环境保护部核与辐射安全中心
Nuclear and Radiation Safety Center

Safety enhancement of NPPs in China after the Fukushima Nuclear Accident

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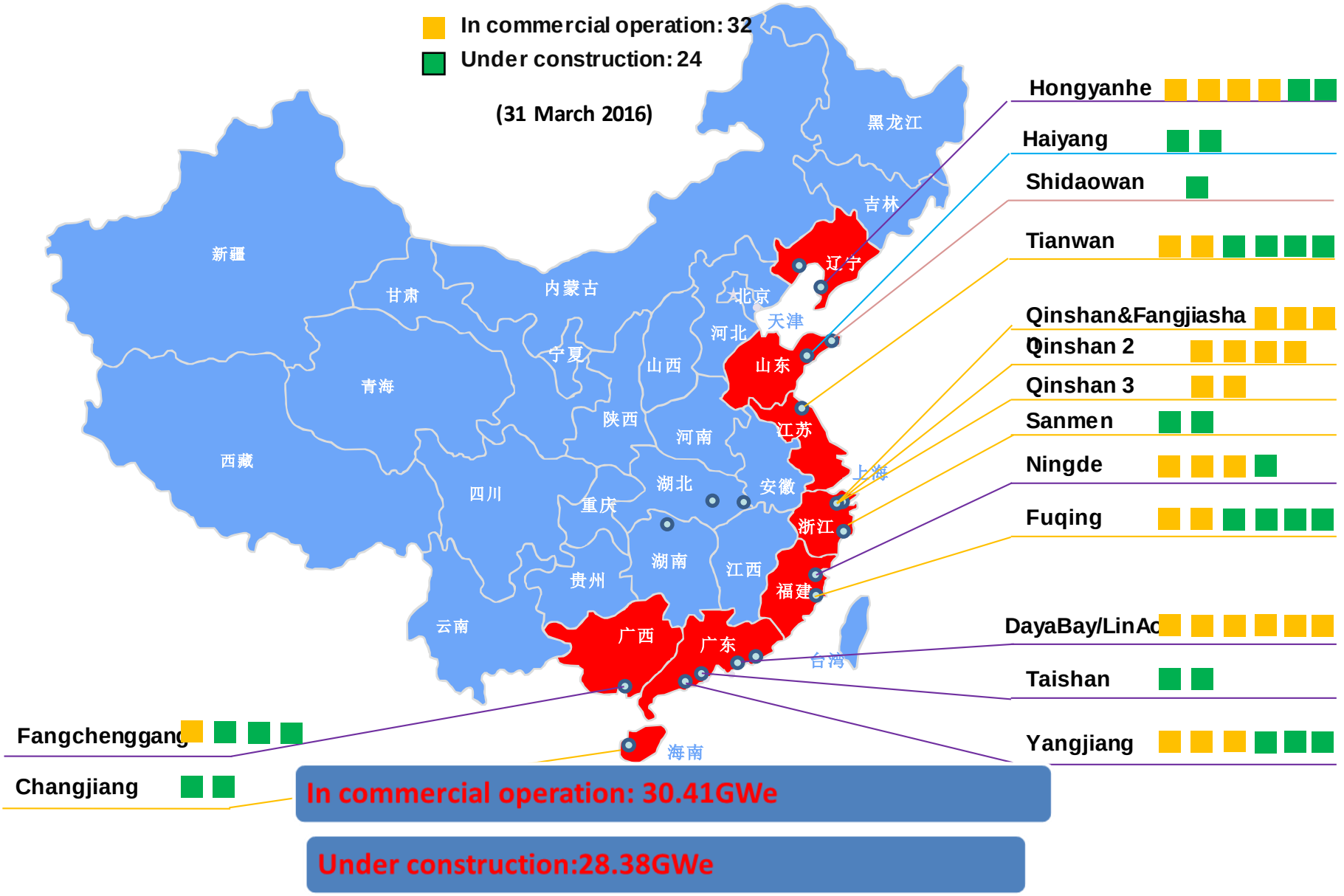
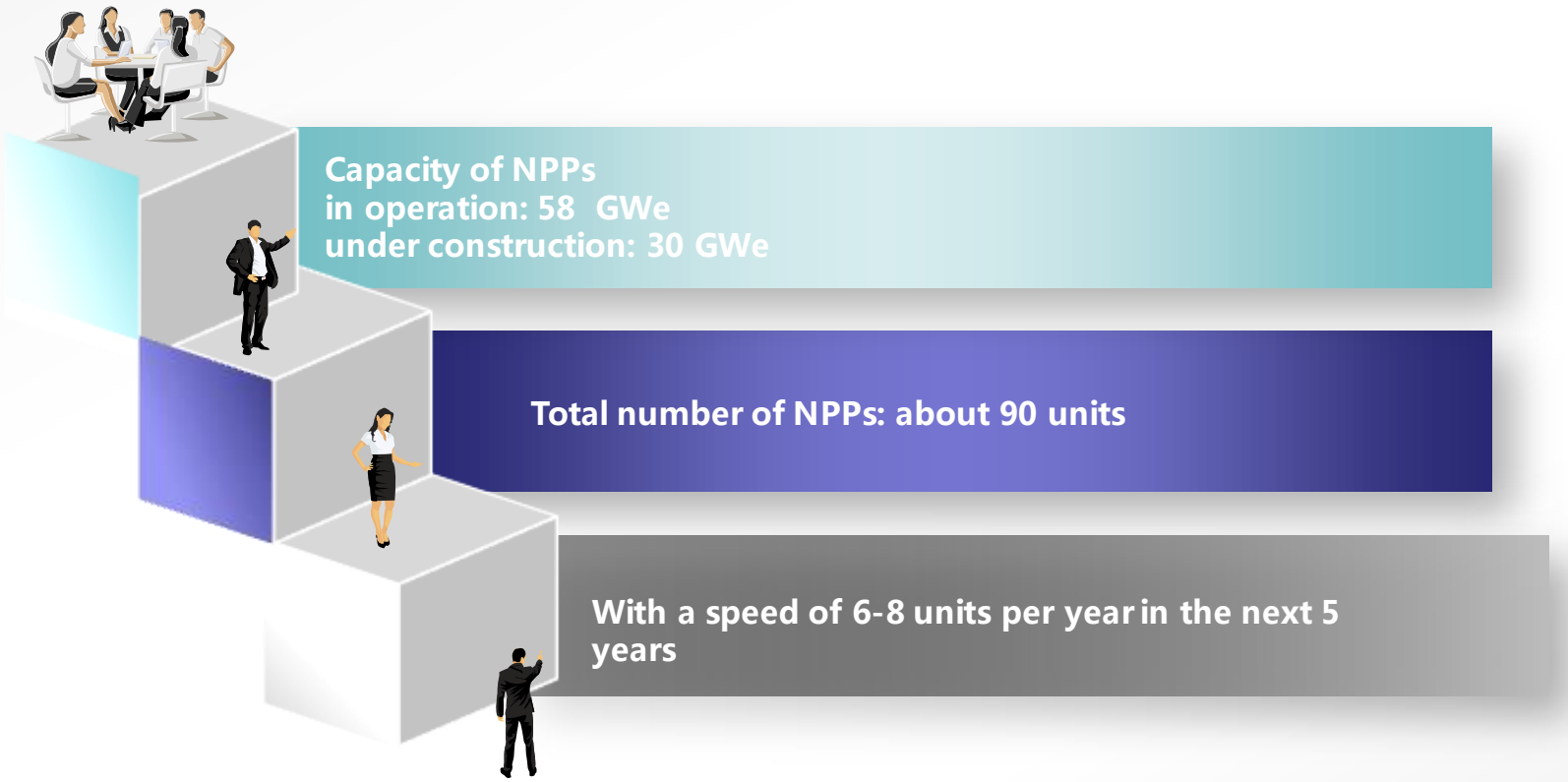
12 April 2016, Vienna

