Forty-Eighth Annual Meeting Program

Emerging Issues in Radiation Protection in Medicine, Emergency Response, and the Nuclear Fuel Cycle

March 12–13, 2012

Hyatt Regency Bethesda
One Bethesda Metro Center
7400 Wisconsin Avenue
Bethesda, MD 20814

NCRP
National Council on Radiation Protection & Measurements

Top: Physicians performing an interventional-radiology procedure [provided by Henry Douglas, Yale University].

Middle: TEPCO photo of the Fukushima Daiichi Nuclear Facility [http://www.tepco.co.jp/en/news/gallery/nuclear-e.html, accessed January 23, 2012].

Bottom: Emergency response personnel at the entrance to the 20 km exclusion zone around the damaged Fukushima Daiichi Nuclear Facility [provided by Steven M. Becker, University of Alabama at Birmingham].

Introduction

Emerging Issues in Radiation Protection in Medicine, Emergency Response, and the Nuclear Fuel Cycle

Forty-Eighth Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP)

Two recent events have focused public and governmental attention on issues surrounding the increasing use of ionizing radiation in medicine and industry. The first was the publication of NCRP Report No. 160, *Ionizing Radiation Exposure of the Population of the United States* (2009), which showed that medical exposures now account for about 50 % of the annual radiation dose received by the entire population of the United States. The second was the accident at the Fukushima Daiichi nuclear reactors and spent-fuel storage facilities in March of 2011. The 2012 Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP) will focus on these events and the resulting societal issues.

The meeting will begin with a session on medical exposures, with a discussion of the latest recommendations of the International Commission on Radiological Protection, the development of a safety culture in radiation oncology, patient protection in interventional radiology, and standardization of nomenclature and protocols in computed tomography scanning.

Turning to the Fukushima accident, the meeting will discuss the circumstances of the accidents and lessons learned, its environmental and community impacts, and guidance for developing community resilience for such events. Finally, the emergency response provided by U.S. federal agencies will be described, including speakers from the Centers for Disease Control and Prevention, the National Nuclear Security Administration, and others.

Each session will include a panel discussion by the invited speakers, with an opportunity for questions and comments from the attendees. The meeting is open to all individuals with an interest in radiation protection and measurements.

Monday, March 12, 2012

Opening Session

8:15 am **Welcome**
Thomas S. Tenforde, *President*

Ninth Annual Warren K. Sinclair Keynote Address

8:30 am **Childhood Exposure: An Issue from Computed Tomography Scans to Fukushima**
Fred A. Mettler, Jr.
New Mexico Federal Regional Medical Center

Radiation Protection of the Patient: An Integral Part of Quality of Care

Julie E.K. Timins, *Session Chair*

9:30 am **Radiological Protection of the Patient: An Integral Part of Quality of Care**
Claire Cousins
Addenbrooke's Hospital NHS Trust, United Kingdom

10:00 am **Enhancing Safety in Radiation Therapy: Structural and Cultural Underpinnings**
Michael Steinberg
University of California–Los Angeles

10:30 am **Break**

10:50 am **Efforts to Optimize Radiation Protection in Interventional Fluoroscopy**
Donald L. Miller
U.S. Food and Drug Administration

11:20 am **Standardization Versus Individualization: How Each Contributes to Managing Radiation Dose in Computed Tomography**
Cynthia H. McCollough
Mayo Clinic

11:50 am **Q&A**

12:20 pm **Lunch**

Implications of the Fukushima Daiichi Accident for Radiation Protection: Part I

Steven M. Becker, *Session Chair*

1:45 pm **What Happened at Fukushima and Lessons Learned**
Michael L. Corradini
University of Wisonsin–Madison

2:25 pm **Fukushima Daiichi Accident: Community Impacts and Responses**
Steven M. Becker
University of Alabama at Birmingham School of Public Health

3:05 pm **Break**

3:20 pm **Rad Resilient City: A Preparedness Checklist to Save Lives Following a Nuclear Detonation**
Monica Schoch-Spana
Center for Biosecurity of University of Pittsburgh Medical Center

4:00 pm **Q&A**

Thirty-Sixth Lauriston S. Taylor Lecture on Radiation Protection and Measurements

4:30 pm **Introduction of the Lecturer**
Roger O. McClellan

From the Field to the Laboratory and Back: The *What Ifs*, *Wows*, and *Who Cares* of Radiation Biology
Antone L. Brooks
Washington State University Tri-Cities (retired)

5:30 pm **Reception in Honor of the Lecturer**

Tuesday, March 13

8:15 am **NCRP Annual Business Meeting**

Implications of the Fukushima Daiichi Accident for Radiation Protection: Part II

Richard E. Toohey, *Session Chair*

9:00 am **U.S. Public Health Response to the Fukushima Radiological Emergency: One Agency's Perspective**
Charles W. Miller
Robert C. Whitcomb, Jr.
Jennifer Buzzell
M. Carol McCurley
Armin Ansari
Lynn Evans
Centers for Disease Control and Prevention

9:30 am **U.S. Department of Energy/ National Nuclear Security Administration's Response to the Fukushima Daiichi Nuclear Power Plant Emergency**
Joseph J. Krol, Jr.
U.S. Department of Energy

10:00 am **Break**

10:30 am **Reference Levels in the Context of Fukushima: Lessons Learned and Challenge to Radiation Protection System**
Kazuo Sakai
National Institute of Radiological Sciences, Japan

11:00 am **Findings of the Blue Ribbon Commission on America's Nuclear Future**
Richard A. Meserve
Carnegie Institution for Science

11:30 am **Q&A**

11:50 am **Closing Remarks**
Thomas S. Tenforde

12:00 pm **Adjourn**

Monday, March 12, 2012

Opening Session

8:15 am

Welcome
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National Council on Radiation Protection and Measurements

Ninth Annual Warren K. Sinclair Keynote Address

8:30 am

Childhood Exposure: An Issue from Computed Tomography Scans to Fukushima
Fred A. Mettler, Jr.
New Mexico Federal Regional Medical Center

Potential radiation effects on children have been, and will continue to be, of great social, public health, scientific, and clinical importance. The focus of interest on ionizing radiation and children has been clear for over half a century and ranges from interest in the effects of fallout from nuclear weapons testing to exposures from accidents and medical procedures. There is a common expression that "children are three to five times more sensitive to radiation than adults." Is this really true? In fact, children are more at risk for some health effects but not all. For a few effects children may be more resistant. Which are those effects and why do they occur? While there are clear instances of increased risk of some tumors in children compared to adults, there are other tumor types in which there appears to be little or no difference in risk by age at exposure, and some in which the published models are not supported by the data. The United Nations Scientific Committee on the Effects of Atomic Radiation has formed a task group to produce a comprehensive report on the subject. The factors to be considered include relevant radiation sources, developmental anatomy and physiology, dosimetry and stochastic and deterministic effects.

Radiation Protection of the Patient: An Integral Part of Quality of Care

Julie E.K. Timins, *Session Chair*

9:30 am

Radiological Protection of the Patient: An Integral Part of Quality of Care
Claire Cousins
Addenbrooke's Hospital NHS Trust, United Kingdom

Modern medicine now demands rapid diagnosis and treatment often centred on multiple investigations using ionizing radiation, particularly computed tomography (CT). Technological development continues at a rapid pace and there is also an inexorable rise in minimally invasive therapy using fluoroscopically-guided techniques. This has offered great benefit to many patients, who otherwise may not be fit enough for more invasive surgery. However, there are now many younger patients being treated using such techniques, where the risks of radiation in the longer term become more of an issue.

Patient dose, and hence, risk can be managed in different ways. Justification and optimization are important principles of radiological protection of the patient, although dose limitation is not applicable in medical practice. It is also important that health professionals are educated to ensure there is justification of investigations and procedures for individual patients. Without such measures, there is a danger that repeated CT scans may be requested and performed as frequently as plain x rays. Any examination also requires appropriate optimization and increasingly, in many subspecialty areas, this necessitates dedicated and specialized teams.

Diagnostic reference levels (DRLs) have been used as a tool to monitor the performance of departments locally, regionally or nationally by establishing a range of doses considered acceptable for different diagnostic examinations. These allow for the identification of "outliers" both above and, also importantly, below the range. However, a DRL should not be applied to an individual patient. More recently, the concept of a DRL is being extended to both radiological and cardiological interventional procedures, where the range of doses is much wider, even for the same procedure. Standardization of data with regard to patient size and weight is an issue and revision of the data produced over the last 10 to 15 y will become necessary as these parameters continue to increase.

The education and training of health professionals in radiological protection needs to be appropriately structured for referrers and operators. Those performing procedures using ionizing radiation require expertise to both complete the procedure and to reduce radiation dose wherever possible. There is also a trend towards the increasing use of ionizing radiation by professionals outside a radiology department, often with little or no training, and this issue will have to be addressed to ensure continuing radiological protection of patients. Such training is expensive in terms of human resource and time, and the number of individuals available to deliver the training is often limited. The International Commission on Radiological Protection has and will publish guidance on training and dose management in these situations.

Parameters to assess the quality of healthcare typically include rates of morbidity, mortality, complications, and waiting times. Yet, the radiation dose to the U.S. population from medical radiation is now almost equal to that of background radiation. Much of this exposure has been a benefit to patients with regard to timely diagnosis and less invasive treatment. Amidst the many factors that constitute good management of the patient, it must not be forgotten that radiological protection of the patient is also an integral part of the total quality of care.

10:00 am

Enhancing Safety in Radiation Therapy: Structural and Cultural Underpinnings

Michael Steinberg
University of California–Los Angeles

Radiation therapy is efficacious for the treatment of many cancers. The complexity of radiation therapy has increased steeply in the past 15 y. Technological developments have led to the automation of complex treatment planning and treatment delivery processes, the addition of in-room imaging systems including cone-beam computed tomography, and the proposal to enable modification of the treatment plan based on the patient's radiation response, a process termed adaptive radiation therapy. These technologies have provided the ability to increase the radiation conformality and precision, improving the outcomes for many radiation therapy patients. This increase in treatment sophistication and complexity requires a commensurate enhancement of quality assurance procedure intricacy and erudition.

Reports of radiation overdoses and misadministrations have come to the attention of healthcare providers and have appeared in the press, highlighting some of the new risks generated by the emerging treatment paradigm. While radiation therapy is extremely safe, the public and radiation therapy professionals want to improve the safety record. There are many initiatives taking place in the radiation therapy professional associations to guide users in methods of improving the safety and quality of treatments. However, most of these either reemphasize or expand on the quality assurance paradigms that were developed prior to this new era of increased complexity.

The fact is that in order to significantly improve the radiation therapy safety track record, we will have to make significant changes in our training, workflow, and monitoring as well as address important cultural aspects of organizational change required to improve safety outcomes. To this end, the main stakeholders in radiation therapy, including physicians and medical physicists, professional organizations, the U.S. Food and Drug Administration, equipment manufacturers, software manufacturers, and patient advocates, will need to come together to articulate a systematic approach to significantly improve safety in radiation therapy. We propose that the components of the plan include: safety recording, monitoring, standardization, training, accreditation, and a robust organizational social infrastructure to implement the safety culture.

- *Safety recording*: An important ingredient in developing a long-term plan to increase radiation therapy safety is having data that tell us the types and causes of errors. Individual institutions are beginning to develop such reporting systems, but to date, there are few and without interconnectivity or data sharing. A broad, national and required reporting system is recommended so that radiation therapy can more accurately gather data and plan safety improvements.
- *Monitoring*: The independent verification that prescribed safety procedures are optimal and correctly implemented. This includes internal and external peer review and in the future will also include automated computer-controlled monitoring systems.
- *Standardization*: The development and use of standardized treatment directives, policies and procedures. Currently, most clinics develop their own procedures based on individual training, conventional wisdom and biases of their providers. This results in wide variation in practice. However, absent treatment outcome differences due to the variation and the potential risk for increased mistakes in treatment delivery, there is little rationale to continue this wide-ranging approach. The safety benefit of standardization would be that sophisticated risk analyses could be broadly implemented.
- *Training*: This includes the concept of retraining using simulations that have built-in errors. Radiation therapy simulations could be used to train, retrain, and evaluate effectiveness of staff in detecting and mitigating errors.
- *Accreditation*: Properly conducted accreditation can ensure minimum

standards of care and safety in each facility.

- *Safety culture*: Beyond implementation of the robust safety infrastructure, the social and cultural aspects of embracing attitudes of "no-fault" reporting in the context of the pursuit of zero mistakes completes the components of an effective approach to safety for radiation therapy.

10:30 am **Break**

10:50 am **Efforts to Optimize Radiation Protection in Interventional Fluoroscopy**

Donald L. Miller
U.S. Food and Drug Administration

While it has been known for decades that fluoroscopy presents radiation risks to both the physician and the patient, patient skin injuries from fluoroscopy became increasingly rare after the 1930s, and radiation risk appeared to be adequately controlled. Beginning in approximately 1975, new technologies and materials for catheters, guide wires, and other interventional devices were developed, and new devices and procedures were introduced. Skin injuries began to occur in patients. These injuries provoked changes in technology and practice that continue today.

At a 1992 American College of Radiology/U.S. Food and Drug Administration workshop, four central issues were identified:

- equipment;
- quality management;
- operator training; and
- occupational radiation protection.

Equipment issues included an inconsistent relationship between radiation dose and image quality, abuse of the high-dose fluoroscopy mode, inability to monitor patient radiation dose, and a lack of dose metrics other than fluoroscopy time. Quality management was inadequate-dose and was neither monitored nor recorded and there was no patient follow-up for radiation effects. Nonradiologist operators typically had little or no training in radiation safety. Other than standard lead aprons, no radiation protection was typically available for operators and staff, because none had been thought necessary.

Numerous advances in equipment design have occurred in the past 20 y. These include digital fluoroscopy, pulsed fluoroscopy, anatomic programming, virtual collimation, stored fluoroscopy loops, automatic spectral filtration, and radiation dose monitoring. Radiation dose monitoring and measurement are among the most important innovations.

In the United States, most physicians who performed interventional-fluoroscopy procedures were not familiar with the new dose measurement capabilities of their fluoroscopy systems, and did not take advantage of them. In any event, no benchmark data were available for comparison. In the past decade, attempts have been made to automate dose data collection and to adapt the concept of reference levels to interventional fluoroscopy. Preliminary U.S. reference levels have been developed for some interventional-radiology procedures, but a national dose registry is a necessary next step.

Europe leads the United States in regard to operator training. AAPM Report No. 58, *Managing the Use of Fluoroscopy in Medical Institutions* (1998) recognized the need for a process for training and credentialing users of fluoroscopy equipment. This was still an issue when NCRP Report No. 168, *Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures*, was released in 2010. As of

2011, only 27 states have enacted legislation regarding radiation education for operators of fluoroscopic procedures. In the United States, most guidelines for training in radiation protection and radiation management have come from professional societies.

NCRP Report No. 122, *Use of Personal Monitors to Estimate Effective Dose Equivalent and Effective Dose to Workers For External Exposure to Low-LET Radiation* (1995) and Report No. 133, *Radiation Protection for Procedures Performed Outside the Radiology Department* (2000) provided specific recommendations for radiation monitoring of individuals who participate in fluoroscopically guided procedures. Current algorithms for estimating effective dose to staff tend to overestimate effective dose, and it is possible that none are optimal for all interventional procedures. This is a minor problem, however, in view of the 25 to 50 % of interventionalists who deliberately refrain from wearing their monitors.

The 2011 *ICRP Statement on Tissue Reactions* recognized the radiation sensitivity of the lens of the eye. It has become clear that physicians and staff involved in interventional-fluoroscopy procedures are at risk of developing radiation-induced lens opacities. Recently, professional societies have issued guidance on occupational radiation protection during fluoroscopically-guided procedures, emphasizing the importance of dose monitoring, optimizing personal protection, and optimizing patient dose. NCRP Report No. 168 addresses these subjects in considerable detail.

Challenges remain for the future, especially in regards to radiation dose recording, quality improvement, and training. However, with the increasing awareness of the importance of these issues, increased attention and resources are being devoted to them.

11:20 am

Standardization Versus Individualization: How Each Contributes to Managing Radiation Dose in Computed Tomography

Cynthia H. McCollough
Mayo Clinic

The radiation required for a computed tomography (CT) examination is dependent on patient size and also highly dependent on the diagnostic task. Thus, individualization of scan parameters is essential to managing dose on a patient-by-patient basis and to achieving the image quality required for the specified diagnostic task.

Standardization, however, is also important to providing high-quality medical care. Variations in the dose delivered and/or the image quality obtained must be identified and reduced. One valuable tool used to accomplish this is use of diagnostic reference levels. For a specific patient size and exam type, surveys of doses in routine clinical practice are performed to determine the distribution of actual doses, and to set diagnostic reference levels (typically, the 75th percentile of the distribution). When a site consistently exceeds these levels, an investigation should occur to determine if and how the site could reduce their dose settings.

Stratification of the results of dose surveys according to patient size is essential, because in the x-ray energy range used in CT, approximately half of the photons are removed from the beam for approximately every 4 cm of tissue traversed. Thus, to deliver the same number of photons to the detector (hence, producing the same level of image noise), the scanner output must be doubled for every 4 cm of additional patient attenuation above standard patient size and halved for every 4 cm of tissue below a standard patient size. A reasonable level of adaptation relative to a "standard" adult (~70 to 80 kg) would be decreasing scanner output by about a factor of five for a newborn, and increasing scanner output by as much as a factor of 10 for a morbidly obese adult.

However, even in reports that have accounted for variations in patient size, considerable variability exists in current clinical practice with regard to the scanner output levels used for similar diagnostic tasks. Hausleiter and colleagues found approximately a factor of two variation in typical output levels for cardiac CT angiography, with the primary predictor of higher scanner output levels being the type of scanner used. However, considerable variability existed between sites using the same scanner model. Raff and colleagues found that this site-to-site variation, and the overall dose levels used, could be reduced through educational initiatives.

One difficultly in such educational efforts, however, is that in CT, acceptable image quality and dose can be achieved using many different combinations of scan parameters. There is no single "right answer." In a movement toward standardization of best practices in CT imaging, the American Association of Physicists in Medicine, with participation from the American College of Radiology, the American Society of Radiologic Technologists, the U.S. Food and Drug Administration, and each of the major CT scanner manufacturers, has begun establishing, and making publically available, a set of reasonable scan protocols for frequently performed CT examinations. These protocols summarize the basic requirements of the exam and give several model-specific examples of reasonable scan and reconstruction parameters. This allows individual users to benchmark their protocols against a reference standard that has received significant peer review, providing guidance as to "best" (or at least reasonable) practices. In addition, the working group has developed and published a CT Lexicon to allow users to translate important CT acquisition and reconstruction terms between different manufacturers' systems, each of which uses brand-specific names to describe similar parameters. The lexicon represents a first step in the ongoing efforts of several organizations to standardize the terminology associated with CT scan parameters.

11:50 am **Q&A**

12:20 pm **Lunch**

Implications of the Fukushima Daiichi Accident for Radiation Protection: Part I

Steven M. Becker, *Session Chair*

1:45 pm

What Happened at Fukushima and Lessons Learned

Michael L. Corradini
University of Wisconsin–Madison

The earthquake, which occurred at 2:46 pm on Friday, March 11th on the east coast of northern Japan, is believed to be the one of the largest earthquakes in recorded history. Following the quake on Friday afternoon, the plants at Fukushima Daiichi, Fukushima Daini, Higashidori, Onagawa, and Tokai Daini sites were affected and emergency systems were activated. The Tohoku earthquake caused a tsunami, which hit the east coast of Japan, and caused a loss of all on- and off-site power at the Fukushima Daiichi site, leaving it without any emergency power. The resultant damage to fuel, reactor and containment caused a release of radioactive materials to the region surrounding the plants. Although not directly affected, the U.S. nuclear power industry will take lessons from this accident.

The American Nuclear Society (ANS) formed a special committee to examine the Fukushima Daiichi accident. The committee was charged to provide a clear and concise explanation of the accident events, health physics, and accident cleanup as well as safety-related issues that emerged. The committee also evaluated actions that ANS should consider to better communicate with the public during a nuclear event.

The committee used publically available source material from the Japanese industry and government as well as their reports to the international community as indicated in the references. The committee views do not reflect any major inconsistencies regarding accident events, health physics, and accident cleanup. The safety-related recommendations identified by the committee are consistent with what has been noted in the reports already issued from many regulatory agencies. Finally, the committee focused on risk communication as a major issue that the ANS needs to address in the future.

2:25 pm

Fukushima Daiichi Accident: Community Impacts and Responses

Steven M. Becker
University of Alabama at Birmingham School of Public Health

In response to the March 2011 Japan earthquake-tsunami disaster and the Fukushima Daiichi nuclear accident, a special nongovernmental Radiological Emergency Assistance Mission flew to Japan from the United States. Invited by one of Japan's largest hospital and health-care groups, and facilitated by a New York-based international disaster relief organization, the mission included an emergency physician, a health physicist, and a disaster management specialist. All three team members had extensive experience with radiation issues and radiological/nuclear disasters and emergencies. During the 10 d mission, which began in April 2011, team members conducted fieldwork in areas affected by the earthquake, tsunami, and nuclear accident; visited cities and towns in the 20 to 30 km Emergency Evacuation Preparation Zone around the damaged nuclear plant; visited other communities affected by the nuclear accident; met with mayors and other local officials; met with central government officials; and exchanged observations, experiences and information with Japanese medical, emergency response, and disaster management colleagues. Perhaps most importantly, the mission also provided radiological information and training to more than 1,100 Japanese hospital and healthcare personnel and first responders. Based on this on-scene work, the mission produced many insights with potential relevance for radiological/nuclear emergency preparedness and response. Several key "lessons learned" were published in December 2011. Since that time, many additional insights from the mission and mission follow-up have been identified. In this presentation, these additional lessons learned—particularly those related to community impacts and responses—will be highlighted.

3:05 pm **Break**

3:20 pm **Rad Resilient City: A Preparedness Checklist to Save Lives Following a Nuclear Detonation**

Monica Schoch-Spana
Center for Biosecurity of University of Pittsburgh Medical Center

The Rad Resilient City Checklist is a local planning tool that can help save tens of thousands of lives following a nuclear detonation. If prevention of nuclear terrorism fails, then reducing exposure to radioactive fallout is the intervention that can save the most lives following a nuclear detonation. Yet, most Americans are not familiar with correct safety measures against fallout, and many believe that nothing can be done to reduce the suffering and death inflicted by a nuclear attack. Moreover, cities have no checklist on how to prepare the emergency management infrastructure and the larger population for this hazard, despite hundreds of pages of useful guidance from the federal government and radiation professional organizations. The Rad Resilient City Checklist reverses this situation by converting the latest federal guidance and technical reports into clear, actionable steps for communities to take to protect their residents from exposure to radioactive fallout. The checklist reflects the shared judgment of the Nuclear Resilience Expert Advisory Group, a national panel led by the Center for Biosecurity and comprised of government decision makers, scientific experts, emergency responders, and leaders from business, volunteer and community sectors.

4:00 pm **Q&A**

Thirty-Sixth Lauriston S. Taylor Lecture on Radiation Protection and Measurements

4:30 pm

Introduction of the Lecturer
Roger O. McClellan

From the Field to the Laboratory and Back: The *What Ifs*, *Wows*, and *Who Cares* of Radiation Biology

Antone L. Brooks
Washington State University Tri-Cities (retired)

My scientific journey started at the University of Utah chasing fallout, it was on everything, in everything, and was distributed throughout the ecosystem. This resulted in radiation doses to humans and caused me great concern. From this concern I asked the question. Are there health effects from these radiation doses and levels of radioactive contamination? I have invested my scientific career trying to address this basic question. While conducting research I became acquainted with many of the ***what ifs*** of radiation biology. The major ***what if*** in my research was; What if we have underestimated the radiation risk for internally deposited radioactive material? While conducting research to address this important question many other ***what ifs*** came up related to dose, dose rate, and dose distribution. I also encountered a large number of ***wows***. One of the first was when I went from conducting environmental fallout studies to research in a controlled laboratory. The activity in fallout was expressed as pCi L^{-1} whereas it was necessary to inject laboratory animals with μCi g^{-1} body weight to induce measurable biological changes, chromosome aberrations, and cancer. ***Wow***, that is seven to nine orders of magnitude above the activity levels found in the environment. Other ***wows*** have made it necessary for the field of radiation biology to make important paradigm shifts. For example, one shift involved changing from "hit theory" to total tissue responses as the result of bystander effects. Finally, ***who cares*?** While working at the U.S. Department of Energy headquarters and serving on many scientific committees I found that science does not drive regulatory and funding decisions. Public perception and politics seem to be major driving forces. If scientific data suggested that risk had been underestimated—everyone cared; when science suggested that risk had been overestimated—no one cared. This result dependent ***who cares*** was demonstrated as we tried to generate interactions by holding meetings involving individuals involved in basic low dose research, regulators, and the news media. As scientists presented their "exciting data" that suggested that risk was overestimated many of the regulators simply said we cannot use such data. The newspaper people simply said it is not possible to get such information by my editors. In spite of these difficulties research results from basic science must be made available and considered by the public as well as by those that make regulatory recommendations. Public outreach and sharing of the data are critical and must continue to be a future focus to properly address the question of ***who cares***. My journey in science, like many of yours, has been a mixture of chasing money, punishment, beatings, and joys of unique and interesting research results. Perhaps we can, through our experiences, improve research environments, funding, and use of the valuable information that is generated. Scientists that study at all levels of biological organization from the environment, to the laboratory and human experience must share expertise and data to address the ***what ifs*, *wows*,** and ***who cares*** of radiation biology.

5:30 pm **Reception in Honor of the Lecturer**

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Tuesday, March 13

8:15 am **NCRP Annual Business Meeting**

Implications of the Fukushima Daiichi Accident for Radiation Protection: Part II

Richard E. Toohey, *Session Chair*

9:00 am **U.S. Public Health Response to the Fukushima Radiological Emergency: One Agency's Perspective**

Charles W. Miller
Robert C. Whitcomb, Jr.
Jennifer Buzzell
M. Carol McCurley
Armin Ansari
Lynn Evans
Centers for Disease Control and Prevention

On March 11, 2011, northern Japan suffered first a magnitude 9.0 earthquake centered ~208 km off the eastern coast and then an ensuing tsunami. These natural events caused widespread death and destruction in Japan. One location hit was the Fukushima Daiichi Nuclear Reactor Complex. The destruction at this site initiated a cascade of events that led to multiple reactors overheating, core meltdown, and radionuclide releases causing widespread radioactive contamination of residential areas, agricultural land, and coastal waters. The public health and medical community in Japan faced many challenges as a result of these multiple events. Our sympathies go out to the Japanese people, who will be dealing with the consequences of this incident for years to come.

As the radionuclide releases from the Fukushima Daiichi Nuclear Reactor escaped into the atmosphere and the ocean, the impact of this disaster was felt around the world. Like many other nations, the U.S. public health system was concerned about the safety of both its citizens living in Japan and citizens residing in the United States as the radioactive materials released from Fukushima were detected in trace amounts as they traveled around the globe. As with any crisis, these events present opportunities to learn and prepare for similar incidents in the future. Events in both Japan and the United States during the response illustrated some U.S. preparedness gaps that previously had been anticipated, and others that were newly identified. The Secretary of Health and Human Services has forwarded a report to the National Security Staff discussing public health preparedness gaps and challenges identified by the Fukushima incident. Some of these gaps include the following:

- equipment and personnel resources to monitor potentially-exposed people for radioactive contamination is insufficient;
- there is no public health authority to detain people contaminated with radioactive materials;
- public health and medical expertise, and treatment capacities, for response to radiation emergencies are limited;
- there is an insufficient number of radiation health experts;
- public health communications regarding radiation emergency preparedness, health effects of radiation exposures, resilience, and response actions are inadequate;
- national and international exposure standards for radiation measurements (and units) and protective action guides lack uniformity;
- access to radiation emergency monitoring data is limited and procedurally complex; and
- the policy on stockpiling potassium iodide in the Strategic National Stockpile should be revisited.

This event was a major disaster for the people of Japan, but it was also a significant public health emergency for the U.S. public health community. We should capitalize upon this rare opportunity to improve our public health preparedness based on the experience of our Japanese colleagues and our own.

9:30 am

U.S. Department of Energy/National Nuclear Security Administration's Response to the Fukushima Daiichi Nuclear Power Plant Emergency

Joseph J. Krol, Jr.
U.S. Department of Energy

The Office of Emergency Operations from the U.S. Department of Energy (DOE) National Nuclear Security Administration deployed an emergency response team to Japan to conduct aerial and ground-based environmental radiation monitoring following the accident at the Fukushima Daiichi Nuclear Power Station. The team partnered with U.S. Forces Japan to support both U.S. military and government of Japan objectives. The deployed team was supported domestically by the Radiation Emergency Assistance Center/Training Site, the National Atmospheric Release Advisory Center, and the DOE Consequence Management Home Team. An overview of the activation, deployment, capabilities, response objectives, coordination, and activities will be discussed.

10:00 am

Break

10:30 am

Reference Levels in the Context of Fukushima: Lessons Learned and Challenge to Radiation Protection System

Kazuo Sakai
National Institute of Radiological Sciences, Japan

After the nuclear accident, a number of reference levels were set, including one regarding the use of school playgrounds in Fukushima. Considering the band of 1 to 20 mSv y^{-1} recommended by the International Commission on Radiological Protection (ICRP) for public exposure under the existing exposure situation, Japanese authorities set 20 mSv y^{-1} on April 19, 2011 as a "start line" for reducing the dose to school children. When the level of 20 mSv y^{-1} was announced, the meaning of a reference level was explained at the press conference. However, the "20 mSv y^{-1}" led to considerable confusion among members of the public and some experts. They thought that the dose limit was increased to 20 mSv y^{-1}, 20 times as high as before and that the school children are to be exposed to 20 mSv y^{-1}. Factually, later in May, based on the measurement of ambient dose rates in schoolhouses as well as playgrounds, the actual dose was estimated around 10 mSv y^{-1} at most.

Confusion was also caused by lack of information on dose dependent characteristics of biological effects of radiation and misunderstanding of radiation protection concepts. A challenging issue was raised in regard to the higher radiosensitivity of children. In ICRP recommendations a higher risk coefficient is given to whole population than to adult population, because the whole population includes children, a subpopulation of higher sensitivity. The point was whether lower reference levels are to be set, when only children are considered.

Including these examples, lessons to be learned will be presented and discussed.

11:00 am

Findings of the Blue Ribbon Commission on America's Nuclear Future

Richard A. Meserve
Carnegie Institution for Science

At the request of the President, Secretary Chu formed the Blue Ribbon Commission on America's Nuclear Future in January 2010. The purpose of the Commission is to provide recommendations for the development of a safe, long-term solution to managing the nation's used nuclear fuel and nuclear waste. The Commission is chaired by former Congressman Lee Hamilton and former National Security Advisor Brent Scowcroft. I serve as a member.

The Commission conducted its work through periodic public meetings at which presentations were made by knowledgeable experts. The Commission also formed three subcommittees, covering disposal, storage and transportation, and advanced technologies. Each of the subcommittees engaged in extensive outreach efforts and developed draft reports that were made publicly available for comment and were considered by the full Commission.

The Commission issued a draft report in July 2011 for public comment. Perspectives on the report were also sought in public meetings that were held in Denver, Atlanta, Boston, Washington and Minneapolis. As this abstract is being written, the comments are being reviewed by the Commission for the purpose of preparing a final report for issuance at the end of January 2012.

The presentation will discuss the various recommendations and findings that emerge in the final report.

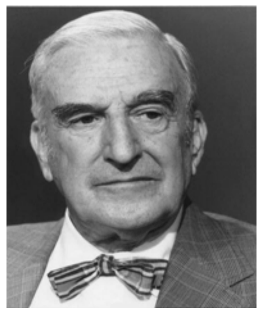
11:30 am **Q&A**

11:50 am **Closing Remarks**
Thomas S. Tenforde
National Council on Radiation Protection and Measurements

12:00 pm **Adjourn**

Mission Statement

To support radiation protection by providing independent scientific analysis, information and recommendations that represent the consensus of leading scientists.



Lauriston S. Taylor
1929–1977

Warren K. Sinclair
1977–1991

Charles B. Meinhold
1991–2002

Thomas S. Tenforde
2002–

NCRP
Scientific Authority Since 1929

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Registration

Monday, March 12, 2012	7:00 am – 5:00 pm
Tuesday, March 13, 2012	7:00 am – 11:00 am

(registration fee is $100 and $35 for students)

Register online: http://ncrp.eventbee.com

2013 Annual Meeting

Radiation Dose and Impacts on Exposed Populations

S.Y. Chen & Bruce A. Napier, *Co-Chairs*

March 11–12, 2013
Bethesda, Maryland

Publications (http://NCRPpublications.org) (http://jicru.oxfordjournals.org)

NCRP	Title	Price
Report No. 168	Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures (2010)	$ 150
Report No. 167	Potential Impact of Individual Genetic Susceptibility and Previous Radiation Exposure on Radiation Risk for Astronauts (2010)	75
Report No. 166	Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident (2010)	85
Report No. 165	Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers (2010)	75
Report No. 164	Uncertainties in Internal Radiation Dose Assessment (2009) [PDF only]	100
Report No. 163	Radiation Dose Reconstruction: Principles and Practices (2009)	150
Report No. 162	Self Assessment of Radiation-Safety Programs (2009)	50
Report No. 161	I. Management of Persons Contaminated With Radionuclides: Handbook (2008)	165
	II. Management of Persons Contaminated with Radionuclides: Scientific and Technical Bases (2008) [PDF only]	80
Report No. 160	Ionizing Radiation Exposure of the Population of the United States (2009)	125
Commentary No. 22	Radiological Health Protection Issues Associated With Use of Active Detection Technology Systems for Detection of Radioactive Threat Materials (2011)	30
Commentary No. 21	Radiation Protection in the Application of Active Detection Technologies (2011)	30
Commentary No. 20	Radiation Protection and Measurement Issues Related to Cargo Scanning with Accelerator-Produced High-Energy X Rays (2007)	40

ICRU	Title	Price
Report 85a-revised	Fundamental Quantities and Units for Ionizing Radiation (2011)	$ 198
Report 86	Quantification and Reporting of Low-Dose and Other Heterogeneous Exposures (2011)	198

Book Review of NCRP Report No. 165:

"As with most NCRP reports, the information supplied is well referenced. I have been involved with emergency preparedness planning for more than 25 years and this is by far the best written guidance I have seen on this subject. I was surprised at how many new insights I got from reviewing this report and would highly recommend it to any one involved in emergency preparedness planning." — *Dean Broga, Ph.D.* [Med. Phys. **38**(10), 2011]

Please visit the NCRP website, http://NCRPpublications.org, for a complete list of publications. Reports and commentaries are available in both soft- and hardcopy formats unless otherwise noted. Book reviews of NCRP publications are also available at this website. Contact NCRP's Executive Director, David A. Schauer (schauer@ncrponline.org), for more information.

Contracts/Grants/Contributors/Sponsors

These organizations have supported the work of the National Council on Radiation Protection and Measurements during the period of January 1 to December 31, 2011.

Contracts

Defense Threat Reduction Agency
National Institute for Occupational Safety and Health
U.S. Department of Homeland Security
U.S. Navy
U.S. Nuclear Regulatory Commission

Grants

Centers for Disease Control and Prevention
National Cancer Institute
U.S. Department of Energy

Contributors

American Academy of Health Physics
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Radiological protection of the patient: An integral part of quality of care

Dr. Claire Cousins, Chair ICRP
Consultant Vascular & Interventional Radiologist,
Addenbrooke's Hospital, Cambridge, UK


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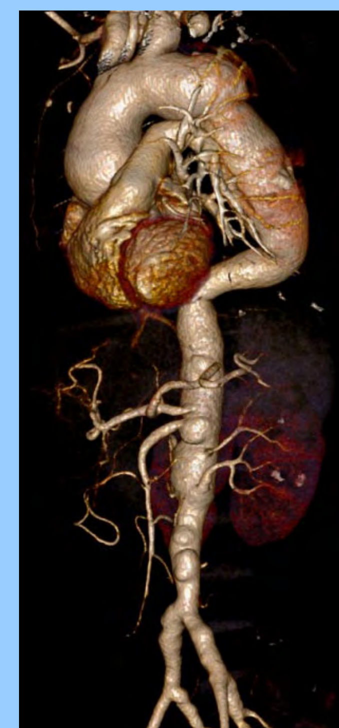


Radiological protection of the patient: An integral part of quality of care

- **What is quality of care?**
- **Protecting the patient**
- **Justification**
- **Optimisation and DRLs**
- **Medical education**

Quality of Care

Hippocratic oath

‘I will follow that system of regimen which, according to my ability and judgement, I consider for the benefit of my patients, and abstain from whatever is deleterious and mischievous’

‘Quality’ of care

- **Difficult to define**
- **Even more difficult to measure**
- **‘Almost anything anyone wishes it to be’**
- **‘Likely that there will never be a single comprehensive criterion by which to measure patient care’**

Donabedian 2005

‘Quality’ of care

- **Outcome of medical care often used as indicator of quality**
  - **Recovery/complications**
  - **Restoration of function**
  - **Survival vs. mortality**

‘Quality’ of care

Government uses waiting times and length of stay as criteria

- **Diagnosis**
- **Treatment**
- **Penalties if ‘targets’ breached**
- **In fact, quantitative measure not quality**
- **Quickly performed bad medicine is not quality**

Radiological protection of the patient

- Justification
- Optimisation
- No dose limitation

Justifying Medical Exposures

Justification

- What do we mean?
- Review the benefits and risks of a practice that will do more good than harm
- Usually relies on professional experience, knowledge, judgement and common sense

Justification

3 levels of justification

- **Radiation in medicine does more good than harm**
- **Generic justification of defined procedure**
- **Justification of a procedure for an individual e.g. complex diagnostic or interventional procedure**

Justifying medical exposures

- Is the x-ray/procedure really necessary
- Will the result change management?
- 'Nice-to-know' disease
- Is there an alternative investigation e.g. US or MRI

Justifying medical exposures

Is the x-ray really necessary?

"This is one of Geoff and the kids taken last summer."

Justifying medical exposures

Is the x-ray/procedure really necessary?

- **Defensive medicine often includes unnecessary investigations**
- **Repeated admissions = repeating same tests e.g. chest/abdomen x-rays, CT scans**
- **Different clinical teams and junior doctors**

Justification – multiple exams

Menu | Appointments | Patient Details | Events

Date	Time	Site	ReqNo	RefLoc	Referrer	Examinations
27/02/2012	1943	ADD	107	AE	RMAD	CABPE
28/10/2011	1132	ADD	106	UROL*ADD	NCS	XABDO
30/09/2011	1407	ADD	104	UROL*ADD	WISO	XABDO
30/09/2011	0917	ADD	105	CL4A	WISO	UXRERL
16/09/2011	1531	ADD	103	CL4A	MHDW	XABDO
07/03/2011	1645	ADD	102	L2DSU*ADD	WISO	FABDO
03/03/2011	1652	ADD	101	CL33	FEK	CABPEC
03/03/2011	1607	ADD	100	CL33	FEK	XABDO
21/10/2010	1443	ADD	99	CL33	FEK	XABDO
14/09/2010	1435	ADD	98	L2DSU*ADD	WISO	FABDO
01/09/2010	1111	ADD	97	M4*ADD	WT	CABPEC
29/08/2010	1100	ADD	96	M4*ADD	WT	INEPBD
29/08/2010	0924	ADD	95	M4*ADD	WT	UUTR
29/08/2010	0042	ADD	94	AE	CM	XABDO
29/04/2010	1600	ADD	93	CL33	FEK	XABDO
01/12/2009	1629	ADD	92	ENDO*ADD	WISO	XABDO
18/11/2009	0907	ADD	91	M4*ADD	NTH	FABDO
13/11/2009	1246	ADD	90	M4*ADD	GCH	CABPEC
27/07/2009	1041	ADD	89	CL4A	KNB	UXRELL
18/06/2009	1624	ADD	88	CL4A	WISO	XABDO
29/05/2009	0920	ADD	87	M4*ADD	NCS	XABDO
27/05/2009	0854	ADD	86	M4*ADD	NCS	FABDO
26/05/2009	1921	ADD	85	M4*ADD	NCS	XABDO
03/04/2009	1611	ADD	84	CL4A	KNB	XABDO
02/02/2009	0941	ADD	83	CL4A	KNB	UXRELL
18/12/2008	1538	ADD	82	OPD	FEK	XABDO
12/09/2008	1559	ADD	81	CL4A	WISO	XABDO
03/09/2008	1200	ADD	80	M4*ADD	WISO	FABDO
03/09/2008	0900	ADD	79	M4*ADD	WISO	XABDO
05/06/2008	1533	ADD	78	CL4A	FEK	XABDO
23/05/2008	1641	ADD	77	CL4A	NCS	UXRELL

Justifying medical exposures

Is the x-ray/procedure really necessary?

- **Risk of radiation effects in elderly patients usually outweighed by diagnostic/therapeutic benefit**
- **May still be at risk of skin injury from high dose interventional procedures**
- **Special consideration of children and pregnant women**

Pregnant female 25 weeks – acute appendicitis

Appendicolith

Justifying medical exposures

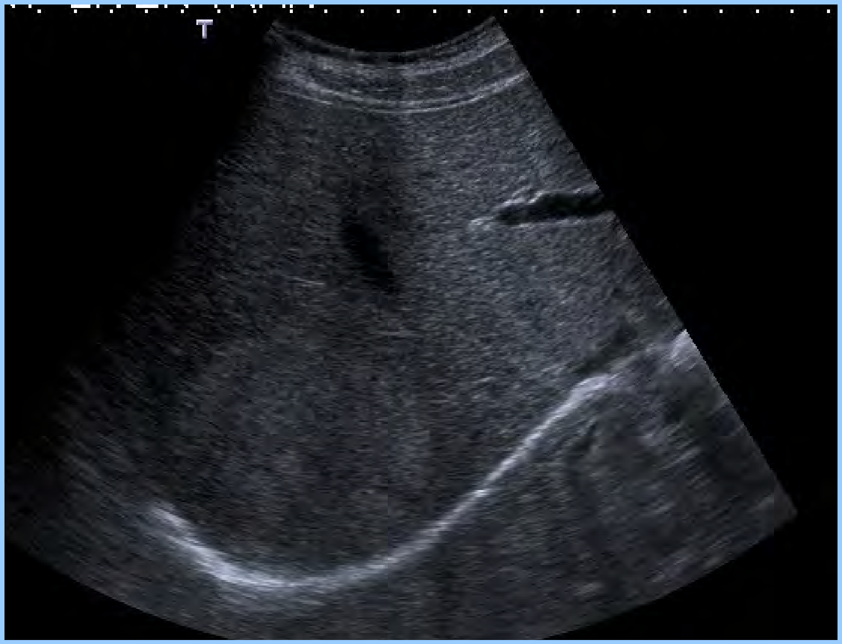
Will the result change management?

- **‘Nice-to-know’ disease**
- **Very elderly**
- **Terminally ill**
- **Incidental findings (VOMIT)**
  - **Victims Of Modern Imaging Technology**

Hayward, BMJ 2003

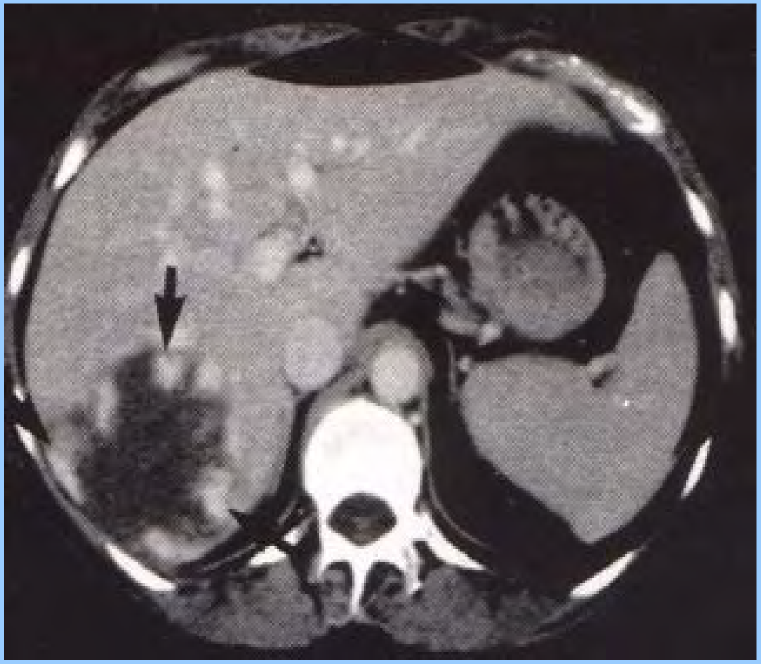
Justification

VOMIT



Ultrasound

Enhanced CT scan



Justifying medical exposures

Is there an alternative investigation?

- **Very many patients require further detailed imaging**
- **MRI may not be readily available out-of-hours**
- **CT often requested instead of US in belief that more diagnostic information**

Optimisation and DRLs

Optimisation of protection for patients

- Usually applied at two levels:
  - appropriate equipment design and installation
  - working practices and procedures
- Means keeping the radiation doses 'as low as reasonably achievable' so the dose is commensurate with medical purpose

Optimisation

Optimisation – Diagnostic Reference Levels (DRLs)

- **Help avoid radiation dose non-contributory to clinical purpose**
- **Derived from relevant local, regional or national data**
- **Aim to promote optimum range of values for specific imaging tasks**

Diagnostic Reference Levels

- **Allows identification of doses both above and below the specified range**
- **Designed to compare examinations and not individual patient doses**

DRLs UK

- **National surveys of patient doses collected by NRPB from early 1990's**
- **Database reviewed and updated every 5 years**
- **Recommendations on national reference doses for common x-ray examinations**
- **Mainly responsibility of radiographers and medical physicists**

DRLs UK - Radiographs

Table 1. National reference doses for individual radiographs on adult patients — 2005 review

Radiograph	ESD per radiograph (mGy)	No. of rooms	DAP per radiograph (Gy cm^2)	No. of rooms
Abdomen AP	4.2	209	2.6	127
Chest LAT	0.55	39	0.31	23
Chest PA	0.14	311	0.11	210
Lumbar spine AP	5.1	237	1.6	118
Lumbar spine LAT	11	232	2.5	120
Lumbar spine LSJ	26	27	2.6	25
Pelvis AP	3.7	231	2.1	150
Skull AP/PA	2.0	42	0.78	20
Skull LAT	1.3	26	0.49	19
Thoracic spine AP	4.1	79	0.93	36
Thoracic spine LAT	7.1	79	1.4	27

ESD, entrance surface dose; DAP, dose–area product; AP, anteroposterior; LAT, lateral; LSJ, lumbosacral joint; PA, posteroanterior.

Hart et al, BJR 2009

DRLs UK - Examinations

Table 2. National reference doses for diagnostic examinations on adult patients — 2005 review

Examination	DAP per exam (Gy cm^2)	No. of rooms	Fluoroscopy time per exam (min)	No. of rooms
Barium (or water-soluble) enema	24	269	2.8	233
Barium follow through	12	97	2.2	90
Barium meal	14	104	2.7	99
Barium meal and swallow	11	75	2.2	75
Barium (or water-soluble) swallow	9.0	173	2.3	159
Coronary angiography[a]	29	110	4.5	101
Femoral angiography	36	52	5.5	14
Fistulography	13	22	3.8	20
Hysterosalpingography	2.9	71	0.95	68
IVU	14	35	-	-
MCU	12	28	1.9	28
Nephrostography	12	35	4.8	34
Sialography	2.0	20	1.7	20
Sinography	8.5	39	2.1	39
Small bowel enema	40	37	9.2	34
T-tube cholangiography	7.9	37	1.9	37
Venography	7.5	27	2.2	26

DAP, dose–area product; IVU, intravenous urography; MCU, micturating cystourethrogaphy.
[a]75–85 kg.

Hart et al, BJR 2009

DRLs Paediatric

- **Optimising equipment performance and operator technique can significantly lower dose**
- **Easier in centres with super specialised units**
- **Fluoroscopy paediatric doses 5-25x lower than DRLs at Great Ormond Street Hospital**

Hiorns et al, BJR 2006

Hospital radiation league tables?

THE INDEPENDENT

High radiation puts child X-ray patients at risk

Requiring hospitals to publish exposure levels could eradicate huge variations in doses

Nina Lakhani

Tuesday, 3 January 2012

Patients are being exposed to unnecessarily high doses of radiation during common X-rays and scans because some hospitals have out-of-date equipment and inadequately trained staff.

Variations between hospitals are so great that adult patients are exposed up to five times as much radiation for identical procedures. Children face the biggest risk, experiencing much larger variations as outside specialist units there are few clinicians with paediatric expertise or equipment.

The British Institute of Radiology will tackle the issue head-on later this month by considering ways to drive up local standards and reduce variations across the country.

Forcing hospitals to collate and publish radiation exposure results, which would allow the public and health professionals to compare departments, could help drive up standards, according to some clinicians and patients.

DRLs - interventional procedures

- **Being developed for some radiological and cardiological interventional procedures**
- **Particularly in USA and Europe**
- **Consideration of patient size important but correction complicates analysis**

Hart et al, BJR 2009

Miller et al, Radiol 2009

DRLs UK - Interventions

Table 3. National reference doses for interventional procedures on adult patients — 2005 review

Interventional procedure	DAP per exam (Gy cm^2)	No. of rooms	Fluoroscopy time per exam (min)	No. of rooms
Biliary drainage/intervention	50	39	15	38
Facet joint injection	5.2	23	1.8	20
Hickman line	3.0	47	1.4	43
Nephrostomy	14	30	5.1	28
Oesophageal dilation	11	22	2.8	22
Oesophageal stent	25	24	5.9	22
Pacemaker	11	45	8.2	45
PTCA (single stent)[a]	50	28	13	26

DAP, dose–area product; PTCA, percutaneous transluminal coronary angiography.
[a]75–85 kg.

Hart et al, BJR 2009

DRLs USA - Interventions

Proposed Patient Reference Levels, Not Corrected for Body Habitus, for Certain Interventional Radiologic Procedures

Procedure	Reference Dose (Gy)	KAP (Gy · cm²)	Fluoroscopy Time (min)	No. of Images
Transjugular intrahepatic portosystemic shunt creation	3.00	525	60	300
Biliary drainage	1.40	100	30	20
Nephrostomy				
For obstruction	0.40	40	15	12
For stone access	0.70	60	25	14
Pulmonary angiography	0.50	110	10	215
Inferior vena cava filter placement	0.25	60	4	40
Renal or visceral angioplasty				
Without stent	2.00	200	20	210
With stent	2.30	250	30	200
Iliac angioplasty				
Without stent	1.25	250	20	300
With stent	1.90	300	25	350
Bronchial artery embolization	2.00	240	50	450
Hepatic chemoembolization	1.90	400	25	300
Uterine fibroid embolization	3.60	450	36	450
Other tumor embolization	2.60	390	35	325
Gastrointestinal hemorrhage localization and treatment	3.80	520	35	425
Embolization in the head				
For AVM	6.00	550	135	1500
For aneurysm	4.75	360	90	1350
For tumor	6.20	550	200	1700
Vertebroplasty	2.00	120	21	120
Pelvic artery embolization for trauma or tumor	2.50	550	35	550
Embolization in the spine for AVM or tumor	8.00	950	130	1500

Miller et al, Radiol 2009

Medical Education

Medical Education

- Often limited radiological protection education outside radiology training
- Increasing use of ionising radiation outside radiology departments with little training
- Teaching expensive and resource limited

Doctors knowledge of radiation doses

- **130 hospital doctors 2 UK district hospitals**
- **0% knew dose from CXR or radiation units**
- **4% scored 0 correct answers**
- **97% marked underestimation of doses**
- **5% thought US uses ionising radiation**
- **8% thought MRI used ionising radiation**

Shiralkar et al, BMJ 2003

Doctors knowledge of radiation doses

- **Doctors 3 university hospitals Turkey**
- **93% marked underestimation of doses**
- **4% thought US uses ionising radiation**
- **27% thought MRI used ionising radiation**

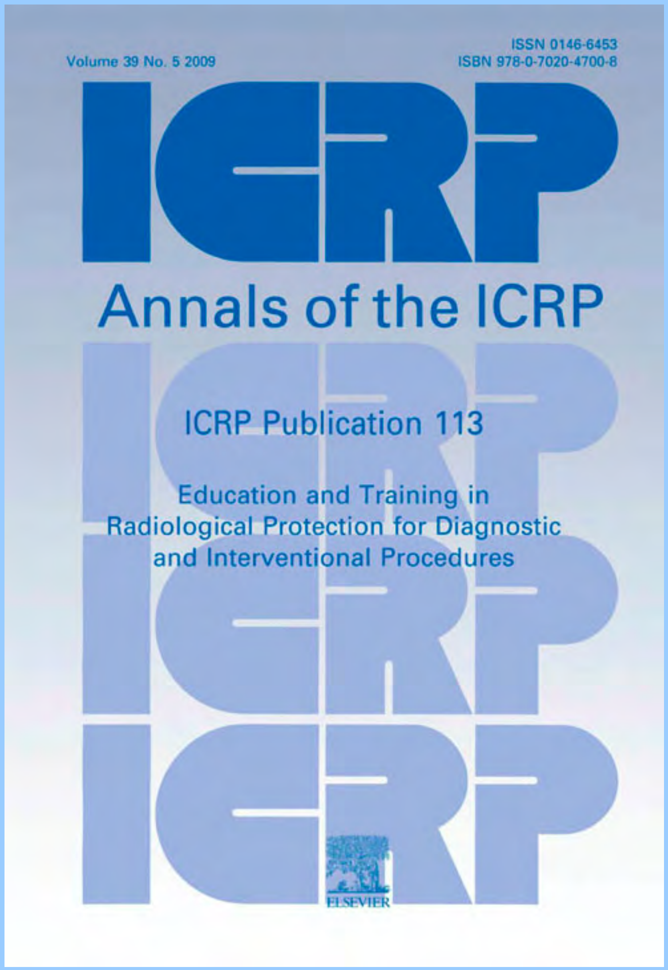
Arslanoglu et al, Diagn Interv Radiol 2007

Medical Education

- **Studies indicate appalling knowledge of radiation doses amongst hospital medical staff**
- **Emphasises need for adequate and appropriate education during medical training**
- **Continuing medical education also important**

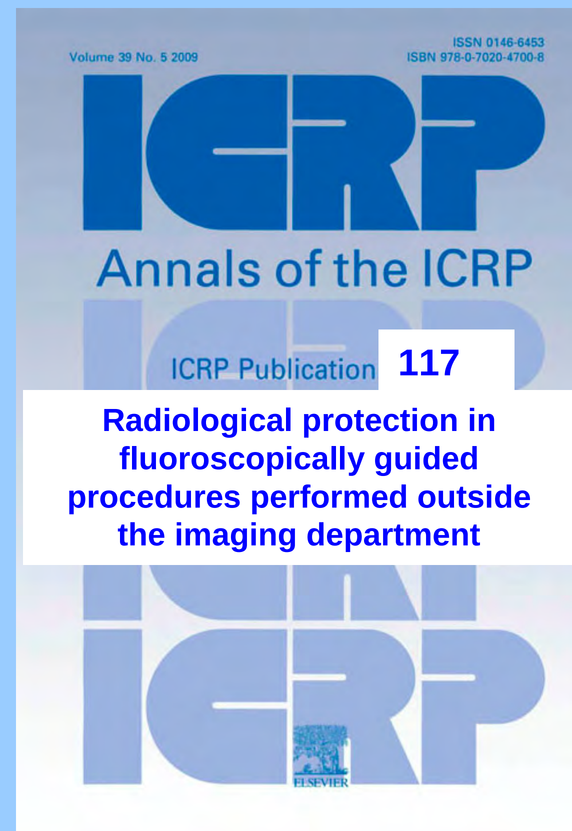
Medical Education

- ICRP 113 2009
- Advice for specific groups of healthcare professionals
- Advice provided on accreditation and certification



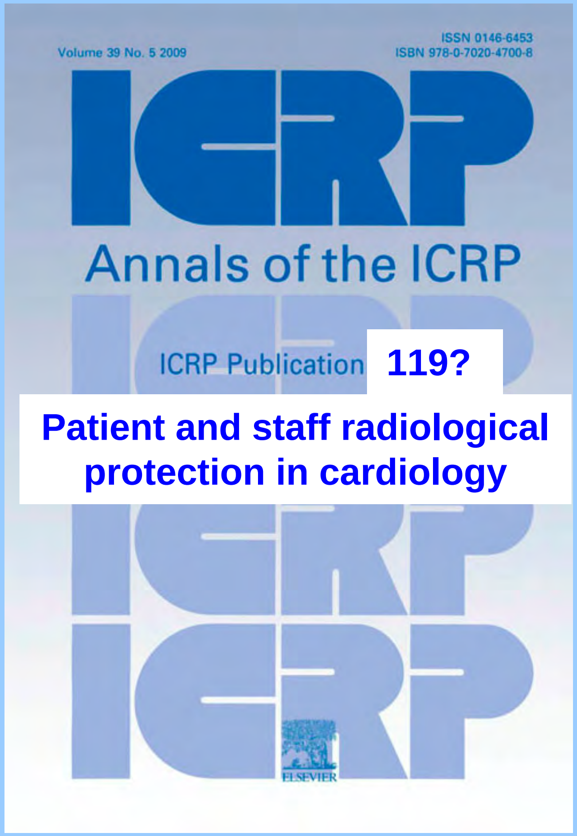
Medical Education

- **ICRP TG 78**
- **Radiological protection in fluoroscopically guided procedures performed outside the imaging department**
- **Final stages of preparation for publication**



Medical Education

- ICRP TG 62
- Patient and staff radiological protection in cardiology
- Final stages of preparation for publication

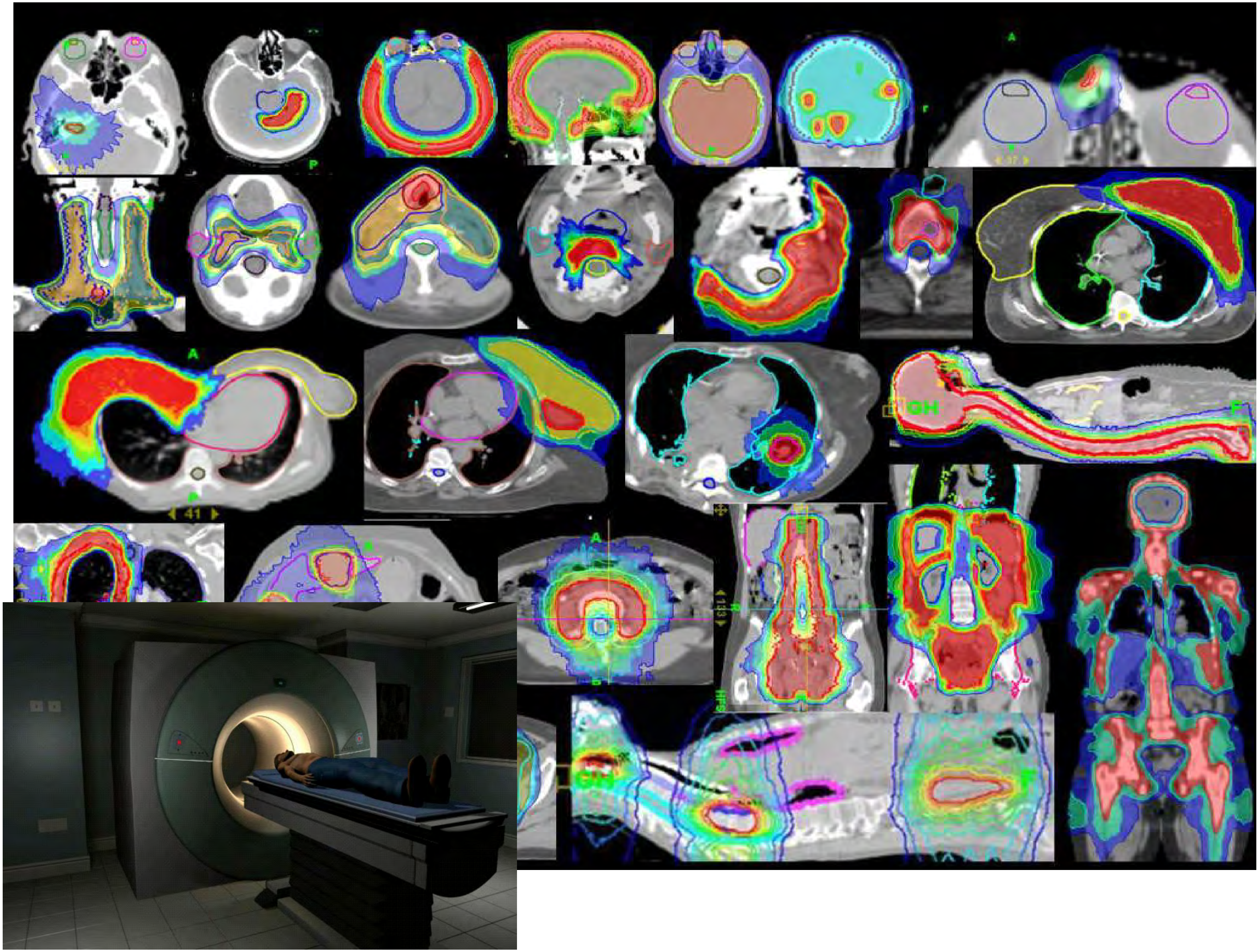


Conclusions

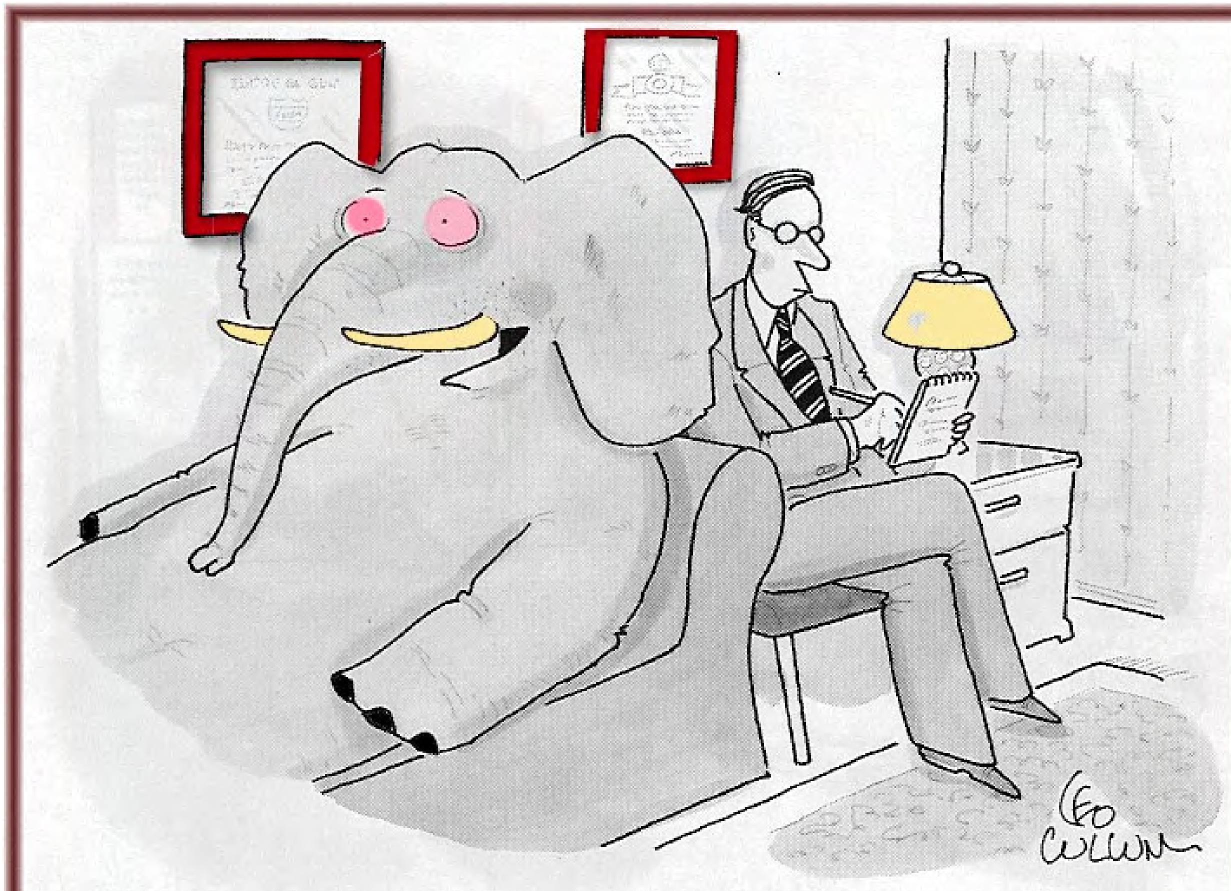
- **X-rays and radiological procedures have increasingly become an essential component of patient diagnosis and management**
- **Huge benefit from modern technologies and less invasive treatments**
- **Many factors contribute to the perception of quality of care and radiological protection should be included as an integral part of the total process**

Enhancing Safety in Radiation Therapy: Structural and Cultural Underpinnings

Michael L. Steinberg, M.D.
Daniel Low, PhD.
Department of Radiation Oncology
David Geffen School of Medicine at UCLA



How did we miss this?



