Post Fukushima safety assessments of the Hungarian research reactor

Dr. Gábor Petőfi
Hungarian Atomic Energy Authority

18th IGORR Conference and IAEA Workshop on Safety Reassessment of Research Reactors in Light of the Lessons Learned from the Fukushima Daiichi Accident
3-7 December, 2017, Sydney, Australia

Outline of presentation

- Hungary
- Hungarian nuclear programme
- Nuclear Safety Requirements, regulatory body
- Post-Fukushima Stress Tests in Hungary
- Periodic Safety Review and Post-Fukushima reassessment results of Budapest Research Reactors

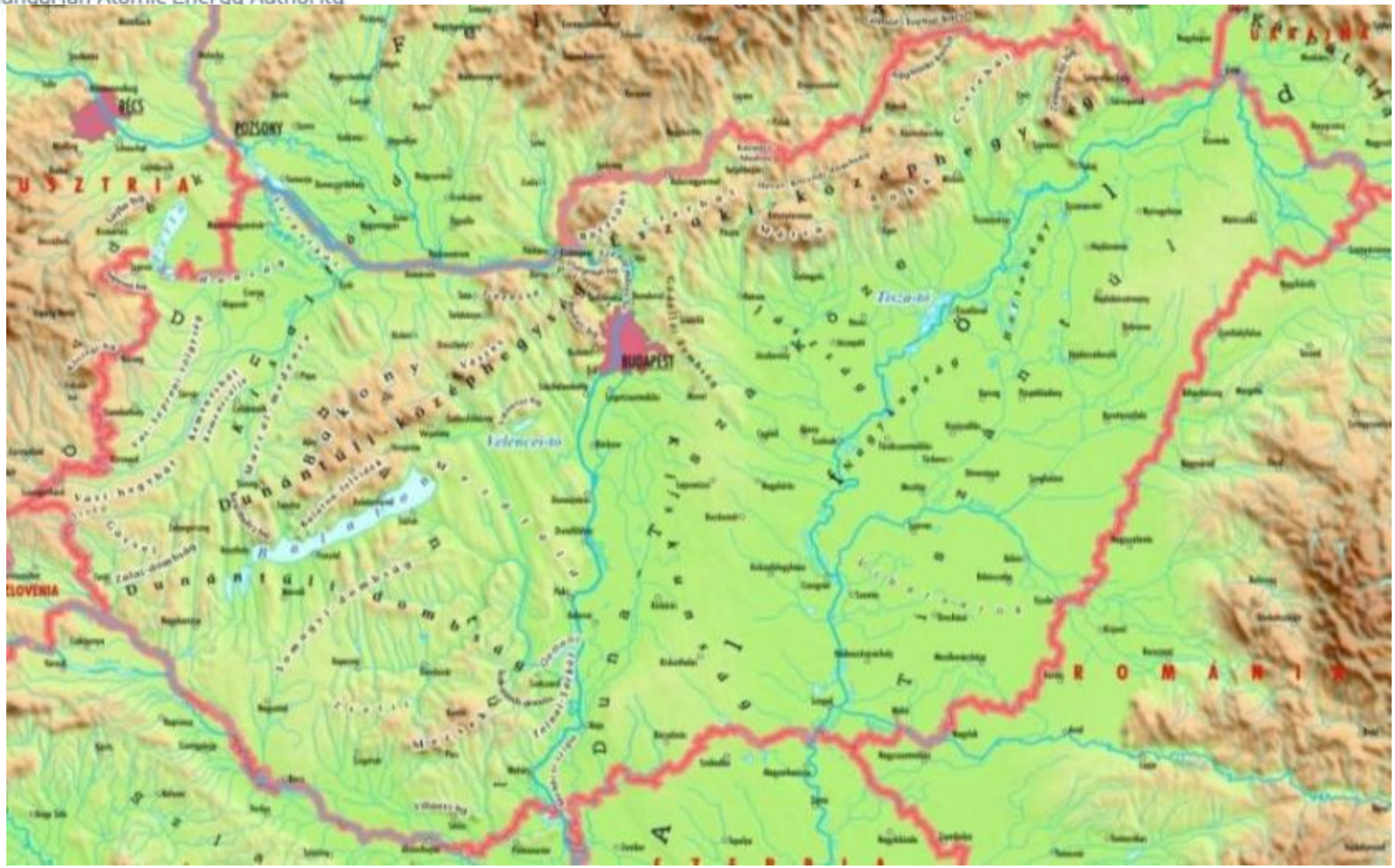
Hungarian Atomic Energy Authority

Basic data on Hungary

- Republic
- Area: 93.000 km^2
- Population: 10 million
- Capital: Budapest (1,8 million)
- Highest point: 1015 m
- Largest lake: Balaton (cca. 75 x 3 km)

Hungarian Atomic Energy Authority

Hungary



Hungarian Atomic Energy Authority

Agriculture

Hungarian Atomic Energy Authority

Parliament

Hungarian Atomic Energy Authority

Vineries

Thermal spas

Hungarian nuclear programme

- Paks NPP
  - four VVER-440/213 type reactors
  - 500 MWe after power uprates
  - commissioned in 1983, 84, 86, 87
  - 20 years design lifetime extension
  - 40-50% of domestic electricity
- Interim spent fuel storage facility
  - dry storage for 50 years
  - next to the NPP

Hungarian Atomic Energy Authority

Hungarian nuclear programme

- 100 kW training reactor
  - Budapest University of Technology and Economics
  - Education
- Radwaste storage facilities
  - For institutional waste since 1977, Püspökszilágyi
  - For NPP waste since 2012 Bátaapáti

Hungarian Atomic Energy Authority

Budapest Research Reactor

- Commissioned in 1959
- Type: 10 MWth VVER-SM after two upgrades
- tank-type reactor
- Light water cooled and moderated
- fuel: VVR-SM and VVR-M2, 36% to 20% conversion
- Operated by Institute for Energy Research (former KFKI)
- Main use: research, neutron source