WEBSITE
http://www.chinansc.cn/

Current NPPs in China



Plan of NPPs in 2020



Newly-built NPPs

CAP1400: 2 units CAP1400 demonstrate project units 1&2, review of PSAR is finished.

HPR1000: 4 units
Fuqing NPP units 5&6, May 2015
Fangchenggang NPP units 3&4, Dec. 2015

CAP1000
Sanmen NPP units 3&4, review of PSAR
Haiyang NPP units 3&4, review of PSAR
Lufeng NPP units 1&2, review of PSAR
Xudapu NPP units 1&2, review of PSAR

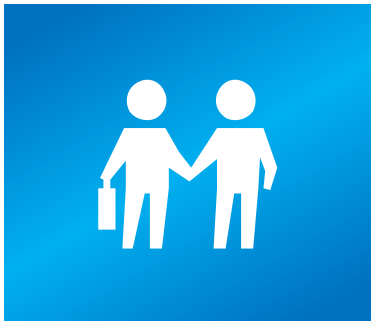



Challenge to NNSA

Heavy working load

Capacity building

Public confidence



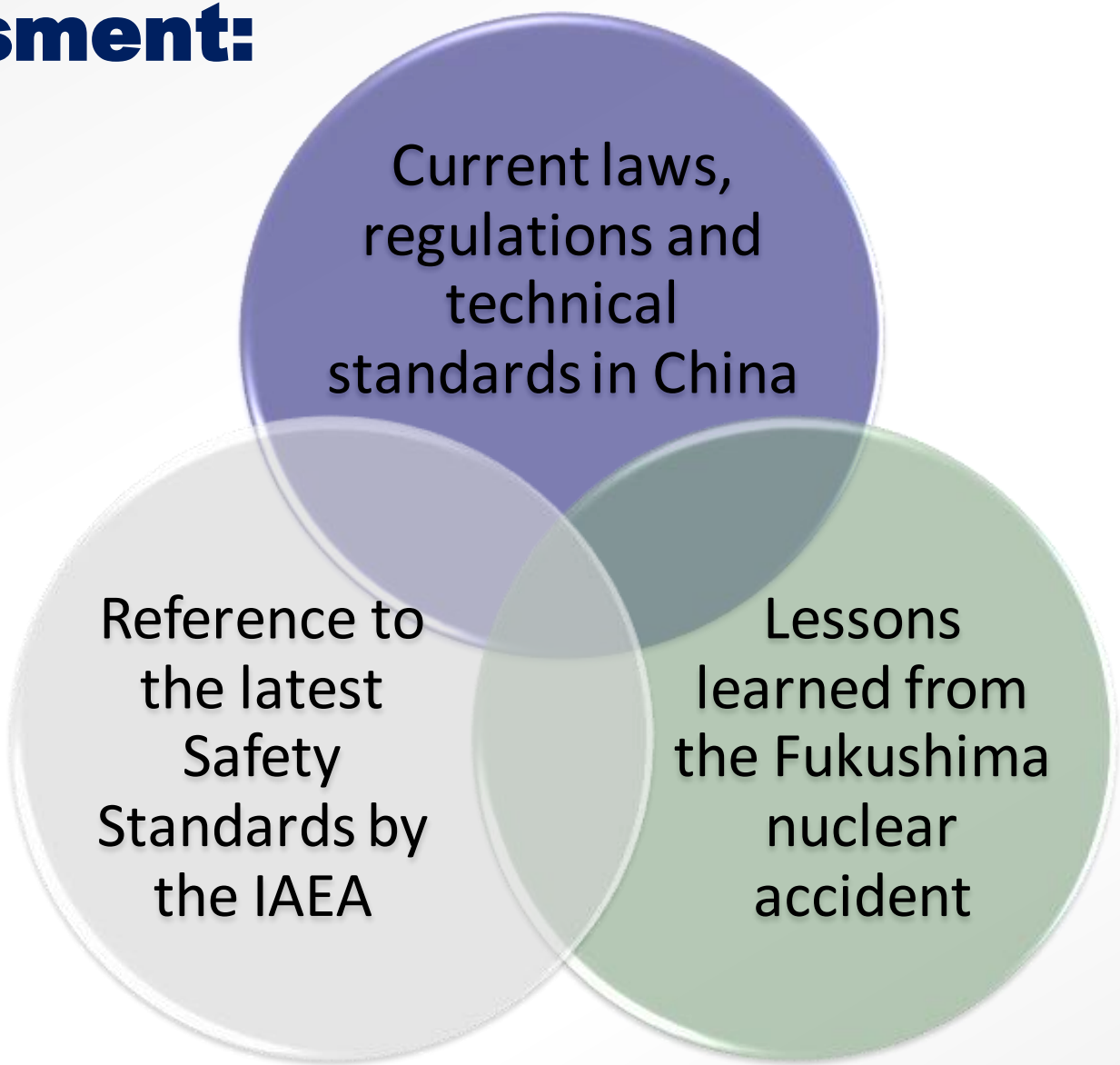
Safety standards

Challenge to NNSA

Set up the safety standards after the Fukushima Nuclear Accident

- Safety standards for existing NPP
- Safety standards for newly-built NPP
- Challenge
  - ✓ Confidence of public to nuclear safety is serious affected.
  - ✓ Investigation of and experience feedback from the Fukushima Nuclear Accident are going on.
  - ✓ A lot of discussion and debate about new safety philosophy and new safety requirement, but without final agreement.

Comprehensive Safety Assessment: Basis



Safety Assessment: Content

- Assessed External Events During Siting
- Plans and Measures Against Flooding
- Analysis and Evaluation of the NPP Black-out Incident and Emergency plan
- Plans and Measures Against Seismic
- Measures to Prevent Accidents from Multiple Extreme Natural Disasters
- Prevention & Mitigation Measures for Severe Accidents
- Effectiveness of Environment Monitoring and Emergency Response Systems

Safety Assessment: Conclusion

NPPs' design, construction and operation satisfy the requirements of Chinese safety regulations, and reach the safety level in IAEA's latest safety standards

The NPPs have certain capabilities to prevent and mitigate severe accidents

- ✓ Additional permanent installed DG for each sites.
- ✓ Diversity turbine driven AFW
- ✓ PARs in the containment
- ✓ Filtered Containment Vent system
- ✓ Improvement with the consideration of Experience feedback, such as LOT93, VD2, VD3, etc.

