

HKU-Cambridge Symposium on Challenges & Priorities for Trust-Based Cross-border Nuclear Safety Emergency Governance

Priorities on Design & Construction

presented on June 12, 2014 (Thursday)

revised on June 21, 2014- advocating **The World Nuclear Safety-Peace Mission**

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World Nuclear Power Generation Capacity

2014 : US is far leading , above 40,000 MW

2006 : US is leading

Russia, China , Japan, each about 40,000 MW

2020 : China: 88,000 MW, surpassing USA

[Ref. 1. 李克強:東部沿海適時建新核電, 21 April, 2014, Wenweipo news of Hong Kong , in Chinese, on nuclear power future in China. <http://news.wenweipo.com/2014/04/21/IN1404210016.htm>

Ref. 2. **List of nuclear reactors** http://en.wikipedia.org/wiki/List_of_nuclear_reactors]

Recent demands for Safety enhancement in *Nuclear Power plants*

Recently emerged nuclear safety concerns which were not considered before 2011:

1 Severity and core-melt down cases of Fukushima reactors in March 2011, due to TSUNAMI and Earthquake → 2 questions:

1.1 For new power plants , do we need higher design provisions for TSUNAMI and Earthquake?

1.2 For existing power plants, How do we make up the safety deficits?

2. Higher chances of Uncontrollable chances of “terrorist attack” on nuclear power plants due to:

2.1 Much higher rate of world terrorism incidents in recent years

2.2 Increasing private spaceflight companies which would open up easier opportunities for possible undesirable attack on nuclear power plants by equipping explosives to such space vehicles [by terrorists] which could easily exercise ballistic *missile trajectory*

[ref. http://en.wikipedia.org/wiki/Ballistic_missile ; http://en.wikipedia.org/wiki/List_of_private_spaceflight_companies]

2.3 More frequent discovery of unidentified flying objects [Ref.http://en.wikipedia.org/wiki/Unidentified_flying_object]

2.4 Unmanned aerial vehicles become common from government, private, military, civil sectors, imposing easier opportunities for possible undesirable attack on nuclear power plants, similar to cruise missiles [ref. http://en.wikipedia.org/wiki/Unmanned_aerial_vehicle]

Are the recent proposals of U.S. Nuclear Energy Institute (USNEI) **safe enough to respond to current safety demand** ?

MAKING SAFE NUCLEAR ENERGY SAFER AFTER FUKUSHIMA

FLEX is a flexible and diverse strategy developed by the nuclear energy industry to quickly and effectively implement the Nuclear Regulatory Commission (NRC's) Fukushima task force recommendations. The FLEX protection strategy addresses the main safety challenges at Fukushima—the loss of cooling capability and electrical power resulting from a severe natural event that exceeded the plant's design basis—to make U.S. facilities even safer. It builds on safety steps taken by industry during the past three decades by providing a fast, effective and efficient way to apply the lessons learned from Japan's experience.

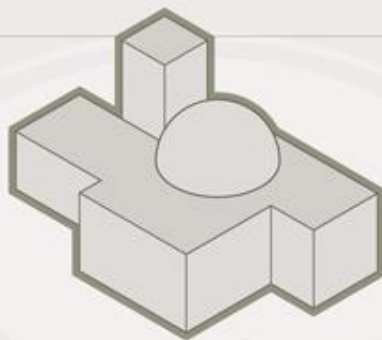
MULTIPLE LAYERS OF POWER SUPPLY

Backup generators provide reliable electrical power and cooling capability if an extreme event disables the normal plant equipment. Additional battery banks provide electrical power and cooling capability if an extreme event disrupts regular and other backup power supply.



ADDITIONAL SPENT FUEL MONITORING

Additional equipment in spent fuel storage pools will provide another layer of monitoring to ensure temperature and water levels are maintained.



ADDITIONAL PUMPS

To ensure cooling procedures are maintained during and after an extreme event, additional pumps can supply water where needed.



PREPARING OUR PEOPLE

Nuclear plant and emergency response workers will use the FLEX approach to support key safety functions across multiple reactors. Capabilities and training will be verified for nuclear plant workers to assure the continued viability and reliability of equipment. Communications capabilities will be expanded to include satellite phones and equipment to connect personnel at the plant with government emergency communications networks. Specific strategies include the following:

Enhanced Training



Expanded Maintenance and Testing of Equipment



Satellite Communications



PUBLIC OPINION

74%

of Americans believe that U.S. nuclear power plants are safe and secure

80%

of Americans believe U.S. nuclear power plants have been made safer as we've learned from experience and added technology

Source: Research Inc. with ORR. Representative of 1,000 U.S. adults. February 2012.