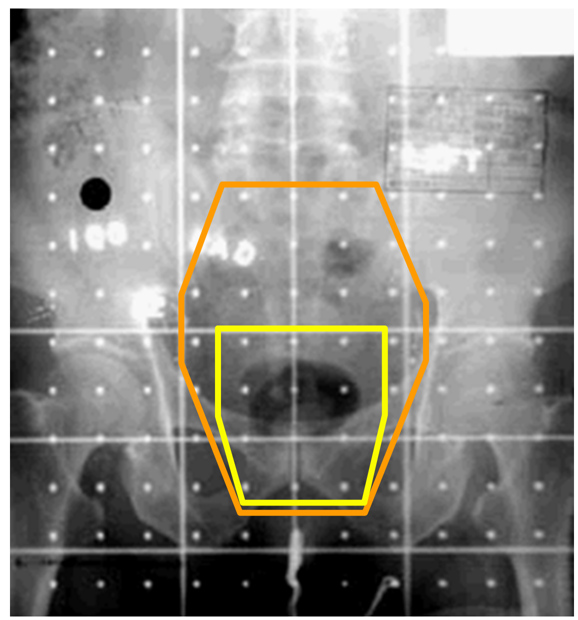
"I'm right there in the room, and no one even acknowledges me."

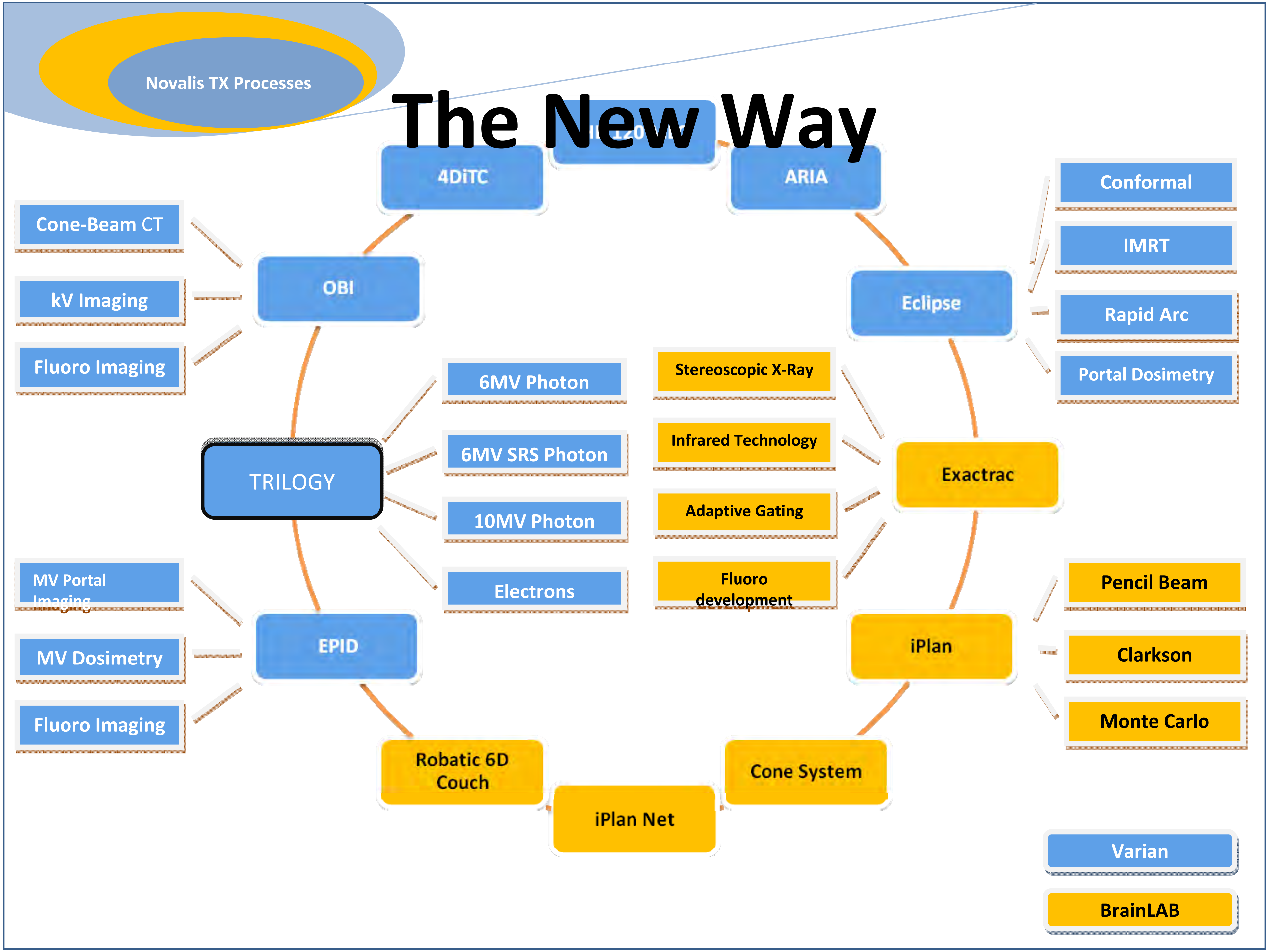
The New Yorker, 9/18/06

The Fundamental Problem: Unprecedented Increase in the Complexity of Healthcare Delivery

- Medical knowledge has grown exponentially
- So has the complexity of our treatments
- Yet, we are basically doing things much the same way we have done them for the past 30 years

The Old Way

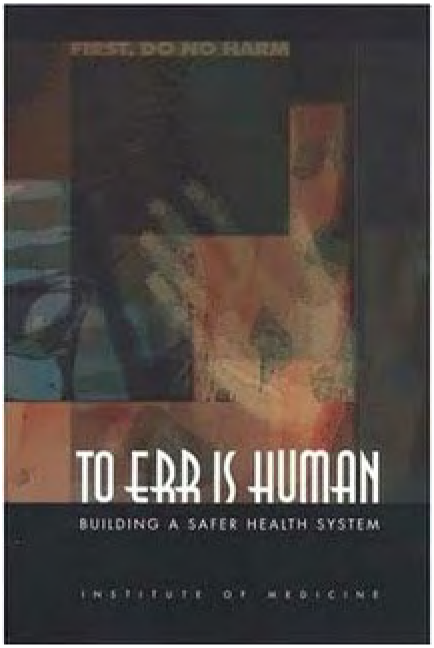


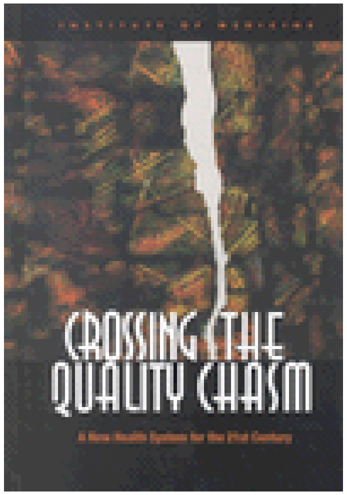


Novalis TX Processes
The New Way
4DiTC
ARIA
Cone-Beam CT
kV Imaging
Fluoro Imaging
OBI
Conformal
IMRT
Rapid Arc
Portal Dosimetry
Eclipse
6MV Photon
6MV SRS Photon
10MV Photon
Electrons
TRILOGY
Stereoscopic X-Ray
Infrared Technology
Adaptive Gating
Fluoro development
Exactrac
MV Portal Imaging
MV Dosimetry
Fluoro Imaging
EPID
Pencil Beam
Clarkson
Monte Carlo
iPlan
Robatic 6D Couch
iPlan Net
Cone System
Varian
BrainLAB

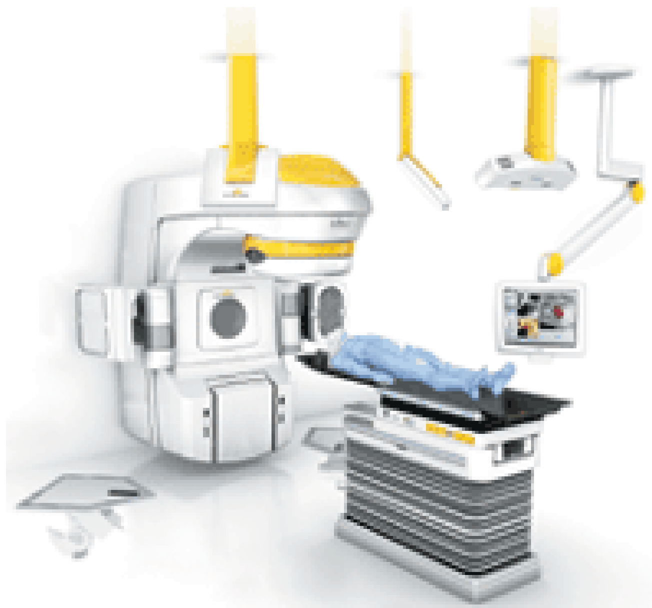
Medicine In General Has a Pervasive Quality Problem

- 1999: Institute of Medicine
  - To Err is Human: Building a Safer Health System
  - Examine level of safety in US medical institutions
  - Medical Errors may cause **98,000** preventable deaths
    - More deaths than automobile (43k), breast CA (43k) or AIDS (16k)



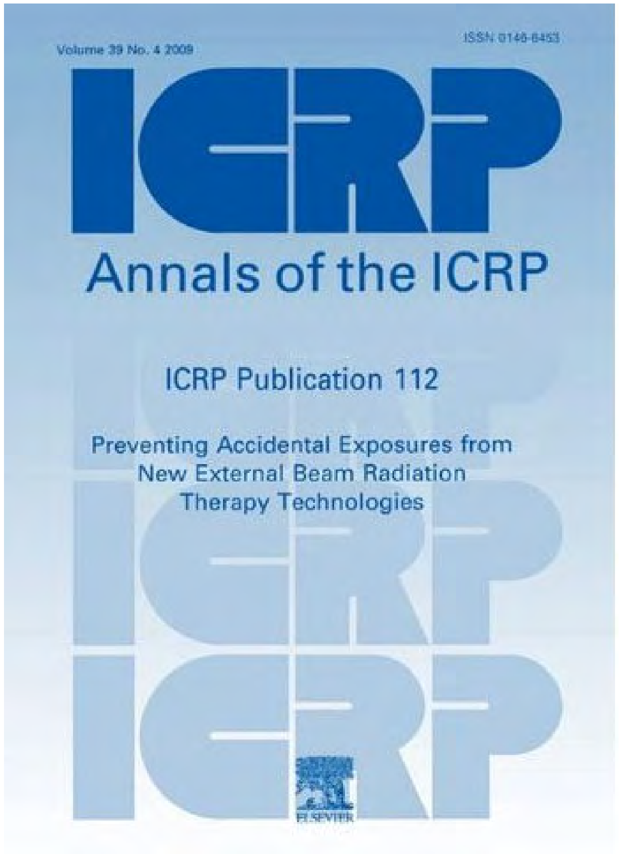


What About Radiation Oncology?



Radiation Oncology Errors Reporting Initiatives

- WHO Radiotherapy Risk Profile (21 actual, 28 potential incidents), 2008
- UK professional bodies: “Towards Safer Radiotherapy” (5 incidents), 2008
- ICRP: “Preventing Accidental Exposures from new External Beam Radiation Therapy Technologies” (11 incidents)
- NY State Reporting



Advanced Technology Clinical Trials

Credentialing - "ATC/RPC Phantom" Test

Table 1. Institution passing rates with the Radiological Physics Center phantoms

Phantom	Head and neck	Prostate	Thorax	Liver
Irradiations	250	64	24	4
Pass	179	55	17	3
Fail	71	9	7	1
Year introduced	2001	2004	2004	2005

"…roughly 30% of institutions failed to deliver a dose distribution to the head-and-neck IMRT phantom that agrees with their own treatment plan to within 7% or 4 mm."

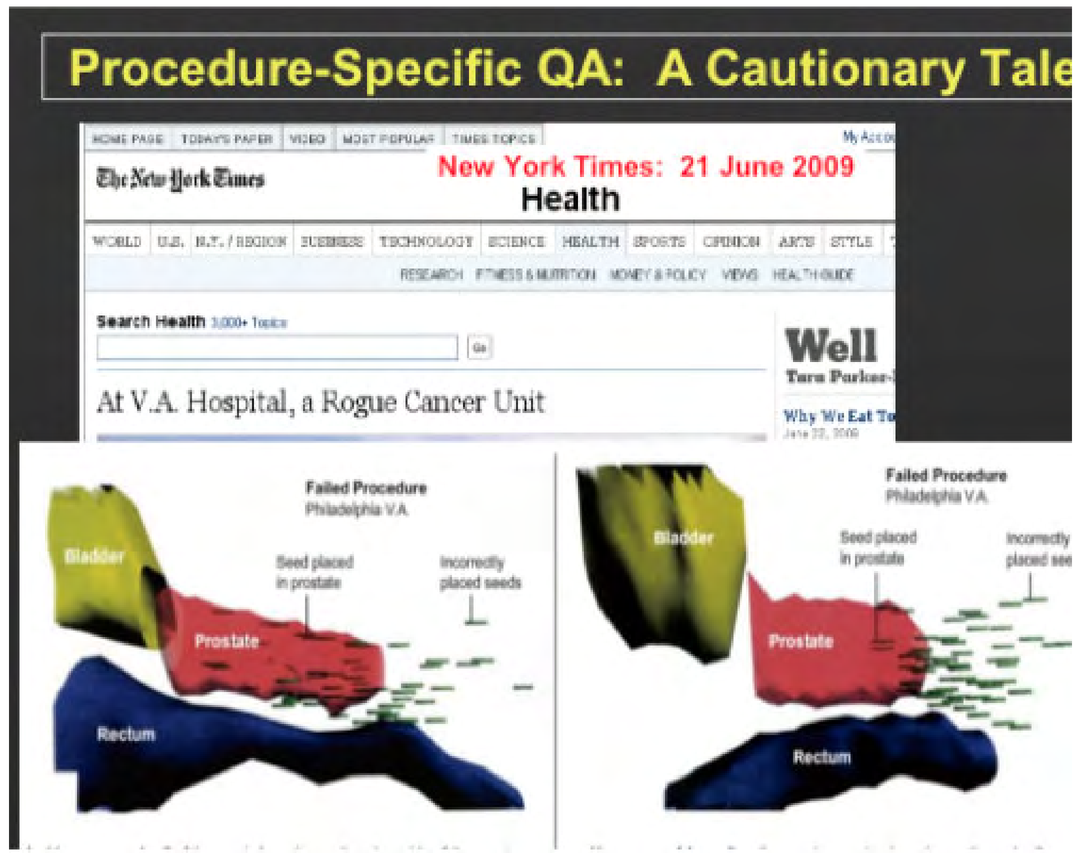
Ibbott, G. S, et al. Challenges in credentialing institutions and participants in advanced technology multi-institutional clinical trials. *Int J Radiat Oncol Biol Phys* 71:S71–S75, 2008.

Current QA Paradigm Focus

- Approach developed in the 2D RT era
  - Most existing guidance is limited to 2D RT
- Tends to focus on devices
  - planning systems, LINACs, imaging systems, afterloaders
  - Acceptance testing, commissioning, periodic QA
  - Process QA: limited to quantitative verification of device outputs, e.g., plan review and chart checks

Device versus Process Errors

- Large catastrophic errors
  - Majority are human or process related errors although poor device design often contributes
- 97 of 116 implants were medical events, many were wrong site
- Failures of process rather than devices
- QA is a team effort: focus on key physician as well as technical steps



Process Design Model (TG-56/TG-59)

- Use 3-6 experts-in–a-room consensus method
  - Guard against rare catastrophic technical errors
  - Enhance quality: every step satisfies specified temporal, positional, and dose delivery tolerances
- Develop simplified process flow map
  - Design information capture forms
  - Identify vulnerable steps where errors are possible
  - Develop redundant checks for high-risk actions
- Useful when
  - Relatively uniform clinical processes and devices
  - Sufficient resources to address all identified risk scenarios

TG-100 Approach

- Goals
  - Provide tools for designing robust, error-resistant clinical processes
  - Include key actions of physicians and therapists as well as physics and dosimetry activities
  - Risk-based allocation of QA resources
  - Provide tools for customizing process and device QA guidance to individual clinics and procedures
- AAPM TG-100 proposal (S. Huq, Chair)
  - Failure modes and effects analysis (FMEA)
  - Fault-tree Analysis (FTA)

FMEA Example

- Assess risk to successful outcome posed by each FM assuming no QA

$$\textbf{Risk} = \left\{\begin{matrix}\textbf{Probability of}\\ \textbf{occurrence}\end{matrix}\right\} \times \left\{\begin{matrix}\textbf{Severity of}\\ \textbf{consequences}\end{matrix}\right\} \times \left\{\mathbf{1} - \begin{matrix}\textbf{probability Error}\\ \textbf{Detected}\end{matrix}\right\}$$

$$\qquad\qquad\textbf{O} \qquad\qquad\qquad \textbf{S} \qquad\qquad\qquad \textbf{P}$$

$$\textbf{Risk Probability Number} = \textbf{RPN} = \textbf{O} \times \textbf{S} \times \textbf{P}$$

  - Assign O,S, and P a value from 1-10
  - 4 Observers: Ibbott, Mutic, Williamson, Thomadsen
  - Significant additions/modifications by JFW
- Reorder list in terms of descending RPN

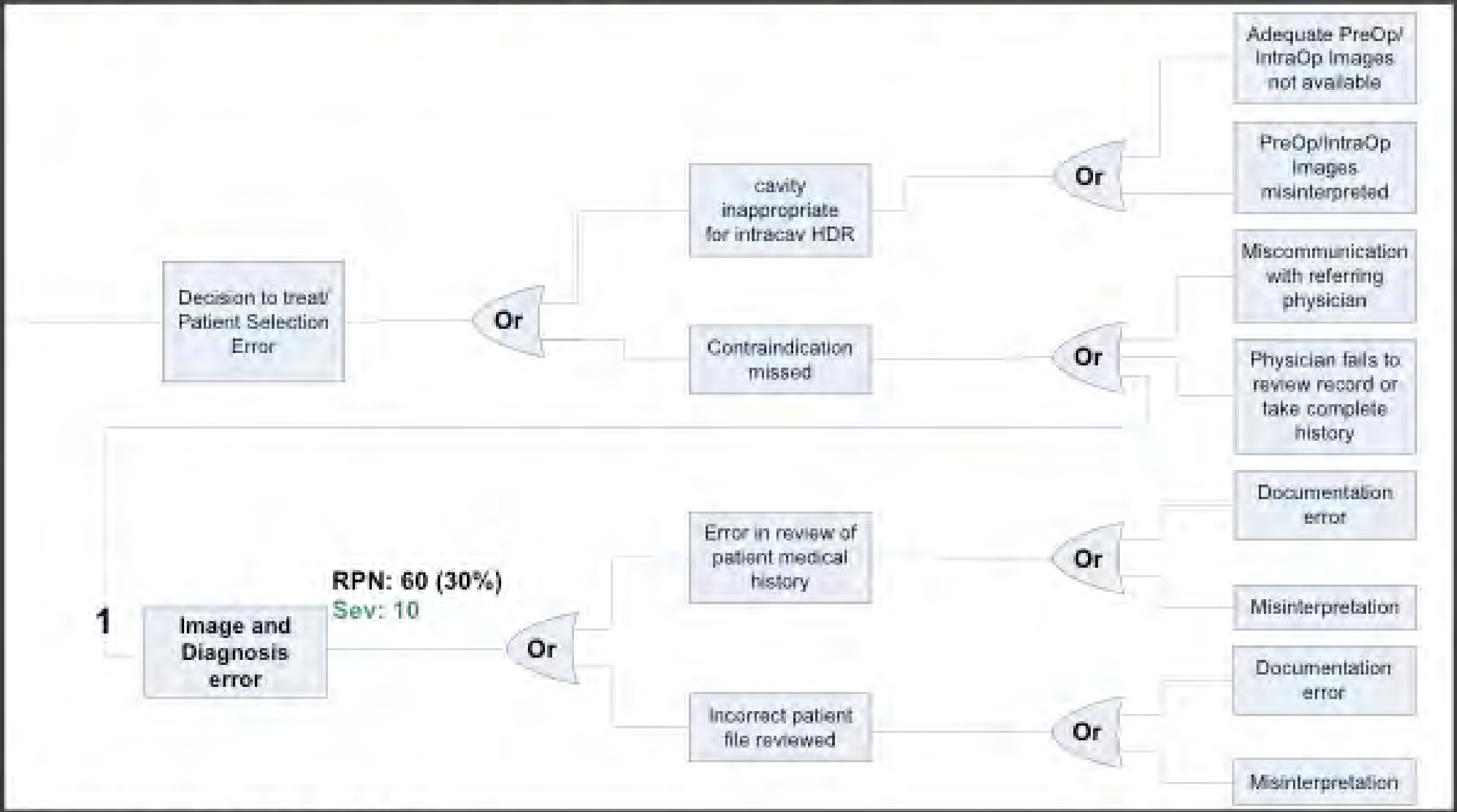
Severity of the Effects Resulting from a Specific Failure Mode (S)

<table>
<tr><td>Not noticeable, no effect on the patient or on the department</td><td></td><td>1</td></tr>
<tr><td>Inconvenience</td><td>Inconvenience to patient or staff</td><td>2-3</td></tr>
<tr><td>Minor dosimetric error</td><td>Suboptimal plan or treatment</td><td>4</td></tr>
<tr><td>Limited toxicity (may not require medical attention) or minor underdose to PTV</td><td rowspan="2">Wrong Dose
Wrong dose distribution
Wrong location
Wrong volume</td><td>5-6</td></tr>
<tr><td>Potentially serious toxicity or injury (may require medical attention) or major underdose to PTV</td><td>7-8</td></tr>
<tr><td>Possible serious toxicities (requires medical attention)</td><td rowspan="2">Very wrong Dose
Very wrong dose distribution
Very wrong location
Very wrong volume</td><td>9</td></tr>
<tr><td>Catastrophic</td><td>10</td></tr>
</table>

6 Highest Risk FMs

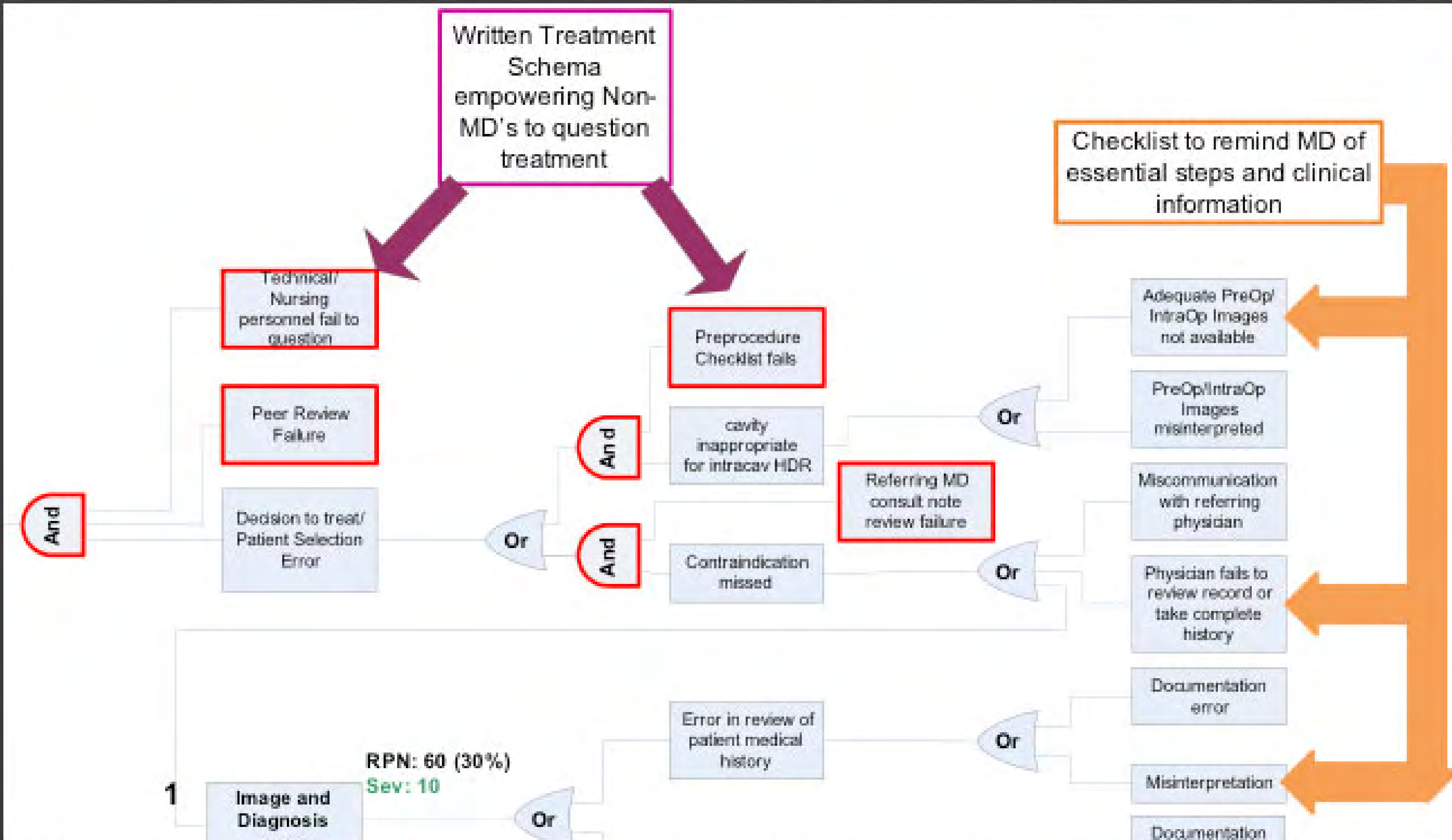
RPN Rank	Step	Potential Failure Modes	Potential Causes of Failure	JFW Comments	Potential Effects of Failure	AVG O	AVG S	AVG D	Avg RPN
1	Review of patient medical history	Error in assessing indications and contraindications to APBI	Information not available, incorrect info filed in chart, inexperience	New JFW FM: E.g., SLN+ with Surg untreated axilla missed	wrong/very wrong dose distribution	6	8	10	480.00
2	Applicator selection	Defective applicator selected	No PreTreatment or intraperative QA	New JFW FM: Leaking, asymetric/misshaped ,or blocked applicator; broken interface	wrong dose distribution, patient inconvenience	10	7	5	350.00
3	Post-procedure image review	Technical contraindications not detected and corrected (skin-cath <5 mm; poor conformance; mispositioning)	Simulation images not reviewed by MD ; poor quality images; reviewed by inexperienced person	JFW: New failure mode some failures might be completely undetectable by CT	wrong/very wrong dose distribution	7	7	7	343.00
4	Absolute dwell time determination	Incorrect source calibration	Inadequately trained, miscalculation, wrong units, lack of attention		Very wrong dose	3.75	9.25	7.25	259.25
5	Deflated balloon placed in center of cavity	damaged/ defective applicator inserted into patient	Defective device selected; inexperience, no backup, no intraoperative imaging	existing mechanism: JFW revised scores	wrong dose distribution, patient inconvenience	9	7	4	252
6	Absolute dwell time determination	Dose specified to the wrong location	Lack of attention		Very wrong dose	4.50	9.00	6.50	241.25

Patient-Selection Fault Tree: No QM



- **Two major FMs**
  - Wrong stage for API or contraindication to API missed
  - inappropriate lumpectomy cavity for balloon catheter

Patient Selection FTA With QM Augmentation



- **QM interventions and process redesign**
  - QC checklist to guide MD consultation
  - QA: Peer- and technical-review of MD decisions
  - QC: National electronic medical record

What is the reality?

- Complexity is increasing
- QA techniques are not keeping up
  - Our associations are trying really hard
- FMEA/FTA is probably unrealistic in the current environment
  - Lack of personnel trained in the method
  - Complexity of the common case
  - Lack of standardization of process
- Need to mitigate mistakes

Agenda for Change to Improve Safety in Radiation Therapy

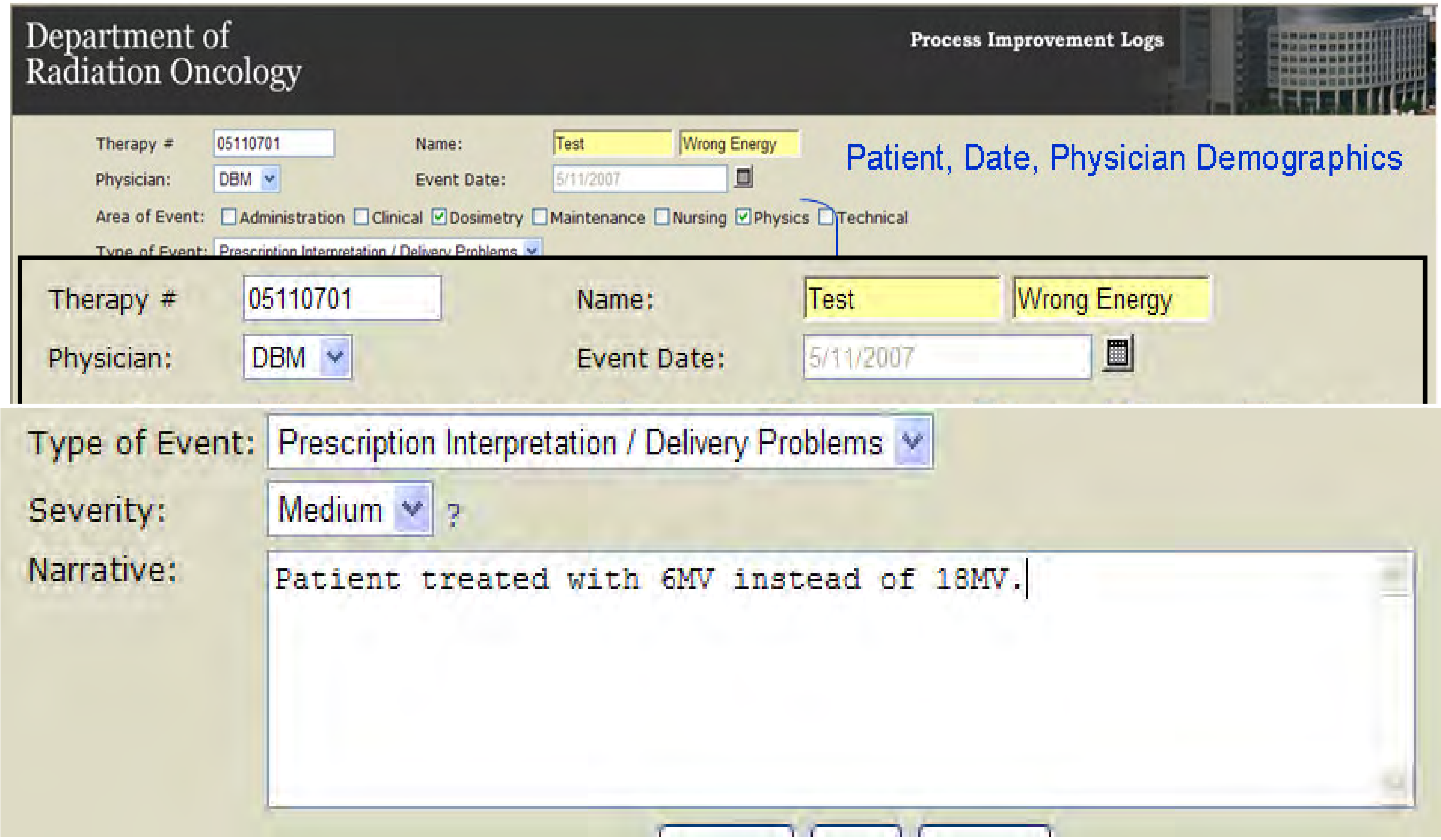
<u>Components</u>

- Safety Recording
- Monitoring
- Standardization
- Training
- Accreditation/QA (external review)
- Culture

Safety Recording

Error Reporting: Grass Roots

- **UCLA - Wash U. Collaboration Electronic Whiteboard to Enhance Safety**
- Electronic whiteboard for reporting and analysis
- All errors and near misses are tracked
- Creates data
- Promotes zero mistake culture with all stakeholders (if implemented correctly)

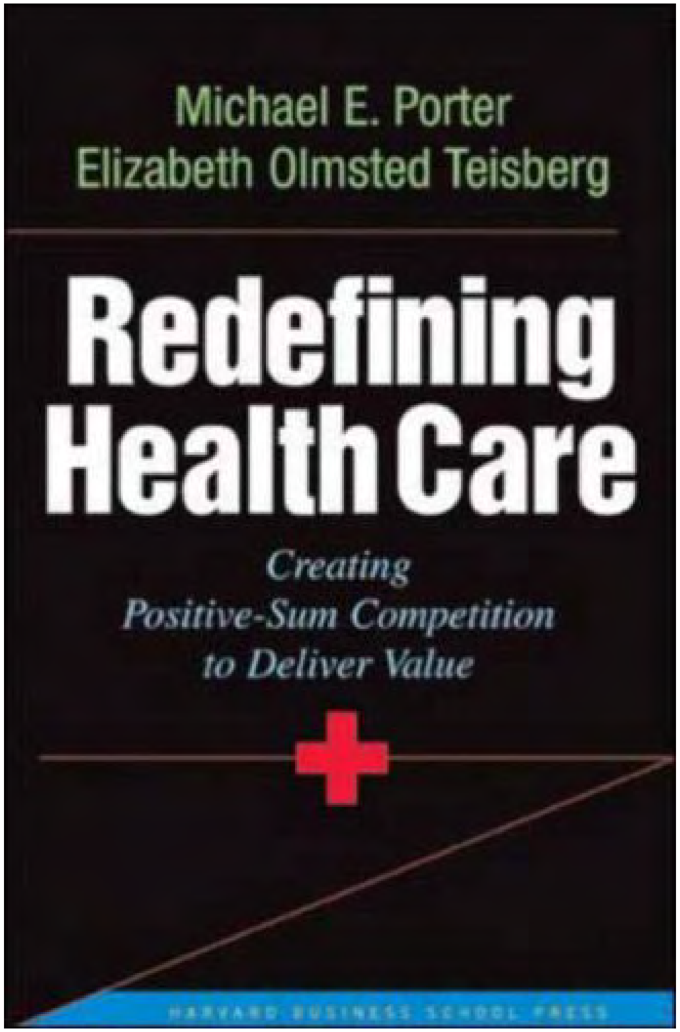

Department of Radiation Oncology
Process Improvement Logs
Therapy # 05110701
Name: Test Wrong Energy
Physician: DBM
Event Date: 5/11/2007
Area of Event: Administration Clinical Dosimetry Maintenance Nursing Physics Technical
Type of Event: Prescription Interpretation / Delivery Problems
Patient, Date, Physician Demographics
Therapy # 05110701
Name: Test Wrong Energy
Physician: DBM
Event Date: 5/11/2007
Type of Event: Prescription Interpretation / Delivery Problems
Severity: Medium ?
Narrative: Patient treated with 6MV instead of 18MV.

National Error Registry

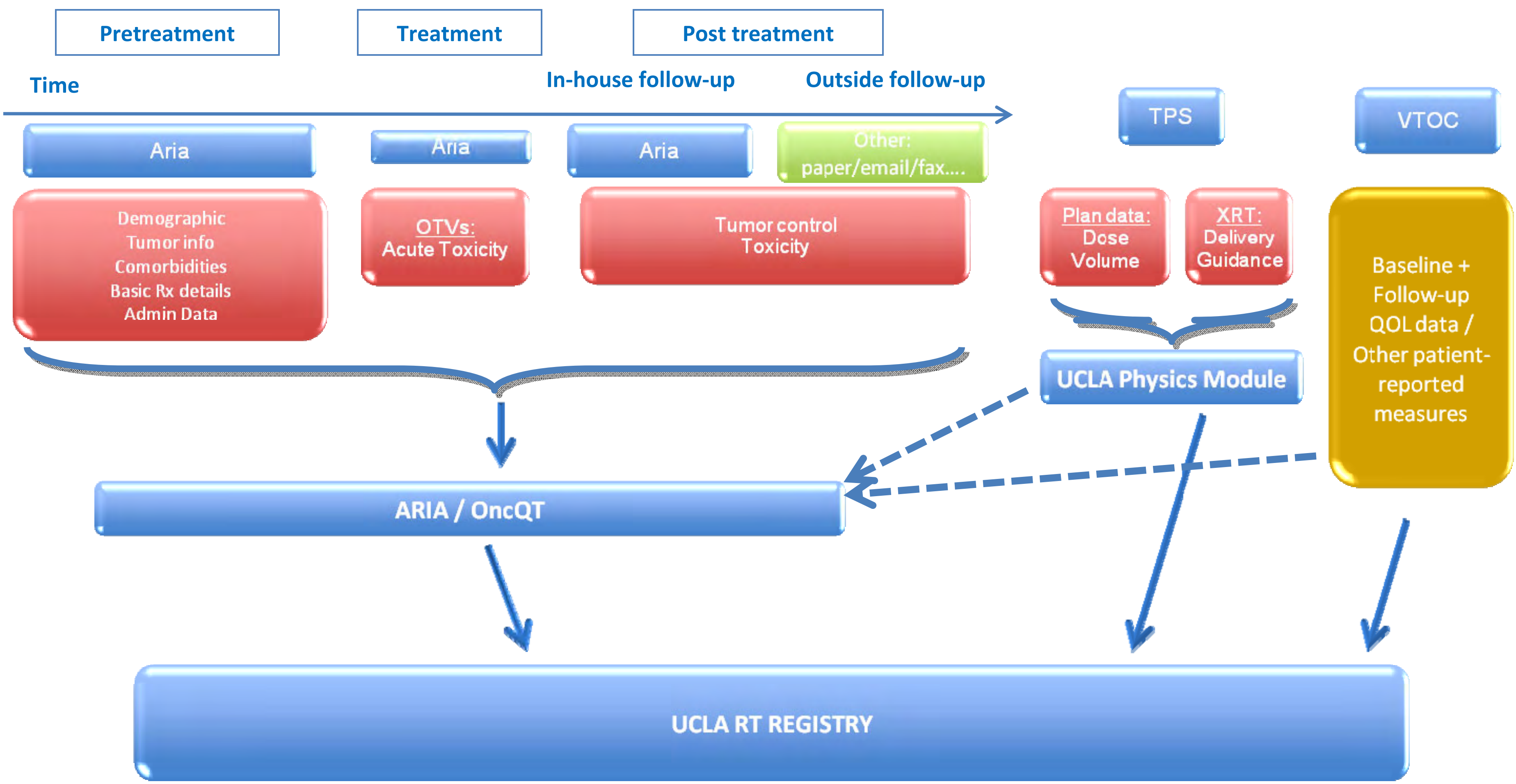
- We need to know what is happening
  - Where are we making mistakes?
  - How often do the mistakes happen?
  - What are the consequences of the mistakes?
- National error registry
  - Aviation: Accident investigations, public results (NTSB)
  - Near accidents or mistakes: Reporting through NASA (ASRS)
- National Patient Registry

ROI
RADIATION ONCOLOGY INSTITUTE

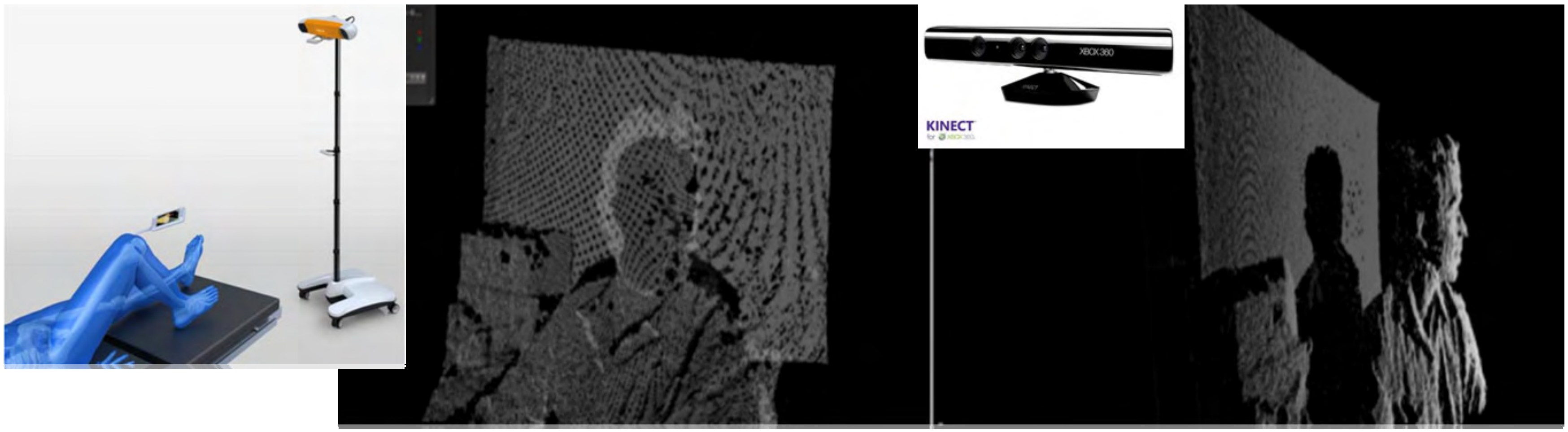
Monitoring



"Results data - even if less than perfect - is the single most important factor in driving health care system improvement."

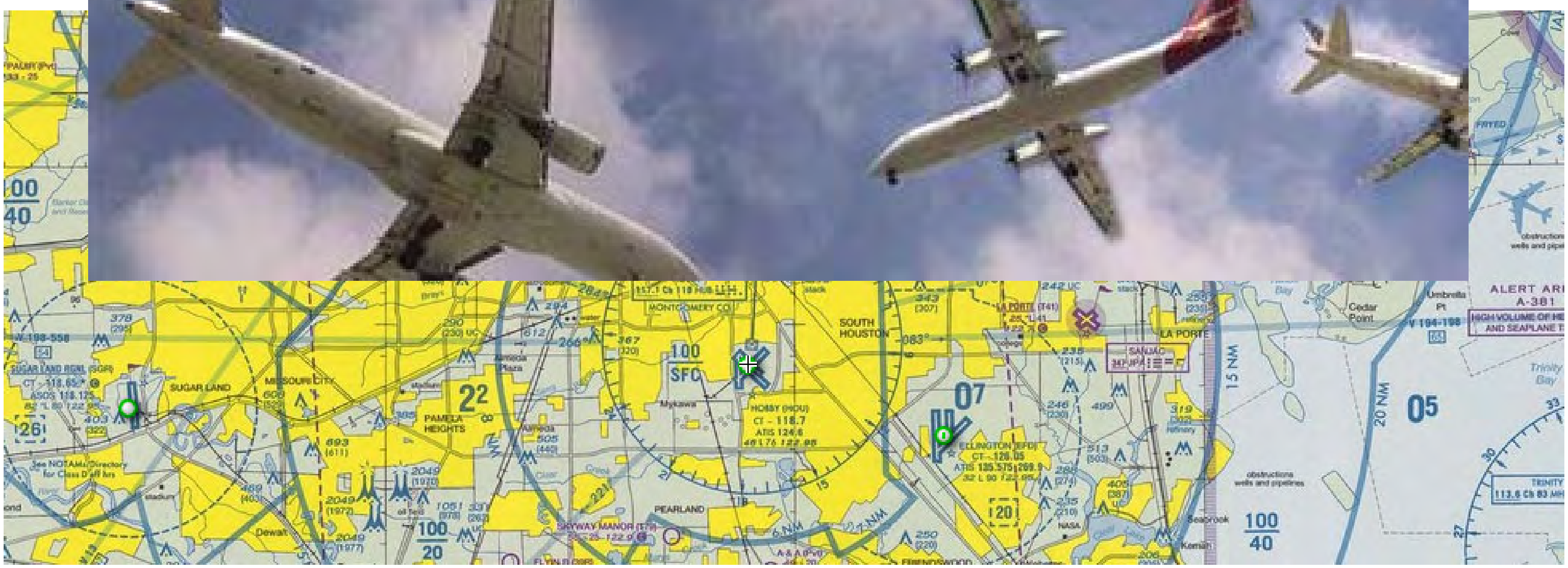

Pretreatment
Treatment
Post treatment
Time
In-house follow-up
Outside follow-up
Aria
Aria
Aria
Other: paper/email/fax....
TPS
VTOC
Demographic
Tumor info
Comorbidities
Basic Rx details
Admin Data
OTVs:
Acute Toxicity
Tumor control
Toxicity
Plan data:
Dose
Volume
XRT:
Delivery
Guidance
Baseline + Follow-up QOL data / Other patient-reported measures
UCLA Physics Module
ARIA / OncQT
UCLA RT REGISTRY

UCLA Safety
“In the room”

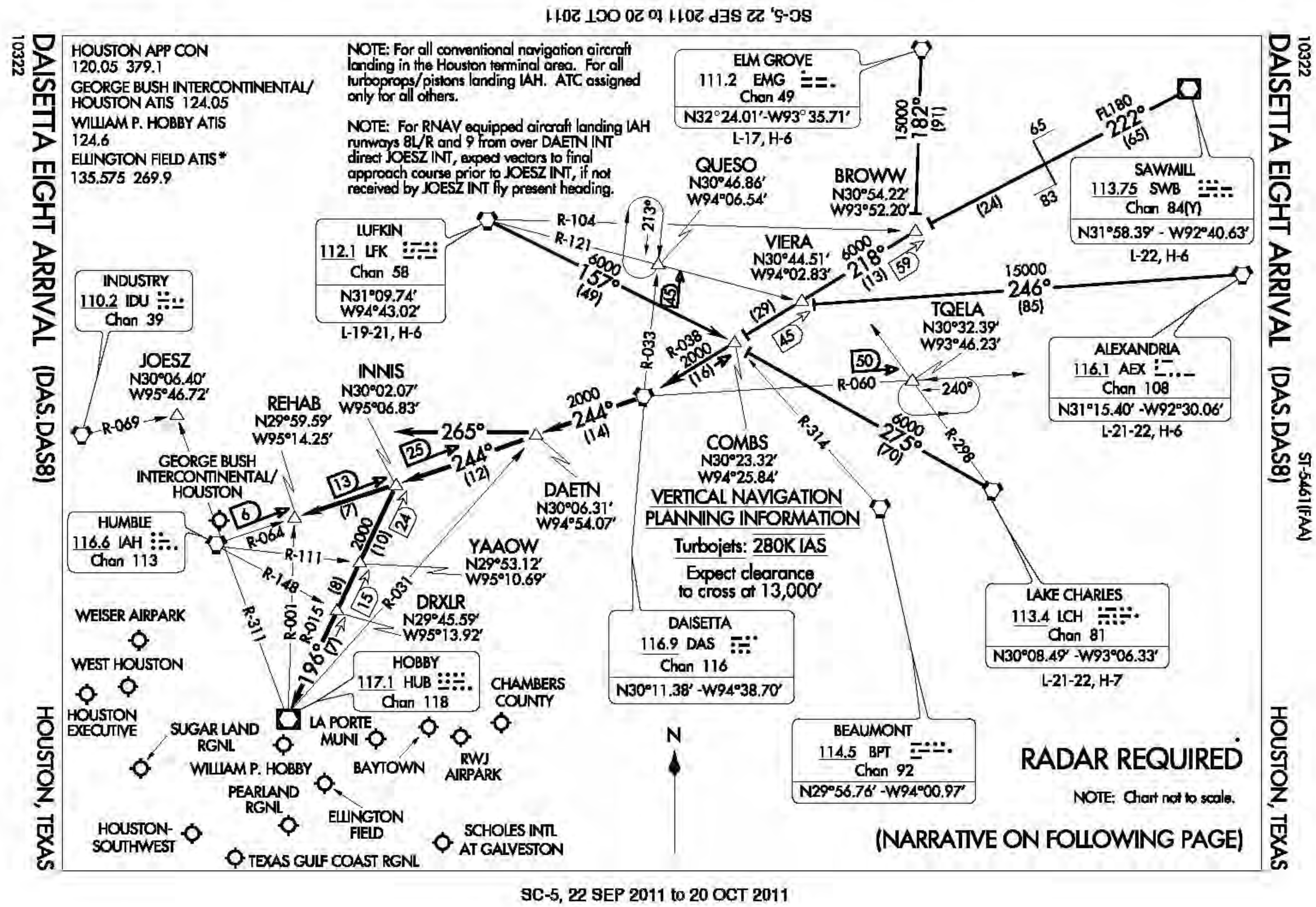


Standardize

Standardize



Standardize



Standardize and Rationalize

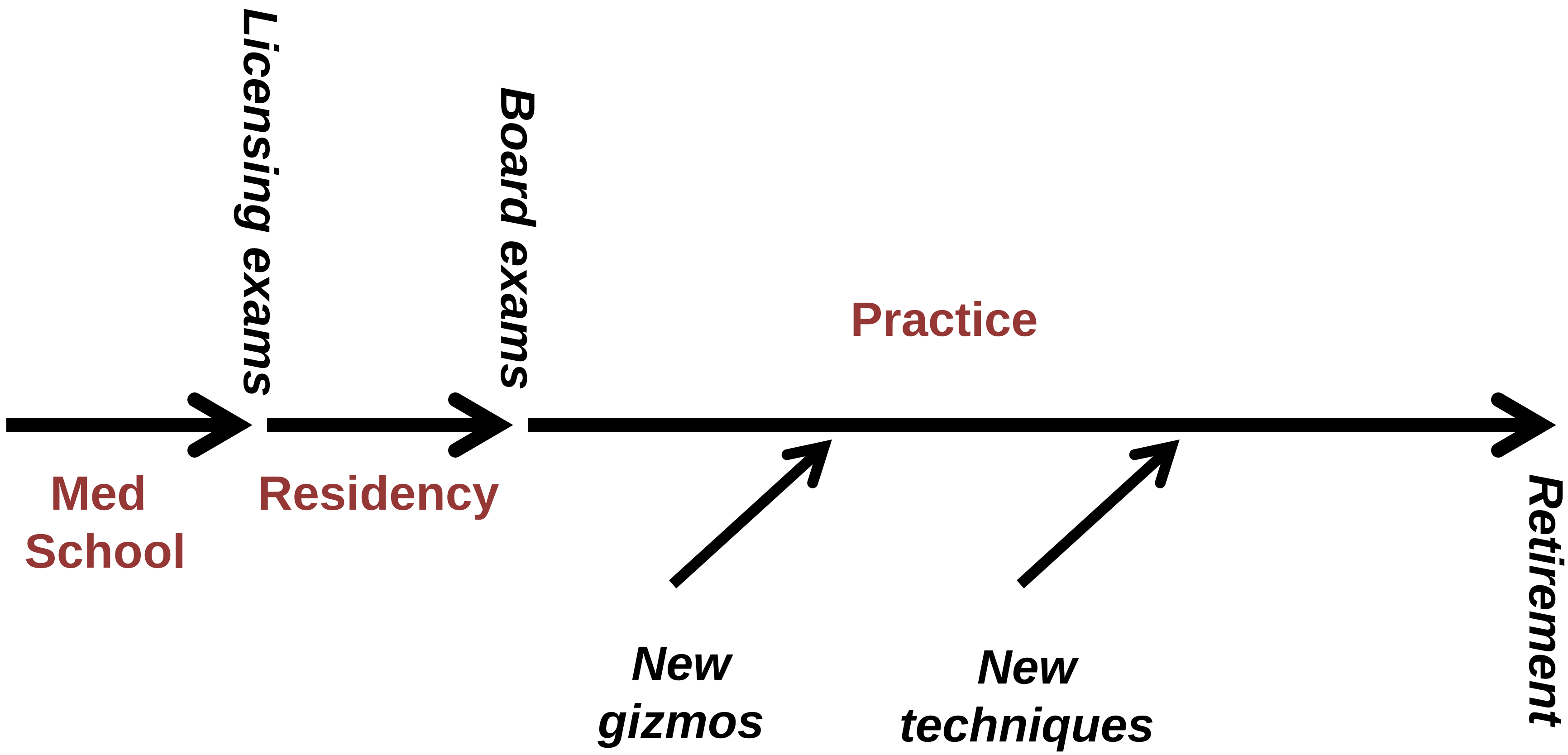
- Treatment Directives
- Care Pathways
- Segmentation, Fusion
- Standardized QC/QA
  - Risk-based QA
- Standardized interfaces, data management, measurement techniques, commissioning, interfaces (human factors)

Standardize

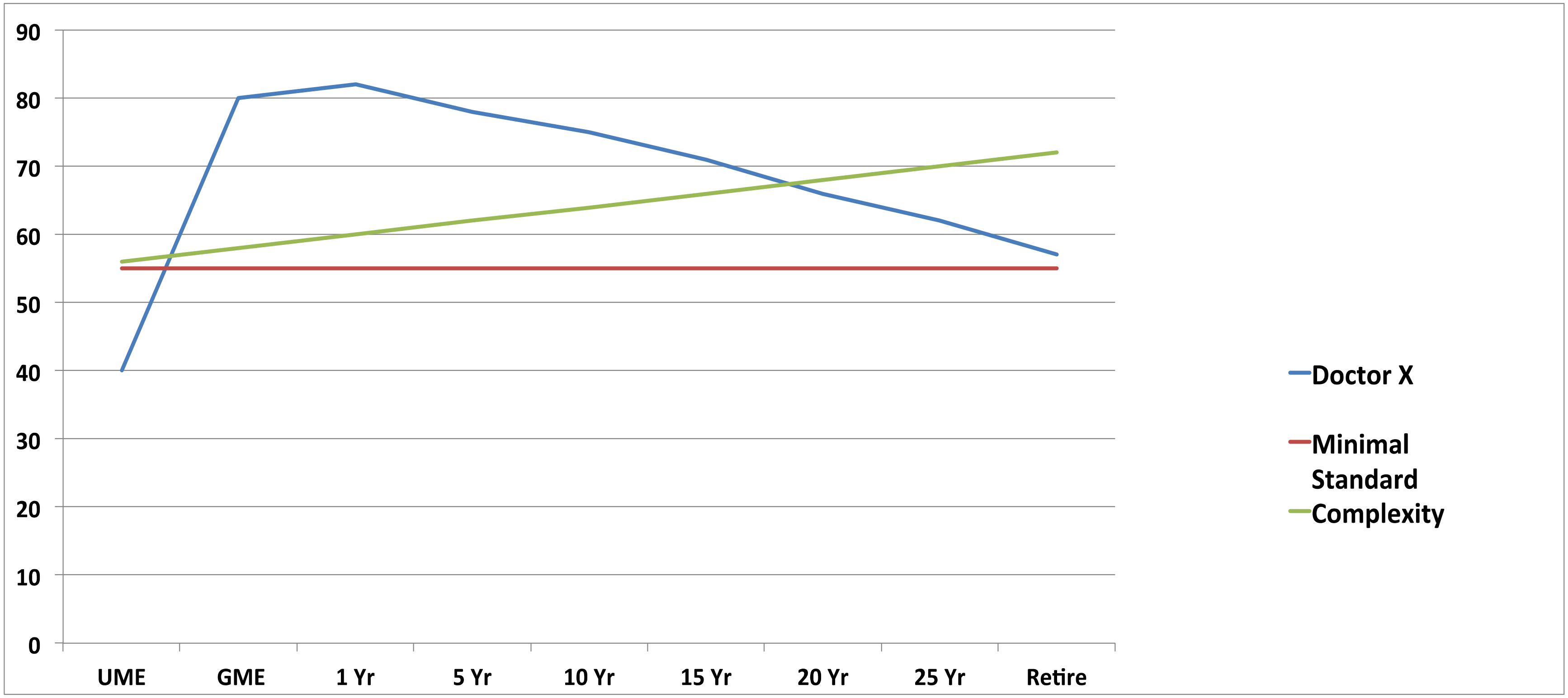
ASTRO QA White Papers	• Provide an overview of QA issues and makes recommendations that should be	Literature review and consensus
ASTRO Best Practices	• Recommendations about "how" to deliver radiation therapy, including the best treatment methods and patient care processes • Basis for measure development for PQRS, MOC, and ROPA • Basis for educational content (webinars, educational sessions)	RAND appropriateness methodology (systematic literature review and formal consensus process); moving toward compliance with IOM recommendations for "guidelines"

Training

Train and Retrain



Competence



90
80
70
60
50
40
30
20
10
0
UME
GME
1 Yr
5 Yr
10 Yr
15 Yr
20 Yr
25 Yr
Retire
Doctor X
Minimal Standard
Complexity

Train and Retrain

- Retrain: MOC as mechanism
- Simulations?
- Performance review?
- Frequency?

Vertual: VERT

The “lifelong learning” movement: Maintenance of Certification

Cannot be dodged

- **Hospital credentialing**
- **Payment**
- **Maintenance of licensure**
- **Participation will soon be public knowledge**

The "lifelong learning" movement: Maintenance of Certification

Light emphasis on knowledge

Good idea in technically expanding field?

Strong emphasis on:

- **Improving practice**
- **Safe processes**
- **Participating in registries**

Accreditation/External Review

ACR/ASTRO Accreditation Partnership

Accreditation is a cooperative effort between the ACR and ASTRO

ACR recommended to Legislators MANDATORY accreditation of all facilities

ASTRO STRONGLY RECOMMENDED Accreditation for all facilities

Safety Culture

What Other Industries Can Teach Us?

- Nuclear Power Industry
- Aviation
  - Commercial Aviation Safety Team (CAST)

    - Standardize work processes
    - Use checklists
    - Use robust scientific methods in collaborative efforts to identify and mitigate risk
    - Improve teamwork and communication to reduce errors (Culture!)
  - Fatal accidents were more than cut in half between 1994 and 2006
  - No passenger or crew killed in major US carrier in more than 10 years
- **High Reliability Organization (HRO)**

Challenges

- Developing safety culture in healthcare is not as straightforward as in a HRO industry model (e.g. airline industry)
- Medicine has specific and unique challenges
  - "We have always done it that way"
  - Medical-legal
  - Lack of hard data/scientific consensus regarding optimal treatment or quality processes
  - The Patient Variable
- **In many HRO industries, person that makes significant error goes down with ship**

How Do We Develop Our Own High Reliability Organization (HRO)?

- **Guiding Principle: Commitment to Excellence and ZERO Mistakes**
- ***Empowerment***
  - **Create stability in infrastructure** (e.g. check lists, processes, procedures, committees, time outs, huddles)
  - **Create acceptance of continuous reevaluation and change**
  - **Train staff and MDs on organizational improvement techniques** (A3s, lean, CQI)
  - **Let staff identify needed change, bottom up rather than top down**
  - **Check "power distance" among staff**
- ***Anonymous/no-fault reporting system***
- ***Standardized work***
- ***Improve Communication***
- ***Registry/EMR* for RadOnc** to optimize available information and facilitate data analyses
  - **Registry changes care from episodic to real time prospective monitoring of care and its quality**

Culture

- Culture of Safety is key ingredient
  - Create the culture that strives to learn what happened
  - Commitment by all personnel
- Current medical culture: “be perfect”
  - Mistake…not what you did was bad , but you are bad
  - You are always supposed to have the right answer
  - Self doubt vs. culture of improvement
    - Errors are ubiquitous
    - Medical events vs. process mistakes
    - Mistakes are inevitable … if we weed out the mistake makers there won’t be anyone left
- Blameless culture

M. Workman, 2009

Efforts to Reduce Dose in Interventional Fluoroscopy

Donald L. Miller, M.D. FACR
Center for Devices and Radiological Health
Food and Drug Administration

FDA

Center for Devices and Radiological Health
CDRH

Nothing to disclose

- Historical background
- Equipment
- Quality management
- Education and training
- Occupational protection
- Dose optimization

1944

EDITORIAL

Howard P. Doub, M.D., Editor

John D. Camp, M.D., Associate Editor

Fluoroscopy and Leukemia

associates. The period of fluoroscopic observation should be kept as short as possible consistent with obtaining the desired information. As a further check a fluoroscopic timer should be installed to guard both the radiologist and the patient.

Radiology September 1944 43:297-298; doi:10.1148/43.3.297

- Skin injuries from fluoroscopy became increasingly rare after the 1930s
- Radiation risk from fluoroscopy appeared to be adequately controlled
- By the late 1980s/early 1990s this had changed

What Happened?

- Before 1975
  - – Relatively stagnant device technology
  - – Limited procedures (diagnostic angiography)
- After 1975
  - – New technologies/drugs
    - Angioplasty (balloon) catheters (mid-1970s)
    - Arterial stents (mid-1980s)
    - Microcatheters (1980s)
    - Embolic agents
    - Thrombolytic agents
  - – New interventional therapeutic procedures

New Procedures

- Angioplasty (late 1970s)
- Embolization (1980s)
- Arterial stents (1980s)
- Catheter-directed lysis of blood clots (1980s)
- Coronary artery stents (1990s)
- RF ablation for cardiac arrythmias (1990s)
- TIPS (1990s)
- Vascular stent-grafts (late 1990s)

Unintended Consequences

- Procedures became more complex
- Radiation doses increased
- Skin injuries began to occur
- Occupational doses increased

1990s

Recognition of the Problem

Initial Attempts at Control

PROCEEDINGS

OF THE

ACR/FDA WORKSHOP

ON

FLUOROSCOPY

STRATEGIES FOR IMPROVEMENT IN PERFORMANCE, RADIATION SAFETY AND CONTROL

DULLES HYATT HOTEL

WASHINGTON, D.C.

OCTOBER 16 AND 17, 1992

Components of the Problem

- Equipment
  - Inconsistent relationship between dose and image quality
  - High dose operation (HLC mode)
  - No ability to monitor radiation dose
  - Inadequate dose metric (fluoroscopy time)
- Quality management
  - Radiation dose neither monitored nor recorded
  - No patient follow-up for radiation effects
- Training
  - Often little or no training in radiation safety
- Worker protection

1994

FDA Public Health Advisory: Avoidance of Serious X Ray-Induced Skin Injuries to Patients During Fluoroscopically-Guided Procedures

(We encourage you to copy and distribute this Advisory)

September 30, 1994

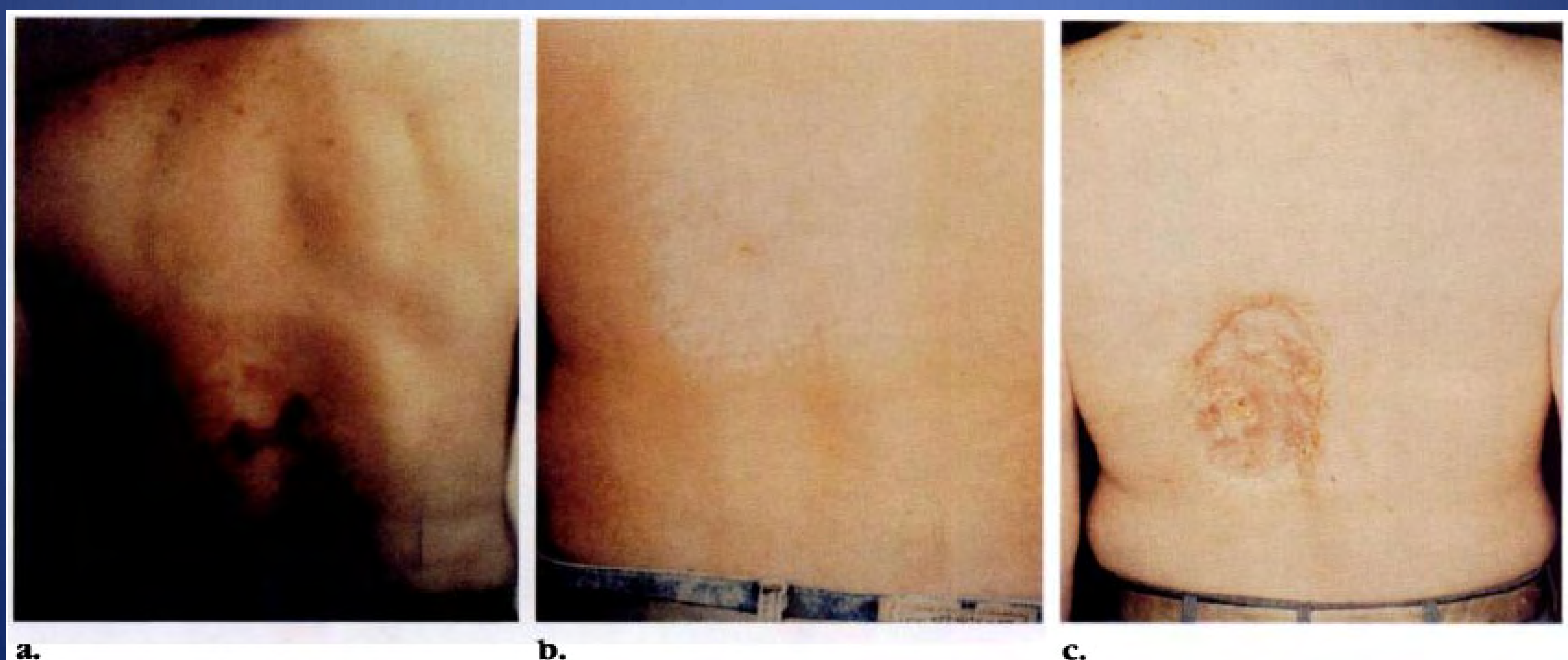
Physicians performing these procedures should be aware of the potential for serious, radiation-induced skin injury caused by long periods of fluoroscopy during these procedures. It is important to note that the onset of these injuries is usually delayed, so that the physician cannot discern the damage by observing the patient immediately after the treatment.

