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Center for Advanced Energy Studies

A research partnership between Boise State University, Idaho National Laboratory, Idaho State University and University of Idaho.

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Lessons Learned and Challenges Ahead, One Year after the Fukushima Nuclear Plant Accident

Dr. Akira Tokuhiro
Center for Advanced Energy Studies & University of Idaho

Presentation to AIChE Virtual Section
Thursday, March 22, 2012

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Education & Training

- Faculty, 2005-07, Kansas State University and 2000-05, University of Missouri-Rolla
- 2000-05, Director and SRO, UMR Nuclear Reactor facility; 200kW
- 1995-2000, International Fellow, Reactor Engineering & Thermohydraulics, Japan Nuclear Fuel Cycle Development Institute (now JAEA)
- 1990-95, Research Engineer, Thermohydraulics, Paul Scherrer Institute, Switzerland; G. Yadigaroglu, B. Smith
- 1991, Ph.D., Nuclear Engineering, Purdue; Paul Lykoudis, Victor Ransom
- 1984, Reactor Analysis and Safety Division, ANL; Mamoru Ishii
- 1984, M.S., Mech. Eng., U. Rochester
- 1981, B.S.E., Eng. Phys., Purdue
- 1978-81, Intern, Battelle Columbus Laboratories, Thermal Sciences Sec., Columbus, Ohio

U of Missouri-Rolla

University of Idaho
College of Engineering

JNC Japan Nuclear Cycle Development Institute

JAEA

PAUL SCHERRER INSTITUT PSI

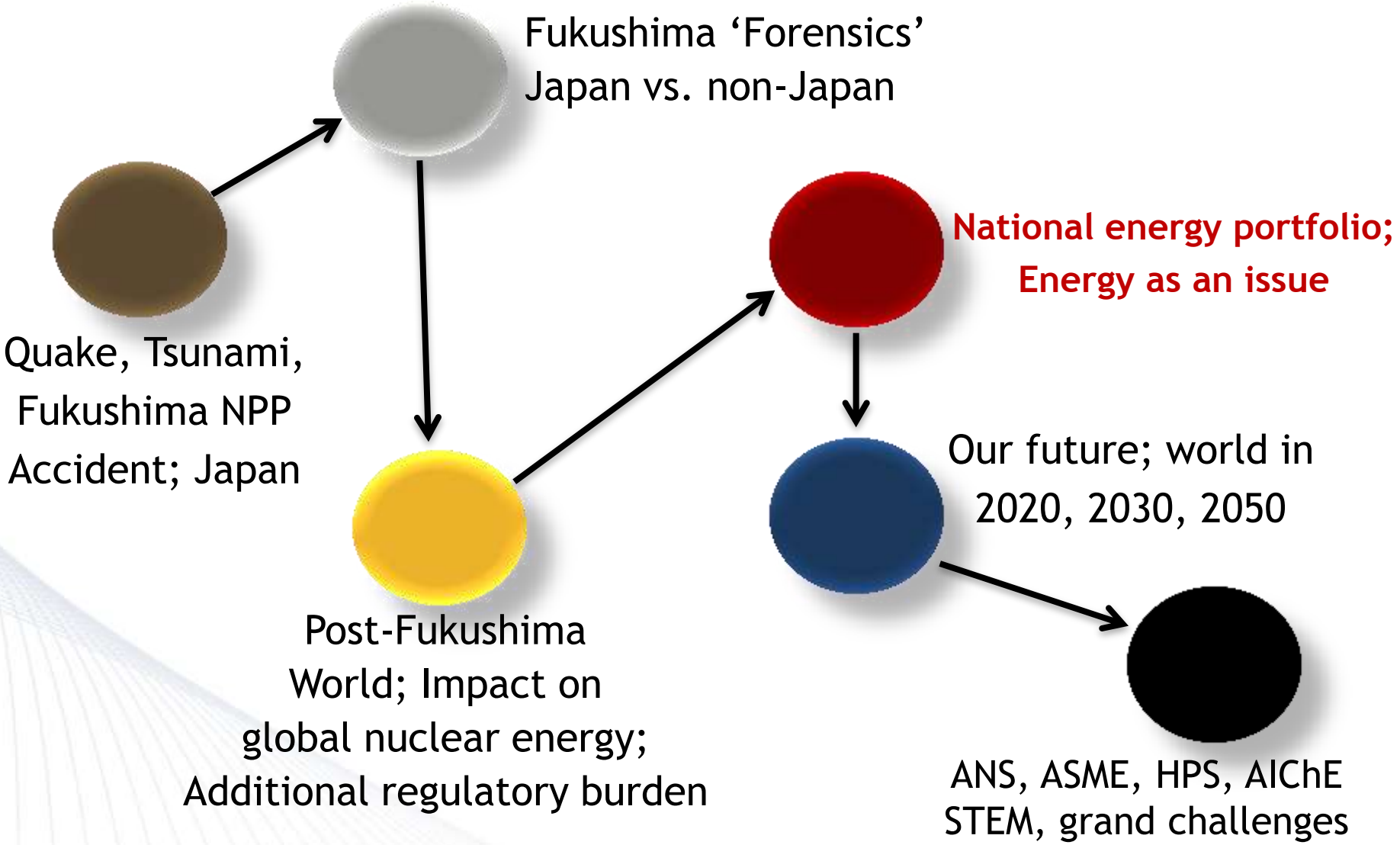
PURDUE UNIVERSITY

Argonne NATIONAL LABORATORY

UNIVERSITY OF ROCHESTER OFFICIAL SEAL MELIORA 1850

Battelle
. . . Putting Technology To Work

Connecting 'Dots'



Message 1

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- We live in a post-Fukushima world; a post-Fukushima nuclear power world
- Global population now >7 billion
- Energy strongly correlated to standard of living and economy
- Global disparity in socio-economic wealth and health; global economy/global coupling
- We live beyond our means in terms of consumption of natural resources
- Sovereignty juxtaposed against global enterprises and issues
- Q: Can a world live without nuclear energy? What would happen without nuclear energy?

Message 2

- Q: Who is the ‘winner’ in the post-Fukushima world?
- (Tokuhiro) We are eliminating the future of nuclear energy by escalating cost associated with overburdening regulation
- (Tokuhiro) Regulation oversight has good intentions but is often additive; without market consideration of economic competitiveness
- (Tokuhiro) Energy & energy security are national security issues; also a global sustainability issue
- (Tokuhiro) We are irresponsible in our use of energy and natural resources; conserve, think process
- (Tokuhiro) Link energy, water and agriculture

9.0 QUAKE

~14M TSUNAMI

Damaged Fukushima Nuclear Power Plants (NPPs)

Complex Issues; 'Metrics' LENDIT

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Length Scales

L 

Energy Scales

E 

Number Scales

N 

Distribution Scales

D 

Purpose:
common communication basis; potentially risky communication effective; applicable across soft and hard domains; linked to analytical approaches

Information Scales

I 

Time Scales

T 

Where It Happened?

