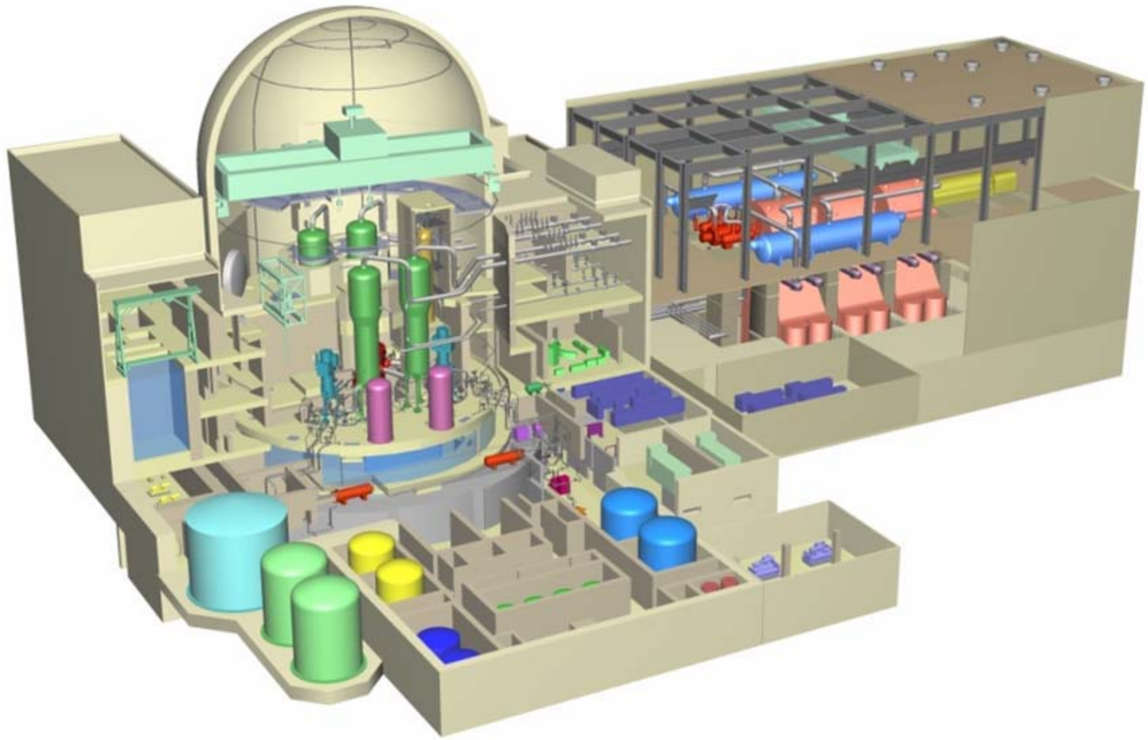
# MITSUBISHI US-APWR

## Severe Accident Mitigation



**June 29, 2007**

MITSUBISHI HEAVY INDUSTRIES, LTD.



