秋の大会　原子力安全部会セッション

SMR等革新炉の安全と安全規制について－今後の取組－
Safety of Advanced and Innovative Nuclear Reactors and the Preparation of Regulatory Infrastructure
– future Initiatives –

（2）海外で検討が進んでいる革新炉の安全設計の特徴等について（事例紹介:NuScale）
(2) Safety design features of innovative reactors - Case study: NuScale

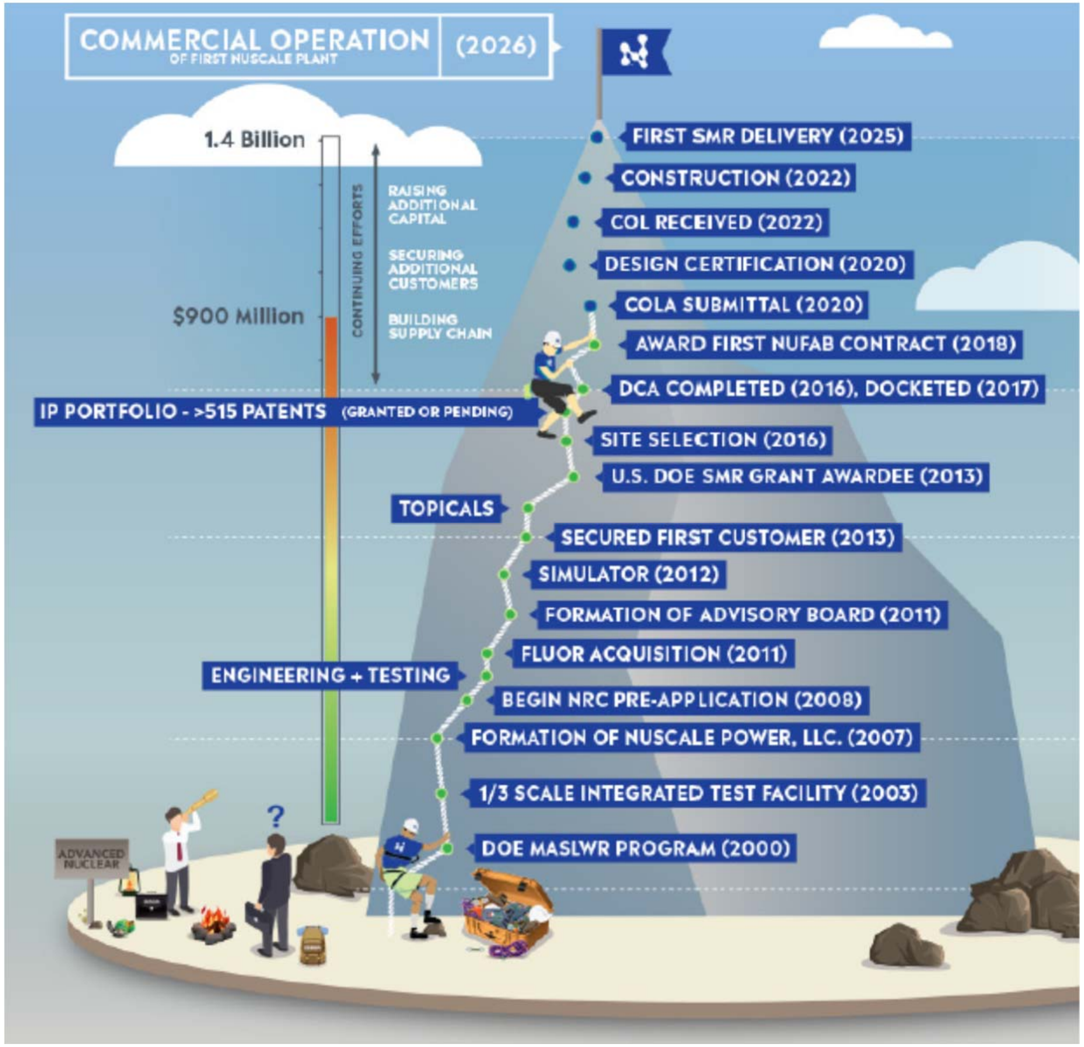
吉田　英爾（日揮）

Sep. 2020

JGC CORPORATION

NuScale power plant current status

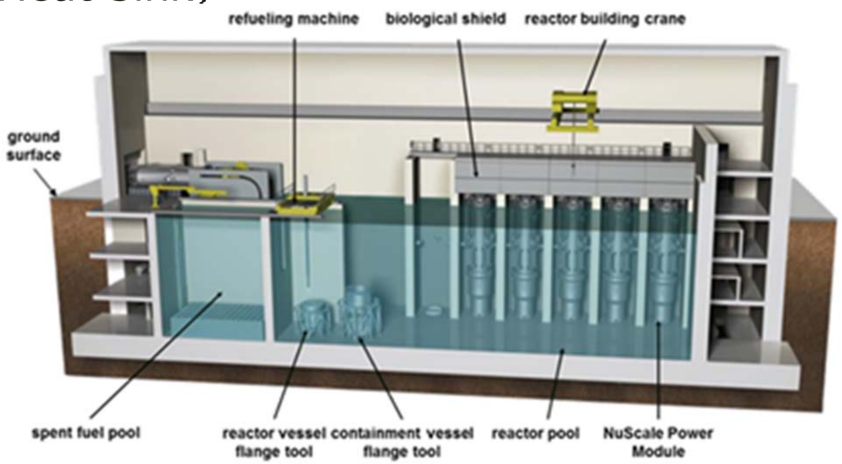
- NuScale Power plant is:
  - based on PWR technology
  - an evolutionary simple and innovative advancement.
  - incorporates unique features that reduce complexity, improve safety and resilience, enhance operability, and reduce costs.