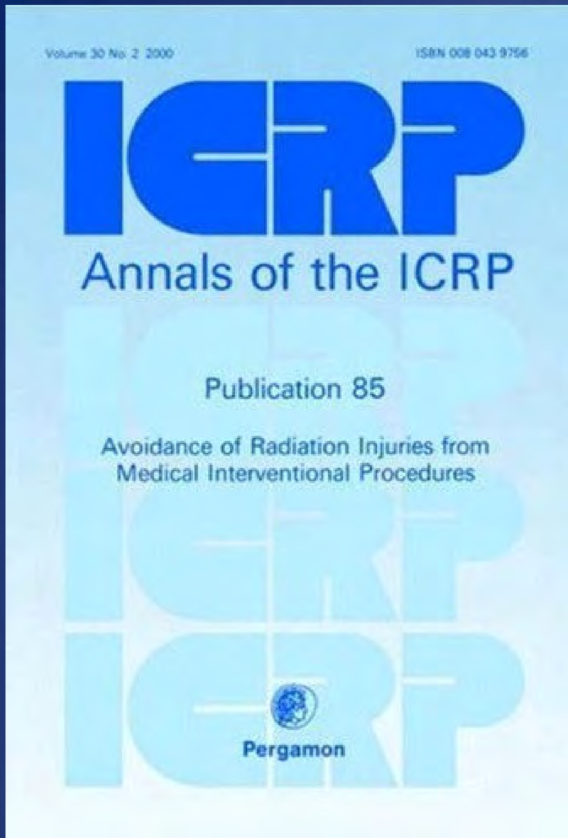
1996

Radiation-induced Skin Injuries from Fluoroscopy[1]

Thomas B. Shope, PhD

RadioGraphics 1996; 16:1195-1199





2000

Avoidance of radiation injuries from medical interventional procedures

ICRP Publication 85

Approved by the Commission in September 2000

- provides information on interventional procedures that have produced serious radiation effects (illustrated by case histories of avoidable injuries);
- explains the basis for the biological effects of ionising radiation on skin and eyes;
- provides practical advice for controlling the procedural doses to patients and for reducing occupational doses to staff, including advice on procurement of new equipment;

2001

Review

Skin Injuries from Fluoroscopically Guided Procedures: Part 1, Characteristics of Radiation Injury

AJR 2001;177:3–11

Titus R. Koenig[1], Detlev Wolff[2], Fred A. Mettler[3], Louis K. Wagner[1]

Review

Skin Injuries from Fluoroscopically Guided Procedures: Part 2, Review of 73 Cases and Recommendations for Minimizing Dose Delivered to Patient

AJR 2001;177:13–20

Titus R. Koenig[1], Fred A. Mettler[2], Louis K. Wagner[1]

Y2K

- The problem is recognized
- Reports published, primarily in the radiology and medical physics literature
- Advice is available to operators
- Equipment largely unchanged

2000s

- New technology for interventional fluoroscopy equipment
- Estimation of skin dose
- Identification of high dose procedures
- Importance of patient follow-up
- Training recommendations

Equipment

New equipment features

Radiation dose monitoring

Skin dose estimation

Pediatrics

Equipment Features

- Digital fluoroscopy
- Pulsed fluoroscopy
- Anatomic programing
  - kV, mA, pulse width, dose settings
- LIH/stored fluoroscopy loops
- Virtual collimation
- Automatic spectral filtration
- Radiation dose monitoring

Equipment

Radiation dose monitoring

1995

U.S. Department of Health & Human Services

FDA U.S. Food and Drug Administration

Home > Radiation-Emitting Products > Radiation-Emitting Products and Procedures > Medical Imaging

Radiation-Emitting Products

Recording Information In The Patient's Medical Record That Identifies The Potential For Serious X-Ray-Induced Skin Injuries

September 15, 1995

- Fluoroscopy time is the only metric required by FDA

Fluoroscopy Time

- Very poor metric for estimating patient radiation dose
- Does not reflect fluoroscopy dose rate
- Does not include dose from radiography

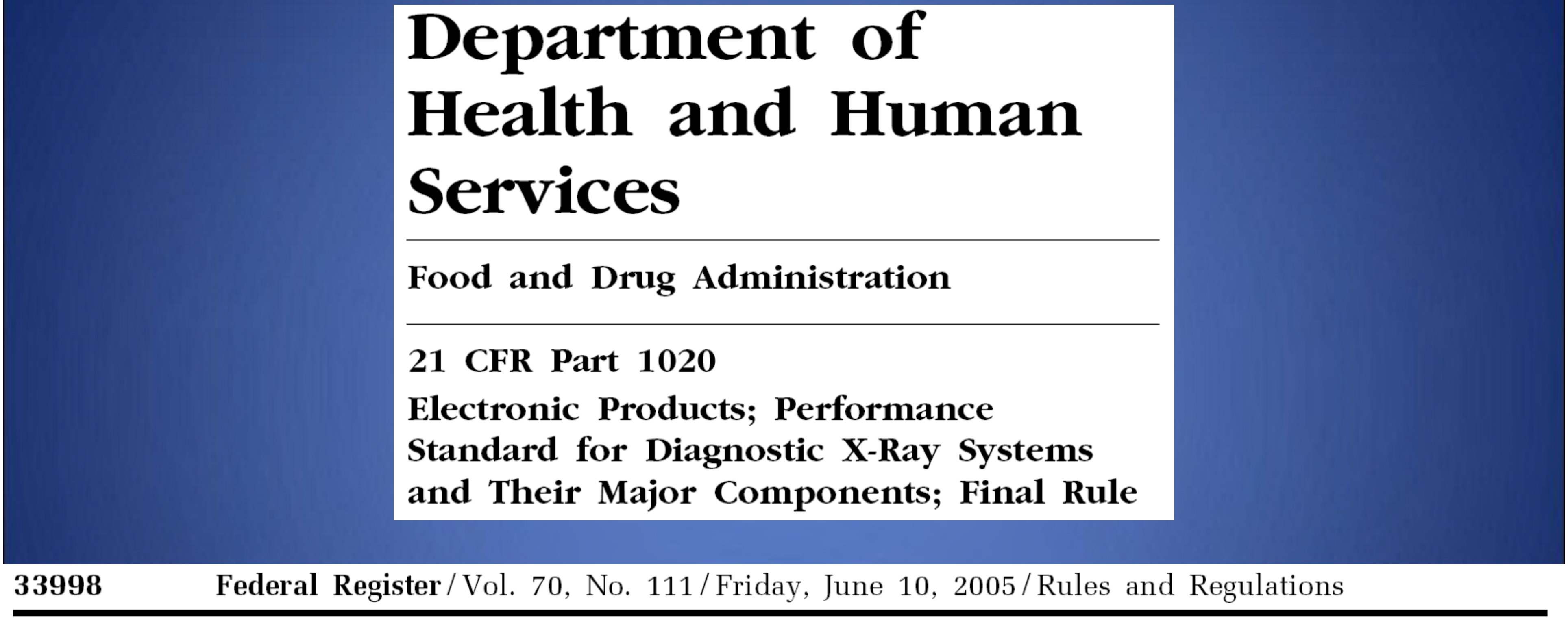
2000

Medical electrical equipment
Part 2-43: Particular requirements for the safety of X-ray equipment for interventional procedures
(IEC 60601-2-43:2000)

Compliant equipment:

- Cumulative air kerma at the IRP
- Dose metric displayed to operator

2005


Department of Health and Human Services

Food and Drug Administration

21 CFR Part 1020

Electronic Products; Performance Standard for Diagnostic X-Ray Systems and Their Major Components; Final Rule

33998 Federal Register / Vol. 70, No. 111 / Friday, June 10, 2005 / Rules and Regulations

- *Requires* display of cumulative air kerma (§ 1020.32(k))
- *Requires* last-image-hold capability (§ 1020.32(j))

2010

IEC

IEC 60601-2-43

Edition 2.0 2010-03

INTERNATIONAL STANDARD

Medical electrical equipment –
Part 2-43: Particular requirements for the basic safety and essential performance of X-ray equipment for interventional procedures

- More prominent display of patient dose
- Radiation dose data exported with images

2011 - 2012

- Radiation Dose Structured Report (RDSR)
- Standardizes export of detailed dosimetric data in an open format
- Facilitates communication of dose data between fluoroscopes and databases
- Based on IEC PAS 61910-1 (2007)

Equipment

Skin dose estimation

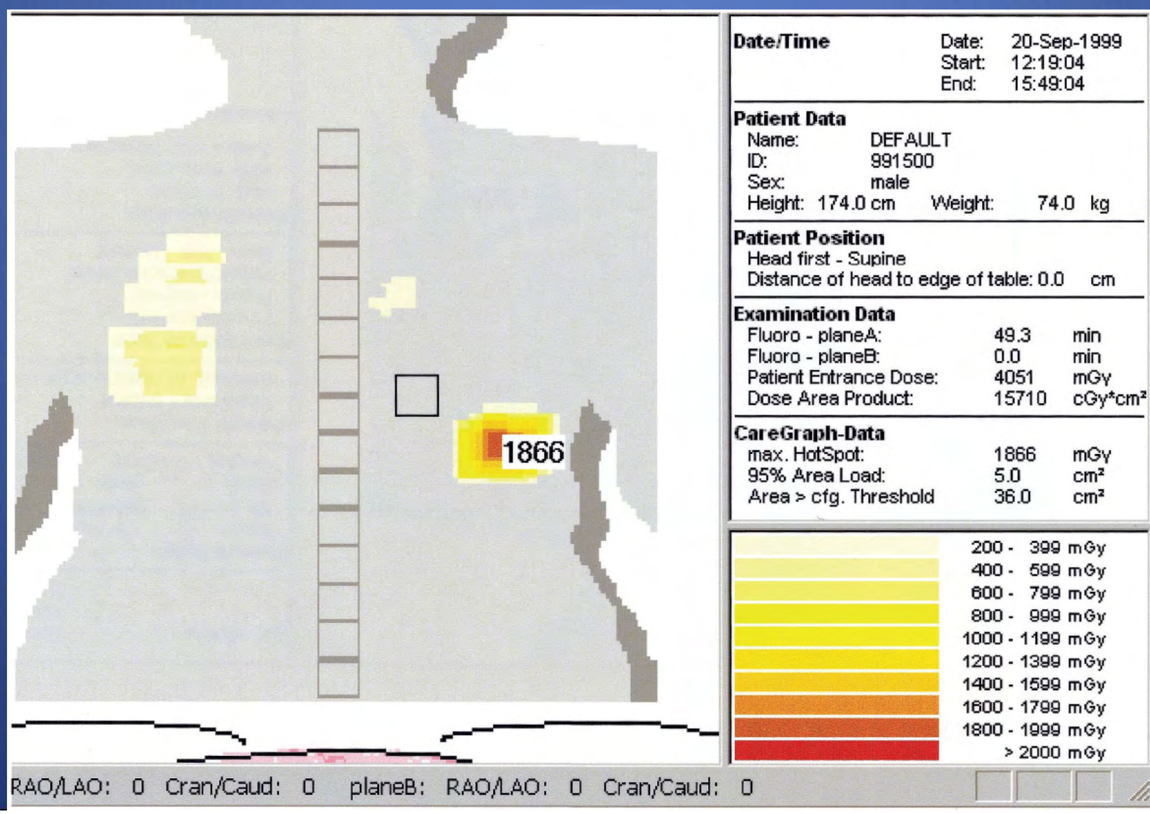
- 1995—FDA recommends recording skin dose and location on the patient
- 2000—ICRP Publication 85 recommends “a suitable body map with the estimated doses, indicating the entry site of the beam at each stage of the procedure”
- No simple method for estimating or mapping skin dose exists

2001

Real-Time Quantification and Display of Skin Radiation During Coronary Angiography and Intervention

Ad den Boer, BS; Pim J. de Feijter, MD; Patrick W. Serruys, MD; Jos R.T.C. Roelandt, MD

(*Circulation*. 2001;104:1779-1784.)



2003

Radiation Doses in Interventional Radiology Procedures: The RAD-IR Study

Part I: Overall Measures of Dose

J Vasc Interv Radiol 2003; 14:711–727

Part II: Skin Dose

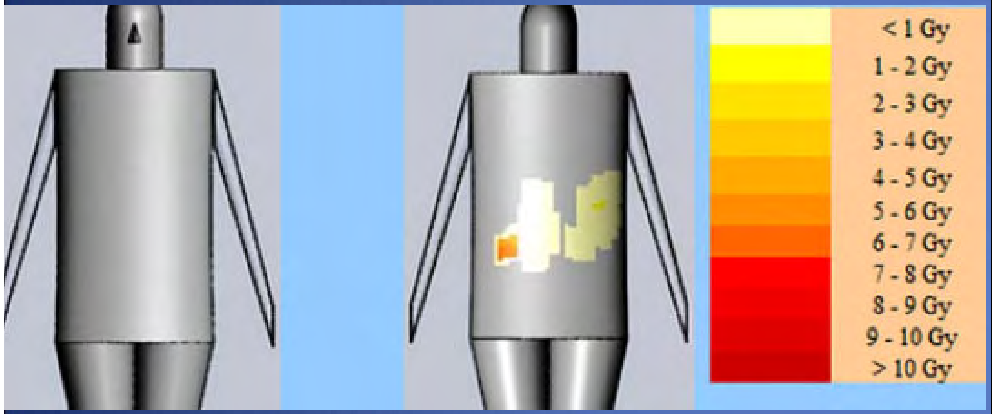
J Vasc Interv Radiol 2003; 14:977–990

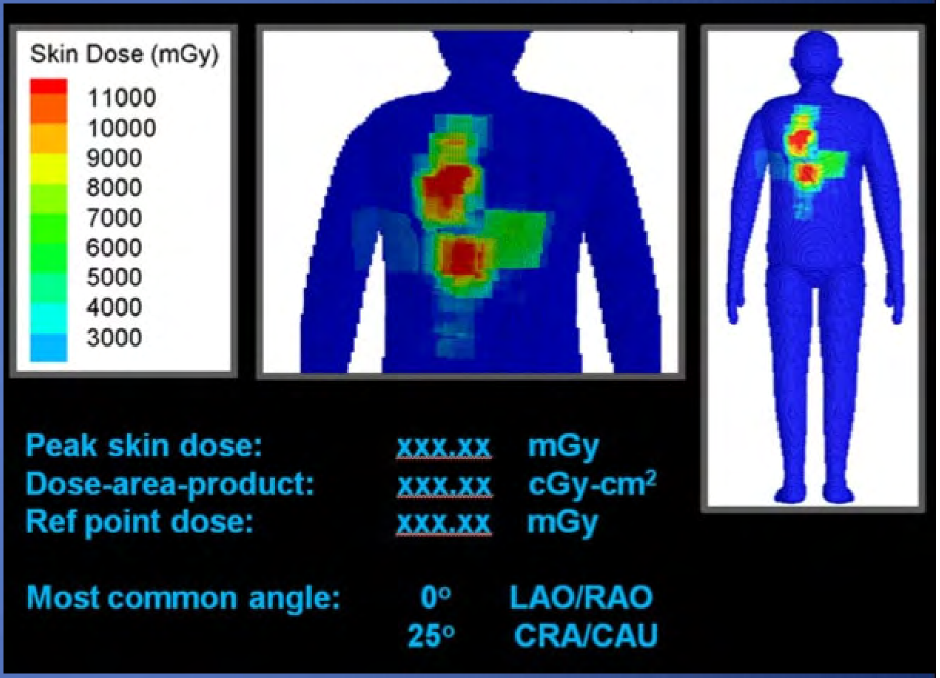
CONCLUSIONS: There are substantial variations in PSD among instances of the same procedure and among different procedure types. Most of the procedures observed may produce a PSD sufficient to cause deterministic effects in skin. It is suggested that dose data be recorded routinely for TIPS creation, angioplasty in the abdomen or pelvis, all embolization procedures, and especially for head and spine embolization procedures. Measurement or estimation of PSD is the best method for determining the likelihood of radiation-induced skin effects. Skin dose mapping is preferable to a single-point measurement of PSD.

- Peak skin dose, cumulative air kerma at the IRP, kerma-area product, fluoroscopy time

2010

2011





Journal of Digital Imaging

Automatic Monitoring of Localized Skin Dose with Fluoroscopic and Interventional Procedures

Yasaman Khodadadegan,[1] Muhong Zhang,[1] William Pavlicek,[2] Robert G. Paden,[2] Brian Chong,[2] Beth A. Schueler,[3] Kenneth A. Fetterly,[4] Steve G. Langer,[3] and Teresa Wu[1]

Skin dose mapping for fluoroscopically guided interventions

Perry B. Johnson and David Borrego
Biomedical Engineering, University of Florida, Gainesville, Florida 32611

Stephen Balter
Radiology, Columbia University Medical Center, New York, New York 10032

Kevin Johnson
Radiology, University of Florida, Jacksonville, Florida 32209

Daniel Siragusa
Radiology, Division of Vascular Interventional Radiology, University of Florida, Jacksonville, Florida 32209

Wesley E. Bolch[a]
Biomedical Engineering, University of Florida, Gainesville, Florida 32611

Equipment

Pediatric considerations

2006

Pediatr Radiol (2006) 36 (Suppl 2): 126–135
DOI 10.1007/s00247-006-0220-4

ALARA

Keith J. Strauss

Pediatric interventional radiography equipment: safety considerations

This discussion illustrates that proper imaging of pediatric patients cannot assume that children are small adults. Imaging equipment needs to be specifically designed and configured for children, while the operator must operate the device to exploit these imaging capabilities at appropriate radiation dose levels. The generator must provide a large

Pediatric Equipment Considerations

- Removable grid
- Variable rate pulsed fluoroscopy
- Adjustable added filtration
- Small focal spot
- Appropriate anatomic programing
  - kV, mA, short pulse width, dose settings
- Fast frame rates

Quality Management

Recording radiation dose

Reference levels

AAPM REPORT NO. 58

MANAGING THE USE OF FLUOROSCOPY IN MEDICAL INSTITUTIONS

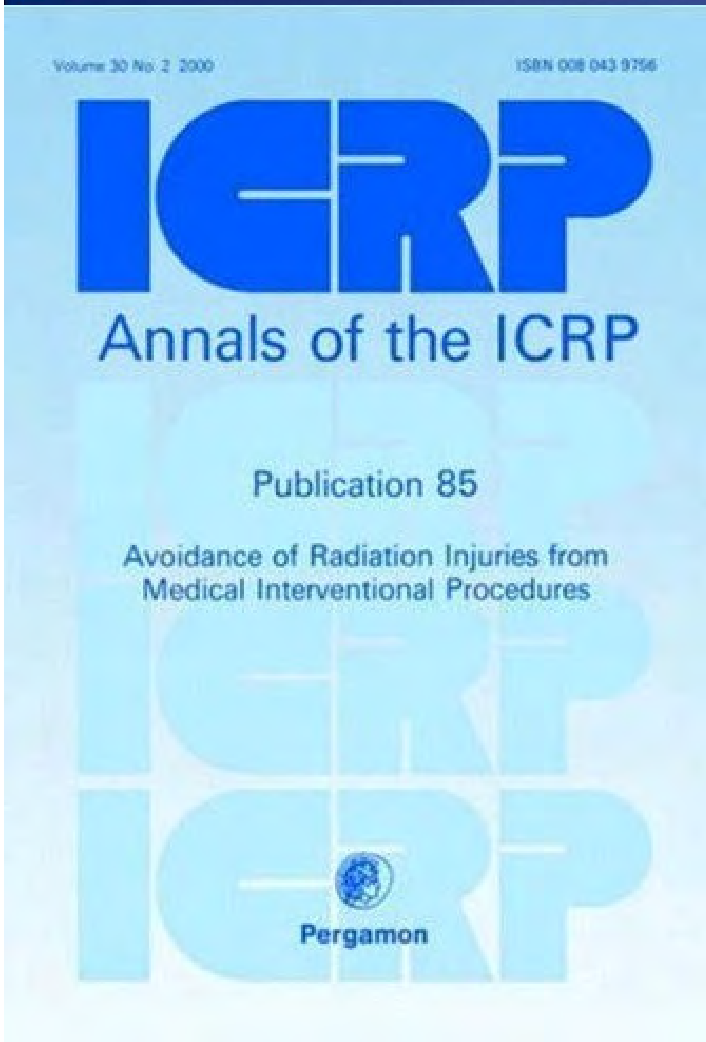
Published for the
American Association of Physicists in Medicine
by Medical Physics Publishing

1998

Two aspects of management of radiation use that have not been dealt with in the past are: 1) a quality management program that monitors radiation usage in general, as well as radiation doses to individual patients and 2) the development of a training and credentialing process for users of fluoroscopy equipment. This

Quality Management

Recording radiation dose



2000

Avoidance of radiation injuries from medical interventional procedures

ICRP Publication 85

Approved by the Commission in September 2000

to control dose. Maximum cumulative absorbed doses that appear to approach or exceed 1 Gy (for procedures that may be repeated) or 3 Gy (for any procedure) should be recorded in the patient record, and there should be a patient follow-up procedure for such cases. Patients

2004

Quality Improvement Guidelines for Recording Patient Radiation Dose in the Medical Record

J Vasc Interv Radiol 2004; 15:423–429

- Which dose metrics should be recorded
- When dose metrics should be recorded

2010

CRCPD Pub. #E-10-8
December 2010

Conference of Radiation Control Program Directors, Inc.

Monitoring and Tracking of Fluoroscopic Dose

Handout developed by CRCPD's H-31 Task Force for Monitoring Patient Dose during Fluoroscopy

Protecting our Patients and Ourselves

- Also included in NCRP Report No. 168 (2010)

Quality Management

Reference levels

Reference Levels

- Quality improvement tool
- Designed to reduce the risk of stochastic effects
- Indicator of dose for average–sized patient
- Guidance for what is achievable with good practice

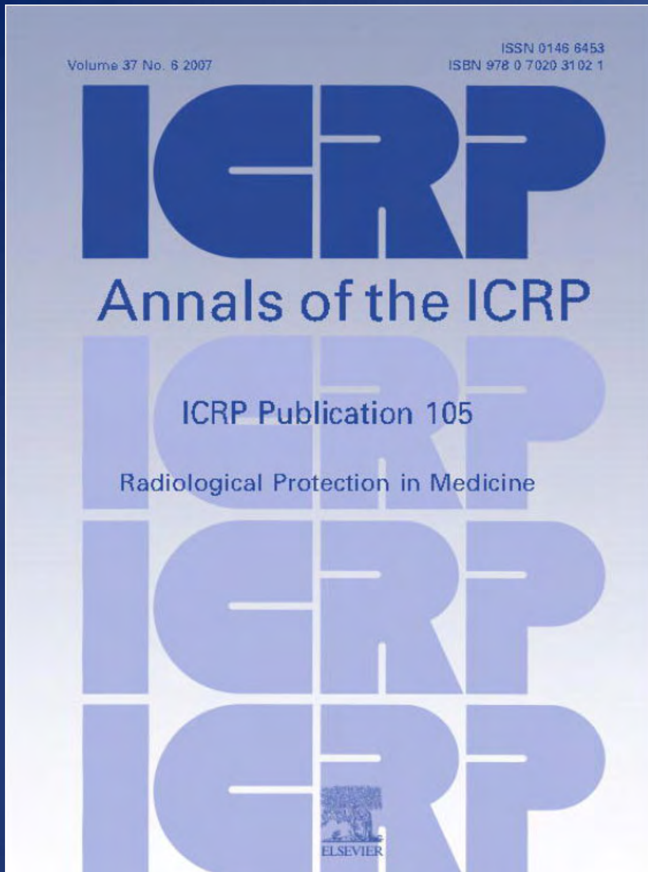
2001

Radiation Protection Dosimetry
Vol. 94, No. 1–2, pp. 109–112 (2001)
Nuclear Technology Publishing

APPROACHES TO ESTABLISHING REFERENCE LEVELS IN INTERVENTIONAL RADIOLOGY

E. Vañó†‡ and L. Gonzalez†

Energy Agency, IAEA) are preparing specific documents related to RP and safety in IR[6,7]. Thus, the topic of RL is relevant for IR procedures, and a strategy to introduce appropriate RL is essential as a basis to optimise the imaging part of the procedure.



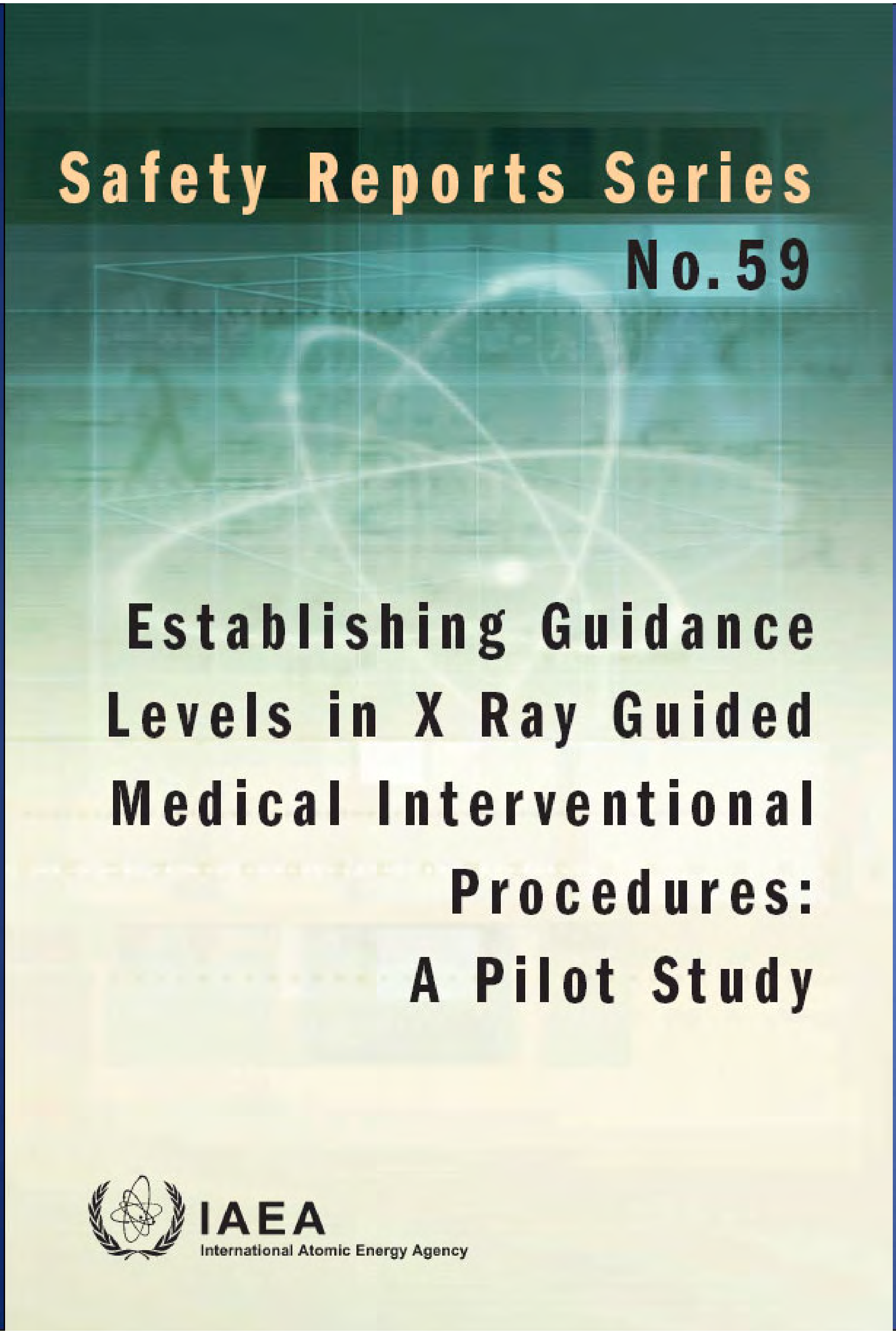
2007

Radiation Protection in Medicine

ICRP Publication 105

Approved by the Commission in October 2007

(90) For fluoroscopically guided interventional procedures, diagnostic reference levels, in principle, could be used to promote the management of patient doses with regard to avoiding unnecessary stochastic radiation risks. However, the observed distribution of patient doses is very wide, even for a specified protocol, because the duration and complexity of the fluoroscopic exposure for each conduct of a procedure is strongly dependent on the individual clinical circumstances. A potential approach is to take into consideration not only the usual clinical and technical factors, but also the relative 'complexity' of the procedure.



2009

Complexity analysis

2009

Radiology

ORIGINAL RESEARCH ■ MEDICAL PHYSICS

Reference Levels for Patient Radiation Doses in Interventional Radiology: Proposed Initial Values for U.S. Practice[1]

Radiology: Volume 253: Number 3—December 2009

Conclusion: Sufficient data exist to permit an initial proposal of values for reference levels for interventional radiologic procedures in the United States. For ease of use, reference levels without correction for body habitus are recommended. A national registry of radiation-dose data for interventional radiologic procedures is a necessary next step to refine these reference levels.

2011

Patient radiation dose audits for fluoroscopically guided interventional procedures

Med. Phys. 38 (3), March 2011

Purpose: Quality management for any use of medical x-ray imaging should include monitoring of radiation dose. Fluoroscopically guided interventional (FGI) procedures are inherently clinically variable and have the potential for inducing deterministic injuries in patients. The use of a conventional diagnostic reference level is not appropriate for FGI procedures. A similar but more detailed quality process for management of radiation dose in FGI procedures is described.

2012

- NCRP Report: Diagnostic Reference Levels in Medical and Dental Imaging: Recommendations for Applications in the United States

Education and Training

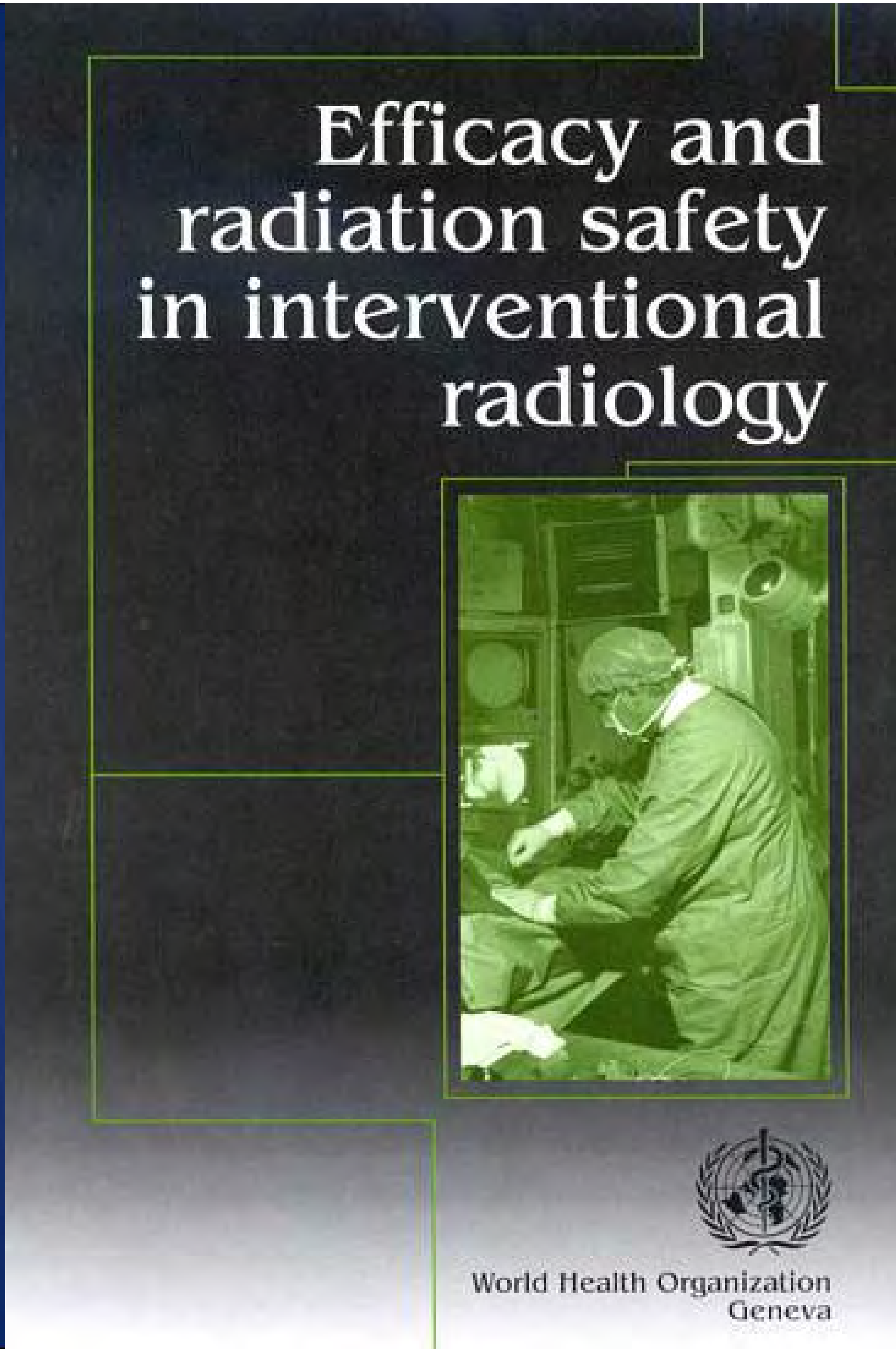
AAPM REPORT NO. 58

MANAGING THE USE OF FLUOROSCOPY IN MEDICAL INSTITUTIONS

Published for the
American Association of Physicists in Medicine
by Medical Physics Publishing

1998

Two aspects of management of radiation use that have not been dealt with in the past are: 1) a quality management program that monitors radiation usage in general, as well as radiation doses to individual patients and 2) the development of a training and credentialing process for users of fluoroscopy equipment. This


Efficacy and
radiation safety
in interventional
radiology
World Health Organization
Geneva

2000

Radiation Protection 116

GUIDELINES ON EDUCATION AND TRAINING IN RADIATION PROTECTION FOR MEDICAL EXPOSURES

European Commission

2000

2003

Training in radiological protection for interventionalists. Initial Spanish experience

[1,2]E VANO, PhD, [1]L GONZALEZ, PhD, [3]M CANIS, MD, PhD and [4]A HERNANDEZ-LEZANA, MD, PhD

[1]*Radiology Department, Complutense University, 28040 Madrid,* [2]*Medical Physics Service, San Carlos University Hospital, 28040 Madrid,* [3]*President of the Spanish Society of Vascular and Interventional Radiology, Reina Sofia University Hospital, Cordoba and* [4]*Past President of the Spanish Society of Vascular and Interventional Radiology, Severo Ochoa Hospital, Leganes, Madrid, Spain*

The British Journal of Radiology, 76 (2003), 217–219

In Spain, a Royal Decree on Quality Criteria for Diagnostic Radiology was enacted in 1999 [14]. For interventional practices its requirements are:

(a) Laboratories or fluoroscopic screening rooms specifically designed for these procedures.
(b) Imaging systems specifically designed for interventional procedures (in compliance with International Electrotechnical Commission standards).
(c) A system for measuring and registering doses received by patients.
(d) An accreditation in RP (called "second level", to differentiate it from the first level which is mandatory for all the radiologists [15]) for the specialists conducting these procedures. This accreditation shall be supervised by the Health Authority.

2004

Journal of the American College of Cardiology

Published by Elsevier Inc.

Vol. 44, No. 11, 2004
ISSN 0735-1097/04/$30.00
doi:10.1016/j.jacc.2004.10.014

ACCF/AHA/HRS/SCAI FLUOROSCOPY CLINICAL COMPETENCE STATEMENT

ACCF/AHA/HRS/SCAI Clinical Competence Statement on Physician Knowledge to Optimize Patient Safety and Image Quality in Fluoroscopically Guided Invasive Cardiovascular Procedures

A Report of the American College of Cardiology Foundation/ American Heart Association/American College of Physicians Task Force on Clinical Competence and Training

This document proposes a curriculum that covers the basic knowledge of radiation physics, radiation biology, radiation safety, and radiological imaging that should be held by practitioners who perform X-ray fluoroscopically guided invasive cardiovascular procedures. The curriculum

2008

Radiation Protection Dosimetry (2008), Vol. 129, No. 1–3, pp. 67–70
Advance Access publication 12 March 2008
doi:10.1093/rpd/ncn005

HIGH PATIENT DOSES IN INTERVENTIONAL CARDIOLOGY DUE TO PHYSICIANS' NEGLIGENCE: HOW CAN THEY BE PREVENTED?

I. Mavrikou[1,*], S. Kottou[2], V. Tsapaki[3] and V. Neofotistou[1]

As hoped, after the cardiologists' training, the patient doses were substantially lower and thus the LRLs were greatly reduced. In general, all cardiologists, except cardiologist F have succeeded in substantially lowering doses. However, more work has

2009

Image Gently, Step Lightly: Increasing Radiation Dose Awareness in Pediatric Interventions through an International Social Marketing Campaign

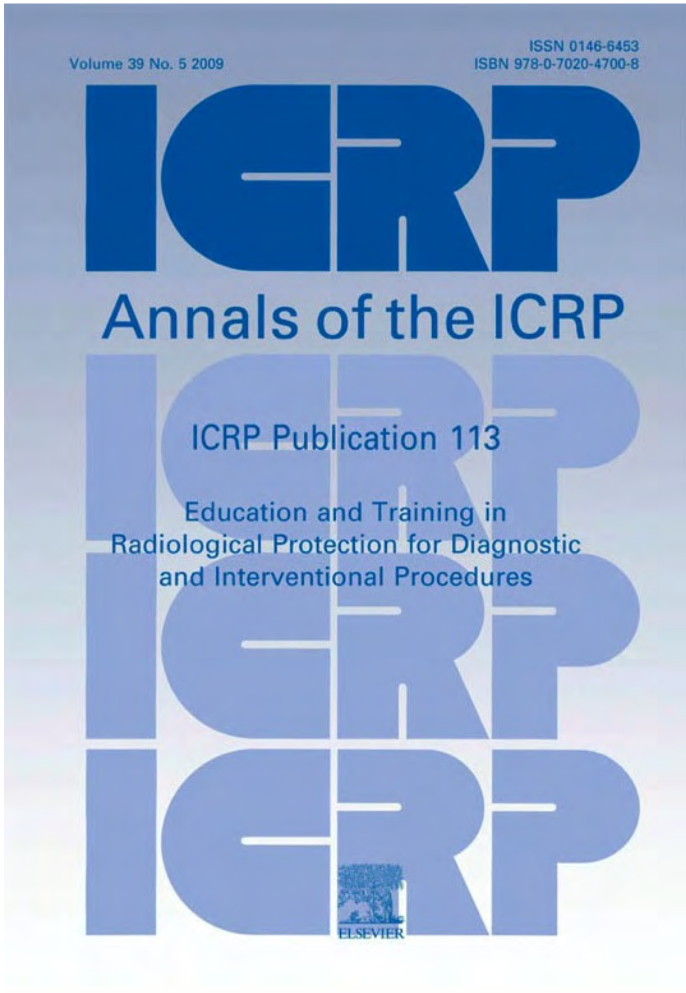
Manrita K. Sidhu, MD, Marilyn J. Goske, MD, Brian J. Coley, MD, Bairbre Connolly, MB, FRCPC, John Racadio, MD, Terry T. Yoshizumi, PhD, Tara Utley, MRT, and Keith J. Strauss, MSc

In the past several decades, advances in imaging and interventional techniques have been accompanied by an increase in medical radiation dose to the public. Radiation exposure is even more important in children, who are more sensitive to radiation and have a longer lifespan during which effects may manifest. To address radiation safety in pediatric computed tomography, in 2008 the Alliance for Radiation Safety in Pediatric Imaging launched an international social marketing campaign entitled Image Gently. This article describes the next phase of the Image Gently campaign, entitled Step Lightly, which focuses on radiation safety in pediatric interventional radiology.

J Vasc Interv Radiol 2009; 20:1115–1119

Children are not small adults

2009



2010

Education and Training in Radiological Protection for Diagnostic and Interventional Procedures

ICRP PUBLICATION 113

Approved by the Commission in October 2010

(e) There should be RP training requirements for physicians, dentists, and other health professionals who request, conduct, or assist in medical or dental procedures that utilise ionising radiation in diagnostic and interventional procedures, nuclear medicine, and radiation therapy. The final responsibility for the radiation exposure

2011

Catheterization and Cardiovascular Interventions 77:546–556 (2011)

Core Curriculum

Radiation Safety Program for the Cardiac Catheterization Laboratory

Charles E. Chambers,[1*] MD, Kenneth A. Fetterly,[2] PhD, Ralf Holzer,[3] MD, Pei-Jan Paul Lin,[4] PhD, James C. Blankenship,[5] MD, Stephen Balter,[6] PhD, and Warren K. Laskey,[7] MD

2012

Radiological Protection in Cardiology

ICRP PUBLICATION XXX

Approved by the Commission in October 2011

Occupational Protection

1993	1995	2000
NCRP REPORT No. 116	NCRP REPORT No. 122	NCRP REPORT No. 133
LIMITATION OF EXPOSURE TO IONIZING RADIATION	USE OF PERSONAL MONITORS TO ESTIMATE EFFECTIVE DOSE EQUIVALENT AND EFFECTIVE DOSE TO WORKERS FOR EXTERNAL EXPOSURE TO LOW-LET RADIATION	RADIATION PROTECTION FOR PROCEDURES PERFORMED OUTSIDE THE RADIOLOGY DEPARTMENT
NCRP	NCRP	NCRP
National Council on Radiation Protection and Measurements	*National Council on Radiation Protection and Measurements*	*National Council on Radiation Protection and Measurements*

2008

Radiation Protection Dosimetry (2008), Vol. 129, No. 1–3, pp. 333–339
Advance Access publication 14 May 2008
doi:10.1093/rpd/ncn082

OVERVIEW OF DOUBLE DOSIMETRY PROCEDURES FOR THE DETERMINATION OF THE EFFECTIVE DOSE TO THE INTERVENTIONAL RADIOLOGY STAFF

H. Järvinen[1,*], N. Buls[2], P. Clerinx[2], J. Jansen[3], S. Miljanić[4], D. Nikodemová[5], M. Ranogajec-Komor[4] and F. d'Errico[6]

In interventional radiology, for an accurate determination of effective dose to the staff, measurements with two dosemeters have been recommended, one located above and one under the protective apron. Such 'double dosimetry' practices and the algorithms used for the determination of effective dose were reviewed in this study by circulating a questionnaire and by an extensive literature search. The results indicated that regulations for double dosimetry almost do not exist and there is no firm consensus on the most suitable calculation algorithms. The calculation of effective dose is mainly based on the single dosemeter measurements, in which either personal dose equivalent, directly, (dosemeter below the apron) or a fraction of personal dose equivalent (dosemeter above the apron) is taken as an assessment of effective dose. The most recent studies suggest that there might not be just one double dosimetry algorithm that would be optimum for all interventional radiology procedures. Further investigations in several critical configurations of interventional radiology procedures are needed to assess the suitability of the proposed algorithms.

2010

Cardiovasc Intervent Radiol (2010) 33:230–239
DOI 10.1007/s00270-009-9756-7

CIRSE GUIDELINES

Occupational Radiation Protection in Interventional Radiology: A Joint Guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology

minimize occupational radiation dose.

The radiation dose received by interventional radiologists can vary by more than an order of magnitude for the same type of procedure and for similar patient dose [4]. Recently, there has been particular concern regarding

2011

Radiation Protection Dosimetry (2011), Vol. 144, No. 1–4, pp. 437–441
Advance Access publication 3 November 2010
doi:10.1093/rpd/ncq326

INTERNATIONAL PROJECT ON INDIVIDUAL MONITORING AND RADIATION EXPOSURE LEVELS IN INTERVENTIONAL CARDIOLOGY

R. Padovani[1], J. Le Heron[2], R. Cruz-Suarez[2], A. Duran[3], C. Lefaure[2], D.L. Miller[4], H.K. Sim[5], E. Vano[6], M. Rehani[2] and R. Czarwinski[2]

Concerning requirements for wearing personal dosemeters, only 57 % of the RB specifies the number and position of dosemeters for staff monitoring. Less than 40 % of the RBs could provide occupational doses. Reported annual median effective dose values (often <0.5 mSv) were lower than expected considering validated data from facility-specific studies, indicating that compliance with continuous individual monitoring is often not achieved in IC. A true assessment of annual personnel doses in IC will never be realised unless a knowledge of monitoring compliance is incorporated into the analysis.

2008

Radiology

Eye Lens Exposure to Radiation in Interventional Suites: Caution Is Warranted[1]

Radiology: Volume 248: Number 3—September 2008

Eliseo Vano, PhD
Luciano Gonzalez, PhD
Jose M. Fernández, MSc
Ziv J. Haskal, MD

ORIGINAL RESEARCH ■ MEDICAL PHYSICS

Purpose: To report estimated radiation doses to the eye lens of the interventionalist from procedures performed with and without use of radiation protection measures.

Conclusion: With typical reported workloads, radiation doses to eye lenses may exceed the threshold for deterministic effects (ie, lens opacities or cataracts) after several years of work if radiation protection tools are not used.

2010

Catheterization and Cardiovascular Interventions 76:826–834 (2010)

Risk for Radiation-Induced Cataract for Staff in Interventional Cardiology: Is There Reason for Concern?

Olivera Ciraj-Bjelac,[1] PhD, Madan M. Rehani,[2*] PhD, Kui Hian Sim,[3] MBBS, FRACP, Houng Bang Liew,[3] MBBS, FRCP, Eliseo Vano,[4] PhD, and Norman J. Kleiman,[5] PhD

lens changes. Conclusions: These findings demonstrate a dose dependent increased risk of posterior lens opacities for interventional cardiologists and nurses when radiation protection tools are not used. While study of a larger cohort is needed to confirm these findings, the results suggest ocular radio-protection should be utilized.

2011

ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

ICRP ref 4825-3093-1464

Statement on Tissue Reactions

Approved by the Commission on April 21, 2011

(3) For occupational exposure in planned exposure situations the Commission now recommends an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv.

Optimization of Protection

1998

The British Journal of Radiology, 71 (1998), 510–516

Dosimetric and radiation protection considerations based on some cases of patient skin injuries in interventional cardiology

[1]E VAÑÓ, MSc, PhD, [2]L ARRANZ, MSc, PhD, [2]J M SASTRE, MSc, [3]C MORO, MD, [4]A LEDO, MD, [4]M T GÁRATE, MD and [3]I MINGUEZ, MD

For high dose cardiology procedures:

- Use dedicated interventional fluoroscopy equipment
- Estimate patient radiation dose
- Record radiation dose in the medical record
- Improve training of operators

2000

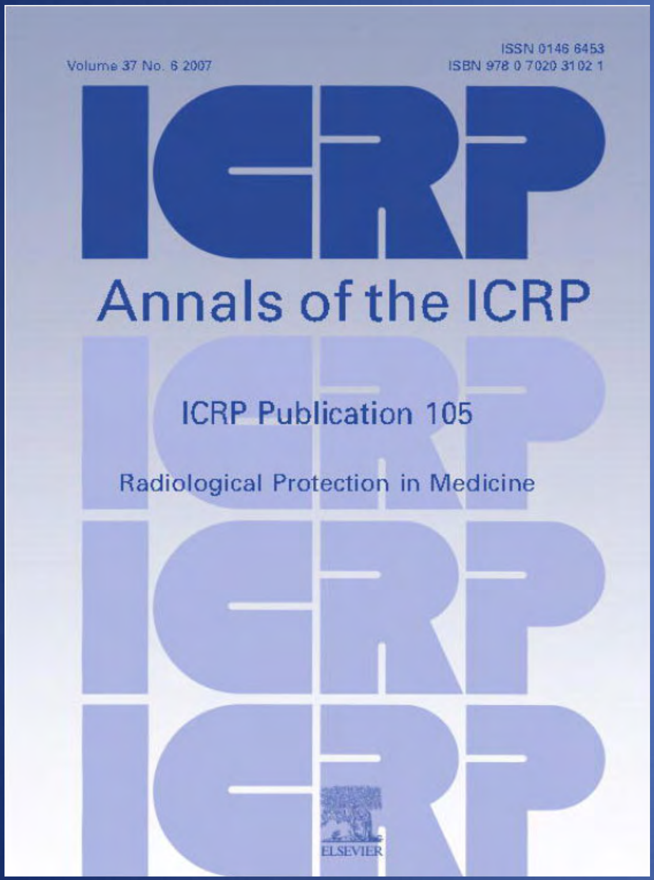
Avoidance of radiation injuries from medical interventional procedures

ICRP Publication 85

Annals of the ICRP

Approved by the Commission in September 2000

- provides information on interventional procedures that have produced serious radiation effects (illustrated by case histories of avoidable injuries);
- explains the basis for the biological effects of ionising radiation on skin and eyes;
- provides practical advice for controlling the procedural doses to patients and for reducing occupational doses to staff, including advice on procurement of new equipment;



2007

- Use appropriate equipment
- Training is essential
- Use information on skin dose
- Use practical techniques to control dose
- Record radiation dose
- Provide appropriate follow-up
- Audit and review the outcomes of procedures for radiation injury

2009

Guidelines for Patient Radiation Dose Management

Michael S. Stecker, MD, Stephen Balter, PhD, Richard B. Towbin, MD, Donald L. Miller, MD, Eliseo Vañó, PhD, Gabriel Bartal, MD, J. Fritz Angle, MD, Christine P. Chao, MD, Alan M. Cohen, MD, Robert G. Dixon, MD, Kathleen Gross, MSN, RN-BC, CRN, George G. Hartnell, MD, Beth Schueler, PhD, John D. Statler, MD, Thierry de Baère, MD, and John F. Cardella, MD, for the SIR Safety and Health Committee and the CIRSE Standards of Practice Committee

J Vasc Interv Radiol 2009; 20:S263–S273

SIR GUIDELINES

Radiation dose management requires a comprehensive approach including preprocedural planning, intraprocedural management, and postprocedural care. It also includes periodic quality assessment.

IAEA-TECDOC-1641

Patient Dose Optimization in Fluoroscopically Guided Interventional Procedures

Final report of a coordinated research project

IAEA
International Atomic Energy Agency

2010

NCRP REPORT No. 168

RADIATION DOSE MANAGEMENT FOR FLUOROSCOPICALLY-GUIDED INTERVENTIONAL MEDICAL PROCEDURES

NCRP
National Council on Radiation Protection & Measurements

2010

- Equipment
- Training
- Credentialing
- Dose management
- Dose monitoring
- Patient follow-up
- Worker protection
- Quality improvement

2011

Catheterization and Cardiovascular Interventions 77:546–556 (2011)

Core Curriculum

Radiation Safety Program for the Cardiac Catheterization Laboratory

Charles E. Chambers,[1*] MD, Kenneth A. Fetterly,[2] PhD, Ralf Holzer,[3] MD, Pei-Jan Paul Lin,[4] PhD, James C. Blankenship,[5] MD, Stephen Balter,[6] PhD, and Warren K. Laskey,[7] MD

for dose management. The components of a radiation safety program include essential personnel, radiation monitoring, protective shielding, imaging equipment, and training/education. A procedure based review of radiation dose management is described including pre-procedure, procedure and post-procedure best practice recommendations. Specific

2012

Annals of the ICRP

ICRP PUBLICATION XXX

Radiological protection in fluoroscopically guided procedures performed outside the imaging department

2012

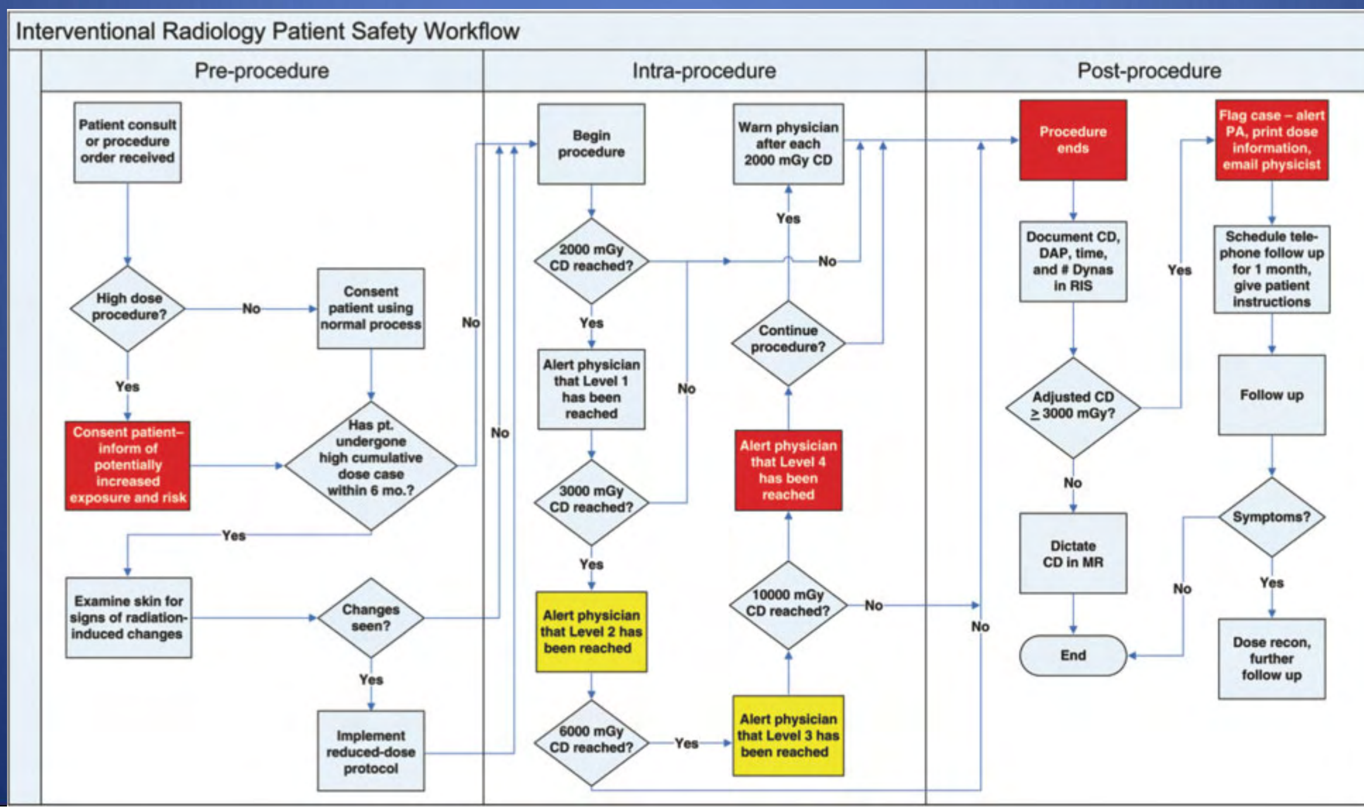
RadioGraphics

Quality Initiatives

Establishing an Interventional Radiology Patient Radiation Safety Program

Joseph R. Steele, MD • A. Kyle Jones, PhD • Elizabeth P. Ninan, PA-C

ONLINE-ONLY CME



What’s Next?

Innovation

- New technologies and devices
- New, more complex procedures
- New equipment features

Optimization—Patients

- Training and credentialing of operators
- Dose monitoring and recording
- National dose registries
- Reference levels
- Regulation?

Optimization—Workers

- Training and credentialing
- Better monitoring and tracking of occupational dose
- Decrease in the Maximum Permissible Dose?
- Regulation?

Radiation Continuing Concern With *Fluoroscopy*

November 1993 / FDA Consumer

MAYO CLINIC

Standardization versus individualization: How each contributes to managing dose in computed tomography

Cynthia H. McCollough, PhD, FAAPM, FACR
Director, CT Clinical Innovation Center
Professor of Radiologic Physics & Biomedical Engineering
Mayo Clinic, Rochester, MN

MAYO CLINIC

DISCLOSURES

Research Support:

NIH	Other
EB 007986	Society of Gastrointestinal Radiologists
EB 004898	Mayo Novel Methodology Development Award
DK 083007	Thrasher Foundation
DK 059933	Siemens Healthcare
DK 090728	
AR 057902	
RR 018898	

Off Label Usage

None

Dose management in CT

- Dose management is about getting the right dose for the *specific* patient and the *specific* diagnostic task
- Since patients and diagnostic tasks vary, doses vary
- How much variation is acceptable?
- How much variation is too much?
- How can we ensure good variations and reduce bad variations?