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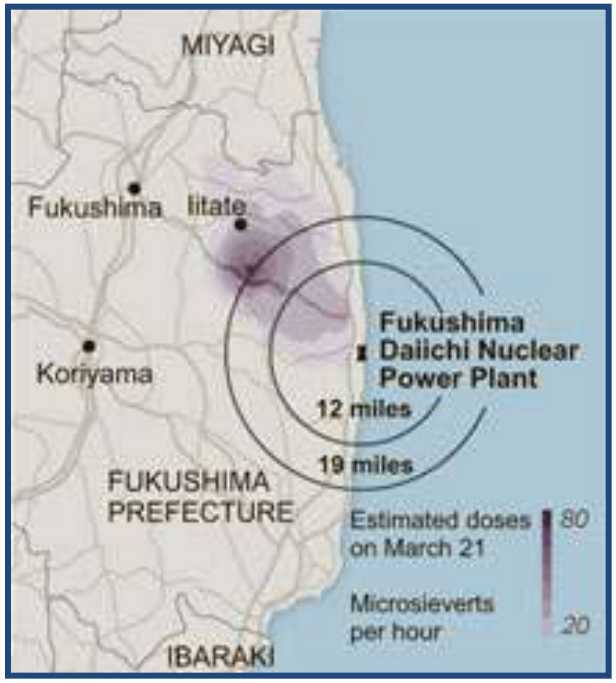
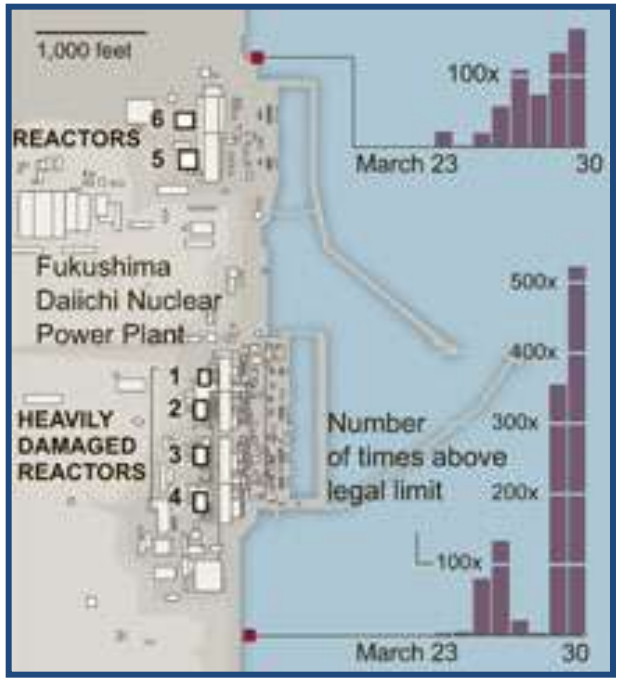
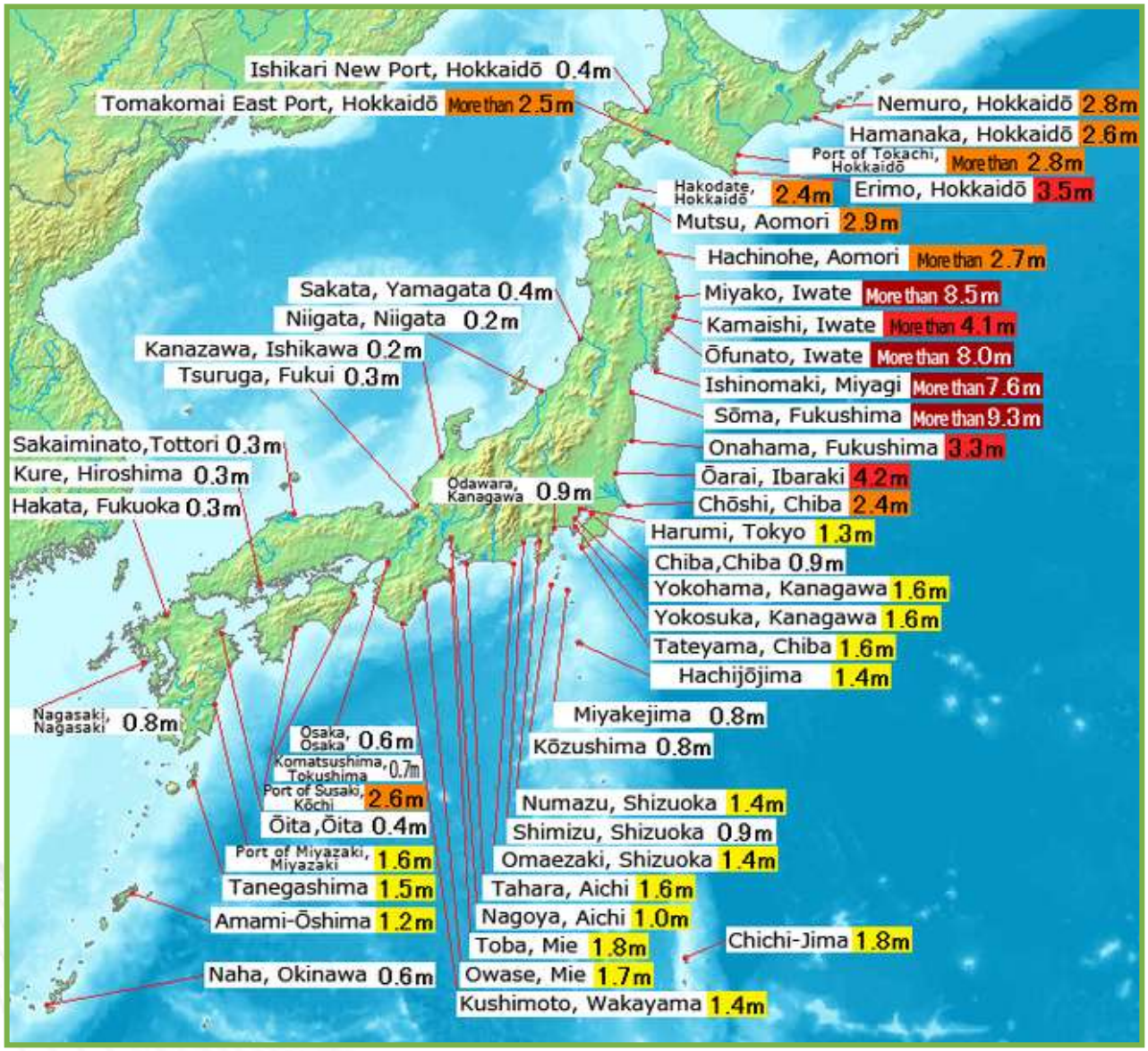
Prefecture, Fukushima NPP, F-NPP Dai-ichi





Note the length-scales (L), extent

Recorded Heights of Tsunami



http://en.wikipedia.org/wiki/File:2011_Tohoku_earthquake_observed_tsunami_heights_en.png

Birdseye View Of Fukushima Dai-ichi NPPs (1F)

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GE BWR, Mark-I Nuclear Reactor