  - progressed to completion of Phase 4 of NRC review in Dec. 2019.
  - on track to meet the significant milestone of NRC design certification in January 2021.

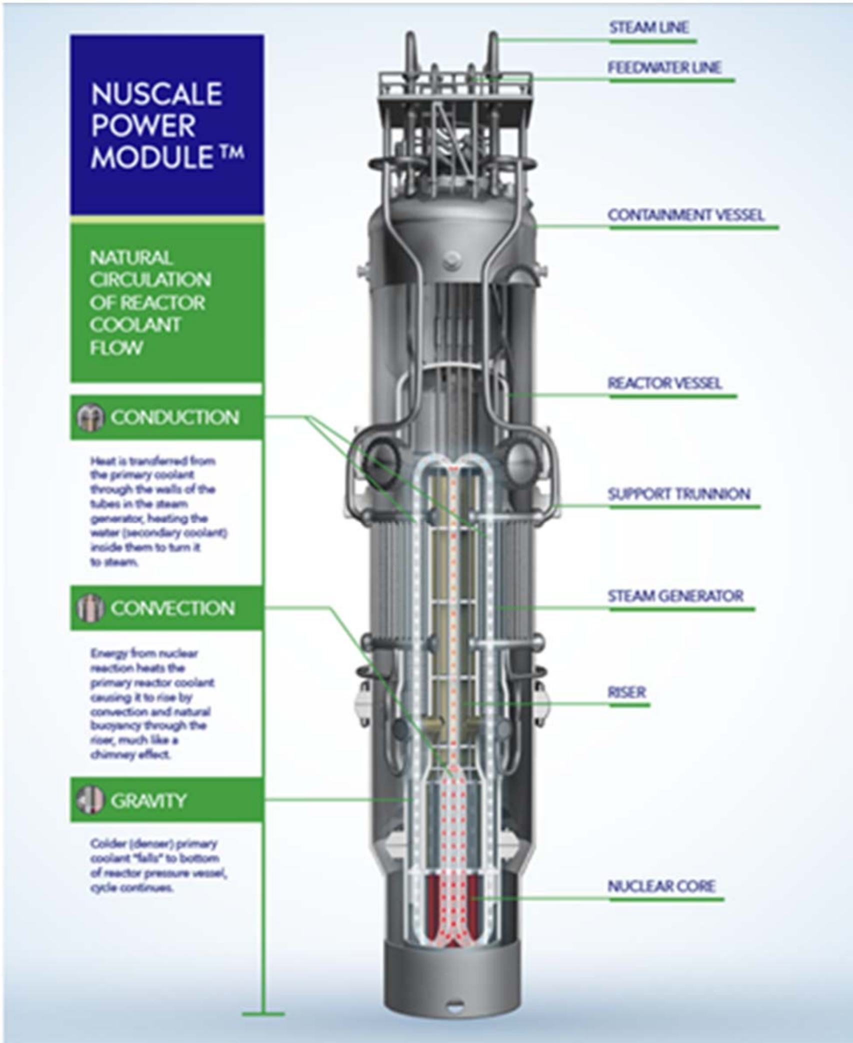


NuScale power plant

NuScale general description

- 60MWe/NuScale Power Module (NPM) x 12 NPMs =720 MWe
- Primary system components in an integral reactor pressure vessel (RPV) surrounded by a steel containment vessel
- NPM immersed in a large pool of water (Ultimate Heat Sink)





Safety features(1)

- Maximizing Simplicity
  - All major reactor coolant systems inside the reactor pressure vessel.
  - By simplifying the NuScale design, the plant's response to design basis and beyond design basis accidents (BDBA) is also simpler.