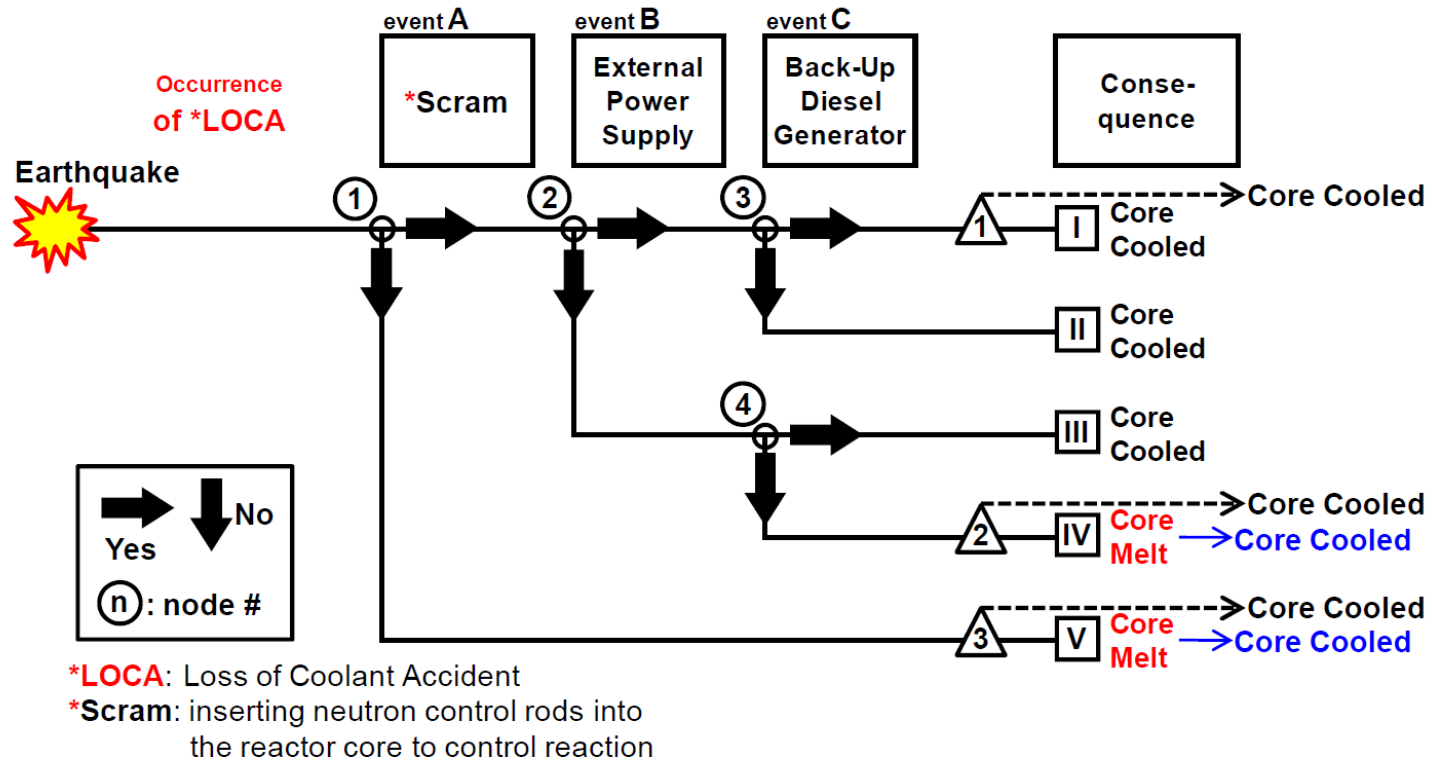
REGIONAL CENTERS

Additional emergency equipment will be stationed in off-site support centers to provide another layer of safety and ensure prolonged reliable operation.



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Recent “Core Cooled” proposals [2012] for Nuclear Power Safety Enhancement