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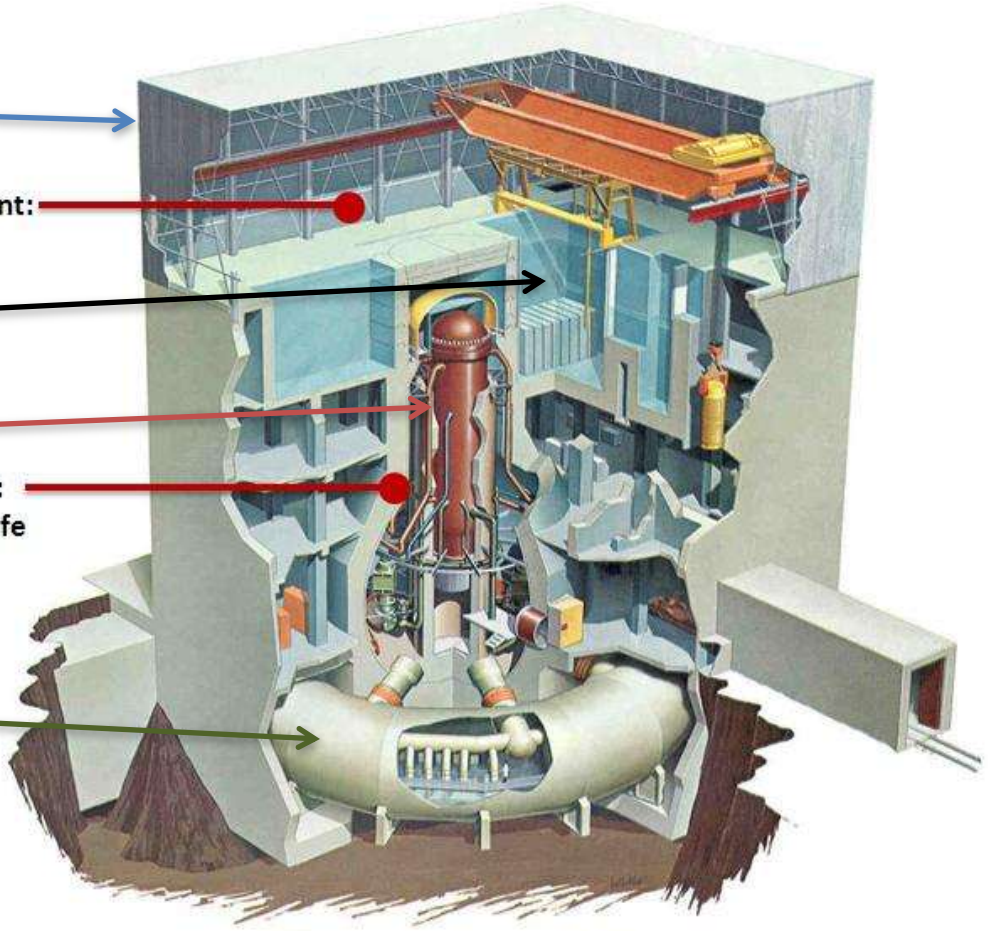
Some Accident Relevant Features

1) SECONDARY CONTAINMENT IS REALLY A CONFINEMENT

2) SPENT FUEL POOL (SFP)

3) REACTOR PRESSURE VESSEL (BROWN)

4) TOROIDAL SUPPRESSION POOL (WETWELL)



Boiling Water Reactor Design

Before and During the Tsunami

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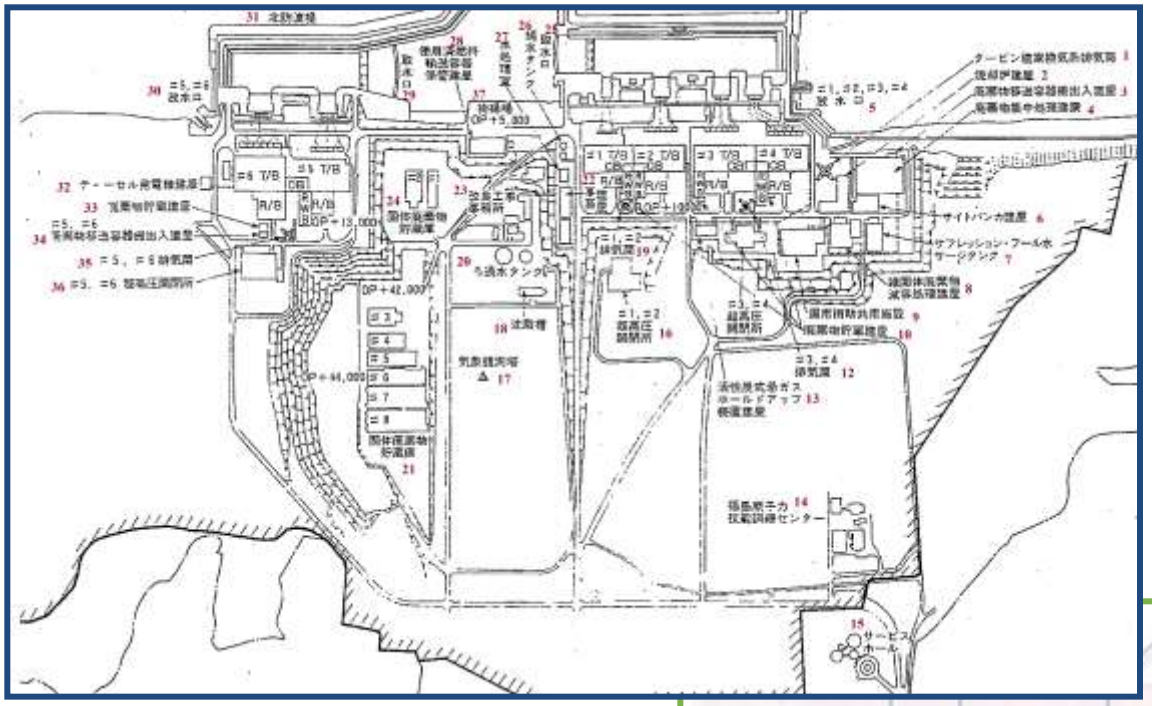
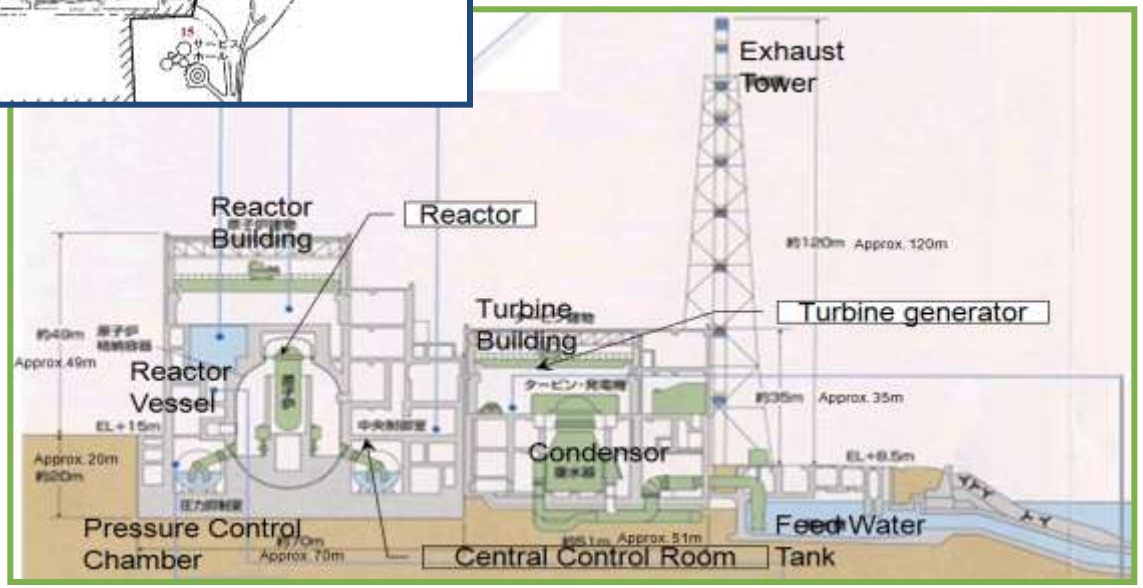
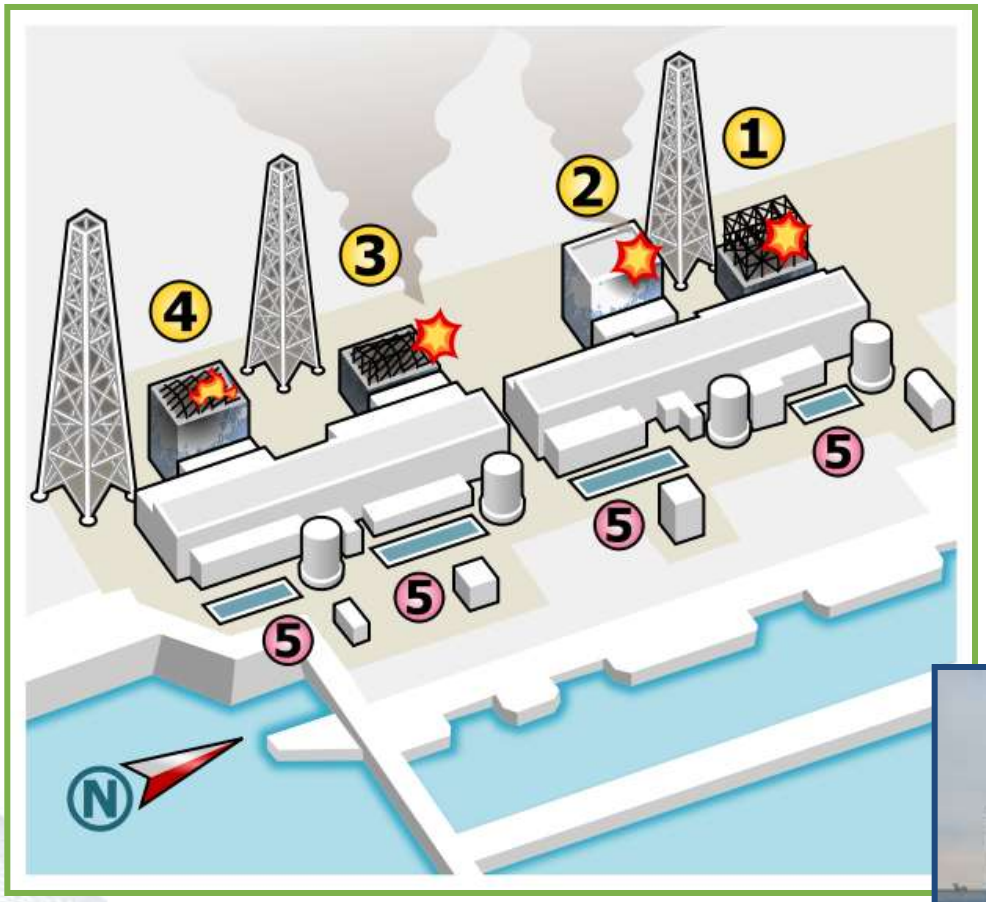
Photos: Reuters/TEPCO

