Extreme Events: AP1000® Safety Concepts and Robustness to External Hazards

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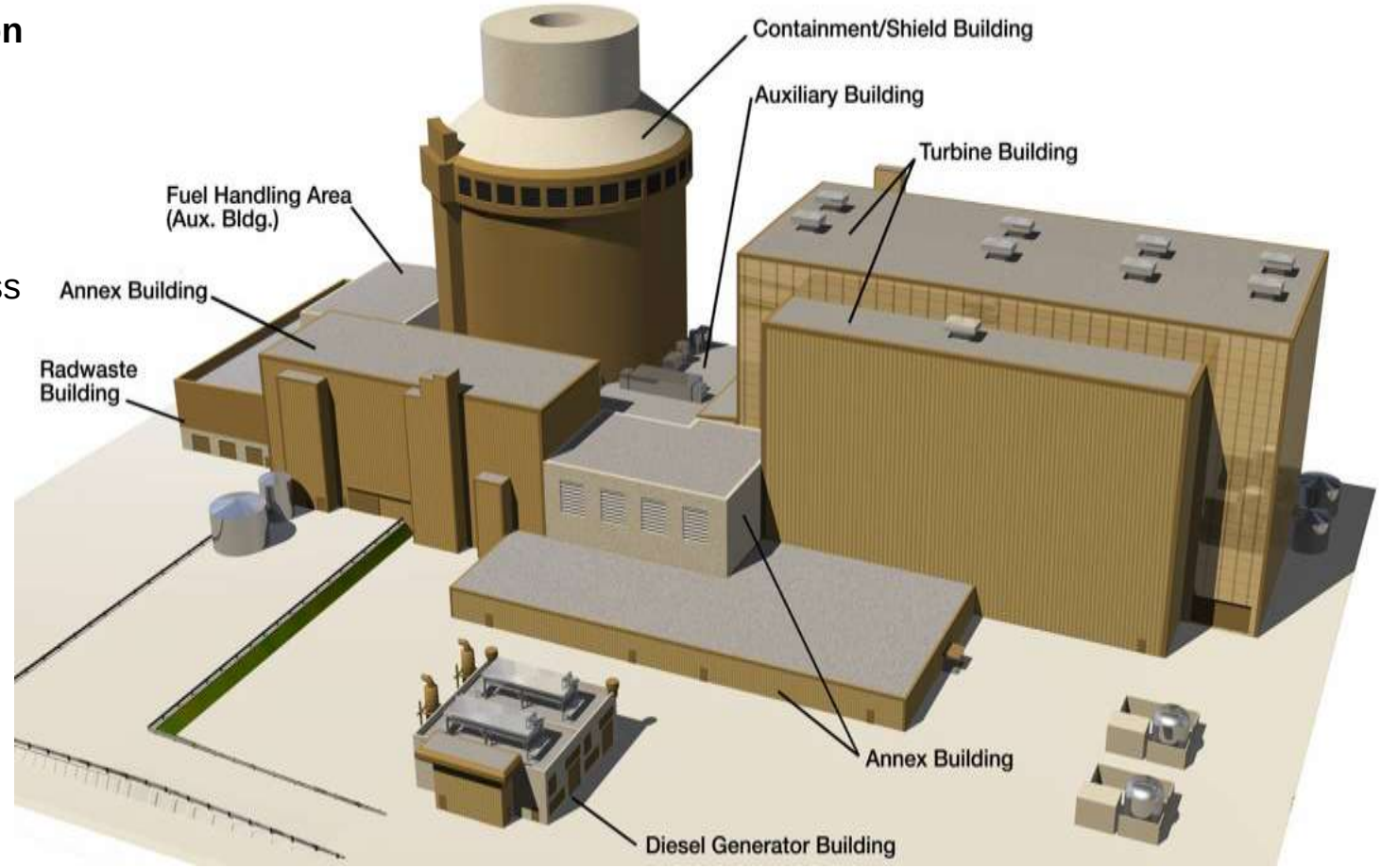
AP1000 Engineering

Westinghouse AP1000 Plant

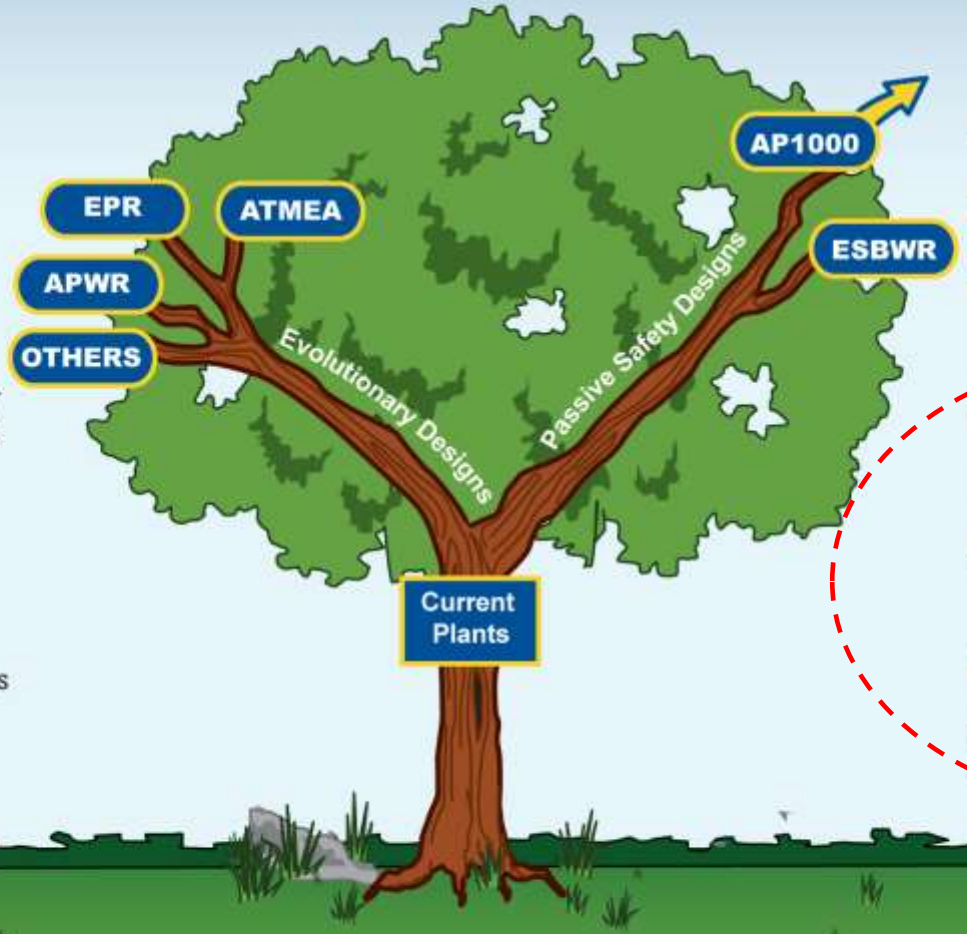
A Compact Station

- Gen III+ technology
- 3415 MWt, primary system
- 1100 MWe Class
- Two-loops, two steam generators



Evolutionary PWRs

- Updates of current 3 & 4-loop designs
- Extensive, safety-grade support systems
- Off-site ac for safety action and safety diesel or turbine -driven generators as backup
- Greater reliance on operator action
- Ultimate heat sink: heat exchangers/water systems



Why AP1000 passive designs?

