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Technical Insight of the High Level Safety Goal for the NPPs Built in China's Thirteenth Five-Year (2016-2020)

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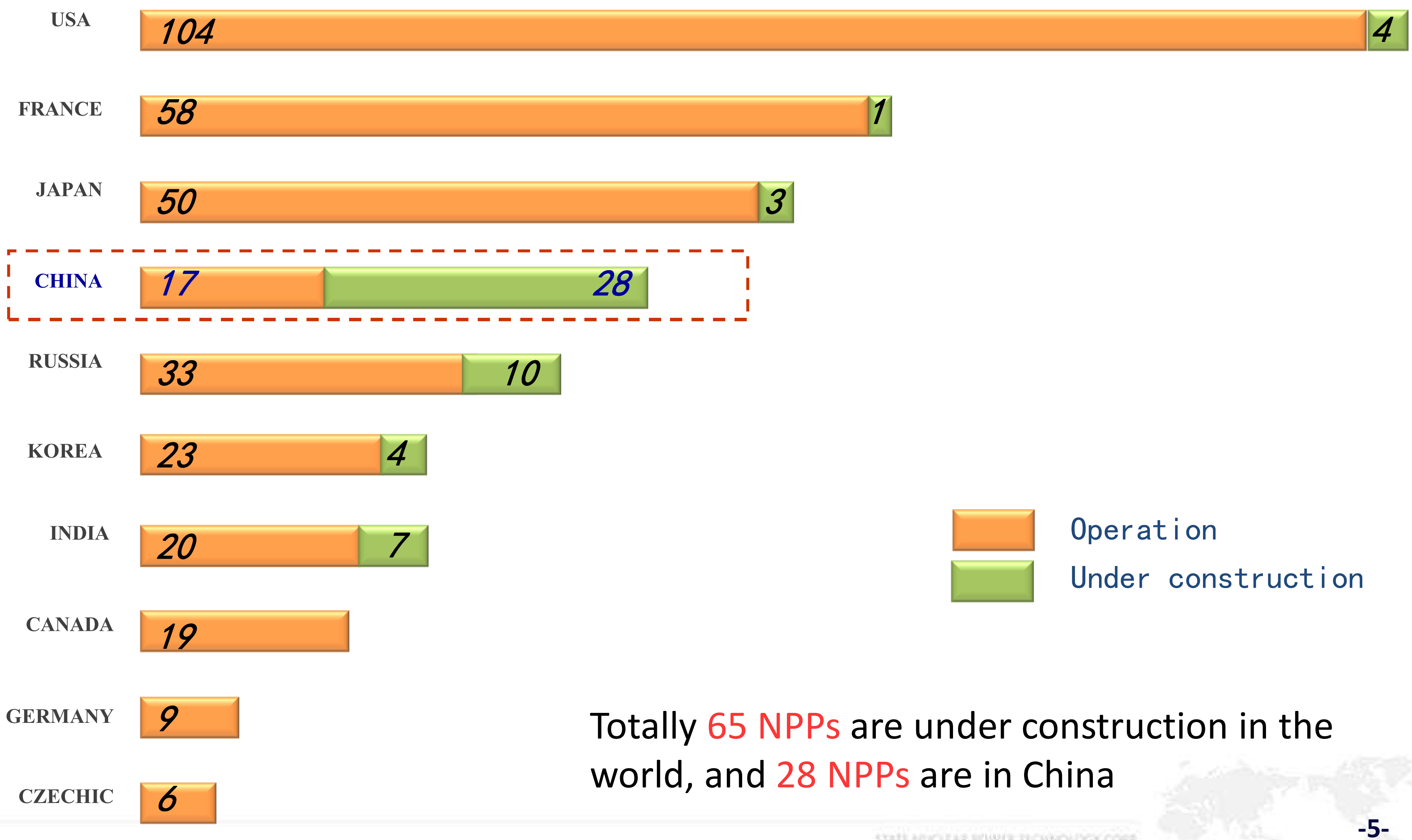
Content

1. Overview of the NPP development and the Safety Goal for the NPPs Built in China's Thirteenth Five-Year

Overview of the NPP development

- Construction of the first NPP (Qinshan Phase 1) in the mainland of China began in 1993
- National Nuclear Safety Administration (NNSA) is the nuclear safety regulator, responsible for development and publication of nuclear safety and radiation protection regulations and guidelines
- In this decade, nuclear power has been looked into as an alternative to coal power
- As of 2013, there are 17 NPPs spread out over 4 separate sites, and 28 NPPs are under construction. Many NPPs are in consideration

The world's NPPs



Totally 65 NPPs are under construction in the world, and 28 NPPs are in China

❑ Safety Goal for the NPPs Built in China's Thirteenth Five-Year

- The government has paid a great attention to the nuclear safety
- On March 16th, 2011, immediately after Fukushima accident, China's State Council meeting made decisions:

