RILEM (International Union of Laboratories and Experts in Construction Materials) program that addresses concrete performance issues. In addition, RES is conducting research on high-radiation effects on concrete and recently concluded work on very high-temperature effects on concrete. RES work on the effects of aging degradation on containment performance is discussed in Chapter 15, "Seismic and Structural Engineering." As a result of emerging issues with regard to degradation of concrete at nuclear power plants (e.g. alkali silicate reactions), discussions are underway with NRR to define additional research in this area.

CHAPTER 10 – NEUTRONICS AND CRITICALITY SAFETY

The staff appreciates the Committee's feedback on the neutronics and criticality safety research program and agrees that research in this area is progressing well. In particular, we agree with the ACRS's recommendation to improve the scale code (fidelity, speed, uncertainty analysis, ease of use) as resources permit.

CHAPTER 11 – OPERATIONAL EXPERIENCE

The staff appreciates the Committee's evaluation of RES's activities related to operational experience and the recognition of good coordination among offices. In the discussion of operational experience, the Committee recommends initiating a program to provide the necessary technical basis needed for enhancement and integration of the various onsite emergency response capabilities and the development of command and control and decisionmaking structures. RES will support the Japan Lessons Learned Project Directorate on Near-Term Task Force Recommendation 8 (operational response to an emergency event) as needed and will continue to work with NSIR to support the NSIR mission.

CHAPTER 12 – PROBABILISTIC RISK ASSESSMENT

The staff appreciates the ACRS review and assessment of the agency's PRA research programs. In particular, the ACRS acknowledges the goal-oriented framework that has been developed to structure PRA research that will be used in support of risk-informing our regulatory processes. We agree that our research priorities are strongly aligned toward user need requests and, in particular, support the reactor oversight process. Although we welcome the ACRS's recommendation for focusing additional effort on advancing the PRA state-of-practice, resource limitations generally result in RES prioritizing regulatory offices' user need requests at a higher level than projects intended to solely to advance the state of the art. We are fundamentally a regulatory research organization and must prioritize our work consistent with regulatory needs. To the extent resources have permitted, we have engaged in research activities to further the state of the art in PRA, though admittedly these activities are not a significant portion of our annual budget. Notable examples of ongoing work that serves to further our PRA state of the art include using the agency's Long-Term Research Plan, agencywide research plans, international activities, and university cooperative agreements to advance our understanding in several areas including dynamic simulation approaches for severe accident analysis; causal-based modeling for common cause failure and human performance; digital instrumentation and control PRA; and advanced quantification techniques. We acknowledge the ACRS's recommendation that RES should continue to explore ways to

engage Regional and licensing office staff more directly in PRA research activities within the context of their mission-related activities. However, the Regions currently lack the necessary resources to support the ACRS proposal, and requiring the Regions to maintain and upgrade the SPAR models would likely divert resources from higher priority oversight tasks. In addition, placement of this work in Regions would result in a number of inefficiencies and would significantly increase program costs. Advantages of the current centralized approach for SPAR model maintenance and development include minimizing the number of highly skilled staff needed to support the program, increased consistency across the SPAR models, better version and configuration control, and the ability to more fully integrate the SPAR models with other PRA-related activities such as data collection, system studies, and new modeling improvements (e.g., support system initiators and enhanced loss of offsite power modeling). As such, NRC does not consider regional assets viable for SPAR model maintenance and support.

With regard to other specific recommendations raised in your report, RES offers the following additional information:

- Level 3 Project – Consistent with your comments regarding applications of the Level 3 PRA project results and as requested by the SRM to SECY 11-0089, the staff will be preparing a Commission paper later this year that will discuss potential uses of the Level 3 PRA project. RES agrees that we should use evolving knowledge and insights from the Level 3 project as much as possible; however, we have to remain cautious recognizing that we are studying a single site and that risk results and insights often are very plant specific.

- Digital I&C PRA – We agree that hardware and software failure modes identification is an important aspect of our research program, and we have a number of activities ongoing to address this issue. However, to support timely progress toward the goal of incorporating digital systems in nuclear plant PRAs, the staff believes we have sufficient knowledge to pursue certain research activities associated with logic model structures, quantification, and data in parallel, rather than in sequence, with the failure mode work.

- Uncertainty Analysis – We agree that consideration of uncertainty in technical analysis is central to ensuring that results are viewed within an appropriate context. However, because the recommendation that “an appropriate characterization of uncertainty is performed in all agency analyses” appears in the discussion on PRA, it might be inferred that it was meant to only apply to PRA analyses. Although risk-informed decisionmaking involves the use of information from non-PRA analyses as well, the scope of the recommendation is unclear. If the ACRS meant to apply this recommendation to all agency technical analyses, this represents an enormous effort (recognizing that many different technical disciplines have different points of view as to what constitutes an appropriate characterization of uncertainty). Within the more limited scope risk-informed decisionmaking area (and building off of the foundation of NUREG-1855, “Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking”), RES has continued to enhance the agency’s PRA infrastructure for uncertainties associated with severe accident progression, external hazards, and low power and shutdown. These efforts will continue in a manner consistent with user office needs and budget limitations.

- Consideration of Site-Level Issues for Small Module Reactor Designs – RES agrees that site-level issues can be particularly important for small module reactor designs. We will continue to work closely with the licensing office to identify appropriate research program

objectives in order to provide timely guidance and risk-tools to support the licensing review of these designs.

- Security – RES appreciates the ACRS comments regarding risk-informed security and plans to continue to work with other NRC offices to make progress in this area in a manner consistent with budget plans and user need requirements.

RES will consider these and other comments provided as we plan future PRA research activities, and we look forward to continued engagement with the ACRS.