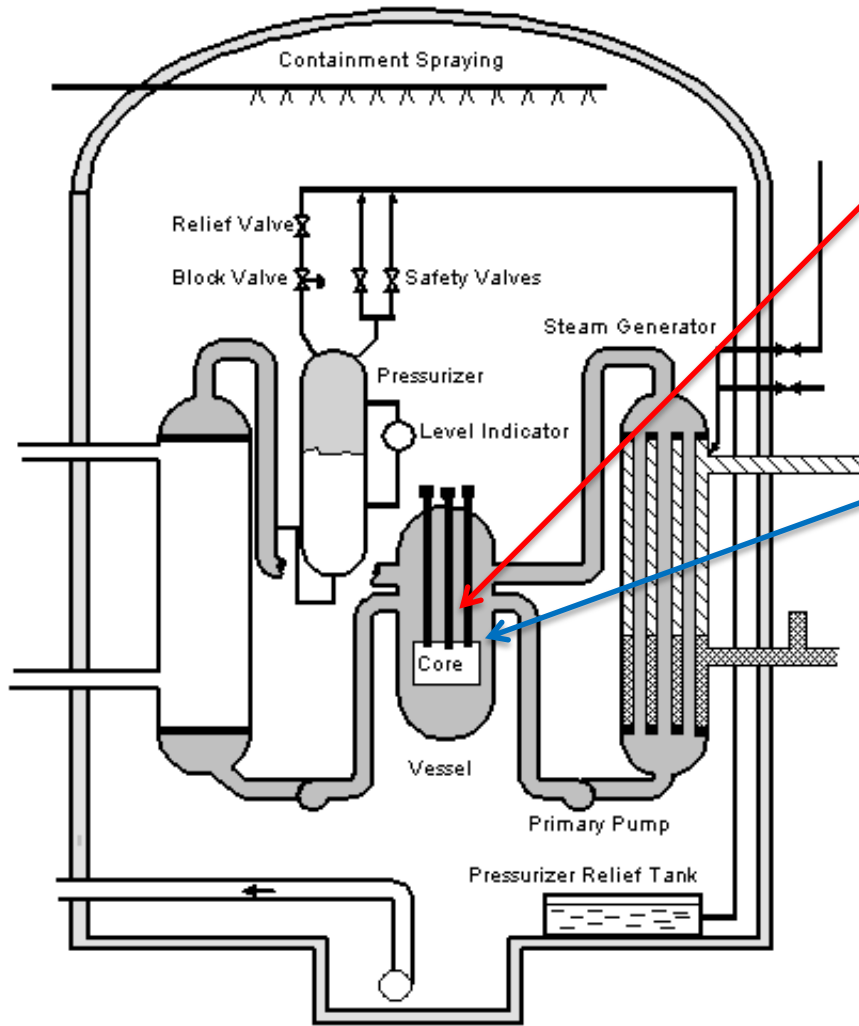


“Core Cooled” as the consequence – A simple event tree illustration

Diagram Source : Shinozuka, M., <http://www.eng.uci.edu/users/masanobu-shinozuka>
Probability and Fukushima Daiichi Nuclear Power Plant Catastrophe. The 15th World Conference on Earthquake Engineering will be held from September 24 to September 28, 2012, in Lisbon, Portugal.
<http://www.coming.pt/15wcee/index.html>

Further ref. : M. Shinozuka, K. P. Cheung, T. Nifuku. **Intelligent damage mitigation for BWR nuclear reactors.** In Proceedings of ICOSAR2013, 11th International Conference on Structural Safety & Reliability, June 16-20, 2013. Columbia University, New York, NY, USA. <http://icosar2013.org/> . Wed, June, 19, session, Session 08: Health Monitoring II, Paper HM08. <http://icosar2013.org/wp-content/uploads/2013/05/Preliminary-Program.pdf>

Recent “Core Cooled” proposals [2012] for Nuclear Power Safety Enhancement



Core melt down [safe enough?]
– unthinkable , current attitude

“Core Cooled” proposals [2012]
-NO Core melt down
– end event, really safe

Are 2012 proposals of U.S. Nuclear Energy Institute **safe enough** ?

MAKING SAFE NUCLEAR ENERGY SAFER AFTER FUKUSHIMA

MULTIPLE LAYERS OF POWER SUPPLY
Backup generators provide power to pumps and cooling capability if an extreme event disables the normal plant equipment. Additional battery banks provide electrical power and cooling capability if an extreme event disrupts engines and other backup power supply.

ADDITIONAL SPENT FUEL MONITORING
Other nuclear reactors have spent fuel pools that are not monitored as closely as those at Fukushima. Additional monitoring systems are being installed at other reactors to ensure that spent fuel is properly stored and monitored.

PREPARING OUR PEOPLE
Nuclear plant and industry workers receive training from the U.S. NRC to ensure they are prepared to respond to emergencies. Additional training and drills are being conducted to ensure that workers are prepared to respond to emergencies. Specific strategies include the following:

- Emergency drills
- Additional training
- Emergency response plans

REGIONAL CENTERS
Additional regional centers are being established to provide emergency response support. These centers will provide additional support to the nuclear industry and the public during emergencies.

PUBLIC OPINION
74% of Americans believe that nuclear power is safe and secure.
80% of Americans believe that nuclear power is the best energy source for the future.

Portable generators are not powerful enough to drive large cooling pumps

Mobile cooling pumps only perform water circulation, but **DO NOT** take away the overall system heat content