Hungarian Atomic Energy Authority

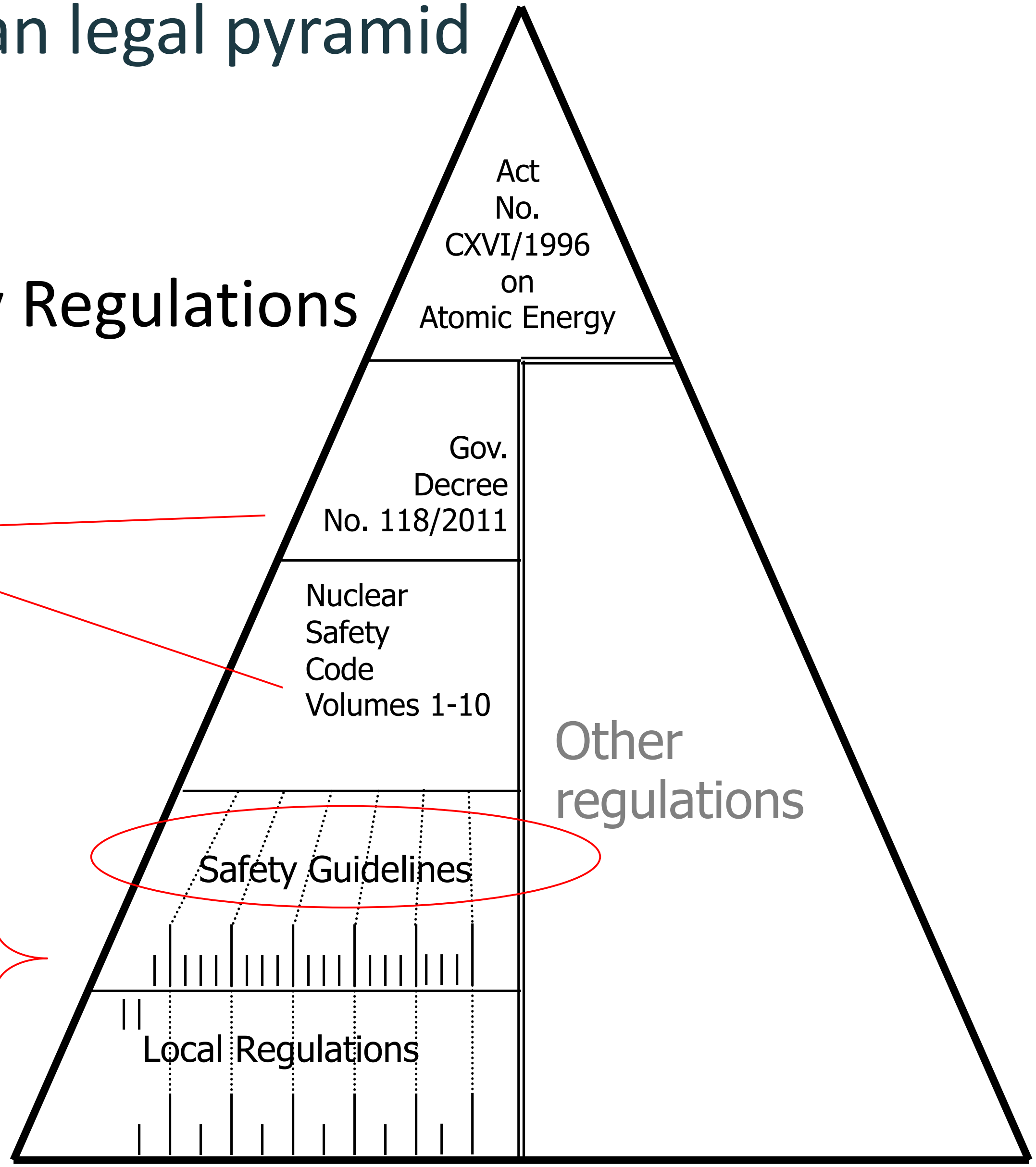
Regulatory background

Hungarian legal pyramid

Hungarian Nuclear Safety Regulations

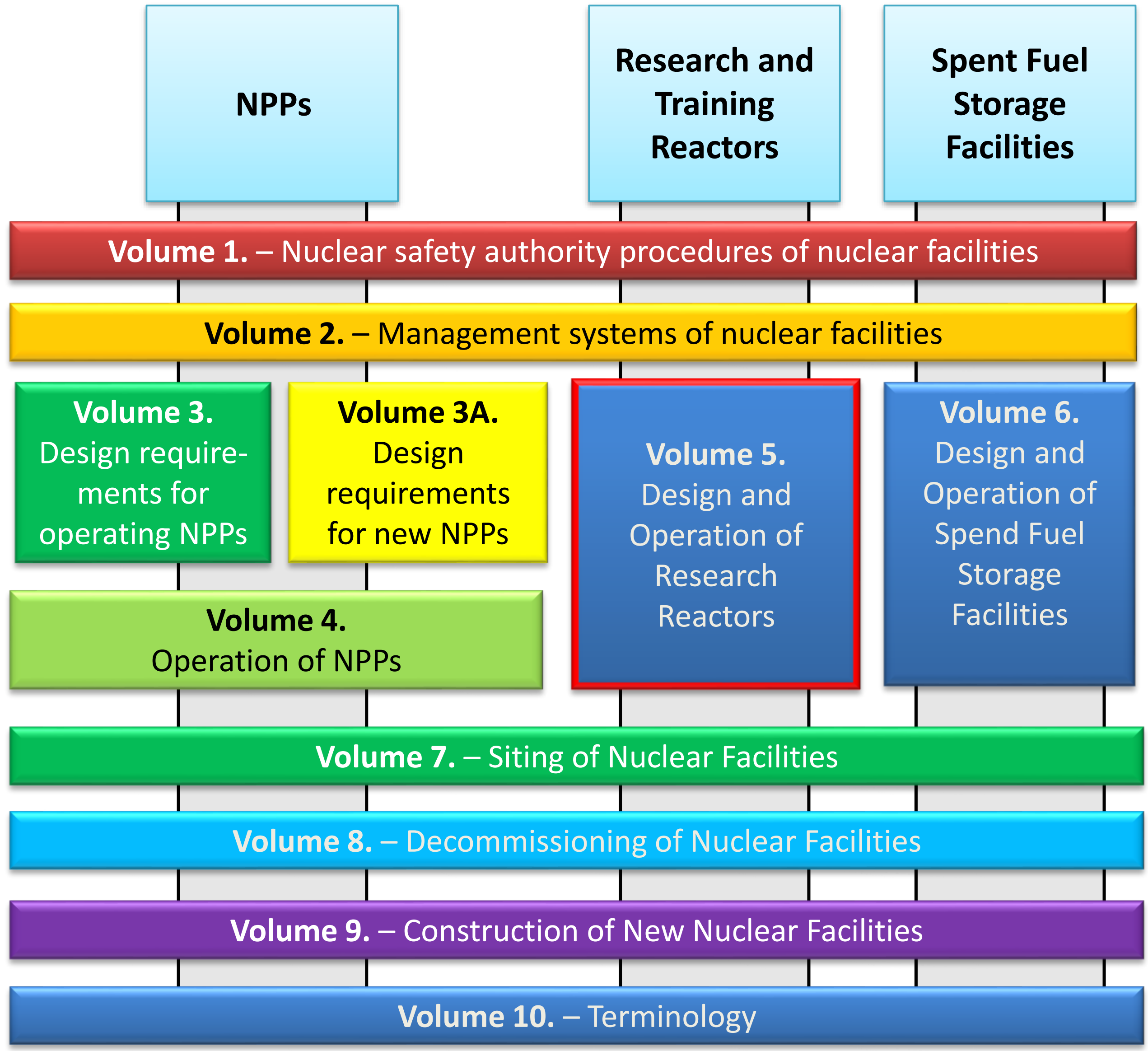
Safety code: shall

Non mandatory: „should”
  Explanations, recommendations, interpretations, methods