Improvement Actions: Operating NPPs

•Short-term actions (to be accomplished before the end of 2011)

- ✓ Water-proofing seal and blocking
- ✓ Additional portable power supply and pumps, etc.
- ✓ Effectiveness of NPP's earthquake monitoring systems and anti-seismic and response capacities

•Long-term projects

- ✓ PSA level 2, PSA for external events, etc.

01

02

03

04

•9 actions

•Medium-term actions (to be accomplished before the end of 2013)

- ✓ Upgrade of flooding prevention facilities, if necessary
- ✓ Thorough assessment of earthquake and tsunami risks, and safety margin evaluation of external events
- ✓ Improvement of SAMG, and improvement of the hydrogen removal facility if necessary
- ✓ Strengthening of Emergency response capacities;
- ✓ Improve information transparency and public communication

Improvement Actions: NPPs under Construction

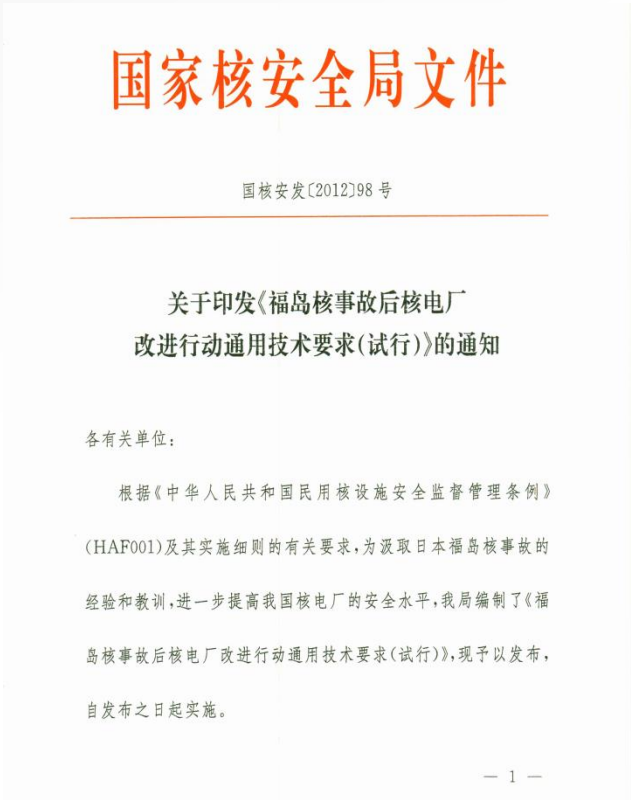
- **Actions before first fuel loading**
  - ✓ Water-proofing measures
  - ✓ Additional portable power generator and pumps, etc.
  - ✓ Habitability and functions of emergency center
  - ✓ Upgrade of flooding prevention facilities
  - ✓ Thorough assessment of earthquake and tsunami risks, and safety margin evaluation of external events
  - ✓ Improvement of SAMG, and improvement of the hydrogen removal facility if necessary
  - ✓ Strengthening the emergency response capacities
  - ✓ Enhancement of the early warning and response capacities in case external disasters should occur
  - ✓ Improve information transparency and public communication

- **10 actions**

- **Long-term projects**
  - ✓ PSA level 2, PSA for external events, etc.

Improvement Actions: General Technical Requirements

- *Generic Technical Requirements on Improvement Actions for NPPs after the Fukushima Nuclear Accident*, published by NNSA in June 2012



国家核安全局文件

国核安发〔2012〕98号

关于印发《福岛核事故后核电厂改进行动通用技术要求(试行)》的通知

各有关单位：

根据《中华人民共和国民用核设施安全监督管理条例》(HAF001)及其实施细则的有关要求，为汲取日本福岛核事故的经验和教训，进一步提高我国核电厂的安全水平，我局编制了《福岛核事故后核电厂改进行动通用技术要求(试行)》，现予以发布，自发布之日起实施。