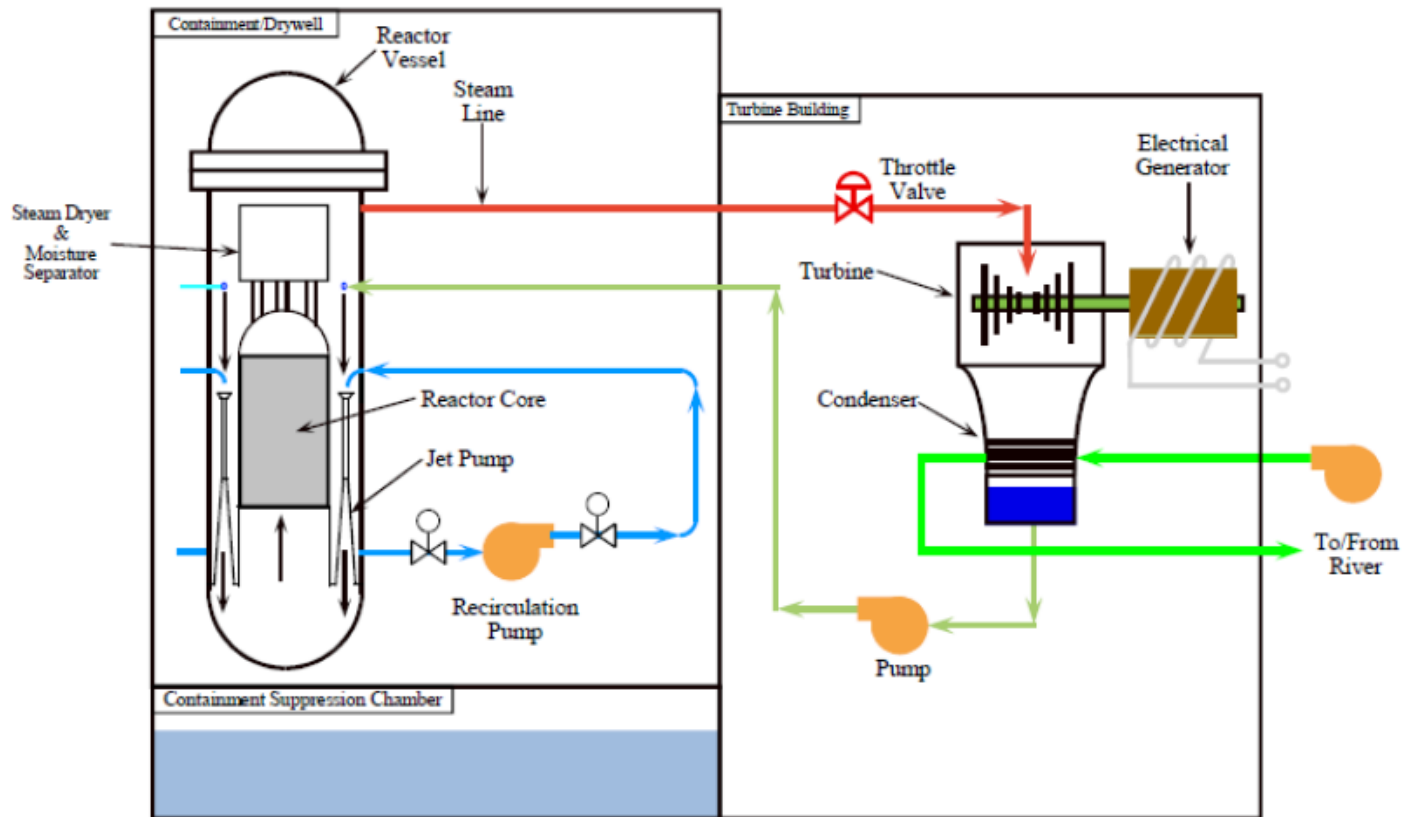


Image source: U.S. NRC. Reactor concepts manual, Boiling Water Reactor (BWR) systems.

After Fukushima of 2011 : **Proposal of Mobile closed-loop water chilling system for Nuclear power plant [Fukushima illustrated]-** to take away the overall system heat content – to attain “Core Cooled” target
- All equipment and devices are currently commercially available

Left image source : <http://www.chinatimes.com/content-images/110504/C0041423.jpg>

Ref. : M. Shinozuka, K. P. Cheung, T. Nifuku. **Intelligent damage mitigation for BWR nuclear reactors.** In Proceedings of ICOSAR2013, 11th International Conference on Structural Safety & Reliability, June 16-20, 2013. Columbia University, New York, NY, USA. <http://icosar2013.org/> . Wed, June, 19, session, Session 08: Health Monitoring II, Paper HM08.

Cheung, K. P., 1991. **A proposed back-up emergency heat removal system for nuclear power plants using mobile pumps and liquid chilling units,** ASHRAE Transactions, 97 (Part 1). <http://industrycodes.com/products/9b0b4c/ashrae-3475-proposed-backup-emergency-heat>