  Licensee shall justify any deviation from guidelines



Hungarian Atomic Energy Authority

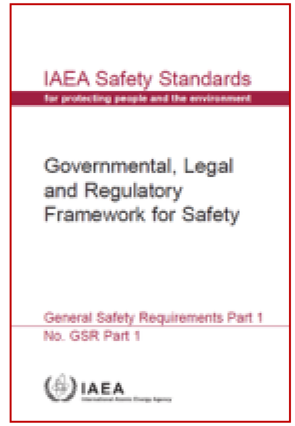
Structure of the Nuclear Safety Code

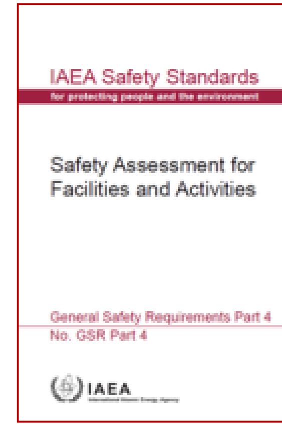


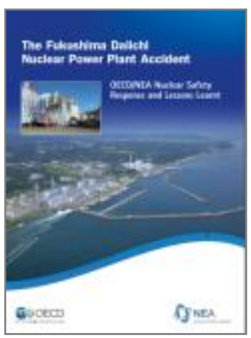
Hungarian Atomic Energy Authority

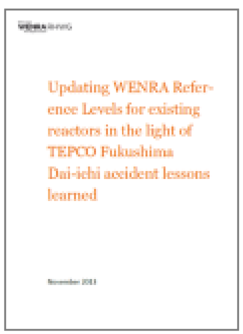
Latest revisions of the nuclear safety code

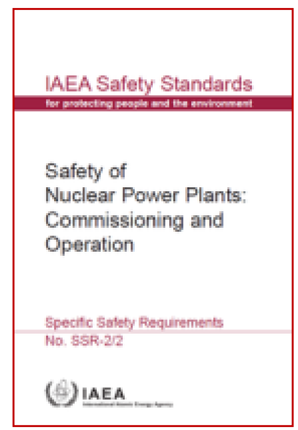
- Post-Fukushima revision
  - Issued at the end of 2014
  - Stress tests
  - IAEA review
  - WENRA review