Site Map and Cross-Sectional Diagrams





Reactor Buildings – before and after



http://en.wikipedia.org/wiki/Timeline_of_the_Fukushima_Daiichi_nuclear_disaster

Did we melt the core?

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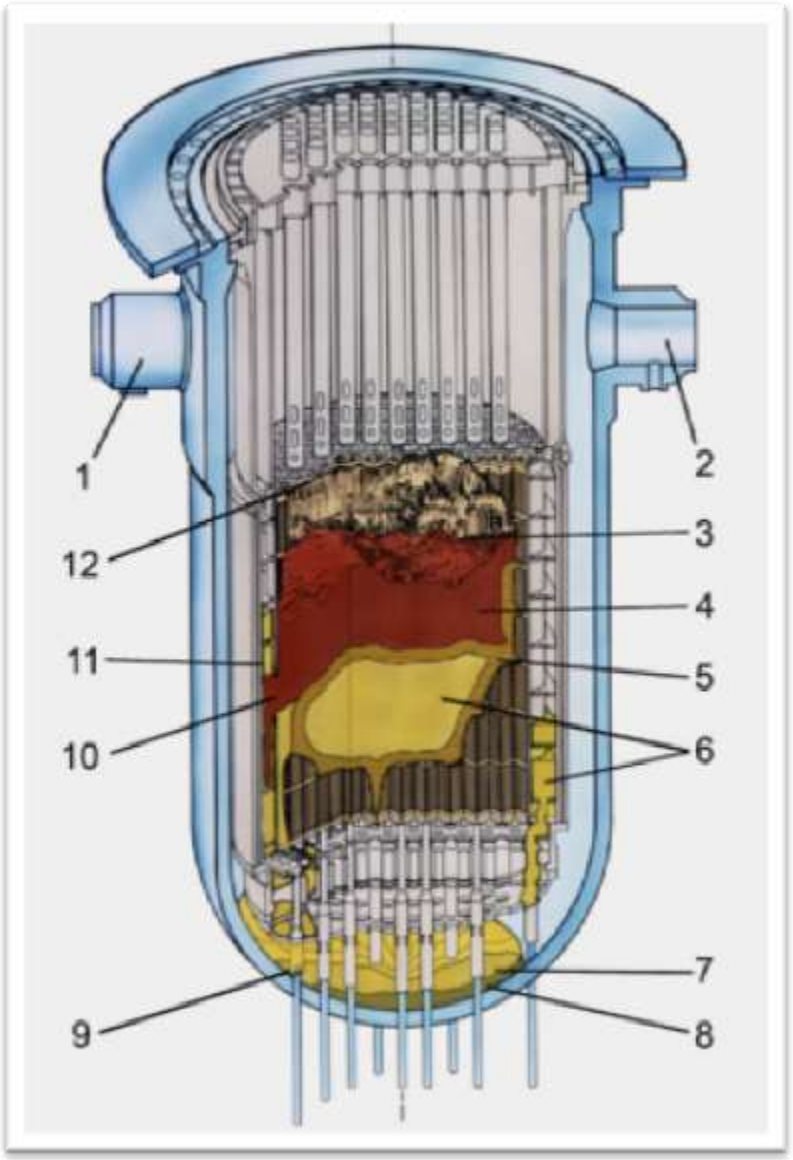
Due to untimely response, the core likely melted (partially). We will not know the extent of core damage until 2015-16 at the earliest.



“GG”- Global Gossip

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Changing How News Is Reported

Social Media Landscape

(http://www.google.com/imgres?q=social+networks&um=1&hl=en&sa=N&rlz=1T4ADFA_enUS341US342&tbm=isch&tbnid=C0Bq_VCYVLtknM:&imgrefurl=http://santaelenaproject.blogspot.com/2011/05/social-networks-project.html&docid=Qr5QB-XAsDpGQM&w=1024&h=768&ei=CviBTvDmKoqHsAKSjsXBBw&zoom=1&biw=1280&bih=568&iact=rc&dur=534&page=2&tbnh=122&tbnw=163&start=18&ndsp=18&ved=1t:429,r:6,s:18&tx=107&ty=80)

Head 'Honcho'