— 1 —

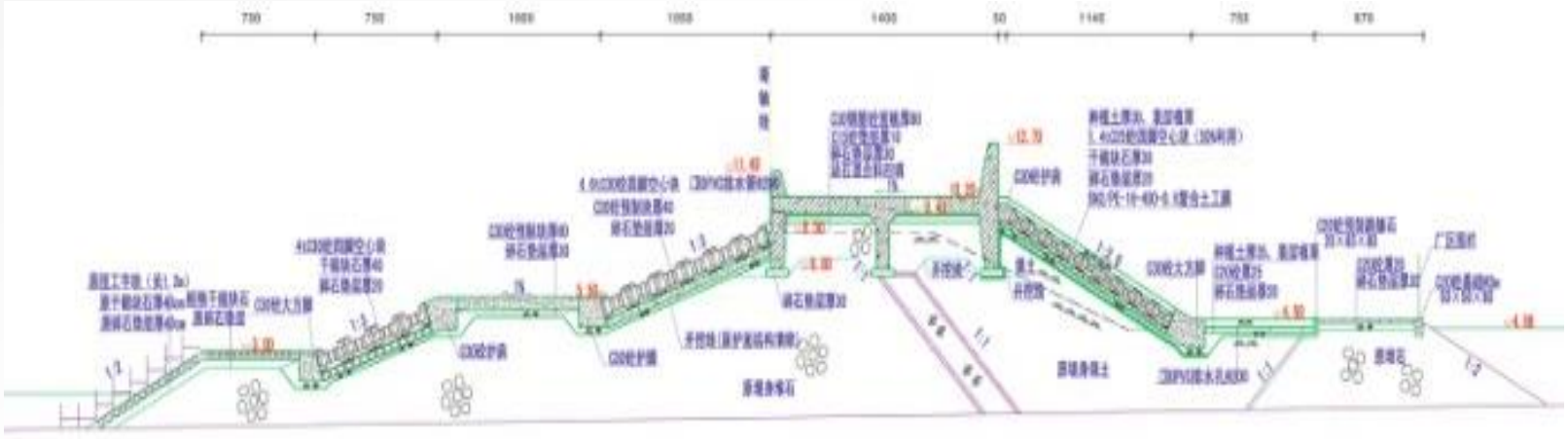
- Flood defense capability improvement
- Emergency Water-Injection and related Equipment
- Portable Power Supply
- Monitoring of Spent Fuel Pool
- Hydrogen Monitoring and controlling system
- Habitability and functions of emergency center
- Radiation environmental monitoring and emergency
- Emergency plan for external natural disasters

Improvement Actions: Implementation Status

- Short-term actions: accomplished before the end of 2011
- Medium-term actions: all accomplished before the end of 2013
- long-term actions: Progress meet the time schedule requirements
- Upcoming lessons learned from Fukushima accident and international good practice will be referred continuously to improve the safety level of NPPs in China

Water Proofing seal and blocking for Safety Important Building

Qinshan NPP, Flood-Prevention Reconstruction



Emergency Portable Water & Power Supply Equipment

Challenge to NNSA and its TSO

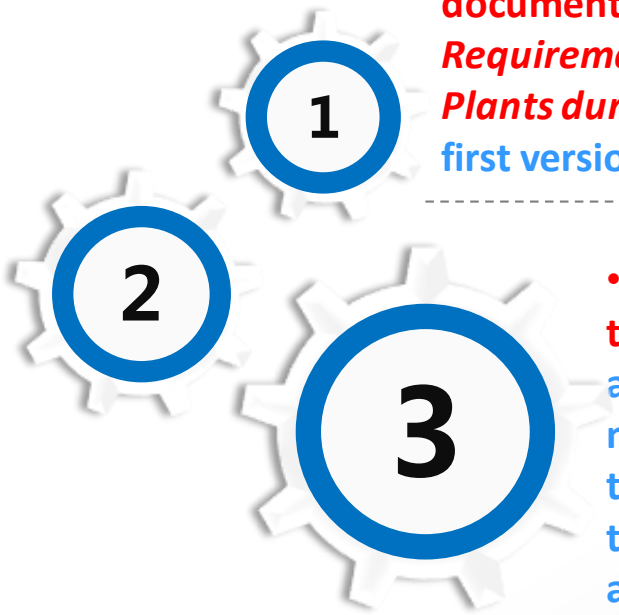
Set up the safety standards for newly-built NPPs

- New safety goal: practical elimination of large radioactive releases
  - Planning on Nuclear Safety and Radioactive Contamination Treatment and a Long-term Goal 2020 (Nuclear Safety Plan)
  - Vienna Declaration on Nuclear Safety

Safety improvement: Requirements for new NPPs

•From June 2012, NNSA and its TSO were preparing an **internal control document** named as ***the Safety Requirements for New Nuclear Power Plants during the 12th five-years***. the first version was finished in Sep. 2013

•Based on implementing the current nuclear safety regulations ,the document **complements and expends some key issues on nuclear safety**



•**Enhancing the concepts of the diversification on design**, and continuously improving nuclear power safety by using the most up-to-date technologies and research achievements

Safety improvement: Requirements for new NPPs

- Adopted new safety concepts and new requirements in the documents such as IAEA SSR-2/1 "Safety of Nuclear Power Plants: Design" issued in 2012, *the "Safety of New NPP Designs"* issued by the Western European Nuclear Regulators Association (WENRA) in March 2013, and the NRC Standard Review Plan (SRP), etc.;
- Reflect *the General Technical Requirements on improvement actions for NPPs after the Fukushima Nuclear Accident* .