CHAPTER 13 – RADIATION PROTECTION

The staff appreciates the Committee's positive evaluation of the radiation protection research program.

The ACRS highlighted the VARSKIN and RADTRAD codes, the Radiological Toolbox, and other computational codes. The staff also uses the Dose and Risk Calculation (DCAL), Integrated Modules for Bioassay Analysis (IMBA), Phantom with Moving Arms and Legs (PIMAL), and Monte Carlo N-Particle (MCNP) computational codes in conducting its work.

The staff agrees with the Committee's assessment that RES has been engaged in monitoring and participating in numerous national and international programs and developing technical information on potential impacts from dose limit reduction and cancer incidence and mortality in population living near nuclear facilities. The staff also agrees with the general recommendation that validation and verification, uncertainty and/or sensitivity analysis should be accompanied with computational data and results. In support of the recommendation as well as strengthening the current program, the staff has several initiatives underway:

- Enhancing the RASCAL computational code to incorporate lessons learned from the SOARCA study and the Fukushima Dai-ichi accident.

- Updating and maintaining environmental risk assessment codes, radiation protection guidance, occupational exposure databases, public health study research information, and the technical basis for new International Commission on Radiological Protection dose coefficients and the U.S. Environmental Protection Agency risk coefficients.

- Expanding international and national cooperative and collaborative research efforts in radiation safety, radiation dosimetry (e.g., DCAL, MCNP and PIMAL), bioassay interpretation (e.g., IMBA), low-dose health effects, statistical and epidemiological sampling, and confirmatory research in assessing radioactive methane radiotoxicity, radiation safety of irradiated gemstones, and ALARA in medical irradiation facilities.

CHAPTER 14 – NUCLEAR MATERIALS AND WASTE

The staff appreciates the Committee's positive evaluation of the nuclear materials and waste research program. RES is conducting an experimental program at Oak Ridge National Laboratory (ORNL) to address issues related to mechanical properties of high burnup spent fuel material under normal transportation conditions. ORNL will perform measurements of rod stiffness and cyclic loading failure (simulating the effect of transportation vibration) of high burnup fueled rodlets. Rod stiffness and cyclic loading failure are parameters used in structural

analyses and the measurements will be used to determine if industry assumptions on the impact of fuel-cladding bonding and irradiated cladding properties are conservative and acceptable, or if high burnup fuel testing should be performed by industry as part of cask licensing.

The staff also has undertaken significant research in support of extended storage and transportation (EST) of spent nuclear fuel. Specifically, RES is supporting NMSS in identifying EST technical gaps by examining vulnerabilities and state-of-knowledge for the structures, systems, and components of dry storage casks including fuel and cladding, metal containment, concrete overpacks and pads, neutron absorbers, and internal structures.

CHAPTER 15 – SEISMIC AND STRUCTURAL ENGINEERING

The staff appreciates the support of the ACRS for the seismic and structural engineering program. The staff will continue its efforts involving seismic hazard characterization and earthquake engineering.

CHAPTER 16 – SEVERE ACCIDENTS AND SOURCE TERM

The staff appreciates the Committee's feedback and support of the severe accident and source term program. The staff will continue to develop MELCOR with experimental data and perform analyses in support of resolution of operating reactor issues and new reactor design certification efforts (e.g., APWR, etc). The staff will continue to grow its severe accident knowledge and analytical capability by participating in international programs such as the European Severe Accident Research NETwork of Excellence (SARNET), NRC Cooperative Search Accident Research Program, Organization for Economic Cooperation and Development (OECD)/Nuclear Energy Agency projects, and Fukushima accident assessment efforts. The staff is fully engaged in the Fukushima assessment that may identify some deficiencies in BWR-specific modeling capabilities and will develop plans to try and obtain the required data to ameliorate these modeling deficiencies. The staff is also actively collaborating with other organizations (SARNET, EPRI, OECD/CSNI, national laboratories, etc.) on knowledge management of severe accident experimental data so that it is available for future modeling efforts.

CHAPTER 17 – THERMAL HYDRAULICS

The staff appreciates the Committee's feedback and support of the thermal-hydraulics program. The staff will continue efforts in computational fluid dynamics particularly in support of TRAC-RELAP Advanced Computational Engine (TRACE). The staff will continue to develop TRACE and gather new experimental data for validation when needed following careful evaluation of regulatory priorities. The staff will continue to participate in international programs to leverage resources. Development of the semi-empirical models in systems codes like TRACE requires experimental data and analysis for model development and validation. The staff understands the ACRS concerns that more experimental data are needed to develop and validate high fidelity models for complex phenomena. This is becoming more important because of the growing emphasis of using numerical simulation in resolving reactor safety issues, both here at NRC and the nuclear industry. The staff plans to continue its current strategy of collaboration with international and domestic institutions to obtain the data needed for validation of both systems-level and high resolution models. The staff has found this approach to be a very cost-effective strategy.

Because of our successful collaboration with other countries, NRC has not found difficulties in gaining access to needed facilities worldwide. To this end, RES has over 90 agreements with

over 30 countries and actively participates in cooperative research programs that leverage experimental facilities all over the world. RES has arranged for rotational assignments of RES employees to these facilities and will consider future opportunities as they arise and are needed.

The ACRS noted that NRC currently has a modest effort in the area of computational fluid dynamics (CFD) which is based on the use of commercial CFD codes. The ACRS also noted that licensees will inevitably capitalize on the extraordinary advances in computer power and computational science to resolve ever more complex multi-dimensional and multiphase safety issues. The NRC thermal-hydraulic staff is prepared to address these types of developments in industry and actively considers options to leverage our limited resources through national and international cooperation. Our current reliance on commercial codes is considered to be the most advantageous at this time.