Safety System or Component	Typical PWR	NuScale	Safety System or Component	Typical PWR	NuScale
Reactor Pressure Vessel	✓	✓	Condensate Storage Tank	✓	
Containment Vessel	✓	✓	Auxiliary Feedwater System	✓	
Reactor Coolant System	✓	✓	Emergency Service Water System	✓	
Decay Heat Removal System	✓	✓	Hydrogen Recombiner or Ignition System	✓	
Emergency Core Cooling System	✓	✓	Containment Spray System	✓	
Control Rod Drive System	✓	✓	Reactor Coolant Pumps	✓	
Containment Isolation System	✓	✓	Safety-Related Electrical Distribution System	✓	
Ultimate Heat Sink	✓	✓	Alternative Off-Site Power	✓	
Residual Heat Removal System	✓		Safety-Related Emergency Diesel Generators	✓	
Safety Injection System	✓		Safety-Related Class 1E Battery System	✓	
Refueling Water Storage Tank	✓		ATWS Mitigation System	✓	

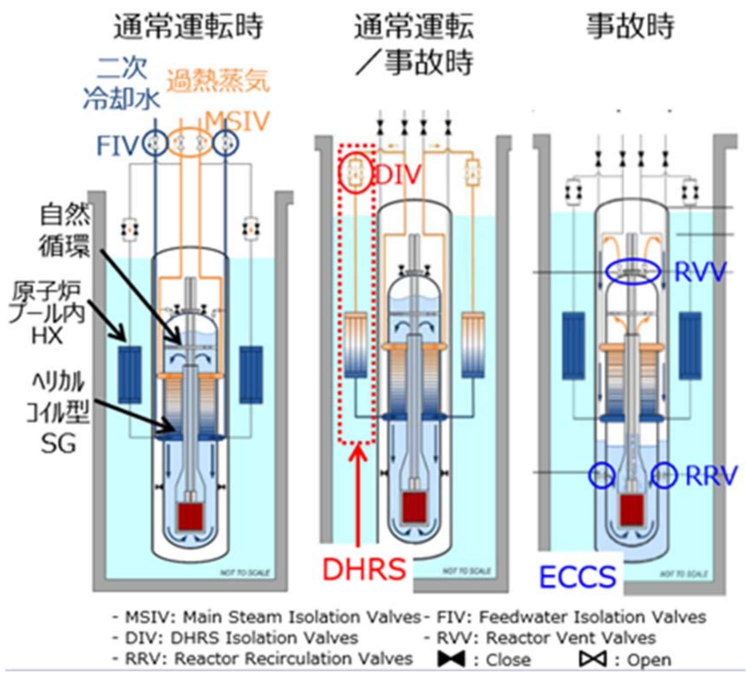
Safety features(2)