Closed-loop warm water from nuclear power plant

Closed-loop Cooled water to nuclear power plant

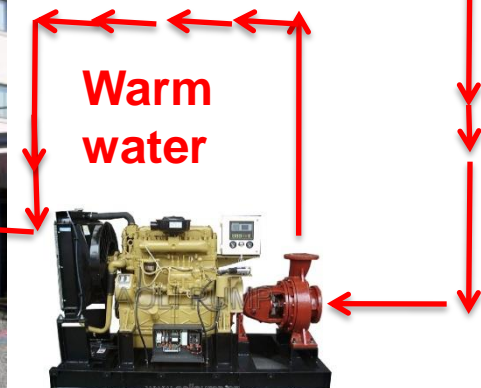
Power to chiller



Mobile diesel power generator

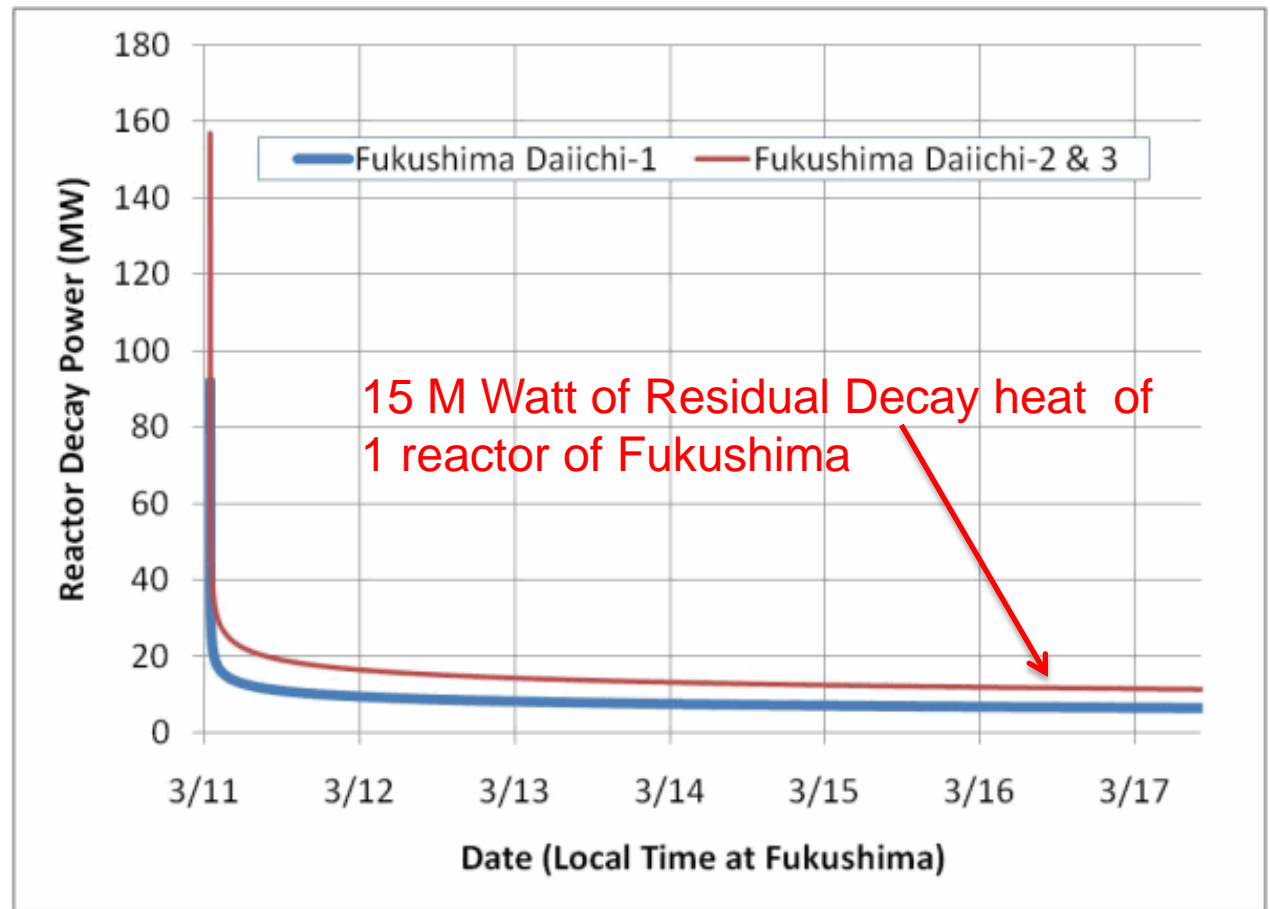
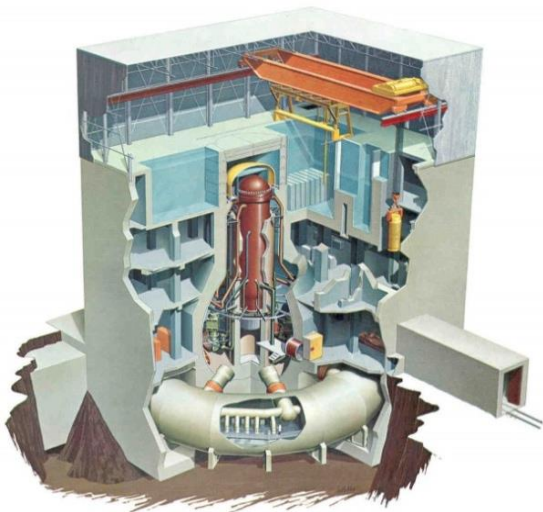
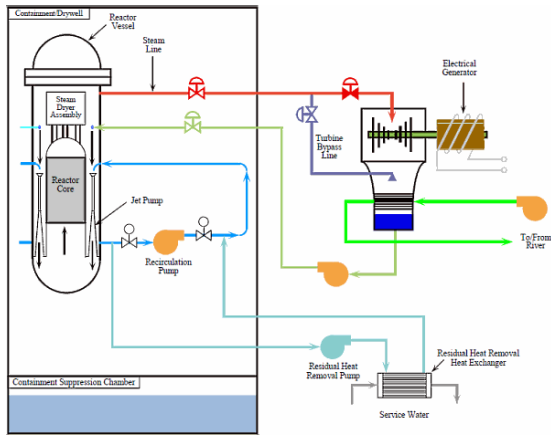


Mobile air-cooled water chiller



Mobile diesel water pump

The nuclear residual heat to be removed



The report http://www.world-nuclear.org/info/fukushima_accident_inf129.html containing figures above shows that nuclear residual heat in Fukushima is averaged to around **10 MegaWatt for each reactor**, going on for several months, in normal situations. **For abnormal conditions, higher heat content is generated, demanding increased cooling.**

After Fukushima of 2011 : **Proposal of Mobile closed-loop water chilling system for Nuclear power plant [Fukushima illustrated]-** to take away the overall system heat content – to attain “Core Cooled” target
- All equipment and devices are currently commercially available

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******* Provisions and deployment of 10 SETS of **Mobile closed-loop water chilling systems [each system of 1.5 M Watt cooling capacity]** to take away 15 M Watt of Residual Decay heat of 1 reactor of Fukushima to attain “Core Cooled” target : demanding Cross-border collaboration between neighbouring countries, and neighbouring states, provinces, prefectures, counties