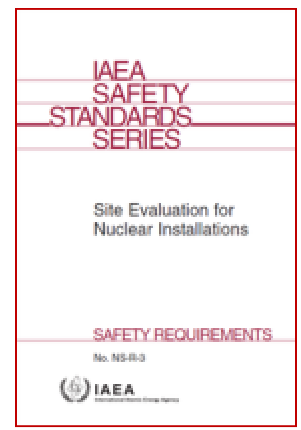












Nuclear Safety Authority: Hungarian Atomic Energey Authority

- Established in 1991, independent government office
- Regulation (drafting laws, regulations, guides)
- Regulatory oversight: licensing, inspection, assessment, enforcement
- Scope of authority
  - nuclear facilities
  - waste management facilities
  - nuclear and radioactive materials
  - transport
- 3S: safety, security, safeguards
- Public information
- Coordination of nucelar safety research
- International relations (IAEA, EU, OECD, bilateral)

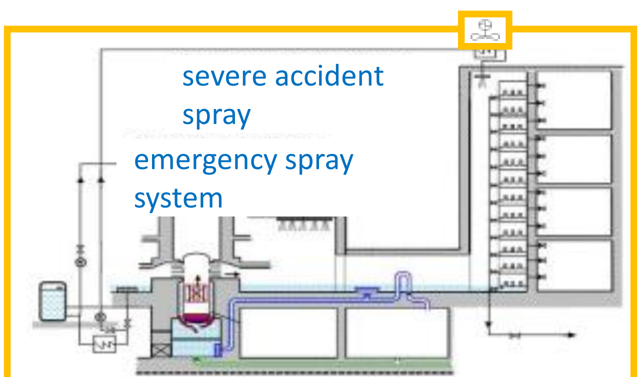
Post-Fukushima stess tests in Hungary

Hungarian Atomic Energy Authority

- European Council (of Prime Ministers): reassess the robustness of all NPPs in EU against extreme natural hazards
- Scope
  - Issues corresponding to external natural hazard factors
    - design basis review and margins for BDB, potential for cliff-edge effects
  - Loss of electric power supply and loss of ultimate heat sink or combination
    - margins of safety functions,
    - timeframes and tools availablility to recover
  - Severe accident management
    - preparedness and tools after an extreme natural disaster including multi-unit scenario
- International peer review
  - expert teams reviewed national reports,
  - dedicated missions visited the countries and the plants
  - national review in the 3 topics above
- National Action Plan
  - Also reviewed and discussed in a workshop, updates every two years

Stress test results

- Confirmation of design basis compliance
- Many modifications to improve robustness
  - Alternative cooling opportunities
  - Power supply by bunkered SA DGs
  - Reinforcement of shelters and command centres
  - Sheltered vehicle for emergency response
  - Communication and computer systems
- National action plan: 51 items till end of 2018



Stess tests for Budapest Research Reactor

- No European effort, but methodology could apply
- Possible occasion
  - Periodic Safety Review that was due in 2012
- PSR practice in Hungary
  - All nuclear facilities are obliged every ten years
  - For research reactors: basis of operation license
  - Detailed regulations + specific guideline on the PSR
  - Scope: reassess compliance with DB including external and internal hazards
  - Results: action plan on identifed gaps (risk factors) and place for improvement
- Consequences
  - Authority reviews results and approve and supplement safety improvement actions
  - Revoke or limit the license or approve without limitation

Hungarian Atomic Energy Authority

Minimal contents of the PSR

- Design in FSAR
- Review of site features, parameters
- Decommissioning
- Conditions of System, Structures and Components
- Equipment qualification
- Ageing
- Safety analyses
- Hazards
- Safety indicators
- Evaluation and feedback of operational experience
- Use of experience of other nuclear facility
- Organisation and administration
- Procedures
- Human factors
- Emergency Preparadness
- Radiation exposure of environment
- Research equipment

+ detailed post-Fukushima guidance for the 2012 PSR

Results of post-Fukushima review

- Budapest Research Reactor was designed based on the defense in depth concept
  - Accident analyses covers BDBA and SA analysis
- Safety objective: prevent dry out of core
- Safety systems are protected against single failure
  - complete loss is not required
- Design feature: if both safety trains fail a diverse system can activate
  - Very conservative, this case was only part of PSA studies to develop the Emergency Response Plan