- Less concrete & steel/MWe
- Simpler, less equipment, less safety-grade equipment, no safety-grade pumps
- Fewer Seismic 1 structures
- Shorter construction schedules
- Less maintenance, maintenance-free canned reactor coolant pumps, simpler Tech Specs
- Much less reliance on operator action to mitigate accidents (72 hours)
- Independent of off-site ac power to operate safety systems
- Ultimate heat sink: ambient air

The preferred technology in the US and China

Simplification and Standardization are Key to Future Nuclear Plant Construction

- Simplicity and standardization in **Design** through reduced number of components and bulk commodities
- Simplicity in **Safety** through use of passive safety systems
- Simplicity in **Construction** through modularization
- Simplicity in **Procurement** through standardization of components and plant design
- Simplicity in **Operation and Maintenance** through use of proven systems and components, and man-machine interface advancements

Improved safety, competitive economics, and optimized performance: improvements in safety do not have to increase plant complexity and costs

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AP1000 Deployment Status
Current Commitments and Contracts

AP1000 Deployment Status
Current Commitments and Contracts

China: 2 units at Haiyang
2 units at Sanmen
Operation begins 2013

USA: 14 units planned
6 units under contract
Operation begins 2016

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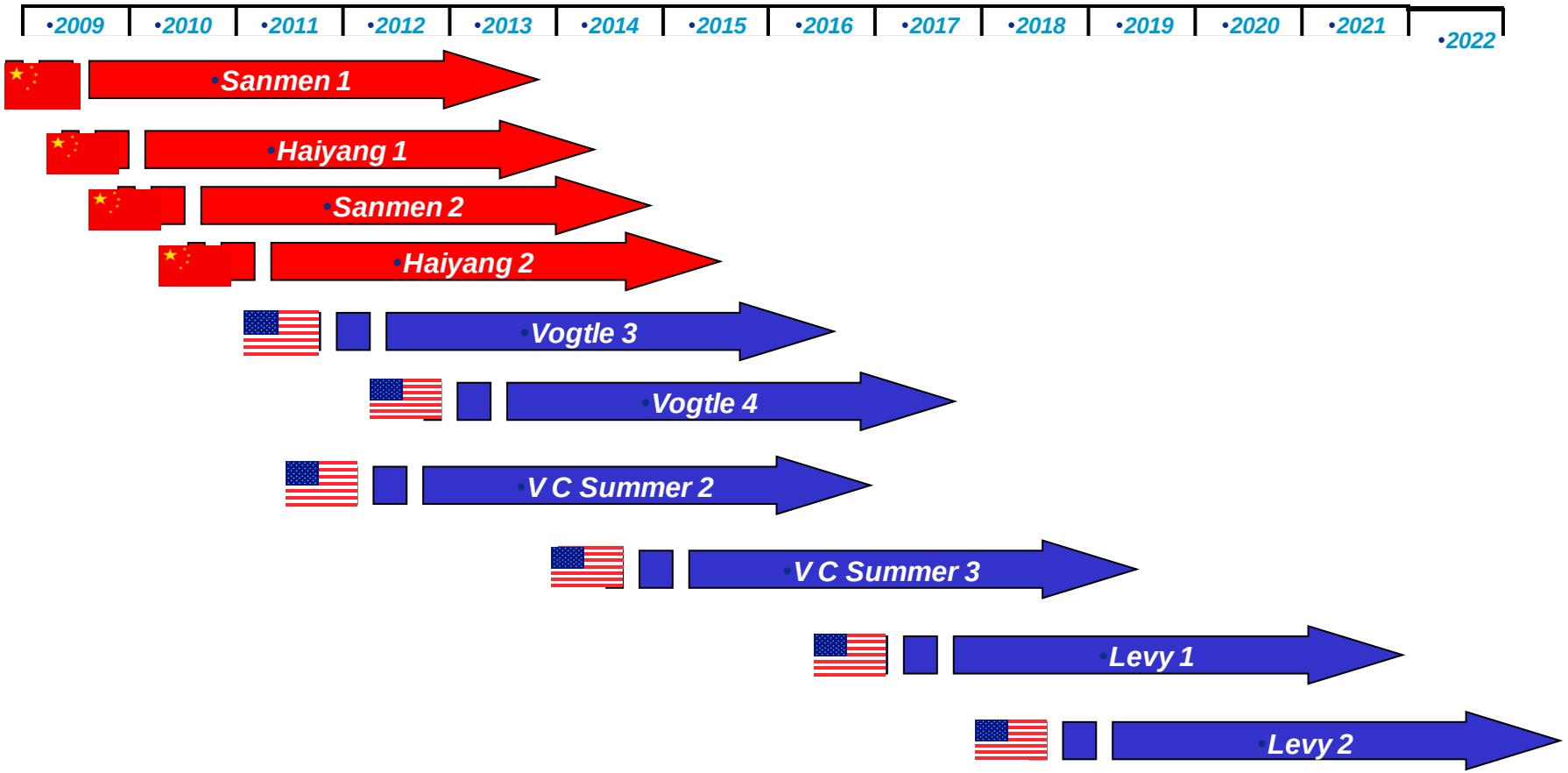
Confidence from Being Part of a Global Fleet



AP1000 in United States

NRC License Applications (12 AP1000 Units)