Closed-loop warm water from nuclear power plant

Closed-loop Cooled water to nuclear power plant

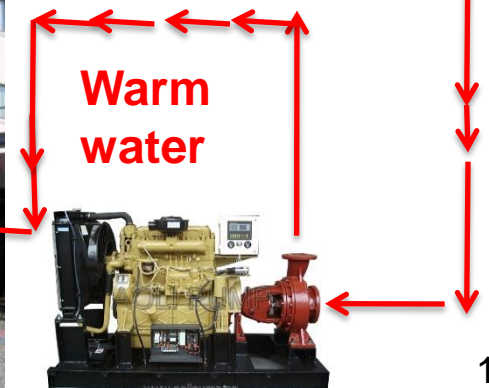
Power to chiller



Mobile diesel power generator



Mobile air-cooled water chiller



Mobile diesel water pump

Proposals for Safety enhancement in **Nuclear Power plants** to attain “Core Cooled” target

Mobile closed-loop water chilling systems, & power plant matching changes [proposed]

Recently emerged nuclear safety concerns which were not considered before 2011:

1 Severity and core-melt down cases of Fukushima reactors in March 2011, due to TSUNAMI and Earthquake:

1.1 For new power plants , do we need **higher safety design provisions for TSUNAMI and Earthquake?**

1.2 For existing power plants, How do we make up the safety deficits?

[proposed]

2. Higher chances of Uncontrollable chances of “terrorist attack” on nuclear power pants due to:

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2.4 Unmanned aerial vehicles become common from government, private, military, civil sectors, imposing easier opportunities for possible undesirable attack on nuclear power plants, similar to cruise missiles [ref. http://en.wikipedia.org/wiki/Unmanned_aerial_vehicle]

Proposed Provisions and deployment of aerial intercepting devices to guard and eliminate flying objects which will attack nuclear power plants : demanding Cross-border international collaboration between neighbouring countries, and neighbouring states, provinces, prefectures, counties

Enhanced security measures such as additional physical barriers and check points [proposed]

“Vulnerability of nuclear plants to attack” discusses

[Ref. http://en.wikipedia.org/wiki/Vulnerability_of_nuclear_plants_to_attack]