MAYO CLINIC

"Dose" Variations in CT

Variations to Consider	Source
Diagnostic task - Colonography or angiography	Indication
Thickness in scan region - Not just weight or BMI	Patient
Scanner characteristics - Beam spectra, bowtie, etc	Scanner
Protocols choices - Scan time, image width, etc	Protocol

MAYO CLINIC

Indication Variability

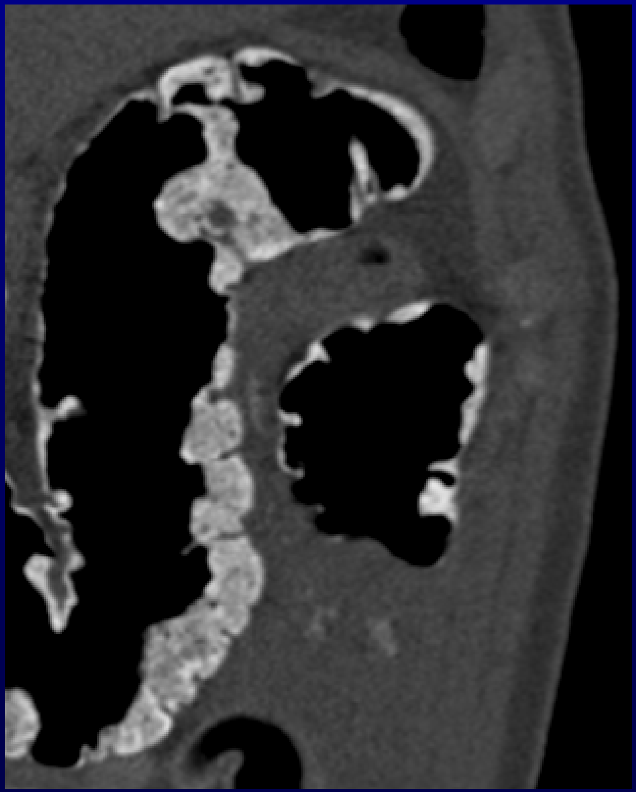
MAYO CLINIC

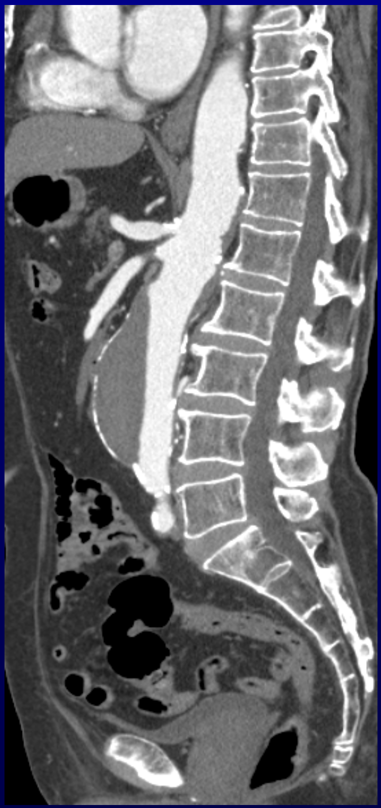
Courtesy of JG Fletcher, MD

Large Attenuation Differences

CT Colongraphy

CT Angiography





3 mGy CTDIvol 18 mGy

Subtle Attenuation Differences

Hepatocellular Carcinoma

CTDIvol = 27 mGy

MAYO CLINIC

Adjusting for diagnostic task

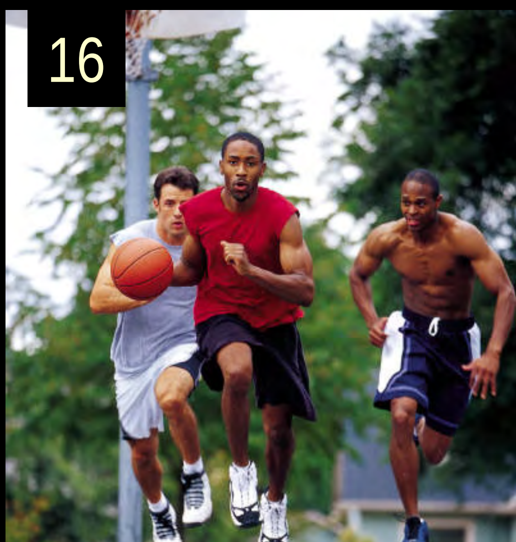
- Ordering physician must
  - understand what exam best answers the clinical questions
  - specify the clinical question so that correct protocol is used
- Require significant changes in workflow and behaviors
  - Decision support tools for ordering need to become mainstream
  - Ordering and radiology communities need to talk to each other
- Medical imaging and radiation protection in medicine principles needs to be taught repeatedly in medical school and residencies

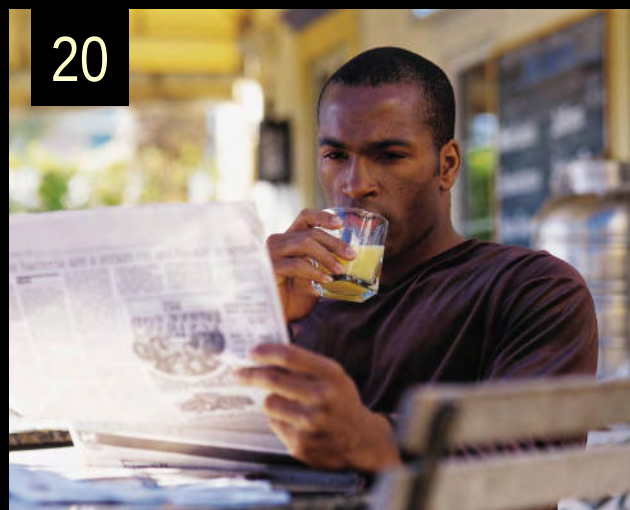
Magnitude of Variation in Patient Dose

Indication $\approx \times 9$

MAYO CLINIC

Patient Variability





"Right-sizing" the dose

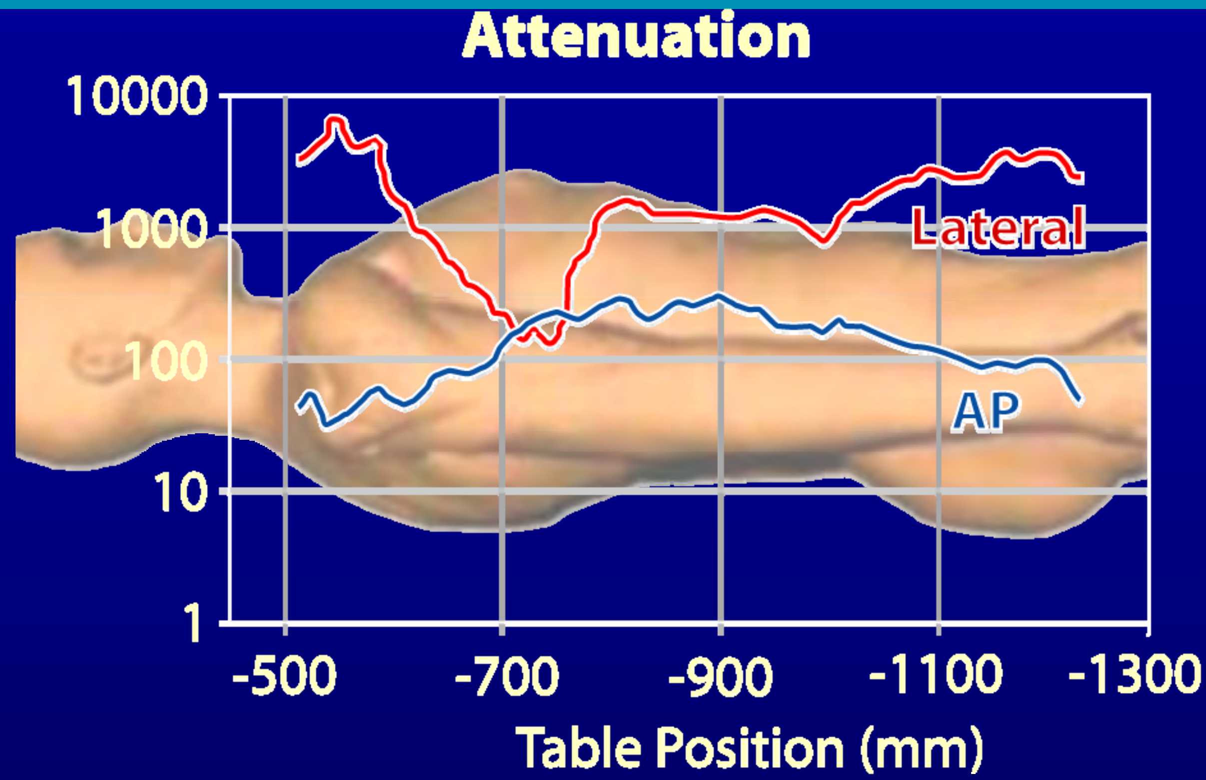
CTDIvol (mGy)

MAYO CLINIC

Technique charts

- Adapt the scan parameters to
  - specific patient
  - specific diagnostic task
- Reduce dose for pediatric and small patients
- Improve image quality for large patients
- Ensure consistency across practice
  - dose and image quality

MAYO CLINIC



X-ray attenuation

- Varies over body region and with projection angle
- Image noise is primarily determined by noisiest projections (thick body parts)
- More photons (dose) to thinner body parts is unnecessary radiation dose

MAYO CLINIC

AEC:
Automatic Exposure Control

Highly successful method of adapting scanner output to individual patient size

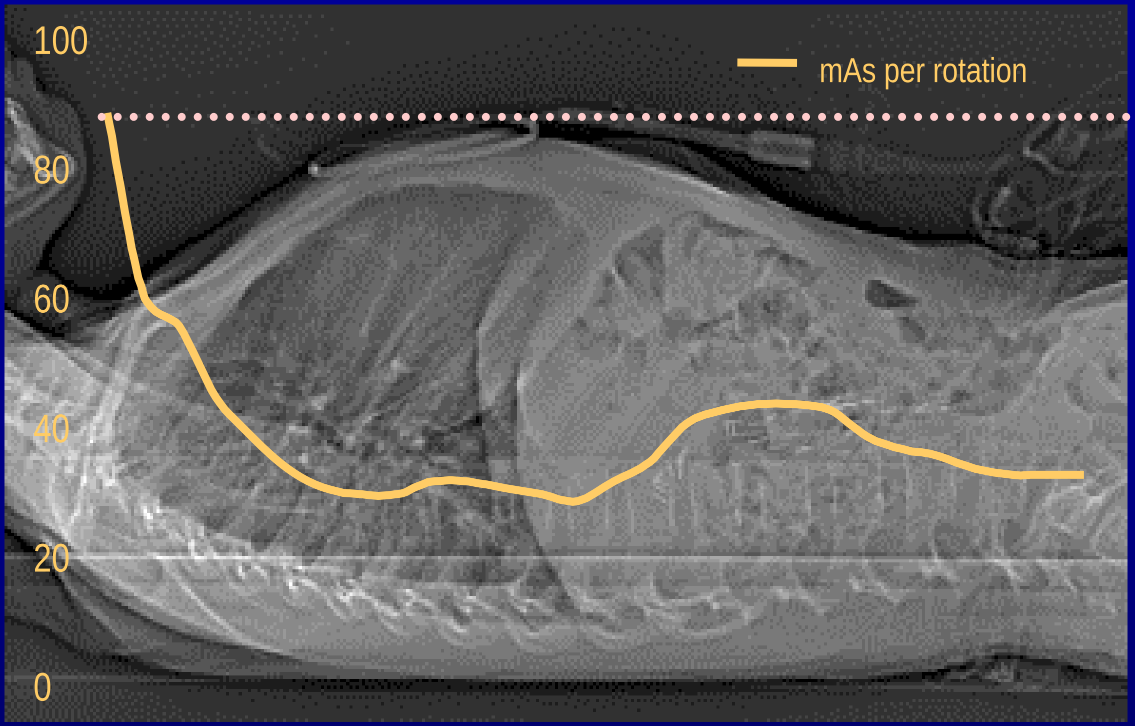
MAYO CLINIC

Three Levels of AEC

- For a single cross section, automatically adjust the mA along different directions
  - (x-y modulation)
- For a single patient, automatically adjust the mA for different body parts
  - (z modulation)
- For different patients, automatically adjust the mA based upon the patient size
  - “Right sizing” dose for each patient

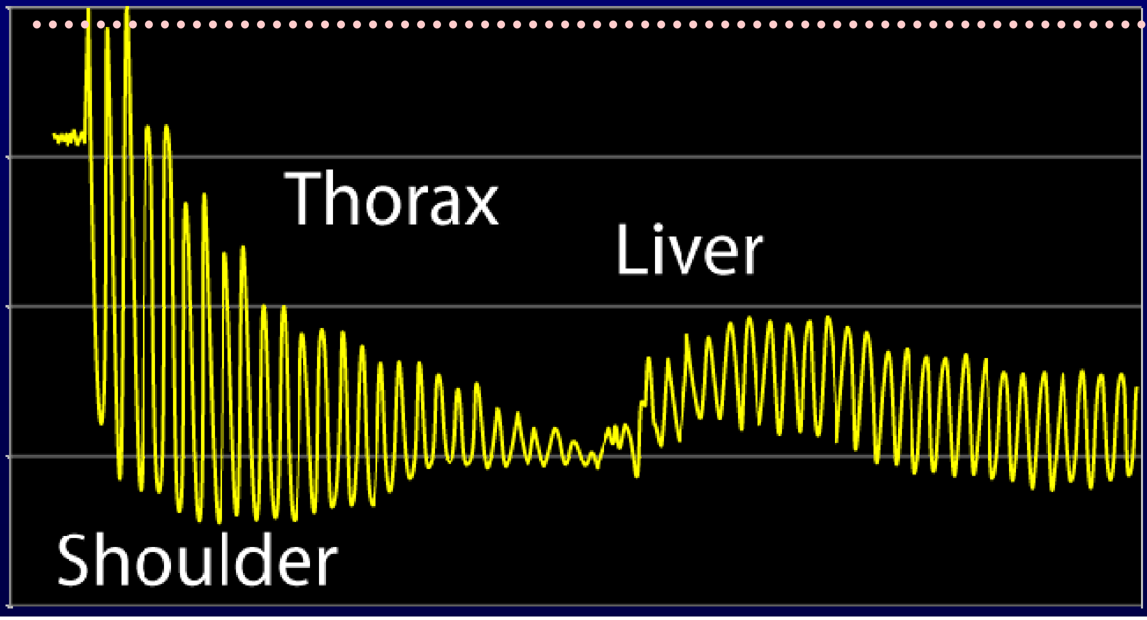
MAYO CLINIC

Z modulation



Without modulation

Angular modulation



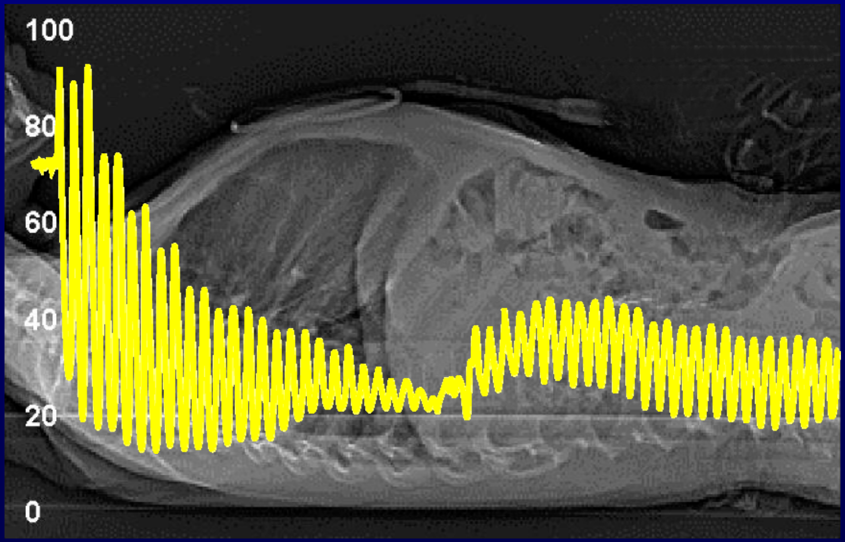
Without modulation

MAYO CLINIC

6 yo scanned with adult protocol

Adult reference eff. mAs = 165

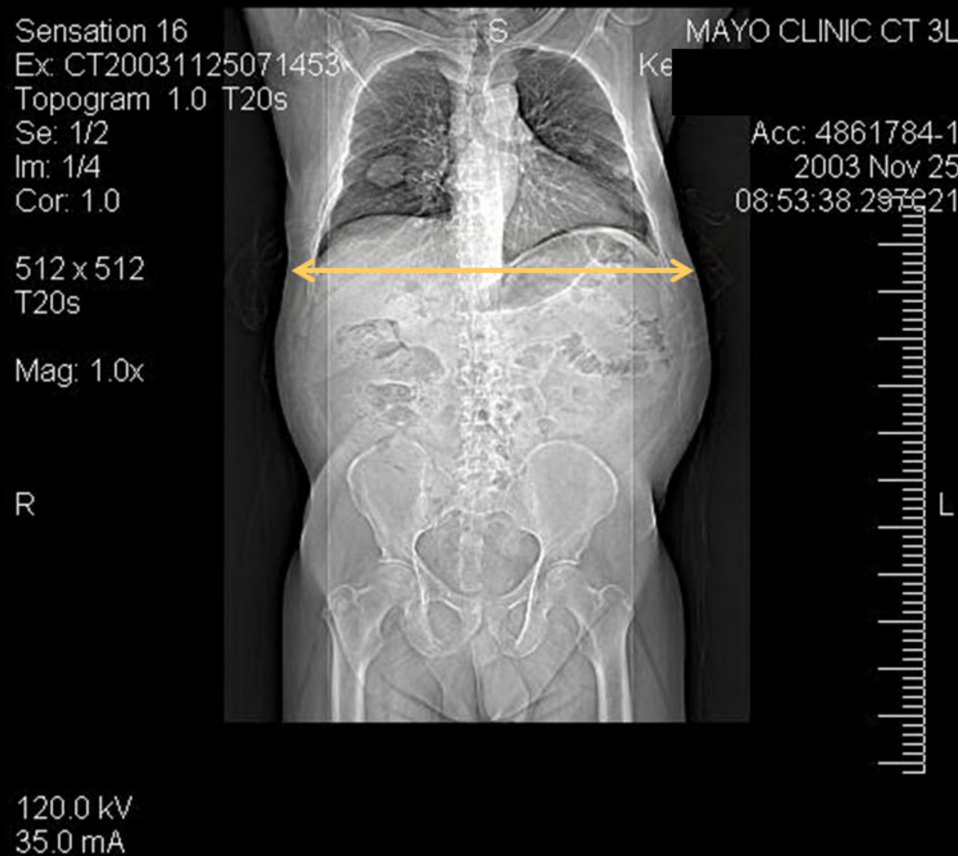
Mean eff. mAs delivered to child = 38

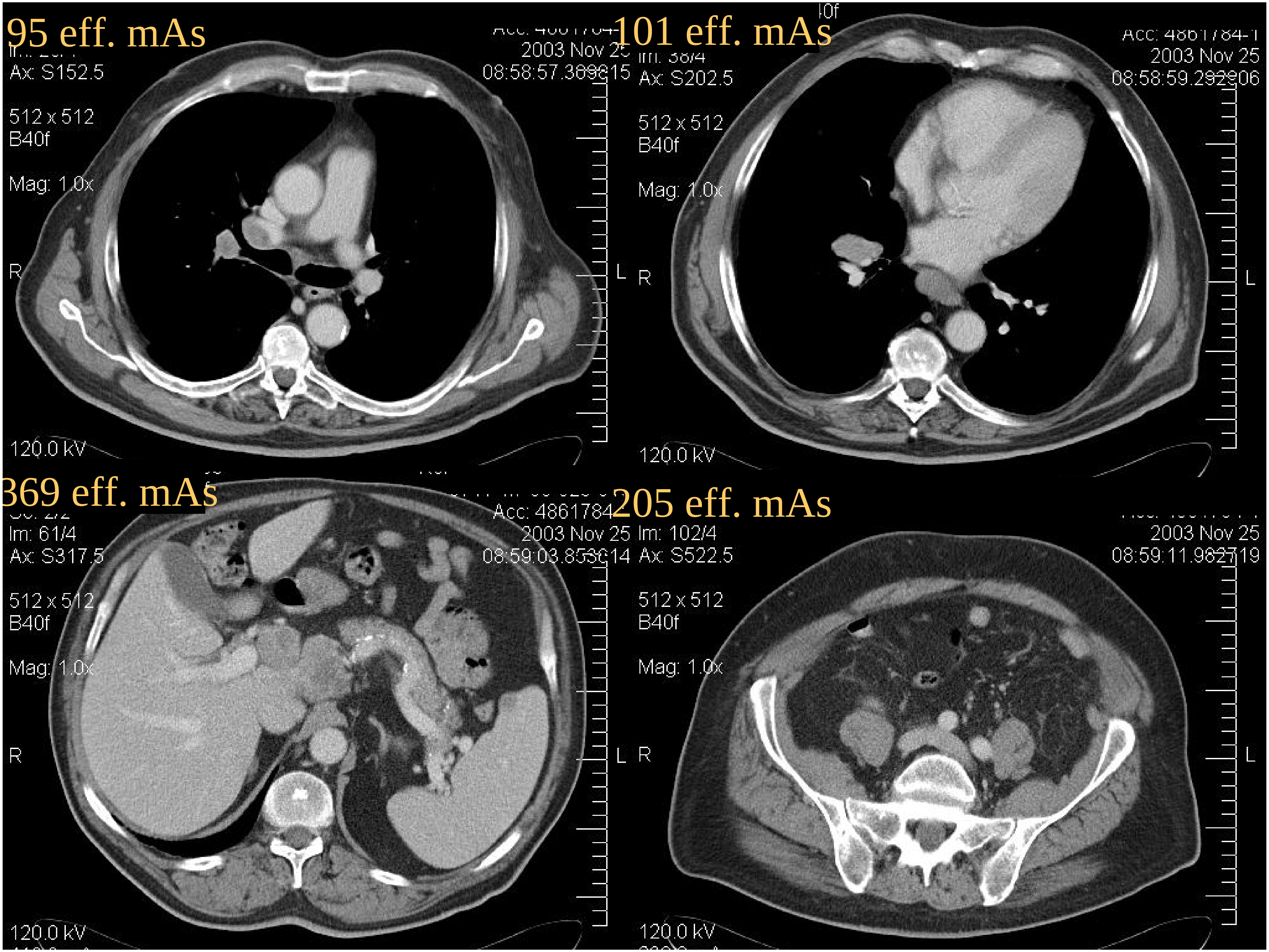


mA variation

Routine Chest/Abdomen/Pelvis (5 mm)
71 y.o. male

43 cm lateral width ->340




95 eff. mAs
Ax: S152.5
512 x 512
B40f
Mag: 1.0x
R
L
120.0 kV
2003 Nov 25
101 eff. mAs
Im: 38/4
Ax: S202.5
512 x 512
B40f
Mag: 1.0x
R
L
120.0 kV
Acc: 4861784-1
2003 Nov 25
08:58:59.292906
369 eff. mAs
Im: 61/4
Ax: S317.5
512 x 512
B40f
Mag: 1.0x
R
L
120.0 kV
Acc: 4861784
2003 Nov 25
205 eff. mAs
Im: 102/4
Ax: S522.5
512 x 512
B40f
Mag: 1.0x
R
L
120.0 kV
2003 Nov 25

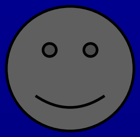
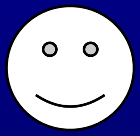
Effective mAs decrease relative to our technique charts

• Exam average	21.0%
• Upper lung	29.7%
• Breast	54.8%
• Liver	13.2%
• Pelvis	23.2%

Automatic exposure control

- User determines IQ (noise) requirements (hard)
  - don’t need “pretty” pictures for all diagnostic tasks
  - very little objective assessment (observer performance studies) done on what is the “right” dose/IQ
  - current practice relies on user experience and preference
- System determines the “right” mAs and kVp (easy)

Magnitude of Variation in Patient Dose

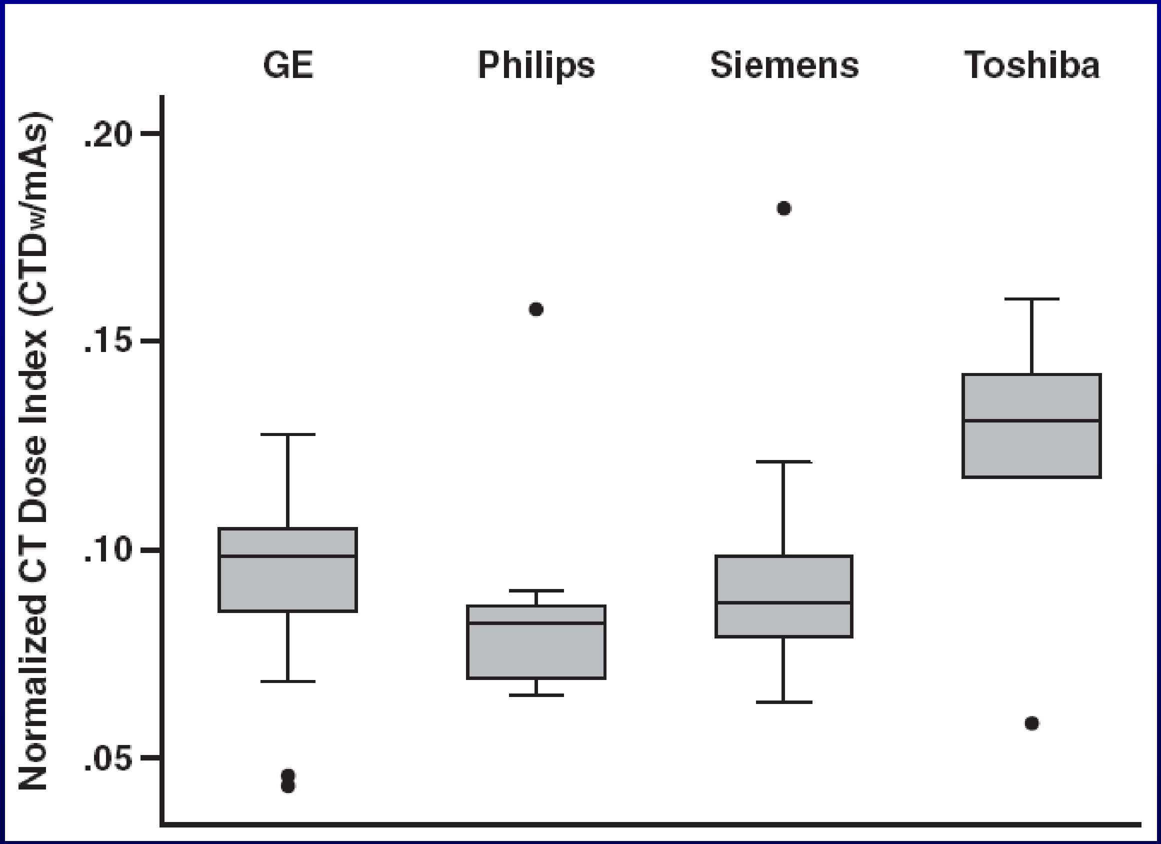
Indication ≈ × 9	
Patient ≈ × 20	

MAYO CLINIC

Scanner Variability

MAYO CLINIC

Variability across models



Cody et al, *Normalized CT Dose Index of the CT Scanners Used in the NLST.* AJR 2010

Shrimpton et al, National survey of doses from CT in the UK: 2003. BJR 2006

MAYO CLINIC

Magnitude of Variation in Patient Dose

Indication ≈ × 9	☺
Patient ≈ × 20	☺
Scanner ≈ × 1.5	

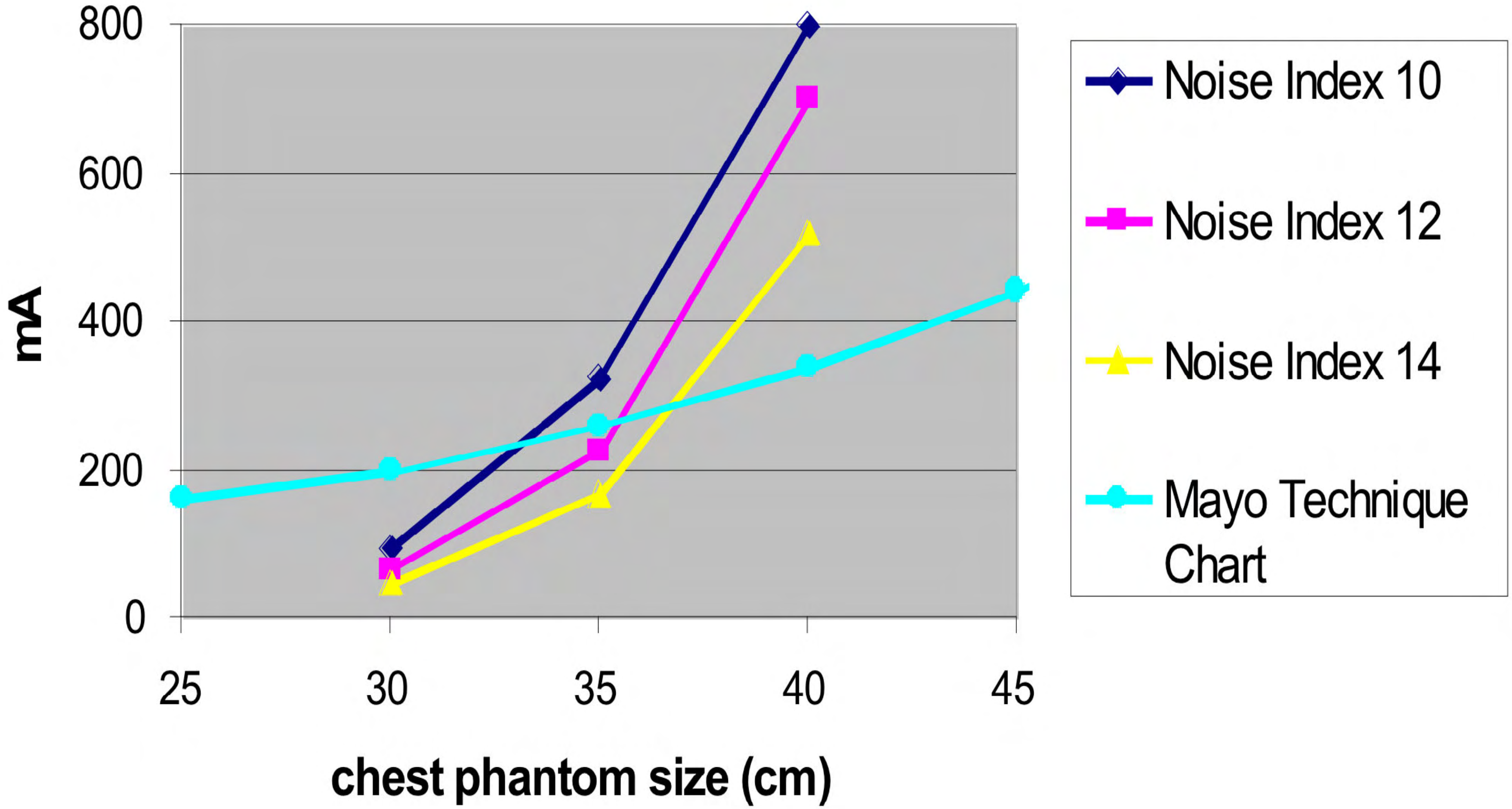
MAYO CLINIC

Lack of standardized nomenclature

Dose Modulation Tools				
Automatic exposure control (AEC) system	*Available in Auto-mA*	*Available in Dose Right*	*Available in CARE Dose4D*	Sure Exposure (Real EC)
X-ray tube modulation around patient x, y	SmartScan *(CT/i only)*	DOM (Dose Modulation)	CARE Dose	*not available as a separate item*
X-ray tube modulation in longitudinal (z) direction	Auto-mA	*Not available as a separate item*	*not available as a separate item (automatically used in head exams)*	Sure Exposure
X-ray tube modulation system in all dimensions (x, y, and z)	Smart-mA *(z or x, y, z)*	Z-DOM	*available in CARE Dose4D*	*Work in progress*
Cardiac x-ray tube modulation (based on ECG)	ECG Modulated mA	Cardiac Dose Modulation	ECG pulsing	*Available on Aquilion 64*
AEC combined with x, y and z tube modulation	Smart-mA	DoseRight ACS (Automatic Current Selection) *and* Z-DOM	CARE Dose4D	*Work in progress*
Image quality reference parameter for automatic exposure control (AEC) mode	Noise Index	Reference image	Quality Reference mAs	Standard Deviation (%) or standard, low-dose, or high-quality

*Circa 2005

Lack of standardized behavior



To accommodate these differences

- Use a noise target technique chart
  - min and max mA values prevent excessive decrease or increase of tube current

Lateral Patient Width (cm)	Noise Index (at 0.5 s)	Minimum mA	Maximum mA
22.1 – 30	9	150	280
30.1 – 40	11.5	220	500
40.1 – 45	14.5	400	720
45.1 – 50+	17 (0.7 s)	450	770

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Protocol Variability

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Knowing terminology, operation, features, quirks and performance of your system(s)

- You can translate across manufacturer (make) and model to yield the desired "deliverables"
- Usually not one way to accomplish the same results
- Usually not a lot of ways
- Evaluate options quantitatively with phantoms
- Evaluate options clinically with patients
  - Some differences between seemingly similar options show up only in patients

Agree on "deliverables"

- Define what the final product needs to look like
  - Scan time (total) and per image (temporal resolution)
  - Image width(s) and image plane(s) required
  - Image sharpness or smoothness
  - Noise level
  - Diagnostic reference level (CTDIvol)
- Critical need for observer performance studies to objectively define required performance criteria

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Routine Chest at Mayo Clinic Rochester

SIEMENS	Sens-16	Sens-40	Sens-64	Def-64	Def-AS+	F-128
Scan Type	Spiral	Spiral	Spiral	Spiral	Spiral	Spiral
Rotation Time (s)	0.5	0.5	0.33	0.33	0.33	0.28
Collimation	16 x 0.75	40 x 0.6	64 x 0.6	64 x 0.6	128 x 0.6	128 x 0.6
Pitch	1.1	1.15	0.9	0.9	0.9	0.9
Feed (mm/rot)	*13.2*	*13.2*	*17.8*	*17.8*	*34.6*	*34.6*
kVp	120	120	120	120	120	120
Quality ref. mAs	180	140	180	180	180	180
CARE Dose4D	ON	ON	ON	ON	ON	ON
API	Inspiration	Inspiration	Inspiration	Inspiration	Inspiration	Inspiration
Prep Delay (s)	20	20	20	20	24	24
Min. Retro (mm)	*0.75*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*
CTDI (mGy)	*14.04*	*15.02*	*14*	*12.98*	*12.13*	*12.16*
Base Protocol	*ThoraxRoutine*	*ThoraxRoutine*	*ThoraxRoutine*	*ThoraxRoutine*	*ThoraxRoutine*	*ThoraxRoutine*

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Variability across scanners and practices

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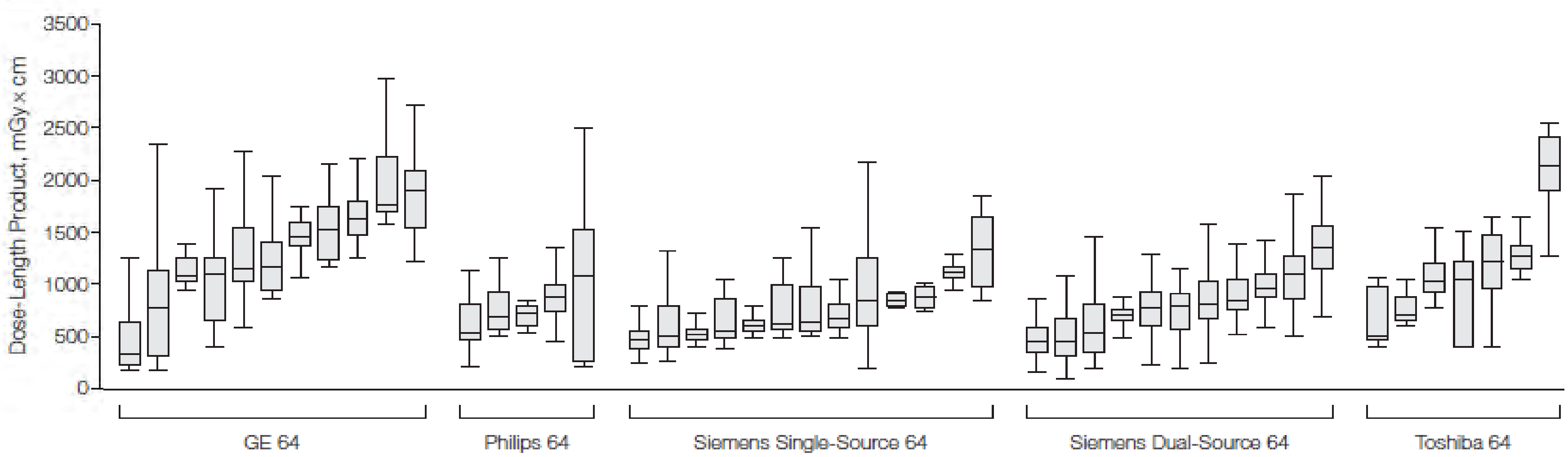
Variability across scanners and practices

Table 2. Patient and CT Scan Characteristics for 64-Slice Coronary CT Angiography[a]

	No. (%) of Patients or Median (Interquartile Range)				
	GE 64 (n = 384)	Philips 64 (n = 123)	Siemens 64 Single-Source (n = 380)	Siemens 64 Dual-Source (n = 521)	Toshiba 64 (n = 138)
Body mass index	25.9 (23.2-29.4)	27.5 (25.4-29.7)	25.8 (23.4-28.4)	26.3 (24.1-28.7)	26.0 (24.3-29.4)
$CTDI_{vol}$, mGy	77.3 (51.3-89.6)	47.0 (42.0-52.9)	39.6 (35.5-65.8)	47.8 (35.8-60.8)	88.0 (60.3-121.1)



Hausleiter et al, *Estimated Radiation Dose Associated With Cardiac CT Angiography. JAMA 2009*

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Magnitude of Variation in Patient Dose

Indication ≈ × 9
Patient ≈ × 20
Scanner ≈ × 1.5*
Protocol ≈ × 3.5

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To appropriately manage dose in CT

- Adjust for patient size and diagnostic task
  - this is GOOD variability
  - this is where INDIVIDUALIZATION is essential
- Systematic, electronic set of protocols
  - Protocol variations should reflect differences in scanner capabilities and characteristics
  - Protocols should be guided by objective measures of diagnostic performance (to minimize practice / user specific variability)
  - this is where STANDARDIZATION is essential

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AAPM Working Group on Standardization of CT Nomenclature and Protocols


Cynthia McCollough
Workgroup Co-Chair


Dianna Cody
Workgroup Co-Chair

Formed May 2010

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Charge

- Develop consensus protocols for frequently performed CT examinations
  - Provide reasonable benchmarks
  - Peer review process, begin with vendor recommendations
- Develop a set of standardized terms for use on CT scanners

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Membership

- AAPM
- ACR
- ASRT
- DICOM
- RadLex
- FDA
- GE
- Hitachi
- Philips
- Neurologica
- Neusoft
- Siemens
- Toshiba
- MITA

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The American Association of Physicists in Medicine

We advance the science, education and professional practice of medical physics

CT Scan Protocols

Statement of Purpose

The American Association of Physicists in Medicine (AAPM) is a professional organization whose members include board-certified medical physicists who specialize in the safe and effective use of radiation in medicine. Medical physicists partner with radiologists, technologists, regulators, manufacturers, administrators and others to ensure that CT scans are performed using the minimum amount of radiation required to obtain the diagnostic information for which the CT scan was ordered.

The collection of settings and parameters that fully describe a CT examination is referred to as the exam *protocol*. These protocols specify how data collection and reconstruction, patient positioning and contrast administration are to be performed. The effect of these settings on the final exam quality or dose can be dramatic; a number of the settings are inter-related, where changing one parameter can require adapting several other parameters if image quality and/or dose are to be maintained at a specified level. Thus, the quality and dose of a CT exam are largely predetermined by the protocol used. In CT, there is however no single protocol that is "the correct protocol"; acceptable image quality and dose can be achieved using many different combinations of scan parameters.

In light of the increase in the number of CT exams performed in the US, concerns about variability in doses and/or image quality used by different practices or scanner models to accomplish similar diagnostic tasks, **and several unfortunate cases of patient injury due to the use of improper scan protocols**, the AAPM is committed to the publication of a set of *reasonable* scan protocols for frequently performed CT examinations, summarizing the basic requirements of the exam and giving several model-specific examples of scan and reconstruction parameters. This work is the charge of the **Working Group on Standardization of CT Nomenclature and Protocols**, whose membership includes academic and consulting medical physicists who specialize in CT imaging, representatives of each of the major CT scanner manufacturers, and liaisons to the American College of Radiology, American Society of Radiology Technologists, and the Food and Drug Administration.

The provided protocols are considered by the Working Group to be reasonable and appropriate to the specified diagnostic task. The settings provided are representative of typical clinical values and they may not always match default protocols.

The provided protocols represent a *sampling* of currently available scanner models. They are not intended to provide comprehensive information for all available scanner models.

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CT Scan Protocols

Statement of Purpose | Scanner Model & Equipment Performance Questions | Role of the Qualified Physicist | Guidelines for the CT Dose-Check Standard | Protocols

Available Protocols

Adult Protocols

- **Brain Perfusion CT** (added 01/11/2011) [**Give Feedback**]

Your feedback regarding the content of this website is welcome. Feedback regarding this website will not be monitored daily. **Users experiencing problems in performing an exam should contact their service provider.**

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ADULT BRAIN PERFUSION CT

Indications

Suspected acute infarction;
Assessment of reperfusion after treatment of acute stroke;
Vasculitis;
New neurological symptoms after subarachnoid hemorrhage suggesting vasospasm;
Evaluation of the hemodynamic significance of a carotid stenosis;
Transient ischemic attack;
Evaluation of the cerebral vascular reserve using acetazolamide challenge;
Evaluation of brain perfusion after significant head trauma;
Brain tumor.

Diagnostic Task

- Detect brain ischemia in stroke, transient ischemic attack, vasculitis;
- Distinguish already-infarcted brain from brain at risk of infarction;
- Identify regions of brain made ischemic by vasospasm;
- Detect altered brain perfusion downstream a significant carotid stenosis;
- Assess altered cerebral vascular reserve in patients with ischemic symptoms;
- Assess altered cerebral perfusion after traumatic brain injury;
- Identify early brain tumor recurrence and higher-grade tumor components.

Key Elements

- Time-resolved scans are used to track the flow of iodinated contrast media through the brain;
- Multiple images (20-40) are acquired over the same section of anatomy;
- Patients must be able to remain still during the exam in order to avoid motion misregistration;
- The table may remain stationary during the entire exam, or move back and forth between a few table positions;
- Whole-brain perfusion CT can be accomplished using CT systems with wide detector arrays (8-16 cm); alternatively, scan modes that move the patient back and forth over the desired scan volumes can be used;
- Acquisitions are repeated at predetermined time intervals (e.g. every second to every 2-3 seconds) for a predetermined duration (e.g. 40-90 seconds);
- Relatively thick image widths are used to minimize image noise (5-10 mm is common);
- Image quality is inferior to a routine head CT. That is, images are noisier and thicker.
- Data are used to generate color maps of hemodynamic significance:
  --Blood volume (BV) and flow (BF), mean transit time (MTT), time to peak perfusion (TPP);
- A non-contrast-enhanced head CT and/or a CT angiogram may be combined with a perfusion CT scan.

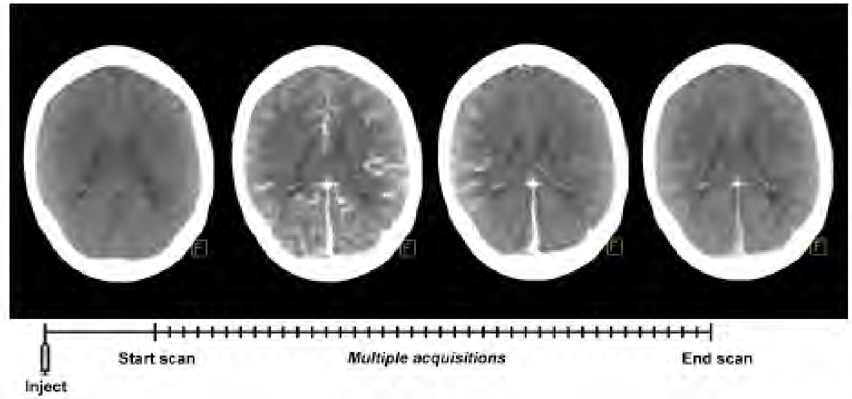
Dose Management

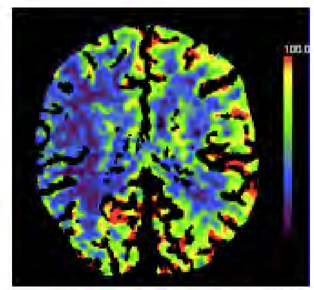
- 80 kV should be used to increase iodine signal brightness;
- Low dose per single scan (i.e. one tube rotation) is critical, since repeated scanning will result in a relatively high cumulative dose;
- Time interval between scans, and hence the total number of scans over the exam duration, should be set carefully, taking into account the analysis algorithm (some approaches require relatively dense data points);
- Dose (tube current) modulation should not be used, as it may interfere with the calculation of the BV and BF parameters;

Additional Resources

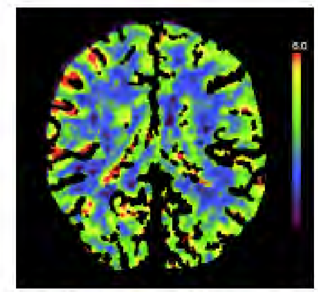
- ACR Practice Guideline for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging. (www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/dx/head-neck/ct_perfusion.aspx);
- AJNR Special Collection. Radiation Dose in Neuroradiology CT Protocols. Collection Editors: Max Wintermark and Michael H. Lev (available at www.ajnr.org/specCol/specCollPCTToc.dtl).

BRAIN PERFUSION CT: Sample Images

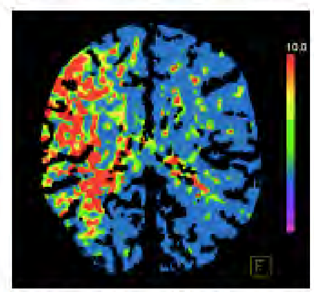




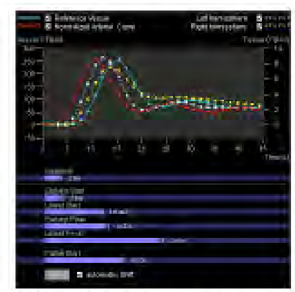
Cerebral Blood Flow (CBF, in mL/100 g/min)



Cerebral Blood Volume (CBV, in mL/100 g)



Mean Transit Time (MTT, in seconds)



Peak Enhancement Curves

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BRAIN PERFUSION CT (Selected SIEMENS Scanners)

GENERAL: This protocol may include an optional, non-contrast-enhanced head scan and/or an optional head CT angiogram. Center the table height, such that the external auditory meatus is located at the center of the gantry. The patient's chin should be tilted toward the chest (i.e. in a "tucked" position).

CONTRAST: **Oral:** None.
IV: 40 mL of 350 mg/cc concentration contrast media at 4 mL/sec followed by 30 mL saline at 4 mL/sec
Preferred injection site: 18–20 gauge IV placed in right antecubital vein

TOPOGRAM: PA and Lateral, 512 mm coverage, 120 kV, 1
(CT Radiograph)

BRAIN PERFUSION CT:
This scan is performed for a continuous 40 or
The radiologist will determine the scan range
No Gantry Tilt for the periodic spiral (ada

SIEMENS	Sensation 64
Scan Type	Multiscan (Cine)
Rotation Time (s)	1.0
Table Motion	None
Collimation	24 x 1.2 mm
Coverage per Rotation (mm)	28.8
Scan Range (mm)	28.8
Cycle Time	1.0 (continuous)
Pitch	—
Feed (mm/rot)	—
kVp	80
Effective mAs	270
CARE Dose 4D	OFF
Scan Field (mm)	200
Prep Delay (s)	5
Scan time (s)	40
CTDI-vol (mGy)	433
Base Protocol	NeuroPCT

RECONSTRUCTION
Kernel
Slice (mm)
Increment (mm)
FOV (mm)
Window width/window center

Perfusion computations are performed on an image-processin

BRAIN PERFUSION CT (Selected GE Scanners)

GENERAL: This protocol may include an optional, non-contrast-enhanced head scan and/or an optional head CT angiogram. Center the table height, such that the external auditory meatus is located at the center of the gantry and the landmarked at the level of the canthomeatal line (S0). The patient's chin should be tilted toward the chest (i.e. in a "tucked" position) to minimize the amount of tilt needed to better avoid the eyes especially for modes that do not support tilt. Perfusion protocols are for adults; modifications must be done for pediatrics.

CONTRAST: **Oral:** None.
IV: 40 ml of 350 -370 mg/cc concentration contrast media at 4 ml
Preferred injection site: 18–20 gauge IV in right antecubital vei
Optional second level can be examined after a 5 to 10 min delay.

SCOUT: PA and Lateral, 200 mm coverage, 120 kV, 10 mA.
(CT Radiograph)

BRAIN PERFUSION CT:
The radiologist will determine the scan range, referring to any pre
The injection rate and volume of contrast directly affects the dura
these factors and patient cardiac output for appropriate scan delay
If a second location is desired, the start location of this group will

Perfusion computations are performed on an image-processing wo

Option 1: Axial mode (non-continuous axial acquisitions).

GE	LightSpeed and BrightSpeed 4/8 slice	LightSpee BrightSpeed
Scan Type	Axial	Axia
Rotation Time (s)	1	1
Detector Rows	16	16
Exam Duration (s)	44	44
Total Exposure Time (s)	22	22
kVp	80	80
Manual mA	150	150
AutomA/SmartmA	OFF	OFF
SFOV	Head	Head
Prep Delay (s)	5	5
ISD (s)	1	1
DFOV (cm)	25	25
Image Thickness	5mm x 4i	5mm x
Interval (mm)	0	0
Reconstruction Algorithm	Standard	Standa
ASiR		
Coverage (mm)	20	20
Temporal Sampling (s)	2	2
CTDI-vol (mGy)	200 @ 150 mA	220 @ 15

BRAIN PERFUSION CT (Selected PHILIPS Scanners)

GENERAL: These protocol parameters should not be used for pediatric patients.

CONTRAST: **Oral:** None.
IV: For Non-Jog scans: 40–50 mL contrast, followed by 20–40 mL saline
For Jog Mode scans: 70 mL contrast, followed by 45 mL saline
For all scans: Injection rate of 4–6 mL per second, 18–20 gau

Option 1: Non-Jog Mode.

	Brilliance 16 slice	Brilliance 40/64 slice
Rotation Time (s)	0.5	0.5
Collimation	16 × 1.5 mm	32 × 1.25 mm
Coverage (mm)	24	40
kVp	90	80
mAs	125	125
ACS/DOM	OFF	OFF
Cycle Time (s)	2.0	2.0
Cycles	30	30
Thickness (mm)	6.0	5.0
Increment (mm)	0.0	0.0
Resolution	Standard	Standard
FOV (mm)	250	250
Filter	UB	UB
WC/WL	80/40	80/40
CTDI-vol (mGy)	240	132

Option 2: Jog Mode (Table moves back and forth between two position

	Brilliance 16 slice	Brilliance 40/64 slice
Rotation Time (s)	0.5	0.5
Collimation	16 × 1.5 mm	32 × 1.25 mm
Coverage (mm)	48	80
kVp	90	80
mAs	125	125
ACS/DOM	OFF	OFF
Cycle Time (s)*	4	4
# of Jog Cycles	15	15
Thickness (mm)	6.0	5.0
Increment (mm)	0.0	0.0
Resolution	Standard	Standard
FOV (mm)	250	250
Filter	UB	UB
WC/WL	80/40	80/40
CTDI-vol (mGy)	120	66

* Cycle time represents the time from the start of one scan to t
over the same piece of anatomy (i.e., the sampling interval of t
For the 4 s cycle time, the manufacturer's perfusion analysis s
rather than absolute, perfusion parameters. Absolute, quantita
are reported for cycle times less than or equal to 2.5 s.

BRAIN PERFUSION CT (Selected TOSHIBA Scanners)

GENERAL: This protocol may include an optional, non-contrast-enhanced head scan and/or an optional head CT angiogram. Center the table height, such that the external auditory meatus is located at the center of the gantry.

CONTRAST: **Oral:** None.
IV: 50 mL of 370 mg/cc concentration contrast media @ 5-6 mL/sec followed by 50 mL saline at 5-6 mL/sec
Preferred injection site: 18–20 gauge IV placed in right antecubital vein

SCANOGRAM: PA and Lateral, 240 mm coverage, 120 kV, 50 mA, caudo-cranial direction.
(CT Radiograph)

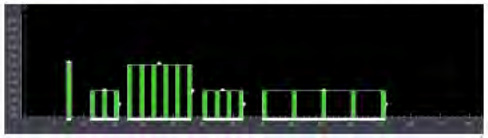
BRAIN PERFUSION CT:
This scan is performed for 60 seconds.
The radiologist will determine the scan range, referring to any previously-acquired (optional) scanned series for the Aquilion Premium. For the Aquilion ONE, the entire head is covered.

Toshiba	Aquilion Premium	Aquilion ONE
Scan Type	Dynamic Volume Intermittent	Dynamic Volume Intermittent
Rotation Time (s)	0.75	0.75
Table Motion	None	None
Collimation	160 x 0.5mm	320 x 0.5 mm
Coverage per Rotation (mm)	80	160
Scan Range (mm)	80	160
Acquisition Interval*	2 s initially, then 5 s	2 s initially, then 5 s
kVp	80	80
mA*	150	300 (arterial phase), 150 (elsewhere)
SURE Exposure	OFF	OFF
Scan Field (mm)	240	240
Delay after injection (s)	7	7
Scan Time (s)	53	53
CTDI-vol (mGy)	122	162

RECONSTRUCTION	Aquilion Premium	Aquilion ONE
Start	Radiologist selects location	Below base of skull
End		Vertex
Kernel	41	41
Slice (mm)	0.5	0.5
Increment (mm)	0.5	0.5
FOV (mm)	240	240

Perfusion computations are performed on an image-processing workstation after scan completion.

*The image below shows the scan protocol for the Aquilion ONE. Each green bar represents a volume scan. The mA is increased for the arterial portion of the scan to provide improved image quality for the digitally subtracted angiogram (DSA) image.



"Reasonable" protocols & doses

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What is the "right" dose?

- The one that makes pretty pictures
- The one that the vendor specifies
- The one that you used previously
- The one presented at meetings
- The one that keeps the radiologists happy (i.e. they don't complain)
- The lowest one you can still read
- The one "proven" to provide the required diagnostic accuracy

Diagnostic Reference Levels (DRLs)

- Used to identify situations where dose is unusually high
- If consistently exceeded, a local review of procedures and equipment should be performed
- If possible, dose reduction measures should be taken

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Diagnostic Reference Levels

- Must be defined in terms of an easily and reproducibly measured dose metric
  - use technique parameters that reflect those used in site's routine clinical practice for <u>average patient size</u>
- CT: CTDIvol and DLP

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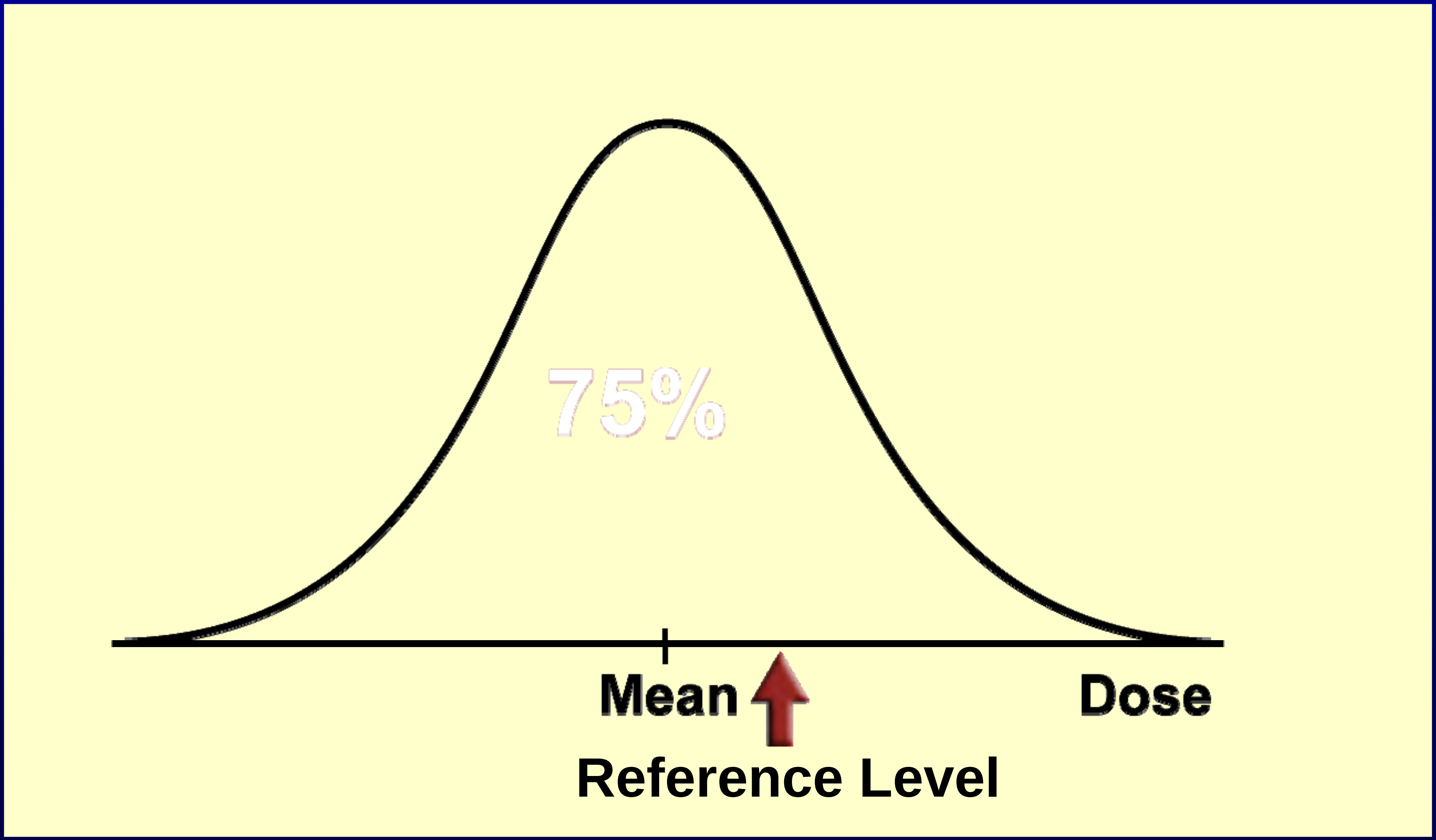
In practice, typical to choose initial values as a percentile point on the observed distribution of doses



DRLs from other countries

Adult Diagnostic Reference Levels for $CTDI_{vol}$ (mGy) and DLP (mGy·cm)

	Head		Abdomen		Pelvis		Abd & Pelvis	
	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
Sweden 2002	75	1200	25	-	-	-	-	-
UK 2003	65-100	930	14	470	-	-	14	560
Netherlands 2008	-	-	-	-	-	-	15	700
EC 2004	60	-	25	-	-	-	15	700
ACR 2008	75	-	25	-	-	-	-	-

EC: European Commission
ACR: American College of Radiology
UK: United Kingdom

Dose Notifications and Alerts

- Need tools **at the point of care** that inform users if there is a potential prescription error
  - “ … inform users when scan settings would likely yield values of CTDIvol that would exceed pre-assigned values”
- Notification value – for a single scan series
- Alert value – cumulative over entire exam
  - at a given table position

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CT Scan Protocols

Statement of Purpose | Scanner Model & Equipment Performance Questions | Role of the Qualified Physicist | Guidelines for the CT Dose-Check Standard | Protocols

Guidelines for the CT Dose-Check Standard

- AAPM Recommendations Regarding Notification and Alert Values for CT Scanners: Guidelines for Use of the NEMA XR 25 CT Dose-Check Standard

AAPM Recommendations Regarding Notification and Alert Values for CT Scanners: Guidelines for Use of the NEMA XR 25 CT Dose-Check Standard[1]

A new U.S. technical standard (XR 25) has been published by the National Electrical Manufacturers Association (NEMA)[1]. CT scanners in compliance with this standard can be configured to inform users when scan settings would likely yield values of $CTDI_{vol}$ or *DLP* that would exceed pre-assigned values. Compliant scanners allow users, before proceeding with scanning, to confirm or correct settings that might otherwise lead to unnecessarily high exposures. Manufacturers may include pre-assigned values in their default protocols, but all values are user-configurable.

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Adult exams

CT Scan Region (of each individual scan in an examination)	CTDIvol Notification Value (mGy)
Adult Head	80
Adult Torso	50

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Why are notification values > DRLs?

- DRL values typically represent the 75th percentile from a regional or national sample of clinically used dose indices for a standard patient size
- 30% of US population is obese
  - use of DRLs as notification values would result in notifications occurring very frequently
  - potentially de-sensitize users and diminish the value of notification values in avoiding erroneously high exposures
- Children require different notification and alert values due to their smaller size

CT Terminology Lexicon

- Translation of terms from different manufacturers
- For the CT technologist who operates multiple scanner models, perhaps from multiple manufacturers, the variability in names for important scan acquisition and reconstruction parameters can lead to confusion, reduced comfort and an increased potential for error
- First step in the terminology standardization effort
  - Phase 2 will form consensus recommendations on preferred terms

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1. Scan acquisition and user interface basics					
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**
The portion of the **user interface** where scans are prescribed	Exam Rx	Scan Procedure	Examination	eXam Plan	Scan Protocol
Other portions of the **user interface**, such as were reconstructed images are viewed	Desktop	Active viewer	Various "task cards", such as "Viewing"	Active display	Image Viewer
CT localizer radiograph (i.e. the scanned projection radiograph, often acquired by the CT system to allow the user to prescribe the start and end locations of the scan range)	Scout	Surview	Topogram	Scanogram	Scanogram
Axial scan mode: Data acquisition while the patient table remains stationary; the table position may be incremented between x-ray exposures to collect data over a longer z axis range.	Axial	Axial	Sequence	Scan & View, Scan & Scan, Volume, Wide Volume (Aquilion One)	Normal
Helical or Spiral scan mode: Data acquisition while the patient table is continuously moving along the z axis.	Helical	Helical	Spiral	Helical	Volume
Dynamic scan mode - single detector width: Data acquisition at multiple time points over the same anatomic location(s) while the patient table remains stationary; x-ray exposure can be continuous or intermittent	Cine or zero interval Axial	CCT (Continuous CT)	Dynamic (continuous) or Serio (intermittent); scan mode name: DynMulti or DynSerio.	Dynamic (Continuous or Intermittent)	Dynamic
Dynamic scan mode - multiple detector widths: Data acquisition at multiple time points over the same anatomic location(s) while the patient table cycles back and forth between designated start and end locations in order image a region wider than the detector	Shuttle	Jog	Adaptive 4D Spiral; scan mode name: DynMulti4D or DynSerio4D (ECG triggered)	N/A	N/A
Interventional CT - Intermittent x-ray exposures	SmartStep	Single CCT	Model dependent: Biopsy or Intervention (i-Sequence/i-Spiral)	CT Fluoro (CTF)	guideShot
Interventional CT - Continuous x-ray exposures	SmartView	Continuous CCT	Model dependent: CARE Vision or Intervention (i-Fluoro)	CT Fluoro (CTF)	Not available
Table increment (mm) per 360 degree rotation of the x-ray tube (axial scan mode)	Interval	Increment (mm)	Feed (mm)	Couch movement (mm)	Table Feed (mm)
Table feed per 360 degree rotation of the x-ray tube (helical scan mode)	Speed (mm/rot)	Table speed (mm/rot)	Table Feed (mm/rot)*	Couch speed (mm/Rot)	Table Speed (mm/rot)
Acquisition field of view: Diameter of the circular region within the scan plane over which projection data are collected. Nominally equal to the diameter of the primary beam at isocenter in the axial plane.	Scan Field of View (SFOV, cm)	Not determined by tech; built into protocol	Not determined by tech; built into protocol	CFOV (Calibrated Field of View)	Scan Field of View (SFOV, mm)

MAYO CLINIC

Summary

- Standardization is essential
  - Team approach
  - Across practices, countries
  - Across manufacturers, scanner models
  - Diagnostic reference levels can reduce practice outliers
  - Notification and alert values can reduce egregious errors
  - Nomenclature standardization will be difficult, but powerful
- Individualization is essential
  - Ordering physicians need decision support tools
  - Radiologists need to tailor exam to clinical indication
  - Technologists need to tailor exam to specific patient

Fukushima-1 Accident: What Happened ?

Michael Corradini
Vice-President/President-Elect
American Nuclear Society

ANS SPECIAL COMMITTEE ON FUKUSHIMA

The special committee will provide a clear and concise explanation of the events surrounding the accident to the general public and U.S. leaders. These communications will include events such as station blackout, the effect on the reactors and on the spent fuel stored at the plant site and the likely health effects of the radioactive substances released to the environment. In addition, the committee will evaluate recommended actions that ANS could or should consider to better communicate with the public and elected officials during a nuclear event.

Co-Chairs: Dale Klein, Univ. of Texas, Michael Corradini, Univ. of Wisconsin

Paul T. Dickman, Argonne National Laboratory

Jacopo Buongiorno, Massachusetts Institute of Technology

Hisashi Ninokata, Tokyo Institute of Technology

Mike Ryan, M.T. Ryan and Associates LLC

Craig D. Sawyer, Retired Senior Engineer

Amir Shahkarami, Exelon Nuclear

Akira Tokuhiro, University of Idaho

Fukushima-1 Accident: What Happened*?

- Basic facts on natural disasters and nuclear power
- Accident at Fukushima Daiichi site
- Health effects of radioactive materials release
- Regulatory safety issues for the U.S.
- Accident cleanup and waste management
- Risk communication and future of nuclear

* Info: TEPCO, NISA, MEXT

Basic facts on natural disasters and nuclear power

- Was the earthquake/tsunami designed for in Japan?
- What about natural disasters in the U.S.
- Describe the design philosophy for natural disasters.
- Describe the current nuclear power position in Japan
- Describe the BWR system and associated safety systems
- What is the regulatory structure in Japan and how is it different that other nations such as France and the U.S.?