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The Art of Bowing

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(N) 23: 1

Fallout and evacuation zones

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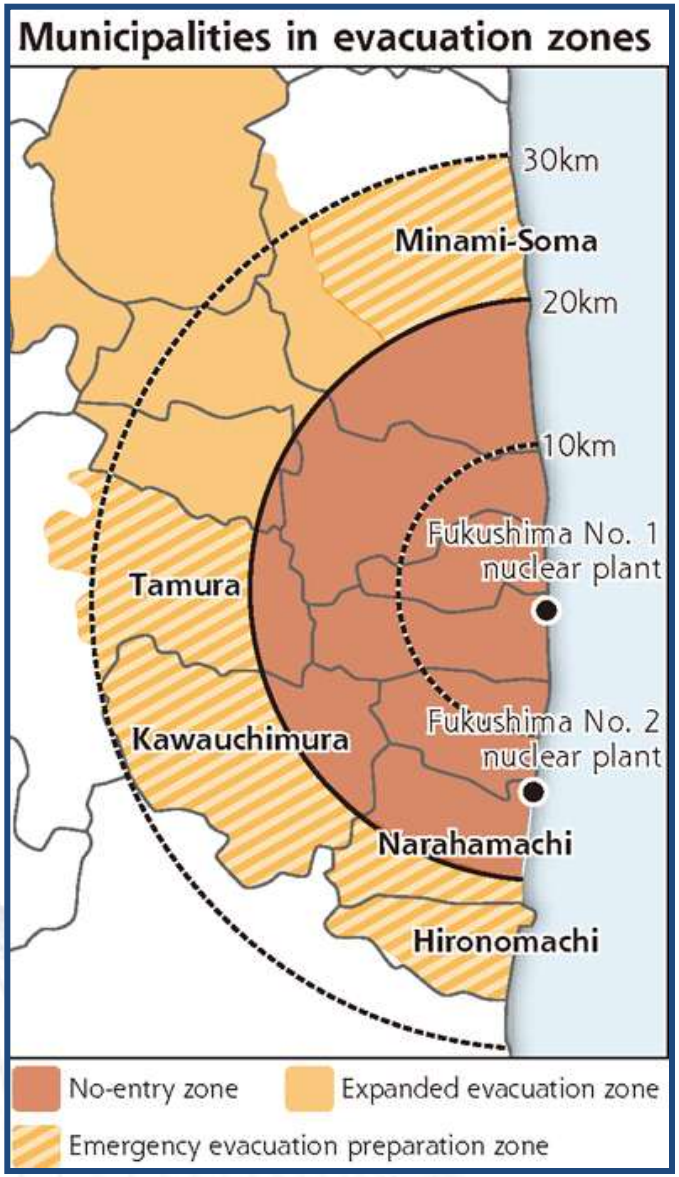
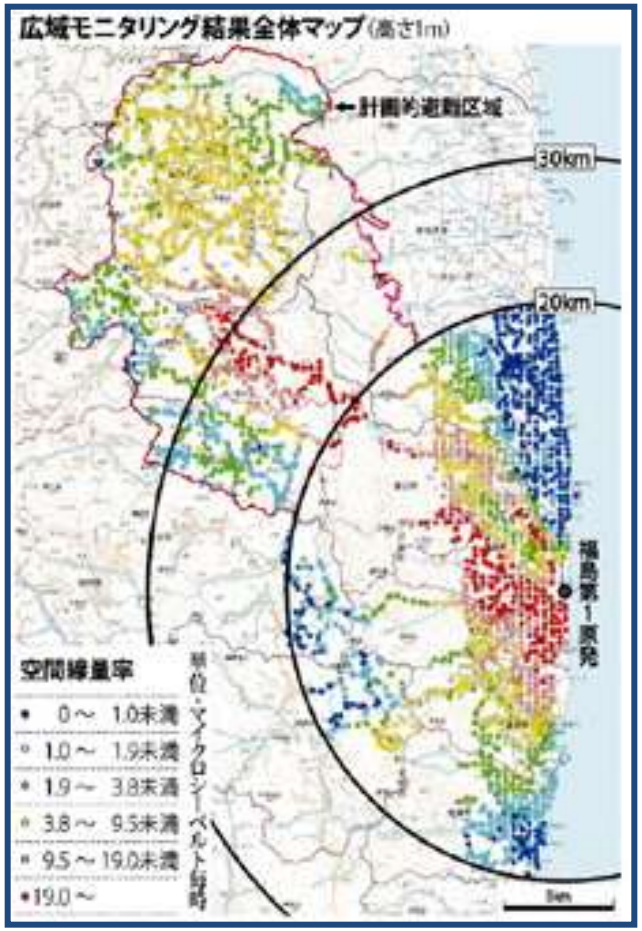


Contamination Map - 'Hot-Spots'

- **Contamination Is Distributed**



http://mdn.mainichi.jp/mdnnews/news/20110914p2a00m0na013000c.html

Relative Radiation Levels

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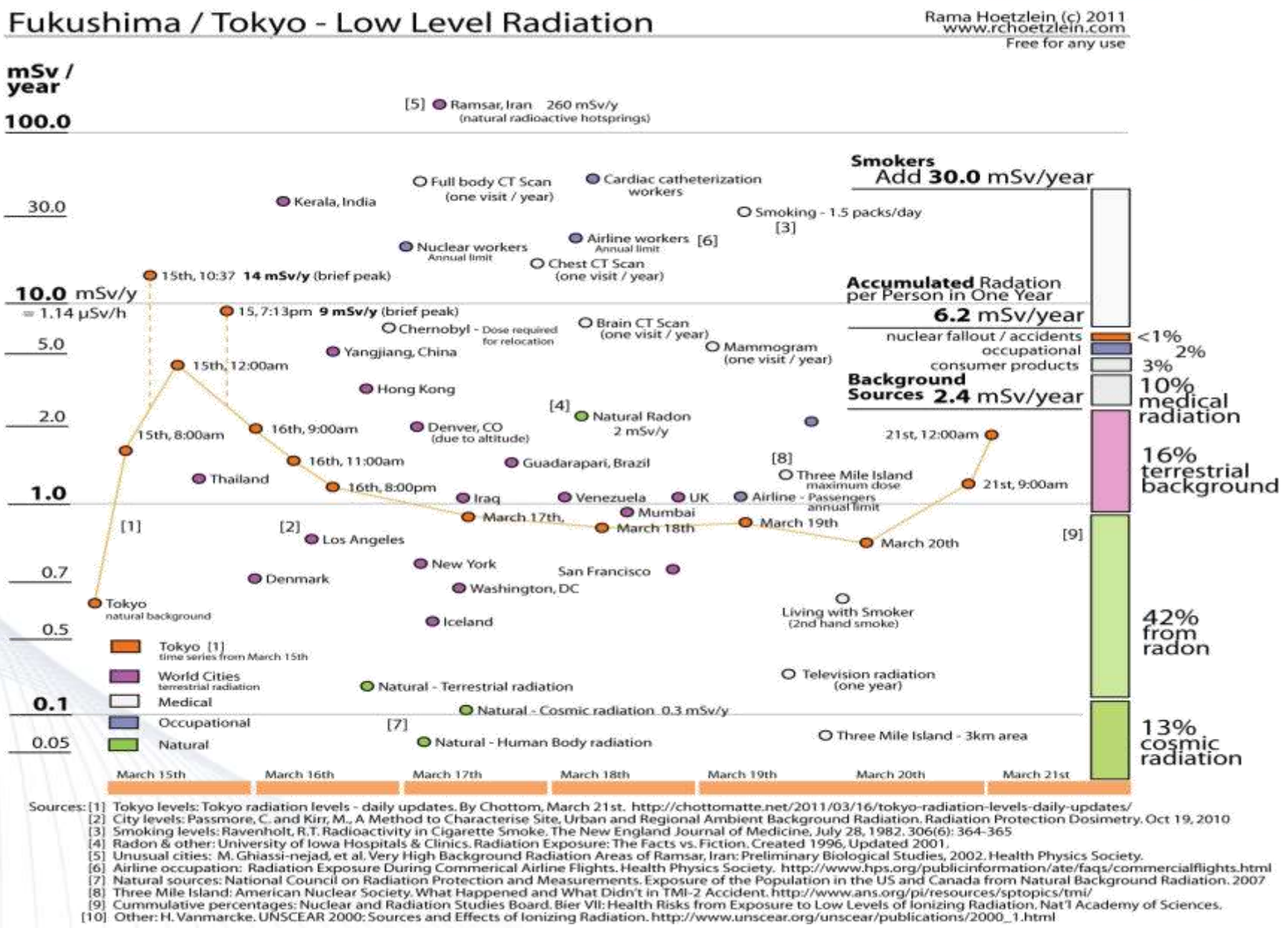