Southern Co. – Vogtle

COL Approved February 10, 2012

Nuclear Construction February 10, 2012

SCE&G – Summer

COL Approved March 30, 2012

Nuclear Construction April 2012

Progress Energy – Levy County

COL Approval 2013

Duke Energy – W.S. Lee

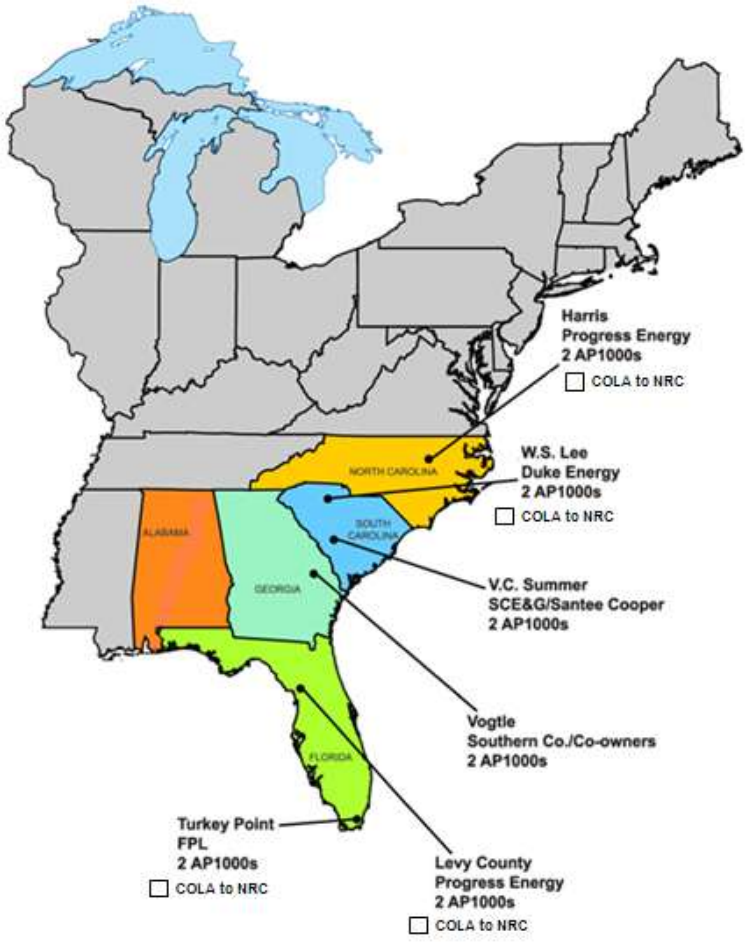
COL Approval 2013

Progress Energy – Harris

COL Approval 2014

FPL – Turkey Point

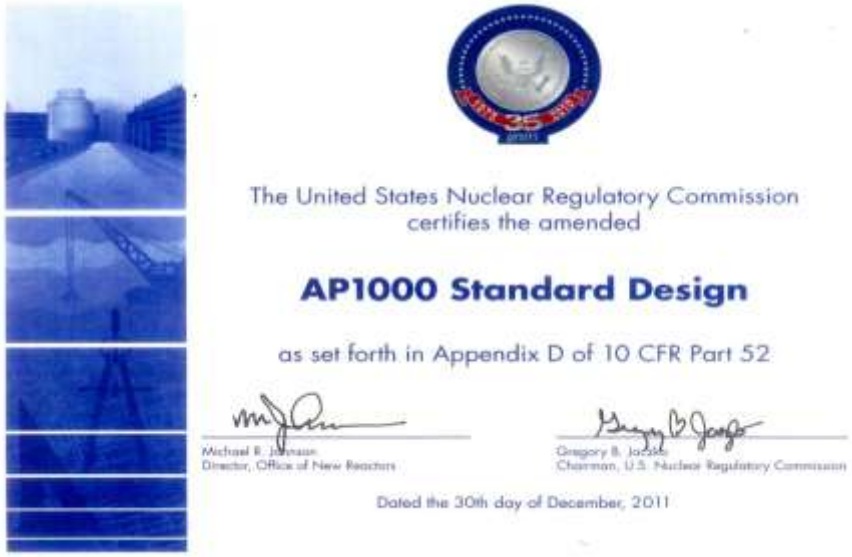
COL Approval TBD



U.S. NRC Review and Approval

Amended Design Approval received from the U.S. NRC in December 2011.

Amended AP1000 certification based on DCD Rev 19.


The United States Nuclear Regulatory Commission certifies the amended

AP1000 Standard Design

as set forth in Appendix D of 10 CFR Part 52

Michael R. Johnson
Director, Office of New Reactors

Gregory B. Jaczko
Chairman, U.S. Nuclear Regulatory Commission

Dated the 30th day of December, 2011

Design Approval received from the US NRC in 2005.

Final Rulemaking in January 2006.

Original AP1000 certification based on DCD Rev 15.

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Summary of Key Conclusions AP1000 Plant Response to Extreme Events

- Westinghouse assessment concluded that AP1000 design maintains all safety limits
- The AP1000 passive design assures
  - Containment integrity
  - No fuel damage (both spent fuel and reactor)
  - No radiological release as a result of the event

AP1000 achieves and maintains Safe Shutdown, protects public health and safety, and prevents loss of utility investment.

> *[…], as has been pointed out to me by Japanese colleagues as they reflect upon Fukushima, had the plant been operating AP1000 reactors, it is likely that the outcome would have been very different. The AP1000's passive safety systems provide the ability to maintain core cooling for at least 72 hours with little human intervention. 72 hours to make repairs, transport emergency equipment, and take other actions in response to the earthquake and tsunami that assaulted the Fukushima site would have made a very significant difference.*
>
> U.S. NRC Commissioner William D. Magwood IV

Summary of Key Conclusions AP1000 Plant Response to Extreme Events

- AP1000 design provides a unique capability to respond to design basis (DB) and beyond design basis (BDB) events due to three fundamental safety advancements:
  1. **Self-Actuates** For station blackouts, critical systems, structures, and components (SSCs) will automatically achieve a fail-safe configuration without the need for operator action or AC/DC power
  2. **Self Sustained** AP1000 design's passive approach to safety deemphasizes the importance of AC power and cooling supply
  3. **Self Contained** SSCs critical to placing the reactor in a safe shutdown condition are protected within the steel containment vessel and further surrounded by a substantial "steel concrete" composite shield building

"By nature of their passive designs and inherent 72-hour coping capability for core, containment, and spent fuel pool cooling with no operator action required, the ESBWR and AP1000 designs have many of the design features and attributes necessary to address the Task Force recommendations. The Task Force supports completing those design certification rulemaking activities without delay. "