DOE Technical Session
UAP-HF-07066

# Contents

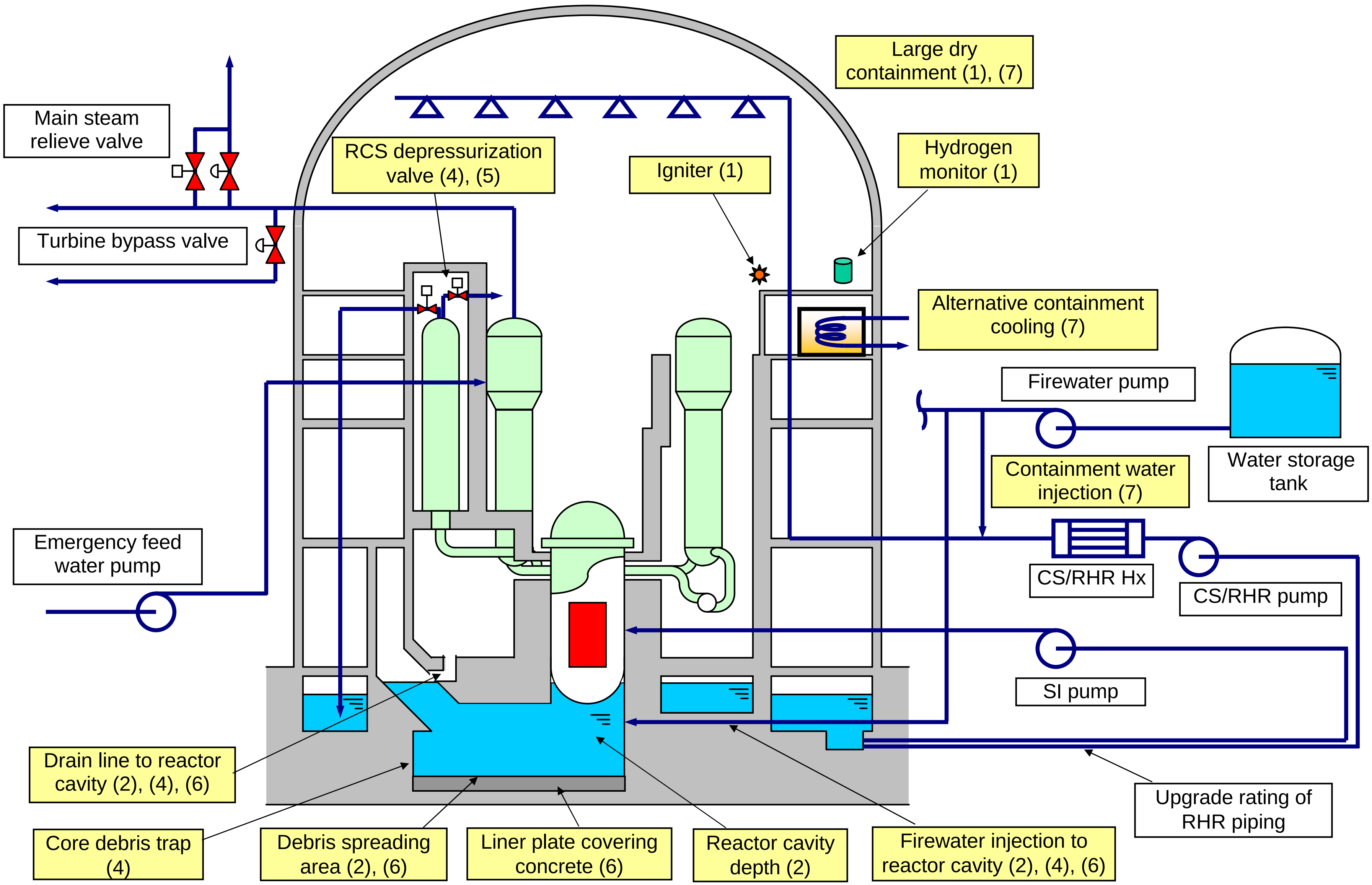
1. Design Concept for Severe Accident Mitigation
2. Severe Accident Mitigation Features
3. Conclusion

# 1. Design Concept for SA Mitigation

## ➢ Rely on approved strategies in former DC applications and existing plants

- ✓ Wet reactor cavity for debris cooling
  - Provide reliable cavity flooding
  - Provide cavity floor area sufficient for debris spreading and quenching
  - Challenge by steam explosion can be limited and acceptable
- ✓ In-vessel core retention is uncertain
  - Consider recovery of partially damaged core by late injection
  - Debris cooling by external vessel cooling is currently not credited
- ✓ Component classification
  - Safety and non-safety grade components are used for severe accident mitigation

# 1. Design Concept for SA Mitigation



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# (1) Hydrogen Mixing and Combustion

- Enhance containment atmosphere mixing and avoid combustible gas accumulation
  - ✓ Large dry containment
    - Widely acknowledged having good ability for containment atmosphere mixing
    - Provide adequate strength to contain most hydrogen burns
- Control combustible gas to prevent deflagration/ detonation
  - ✓ Igniters
    - Proven technique for combustible gas control
    - Advantages such as no poisoning, good capability to control combustible gas (amount and speed), compact, easy to maintain, etc
    - MHI has experience to employ this device
  - ✓ Hydrogen monitor