Sources: [1] Tokyo levels: Tokyo radiation levels - daily updates. By Chottom, March 21st. http://chottomatte.net/2011/03/16/tokyo-radiation-levels-daily-updates/
[2] City levels: Passmore, C. and Kirr, M., A Method to Characterise Site, Urban and Regional Ambient Background Radiation. Radiation Protection Dosimetry. Oct 19, 2010
[3] Smoking levels: Ravenholt, R.T. Radioactivity in Cigarette Smoke. The New England Journal of Medicine, July 28, 1982. 306(6): 364-365
[4] Radon & other: University of Iowa Hospitals & Clinics. Radiation Exposure: The Facts vs. Fiction. Created 1996, Updated 2001.
[5] Unusual cities: M. Ghiassi-nejad, et al. Very High Background Radiation Areas of Ramsar, Iran: Preliminary Biological Studies, 2002. Health Physics Society.
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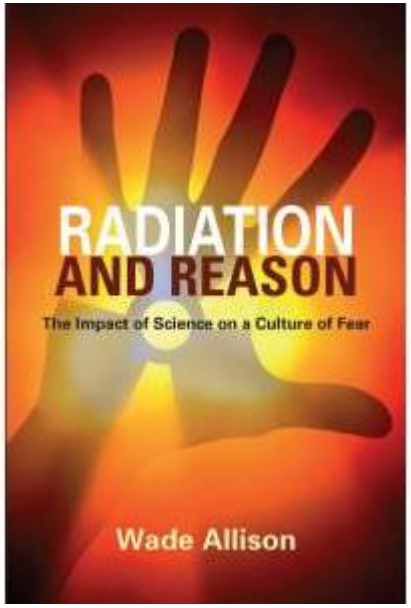
[8] Three Mile Island: American Nuclear Society. What Happened and What Didn't in TMI-2 Accident. http://www.ans.org/pi/resources/sptopics/tmi/
[9] Cummulative percentages: Nuclear and Radiation Studies Board. Bier VII: Health Risks from Exposure to Low Levels of Ionizing Radiation. Nat'l Academy of Sciences.
[10] Other: H. Vanmarcke. UNSCEAR 2000: Sources and Effects of Ionizing Radiation. http://www.unscear.org/unscear/publications/2000_1.html

Radiation and Reason



ISBN-10: 0956275613
ISBN-13: 978-0956275615

Radiation and Reason:
The Impact of Science on a Culture of Fear

by Wade Allison
Oxford University, Professor Emeritus, Physics

REPLACE
The human race is in a dilemma; it is threatened by economic instability on one hand and climate change on the other. Either of these could lead to widespread unrest and political turmoil, if the right choices are not made now. In particular, prosperity without carbon emission implies a comprehensive switch in our sources of energy. With luck, the activity generated by the process of switching will also contribute to prosperity in the short and medium term. There are many solutions wind, tidal, solar, improved efficiency but the most powerful and reliable source is nuclear. However, it is widely supposed that this presents a major problem of safety. Is this long-held concern about radiation and nuclear technology fully justified? Straightforward questions should have simple answers, and the simplest answer is No. Explaining and exploring the question and this answer in accessible terms is the subject of this book.

Risk Map – U.S. vs. Japan

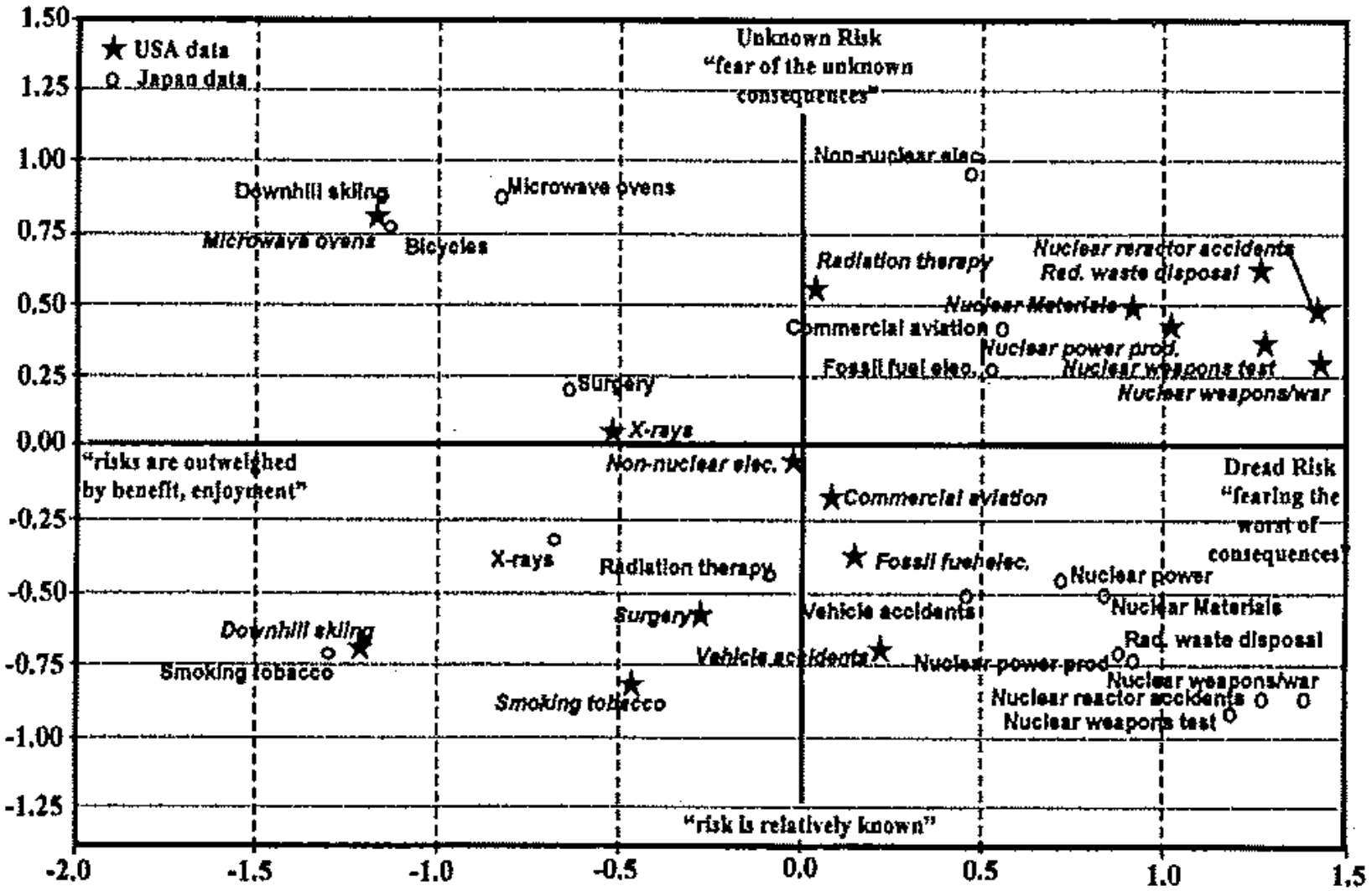
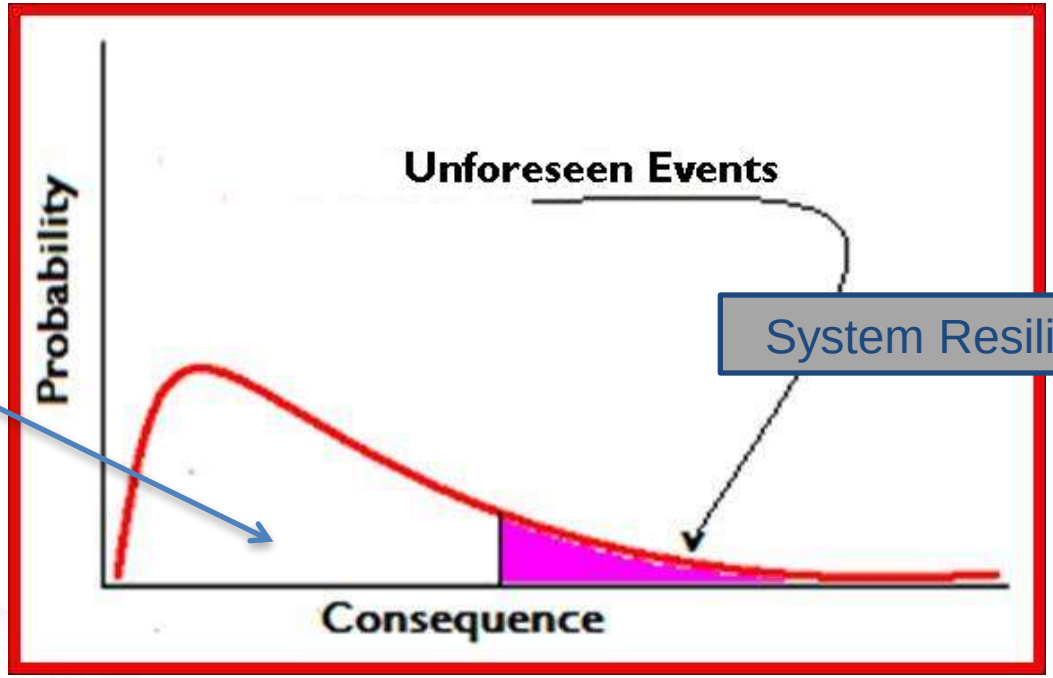