➢ perform a comprehensive safety inspection of the operating NPPs and NPPs under construction

➢ suspend the construction permit issuance process for new NPPs

➢ publication of Nuclear Safety Planning as soon as possible

- The State Council approved Nuclear Safety Planning in Oct. 2012, the safety requirements for NPPs were stipulated
  - The safety requirements for NPPs built in China's Twelfth Five-Year (2010-2015) : severe accident prevention and mitigation measures should be considered thoroughly in the design, and core damage frequency and large release frequency should be assessed to be lower than 1E-5/reactor-year, 1E-6/reactor-year respectively
  - The safety requirements for NPPs built in China's Thirteenth Five-Year (2016-2020) and later : the possibility of the large radioactive release should be practically eliminated by design

- The safety requirements for NPPs built in China's Thirteenth Five-Year (2016-2020) and later is high level safety goal, need to be developed in a coherent and consistent manner into lower level safety goals and targets

MDEP Hierarchy of Safety Goals

2. Safety Goals of Nuclear Organizations and Several Countries

❑ IAEA

- SF-1, 2006: The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation
- INSAG-12，1999，for New Build NPPs
  - ➢ The CDF should be lower than 1E-5/reactor-year
  - ➢ Accident sequences that could lead to large early release could be practically eliminated
- NS-G-1.10
  - ➢ The possibility of certain conditions occurring is considered to have been practically eliminated if it is physically impossible for the conditions to occur or if the conditions can be considered with a high level of confidence to be extremely unlikely to arise

❑ WENRA

- O1. Normal operation, abnormal events and prevention of accidents
- O2. Accidents without core melt
- O3. Accidents with core melt
  - Accidents with core melt which would lead to early or large releases have to be practically eliminated
  - For accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public and that sufficient time is available to implement these measures
- O4. Independence between all levels of defense-in-depth
- O5. Safety and security interfaces
- O6. Radiation protection and waste management
- O7. Management of safety

❑ US NRC

- Safety goal policy statement issued in 1986

  two qualitative goals two quantitative health objectives (QHOs)

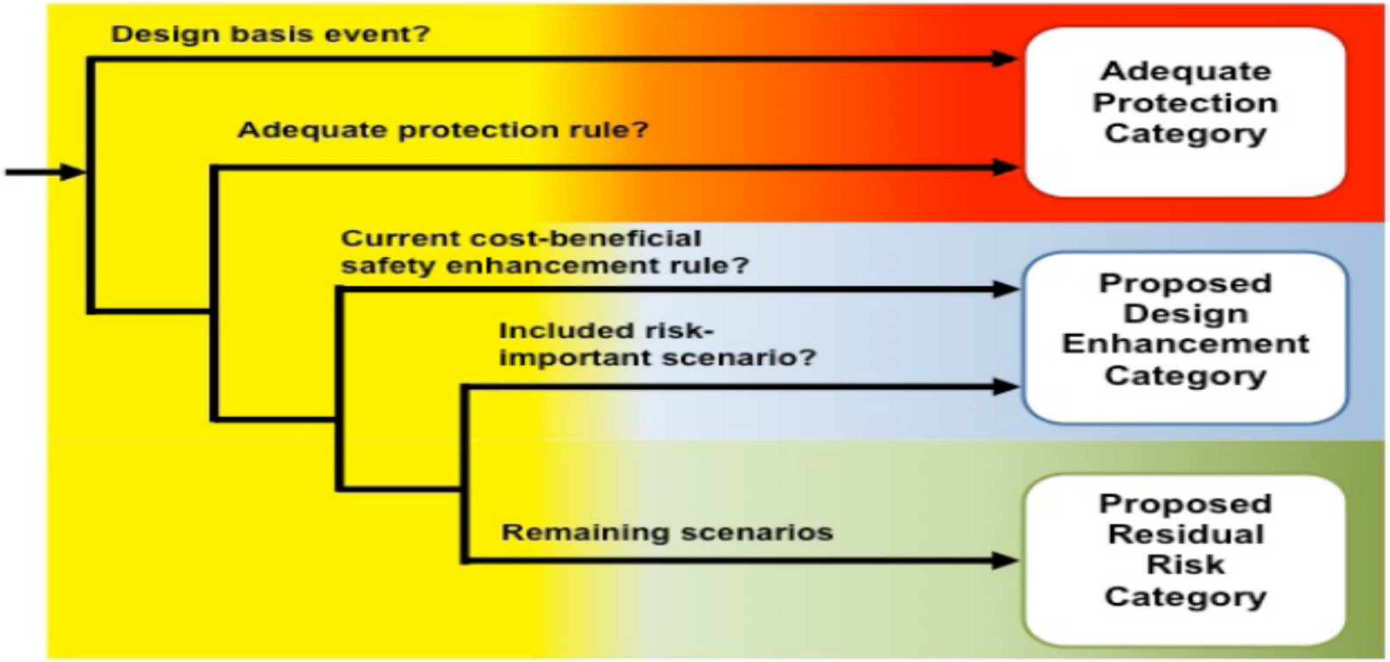
- Commission provided additional guidance in 1990, endorsing surrogate objectives