The Event

- The Fukushima nuclear facilities were damaged in a magnitude 9 earthquake on March 11 (2.46pm Japan time), centered offshore of the Sendai region (Tokyo is about 250km southwest).
  - Plant designed for magnitude 8.2 earthquake. A 9 magnitude quake is much greater in size.
- Serious secondary effects followed including a significantly large tsunami (>factor of 3), significant aftershocks and fires at many industrial facilities.
- Almost 16,000 dead, 6,000 missing, 80,000 homeless limited resources - over 1000sq.km. land excluded

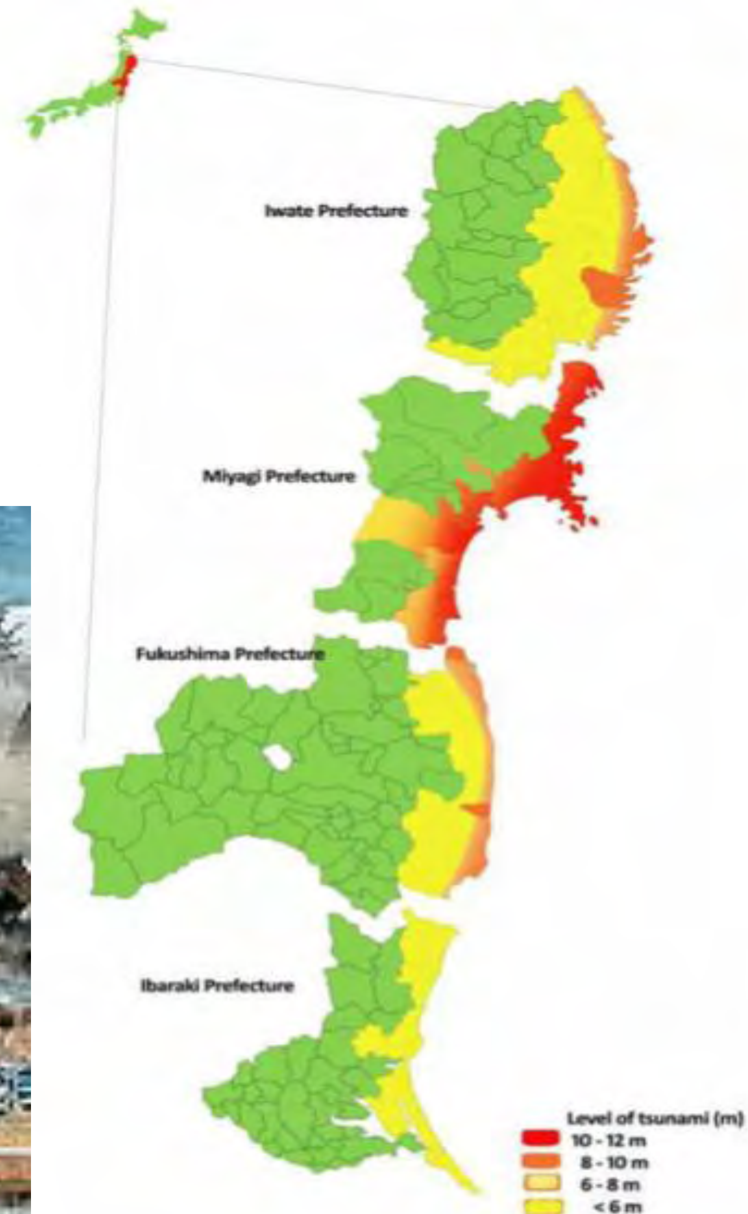
UNIT	MAX OBSERVED MOTION (Direction)	DESIGN EARTHQUAKE MAX MOTION (Direction)
UNIT 1	460 gal* (Horizontal N-S)	487 gal* (Horizontal N-S)
UNIT 2	550 gal (Horizontal E-W)	438 gal (Horizontal E-W)
UNIT 3	507 gal (Horizontal E-W)	441 gal (Horizontal E-W)
UNIT 4	319 gal (Horizontal E-W)	445 gal (Horizontal E-W)
UNIT 5	548 gal (Horizontal E-W)	452 gal (Horizontal E-W)
UNIT 6	444 gal (Horizontal E-W)	448 gal (Horizontal E-W)

Describe design philosophy for natural disasters

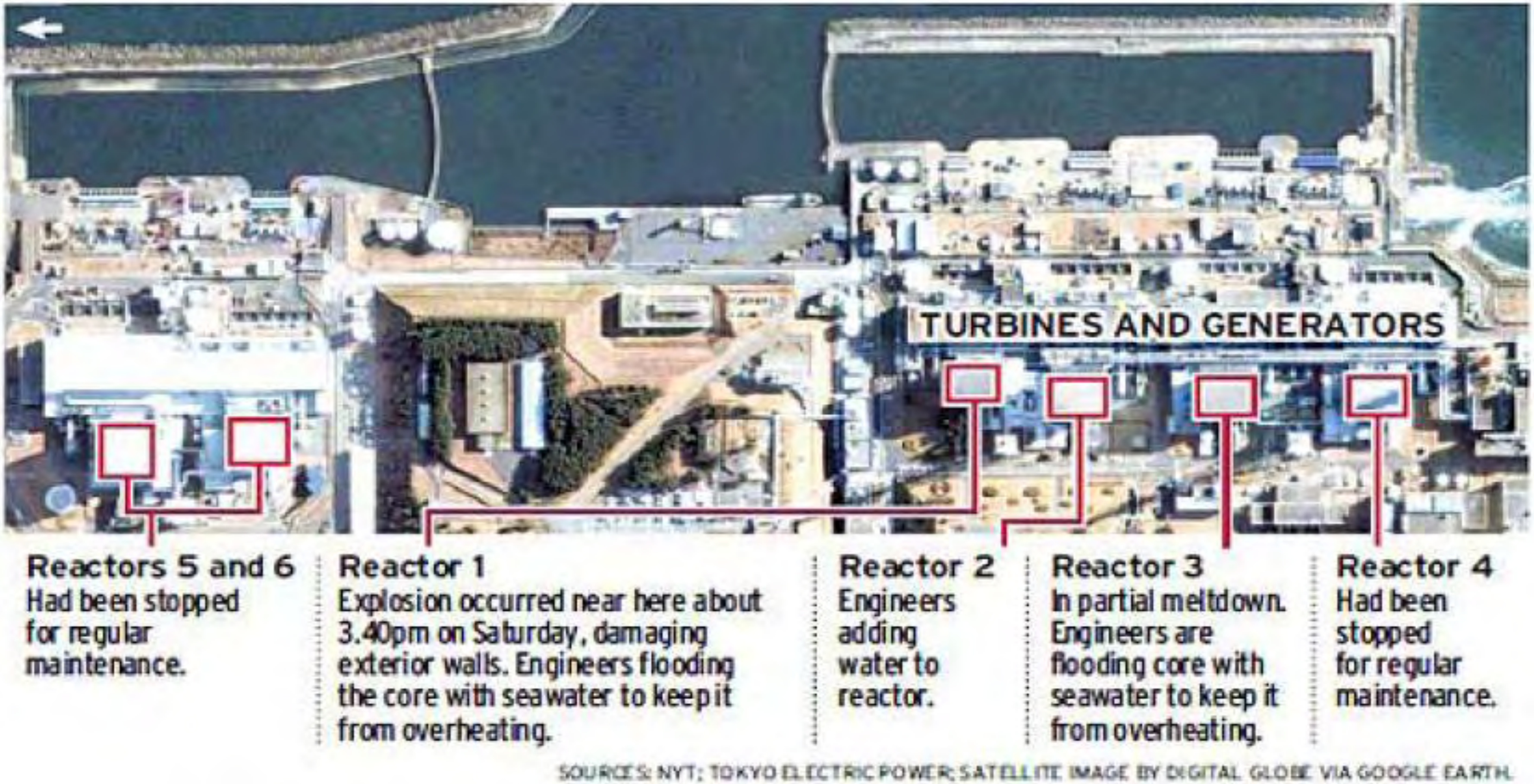
- All civil infrastructures are designed against natural disasters
- Nuclear power plants in the U.S. are designed to safely shutdown without incident based on historical disasters
  - Largest event in the region (earthquake, tornado, flood, hurricane)
  - Recent large U.S. natural disasters have not resulted in plant damage
  - Katrina, Southeast tornadoes, Midwest floods were devastating in loss of life/property and in all cases the nuclear plants safely shutdown
- Japanese philosophy is similar but not the exactly the same

Tsunami was historically large but not 'unforseen'

Japanese officials knew of past tsunamis that were at or above the March event (869 AD larger tsunami)

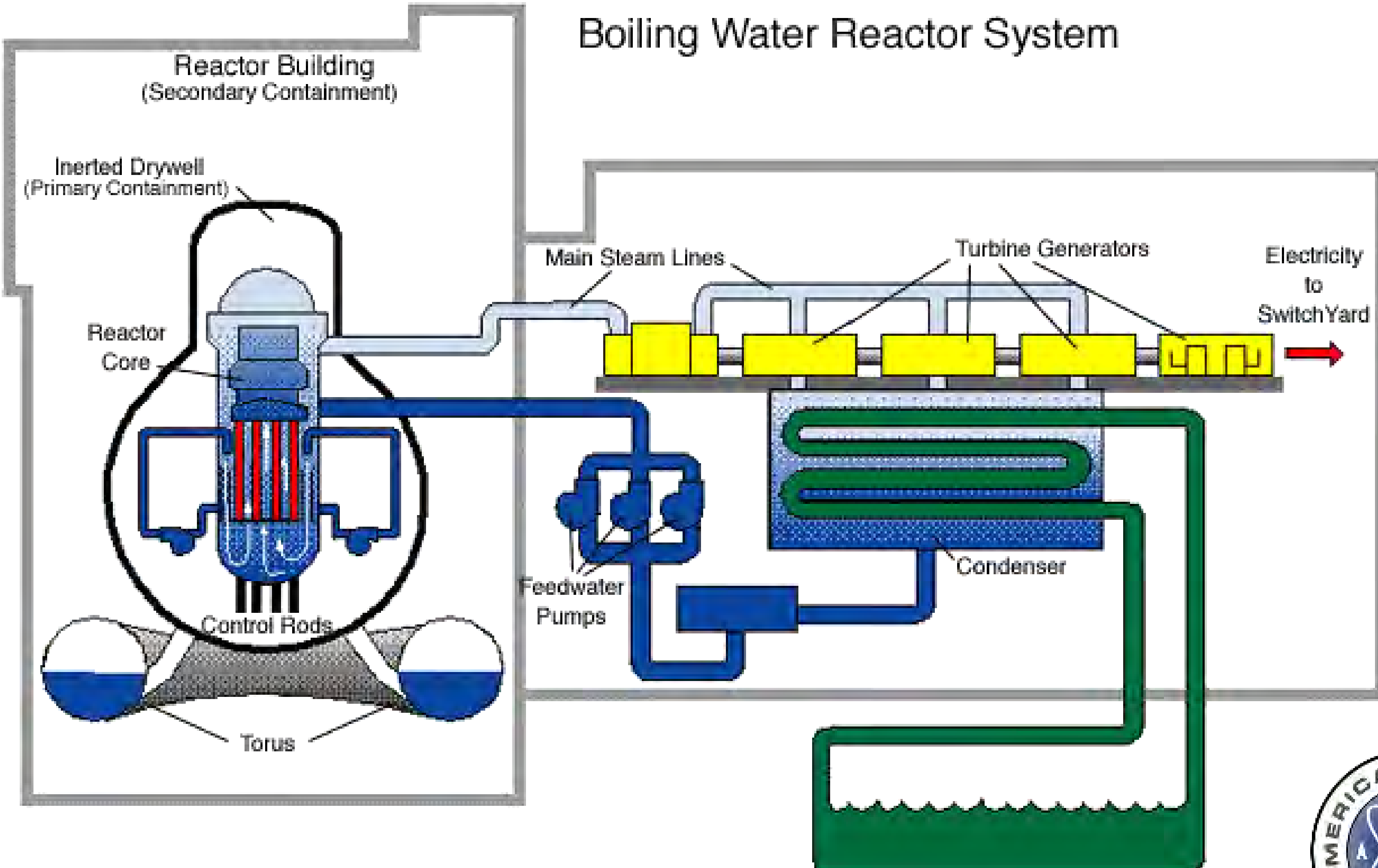


- **Six BWR units at the Fukushima Nuclear Station:**
  - Unit 1: 439 MWe BWR, 1971 (unit was in operation prior to event)
  - Unit 2: 760 MWe BWR, 1974 (unit was in operation prior to event)
  - Unit 3: 760 MWe BWR, 1976 (unit was in operation prior to event)
  - Unit 4: 760 MWe BWR, 1978 (unit was in outage prior to event)
  - Unit 5: 760 MWe BWR, 1978 (unit was in outage prior to event)
  - Unit 6: 1067 MWe BWR, 1979 (unit was in outage prior to event)

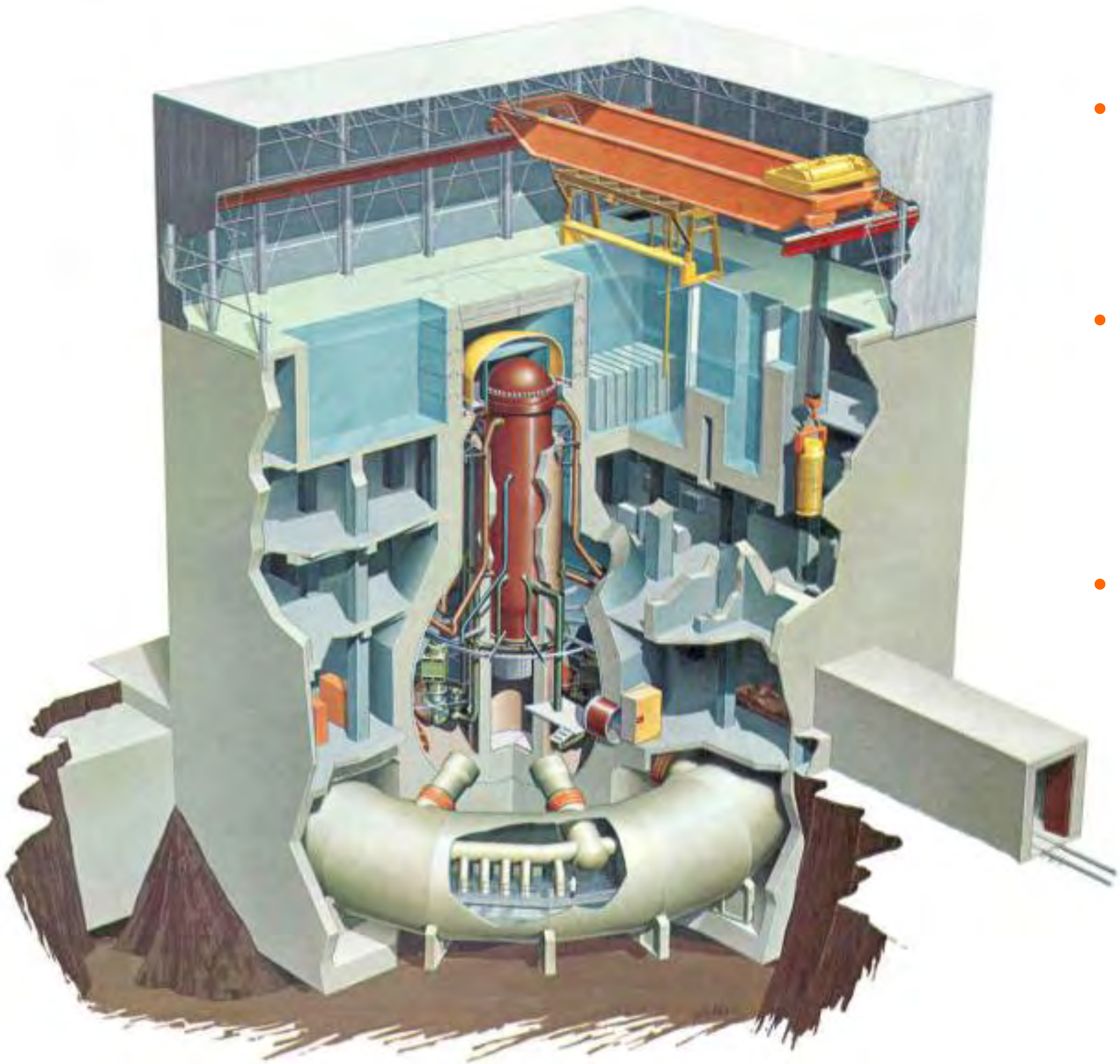


Overview of Boiling Water Reactor

- Typical BWR 3 and 4 Reactor Design
- Some similarities to Duane Arnold Power Plant in Iowa



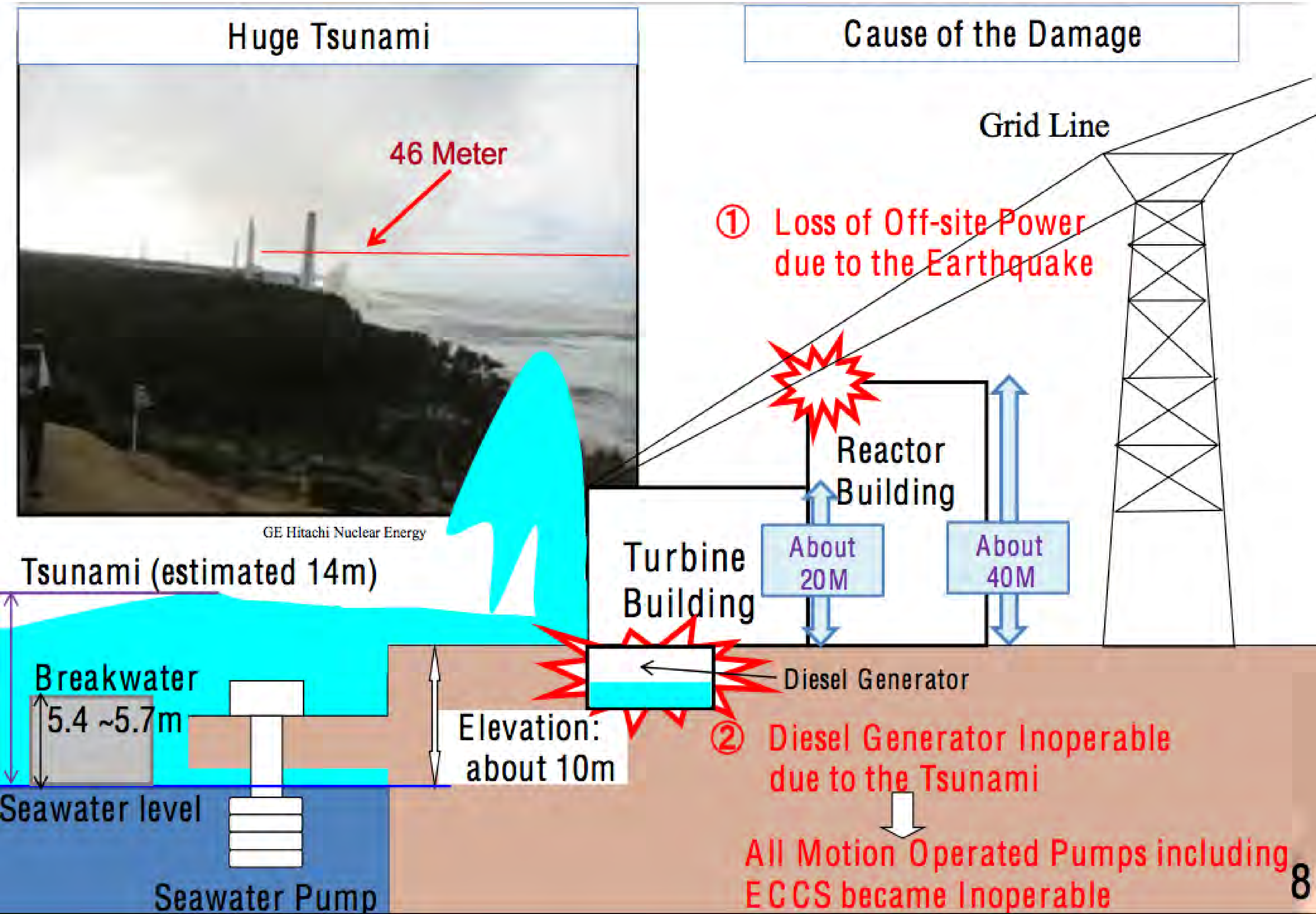
GE Mark 1 Reactor Building



- There are 23 reactors in the United States utilizing Mark I containments.
- Available data suggests similarities exist in the design and operation of Japanese and US Mark I containments.
- Following 9/11, the NRC required licensee's to develop comprehensive beyond design basis mitigation strategies (i.e. procedures, staging of portable equipment).

Browns Ferry Primary Containment

Fukushima Accident Initiation

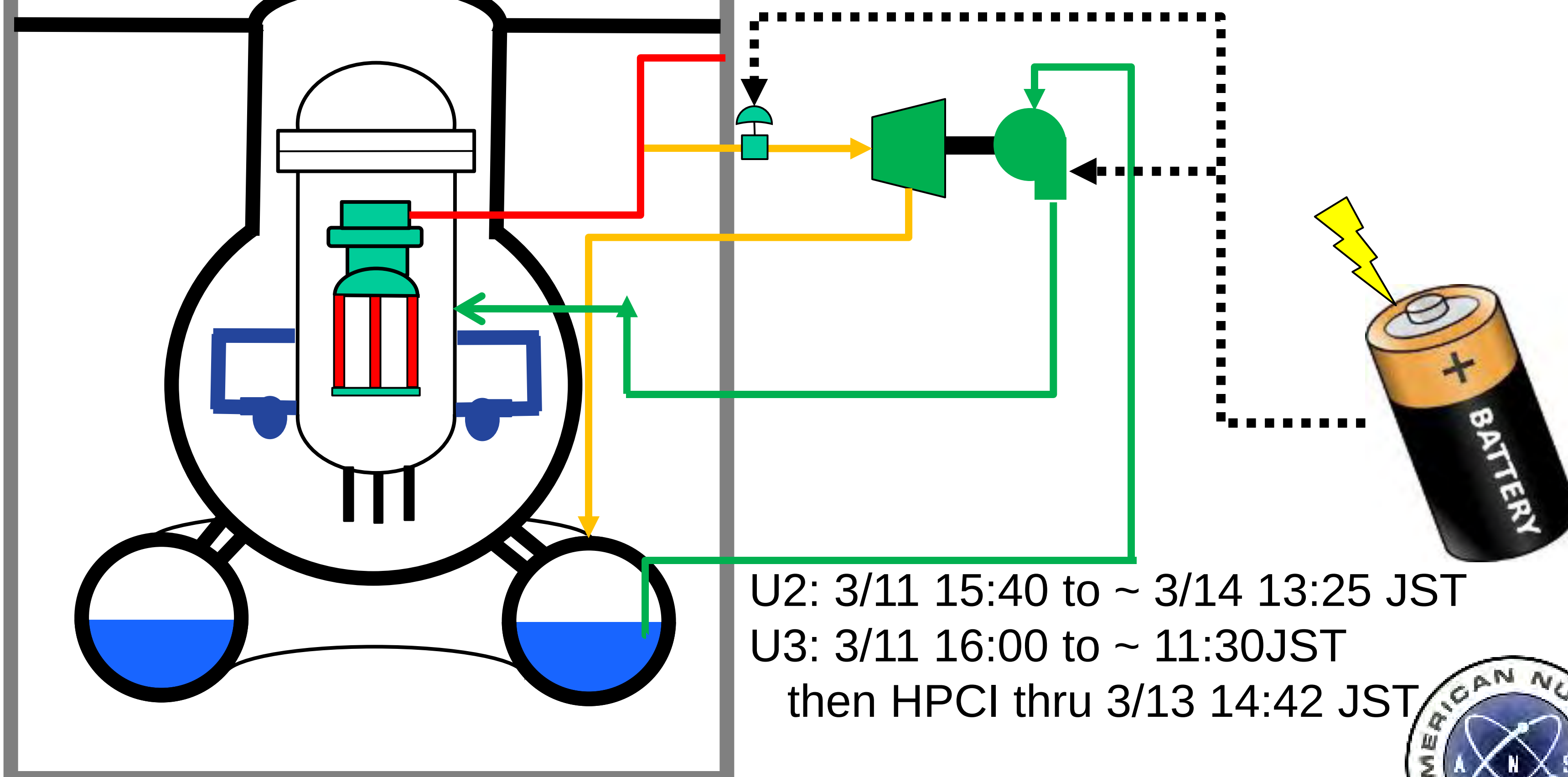


Initial Accident Response

- Nuclear reactors were shutdown automatically due to seismic event.
- Earthquake resulted in the loss of offsite power
- Emergency Diesel Generators powered station emergency cooling systems.
- An hour later, the station was struck by the tsunami. The tsunami was much larger than what the plant was designed for (14m waves) The tsunami took out all multiple sets of the Emergency Diesel generator, AC buses, DC batteries (U1) and damaged service water that provide cooling from the sea.
- Unit 1 was in total station blackout w/o the isolation condenser operable
- Reactor operators used emergency battery power for U2 and U3 reactors for cooling for a day or more – but lack of ability to stabilize causing damage

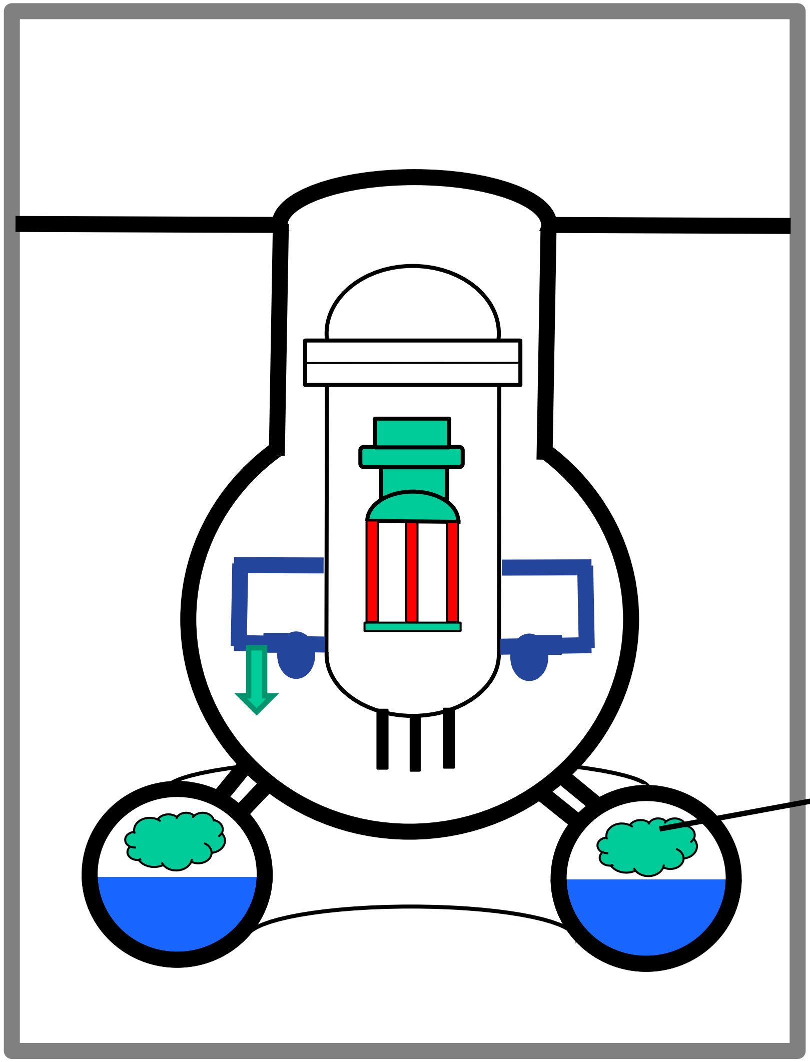
Unit 2 & 3 Battery Power Controlled Steam-Driven Reactor Core Isolation Cooling (RCIC) System

Unit 1 had a different design with Isolation Condenser but it is not clear that it functioned



U2: 3/11 15:40 to ~ 3/14 13:25 JST
U3: 3/11 16:00 to ~ 11:30JST
then HPCI thru 3/13 14:42 JST

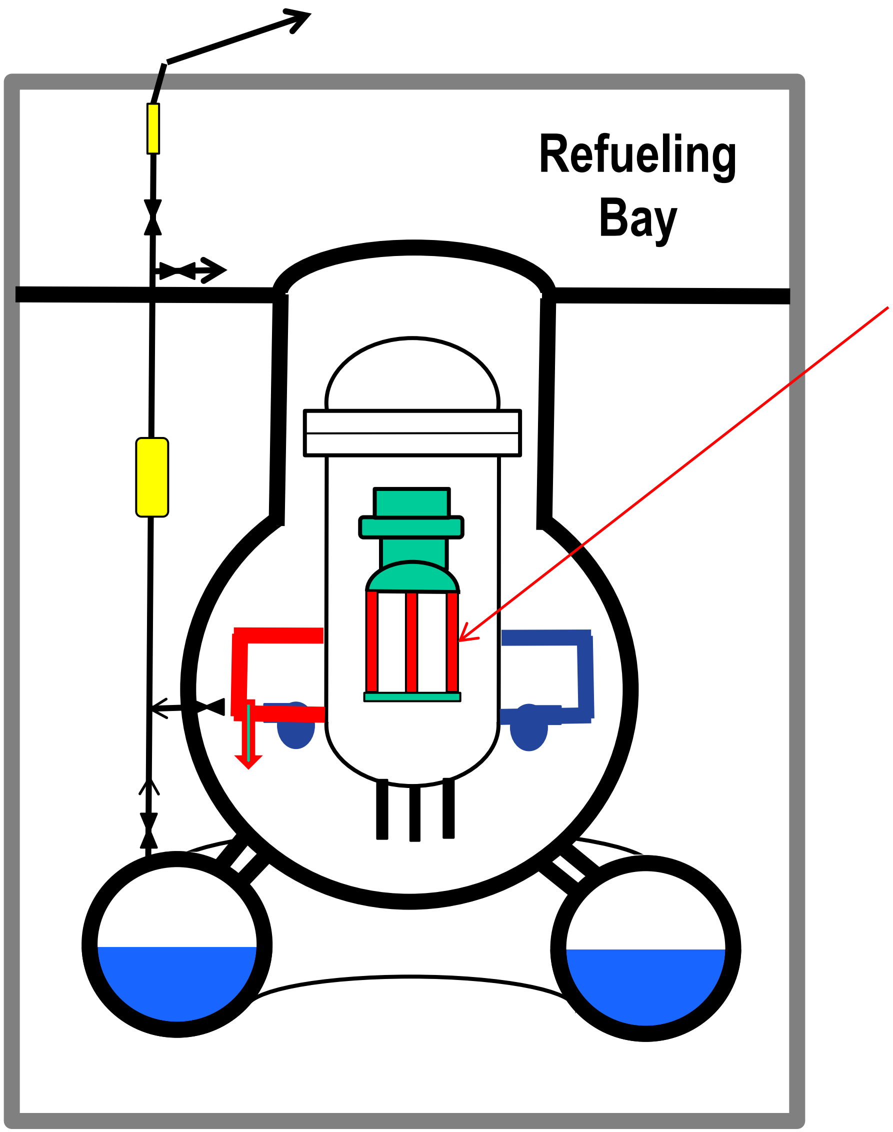
Unit 2 & 3 Battery Power Controlled Steam-Driven Reactor Core Isolation Cooling (RCIC) System



Safety systems (RCIC and HPCI) operated for at least another day on both units

Suppression pool (wet well) becomes saturated and cooling degraded

Venting Primary Containment

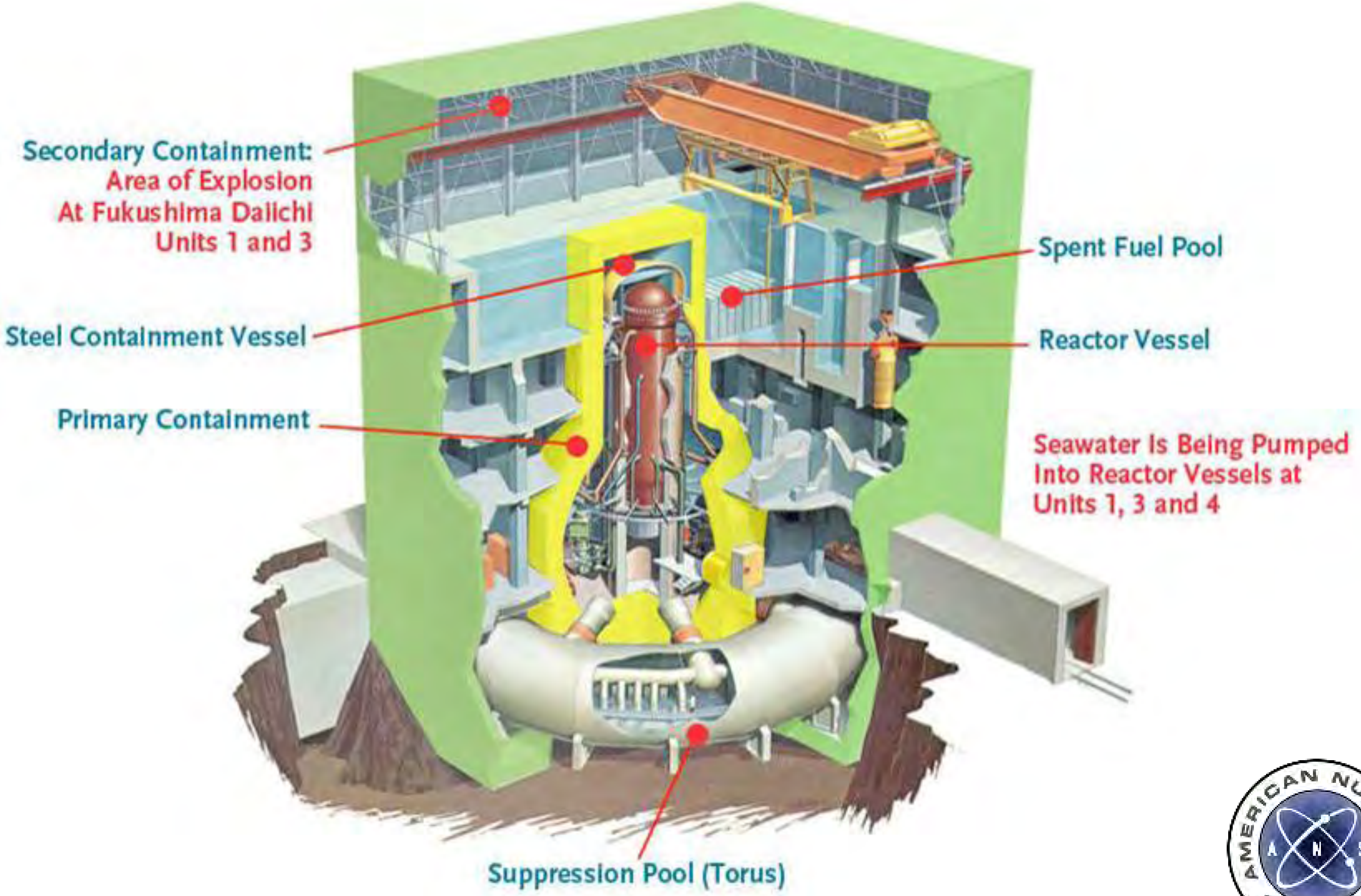


Reactor core uncovered, overheated, oxidized and released steam and H2 to the containment (DW, WW)

Primary Containment
Pressures were above 100psi

3/12 ~ 14:30 U1 attempted
3/13 ~ U2 is not clear
3/13 ~ 09:40 U3

Fukushima Containment System



Unit 4 Reactor Building: Hydrogen Explosion

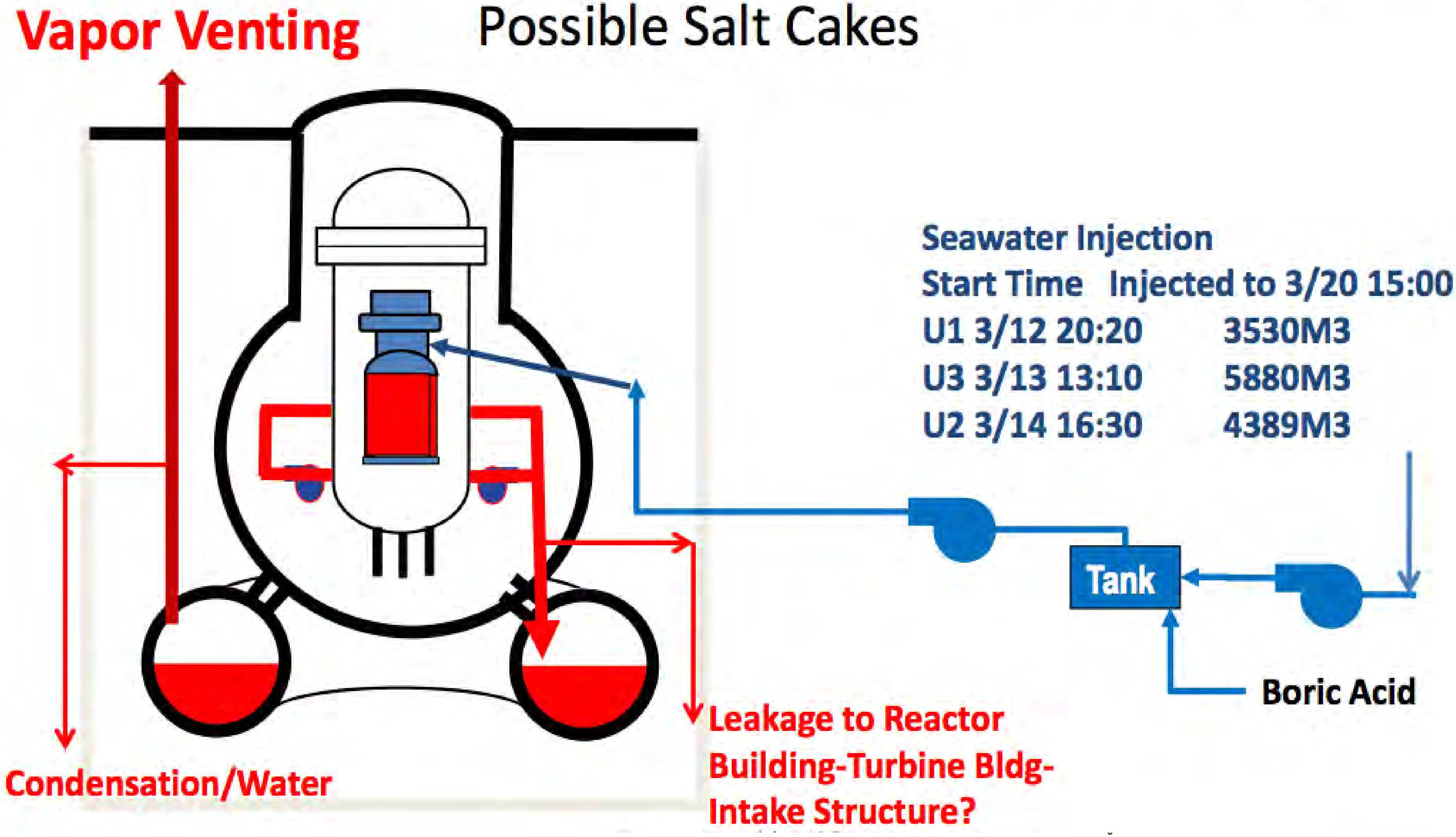
Hydrogen Explosion

- Unit 1: March 12 15:36 (Reactor Building)
- Unit 2: March 15, 6:00 (Torus?)
- Unit 3: March 14,11:01 (Reactor Building)
- Unit 4: March 15, 6:00 (Reactor Building)

Bleed & Feed Cooling Established

Seawater Injection Started Using Fire Engine Pump

Shift to Fresh Water Injection ~3/26-Present:To Dissolve Possible Salt Cakes



Accident Description at Fukushima Dai-ichi site

- What happened to the spent fuel pools in each unit?

  From what is known spent fuel pools were not damaged

- Why did other plants survive the earthquake and tsunami?

  Daini plants were in position that mitigated tsunami effects

- What was the command and control structure in Japan as compared to the U.S.? In the U.S. the plant manager on-duty has complete authority during any site emergency

- What were the emergency procedures for the Japanese plants and U.S. differences? As we know the procedures were generally similar for the Japanese plants

AMERICAN NUCLEAR SOCIETY

Lessons-Learned from the Fukushima Event

- Confirm U.S. plants have consistent design base for natural disasters
- Risk-informed approach should be applied to extreme natural events
- Emergency planning for nuclear plants should be reviewed
- Command/control of an accident should reside close to plant
- Emergency planning needs to use risk information
- Harmonize Emergency operating proc. and severe accident proc.
- Risk-informed approach should be considered for hardware changes
  - Coping with a station blackout could be accommodated for longer periods of time with innovative plant modifications (three phases)
  - Spent fuel cooling was maintained but uncertainty suggested that better instrumentation and assured cooling water refill needed
  - Modifications after 911 may be used as added safety systems
  - Severe accident management guidelines need to be regularized

Risk Communication: Accident Comparison

- Chernobyl released over 10 times more radioactive material over a few days due to the explosion
- TMI released over 10 times less radioactive material
- Earthquake and Tsunami damage was extensive (25,000 dead/missing; disaster costs range from $500b - $1000b)
- Fukushima accident has not caused any loss of life but is estimated to cost 5-10% of this total damage (estimate of latent cancers ~100 out of 10’s millions)
- Chernobyl accident early fatalities were over 50 with ~5000 cases of children treated with thyroid cancer
- TMI cost ~$2b on-site with off-site damages $150m, and no deaths or statistically significant latent effects

References

Japan's Countermeasures

- 1.http://www.kantei.go.jp/foreign/incident/index.html
- 2.http://www.meti.go.jp/english/index.html
- 3.http://www.nisa.meti.go.jp/english/

Measurement of Radioactivity Level

- 1.http://www.mext.go.jp/english/radioactivity_level/detail/1303962.htm
- 2.http://www.nisa.meti.go.jp/english/
- 3.http://www.worldvillage.org/fia/kinkyu_english.php
- 4. http://www.tepco.co.jp/en/press/corp-com/release/index-e.html

Drinking Water Safety

- 1.http://www.mhlw.go.jp/english/topics/2011eq/index.html
- 2.http://www.waterworks.metro.tokyo.jp/press/shinsai22/press110324-02-1e.pdf

Food Safety

- 1.http://www.maff.go.jp/e/index.html
- 2.http://www.mhlw.go.jp/english/topics/2011eq/index.html

Ports and Airports Safety

- 1.http://www.mlit.go.jp/page/kanbo01_hy_001428.html
- 2.http://www.mlit.go.jp/koku/flyjapan_en/index.html
- 3.http://www.mlit.go.jp/page/kanbo01_hy_001411.html

Health Physics Slides

Health effects of Radioisotope Release

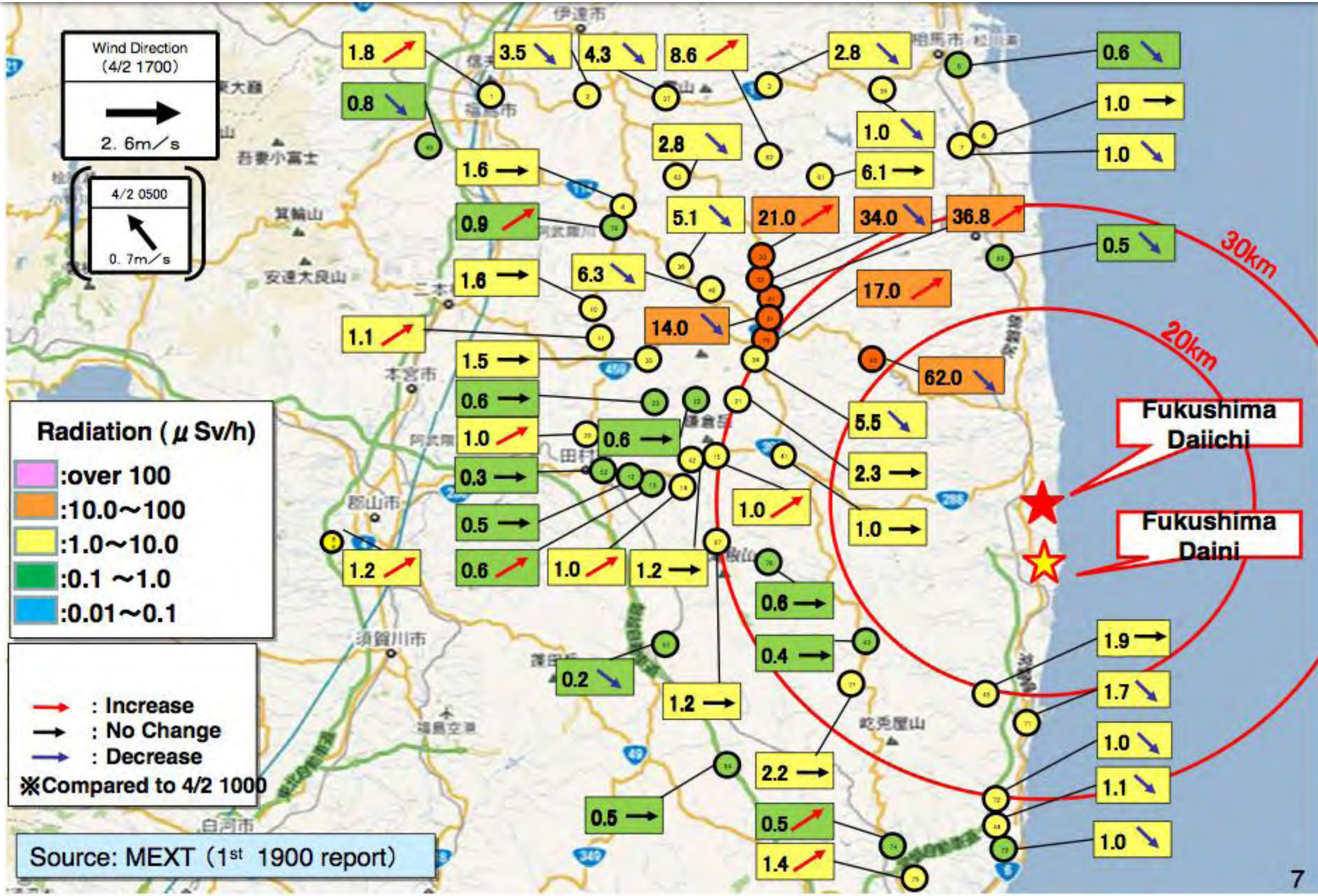
- What was the emergency response for general public?
- What were the on-site dose effects to workers?
- What were the off-site dose effects to the public?
- What were the long-term land contamination effects off-site?

Emergency Response

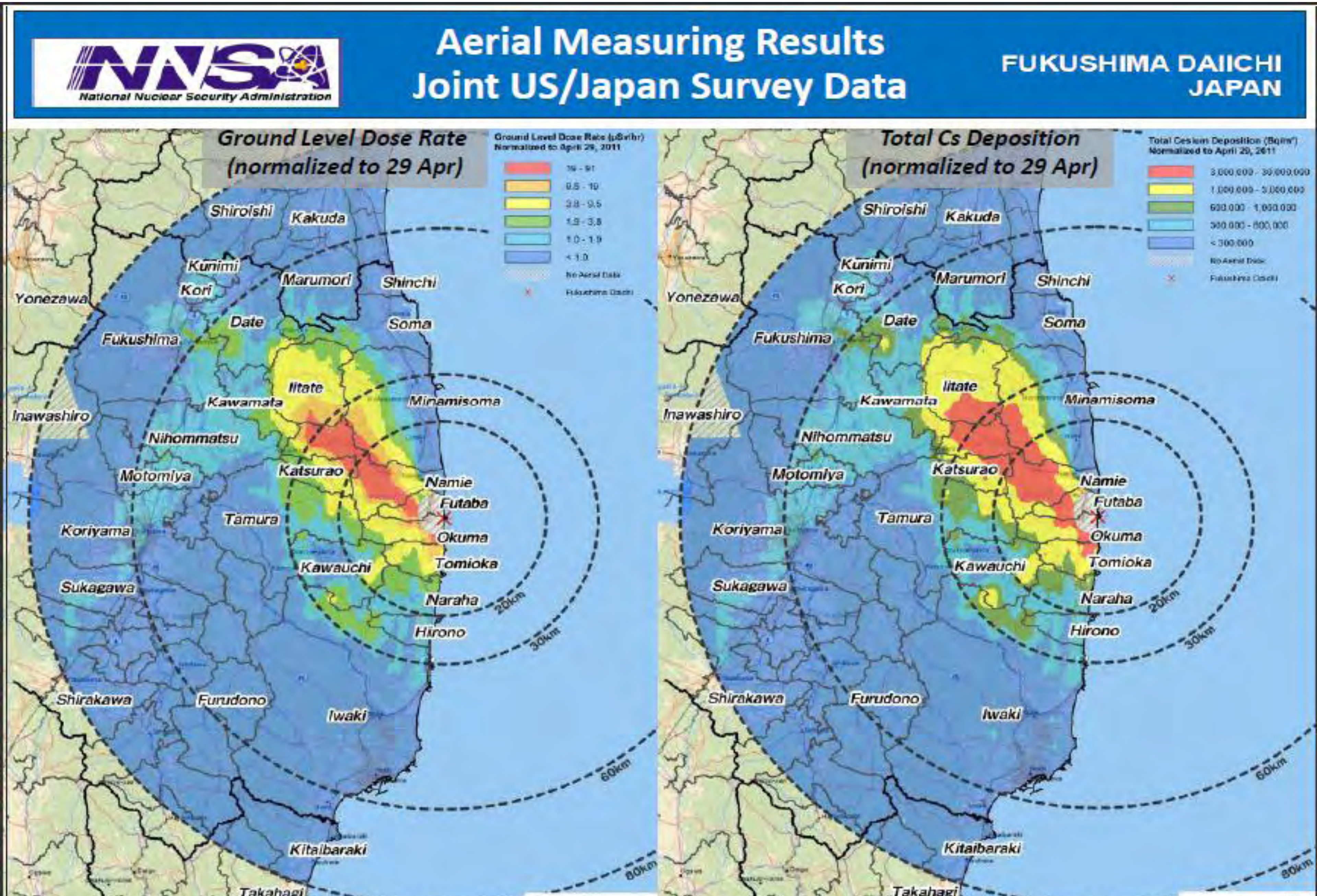
- General Emergency declared to the initial events in Unit 1 on Friday.
- Evacuation of public performed within 20 km of plant; approximately 200,000 people evacuated and sheltered in place within 30km.
- Recorded radiation levels spiked after each explosion (above).
- The NRC's radiation dose limit for the public is 100 mrem/yr (1000μSv/yr) and natural background is about 300 mrem/yr (3000μSv/yr or 0.34μSv/hr).
- Some workers reported with radiation exposure: six above allowable limit
- Potassium-iodide tablets given to protect the public from iodine.
- 100's aftershocks have occurred

Dose Category (mSv)	External	Internal
>250	0	6
200-250	0	3
150-200	7	7
100-150	17	13
50-100	116	100
20-50	297	321
10-20	527	369
<10	2762	1548
Total	3726	2367

Spatial Dose Rate Comparisons – April 1st



Dose Rate Comparisons to May 1st



Fukushima Daiichi Unit 1

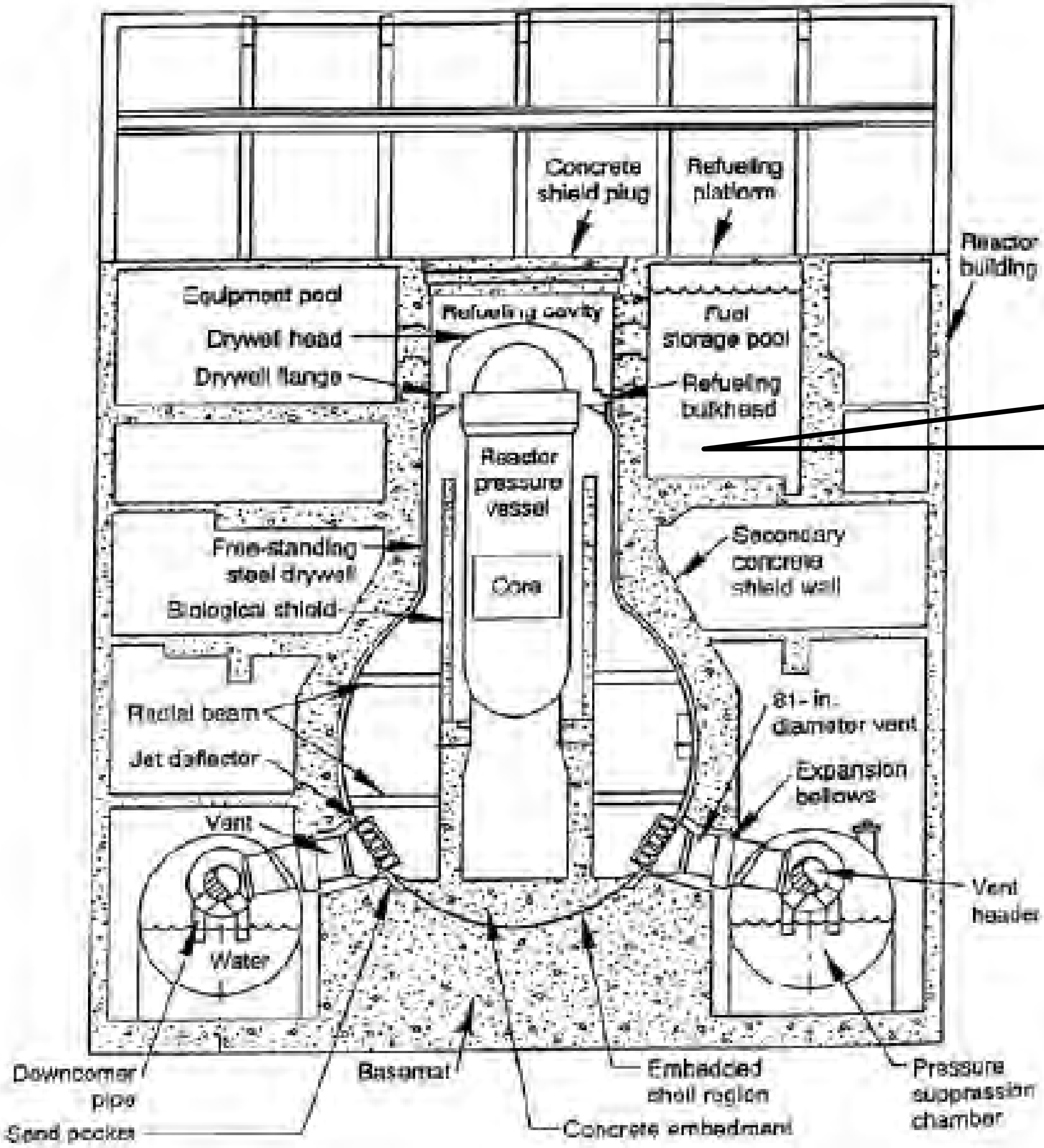


Figure 20. Mark I General Electric GE BWR Containment.

Three Mile Island Comparison

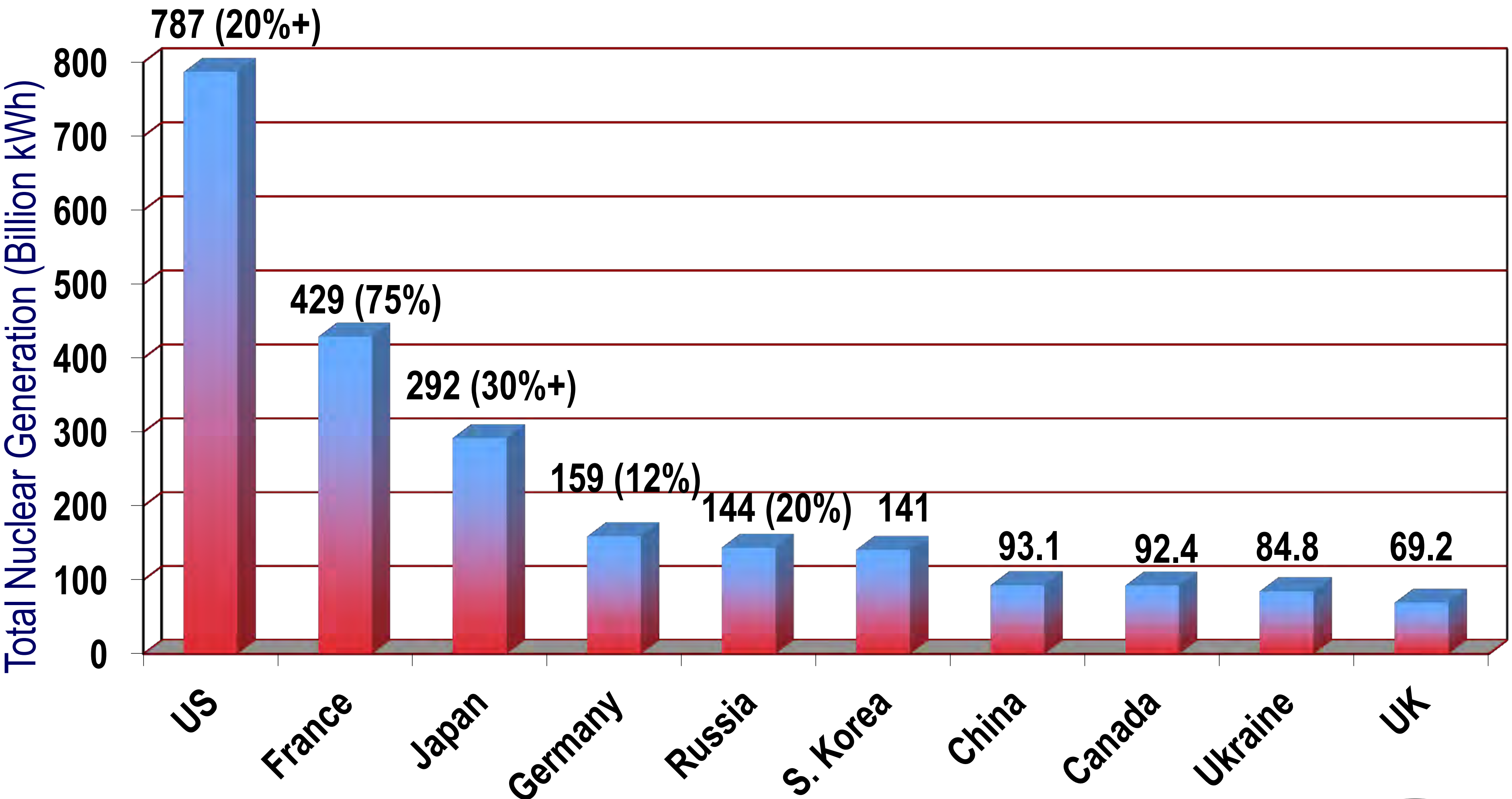
- Reactor Scram: 04:00 3/28/79
- Core melt and relocation: ~ 05:00 – 07:30 3/28/79
- Hydrogen Deflagration: 13:00 3/28/79
- Recirculation Cooling: Late 3/28/79
- Phased Water Processing: 1979-1993
- Containment Venting: July 1980
- Containment Entry: July 1980
- Reactor Head removed and core melt found: July 1984
- Start Defuel: October 1985
- Shipping Spent Fuel: 1988-1990
- Finish Defuel: Jan 1990
- Evaporate ~2M gallons Processed Water: 1991-93
- Cost: ~$2 Billion
- **F1 - Water Decon. and Cost at least 10 times larger**

Chernobyl Long-term Radiation Dose

Population (years exposed)	Number	Average total in 20 years (mSv)[1]
Liquidators (1986–1987) (high exposed)	240 000	>100
Evacuees (1986)	116 000	>33
Residents SCZs (>555 kBq/m2) (1986–2005)	270 000	>50
Residents low contam. (37 kBq/m2) (1986–2005)	5 000 000	10–20
Natural background	2.4 mSv/year (typical range 1–10, max >20)	48
Approximate typical doses from medical x-ray exposures per procedure:		
Whole body CT scan	12 mSv	
Mammogram	0.13 mSv	
Chest x-ray	0.08 mSv	

[1] These doses are additional to those from natural background radiation.

Who uses Nuclear Power?



Accident Description at Fukushima Dai-ichi site

- Discuss accident sequence for Units at Fukushima Dai-ichi?
- What happened to the spent fuel pools in each unit?
- Why did other plants survive the earthquake and tsunami?
- What was the command and control structure in Japan as compared to the U.S.?
- What were the emergency procedures for the Japanese plants and how are they different within U.S.?

Nuclear Safety Regulation System in Japan

Licensee

Application for Establishment Permit

Application →

Regulatory Bodies

Nuclear and Industry Safety Agency (**NISA**) for NPPs

↑ *Technical supports*

Japan Nuclear Energy Safety Organization (**JNES**)

Ministry of Education, Culture, Sports and Science and Technology (**MEXT**) for RRs

Inquiry →

← *Report*

Cabinet Office
Nuclear Safety Commission **(NSC)**

- Secondary Review: "Double check"
- Supervise and audit the regulatory bodies
- Receive and respond to reports on accidents and problems

NISA :
- Issue license for NPPs and related facilities
- Approve construction and suitability of safety program and pre-service inspection
- Conduct periodic inspections of facilities, suitability of safety inspection, emergency preparedness

MEXT :
- The same function as NISA for test and research reactor facilities

JNES :
- Inspection and cross-check analysis, etc. for NPPs
- Investigations and tests to be reflected onto the safety regulations

Subsequent Regulation

(NISA/JNES and MEXT)

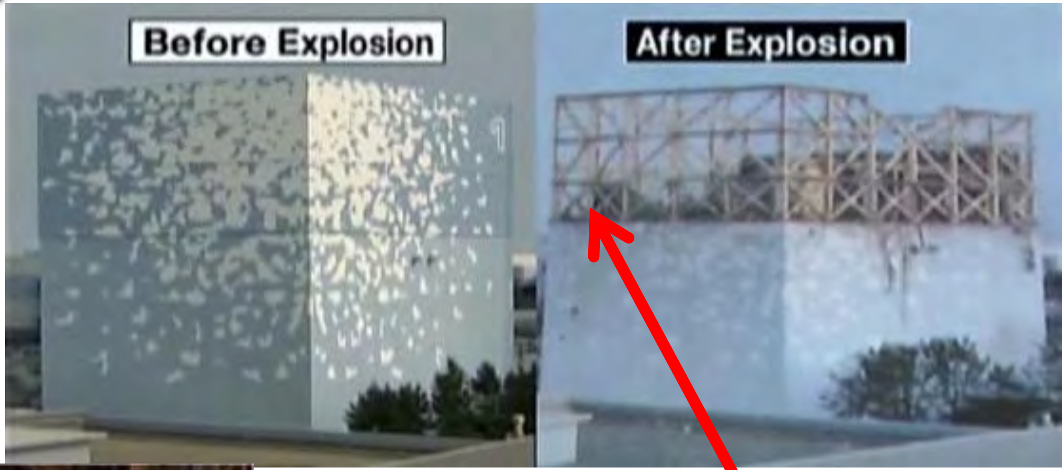
Construction phase
Approve design, ---
Operation Phase
Periodic inspections etc
Others
Periodic inspections etc

Periodic Report →

← *Supervise & Audit*

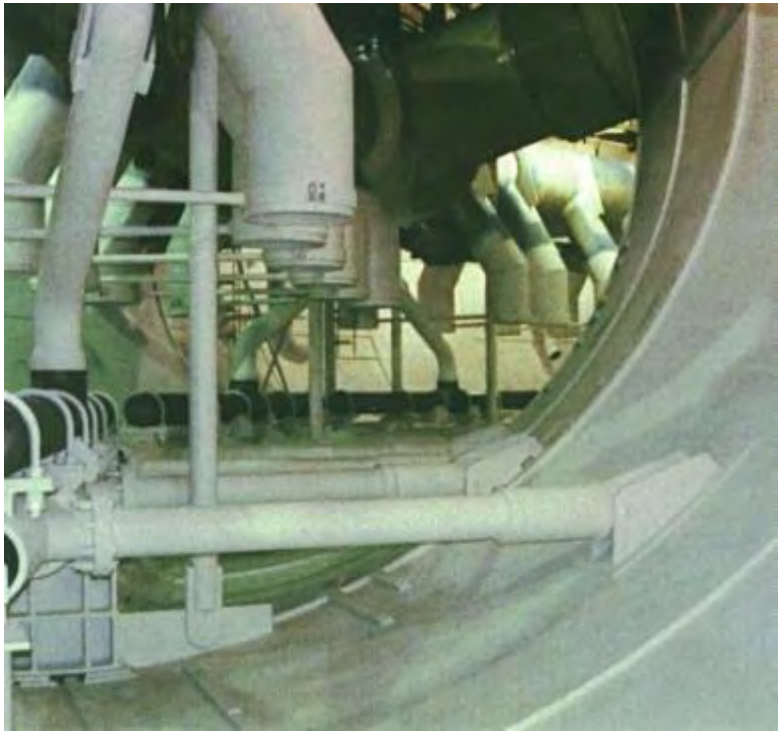
(NSC)
Review subsequent regulation

Hydrogen Explosion in all the Units

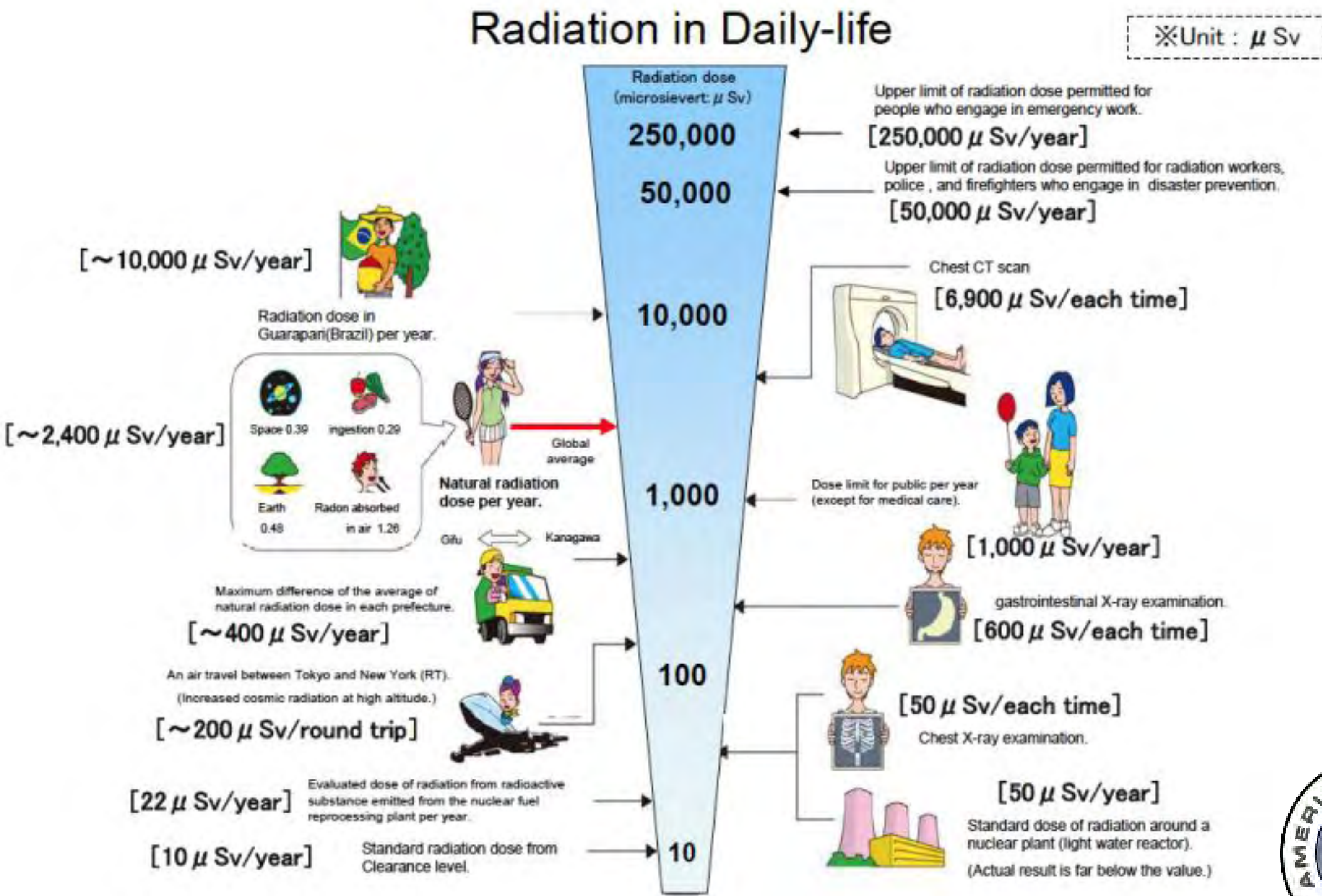


Reactor Building

Refuel Floor



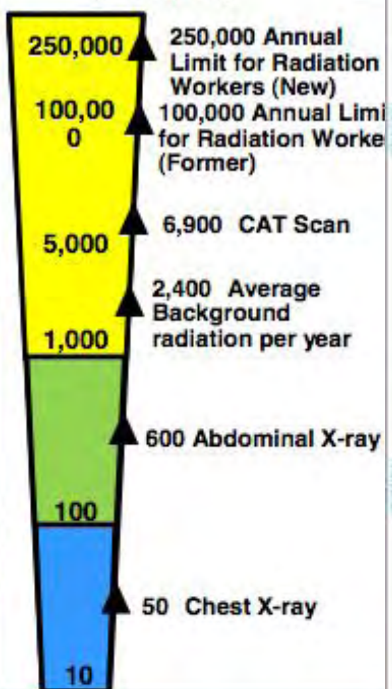
Radiation Levels Put Into Context



http://www.mext.go.jp/english/radioactivity_level/detail/1303962.htm

Integra

Radiation Level Reference
(Unit: μSv)

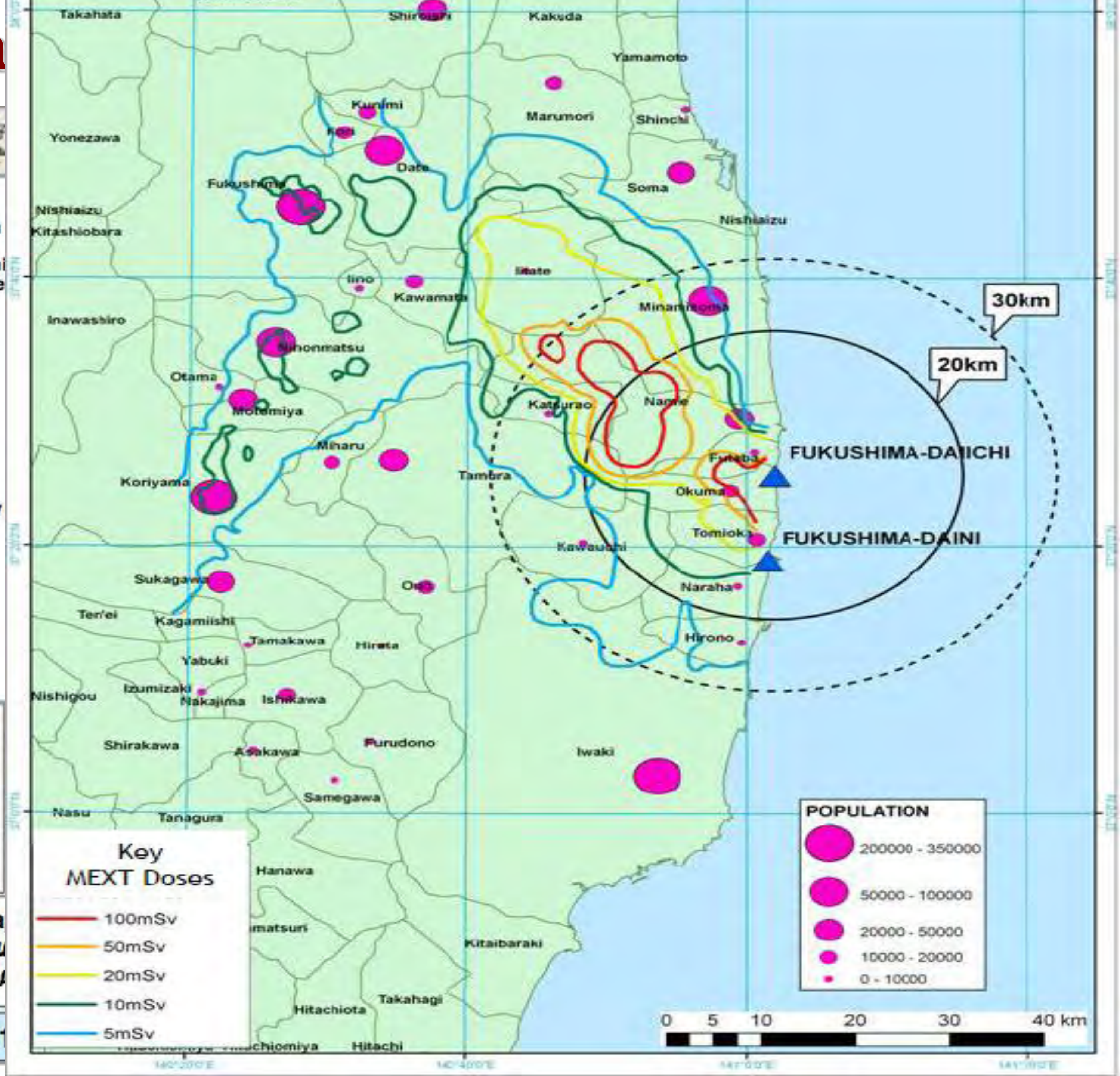


Legend

: over 1000.0
: 100.0-1000.0
: under 100.0
(μSV)

Accumulated radiation (a
days of accumulation) (μ
(Average exposure/hr) (

Source: MEXT (2 APR1



Short-Term Health Risks

Exposure (Sv)	Exposure (μSv - microSv)	Health Effect
0.05	50,000	changes in blood chemistry
0.5	500,000	nausea
0.55	550,000	fatigue
0.7	700,000	vomiting
0.75	750,000	hair loss
0.9	900,000	diarrhea
1	1,000,000	hemorrhage
4	4,000,000	possible death (2 months)
10	10,000,000	death (1-2 weeks)
20	20,000,000	death (hours-days)

Public not at risk for any short-term health effects.