Safety improvement: Requirements for new NPPs

- Safety Analysis

The results of deterministic and probabilistic safety analysis must be considered;

PSA Level 1 and 2 on internal and external events during the plants states including power operation and outages must be fulfilled. The analysis objects include core, spent fuel pool.

Safety improvement: Requirements for new NPPs

- Defense in Depth (DID)
  - Emphasize the effectiveness of DID and the independence between individual levels. The DID approach is also requested for defensing external events, especially through multi-level defense to prevent and mitigate severe accidents caused by extreme external events.

Safety improvement: Requirements for new NPPs

- **External events defense**
  - **For new NPPs, the Design Basis Earthquake Motion Level（SL-2, or SSE）should not be lower than 0.30g; the earthquake warning system in NPPs should be able to initiate the reactor trip automatically.**
  - **The Flood defense design of NPPs must consider the impact of extreme flood events and combined flood events. The NPP floor elevation should be higher than the design basis flood level.**
  - **For the NPPs with crash risk by large-size commercial airplanes, the design should consider the effects by large-size commercial airplanes crash..**

Safety improvement: Requirements for new NPPs

- **Station Black Out**
  - **Besides the stationary additional power supply at the plant site, on a multi-units site at least two portable DGs and portable pumps should be equipped.**
  - **The reliability of the offsite power should be enhanced, or appropriate compensatory measures should be considered.**

Safety improvement: Requirements for new NPPs

- Severe accidents prevention and mitigation
  - Place equal emphasis on prevention and mitigation.
  - Confirm to formulate and improve the Severe Accidents Management Guideline.
  - Measures such as responding station blackout , high-pressure core melt, global hydrogen explosion, molten-core concrete interaction, and containment bypass, etc. should be adopted in design.