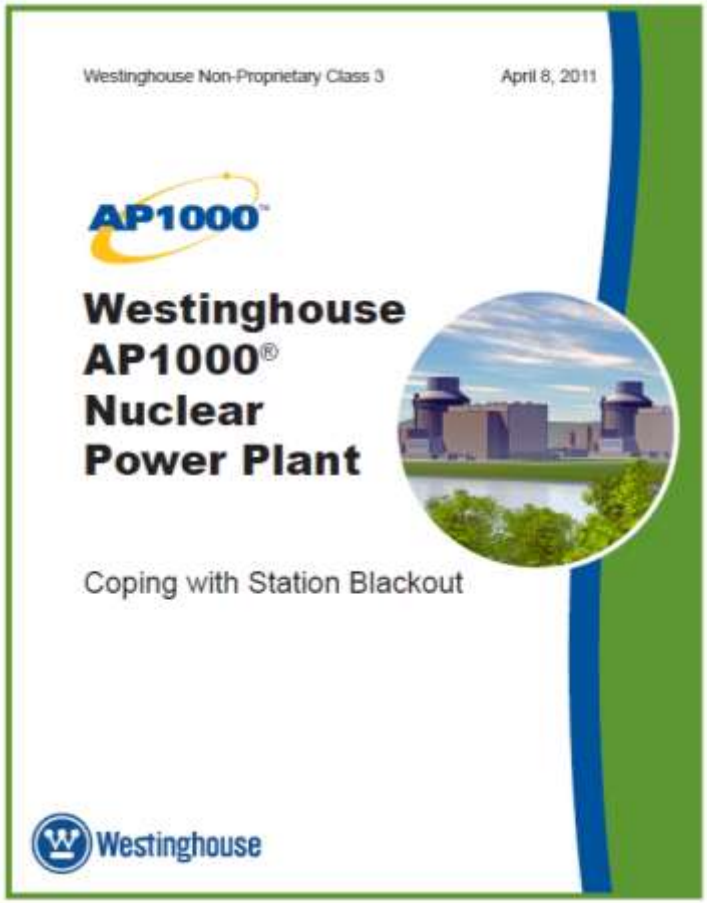
U.S. NRC Near Term Task Force Report

Westinghouse Fukushima Response Approach

- Westinghouse has generated three technical white papers addressing key issues from Fukushima to distribute to customers:
  1. Coping with Station Blackout
  2. Spent Fuel Pool Cooling
  3. Response to External Hazards
- Westinghouse has also created a public website, providing animations to illustrate the AP1000 features for Station Blackout response at:

http://ap1000.westinghousenuclear.com/station_blackout_home/

- The reports demonstrate robustness of AP1000 design and provide customers confidence in the design's resiliency and reliability
- They also summarize the technical basis of the AP1000 assessment and are meant for a wide distribution



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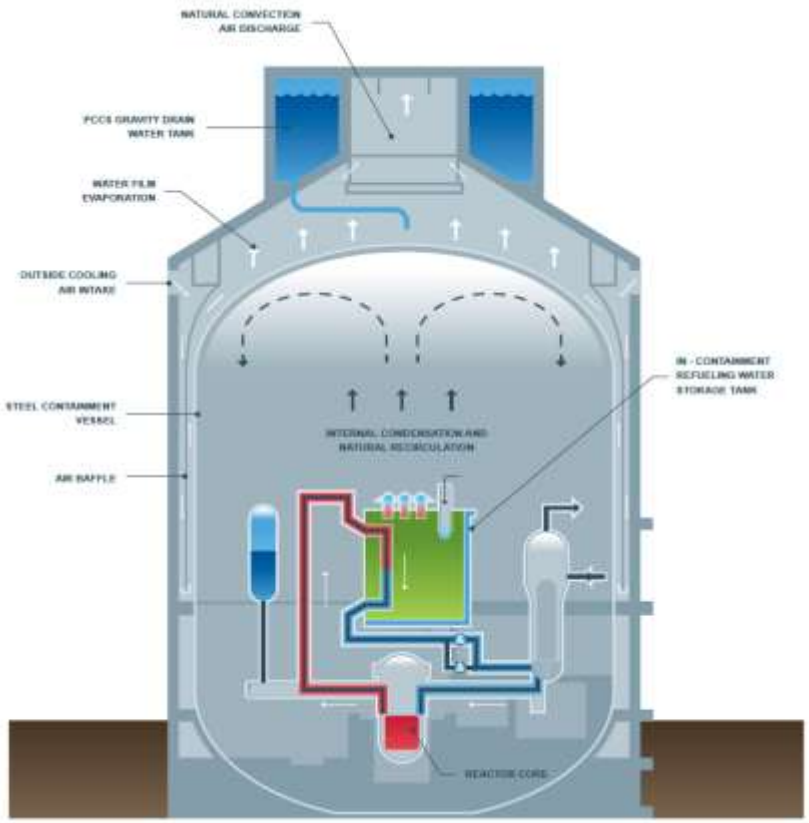
Standard AP1000 Plant Features and Key Safety Advancements

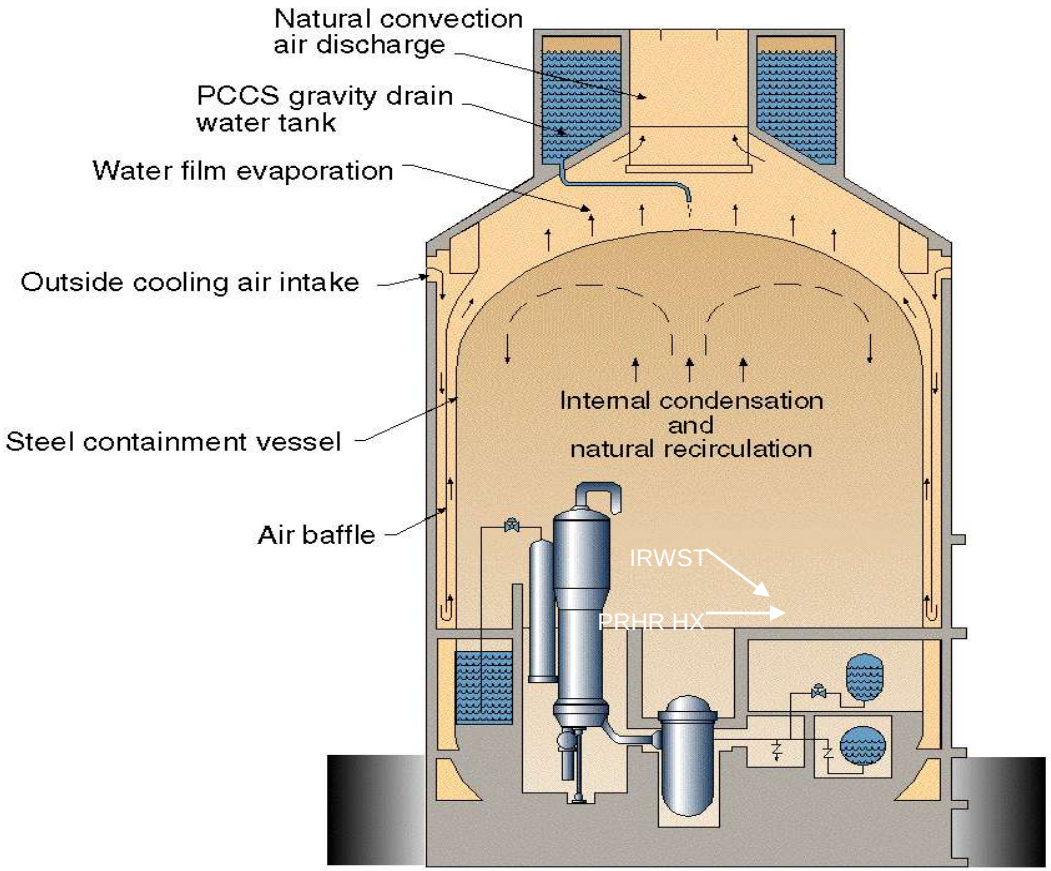
Major Safety Advancements of AP1000 Plant
The AP1000 Safety Approach