  CDF (1E-4/reactor-year) and LERF (1E-5/reactor-year)

- New reactor designs, such as AP1000 and ESBWR, should provide a higher level of safety comparing with the current operating plants

- Issued 10 CFR 50.150 “Aircraft impact assessment” in 2009 considering the lessons learnt from 9.11 incident

- "Recommendations for enhancing reactor safety in the 21st century" published after Fukushima accident
- Commissioner George Apostolakis and his team published "A proposed risk management regulatory framework" in April 2012



❑ France, Design of EPR

- "Technical guidelines for design and construction of the next generation of NPPs" published in 2000

➢ Accident situations with core melt which would lead to large early release have to be practically eliminated

→ Applies to high pressure core melt sequences, accident sequences involving containment bypass, global hydrogen detonation, and etc

➢ If they cannot be considered as physically impossible, design provisions have to be taken to design them out

→ Applies to low pressure core melt consequences. No permanent relocation, no need for emergency evacuation outside the immediate vicinity of the plant, limited sheltering, no long term restrictions in consumption of food

3. Technical Insight of the Safety Goal for NPPs Built in China's Thirteenth Five-Year

❑ The possibility of the large radioactive release should be practically eliminated by design

- High level safety goal, need to be developed into lower level safety goals and targets, such as DID requirements and Probabilistic requirements
- Reflects the lessons learned from Fukushima accident
- Statement from Mr. Li Ganjie, Vice Minister and NNSA Administrator

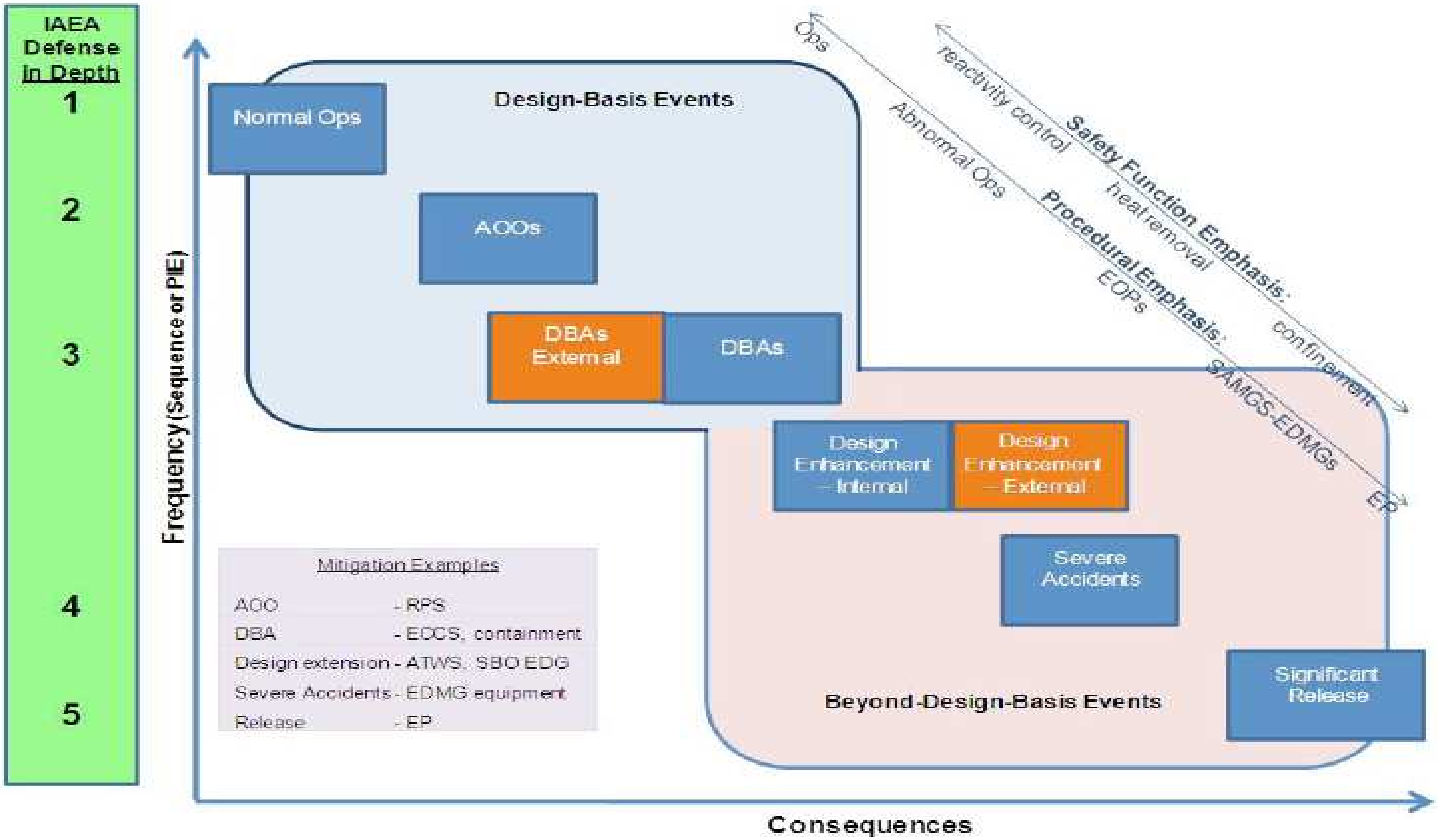
➢ The possibility of the large radioactive release should be practically eliminated by design, and effective confinement of radioactive materials even in the case of core melt accident should be ensured, consequently to protect people and the environment from unacceptable effects