Fig. 2 Cognitive risk map showing hazards of interest in the US and Japan

Resiliency

1970 vs. 2011

Unwanted events are engineered ‘out’; Design Basis Engineered



System Resiliency

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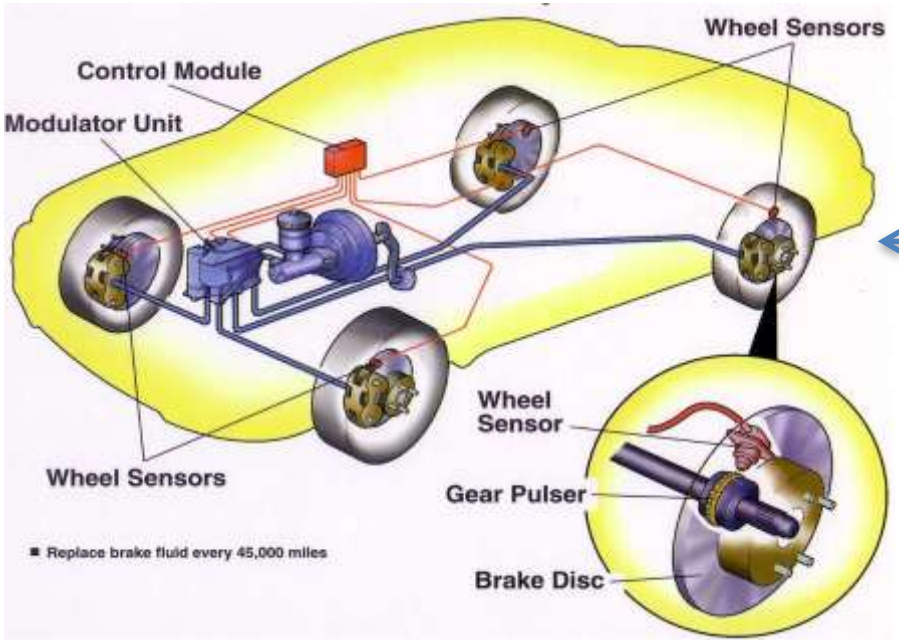
Take an automobile for example



← ***Design Basis Safety System***

System Resiliency (unforeseen) →

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(projected)

LESSONS LEARNED
TECHNICAL
NON-TECHNICAL

TLEDN, Clean-Up (update needed!)

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- At least 10 years (T)
- At least $100Billion (N)
- At least 10,000 (N) workers
- Perhaps 100,000 sq. mi.
- More than 100,000 gals.

Technical Lessons Learned

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DESIGN:

- Reconsider SFP design; need for passive design with consideration of blockage
- Reconsider soundness of placing SFP near reactor core
- Reconsider core design with lower aspect ratios

Technical Lessons Learned

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DESIGN/R&D:

- Reassess the use of zircaloy as fuel cladding
- Learn more about cladded fuel degradation dynamics; that is, ’reconfiguration’ under meltdown

R&D/REACTOR DESIGN BASIS:

- Means to assess system ‘resiliency’ seem lacking

Technical Lessons Learned

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DESIGN/SITE DESIGN BASIS:

- Soundness of multiple units – an accident at one may limit access to the other
- Consider large-scale hydrodynamics of water ingress to minimize loading/damage to structures large & small
- ‘Double’ design basis accidents can occur for some reactor sites (loss of offsite power, loss of heat sink)
- Consider loss-of-offsite power with only partial or limited availability of EDGs and back-up batteries

Technical Lessons Learned

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OPERATIONAL:

- Roads need to be clear of debris quickly and wide enough for large-scale first response equipment to reach the reactor; access from water is needed
- Offsite or e-center needs access to key indicators; foremost direct measurement of water level in core
- Volumetric analysis is needed; empty tanks & filled tanks

OPERATIONAL/DESIGN:

- Reconsider ‘non-electrical’ and remotely controlled valves

OPERATIONAL/STANDARDIZATION:

- Color-code major components so that they can be identified after accidents; too much grey-scale

Technical Lessons Learned

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OPERATIONAL/INTERNATIONAL:

- International team of first responders, then accident management team needed
- International agreement and commitments to radiation exposure for workers, general public, women of child-bearing years and children
- International agreement and commitments on retrofitting safety-related
- International standards to maintain intermediate-to-longer term radiation monitoring and health effects are needed

Technical Lessons Learned

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OPERATIONAL/NATIONAL:

- Nations do need to replace aging reactors with new plants
- Reconsider severe accident analysis scenario in which operators abandon control room due to high radiation field; or counter with partial measures to manage accident

INTERNATIONAL:

- (AT) commercial nuclear power nations should participate in the international cleanup of the Fukushima nuclear power plants in order to actively learn lessons

QUESTIONS?

The Challenge

ENERGY & ENVIRONMENT: $45 trillion to wean the world off oil

The world will face a bill in excess of $45 trillion to keep global temperature increases below 2.4° C - and would need to build ***32 new nuclear power plants per year*** to help achieve it, says a new report from the International Energy Agency (IEA).

IEA spells out carbon reduction challenge

The OECD International Energy Agency's biennial publication *Energy Technology Perspective* has outlined what it says is necessary to halve today's CO_2 emissions by 2050 in order to keep global temperature increase below 2.4 degrees C.