- **Passive Safety-Related Systems**
  - Use “passive” processes only, no active pumps, or diesels
    - One time alignment of valves
    - No support systems required after actuation
  - Greatly reduced dependency on operator actions
- **Active Defense-in-Depth-Related Systems**
  - Reliably support normal operation
    - Redundant equipment powered by onsite diesels
  - Minimize challenges to passive safety systems
  - Unnecessary to mitigate design basis accidents



All Critical Station Blackout Response Features FAIL SAFE

Passive Containment Cooling System



- Simple, “fail safe,” water drain actuates system
- Decay heat transferred to air and passive containment cooling system (PCS) water through the steel containment vessel
- No recirculation of water outside containment
- Maintains containment integrity with no actions or power required.
- No radiation releases

Safety Functions Required to Mitigate SBO

1. Core cooling, inventory, and reactivity control
2. Containment cooling and ultimate heat sink
3. Spent Fuel Pool cooling

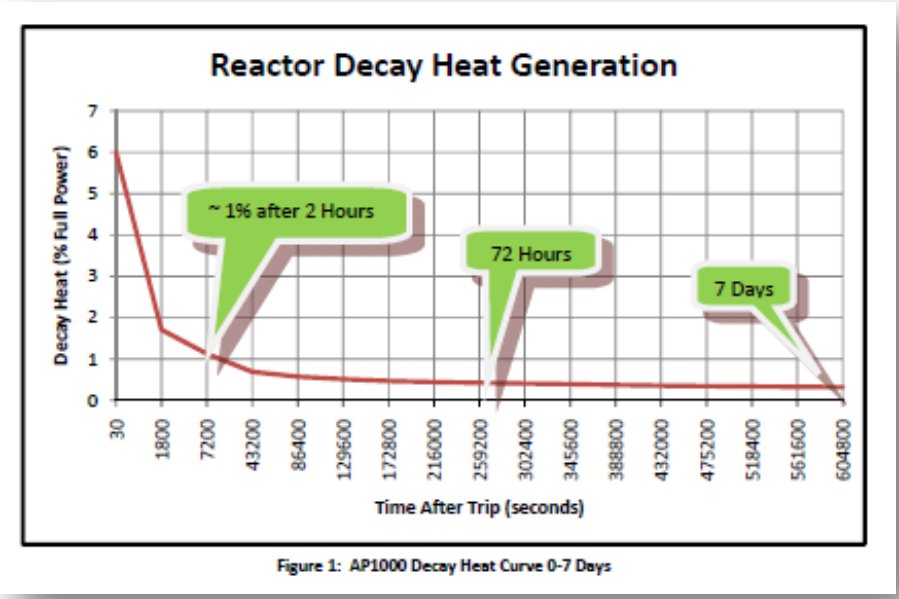
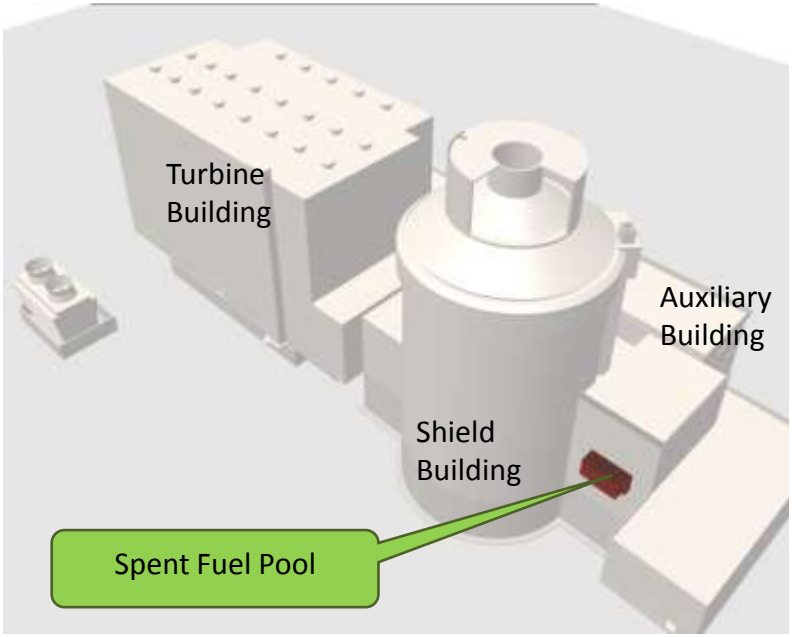


Figure 1: AP1000 Decay Heat Curve 0-7 Days



Initiation of Natural Circulation & Decay Heat Removal

0 – 72 hours

- SBO results in reactor trip
- Decay heat removal by passive HX
- RCS makeup / boration by passive makeup tanks
- Passive containment cooling