Long-Term Health Risks

Above 0.1 Sv (100,000 μSv) the cancer risk can be approximated by using 5% per Sv (accepted via the linear dose model).

- For example, the occupational worker who received as dose of 0.1 Sv has a 0.5% increased risk of developing a cancer in their life.
- Estimating cancer risks to the general public is difficult because of the low dose rates outside of the plant and large overall cancer rates.
- If radiation levels in Tokyo remained at the current level (0.14 μSv/hr) it would take one month of exposure for residents to experience the same risks than received from a common dental X-ray exam.

Release Inventory

Uranium and Transuranium Elements

Isotopes	Half life
Pu-238	88 – years
Pu-239	24,200 – years
Pu-240	6563 – years
U-234	246,000 – years
U-235*	7.0E+08 – years
U-238*	4.5E+09 – years
Am-241	432 – years
Cm-242	160 – days

*naturally occurring

Fission Products

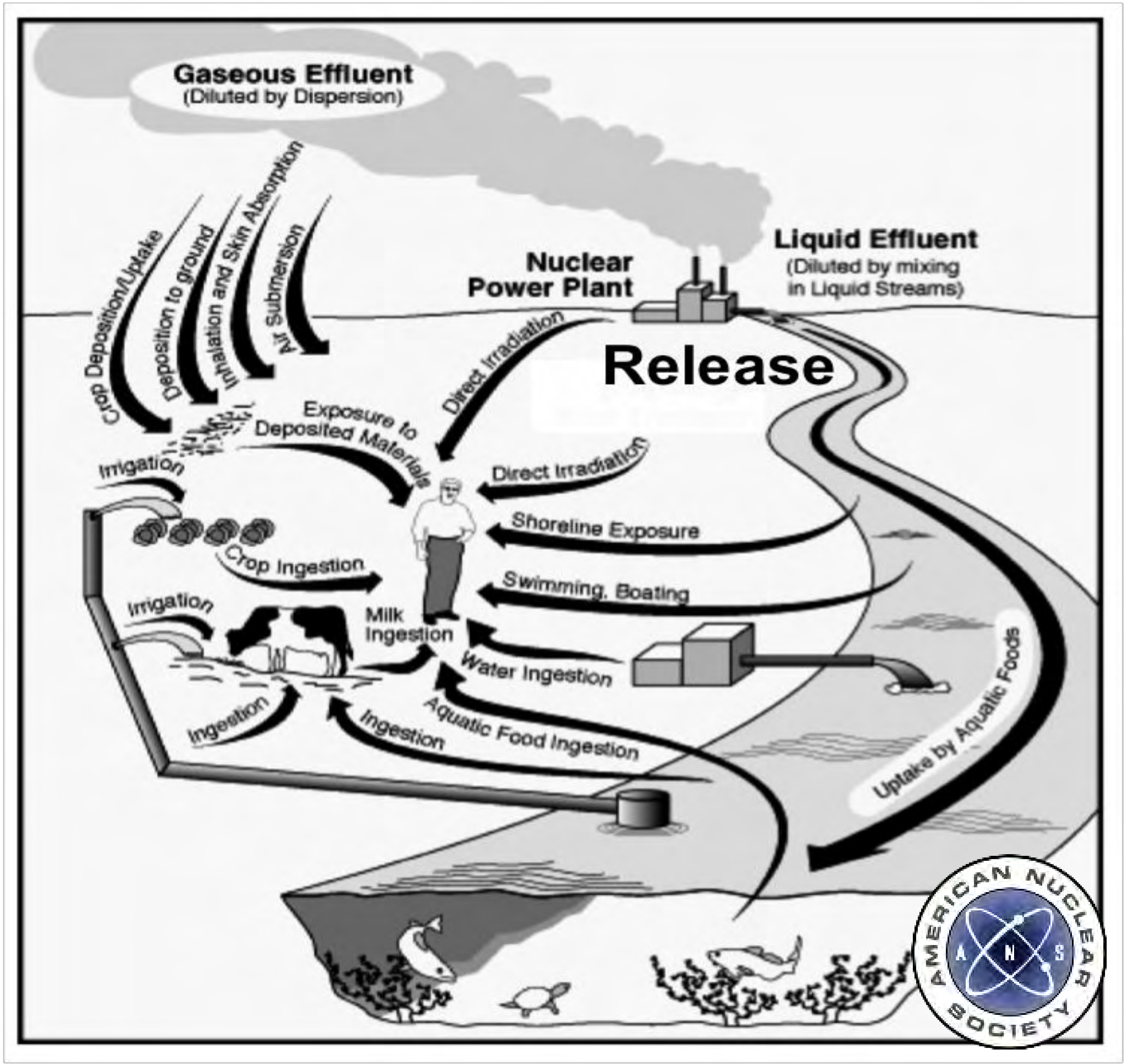
Isotopes	Half life
I-131	8 – days
I-132	2 – hours
Cs-134	2 – years
Cs-137	30 – years
Te-129m	34 – days
Te-132	3 – days
Ba-140	13 – days
Nb-95	35 – days
Ru-106	370 – days
Mo-99	66 – hours
Tc-99m	6 – hours
Sr-90	29 – years
Ag-110m	250 - days

50% of all Iodine was released
1% of all Cesium was released
Minimal amount of Sr released

Pathways To Humans

Pathways to humans is diverse:

- Air
- Water
- Soil

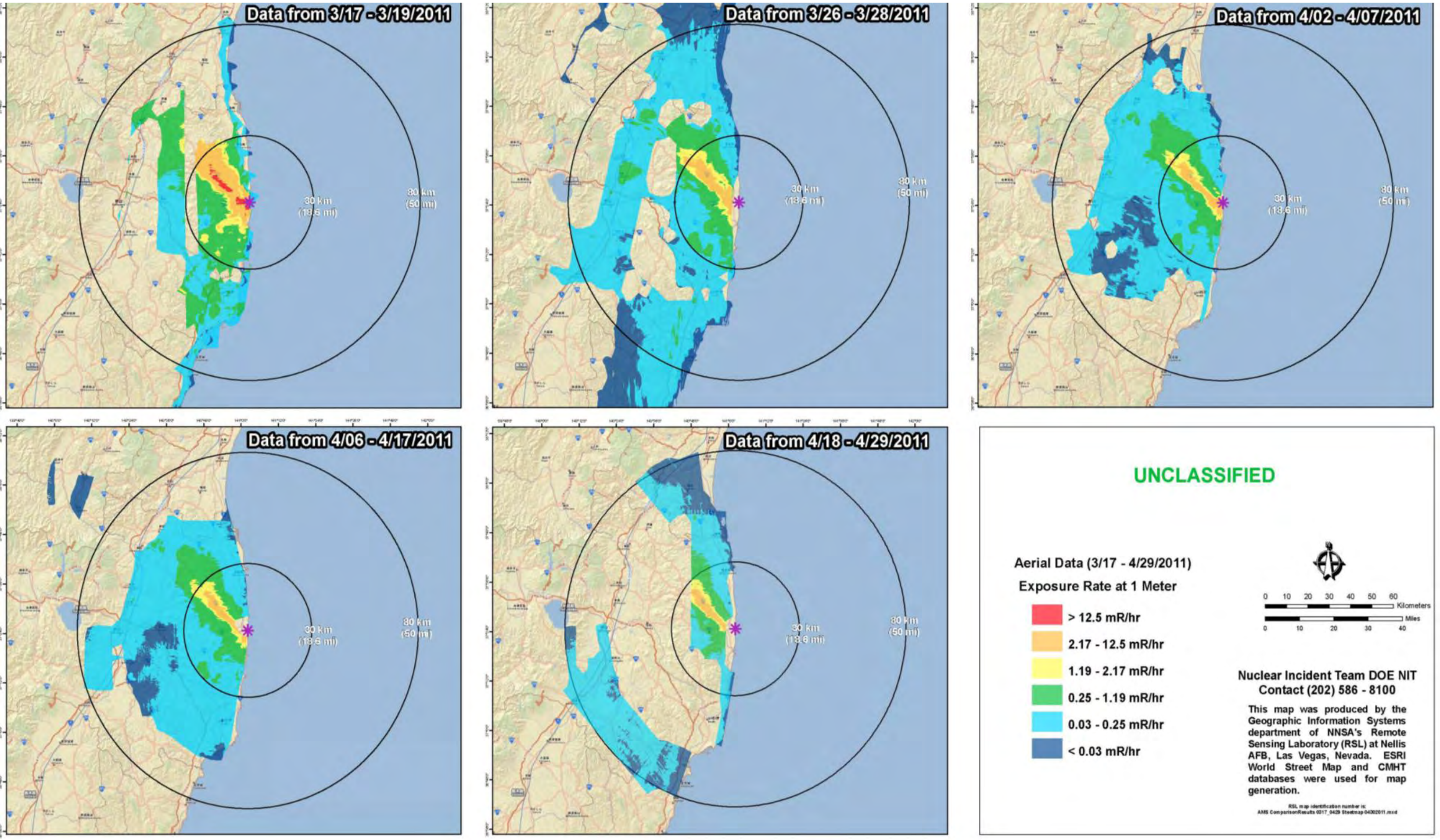


Source: ORNL/M-4227. Oak Ridge National Laboratory, Oak Ridge, TN

Continuous Environmental Monitoring

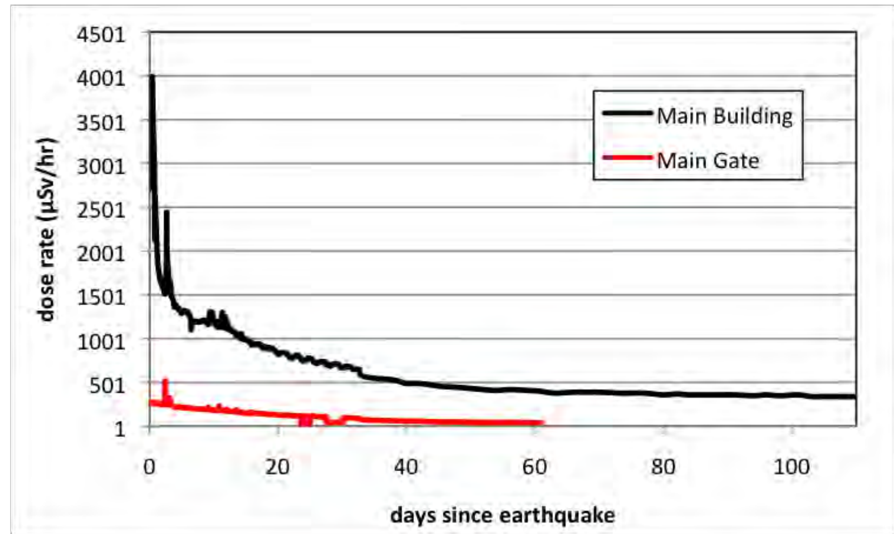
Monitoring	Onsite	Offsite
• Area Monitoring	O	O
• Air Monitoring	O	
• Soil Monitoring	O	O
• Water Monitoring		
• Freshwater		O
• Seawater	O	O
• Food		O

Area Monitoring - Offsite



Source: NNSA. http://nnsa.energy.gov/mediaroom/pressreleases/fukushimadata

Area Monitoring - Onsite

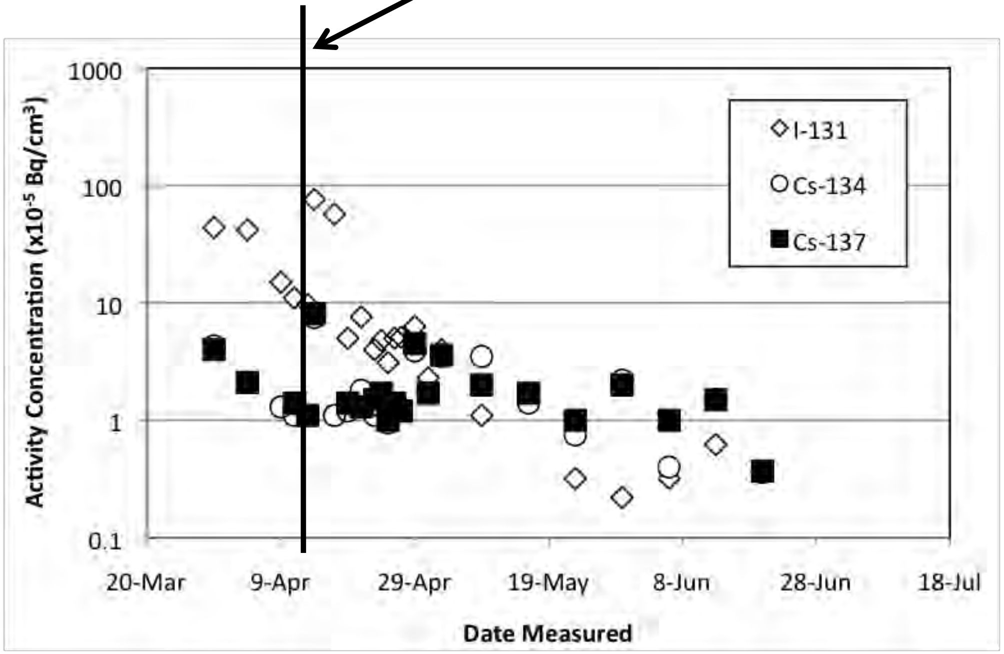


Source: TEPCO, http://www.tepco.co.jp/en/press/corp-com/release/index-e.html

Air Monitoring - Onsite

Fukushima NPP

Transfer of contaminated water from Unit 2 to condenser 4/12-4/13.

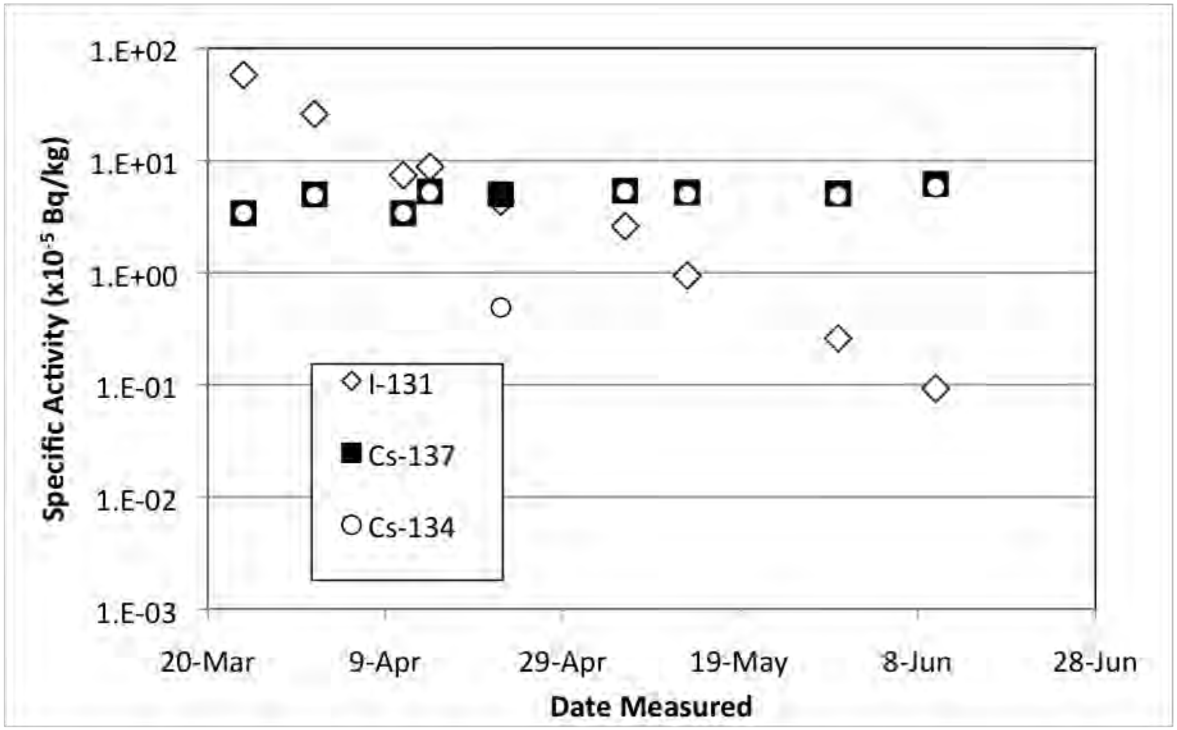


Important for monitoring internal exposures.

Source: TEPCO, http://www.tepco.co.jp/en/press/corp-com/release/index-e.html

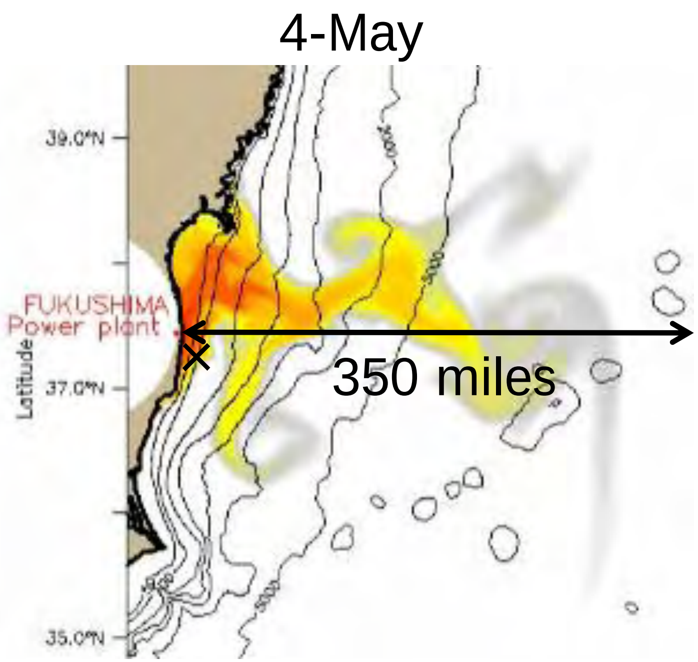
Soil Monitoring - Onsite

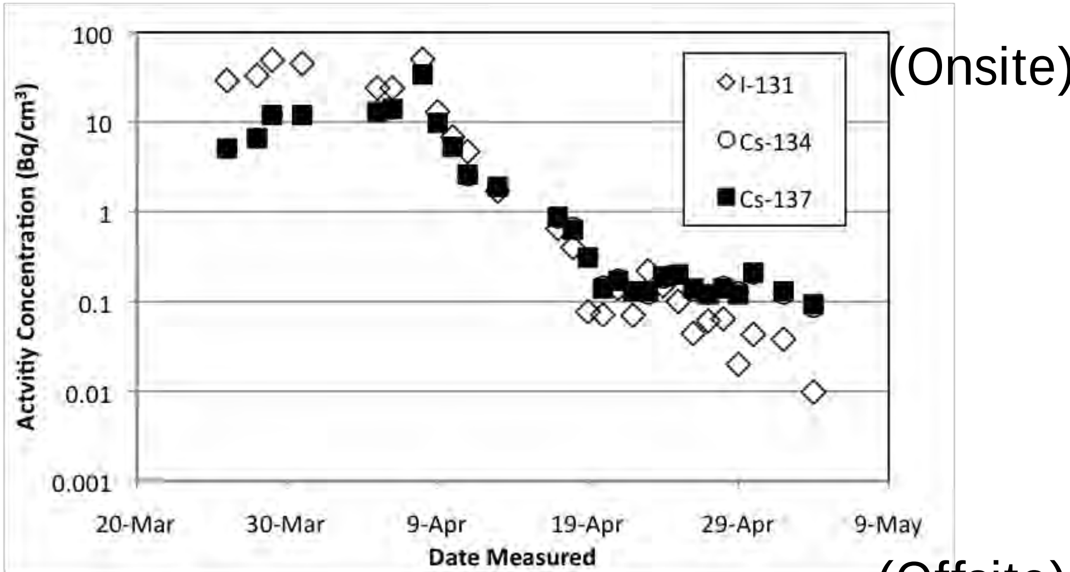
Fukushima NPP

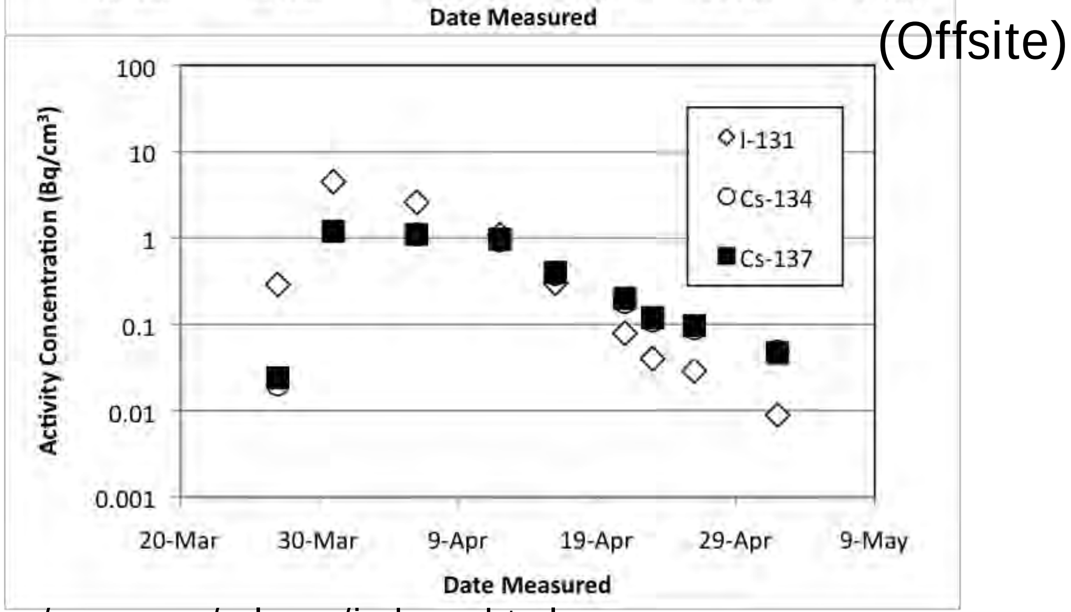


Source: TEPCO, http://www.tepco.co.jp/en/press/corp-com/release/index-e.html

Water Monitoring





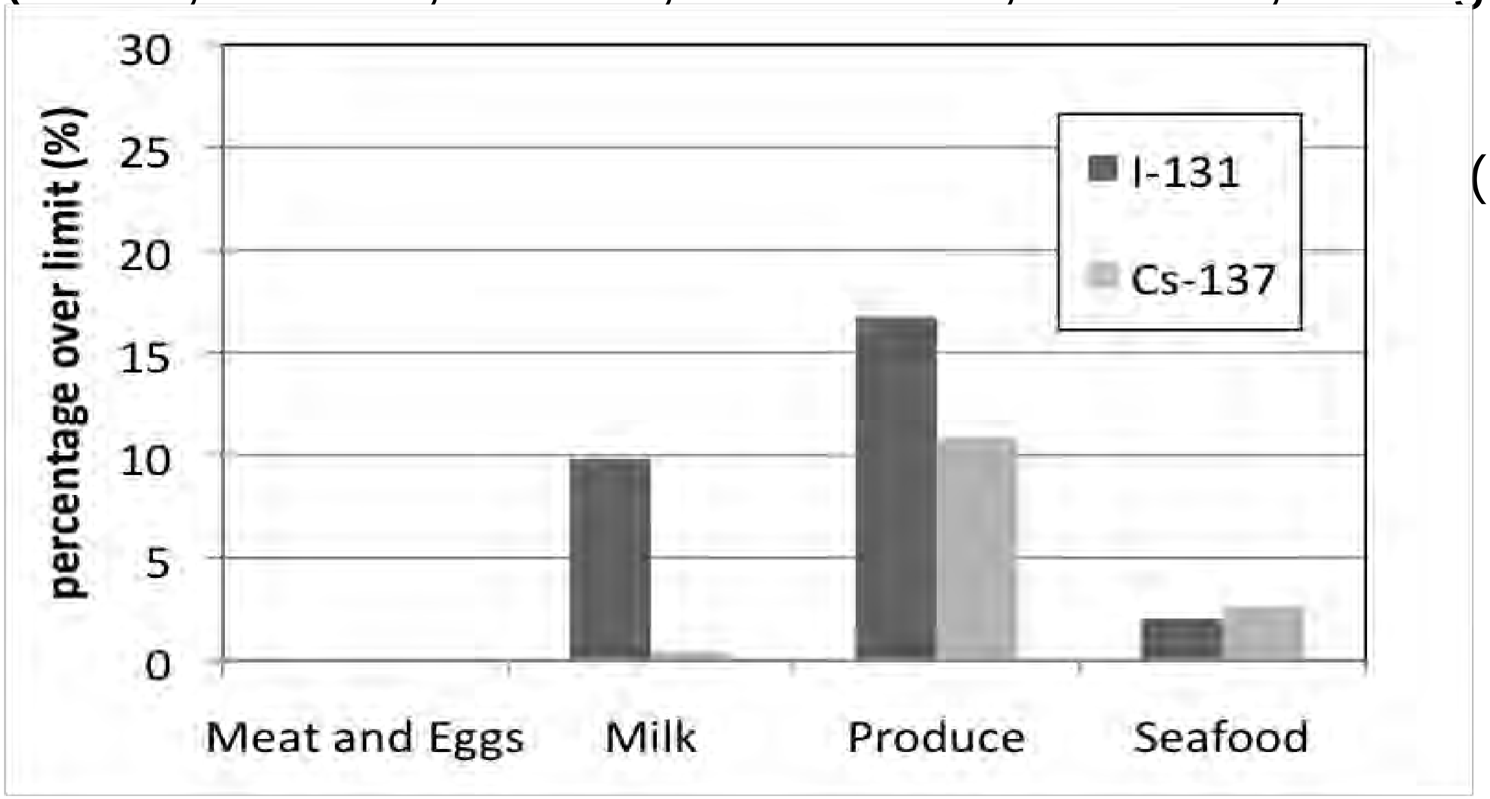


Source: TEPCO, http://www.tepco.co.jp/en/press/corp-com/release/index-e.html

Source: SIROCCO, http://sirocco.omp.obs-mip.fr/accueil/Accueil.htm

Food and Water Monitoring

6 out of 16 prefectures have tested positive for contamination in the food chain and removed (Chiba, Gunma, Ibaraki, Fukushima, Saitama, Tochigi*)



(Offsite)

*FDA has banned milk, milk products, vegetables, and fruits from the 6 prefectures

Source: WHO. Situation Report: Focus on food safety and water quality

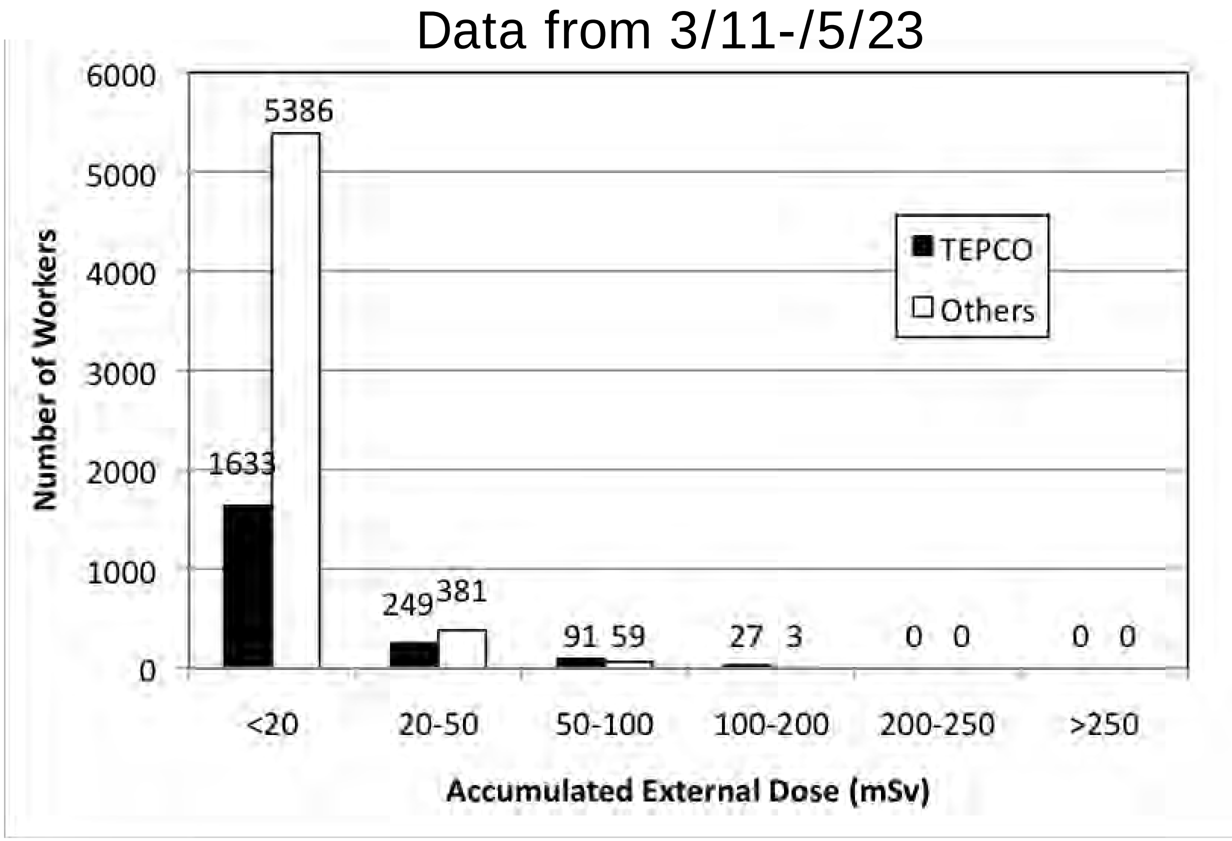
Food and Water Monitoring

23 villages/cities in 5 different prefectures have placed bans on drinking water for infants. All but one has been removed.

1 village in Fukushimi placed a ban on drinking water for both adults and infants, but this ban has been removed.

(Offsite)

Dose to Employees



There have been no reported cases of acute radiation syndrome or deaths due to exposure. Three workers over the allowable exposure limits. (Chernobyl: 134 workers developed ARS and 28 died)

http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html

Spatial Dose Rate Comparisons - March 18th

Avg. Radiation Doses

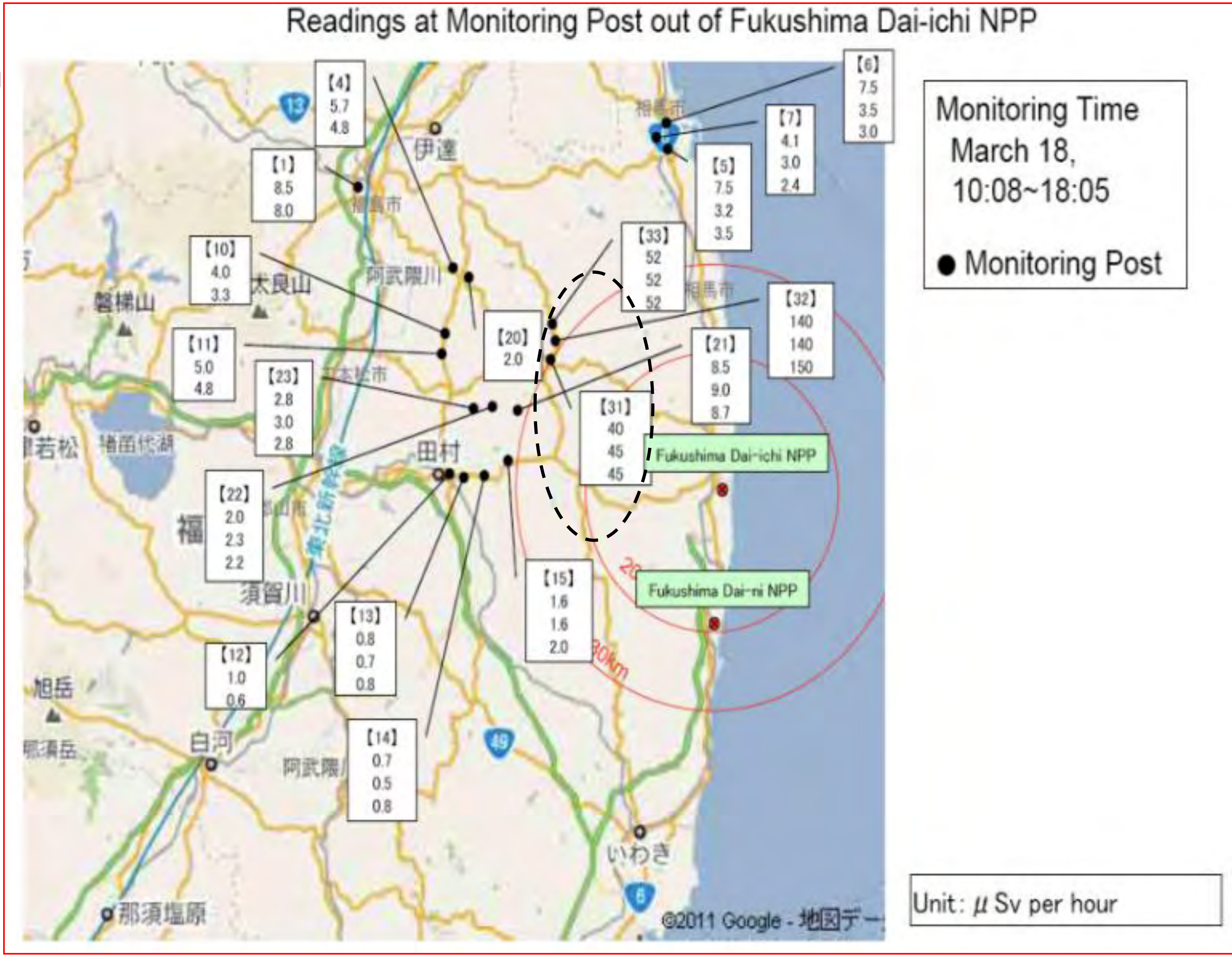
U.S. Natural Dose
(0.34 µSv/hr)

U.S. Medical Dose
(0.37 µSv/hr)

Single Chest Xray
(40 µSv)

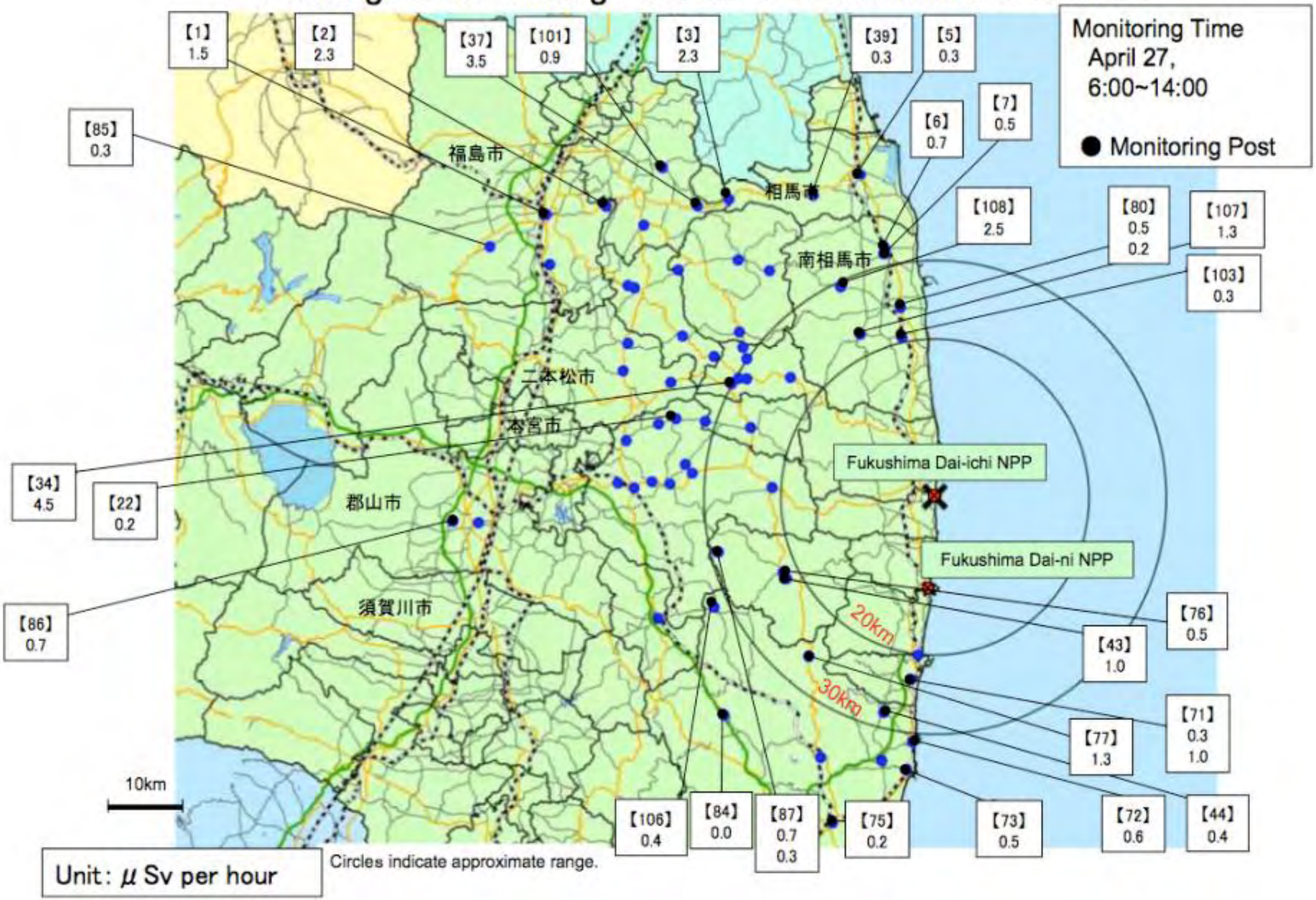
Mammogram
(300 µSv)

LA-to-NYC flight
(20 µSv/trip)

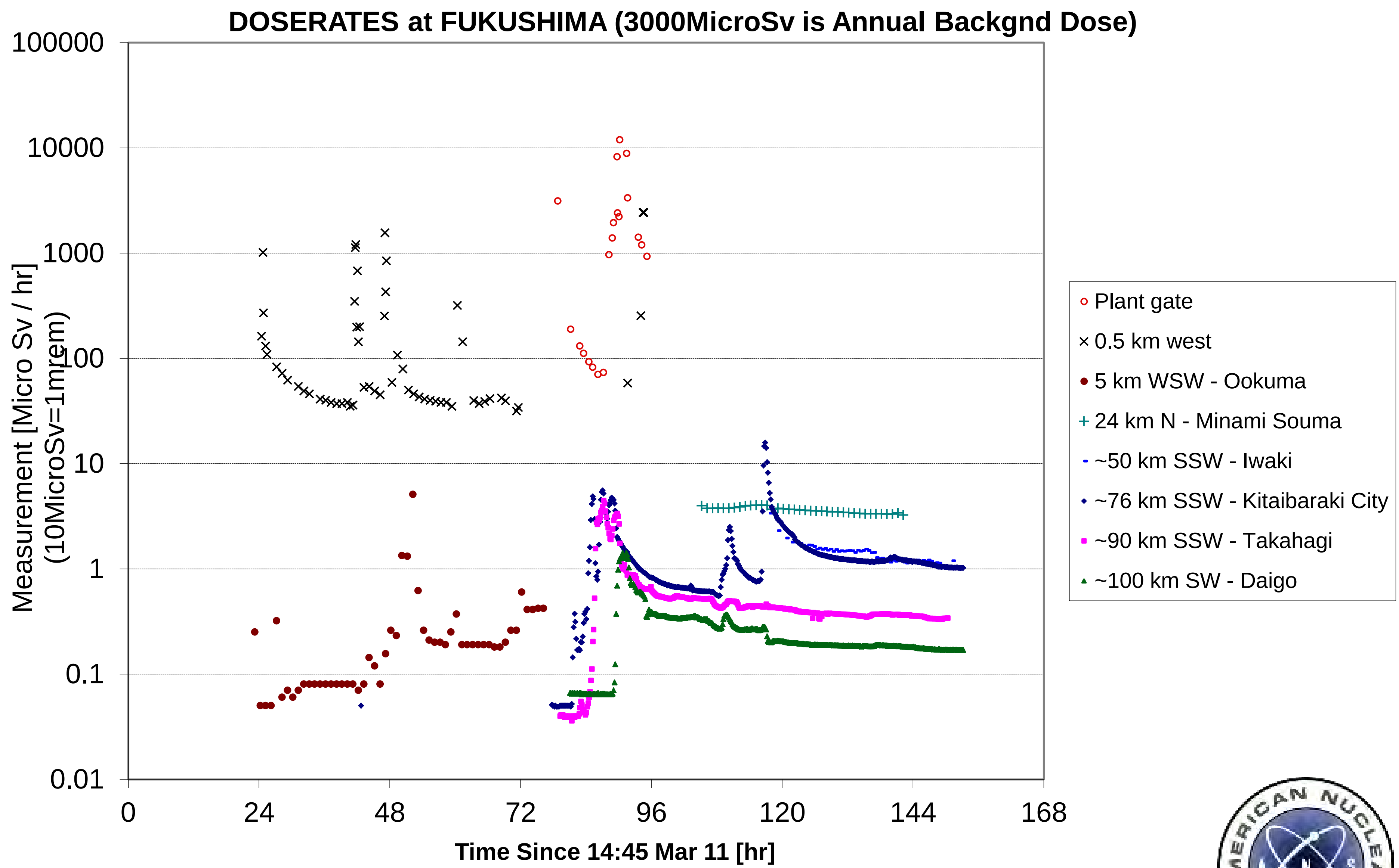


Spatial Dose Rate Comparisons – April 27th

Readings at Monitoring Post out of Fukushima Dai-ichi NPP

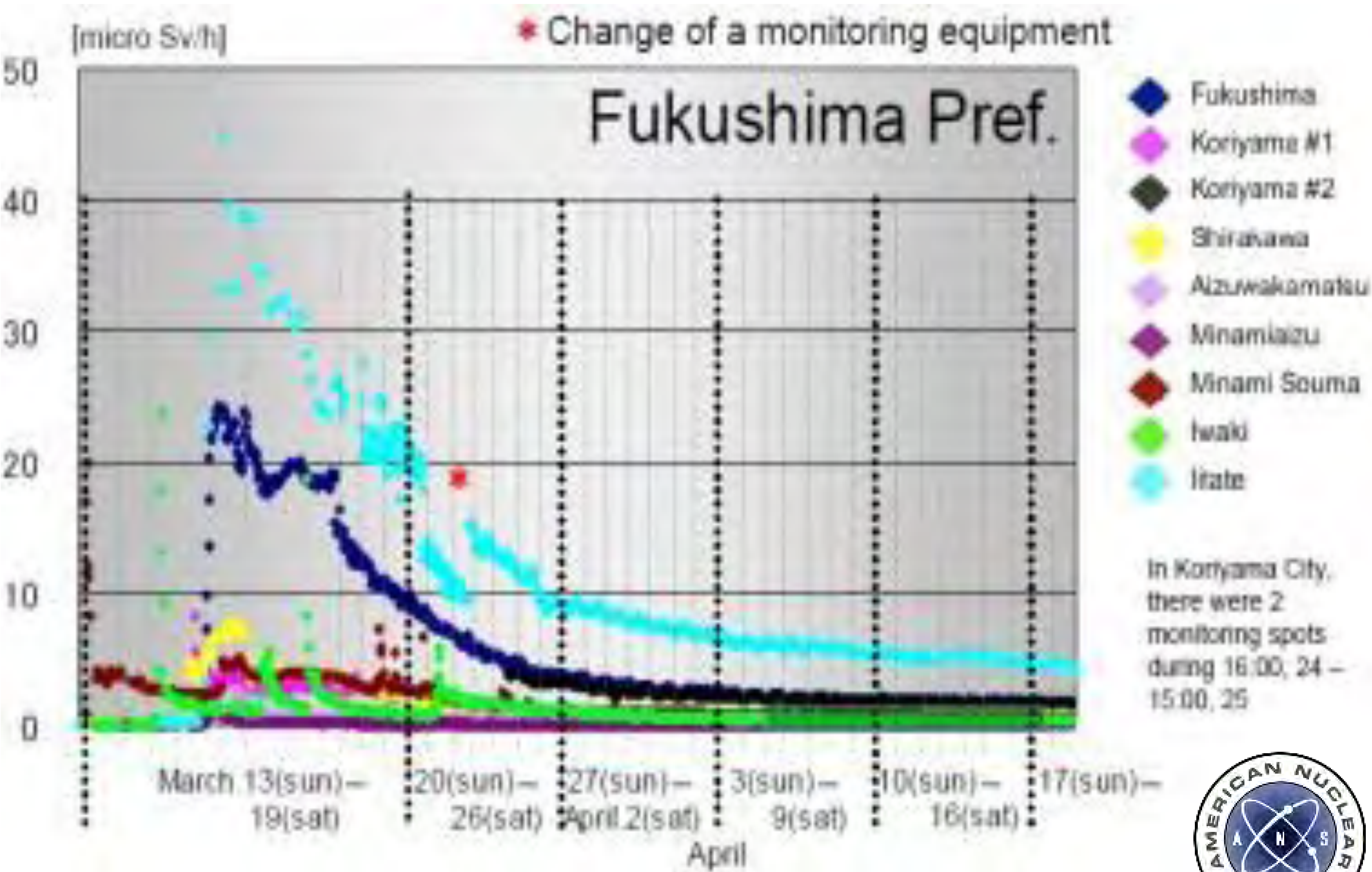


Dose History at Selected Locations



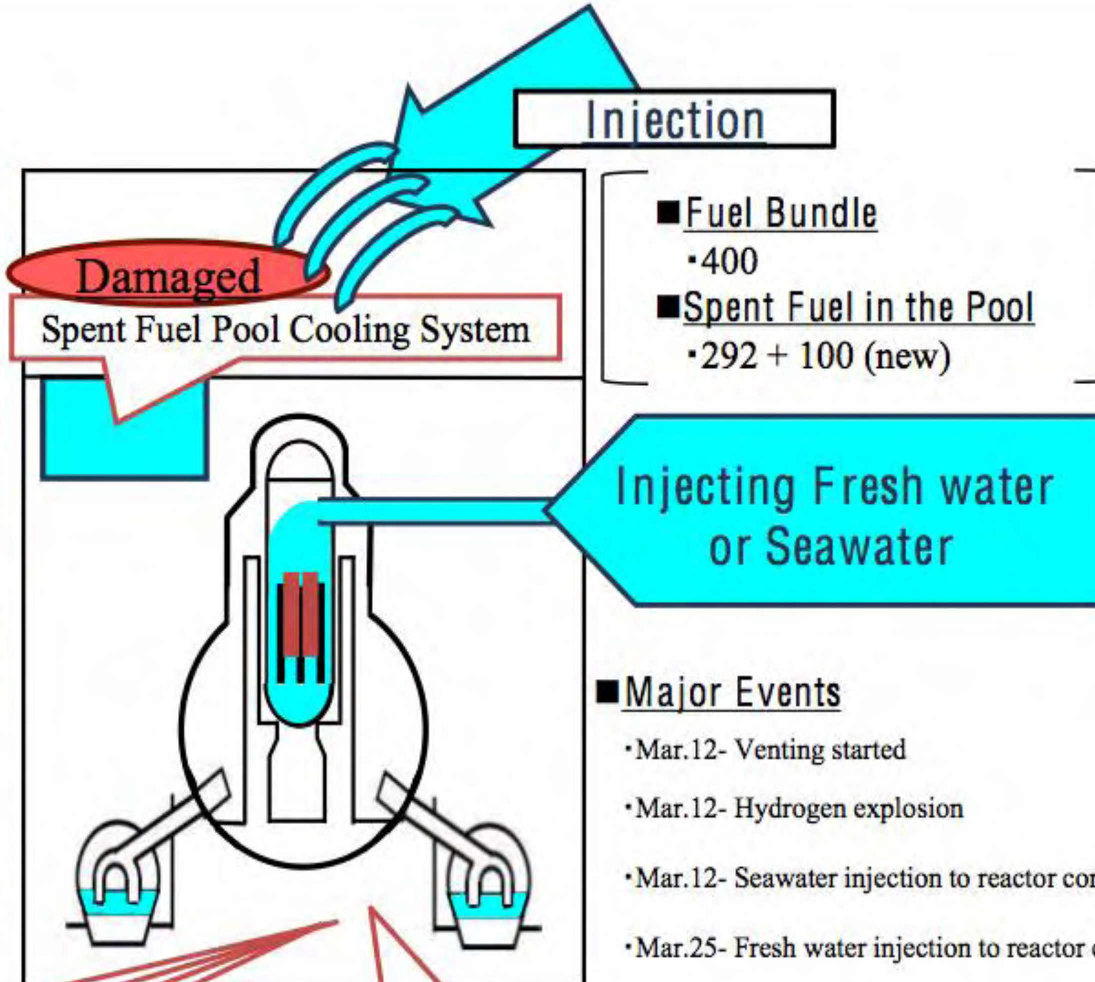
http://www.mext.go.jp/english/radioactivity_level/detail/1303986.htm

Dose Comparison History



Unit #1 Situation

TEPCO



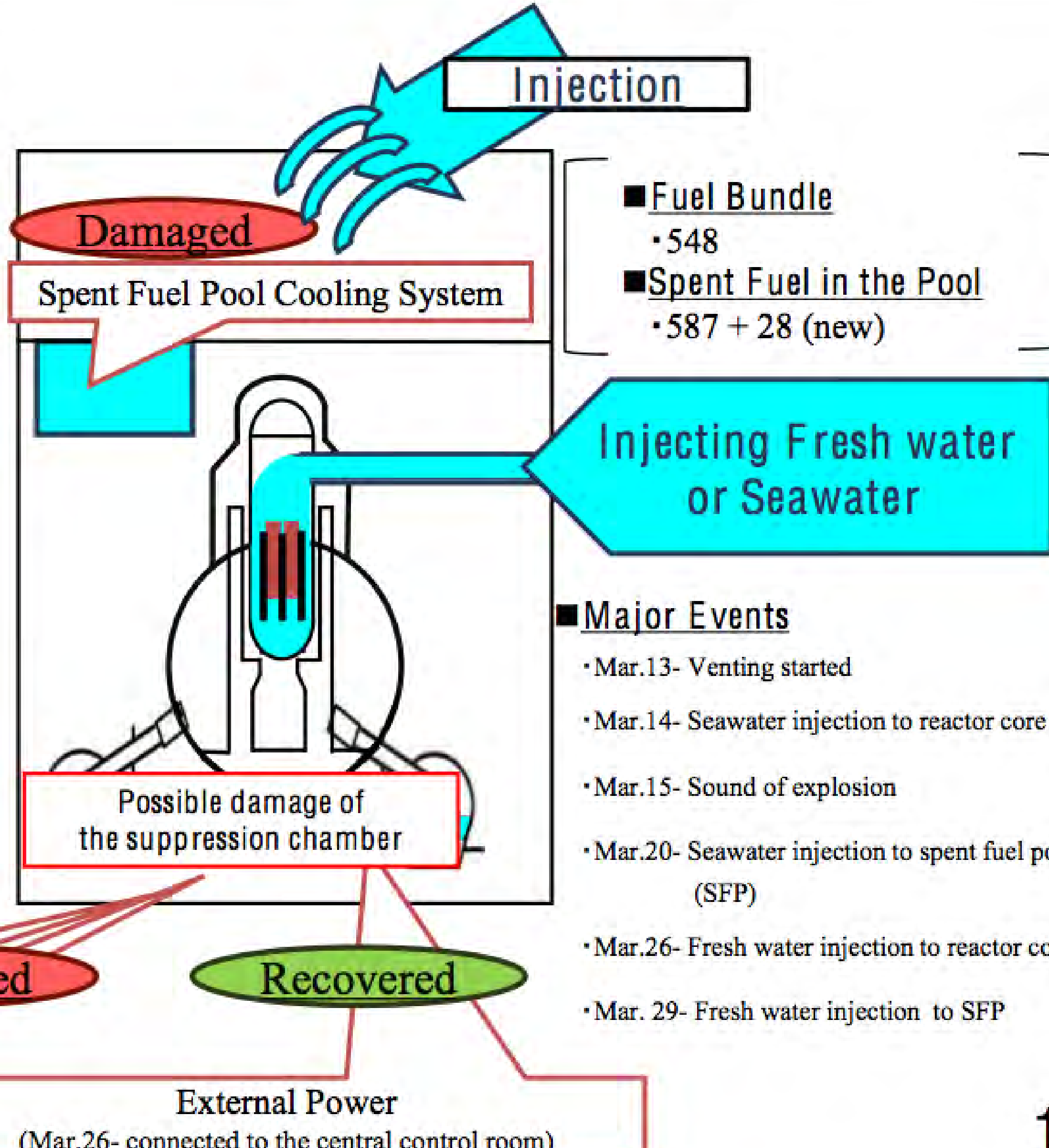
■Fuel Bundle
- 400

■Spent Fuel in the Pool
- 292 + 100 (new)

■Major Events
- Mar.12- Venting started
- Mar.12- Hydrogen explosion
- Mar.12- Seawater injection to reactor core
- Mar.25- Fresh water injection to reactor core
- Mar.31- Fresh water spray by concrete pump trucks
- Apr. 7- Injection of nitrogen to the reactor

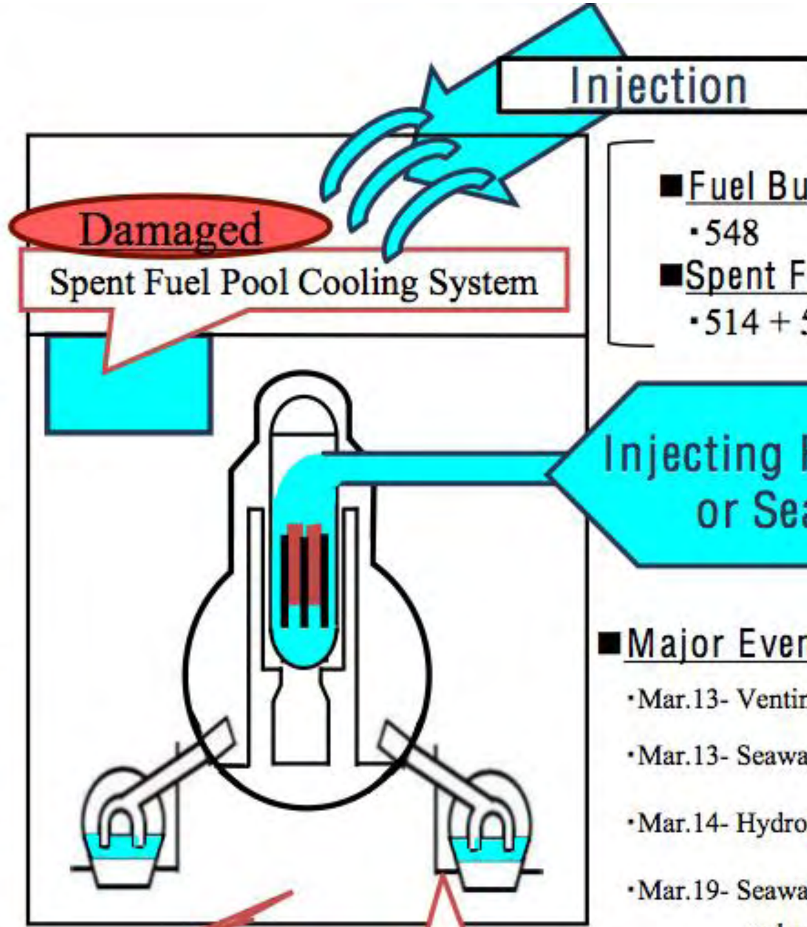
Unit #2 Situation

Ministry of Defense



Unit #3 Situation

Air Photo Service Inc (Myoko, Niigata Japan)

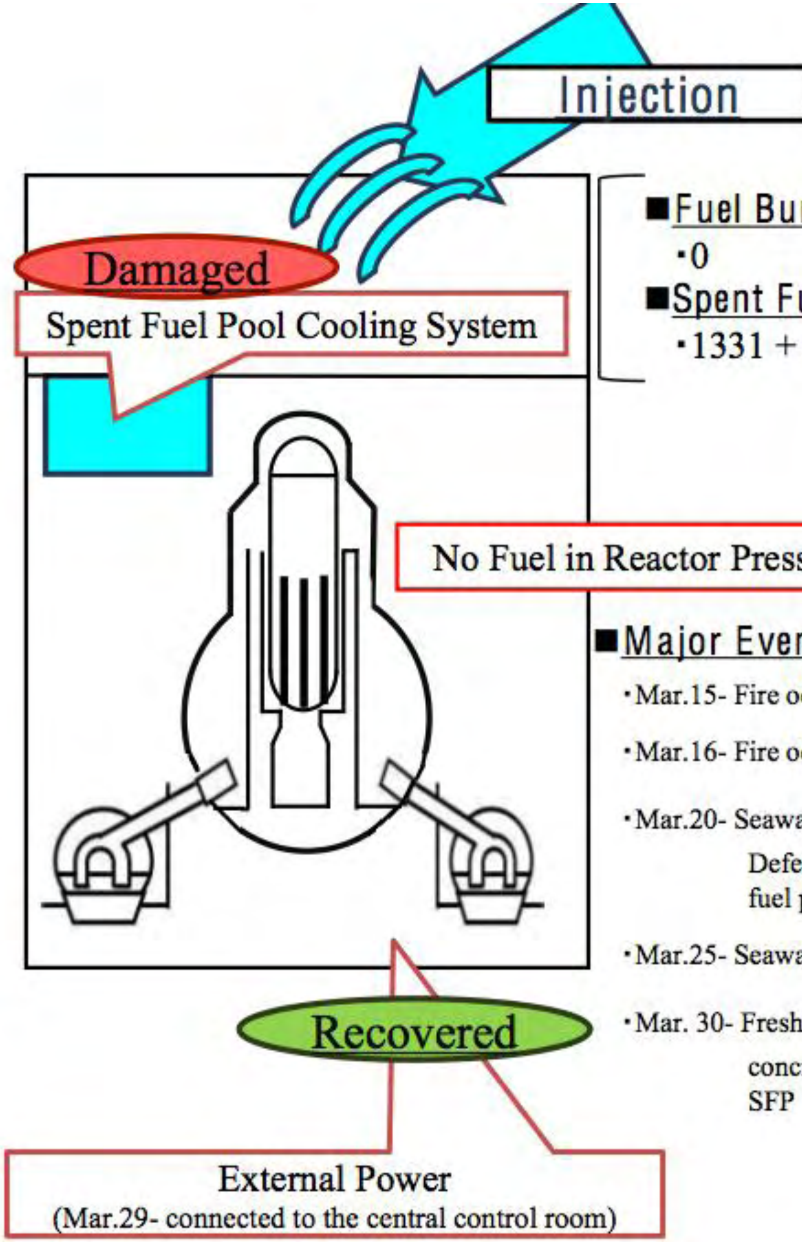


■Fuel Bundle
・548
■Spent Fuel in the Pool
・514 + 52 (new)

■Major Events
- Mar.13- Venting started
- Mar.13- Seawater injection to reactor core
- Mar.14- Hydrogen explosion
- Mar.19- Seawater discharge by helicopters and sprayed to spent fuel pool (SFP) by Tokyo Fire Department etc,
- Mar.25- Fresh water injection to reactor core
- Mar.27- Fresh water spray by concrete pump trucks to SFP

Unit #4 Situation

Air Photo Service Inc (Myoko, Niigata Japan)

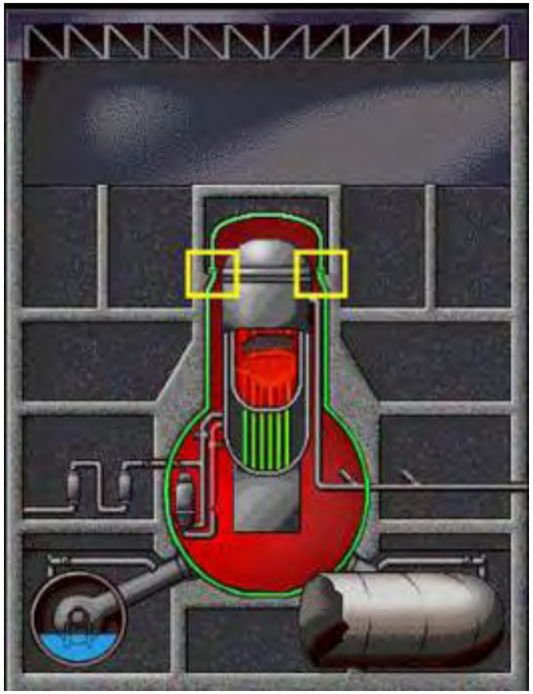


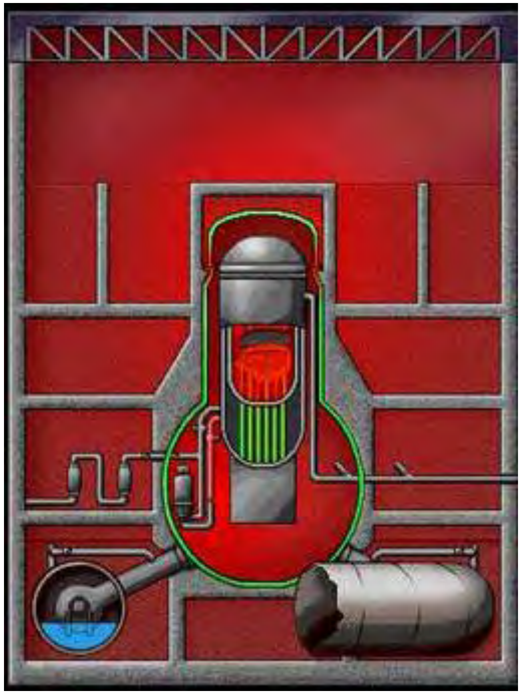
■ Fuel Bundle
- 0

■ Spent Fuel in the Pool
- 1331 + 204 (new)

■ Major Events
- Mar.15- Fire occurred
- Mar.16- Fire occurred.
- Mar.20- Seawater spray by Self-Defense Forces to spent fuel pool (SFP)
- Mar.25- Seawater injection to SFP
- Mar. 30- Fresh water spray by concrete pump trucks to SFP

Fukushima Reactor Vessel-Primary Containment Sequence



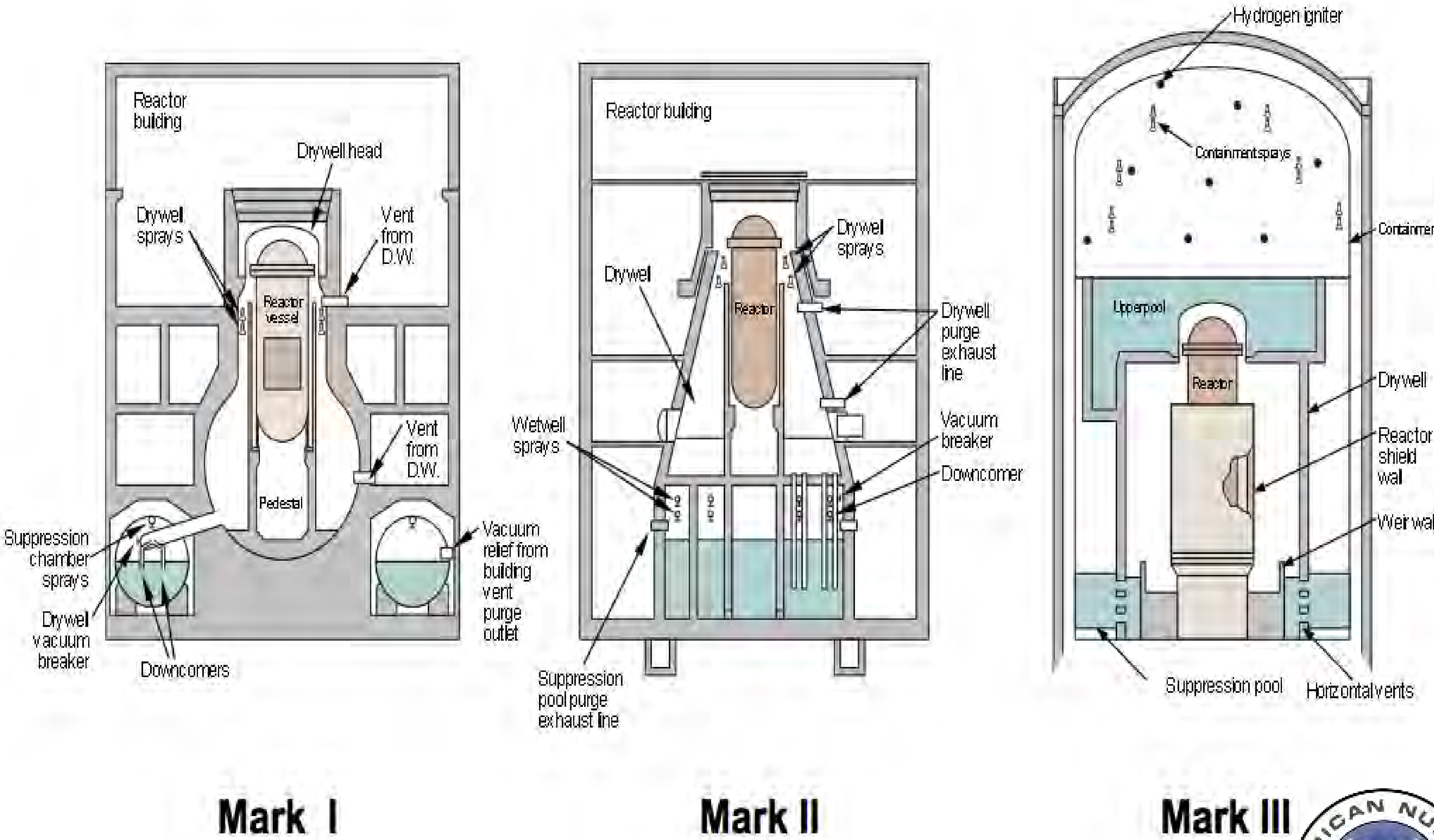


Core Over Heat
-Clad Burst ~900C
-Clad Oxidize ~1200C
-H2 Release
-Partial Melt~1800C-2700C
-Primary Sys Overpressure

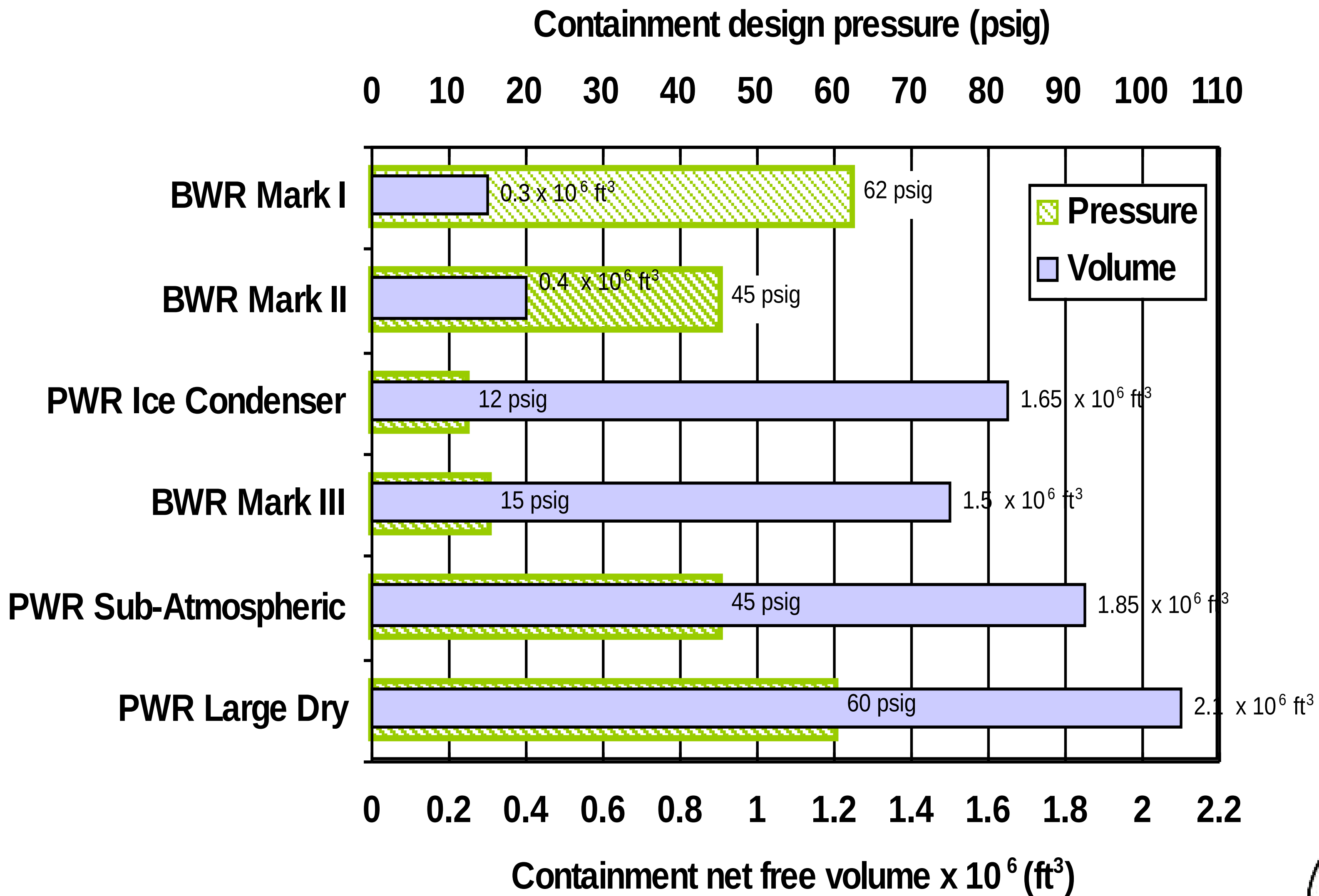
Vent from Primary Coolant Sys to Primary Containment- H2, Steam, & Fission Products (Xe, Kr, I, Cs...)