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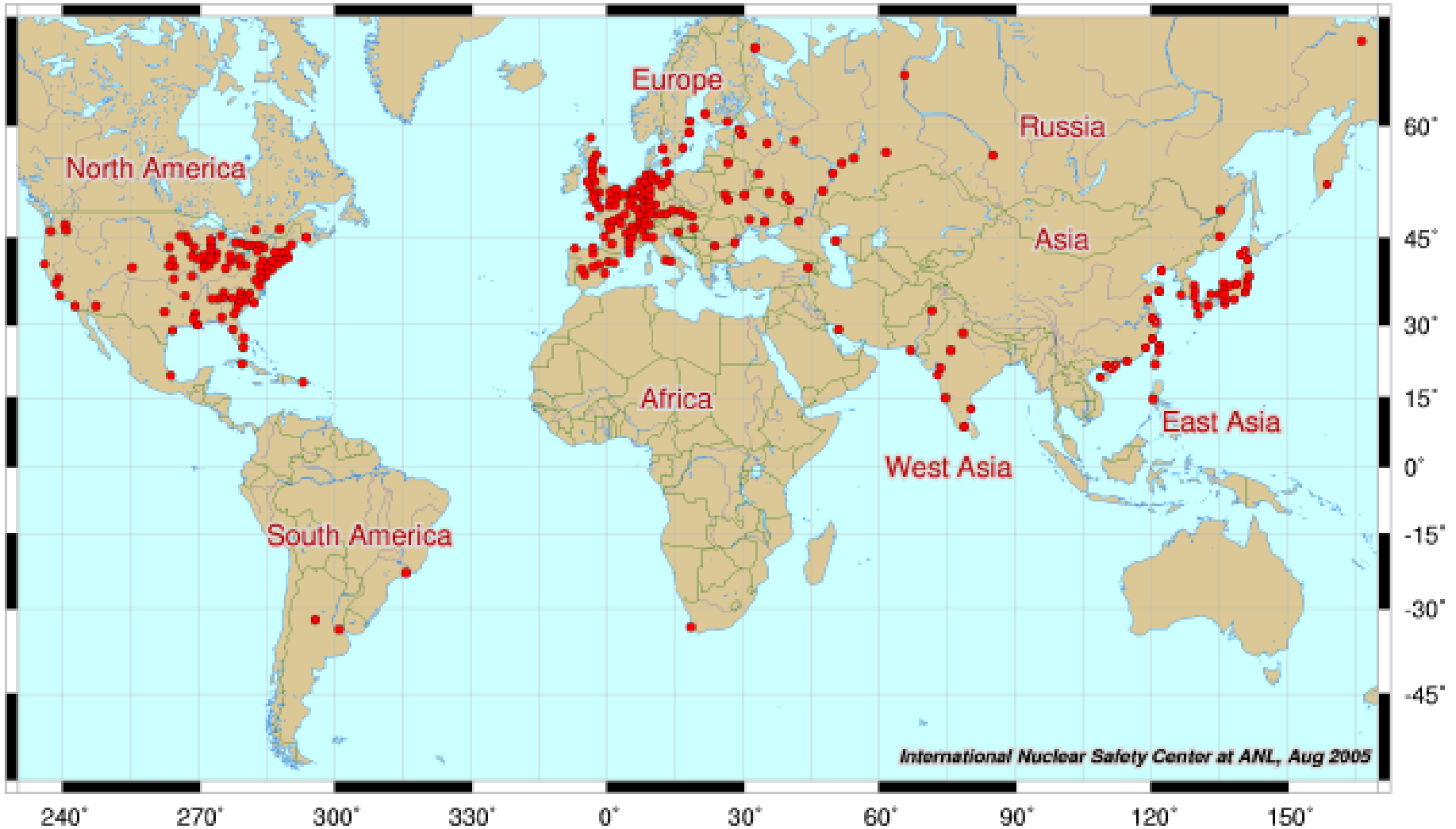
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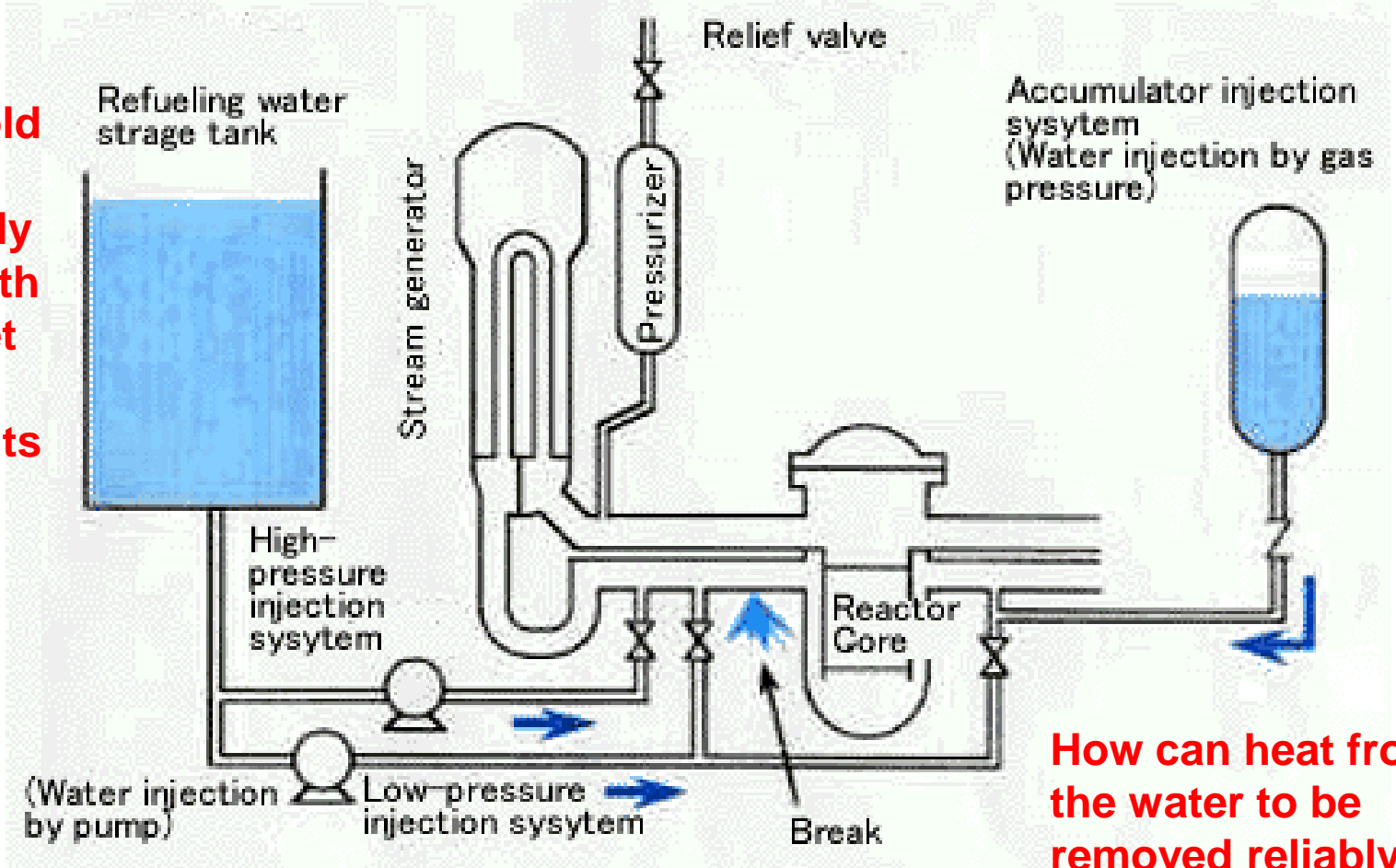
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The unwanted attack on nuclear facility [not country-military] is ever increasing in probability, beyond the ability of the current nuclear engineering safety and provisions to cope with, WITHOUT nuclear core melt down.



Worldmap of all nuclear power stations (2006)- many more in 2016, 2026- **Vulnerability to attack** Ref.