3 – 7 days

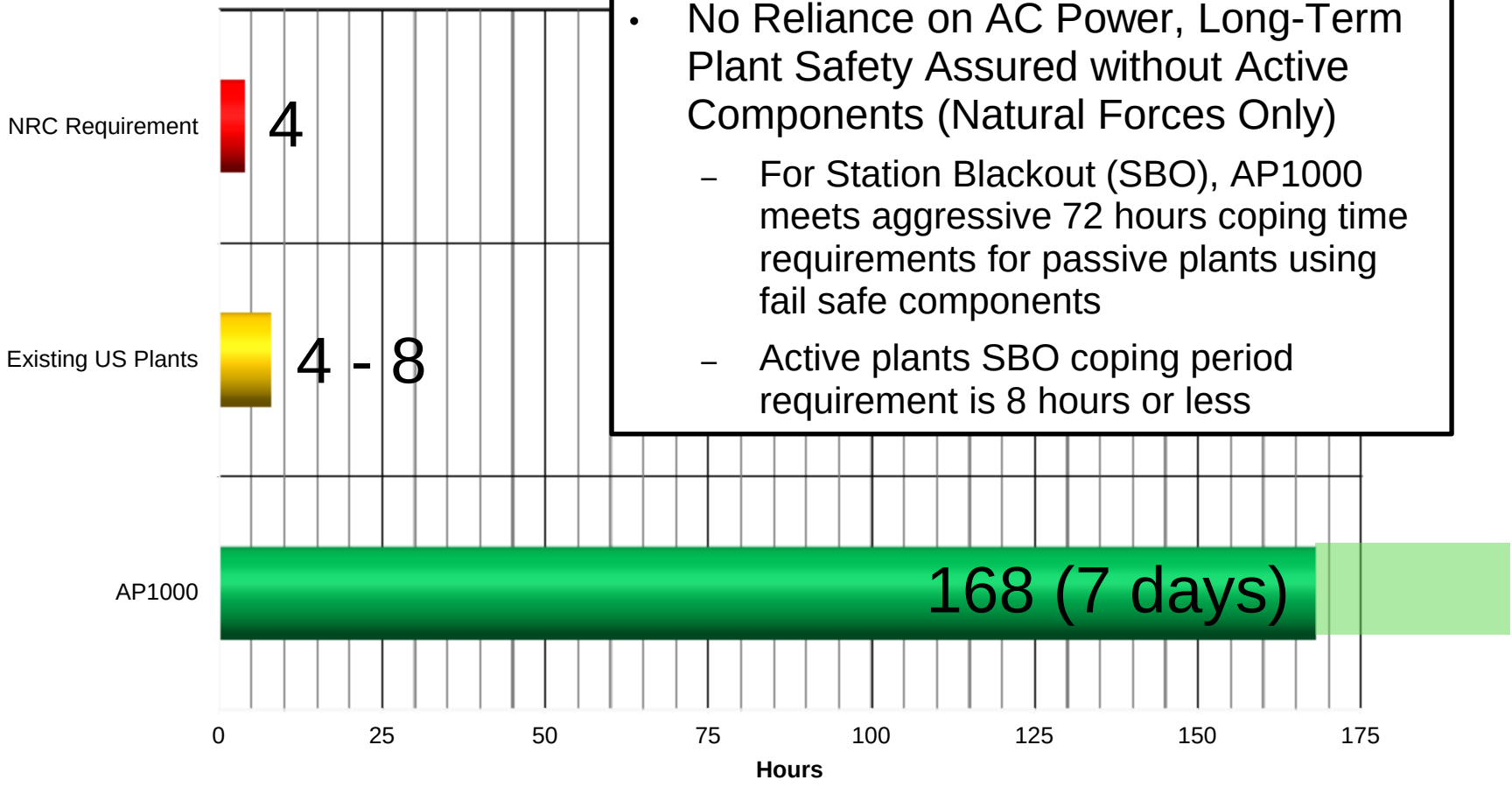
- Control room displays / lighting provided by PMS (power by Ancillary Diesel Generators*).
- PCS Recirculation Pumps* (powered by the Ancillary Diesel Generators*) transfer water from Ancillary Tank to PCS.

7 days & beyond

- Additional sources of makeup water available onsite to continue operation of Containment Cooling indefinitely
- Bad quality water (sea water) can be used for PCS makeup without damaging plant
- External water sources (tanker trucks, emergency vehicles) can be used to transport fresh water

* Backup provided through built-in plant connections and pre-arranged offsite supply of emergency power and portable pumps.

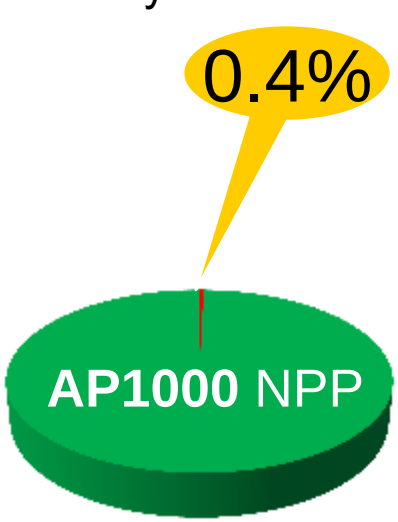
AP1000 Coping with a Station Blackout

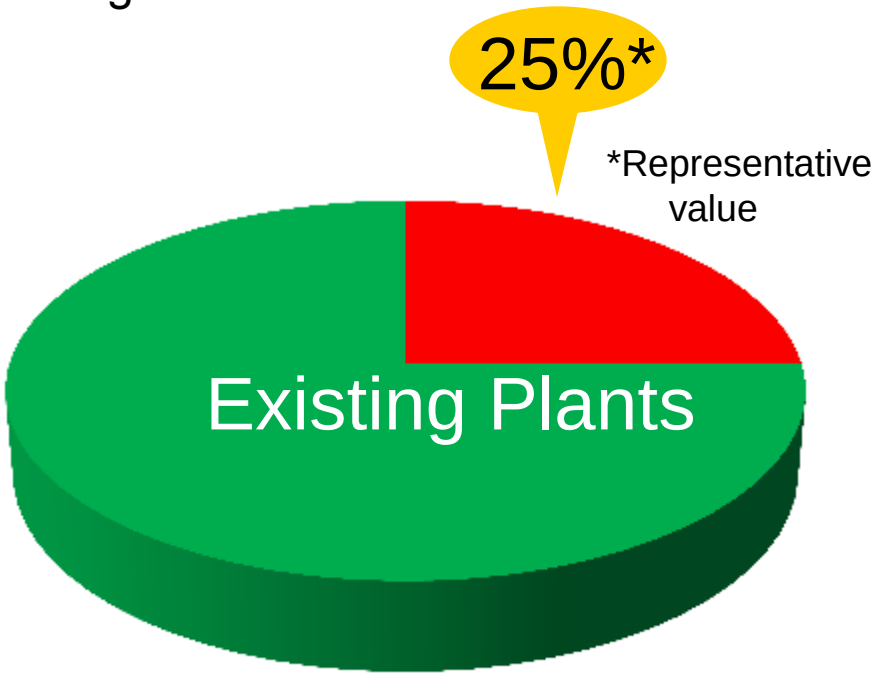


- No Reliance on AC Power, Long-Term Plant Safety Assured without Active Components (Natural Forces Only)
  - For Station Blackout (SBO), AP1000 meets aggressive 72 hours coping time requirements for passive plants using fail safe components
  - Active plants SBO coping period requirement is 8 hours or less