No Primary Containment Cooling therefore Primary Containment Overpressure-Vent to Secondary Containment

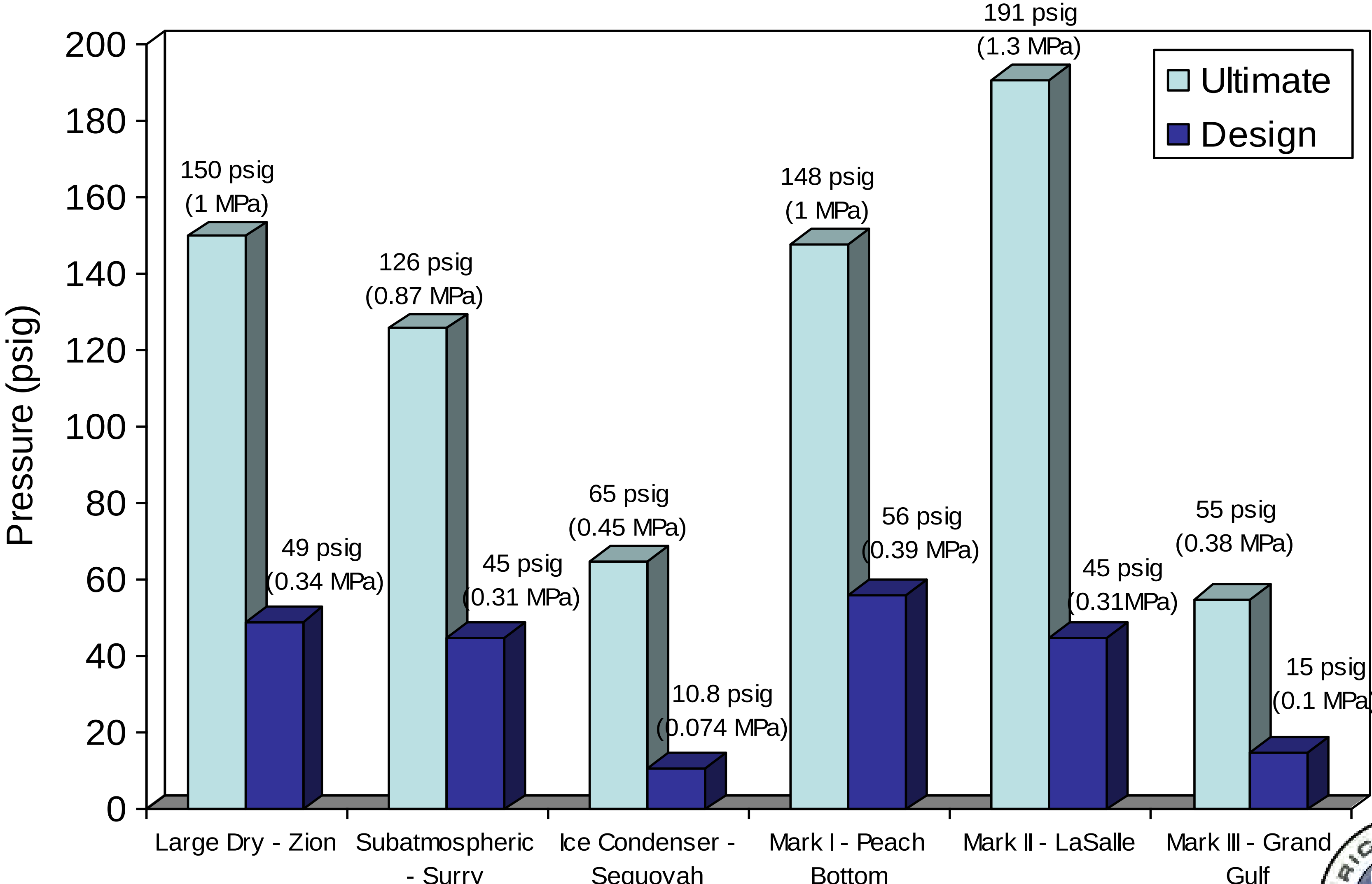
Generations of BWR Containments



Range of Containment Design Pressures



Containment Failure Pressures



Roadmap towards Settling the Situation of Fukushima Dai-ichi Accident

	Step1 Around 3 Months	Step 2 Around 3 to 6 Months (after achieving step 1)
Target	Radiation Dose in Steady Decline	Controlling Release of Radioactive Materials (significant reduction of dose level)
Reactors	Stable Cooling (flooding up to top of active fuel)	Achieving Cold Shutdown
Spent Fuel Pools	Stable Cooling	More Stable Cooling (keeping sufficient level of water by remote-control)
Contaminated Water	Prevention of Outflow to the outside of the Site	Decreasing Contaminated Water (decontamination and desalt)
Contaminated Atmosphere/Soil	Prevention of Spread	Covering Up the Entire Reactor Building (as temporary measure)

April 17, TEPCO

Center for Biosecurity of UPMC

Rad Resilient City

A Preparedness Checklist for Cities to Diminish Lives Lost from Radiation after a Nuclear Terrorist Attack

Monica Schoch-Spana, Sr. Associate

Purpose

Provide cities and their neighbors with a checklist of preparedness actions that could save tens of thousands of lives or more following a nuclear detonation, through adequate protection against radioactive fallout.

Briefing overview

- Why is the Checklist needed?
- What knowledge grounds the Checklist?
- What myths does the Checklist dispel?
- What actions does the Checklist recommend?
- What tools make the Checklist doable?
- How does the Checklist benefit communities?
- How has the Checklist been received?

"Two decades after the end of the Cold War, we face a cruel irony of history – the risk of a nuclear confrontation between nations has gone down, but the risk of nuclear attack has gone up."

- President Obama, Opening Plenary Session of the Nuclear Security Summit, April 13, 2010.

" …one of the greatest dangers we continue to face is the toxic mix of rogue nations, terrorist groups and nuclear, chemical, or biological weapons." - Robert Gates, U.S. Secretary of Defense, January 27, 2009.

"We judge that, if al-Qa'ida develops chemical, biological, radiological, or nuclear (CBRN) capabilities and has operatives trained to use them, it will do so."

- *Annual Threat Assessment of the Intelligence Community for the Senate Armed Services Committee*; Director of National Intelligence, Dennis C. Blair, February 2, 2010.

Nuclear terrorism is a real threat.

- The raw materials exist
  - 9 countries are judged to have nuclear weapons
  - The global stockpile of fissile materials is enough to make more than 120,000 crude nuclear devices
- The technology is readily available
  - Sufficient public information is available to construct and detonate a 10 kiloton nuclear weapon
- There is motivation to make nuclear weapons
  - Known terrorist groups have expressed interest in making nuclear weapons

Why is the checklist needed?

- Most Americans do not know how to protect themselves against fallout exposure
- Local emergency management structures are not well equipped to instill this knowledge
- Cities have no checklist for fallout preparedness despite all the recent guidance

What knowledge grounds the checklist?

NUCLEAR RESILIENCE EXPERT ADVISORY GROUP

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Jessica Wieder, Public Affairs Specialist, Radiation Protection Division, Environmental Protection Agency

- Emerging federal guidance and technical reports on IND response
- Input and professional judgment of Expert Advisory Group
- Research studies on community preparedness
- Select local radiation emergency plans

What myths does the checklist dispel?

- MYTH: Death is certain for all after a detonation.
  - **FACT: Fallout-related casualties can be prevented.**
- MYTH: Fleeing is the way to avoid radiation exposure.
  - **FACT: Quickly sheltering in the right place is best.**
- MYTH: People must wait for responders to help them.
  - **FACT: Informed citizens can protect themselves.**

Checklist for fallout preparedness

- ❑ 1. Obtain broad community backing for nuclear preparedness
- ❑ 2. Conduct pre-event public education on protective behaviors
- ❑ 3. Have building owners/operators rate shelters & teach others
- ❑ 4. Hone ability to deliver public warnings post-incident
- ❑ 5. Establish rapid system for mapping dangerous fallout zone
- ❑ 6. Develop capabilities for a large-scale, phased evacuation
- ❑ 7. Integrate, test, and train on all preparedness elements

ACTION 1—Obtain broad community backing for nuclear preparedness

- Fallout preparedness is a public service no single entity can deliver
- Businesses, schools, nonprofits, and citizens must stand by emergency professionals
- Diverse coalition can overcome reticence to plan for a nuclear detonation

ACTION 2—Conduct pre-event public education on fallout protection

- "No notice" nuclear detonation requires a public capable of acting on its own
- It will be difficult to issue fallout warnings to those who need them the most post-incident
- Key message of sheltering for at least 24 hours resonates with "all hazards" guidance

ACTION 3—Equip building owners & operators with shelter rating guide

- People in U.S. spend about 90% of their time in enclosed buildings
- We can encourage people to learn about the protective attributes of everyday buildings through:
  - Neighborhood associations
  - Commercial building managers
  - Public building operators
  - School facility administrators

ACTION 4—Hone ability to deliver public warnings on fallout post-incident

- Cities need pre-ready mix of "no tech," "low tech," and "high tech" ways to deliver warnings
- Advance scripting of messages about protective actions saves time and lives
- Deciding "who" should say "what" after the fact will cost lives

ACTION 5—Build rapid system for mapping dangerous fallout zone

- Knowing the fallout "footprint" refines guidance on who to evacuate, when, and by which route
- Mapping and communicating where fallout *isn't* is just as important

ACTION 6—Develop supports for large-scale, phased evacuation

- People eventually need to move from a protective shelter to a place of greater safety
- Advance plans on how to decide who goes first and where are complex, though essential

ACTION 7—Integrate, test, & train on all fallout preparedness elements

- Training and practicing will enhance performance when it really matters
- Linkages are necessary among the technical, organizational, social, and human elements

TOP PRIORITY—Informed residents who seek shelter swiftly and independently

- Mass education campaign with focus on self-sufficiency and sheltering
- Neighborhood-based training and education program to seed grassroots conversations
- Shelter "rating guide" broadly disseminated to private and public building owners/operators

What tools make the checklist doable?

- Phased implementation plan that breaks preparedness into prioritized steps
- Compilation of critical topics for public education campaign on fallout preparedness
- Tips on how to write effective post-detonation fallout warning messages
- Sample fallout warning messages
- “FAQ” on best places in which to shelter

Checklist benefits to communities

- Genuinely comprehensive “all hazards” planning and response efforts that can confront nuclear terrorism
- Spillover effects in planning for other complex disasters (eg, improved public warning protocols)
- Momentum to tackle other response/recovery issues (eg, medical surge; mass sheltering for the displaced)
- Tens of thousands of lives saved in the event of an actual nuclear attack

Reactions to the checklist

- Since Sept 2012, the Checklist has been briefed at 11 major professional gatherings; more to come
- Government officials at all levels, emergency managers, health officials, care providers, and building owners have welcomed the tool
- Enthusiasm for Checklist is motivated by fact that:
  - Trusted NGO is willing to take "political hit" for taboo subject
  - Technical information is translated into action steps
- People desire even more granular, operational guidance as well as public education campaign materials

"You all have done a wonderful job on this project, and as an end user, all I can say is a big and hearty 'thank you'!"

— Special Advisor, Emergency Preparedness and Response
Inova Health System

"I just got my copy of the Preparedness Checklist. Have just skimmed it and it looks like a really useful document. We will make use of it as we move forward. Thank you and your team for taking the time to help us begin to assess the gaps between risk and capability and between reality and generational fears."

— Director, Office of Preparedness and Response
Maryland Department of Health and Mental Hygiene

"What you all are doing is very vital to our nation."

— Director, Disaster Services
American Red Cross Northeast Area

“In *World at Risk*, we expressly recommended the development of ‘a publicly available checklist of actions each level of government should take to prevent or ameliorate the consequences of WMD terrorism. Such a checklist could be used by citizens to hold their governments accountable for action or inaction.’ The Rad Resilient City project has answered this call to action.”

— Senator Bob Graham (D-FL), Chairman
Senator Jim Talent (R-MO), Vice Chairman
Bipartisan WMD Terrorism Research Center;
Congressional Commission on the Prevention of WMD Proliferation and Terrorism

The U.S. Public Health Response to the Fukushima Radiological Emergency: One Agency's Perspective

Charles W. Miller, Robert C. Whitcomb, Jr., Jennifer Buzzell, M. Carol McCurley, Armin Ansari, and CAPT Lynn Evans, USPHS

Radiation Studies Branch
Centers for Disease Control and Prevention

Annual Meeting
National Council on Radiation Protection and Measurements
March 13, 2012

CDC Response Activities During Fukushima Daiichi Nuclear Power Plant Incident

- **Activation of CDC EOC - March 11, 2011**
  - *First time CDC EOC activated for "real world" radiation incident*
  - *Some CDC EOC staff felt this response was more intense than 2009 H1N1 flu response when CDC had leading role*
    - *New players*
    - *Few experienced SMEs*
    - *New terminology*
    - *International incident*
- **Deployment of CDC Staff**
  - *CDC Liaison to National Security Staff, Executive Office of the President, White House*
  - *CDC Liaison to NRC Headquarters*
  - *To Japan - Health Communicator & Strategic National Stockpile Rep.*

CDC Response

- **CDC Concerns**
  - *Citizens of Japan*
  - *US citizens living/working/visiting Japan*
  - *Pacific Islanders*
  - *Residents of continental US*

CDC Response

CDC Activities

- **Public protective action guidance**
  - *Potassium Iodide*
  - *Passenger screening*
  - *Cargo screening*
  - *Air, water and food contamination*
- **Public communications materials**
- **Coordination with Partners**
  - *HHS*
  - *White House*
  - *Advisory Team*
  - *NRC*
  - *EPA*
  - *Tokyo Embassy*
  - *WHO*
  - *NARR*
  - *CRCPD*
  - *ASTHO*
  - *NACCHO*
  - *CSTE*
  - *APHL*
  - *Others*

After Action Reports Being Prepared

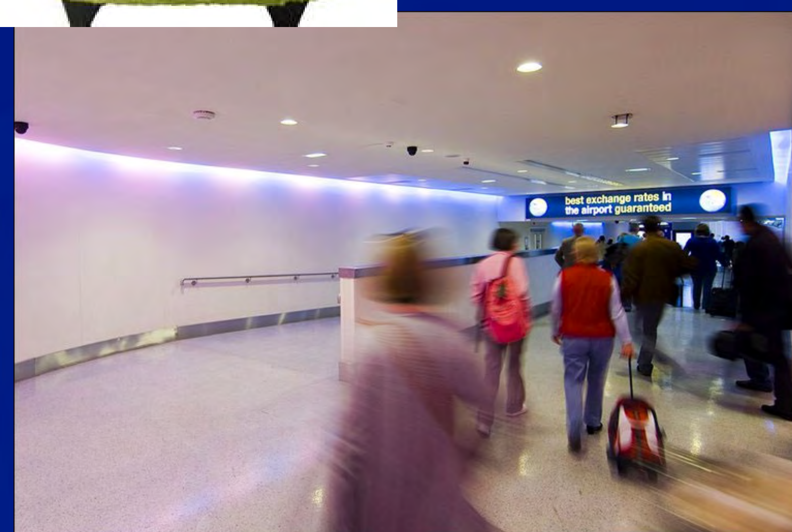
- State, local, and federal agencies identifying challenges they faced during response
- Federal reports being forwarded to the White House
- CDC participated in this process

BRIDGING THE GAPS:
Public Health and Radiological Emergency Preparedness

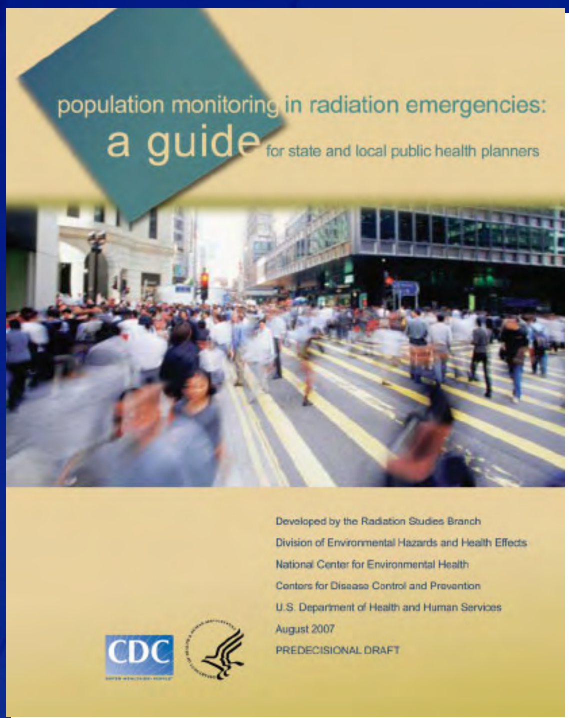
- **March 21 – 24, 2011, Atlanta, Georgia**
- **Public health, clinician, and emergency response workforce**
- **State, local, federal**
- **National Alliance for Radiation Readiness**
- **Fukushima dialogue initiated**

Radionuclide Transport into the U.S.

- Atmospheric Transport
- Cargo ships
- Passenger luggage
- Airline passengers



Monitoring of People is a State and Local Responsibility



www.emergency.cdc.gov/radiation

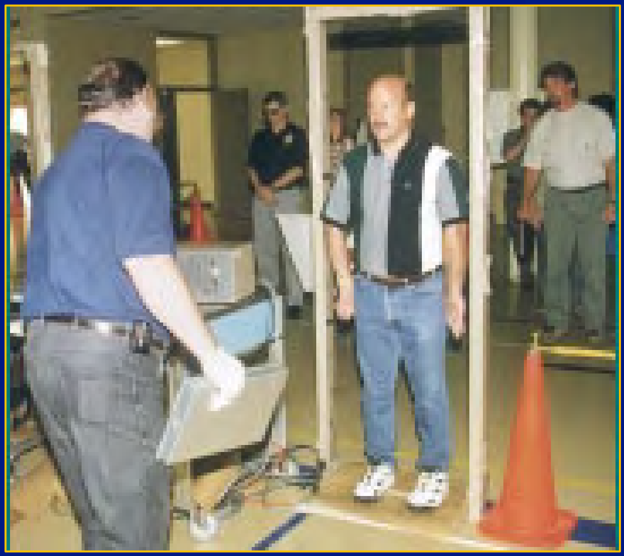
- **Customs & Border Protection screened incoming passengers and cargo**
- **CDC, state, and local public health officials developed protocol for further monitoring**

http://www.bt.cdc.gov/radiation/pdf/Japan-CDCRevisedRecommendationtoRadiationControlHealthPhysicsStaff4_13_2011.pdf

- **Some contaminated passengers were found**

Challenges Identified for Passenger Screening

- Unexpected role for all parties involved
- Shortage of personnel to implement detailed monitoring
- No authority to quarantine contaminated passengers

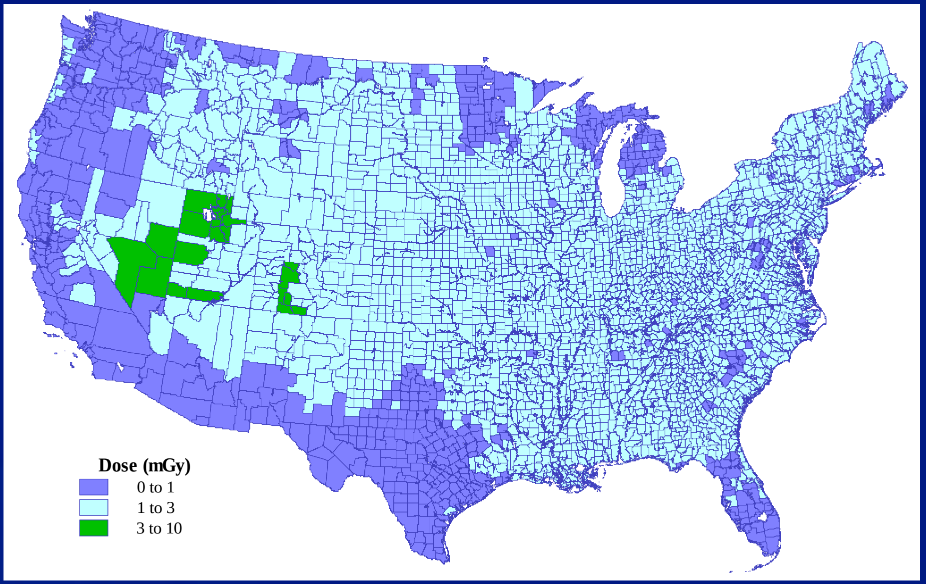


Medical Follow up

- *No* medical follow up was required for airline passengers
- The US healthcare system would have been tested if extensive internal contamination had been found
- The US healthcare system needs to become more robust for radiological emergencies

Subject Matter Experts in Environmental Transport & Dosimetry

- Extensive studies of radionuclide fallout have been performed
- No new activities have been undertaken recently
- Budget cuts have resulted in environmental dosimetry programs being cut at all levels of government



An estimate of the total external dose from Nevada Test Site and global fallout for all radionuclides
- Miller et al. 2001

The Advisory Team for Environment, Food, and Health (A-Team)

The goal of the A-Team is to provide coordinated advice and recommendations to the State, Coordinating Agency, and DHS concerning environmental, food, and health matters.

Membership is comprised principally of :

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

USDA

CDC
SAFER • HEALTHIER • PEOPLE™

FDA

and other Federal agencies as needed

A Team Activated During Fukushima Response

- Maintained a telephone bridgeline with regular meetings
- Members often did double duty, e.g. agency EOC
- Not enough personnel to establish an A Team at the US embassy in Tokyo

The Shortage of Subject Matter Experts is Widespread

- All state, local, and federal agencies are short-handed
- Few new jobs in environmental dosimetry
- Agencies used contractors in the Fukushima response
- Many experienced personnel are nearing retirement
- Who will respond the next time?

Communications Challenges

- No national spokesperson
- Public health messaging was not prioritized
- Initially, federal government experts could only speak “off the record”
- Communication between federal agencies and their state and local partners was initially limited

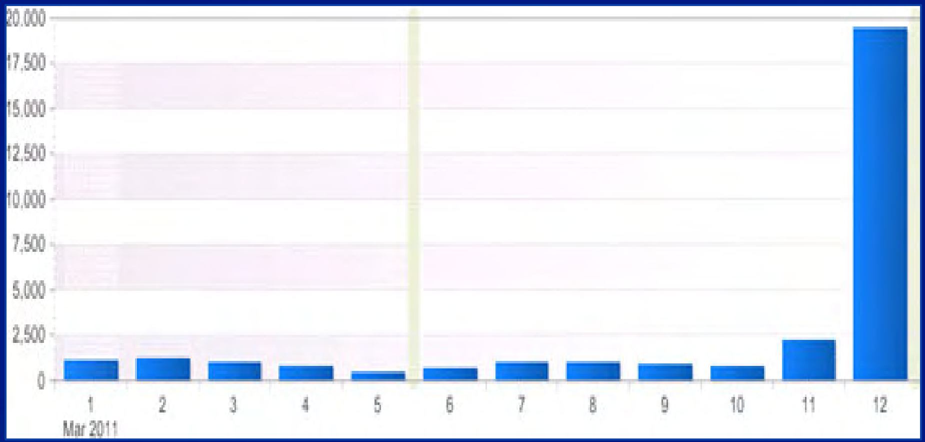
These Problems are not Insurmountable

- Communications on radiation issues will always be a challenge
- Many members of the public believe that LNT is a fact, not a hypothesis
- Public health messaging must be a priority for any incident involving radioactive materials
- Federal agencies must keep their state and local partners fully informed, even for international incidents

Methods of Communication are Changing

Fukushima was a "wired" event

- The internet was a major source of "information"
  - Views of CDC's radiation emergencies website jumped to almost 20,000 on March 12
  - Many from Japan
- Social media heavily used
- "What is a radio?"



Units of Radiation Measurement

- Radiation data reaching the U.S. from Japan were in S.I. units
- Since S.I. units are not widely used in the U.S., these data had to be "translated" into the traditional units for communications and decision making purposes
- Such works is time-consuming, and it introduces the potential for numerical errors
- "After 1989 it is recommended that SI units be used exclusively."

  \- NCRP Report No. 82 (1985)

Protective Action Guides (PAGs)

- The EPA has developed early-phase PAGs for use in the U.S.
  - *A PAG is "the* **projected** *radiation dose to reference man, or other defined individual, from an accidental release of radioactive material at which a specific protective action to reduce or avoid that dose is warranted."*
- FDA has developed similar guidance for interdiction of foods
- Other nations and international organizations have also developed PAGs, some using a direct measurement approach
- There is often a lack of harmony between U.S. and international PAGs

Drinking Water

- When ^{131}I was measured in some samples of potential drinking water in Tokyo, Japan applied PAGs of 100 Bq L^{-1} for children and 300 Bq L^{-1} for adults
- The US embassy asked if the US agreed with these PAGs
- The problem: the U.S. has no PAG for drinking water
- An ad-hoc analysis determined that the U.S. did not disagree with the PAGs being used by the Japanese government
- Harmonization of PAGs would facilitate communication and decision making in future radiological incidents

Access to Radiation Data was Initially Limited

- For domestic events, the Federal Radiological Monitoring and Assessment Center collates monitoring data and makes it available, e.g. to states
- Who owns data gathered to support an international event?
- State, local, and tribal public health officials still need information
  - *Projected plume arrival time and locations*
  - *Radionuclides identified in the release*
  - *Monitoring data collected within their juristiction*
  - *Monitoring information for incoming cargo*
- Procedures that ensure the appropriate distribution of these data need to be developed

The Role of Potassium Iodide (KI) in an Emergency

- Potentially can help protect the thyroid gland from radioiodine exposure
- KI a supplement to the primary protecive actions of evacuation, shelter-in-place, and food interdiction
- Significant logistical problems with distribution
- Over the counter supplies of KI exhausted along the west coast of the U.S. during Fukushima although CDC recommended that KI *not* be taken
- The supply of KI in the Strategic National Stockpile (SNS) is limited
- HHS considering additional KI for SNS to provide strategic flexibility

Conclusions

- Fukushima was a trajedy for the people of Japan
- It was a public health emergency for the U.S.
- The U.S. public health community did many things well
- We should learn from the challenges identified
- Failure to learn could severely impact our next response to a radiological emergency

U.S. DOE/NNSA Response to the Fukushima Dai-ichi Nuclear Power Plant Emergency

Joseph J. Krol, Jr.
DOE/NNSA

National Nuclear Security Administration

Source: Nuclear and Industrial Safety Agency (NISA)

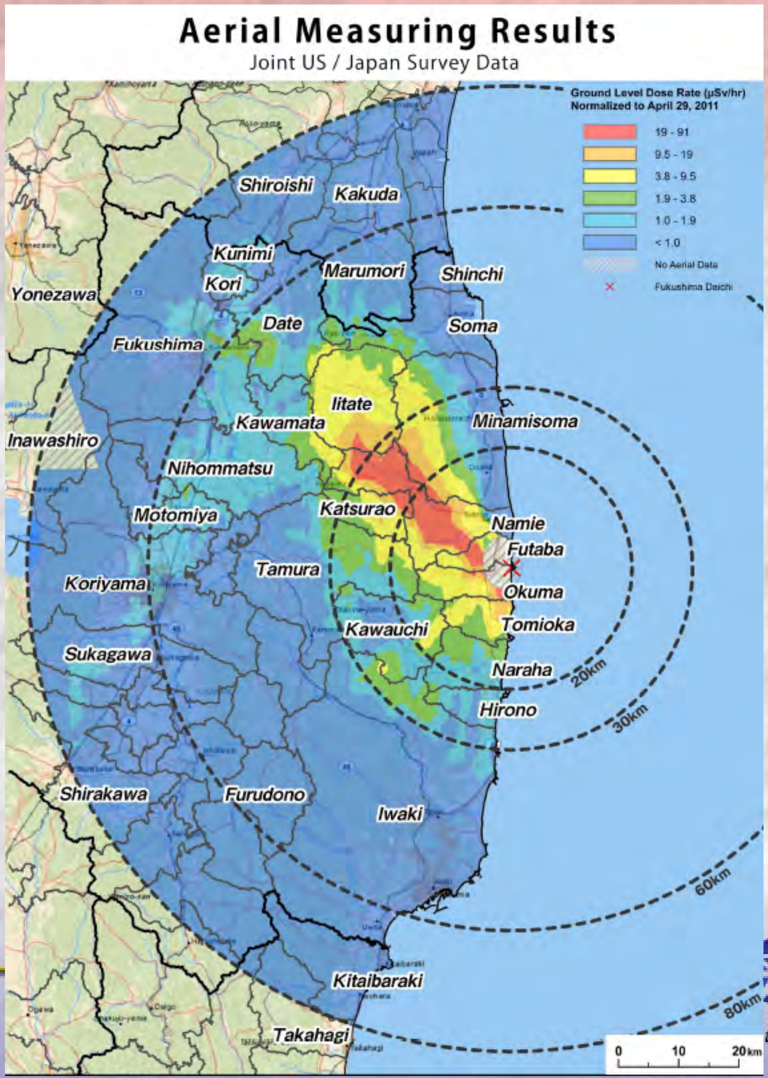
Fukushima Dai-ichi NPP

Fukushima Dai-ni NPP

- Occurred 14:46 March 11, 2011
- Magnitude:9.0 Mw
- Epicenter location: 38° 6''N and 142° 51''E, and 24km in depth
- It is said that the height of tsunami attacked Fukushima NPP was more than 14m

Source: Nuclear and Industrial Safety Agency (NISA)

Fukushima Dai-ichi Damage & Deposition (DOE AMS Perspective)



Partners

United States

- Department of State
  - American Embassy
- Department of Defense
  - US Forces Japan (USFJ)
- Department of Energy (DOE)
- National Nuclear Security Administration (NNSA)
  - All consequence management assets
  - And then some
- Nuclear Regulatory Commission
- Advisory Team for Environment , Food and Health

Japan

- Japan Atomic Energy Agency (JAEA)
- Nuclear Safety Commission
- Ministry of Defense (MOD)
- Ministry of Economy, Trade and Industry (METI)
  - Nuclear and Industrial Safety Agency (NISA)
- Ministry of Education, Culture, Sports, Science & Technology (MEXT)
  - Nuclear Safety Technology Center (NUSTEC)
- Ministry of Agriculture, Forestry and Fisheries (MAFF)
- Ministry of Health, Labour & Welfare (MLHW)

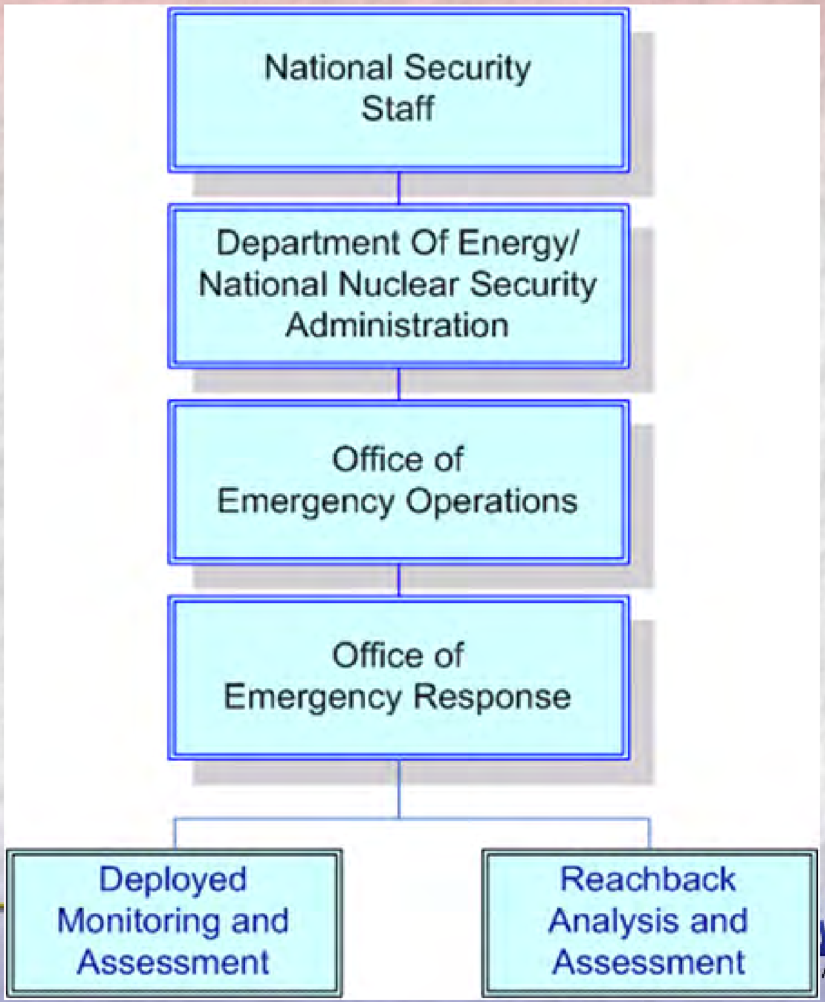
DOE/NNSA provided surge capacity

ar Security Administration

DOE Support to Operation Tomodachi

<u>Mission</u>:

Assess the consequences of releases from the Fukushima Dai-ichi Nuclear Power Plant (FDNPP)



DOE Timeline

- March 11:
  - DOE/NNSA activated its assets
- March 14, 2011
  - At White House direction, DOE deployed a tailored CMRT and AMS capability via military airlift to Yokota Air Base

DOE Timeline (cont'd)

- March 16: CM Assets arrive at Yokota AB and fly first AMS Test flight
- March 17: First aerial measurement activities over plant conducted; first field monitoring mission completed
- March 22: Initial data published on DOE website

DOE's home at Yokota AB

Distribution of Responsibilities

- Field
  - monitoring and sampling
  - preliminary data assessment
  - product development
- CMHT
  - detailed assessment
  - coordination of sample analysis
  - predictive modeling
  - response to requests for information/assistance
- NIT
  - initial command and control of deploying assets
  - coordination and communication for field assets and headquarters elements
- Embassy
  - assessment interpretation for Ambassador
  - coordination of bilateral monitoring and assessment activities

National Nuclear Security Administration

Field Team

Attributes

- **Experienced** : operate in a unique mission space.
- **Interdisciplinary:** address all aspects of mission.
- **Adaptable:** dynamic environment and non-standard measurement platforms.
- **Communicate risk** to partners and decision-makers.

Composition

- Small field footprint with large capability
- 33 personnel to Yokota AB
  - 12 scientists of many disciplines (nuclear, GIS, environmental, 5 PhDs, 2 CHPs)
  - Technicians with a diverse skill set
- 1 DOE HQ liaison to US embassy, Tokyo

National Nuclear Security Administration

Aerial Monitoring

What was done

- Fixed wing and helicopter
- Up to 3 aircraft per day
- DOE & GOJ joint survey

Why it was done

- Map ground deposition out to 80 km from FDNPP
- Support evacuation, relocation, agricultural decisions

Ground Monitoring

What was done

- Mobile mapping
- In-situ & exposure rate
- Air & soil sampling
- Contamination swipes
- DoD & GOJ data aggregation

Why it was done

- Calibrate aerial measurements
- Define isotopic mix
- Characterize the inhalation component of integrated dose
- Assess vertical and horizontal migration of deposited material

Activity to Date

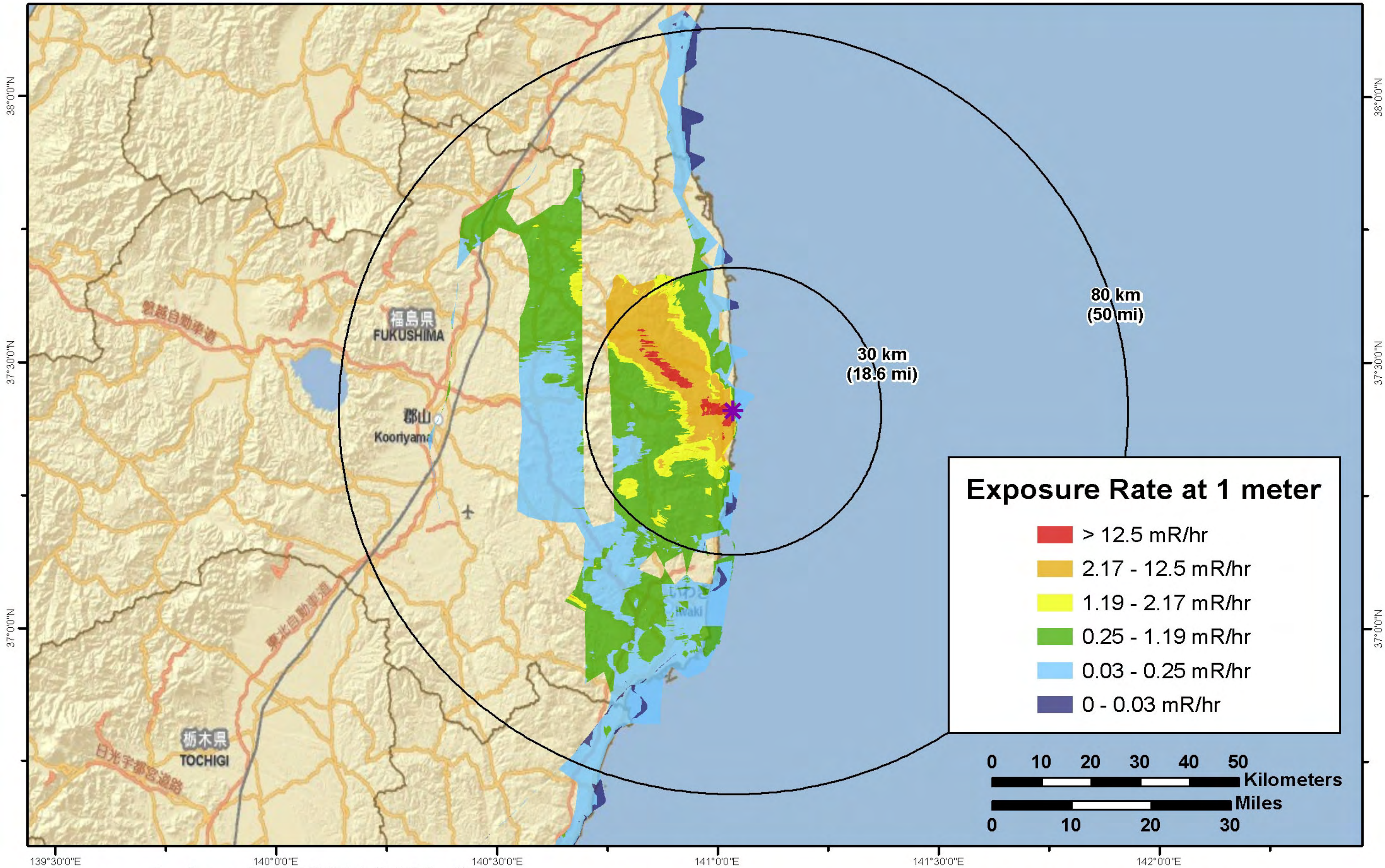
- Daily Aerial Measuring System missions over US installations and in the area around the FDNPS
  - > 85 flights
  - > 500 flight hours
- Daily monitoring activities at the U.S. Embassy, U.S. military installations, and in support of “ground truth” measurements for AMS
  - 620 air samples
  - 117 *in situ* spectra
  - 141 soil samples

National Nuclear Security Administration

Aerial Monitoring Survey Area

Overview of Aerial Monitoring Contoured Results (3/17-03/19 2011)

FUKUSHIMA DAIICHI JAPAN



Map created on 05142011 0200 JST

Name: CMHT ComparisonResults0317_0319 13May2011

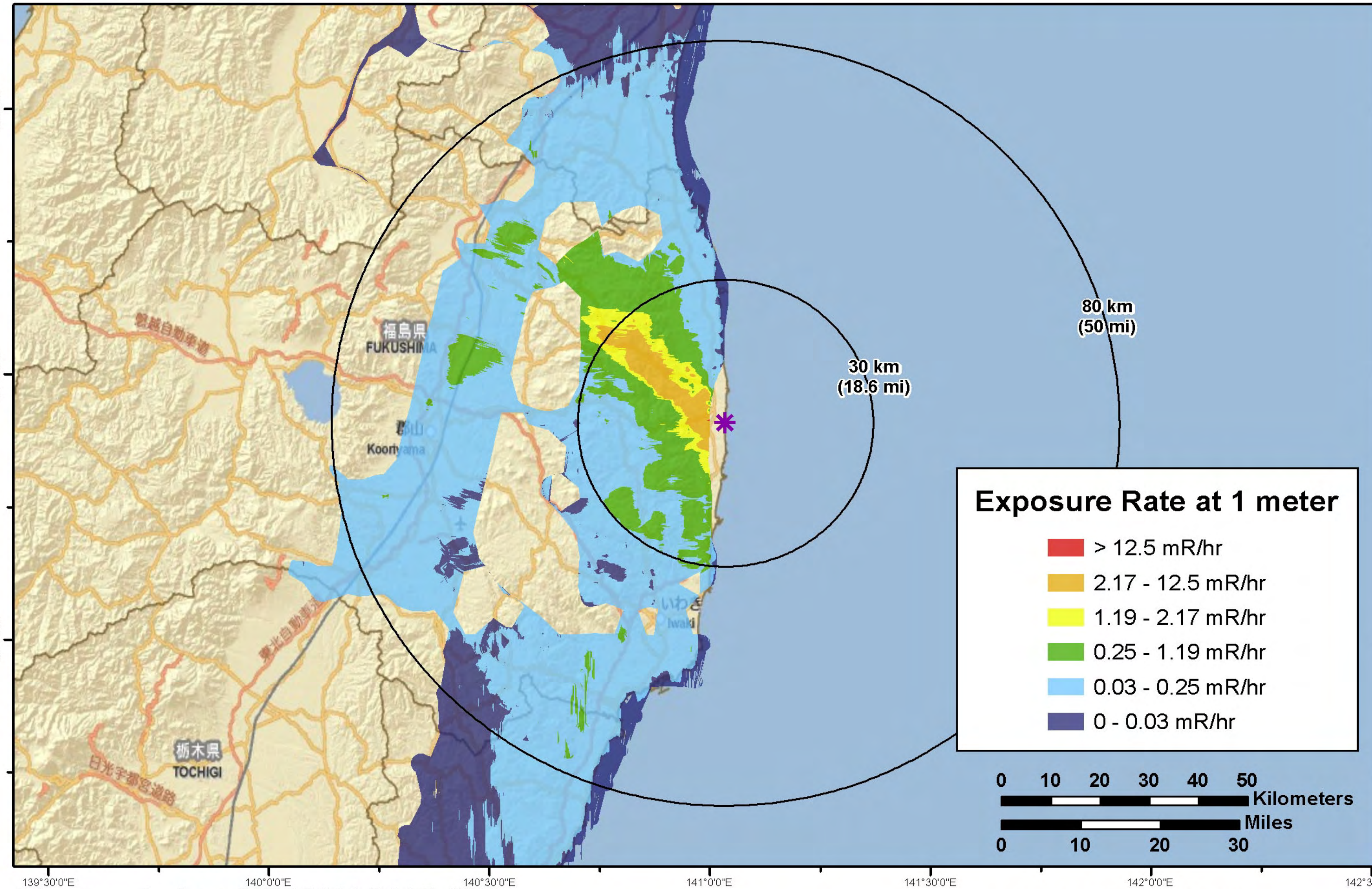
UNCLASSIFIED

Nuclear Incident Team DOE NIT
Contact (202) 586 - 8100

Aerial Monitoring Survey Area

Overview of Aerial Monitoring Contoured Results (3/26-03/28 2011)

FUKUSHIMA DAIICHI
JAPAN



Map created on 05142011 0215 JST

Name: CMHT ComparisonResults0326_0328 13May2011 0100JST

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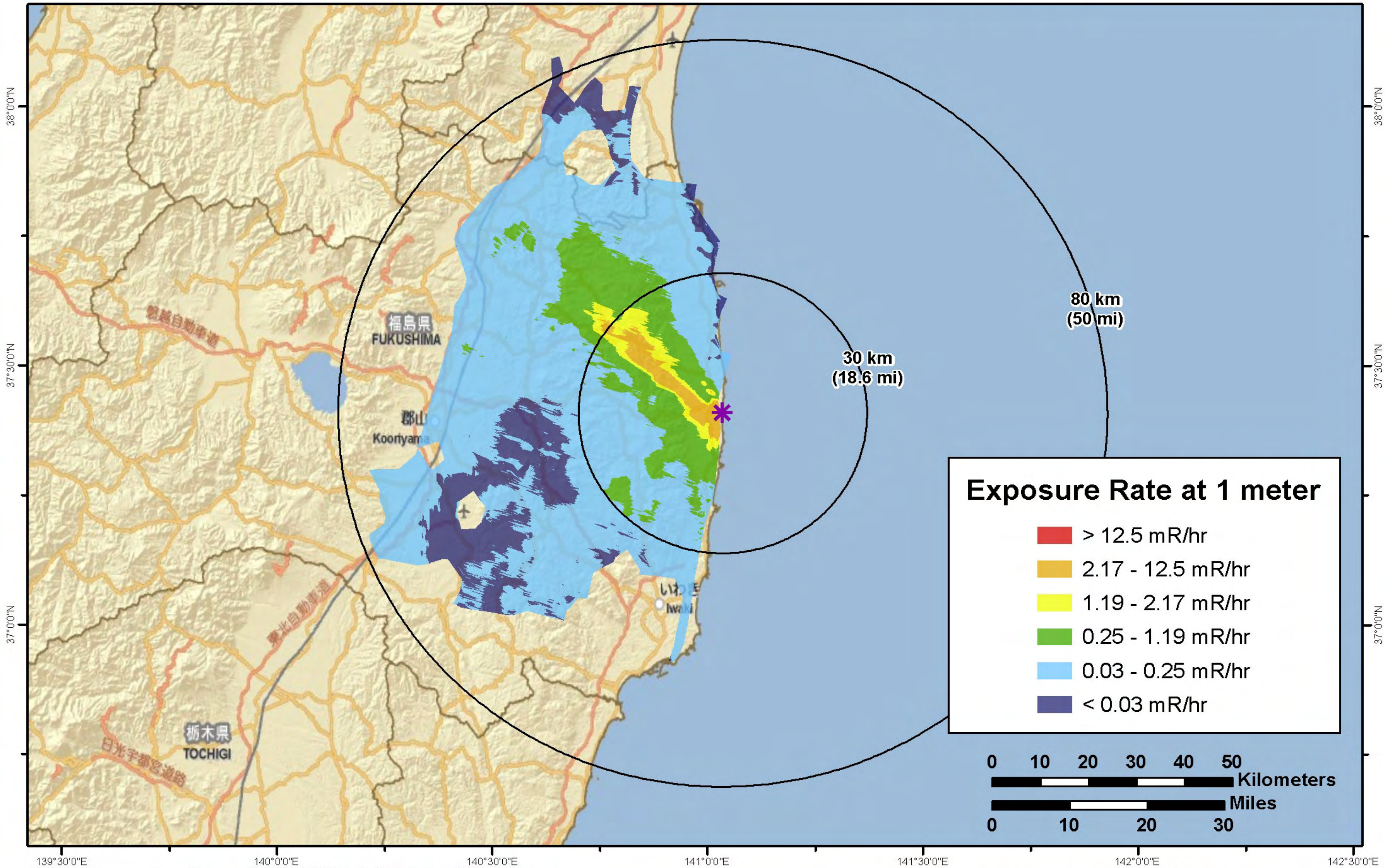
Nuclear Incident Team DOE NIT
Contact (202) 586 - 8100

Aerial Monitoring Survey Area

Overview of Aerial Monitoring Contoured Results (4/02-04/07 2011)

FUKUSHIMA DAIICHI
JAPAN

National Nuclear Security Administration



Map created on 05142011 0219 JST

Name: CMHT ComparisonResults0402_0407 13May2011 0100JST

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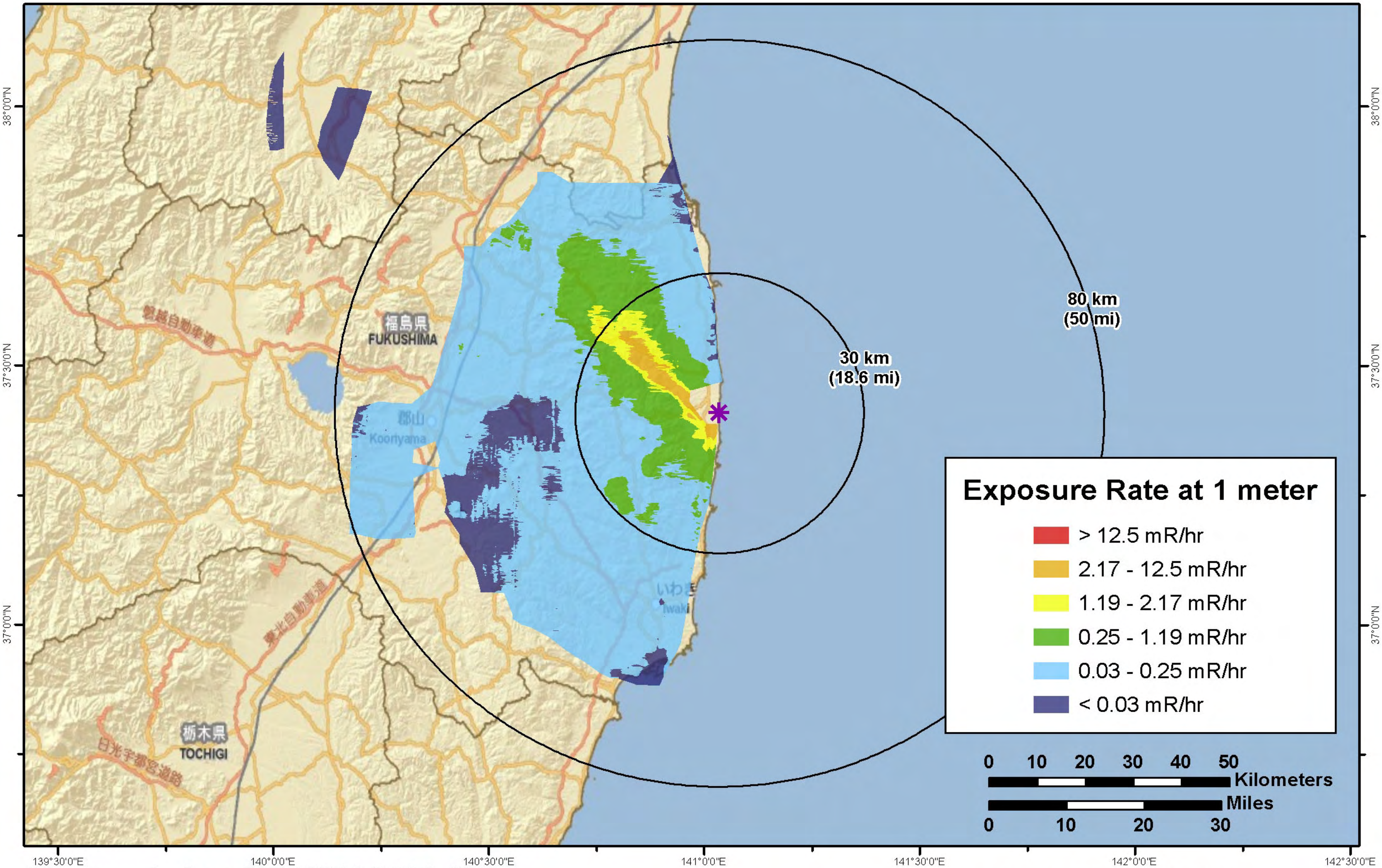
Nuclear Incident Team DOE NIT
Contact (202) 586 - 8100

Aerial Monitoring Survey Area

Overview of Aerial Monitoring Contoured Results (4/06-04/17 2011)

NNSA National Nuclear Security Administration

FUKUSHIMA DAIICHI
JAPAN



Map created on 05142011 0224 JST
Name: CMHT ComparisonResults0406_0417 13May2011 0100JST

UNCLASSIFIED

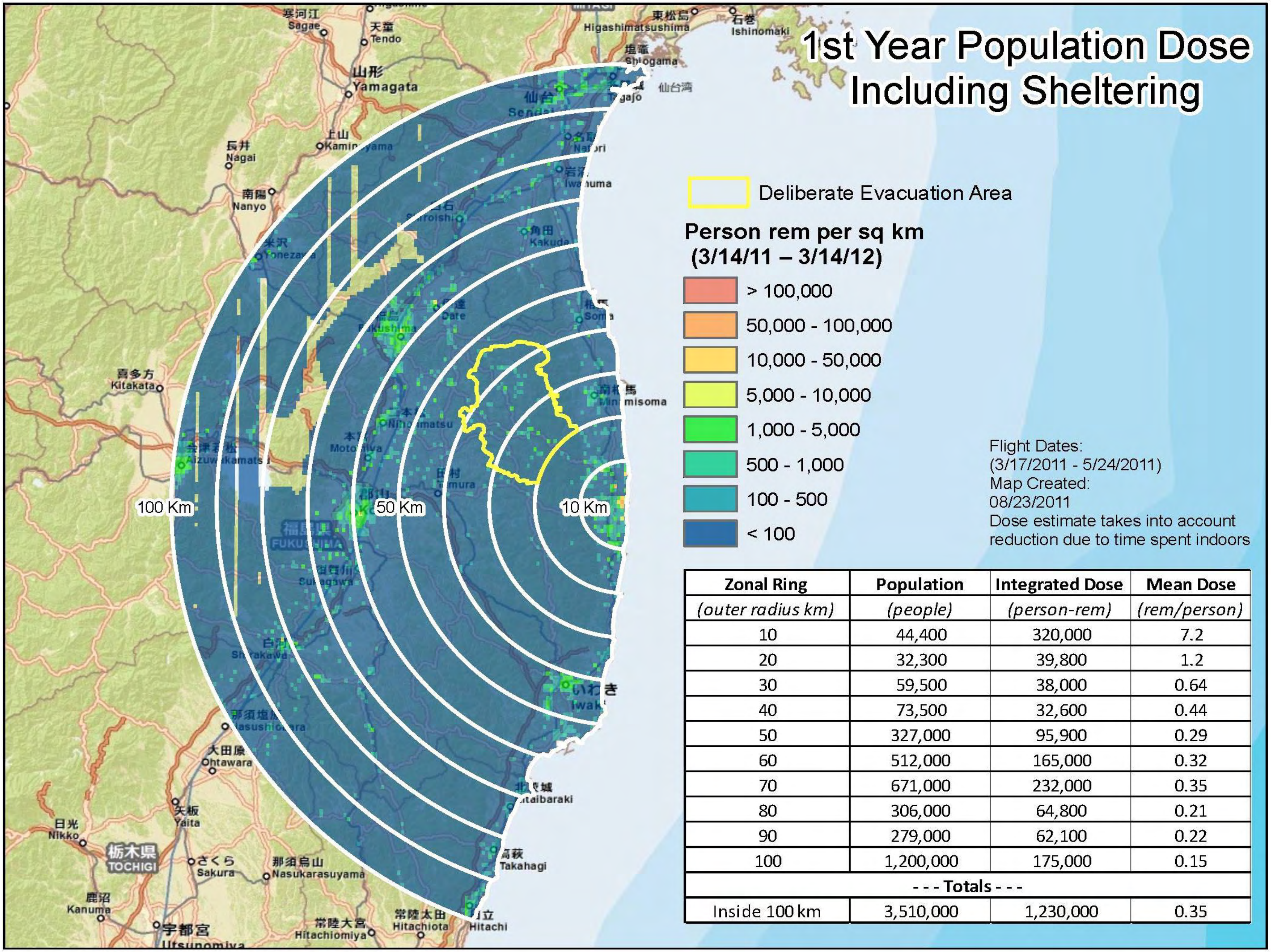
Nuclear Incident Team DOE NIT
Contact (202) 586 - 8100

Field Team Activity Successes

- DOE was able to perform on-the-fly analysis to deal with multiple ongoing releases, unknown source terms, challenging terrain as well as non-technical pressures.
- DOE Scientists developed customized products for U.S. military (data products, InField Monitoring System).
- DOE scientists embedded with Japanese scientists to create joint data products.