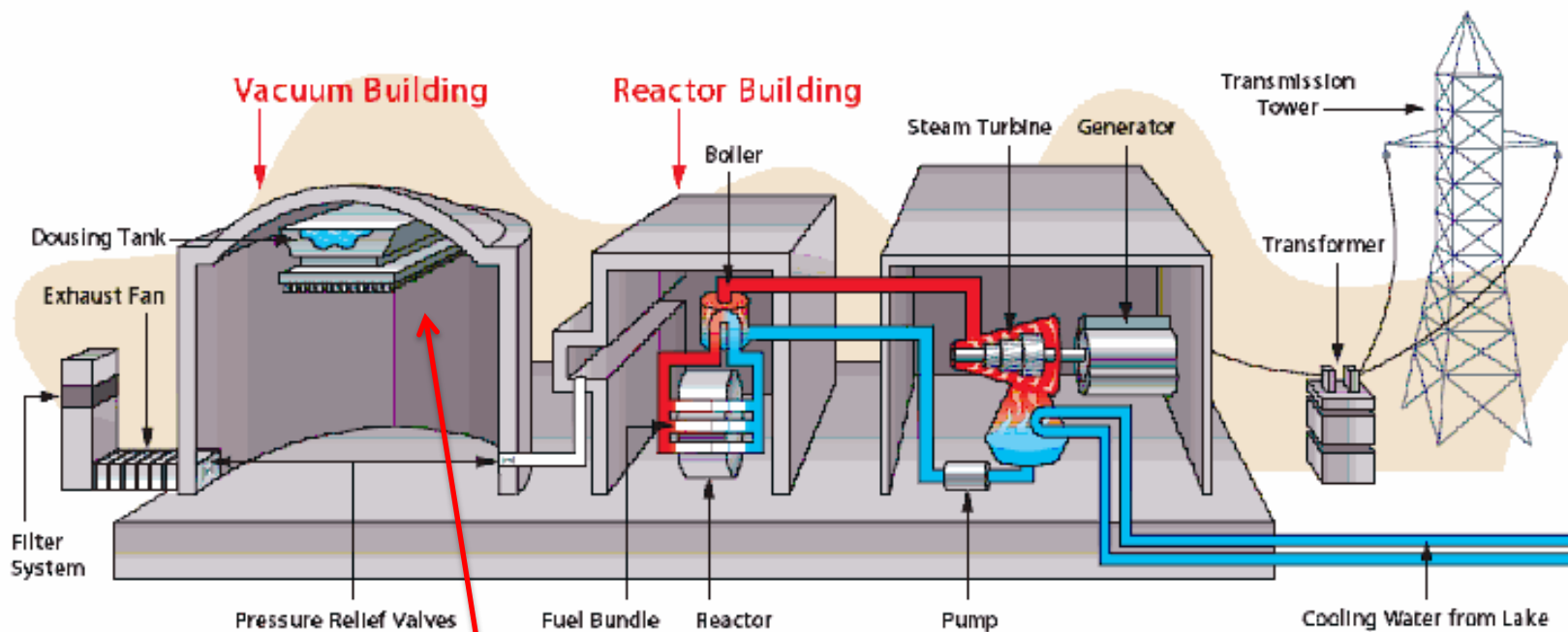
http://en.wikipedia.org/wiki/Vulnerability_of_nuclear_plants_to_attack ;
http://en.wikipedia.org/wiki/List_of_nuclear_power_stations]



How would effective cooling go on when all the pumps fail to operate and gas pressure is gone?

Concept of reactor core cooling – CURRENT PROBLEMS

[Diagram source <http://www.jaea.go.jp/jaeri/english/press/980917/gif/zu01-2.gif>]



**Cooling spray is also needed
-the mobile close-loop water chilling systems would help**

Image source - FIGURE 2.3 : PRIMARY ZONE AND RESPONSE SECTORS

https://www.emergencymanagementontario.ca/english/beprepared/ontariohazards/nuclear/nuclear_plan_bruce.html

“Vulnerability of nuclear plants to attack” discusses

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The unwanted attack on nuclear facility [not country-military] is ever increasing in probability, beyond the ability of the current nuclear engineering safety and provisions to cope with, WITHOUT nuclear core melt down.

Provisions and deployment of **Mobile closed-loop water chilling systems** to take away Residual Decay heat of reactors will attain “Core Cooled” target : demanding Cross-border collaboration between neighbouring countries, and neighbouring states, provinces, prefectures, counties

To increase nuclear power plant safety against Unwanted attack:

- To put nuclear reactor building underground?
- To build stronger enclosure for related facilities such as power center, control center, cooling water intake and outfall, etc.?
- Internationally collaborative military protection against aerial attack on nuclear power plants, by detecting, monitoring, shooting down of flying objects likely to attack nuclear facilities; calling for **Cross-border collaboration between neighbouring countries, and neighbouring states, provinces, prefectures, counties**
– **The World Nuclear Safety-Peace Mission ?**

The World Nuclear Safety- Peace Mission

Thank you very much

Acknowledgment : This is a research project of HKU- Initiative on Clean Energy & Environment, <http://icee.hku.hk/index/index.html> , An area of HKU Strategic Research Area on Environment, <http://www.hku.hk/research/sras/areas-and-themes.html> , supported by University Development Fund, HKU

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[<http://icee.hku.hk/index/index.html>] 其中一項研究項目，承蒙香港大學發展基金資助。