Major Safety Advancements of AP1000 Design

… Significantly reduce risk and are key to mitigate extreme external events



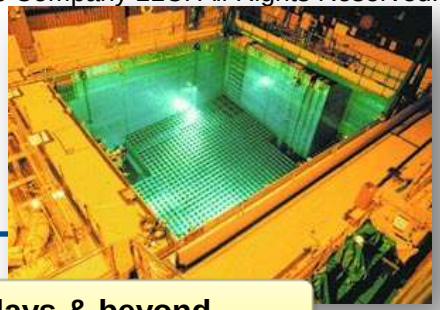


AP1000 Passive Safety Concept achieves a dramatic reduction in risk resulting from loss of offsite power events (e.g., Station Blackout) compared even to the most advanced active PWR designs

Spent Fuel Pool Cooling: Lines of Defense

- **During Normal and Abnormal Conditions, the active defense-in-depth and duty systems provides highly reliable spent fuel pool cooling**
  - Spent fuel cooling system, residual heat removal system, component cooling water system, and service water system all have 2*100% design for active components
  - Offsite power backup provided by 2*100% onsite standby diesel generators with automatic startup on loss of offsite power
- **For unlikely events with extended loss of AC power (station blackout) and/or loss of heat sink, the safety case for the AP1000 design is provided by passive means**
  - Simple or no operator actions are required for 72 hours
  - Beyond 72 hours, one of the two PCS RECIRCULATION PUMPS (powered by the ancillary diesel generators) is used to pump water from the ancillary tank to the spent fuel pool. The ancillary tank contains sufficient volume of makeup water to continue this action from 72 hours to approximately 7 days. Backup is provided by offsite portable equipment.
- **For extreme events, the spent fuel pool spray system provides an additional line of defense to provide fuel cooling**

Spent Fuel Pool Cooling and Makeup SBO



0 – 72 hours

- SBO results in loss of normal SFS cooling
- Decay heat is removed by heat up and boiling
- SFP provides significant water for boil off.
- Makeup to SFP is available from adjacent pools. Additional gravity makeup water available to maintain level above assemblies.
- Building vent panel opens automatically

3 – 7 days

- PCS Recirculation Pumps* (powered by the Ancillary Diesel Generators*) transfer water from Ancillary Tank to SFP.

7 days & beyond

- Additional sources of makeup water available onsite to continue SFP cooling indefinitely
- Bad quality water (sea water) can be used for SFP makeup without damaging plant
- External water sources (tanker trucks, emergency vehicles) can be used to transport fresh water.

* Backup provided through built in plant connections and pre-arranged offsite supply of emergency power and portable pumps.

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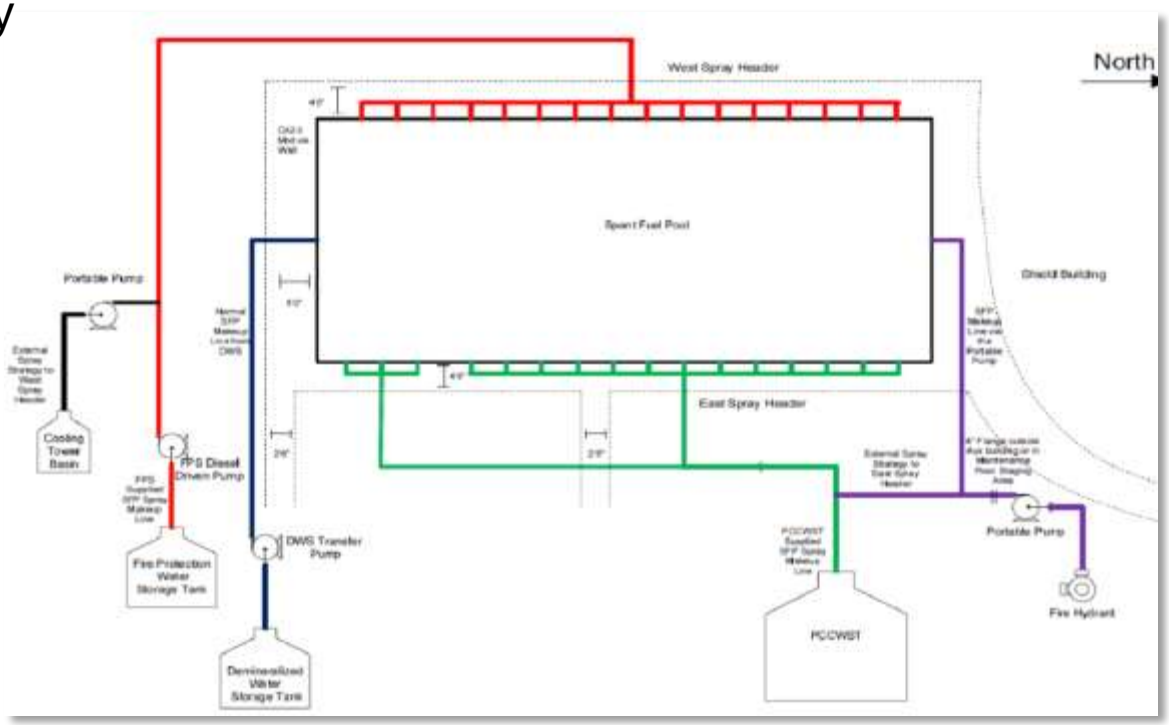
Spent Fuel Pool Cooling >7 days (Long Term)

- After seven days, the Ancillary diesel generators will require additional fuel from offsite.
- Operator action is required to align additional water supplies. Water is available from plant storage tanks, offsite, and onsite service water (sea water).
- On-site water sources have a capacity of over 2 million gallons (>7,600 m^3). Only 35 gallons/min (7.9 m^3/hr) is required to cool the spent fuel.