This would require the virtual de-carbonizing of the power generation sector and entail investment in new technology of over $45 trillion by 2050 plus carbon emission costs of $200 to $500 per tonne CO_2. Apart from conservation, nuclear power and carbon capture and storage are the main technologies to achieve this, and ***some 1400 new nuclear plants are likely to be required by 2050.***

US Outlook (according to AT)

- ~104 operating NPPs, providing ~20% of electricity demand
- Most of the current fleet of 'Gen' II' LWRs will reach EOL by 2050 ± 10 yrs (w/ 60-yr operating license); D&D starts as early as 2040
- Electricity demand continues to increase
- We will have to replace ~100 NPPs, construct as many as ~100 additional NPPs
- Total fleet likely to decrease before increasing; likely energy shortages
- Next administration likely to commit to mitigating 'climate change' and 'global warming'
- We don't conserve; we use a LOT of energy

Past, present & (near) future

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Generation IV: Nuclear Energy Systems Deployable no later than 2030 and offering significant advances in sustainability, safety and reliability, and economics

Generation I

Early Prototype Reactors

- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors

- LWR-PWR, BWR
- CANDU
- VVER/RBMK

Generation III

Advanced LWRs

- ABWR
- System 80+
- AP600
- EPR

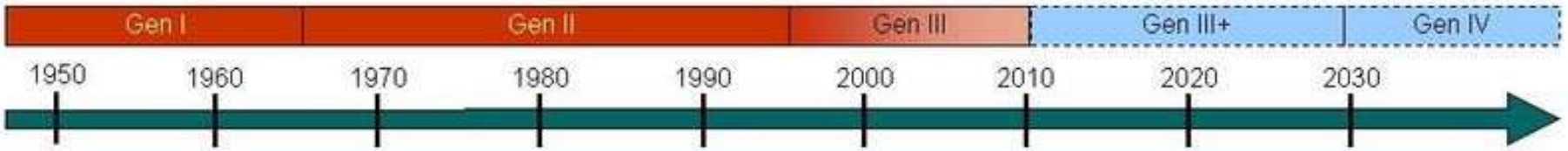
Near-Term Deployment

Generation III+ Evolutionary Designs Offering Improved Economics

.....

Generation IV

- Highly Economical
- Enhanced Safety
- Minimal Waste
- Proliferation Resistant



Global Earthquake Regions & Nuclear Power Plants

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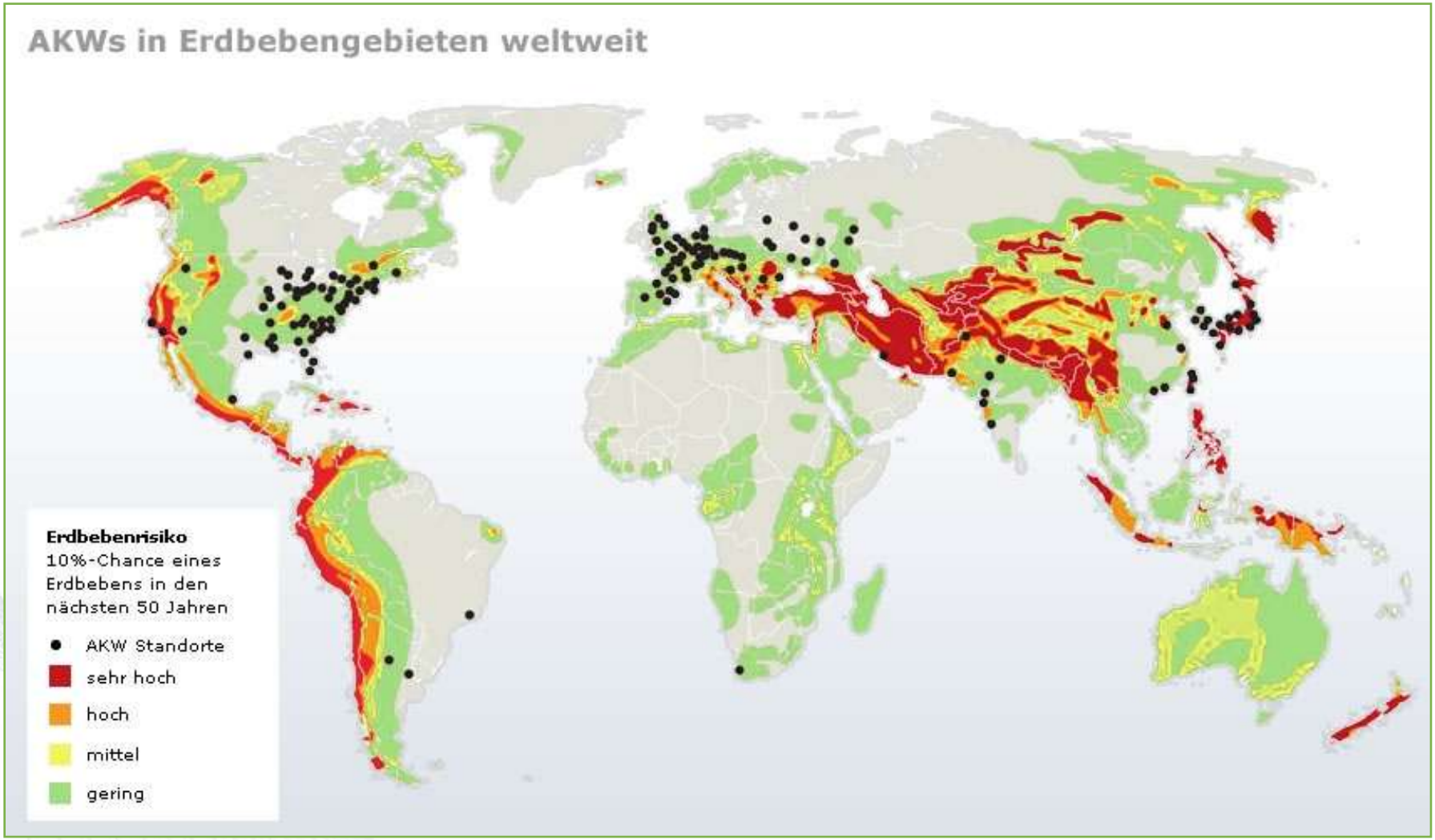

Today

- More than 10 COLs documented at NRC
- Gen' III/II+ plants (ABWRs), EPRs under construction
- Record construction time held by Hitachi; Shika Unit 2; 43 months!

Construction site of the Olkiluoto nuclear power plant unit 3 (EPR, 1,600MW)

Exposure to toxins

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Internal/External Exposure

- Emerging confirmation of ‘hot spots’; mostly northwesterly locations
- Grassroots remediation efforts at schools
- Detection of Cs-134,137 in various locations; most notably metropolitan Tokyo
- Resulting inhalation, ingestion; internal and external exposure general public; outcry by mothers with respect to undue exposure of children
- ‘Contamination’ of the food chain, planting and harvesting – summer, fall… to continue

Balancing Perception of Benefit
Vs.
Perception of Risk

PERSONAL

Science Cannot Predict the Individual ‘Resiliency’ of Inhaled/Ingested Toxins

Acknowledgments

Edward Dowhanycz
Christ Fisk
Paul Nardone
Clemente Parga
Christian Bakken
Bryon Curnutt
Daniel Anders
Gannon Johnson
Marvin Fielding
Anne McCartin
Leslie Kerby
Richard Skifton
Bryan Riga
Jordon Marquis
Cory Griffard
Olumuyiwa Omotowa
David Wagner
Dan Yurman
Wade Allison
… and many others

CFS:

NISA , JAIF, JAEA, ANS, Der Spiegel, Wikipedia, JiJi Press, Kyodo Press, Japan Times, Fuji News Network, Tokyo Broadcasting, NHK Channel BS2, WNN, IAEA, CRIIRAD, TEPCO, PM Kan's Office Website, Cryptome, Mainichi Shimbun, Yomiuri Shimbun, LinkedIn 'nuclear groups', ANS, NEI, CNIC Nuclear Exchange, KCI Publishing

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NUCLEAR EXCHANGE

http://www.nuclear-exchange.com/misc/ShowPage.aspx?pageID=1683

- UpdatedTechnical Lessons Learned 100 Days After Quake, Tsunami at the Fukushima Dai-ichi, Units
- Initial Technical Lessons Learned following the Post-Quake, Post-Tsunami, Fukushima Dai-ichi, Units 1-6, Nuclear Power Plant Accident