Safety improvement: Requirements for new NPPs

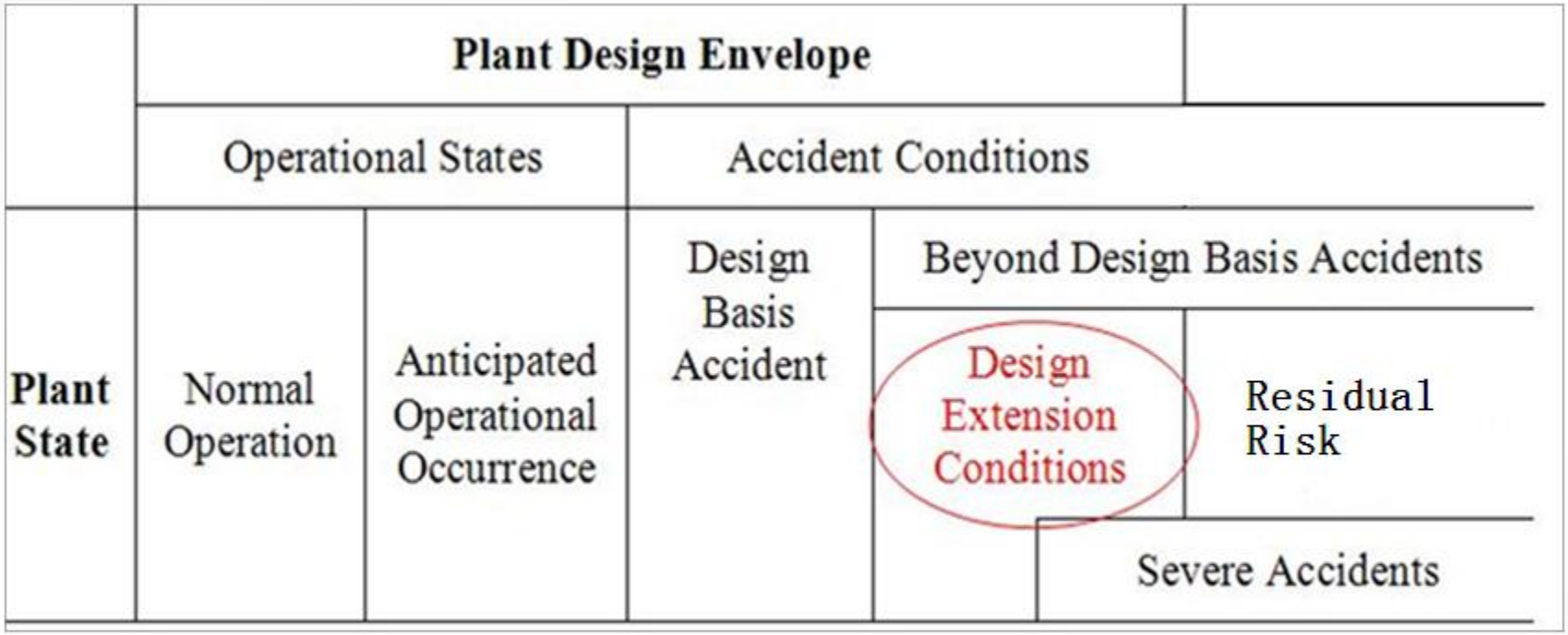
Reactor coolant system

Remove the residual heat from the safety important item of nuclear power plant to the ultimate heat sink with high reliability in all plant operating modes; meanwhile the diversity of heat sink should be considered.

Safety improvement:
Consideration of Update of safety requirements for new NPPs

- Practical elimination of large radioactive releases.
  - ✓ Extend the plant design envelope.
  - ✓ Enhance the concept of defense in depth.

States of Nuclear Power Plant



Levels of defense in depth

Level of defense in depth	Safety goals	Basic measures	Plant states
1	Prevention of abnormal operation and failure	Conservative design and high quality construction and operation	Normal operation
2	Control of abnormal operation and detection of failures	Control, limiting and protection system and other surveillance features	Anticipated operational occurrence
3	Control of accidents within design basis	engineered safety features and Emergency operating procedures	Design basis accident（single failure postulated initial event）
4	Control of severe accident, including prevention of severe accident（4a） and mitigation of consequence（4b）	Additional safety systems and severe accident management	Design extension condition, including multiple failure（4a） ,serve accident（4b）