National Nuclear Security Administration

1st Year Population Dose Including Sheltering



Zonal Ring *(outer radius km)*	Population *(people)*	Integrated Dose *(person-rem)*	Mean Dose *(rem/person)*
10	44,400	320,000	7.2
20	32,300	39,800	1.2
30	59,500	38,000	0.64
40	73,500	32,600	0.44
50	327,000	95,900	0.29
60	512,000	165,000	0.32
70	671,000	232,000	0.35
80	306,000	64,800	0.21
90	279,000	62,100	0.22
100	1,200,000	175,000	0.15
- - - Totals - - -			
Inside 100 km	3,510,000	1,230,000	0.35

End State

- USFJ and Government of Japan to continue monitoring activities as needed
  - Japanese trained & equipped to fly DOE AMS
  - Japanese equipped with an enhanced laboratory analysis capability
  - USFJ trained & equipped to fly contingency AMS
  - DOE continues to support Japanese and USFJ from Home Team

Resilience following a nuclear catastrophe

National Nuclear Security Administration

Reference Levels in the Context of Fukushima
--- Lessons Learned and Challenge to Radiation Protection System

Kazuo Sakai

National Institute of Radiological Sciences, Japan

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1. Reference Levels
2. Use of Playground of Schools in Fukushima: as an Example
3. Lessons Learned
4. Conclusion

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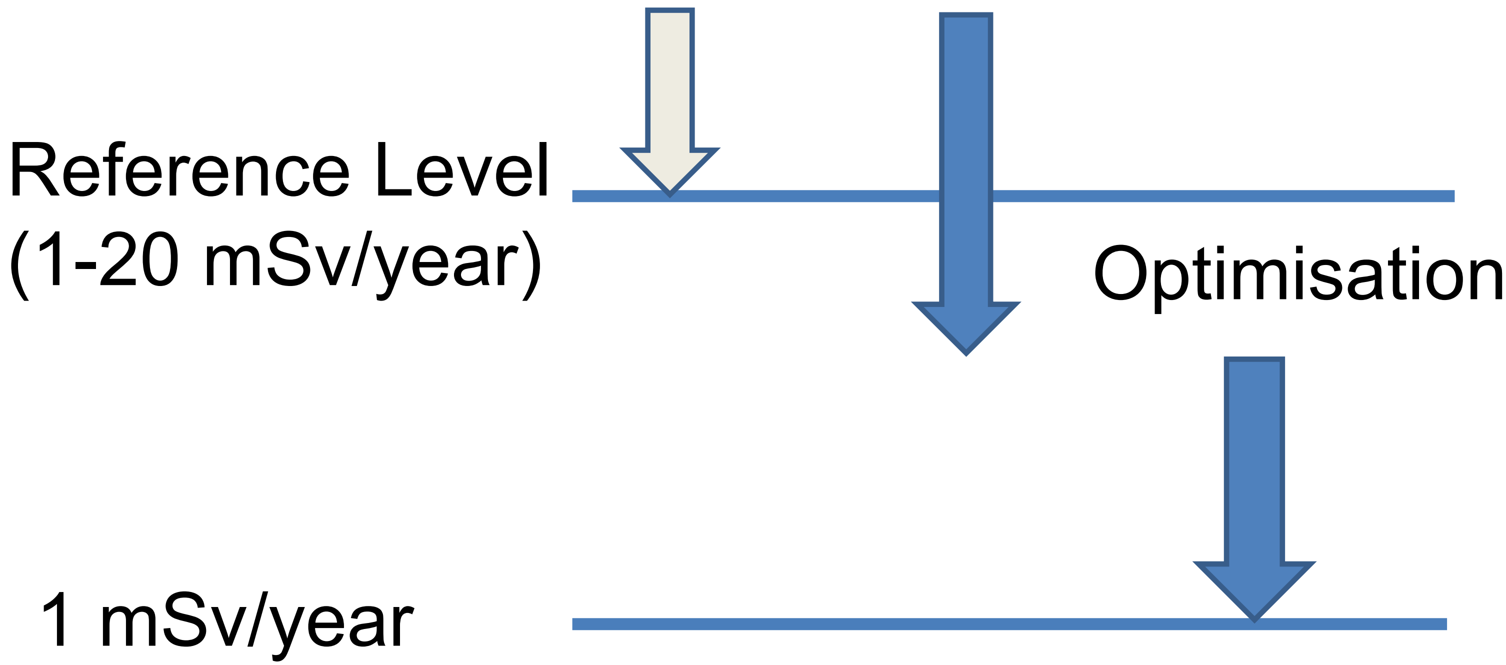
Reference level

In emergency or **existing exposure situations**, this represents **the level of dose, above which it is judged to be inappropriate to plan to allow exposures to occur**, and **below which optimisation of protection should be implemented.**

The chosen value for a reference level will depend upon the prevailing circumstances of the exposure under consideration.

Reference Level for General Public under Existing Exposure Situation



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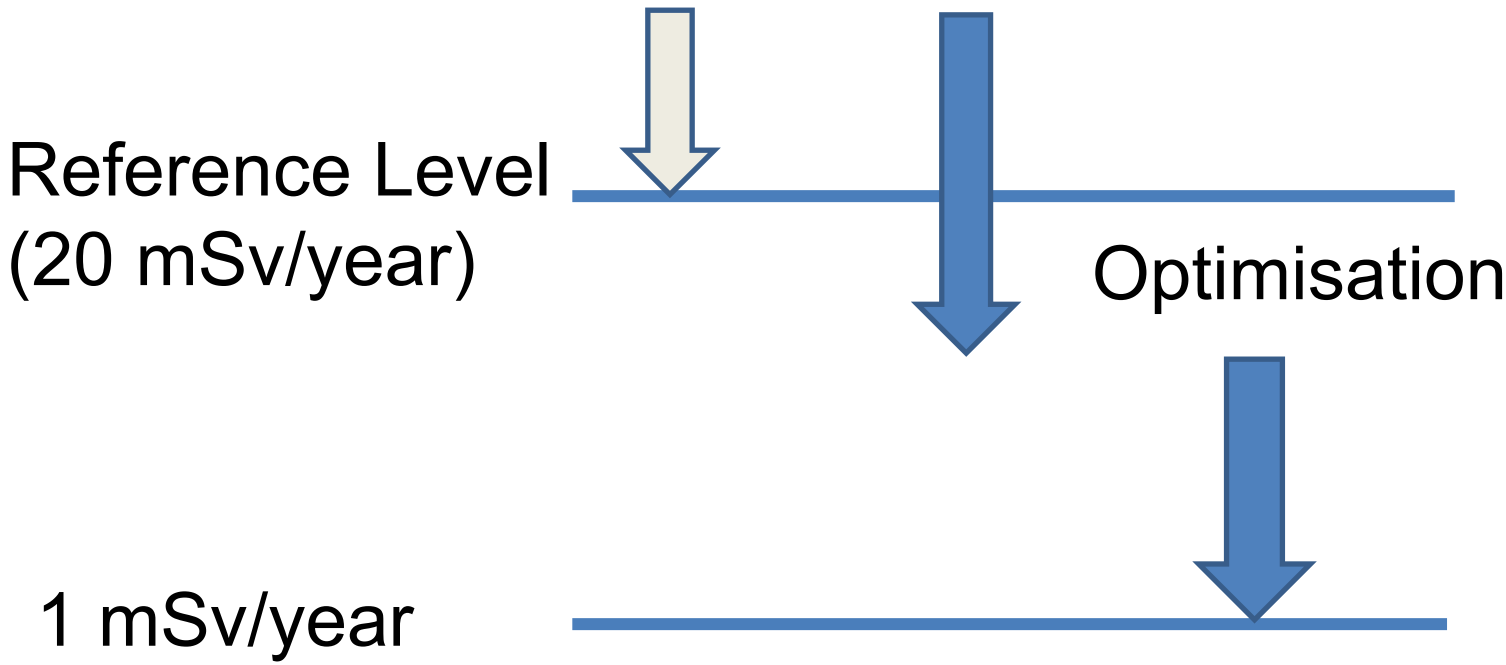
For use of Playground of Schools

- MEXT selected 20mSv/y in the dose band of 1 to 20mSv on Aril 19.
- A level of 20mSv was selected as a starting line for optimization

For use of Playground of Schools

A dose 20 mSv in 1 year time was set as a "start line" to reduce exposure.



Contents

Lessons Learned

- Practical Issues
- Misunderstanding: RP Concepts
- Misunderstanding: Radiation Effects
- Challenge to RP System

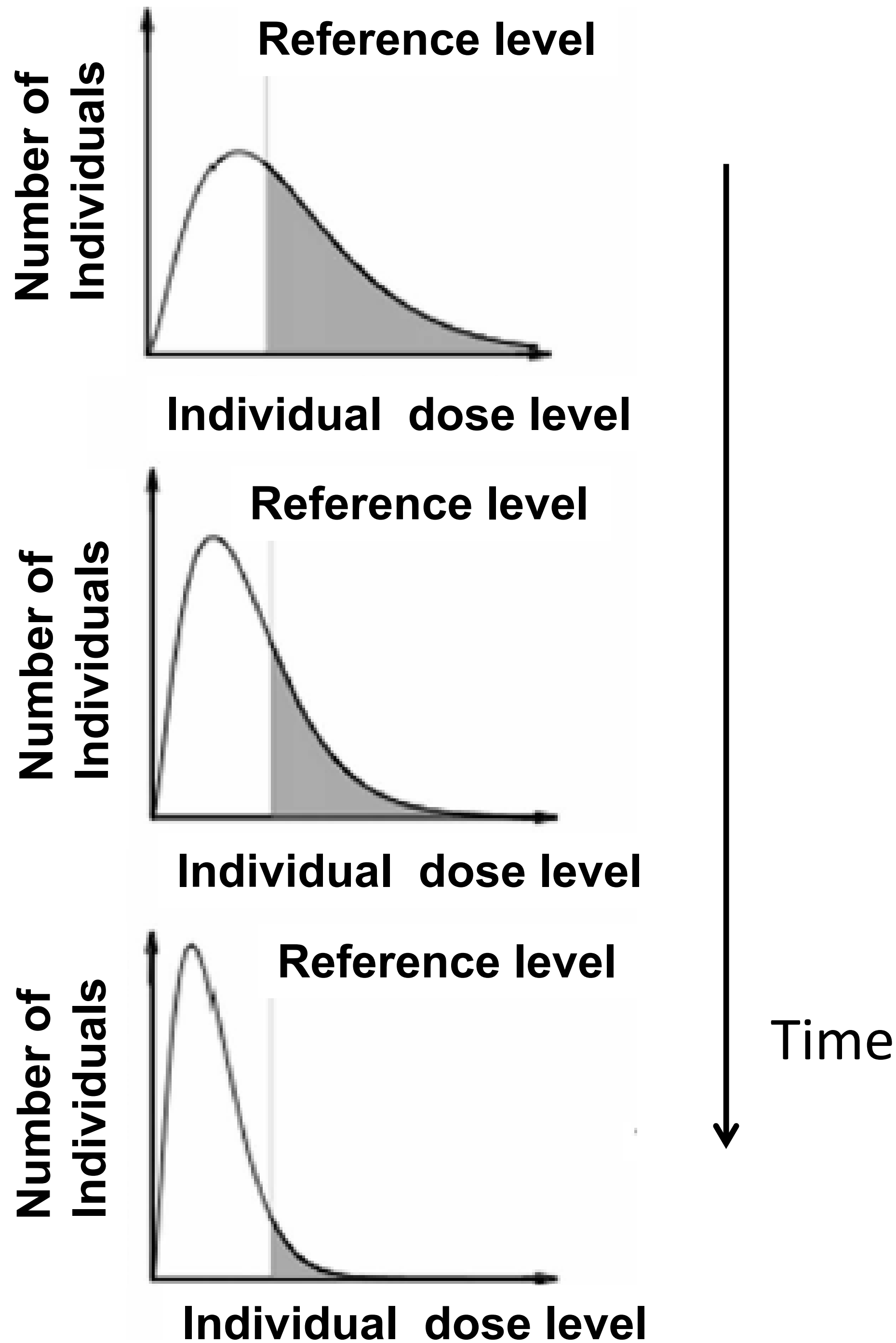
Lessons Learned (1)

Setting a Start Line for Optimization

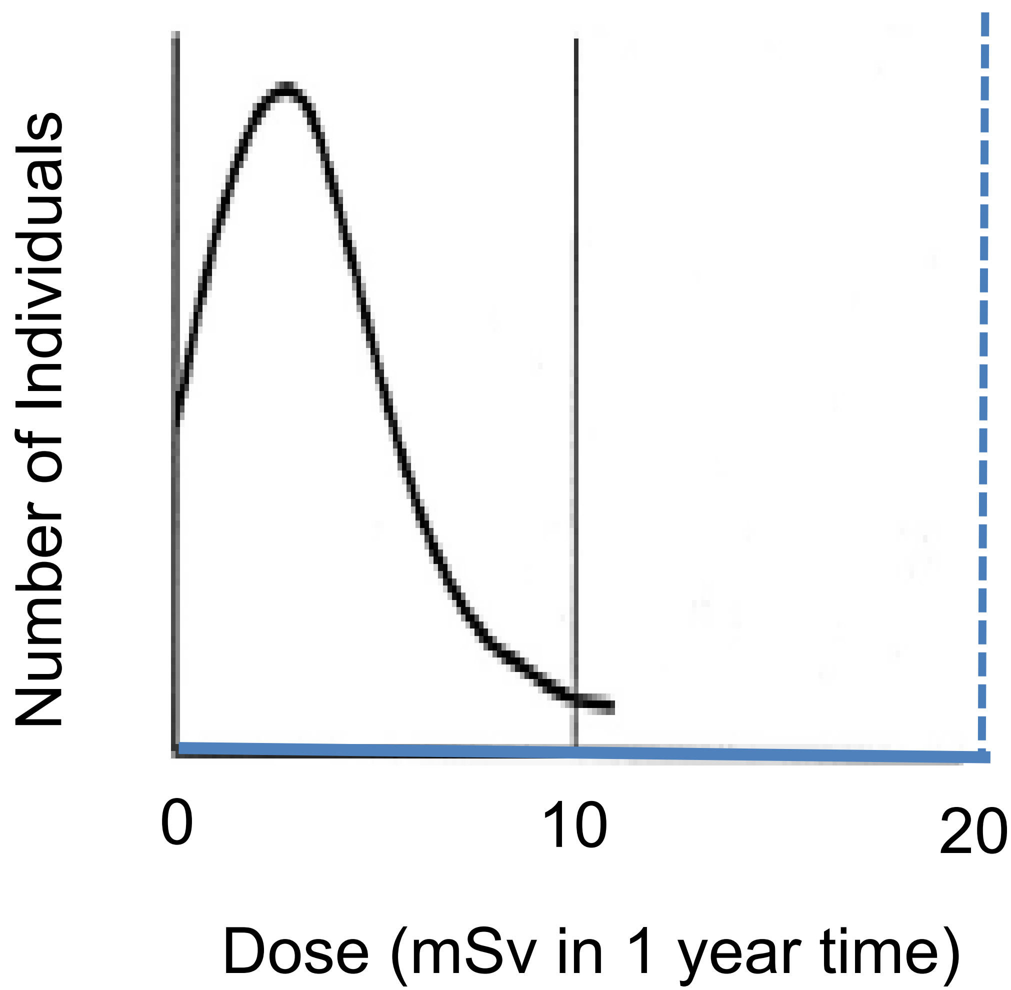
- MEXT, looking at the dose band of 1 to 20 mSv/a, selected a level of 20mSv/a as a start line for optimization on April 19.

- Later in May, based on the measurement of ambient dose rates in schoolhouses as well as playground, actual dose (projected dose for one year time)was estimated around 10 mSv at most.

Reference Level and Optimisation



Based on the measurement of ambient dose rates in schoolhouses as well as playground, actual dose was estimated around 10 mSv/year at most.



Lessons Learned (2) Misunderstanding: RP Concepts

- Any dose more than 1 mSv should be dangerous.

… It must also be realised that neither dose and risk constraints nor reference levels represent a demarcation between 'safe' and 'dangerous' or reflect a step change in the associated health risk for individuals. (Paragraph 228, Publication 103)

Lessones Learned (3) Misunderstanding: RP Concept

- Tens of thousands people shall die due to radiation from the accident.

…the Commission emphasises that whilst the LNT model remains a scientifically plausible element in its practical system of radiological protection.…the Commission judges that it is not appropriate, for the purposes of public health planning, to calculate the hypothetical number of cases of cancer or heritable disease that might be associated with very small radiation doses received by large numbers of people over very long periods of time. (Paragraph 66, Publication 103)

Lessons Learned (4)
Misunderstanding: Radiation Effects

School girls in Fukushima are not able to have a baby in future.

Tissue and Effect	Threshold	
	Total dose received in a single brief exposure (Gy)	Annual dose rate if received yearly in highly fractionated or protracted exposures for many years (Gy y^{-1})
Testes Temporary sterility	0.15	0.4
Permanent sterility	3.5-6.0	2.0
Ovary Sterility	2.5-6.0	>0.2

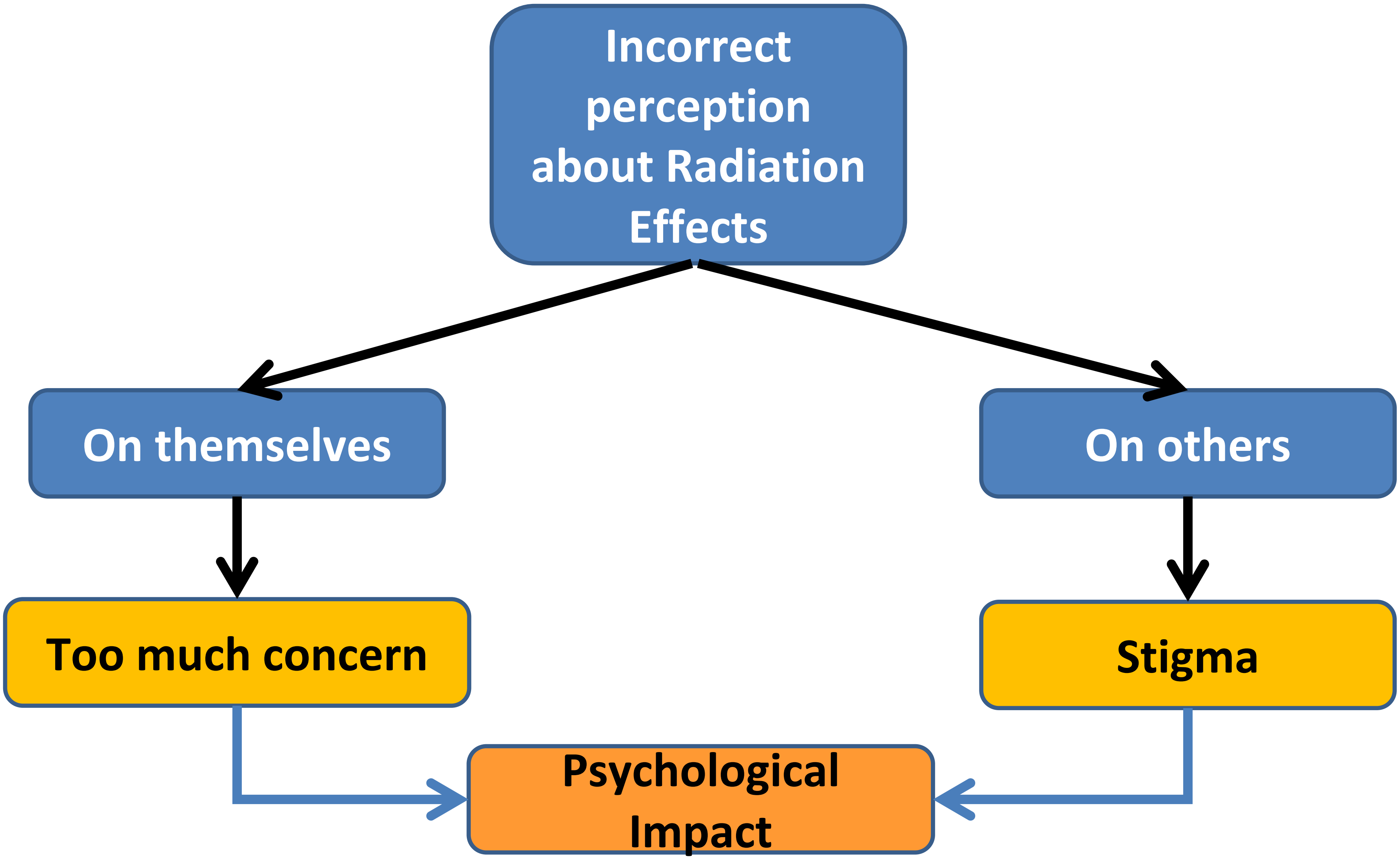
Lessons Learned (5)
Misunderstanding: Radiation Effects

I should terminate my pregnancy.

- Lack of knowledge is responsible for great anxiety and probably unnecessary termination of pregnancies.
- Termination of pregnancy at fetal doses of less than 100 mGy is **NOT** justified based upon radiation risk.

(Publication 84)

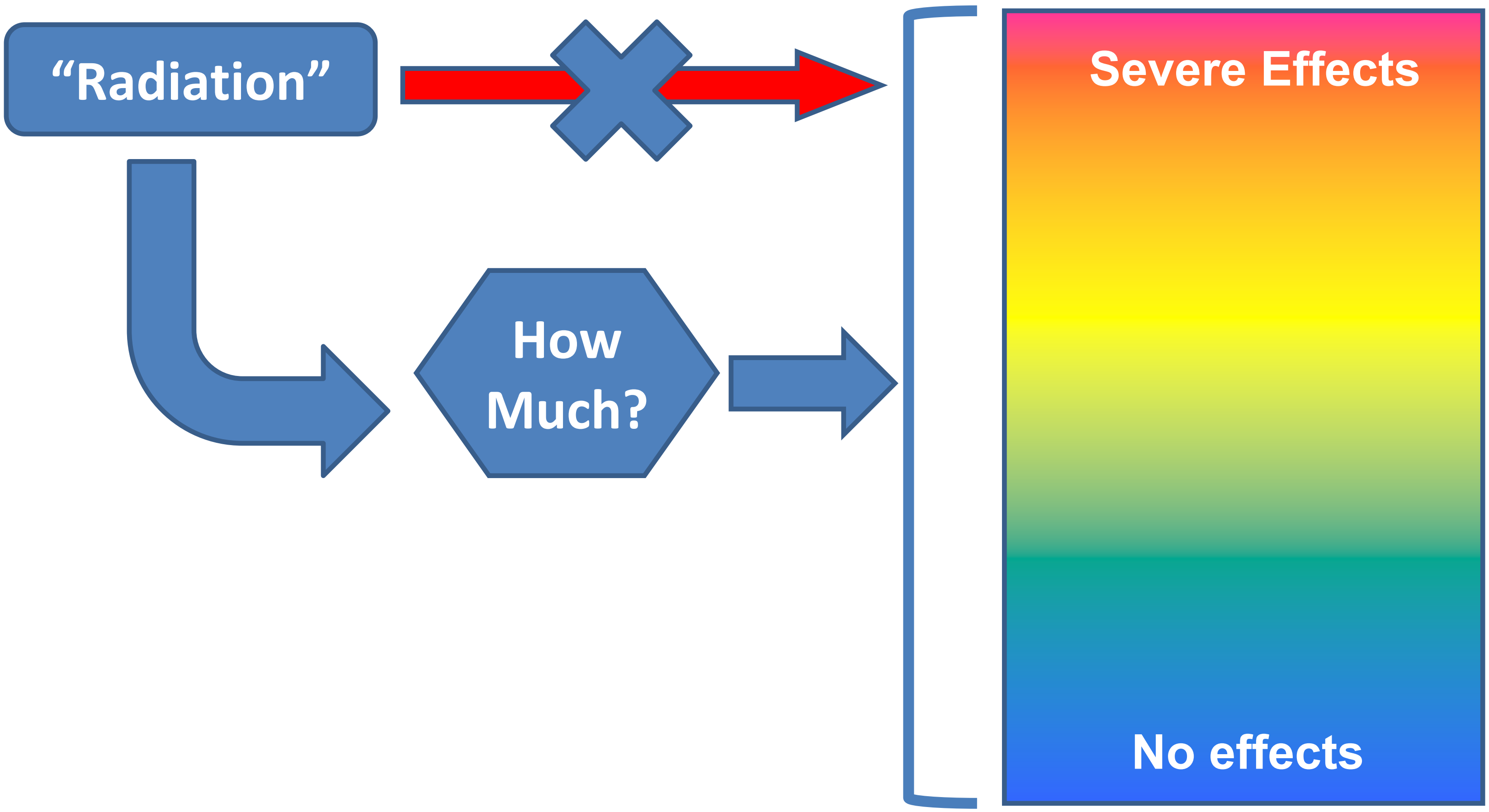
Consequence of Misunderstanding about Radiation Effects



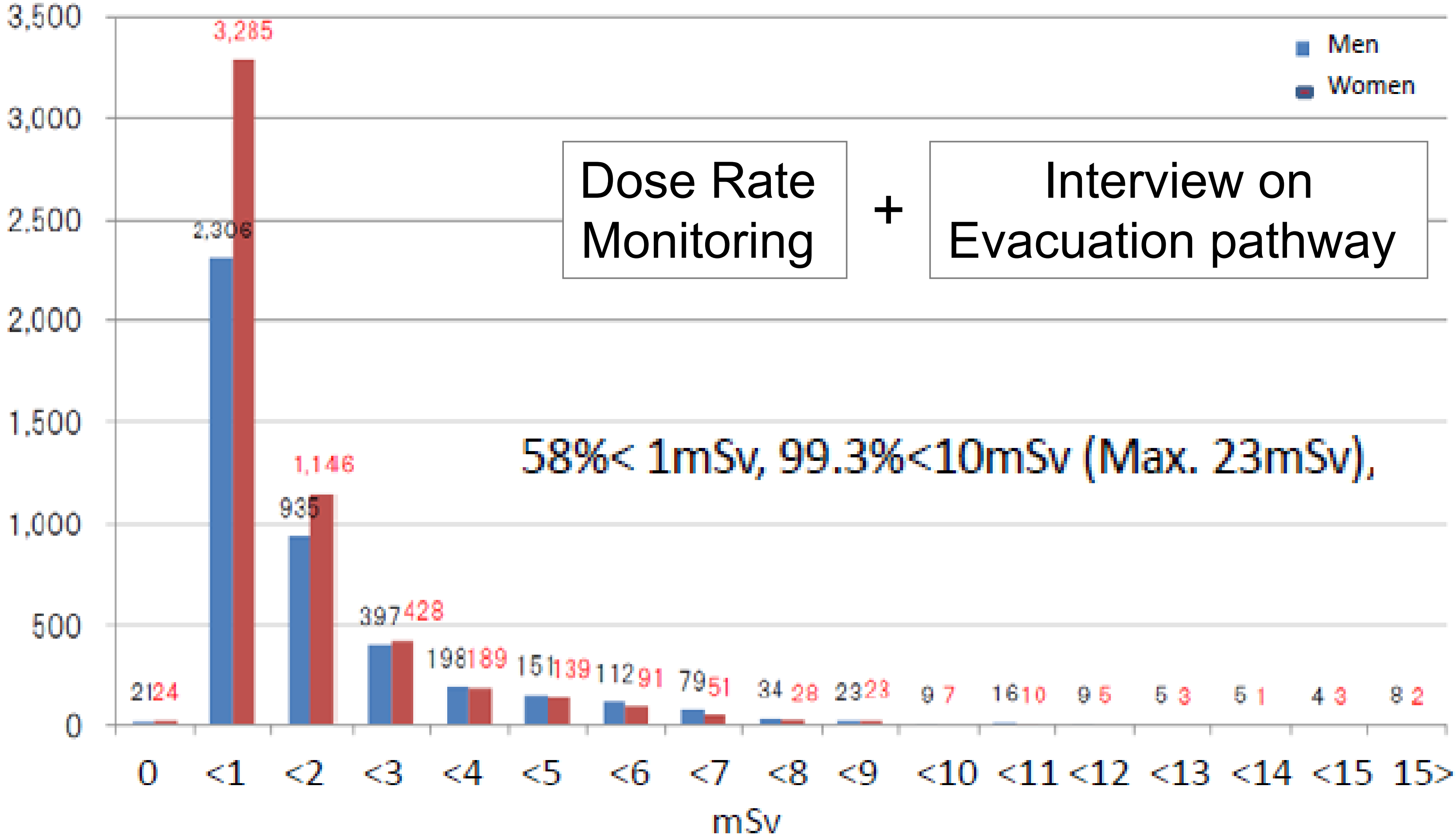
Perception of Radiation among General Public

Direct connection between “Radiation” and “Severe Effects, Cancer, Death”

Shift of Thinking: Need for the Concept of "Dose-Effect Relationship"



External exposure estimation among 9747 evacuees (except for radiation workers)



As of Feb 20, 2012

http://www.pref.fukushima.jp/imu/kenkoukanri/240220siryo.pdf

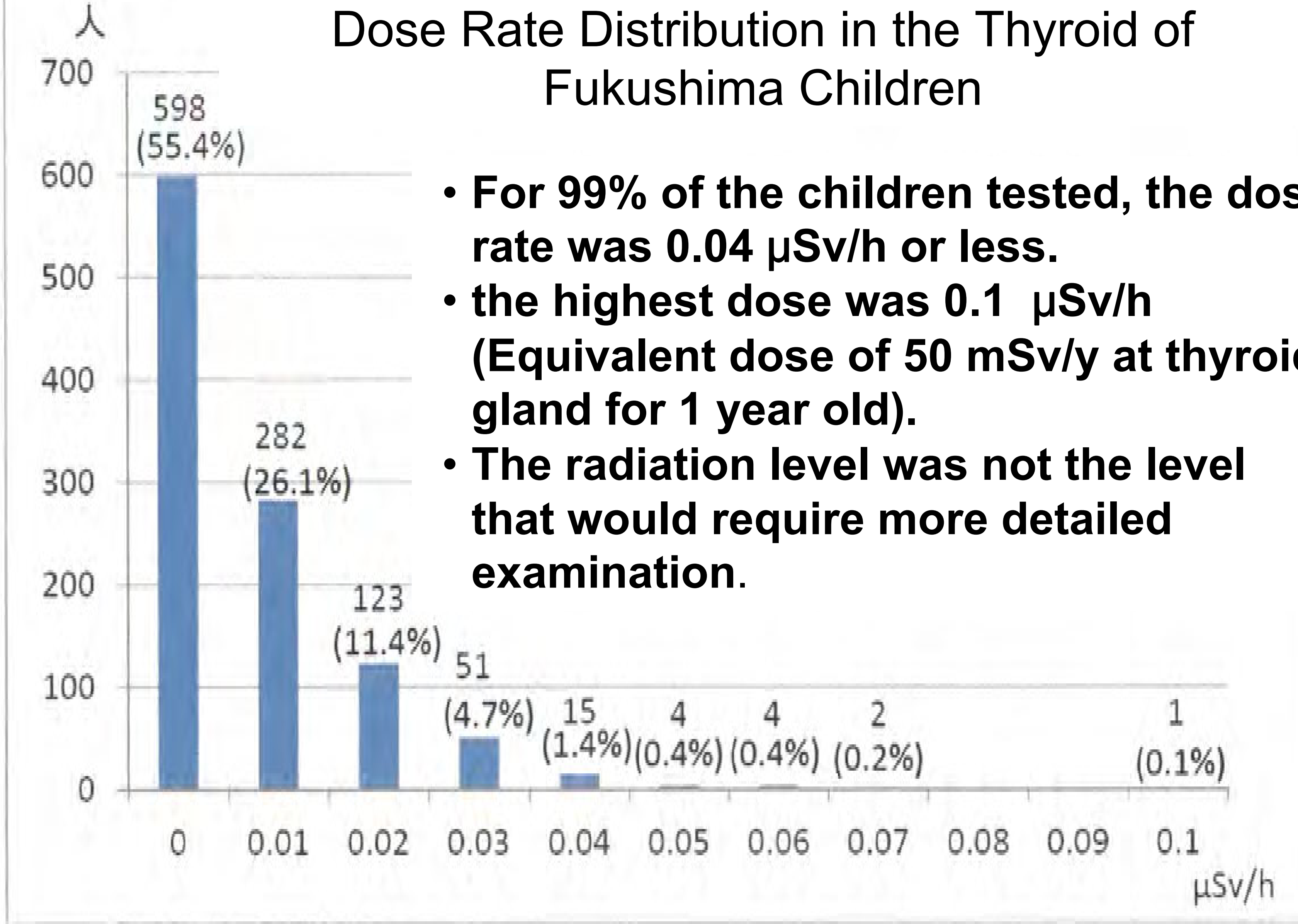
Measurement of Radioactivity in Thyroid in Children.

- The survey was conducted from March 26 to 30 in Iwaki City, Kawamata town, and Iitate village, where the high probability of internal radiation exposure at the thyroid gland was suspected.

- 1,080 children aged zero to 15 were measured.

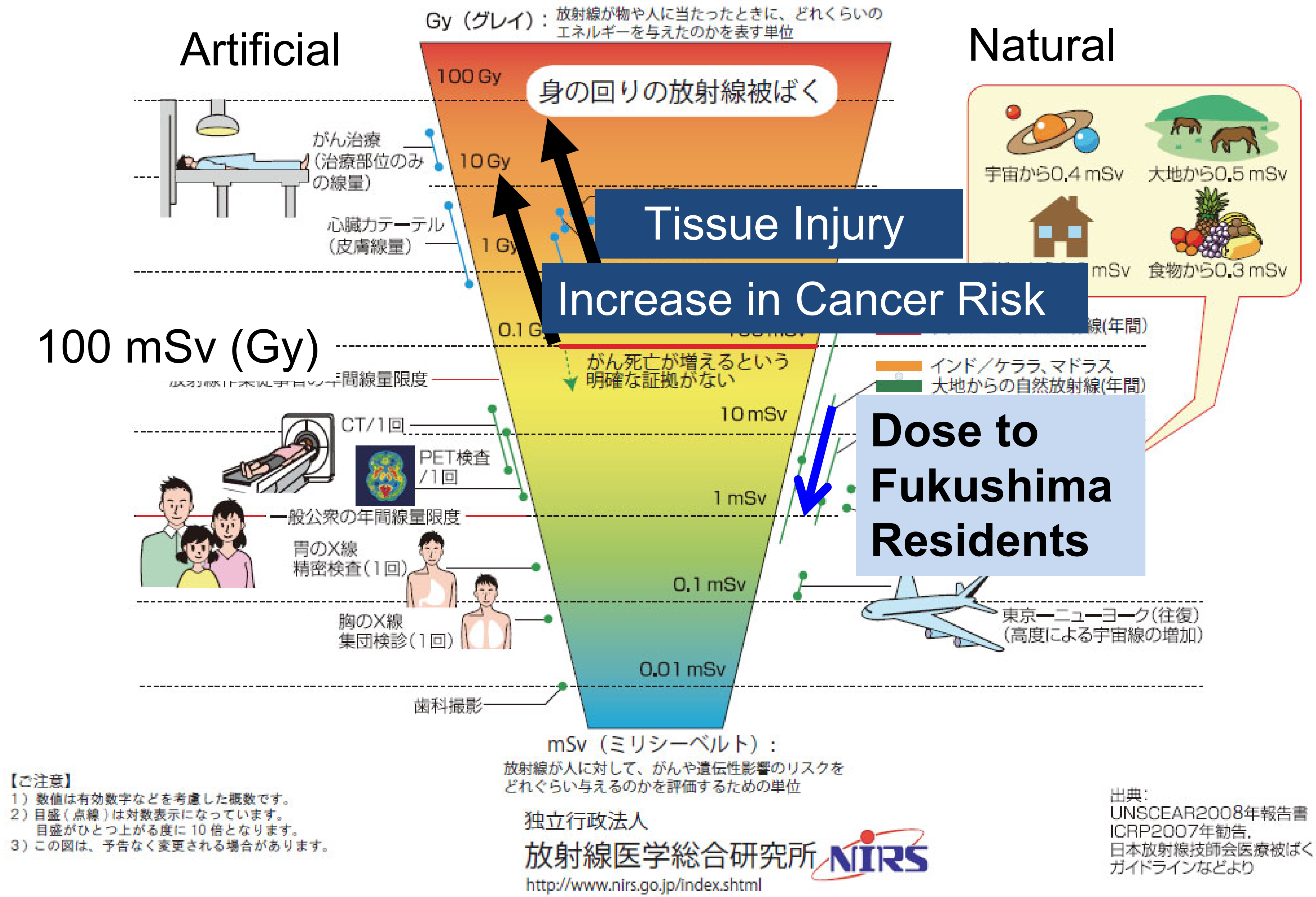
Dose Rate Distribution in the Thyroid of Fukushima Children

- **For 99% of the children tested, the dose rate was 0.04 µSv/h or less.**
- **the highest dose was 0.1 µSv/h (Equivalent dose of 50 mSv/y at thyroid gland for 1 year old).**
- **The radiation level was not the level that would require more detailed examination.**



(From NSC website)

Radiation Exposure/Effects at a Glance



Lessons Learned (6)
Challenge to RP System

Lower reference levels are to be set, when only children are considered?

In the ICRP recommendations a **higher risk coefficient** is given to whole population than to adult population, because the whole population includes children, a sub-population of higher sensitivity and longer life span.

Exposed population	Cancer	Heritable effects	Total
Whole	5.5	0.2	5.7
Adult	4.1	0.1	4.2

Nominal risk coefficients (10^{-2} Sv^{-1})
(from Table 1, Publication 103)

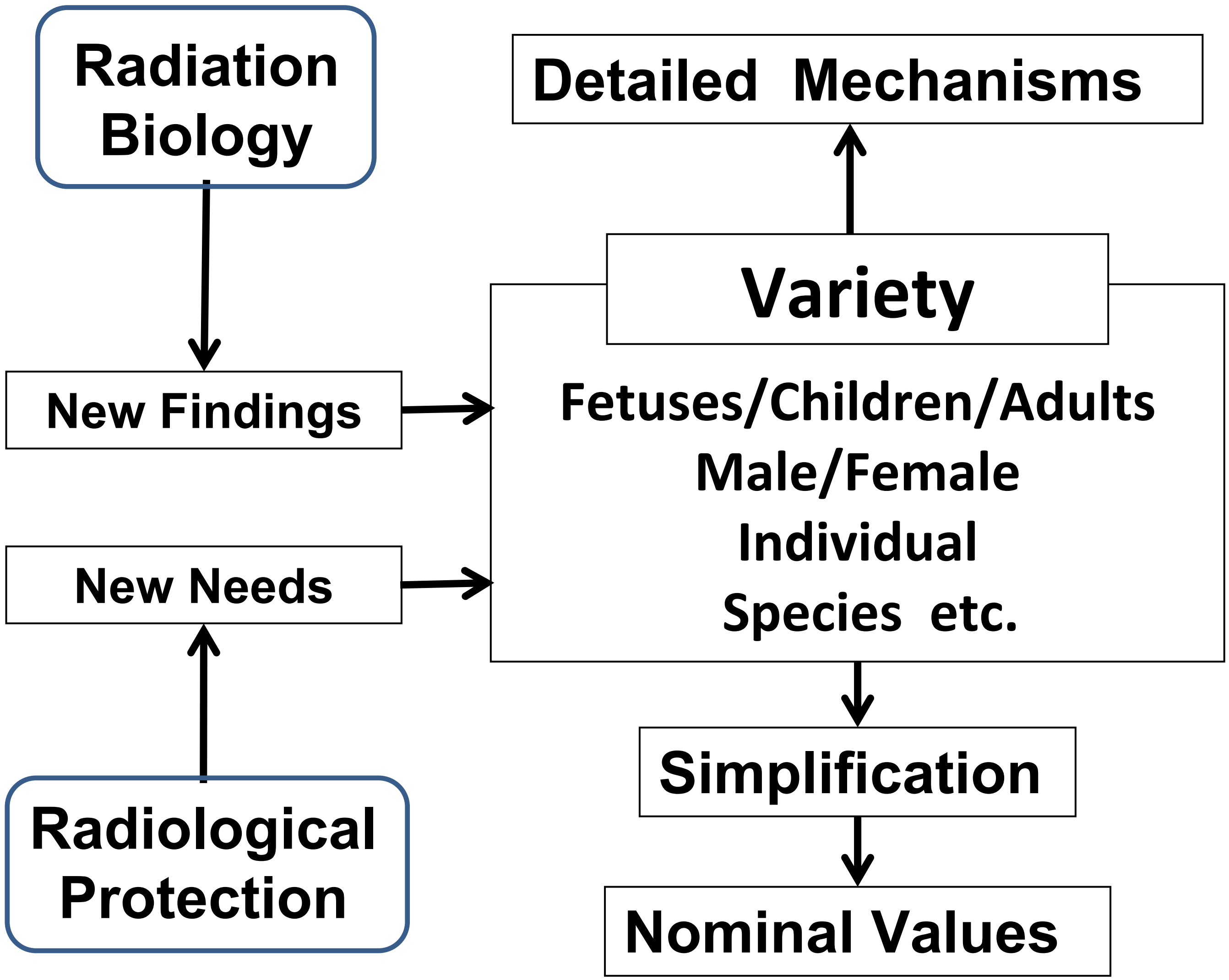
Special consideration for children is recommended

… After an emergency situation has occurred, planned protection measures should evolve to best address the actual conditions of all exposed populations being considered. **Particular attention should be given to pregnant women and children.**

(Paragraph 280, Publication 103)

Yet, dose limits/constraints/reference levels specific to children have not been provided.

Science and RP



Difference significant to set different regulation level under the conditions considered?

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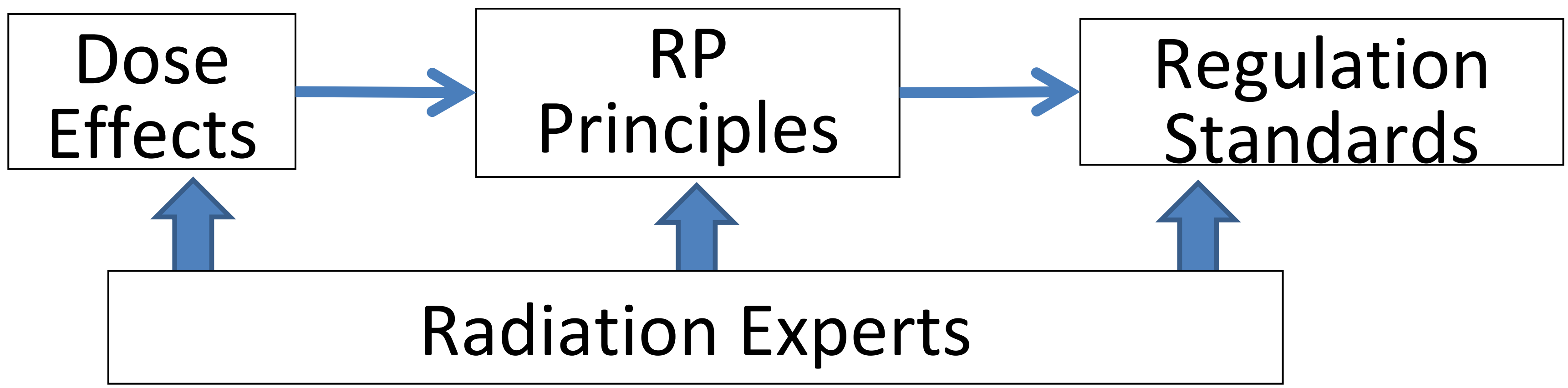
Conclusion

- For setting a reference level, care must be taken for understanding and acceptance by public/stakeholders.
- Residents in Fukushima who had not been aware of radiation effects nor radiological protection, has been affected and confused by information on the exaggerated story on radiation effects and lack of explanation about radiological protection procedures.
- Radiation experts should disseminate;

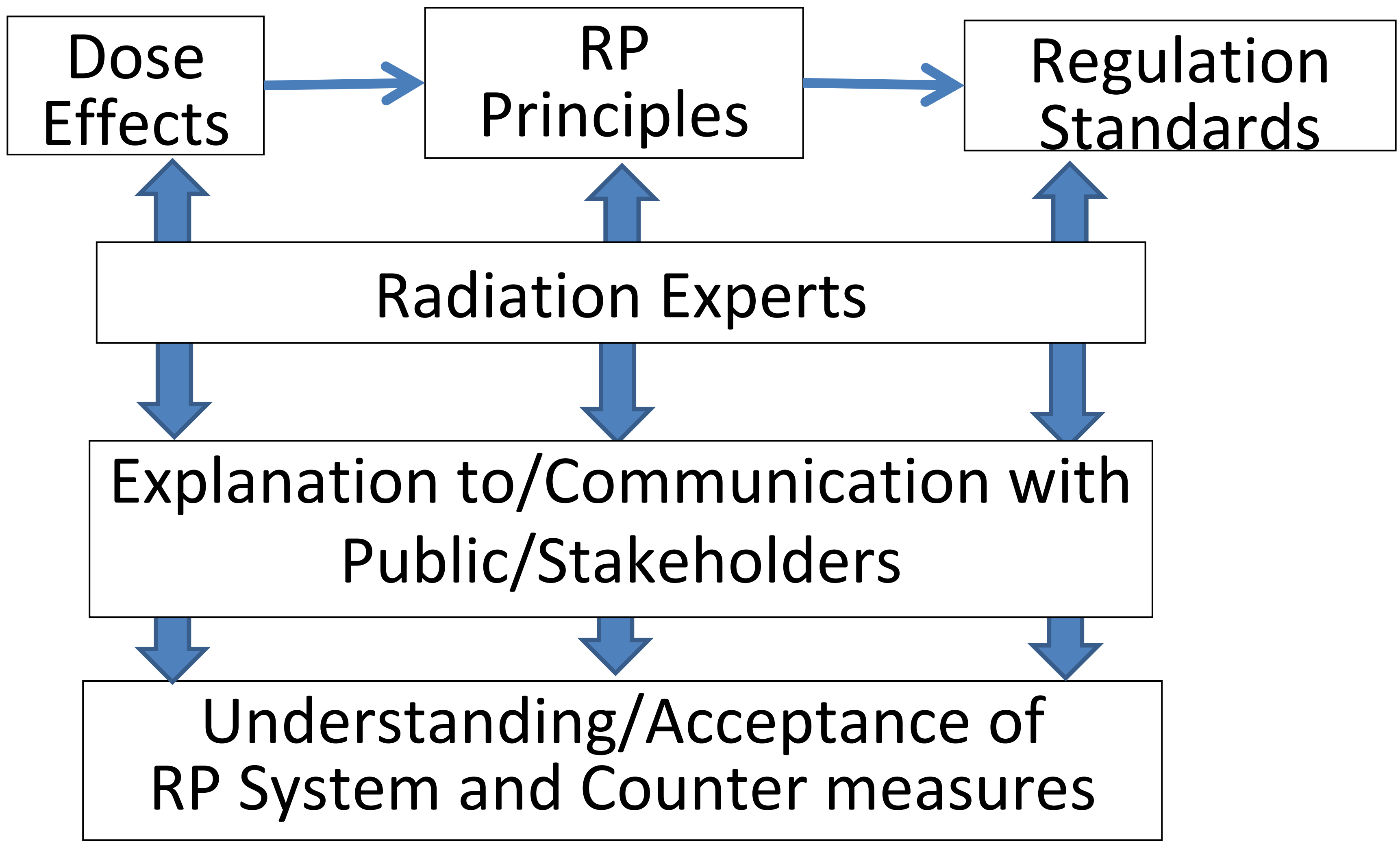
  (i) precise information on effects of radiation,

  (ii) plain explanation on RP.

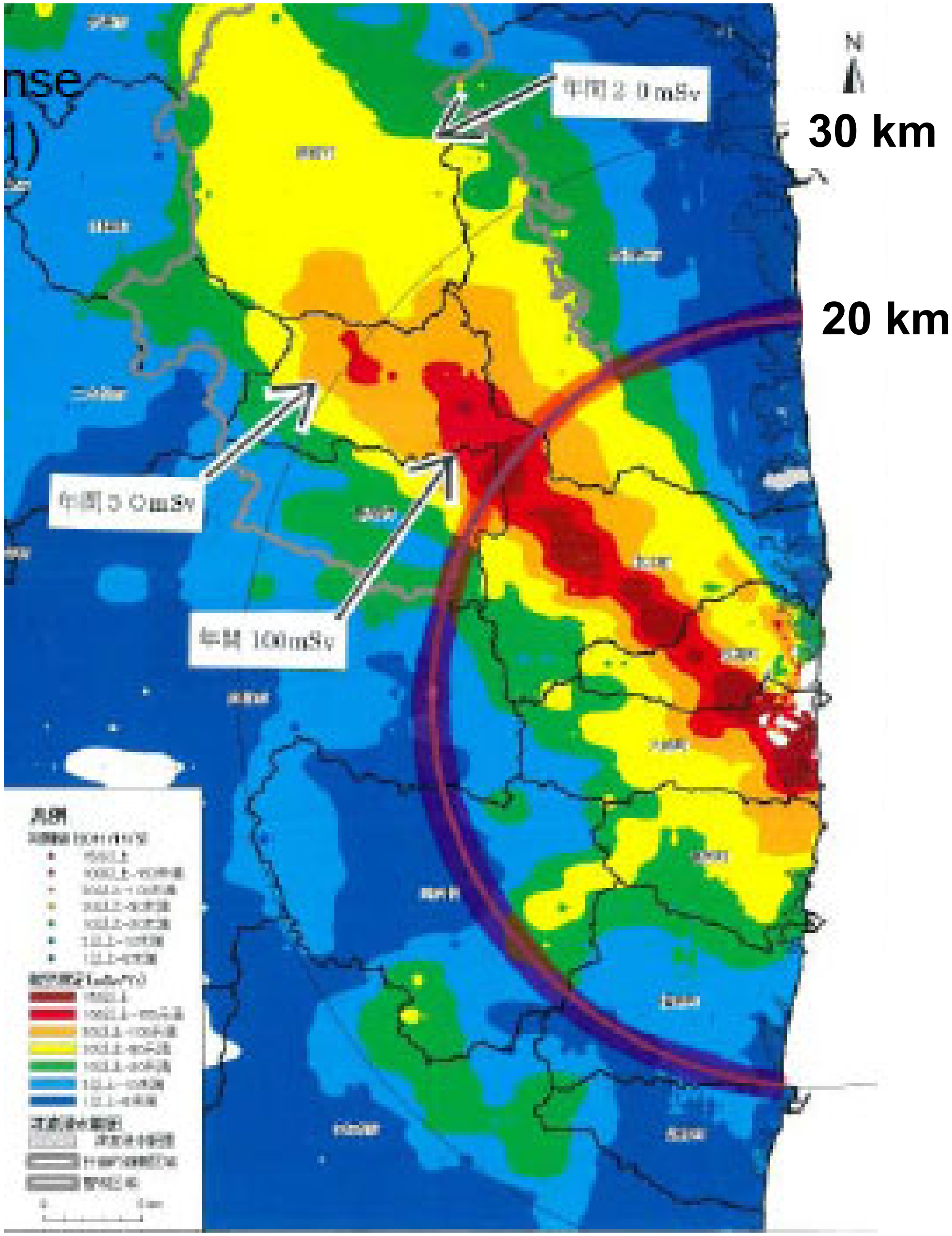
Roles of Radiation Experts



Roles of Radiation Experts



New Zoning as of April 2012



<u>Green and Blue within 20 km radius.</u>

To prepare lifting “evacuation order”

<20 mSv/a

<u>Yellow</u>

Continued off –limit area

Shift to the above category after decontamination.

20 – 50 mSv/a

<u>Brown and Red</u>

(25,000 residents)

Areas difficult to return.

50mSv/a<

Emergency to Recovery
- Issues one after another-

Optimization in countermeasures

- Decontamination
- Radioactive waste
- Radioactivity control in food
- Returning home
- Relocation
- …

Overview of the Final Report of the Blue Ribbon Commission on America's Nuclear Future

Richard A. Meserve
Carnegie Institution for Science

Blue Ribbon Commission on America's Nuclear Future

Origins and Purpose

- Blue Ribbon Commission on America's Nuclear Future established by the President's Memorandum for the Secretary of Energy on January 29, 2010
- Charge to the Commission: Conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle and recommend a new strategy
- Deliver recommendations to the Secretary of Energy by January 29, 2012

BLUE RIBBON COMMISSION
ON AMERICA'S NUCLEAR FUTURE

Commission Members

- **Lee Hamilton**, Co-Chair – Director of the Center on Congress at Indiana State University, former Member of House of Representatives (D-IN)
- **Brent Scowcroft**, Co-Chair – President, The Scowcroft Group, and former National Security Advisor to Presidents Ford and George H.W. Bush
- **Mark Ayers**, President, Building and Construction Trades Department, AFL-CIO
- **Vicky Bailey**, Former Commissioner, Federal Regulatory Commission; former Indiana Public Utility Commissioner; former DOE Assistant Secretary for Policy and International Affairs
- **Dr. Albert Carnesale**, Chancellor Emeritus and Professor, UCLA
- **Pete V. Domenici**, Senior Fellow, Bipartisan Policy Center; former U.S. Senator (R-N.M.)
- **Susan Eisenhower**, President, Eisenhower Group, Inc.
- **Chuck Hagel**, Distinguished Professor at Georgetown University; former U.S. Senator (R-NE)

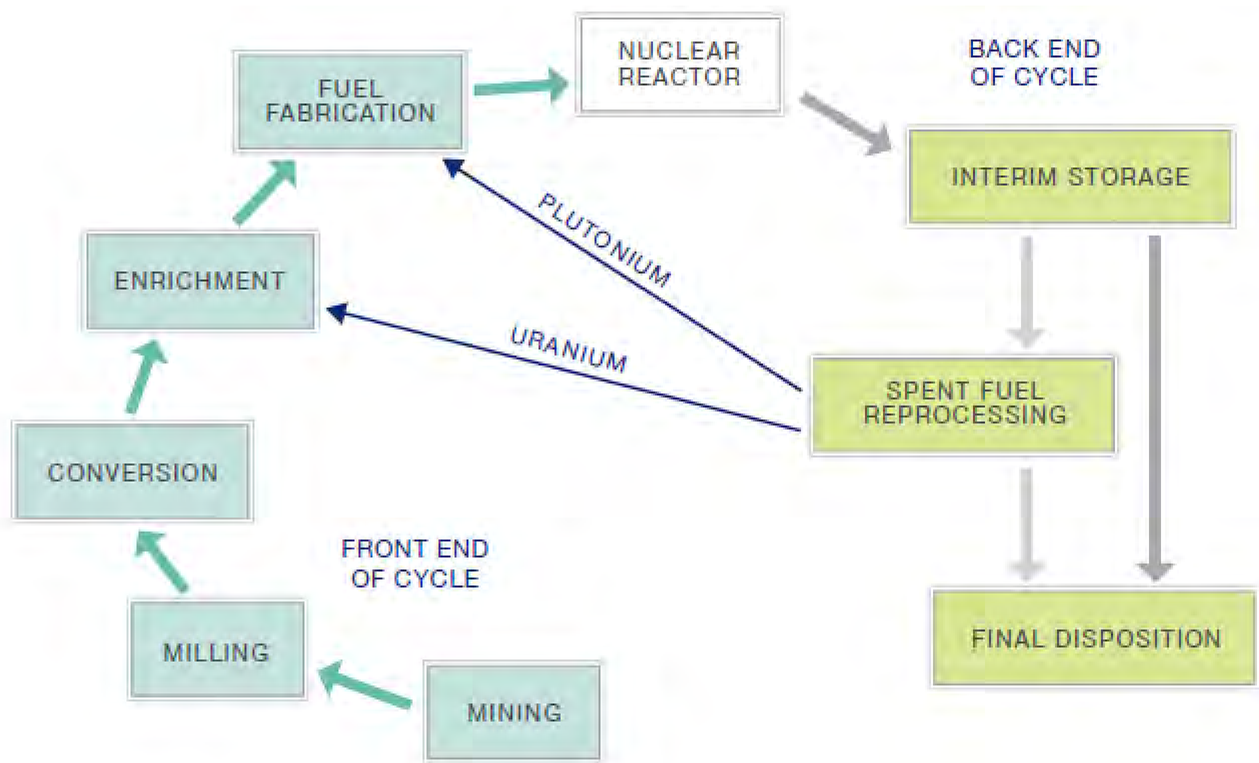
BLUE RIBBON COMMISSION ON AMERICA'S NUCLEAR FUTURE

Commission Members

- **Jonathan Lash**, President, Hampshire College; former President, World Resources Institute
- **Dr. Allison Macfarlane**, Associate Professor of Environmental Science, George Mason University
- **Dr. Richard Meserve**, President, Carnegie Institution for Science and Senior Counsel, Covington & Burling LLP; former Chairman, U.S. Nuclear Regulatory Commission
- **Dr. Ernest Moniz**, Professor of Physics and Cecil & Ida Green Distinguished Professor, MIT
- **Dr. Per Peterson**, Professor and Chair, Department of Nuclear Engineering, University of California-Berkeley
- **John Rowe**, Chairman and CEO, Exelon Corporation
- **Dr. Phil Sharp**, President, Resources for the Future, former Member of the House of Representatives (D-IN)

BLUE RIBBON COMMISSION
ON AMERICA'S NUCLEAR FUTURE

Nuclear Fuel Cycle



Blue Ribbon Commission on America's Nuclear Future

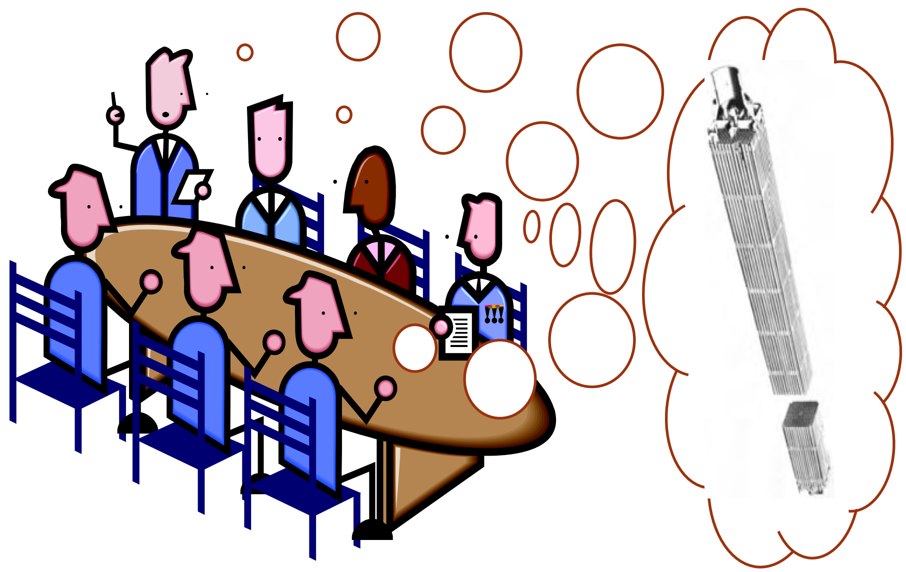
Overview of 8 Key Recommendations

1. A new, consent-based approach to siting and development

BLUE RIBBON COMMISSION
ON AMERICA'S NUCLEAR FUTURE

Overview of 8 Key Recommendations

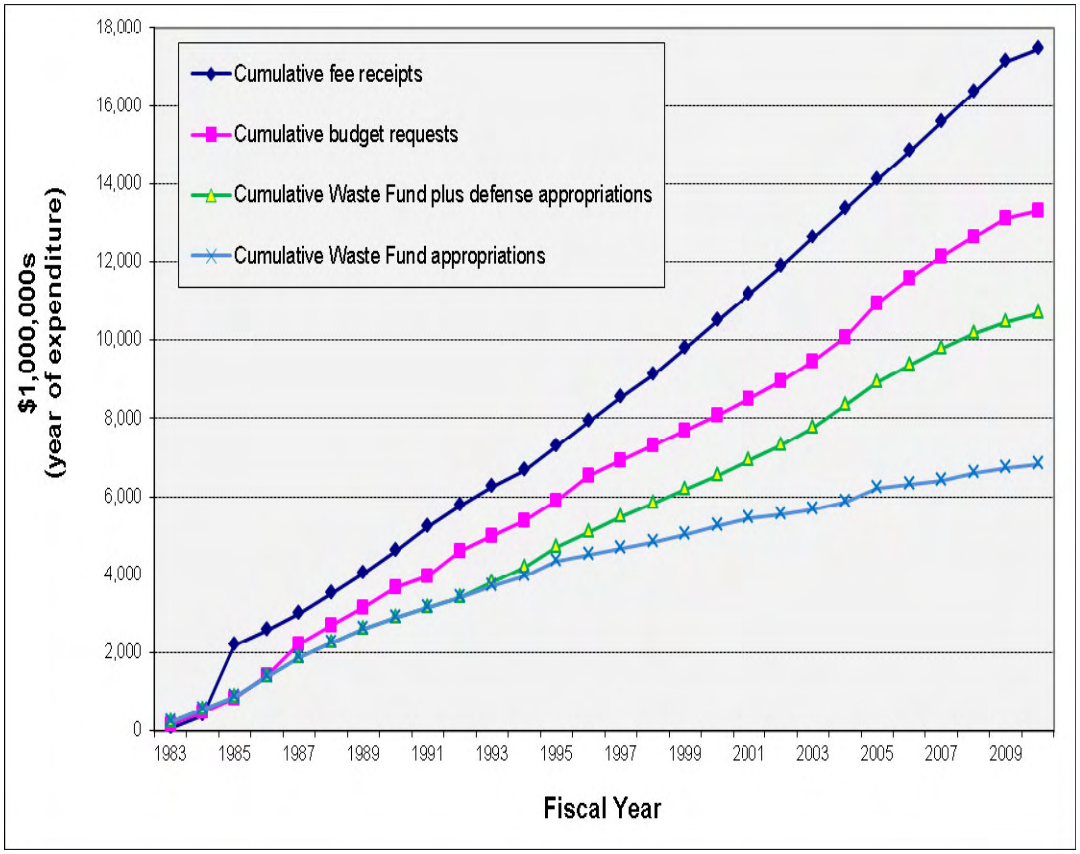
2. A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed



Blue Ribbon Commission on America's Nuclear Future

Overview of 8 Key Recommendations

3. Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management



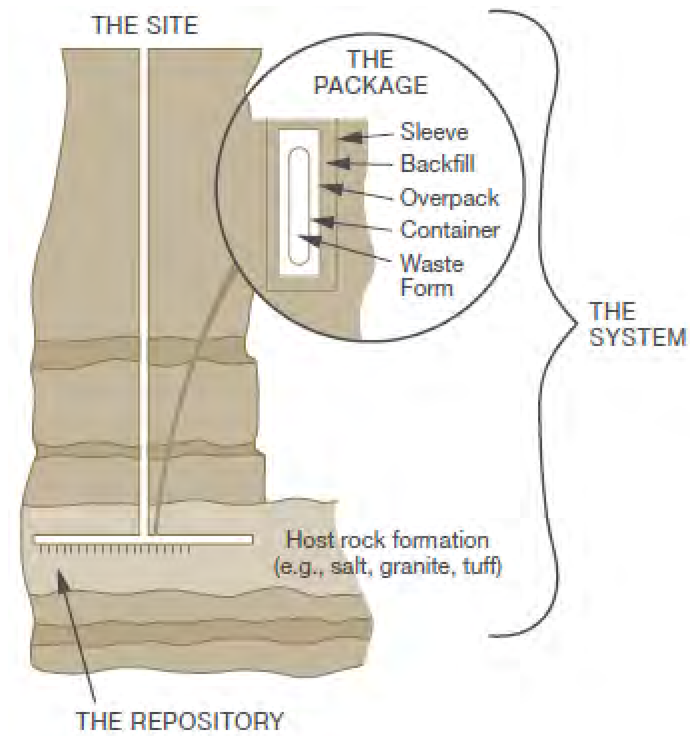
BLUE RIBBON COMMISSION ON AMERICA'S NUCLEAR FUTURE

Fixing the Funding Problem: A Two-Step Approach in the Near Term

- First, amend the Standard Contract so that nuclear utilities remit only the portion of the Nuclear Waste Fund fee that is actually appropriated for waste management activities each year.
- Place the remainder of fees collected each year in a trust account held by a qualified third-party institution
- Second, change the budgetary treatment of fee receipts so they directly offset appropriations for waste program
- Longer term, legislative action is needed to transfer unspent balance of Fund to new organization

Overview of 8 Key Recommendations

4. Prompt efforts to develop one or more geologic disposal facilities



BLUE RIBBON COMMISSION ON AMERICA'S NUCLEAR FUTURE

Overview of 8 Key Recommendations

5. Prompt efforts to develop one or more consolidated storage facilities

Blue Ribbon Commission on America's Nuclear Future

Overview of 8 Key Recommendations

6. Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available

BLUE RIBBON COMMISSION
ON AMERICA'S NUCLEAR FUTURE

Overview of 8 Key Recommendations

7. Support for continued U.S. innovation in nuclear energy technology and for workforce development

BLUE RIBBON COMMISSION
ON AMERICA'S NUCLEAR FUTURE

Overview of 8 Key Recommendations

8. Active U.S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns

BLUE RIBBON COMMISSION
ON AMERICA'S NUCLEAR FUTURE

Proposed Legislative Changes

Fully implementing these recommendations will require changes to the NWPA or other legislation to:

- Establish a new facility siting process
- Authorize consolidated interim storage facilities
- Broaden support to jurisdictions affected by transportation
- Establish a new waste management organization
- Ensure access to dedicated funding
- Promote international engagement to support safe and secure waste management

Blue Ribbon Commission on America's Nuclear Future

Responding to Fukushima

- Commission recommends the National Academy of Sciences undertake a comprehensive study of the accident and implications for U.S. policy & practices
- Dry cask storage and away-from-reactor pool storage at Fukushima performed well during crisis
- Fukushima points to importance of having long-term strategy & better near-term options for managing spent fuel

Conclusion

- The overall record of the U.S. nuclear waste program has been one of broken promises and unmet commitments
- The Commission finds reasons for confidence that we can turn this record around
- We know what we have to do, we know we have to do it, and we even know how to do it
- We urge the Administration and Congress to act on our recommendations, without further delay

Blue Ribbon Commission on America's Nuclear Future