# (2) Core Debris Coolability

- Flood reactor cavity with high reliability
  - ✓ Diverse reactor cavity flooding system
    - Drain line to reactor cavity
    - Firewater injection system to reactor cavity
- Enhance fragmentation for debris coolability
  - ✓ Appropriate reactor cavity depth
    - Enhance melt break-up and debris bed formation
- Enhance spreading on cavity floor for debris coolability
  - ✓ Sufficient reactor cavity floor area for debris spreading
    - Analytically demonstrate that the floor area is sufficient for debris cooling

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# (3) Steam Explosion

(In-vessel)

- ✓ Probabilistic consideration from previous research
  - Very low probability of alpha-mode failure, such as $10^{-4}$ (NUREG-1524) is widely recognized
  - Evaluate applicability of NUREG-1524 conclusions to US-APWR
  - Specific mitigation features are not anticipated at this time

(Ex-vessel)

- ✓ Analytical consideration
  - Examine previous studies for occurrence probability, boundary conditions, etc (for example NUREG-1150)
  - If appropriate, evaluate containment loads and integrity. Demonstrate that the failure probability is acceptable
  - Specific mitigation features are not anticipated at this time

# (4) High Pressure Melt Ejection (HPME) and Direct Containment Heating (DCH)

- Reduce RCS pressure to avoid HPME and DCH
  - ✓ RCS depressurization valve
    - HPME and DCH are negligible if RCS pressure is low
    - Provide dedicated valves for severe accident
- Enhance core debris cooling by cavity water
  - ✓ Diverse reactor cavity flooding system
    - Drain line to reactor cavity and firewater injection system
- Reduce amount of core debris going out from cavity to containment atmosphere
  - ✓ Core debris trap
    - Enhanced capturing of ejected molten core in cavity

# (5) Temperature Induced Steam Generator Tube Rupture (TISGTR)

- Evaluate applicability of existing data on TISGTR to US-APWR
  - ✓ TISGTR competes with hot leg creep rupture, surge line creep rupture and vessel melt-through
  - ✓ NUREG-1150 have shown TISGTR to be unlikely failure mode under high pressure core melt scenarios
- Reduce RCS pressure to further reduce likelihood of TISGTR
  - ✓ RCS depressurization valve
    - Creep rupture more likely at high temperature and pressure
    - Provide dedicated valves for severe accident

# (6) Molten Core Concrete Interaction (MCCI)

- Enhance ex-vessel debris coolability as discussed under (2) Core Debris Coolability
- Protect containment boundary
  - ✓ Covering concrete of reactor cavity liner plate
    - Provide protection against challenge of reactor cavity liner plate due to short term MCCI during debris spreading and quenching
    - Utilize basaltic concrete to reduce non-condensable gas generation comparing to limestone/common sand

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# (7) Long Term Containment Overpressure

- Provide sufficient capability to withstand pressure and temperature
  - ✓ Large dry containment
    - Provide sufficient strength to delay long term overpressure failure at elevated temperature due to generation of steam or non-condensable gases
- Provide containment cooling for decay heat removal
  - ✓ Alternative containment cooling
    - Utilize containment recirculation cooling unit
    - Supply CCW to cooling units and enhance condensation of surrounding steam
  - ✓ Water injection to spray header by firewater pump
    - Delay containment failure (no cooling)

# (8) Equipment Survivability

- Assure containment maintains structural integrity under most hydrogen burn conditions
  - ✓ Analytical demonstration of equipment capability
    - Analytically demonstrate that the combustible gas control maintains containment conditions within the capability of needed equipment inside containment

# 3. Conclusion

- **US-APWR design features consider commonly recognized severe accident challenges and satisfy US regulatory requirements**

- **Severe Accident countermeasures rely on strategies widely accepted in former DC applications and existing plants**