5	Emergency rescue work on extremely condition, mitigation of offsite radioactivity	supplementary safety measures, Extensive Damage Mitigation, offsite emergency response	Beyond design extension condition (Rresidual risks), i.e. extensive damage state

Safety improvement: Method to mitigate accident

01

Engineered safety features

For the design basis accidents. such as ECCS. safety level, seismic category I, conservative analysis Single failure criteria

02

Additional safety systems

For the design extension condition. such as severe accident rapid Relief Valves. non safety class, functional after SSE, realistic analysis
Redundancy for some key functions

03

Supplemental safety measures

to minimize the consequences of residual risk. such as portable DG, portable pump and reservoir for mitigating extensive damage state of NPP; flittered containment venting measures, store and treatment features of radioactive waste liquid; the safety storage building for portable equipment ; offsite assistant team with portable equipment.

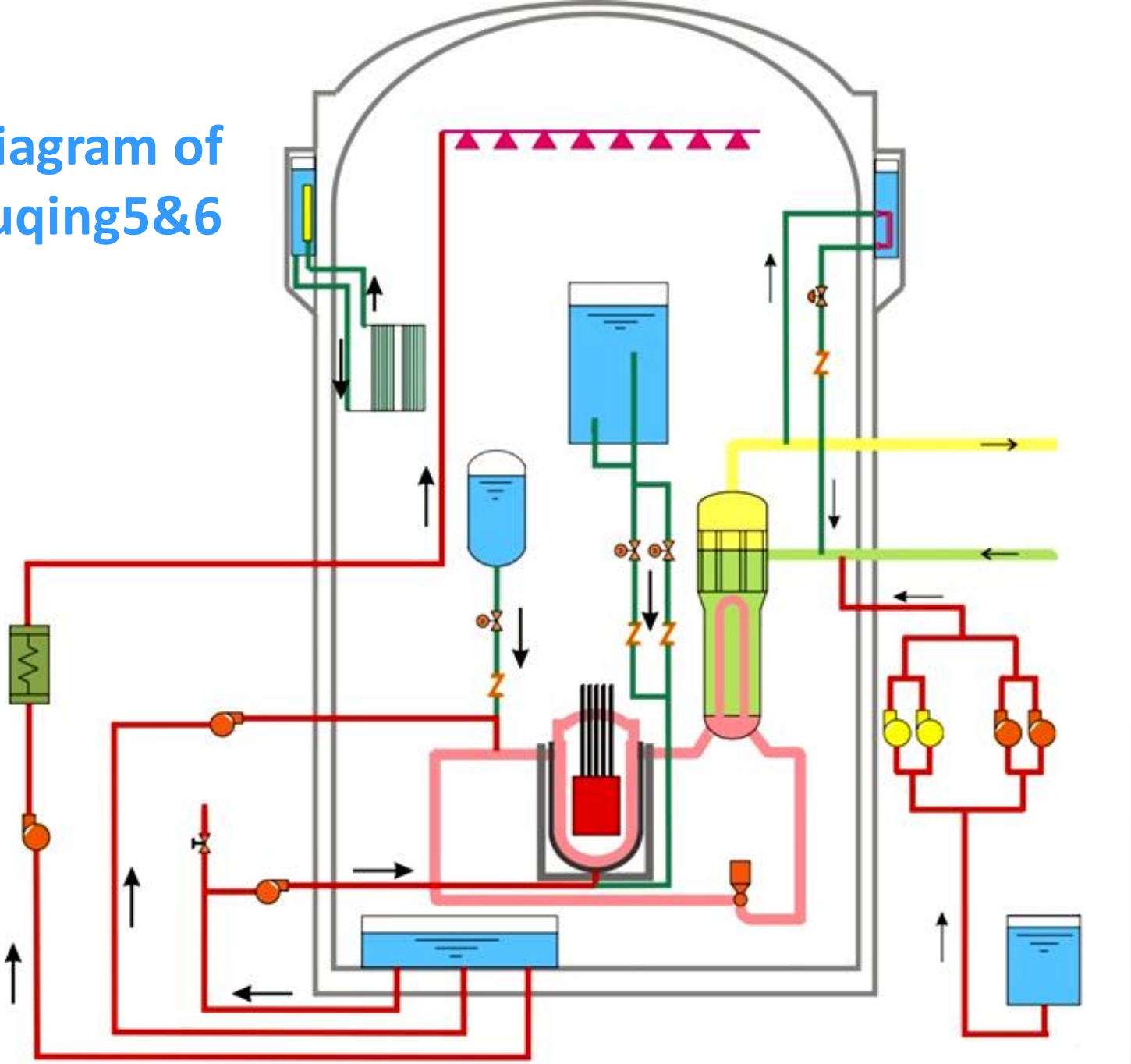
Safety improvement:
Application of new safety requirements in new NPP designs