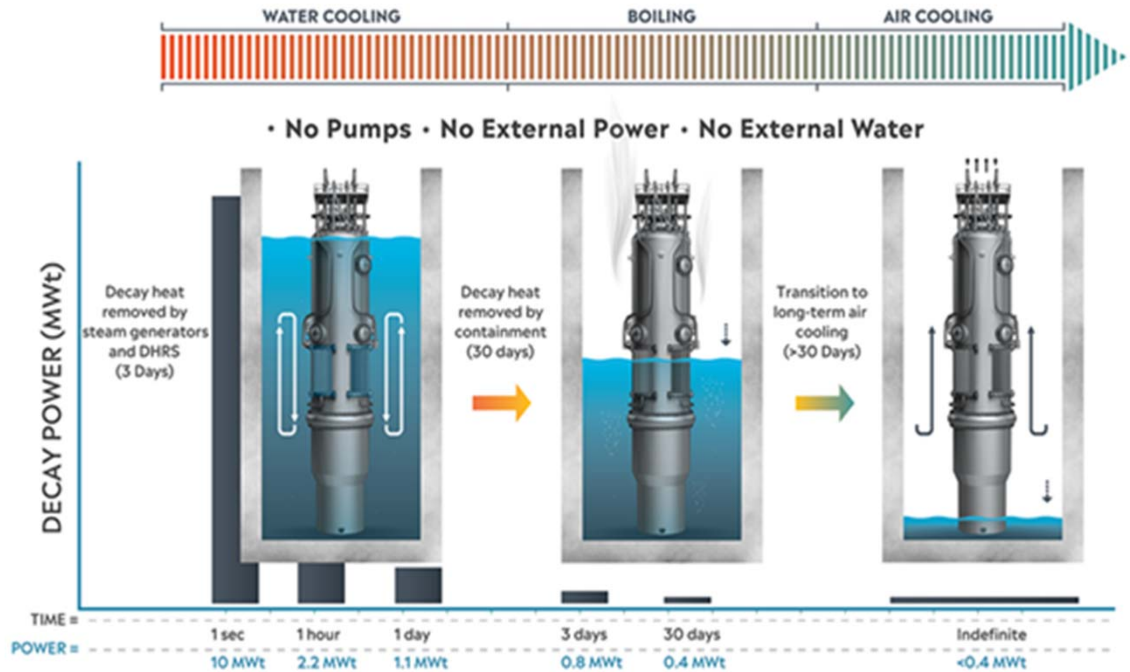
- Design basis accident
  - Risk information is used in early design stages and simultaneously improves safety and reduces cost.
  - Enhancing plant safety through its deliberate design choices that eliminate or reduce the likelihood of potential accident initiators.
  - Six of eight traditional design basis accidents applicable to existing PWRs are eliminated or have reduced risks for NuScale NPMs.

Design Basis Accident	NuScale Response
Steam system pipe break	Reduced consequences from lower fuel failure fraction
Feedwater system pipe break	No change
Reactor coolant pump shaft failure	Eliminated with natural circulation of primary coolant
Spectrum of control rod ejections	No change
Steam generator tube rupture	Reduced likelihood from tubes in compression (shell-side primary flow)
Large break LOCA	Eliminated by use of integral primary system configuration
Small break LOCA	Reduced consequences from no fuel heatup
Design basis fuel handling accidents	Reduced source term from half-height fuel assemblies and 15.2 m of water above spent fuel assemblies

Safety features(3)

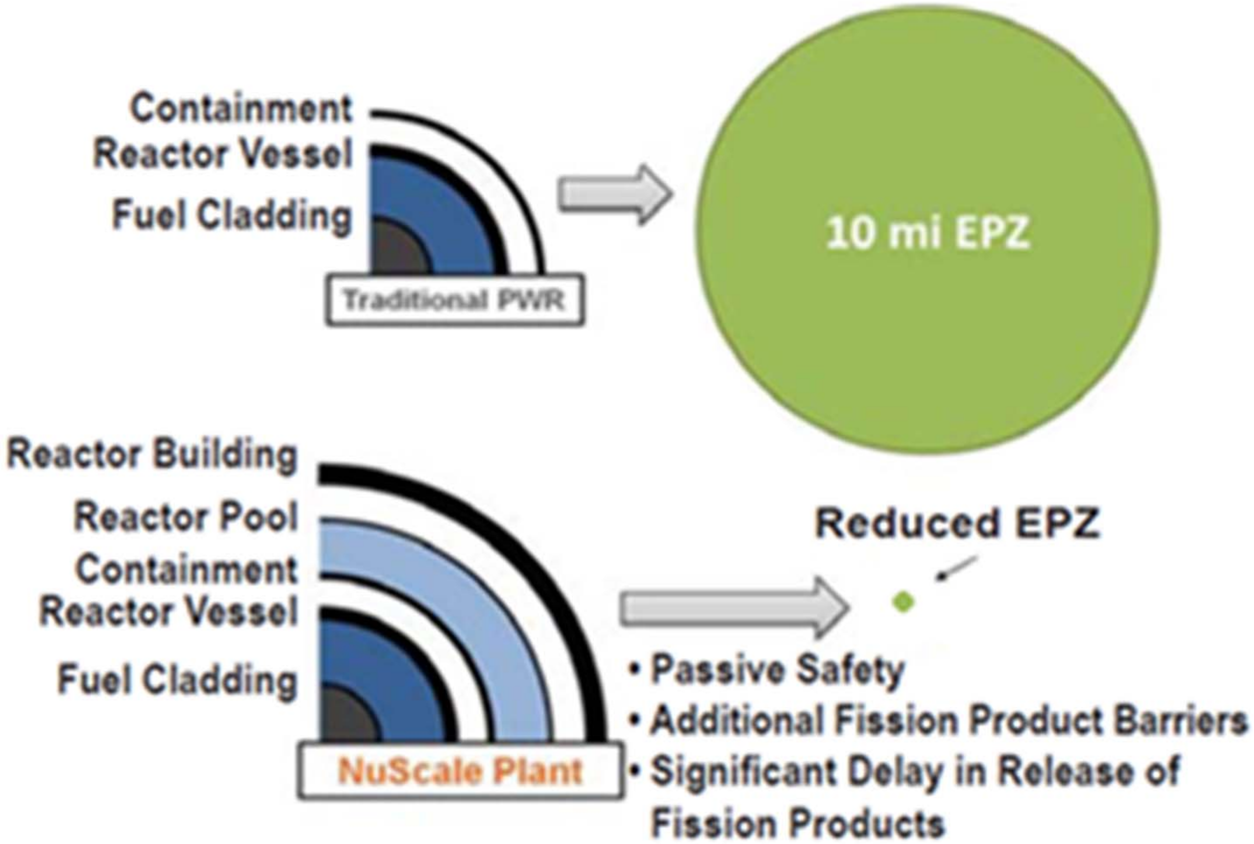
- DHRS and ECCS
  - The NPMs are submerged in the reactor pool, which is part of the UHS.
  - Passive heat removal to the UHS using Decay Heat Removal System (DHRS) and Emergency Core Cooling System (ECCS) maintains core cooling without pool inventory makeup or operator action.