Large radioactive release

- 5.0E14 Bq of I-131 equivalent, the low radioactive release limit of INES level 5, is proposed as the limit of large radioactive release
- This release would result in whole body dose of less than 20mSv in one week at the boundary of site, therefore no emergency evacuation is required according to GB18871
- For the advanced NPPs with low containment leak rate, such as AP1000 and EPR, the radioactive release is below this quantitative value in the case of core melt accident with intact containment condition

❑ DID requirements

- Application of the concept of DID in NPP design, pay great attention to the independent effectiveness of each level



❑ DID requirements

- For the safety systems (DID level 3), minimum redundancy (N-1) is required. However, Based on the overall safety goal (CDF) and the frequency of the initiating events, the corresponding reliability of the mitigation systems could be estimated, and then additional redundancy or diversity could be considered
- The mitigation measures (DID level 4) should be specifically designed for fulfilling the functions required in core melt accident, and specific assessments should be performed to prove their effectiveness
- Counter-measures (DID) should be designed against the external hazards and beyond design basis external hazards, for example, malevolent airplane impact and external flooding
- EOP, SAMG and EDMG should be available for accident prevention and mitigation

- The following scenarios should be practically eliminated
  - severe accident conditions that could damage the containment in an early phase: direct containment heating, steam explosion or hydrogen detonation
  - severe accident conditions with containment bypass: the rupture of a steam generator tube or an interfacing system LOCA
  - severe accident conditions with an open containment — notably in shutdown states

- severe accident conditions that could damage the containment in a late phase: base-mat melt-through or containment over-pressurization
  - → IVR or core catcher is the recommended engineering measure for the melt retention
  - → the containment decay heat removal system independent of the systems used to prevent melting of the core, or passive containment heat removal system should be installed
- total loss of core/containment cooling resulted from external hazards
- spent fuel melt in spent fuel pool

❑ Probabilistic requirements

- The total LRF from the containment and the spent fuel pool should be extremely unlikely with a high level of confidence
- The probabilistic requirement of 1.0E-6/reactor-year or 5.0E-7/reactor-year is proposed as quantitative safety goals in several countries, which corresponds with the high level safety goal of practical elimination of large early radioactive release. 1.0E-7/reactor-year (point estimated value, single unit) is proposed as PSA LRF target for the high level safety goal of practical elimination of large radioactive release
- This reflects the extremely low residual risk, and 10 times lower than the probabilistic requirements for the NPPs which will be built in China's Twelfth Five-Year

- Quality and Scope of the PSA

- Level 1 and level 2 including all modes of operation, all relevant initiating events, including internal fire, internal flooding and all external hazards
- PSA of spent fuel pool should be included
- PSA shall be performed according to up-to-date proven methodology, and taking into international experience currently available

4. Conclusion

- After Fukushima accident, the higher safety requirements for new built NPPs were required by Government, as stipulated in Nuclear Safety Planning (published in Oct. 2012)
- For NPPs built in Thirteenth Five-Year (2016-2020) and later: the possibility of the large radioactive release should be practically eliminated by design
- This high level safety goal were developed into lower level safety goals, including DID requirements and Probabilistic requirements in a coherent and consistent manner
- Large radioactive release limit is proposed as 5.0E14 Bq of I-131 equivalent

- DID requirements include the generic requirements and practical elimination of the specific scenarios
- 1.0E-7/reactor-year (point estimated value, single unit) is proposed as PSA LRF target

NOTE: This presentation is based on our own interpretation, does not present the opinions of NNSA

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Thank you for your attention!