Hungarian Atomic Energy Authority

Results of post-Fukushina review

- PSR re-assessment covered
  - loss of ultimate heat sink
  - total loss of electric power supply (normal supply and emergency diesel generators)
  - severe accidents
  - accidents during fuel element storage
  - severe accident management and emergency preparedness
- Much simpler than for NPPs because of simpler configuration

Hungarian Atomic Energy Authority

Loss of ultimate heat sink

- Heat sink: atmosphere (via primary heat exchanger and secondary circuit)
  - Loss of regular path of coolant
  - Decay heat: removed via gravitational cooling/emergency pumps/gravitational tank
- Passive method cannot be lost, pumps can be lost if diesels are lost, third method needs only an operator intervention
  - Passive gravitational cooling would be provided
  - Later natural circulation + cooling by free water surface of reactor vessel and other surfaces (e.g. pipelines) until 3 hours, after which local boiling could no occur
  - Evaporation: 2.5 cm/h level decrease, sprinkler system needs to make up after 32 hours
- Spent fuel storage
  - very low decay heat, no cooling needed, intactness should be maintained
  - fuel cladding is aluminum: no hydrogen production
- Safety systems
  - diesel generators air cooled, loss of heat sink is not an issue

Total loss of electric power supply

- Loss of normal supply
  - Electric supply is from two directions, can be lost only in extreme natural disaster. Switching is a routine act
- Loss of DGs too (very unlikely)
  - Battery stations can supply for 24 hours (electric supply not required even if heat sink is lost)
  - LOCA: refilling systems should operate
    - LOCA + loss of electric supply was not even assumed for NPP stress tests
    - LOCAs are very improbable (pipelines of aluminum) and low pressure
    - Communal water system and fire water system are still available
    - Altogether: very improbable
- Spent fuel cooling: no need for electric supply

Hungarian Atomic Energy Authority

Severe accidents

- Can be practically excluded
- Extreme natural phenomena
  - strong earthquake is the only such hazard
  - Crash of a big aircraft and malevolent acts are not part of the analysis
  - Design PGA is 0.15 g (safe shutdown)
- Higher values: LOCA and reactor hall lost
  - core damage prevented if reactor under water for at least 4 hours after shutdown
  - core dry out will never cause complete core melt
  - If pipeline can be repaired then water level can be retrieved. Special repair methods are available and trained
  - If communal water lines are not availabe and reactor hall is destroyed due to earthquake: doses would not justify any off-site action, but the site should be evacuated

Hungarian Atomic Energy Authority

Fuel storage accidents

- Cooling of internal spent fuel storage is passive: no effect of loss of heat sink or electricity
- Critical phenomenon: loss of coolant what is excluded by material selection, construction
- But: fuel melt does not take place even if total loss of coolant, only some fuel elements would damage
- Timing: 1-1,5 hours, intervention is possible (make-up water (passive) system, closing outlet line valve. Feasible in 40 minutes
- Structure of storage will remain intact, but loss of coolant due to stronger earthquake cannot be excluded
- External spent fuel store: structure will remain intact
  - due to low decay heat, heat up is a very long process

Summary

- BRR is prepared for
  - coping with loss of ultimate heat sink
  - total loss of electric supply
  - managing severe accidents
- Severe accidents are extremely improbable
  - only due to extreme earthquakes or similar events
  - if reactor building is also lost: environmental impact within the site area
- Conclusion
  - Due to physical properties and former safety improvement the BRR was prepared for extreme hazards even before Fukushima
  - No additional safety improvement action is necessary

Hungarian Atomic Energy Authority

Regulatory conclusion

- Approach and methods accepted
- Supplementary Fukushima examinations sufficient and did not reveal new hazards or vulnerability
- FSAR chapters are still valid, conclusions of licensee accepted
  - Important: acceptance was made with a graded approach in relation to the depth of expectable analysis for the research reactor

Hungarian Atomic Energy Authority

Questions?

Thank you for your attention!