Safety features(4)

- EPZ reduction
  - Reducing the size of the NuScale plant emergency planning zone (EPZ) from the current 10-mile radius of most U.S. nuclear plants to the site boundary.
  - Reducing the EPZ size due to the incredible NuScale safety



Regulatory Perspective

- NuScale requests in design certification application:
  - Exemptions
    - are necessary to address the passive safety approach inherent in NuScale design
    - are an alternative to existing requirements
    - are not requesting NRC to relax safety requirement, this exemption process ensures that alternatives to existing requirements protect public health and safety.

No.	Regulation or Regulatory Guide	Description
1	10 CFR 50, Appendix A, GDC 17 & 18	Electric Power Systems
2	10 CFR 50, Appendix A, GDC 19	Control Systems
3	10 CFR 50, Appendix A, GDC 27	Combined Reactivity Control Systems
4	10 CFR 50, Appendix A, GDC 33	Reactor Coolant Makeup
5	10 CFR 50, Appendix A, GDC 40	Testing of Containment Heat Removal System
6	10 CFR 50, Appendix A, GDC 52	Containment Leakage Rate Testing
7	10 CFR 50, Appendix A, GDC 55, 56, &57	Containment Isolation
8	10 CFR 50.34(f)(2)(viii)	Post-Accident Sampling
9	10 CFR 50.34(f)(2)(xx)	Power Supplies for Pressurizer Relief Valves, Block
10	10 CFR 50.34(f)(2)(xiii)	Pressurizer Heater Power Supplies
11	10 CFR 50.34(f)(2)(xiv)(E)	Containment Evacuation System Isolation
12	10 CFR 50.46a and 10 CFR 50.34(f)(2)(vi)	Reactor Coolant System Venting
13	10 CFR 50.44	Combustible Gas Control
14	10 CFR 50.46	Fuel Rod Cladding Material
15	10 CFR 50, Appendix K	Emergency Core Cooling System Evaluation Model
16	10 CFR 50.54(m)	Control Room Staffing
17	10 CFR 50.62(c)(1)	Reduction of Risk from Anticipated Transients Without Scram

Summary

JGC IHI NUSCALE

- New requirements and safety standards
  - New safety requirements and safety standards different from existing light water reactors should be considered and established for innovative reactors such as SMR.
  - When considering safety requirements and safety standards suitable for an innovative reactor, it is necessary to aim for the establishment of safety requirements and safety standards that higher safety can be achieved.

- Approach to develop the requirements and the standards
  - A serious discussion on “What should be the safety requirements and safety standards for innovative reactors such as SMR?” should be started.
  - A new regulatory framework be applied to innovative reactors such as SMR are created based on the results of such discussions.