- Experts and representatives from industry were involved during preparation of new safety requirements
- Experts and representatives from NNSA and its TSO were invited to participate in the meeting related to new design of NPP
- A lot of discussion and debate during PSAR review
- New safety requirements have been considered in the new design of NPP after Fukushima nuclear accident.
  - HPR1000 (Hualong-1)
  - CAP1400
  - CAP1000

Safety enhancement: New built NPPs: HPR1000

- Chinese-designed new reactor type, considering the experience feedback from the Fukushima nuclear accident, fully considering the measures of preventing and mitigating severe accident:
  - ✓ Equipped with double containments;
  - ✓ Equipped with sealing function for main coolant pump in case of pump shutdown;
  - ✓ Equipped with DAS system which is SSE seismic designed;
  - ✓ Equipped with a backup DG for each reactor;
  - ✓ Equipped with Dedicated SSCs to cope with severe accident;
  - ✓ Adopt many diversity safety system design (active+passive);
  - ✓ Equipped with rapid pressure release valves during severe accident that can satisfy redundancy requirements;
  - ✓ Adopt IVR cooling function;
  - ✓ Equipped with filtered containment venting system, etc.

Diagram of Fuqing5&6



Safety enhancement: New design of NPPs: CAP1400

- Chinese-designed new reactor type, expected to be built in China in near future, has made great safety improvements:
  - ✓ Improve the seismic resistance of DAS system and adds earthquake automatic reactor trip signal;
  - ✓ Improve the seismic resistance of SSCs dedicated to mitigate severe accident consequence;
  - ✓ Improve the seismic resistance of standby DG in NPPs;
  - ✓ Improve the seismic resistance of Ignitor, and add some PARs to control hydrogen in containment;
  - ✓ Enhance the seismic resistance of CCWS and SWS which can transfer the residual heat into the sea, so that the sea can be the diversity ultimate heat sink, and perform the function as defense-in-depth (passive+active);
  - ✓ Improve filtered containment venting measures;
  - ✓ Equipped with portable DG and portable pump.

Safety enhancement:
Revision of HAF102

- SSR-2/1 (Rev.1) has been issued in Feb 2016 by IAEA.
- HPR1000 and CAP1400 can meet its requirements.
- NNSA is planning to update HAF102 with reference to the latest version of SSR-2/1 (Rev.1)

Technical Issues need to be considered

- How to calculate the Radiological consequence of DBA?
  - Should the Source Term of DBA be conservative or realistic?
- How to consider the external events?
  - Should it be considered as PIEs?
- What's the design requirement for SSCs dedicated to mitigate Severe Accidents?
  - Should it be safety class or non safety class with specific requirement?
- What's kind of and how many portable equipment are need?
  - What's the design basis for portable equipment?

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Thanks for Attention!

Questions & Comments?

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