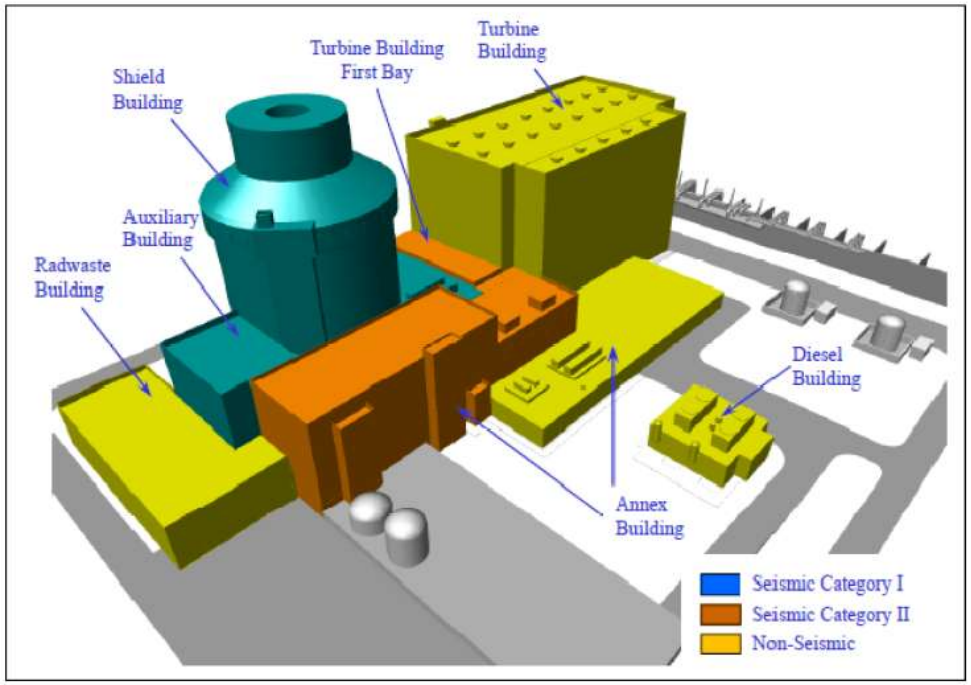
AP1000 External Hazards Design Basis

AP1000 Design for External Hazards Seismic Design Basis and Seismic Margins

- Safe shutdown earthquake (SSE) of 0.3g is the basis for the seismic design of Seismic Category I & II structures
- Seismic margin analysis performed as part of U.S. licensing process to demonstrated high confidence in low probability of failure (HCLPF) for >0.5g

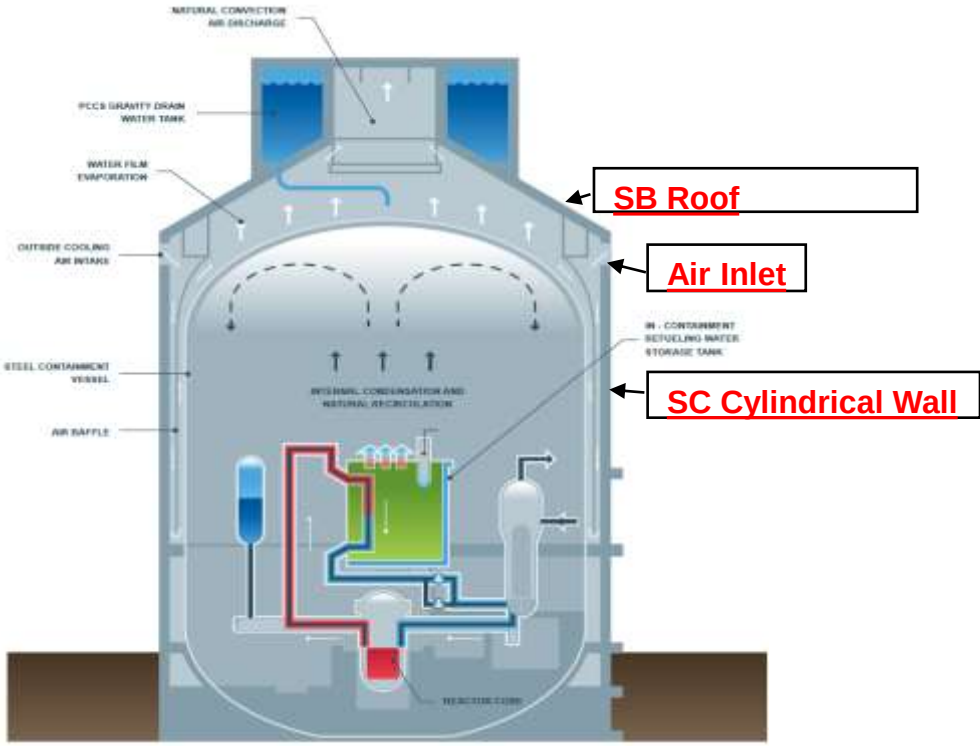
Portions of Various SC-I Structures	HCLPF (PGA)
Shield Building Tension Ring	0.73 g
Shield Building PCS Water Tank	0.81 g
Shield Building Conical Roof	0.71 g
Shield Building SC Cylindrical Wall	0.74 g
Steel Containment Vessel - Buckling	0.73 g
Exterior Walls of Auxiliary Building – Wall 11	0.88 g

*Sample of HCLPF Values for Various SC-1 Structures



Malicious Aircraft Impact

- AP1000 is designed to protect against both military and large commercial aircraft impacts
  - Evaluations complete for both the United States and Europe
  - Assessments demonstrate that the Shield Building prevents containment damage
  - Assessments consider the effect of structural damage, shock and vibration, and large fires
- Assessments have been extensively reviewed by U.S. NRC, U.K. ONR, and independent industry peer review committee



AP1000 Design for External Hazards Flooding

Design Basis Flooding

- AP1000 design requirements specify that site grade elevation, site Elevation 100’-0”, be above the maximum probable flood limits
- Flooding that does not exceed site grade elevation would not affect safe shutdown components
- Additional margin expected as result of site-specific evaluations

External Flooding Margin

- Site suffers a severe flood which greatly exceeds the basis (i.e., flooding one floor above design basis), the reactor core and SFP remain protected
- Containment would remain unaffected
- Fail-safe nature of SBO passive safety features results in their automatic actuation for decay heat removal and containment cooling even with a postulated loss of all AC and DC power

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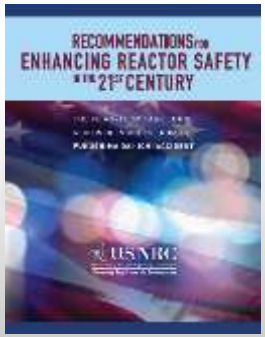

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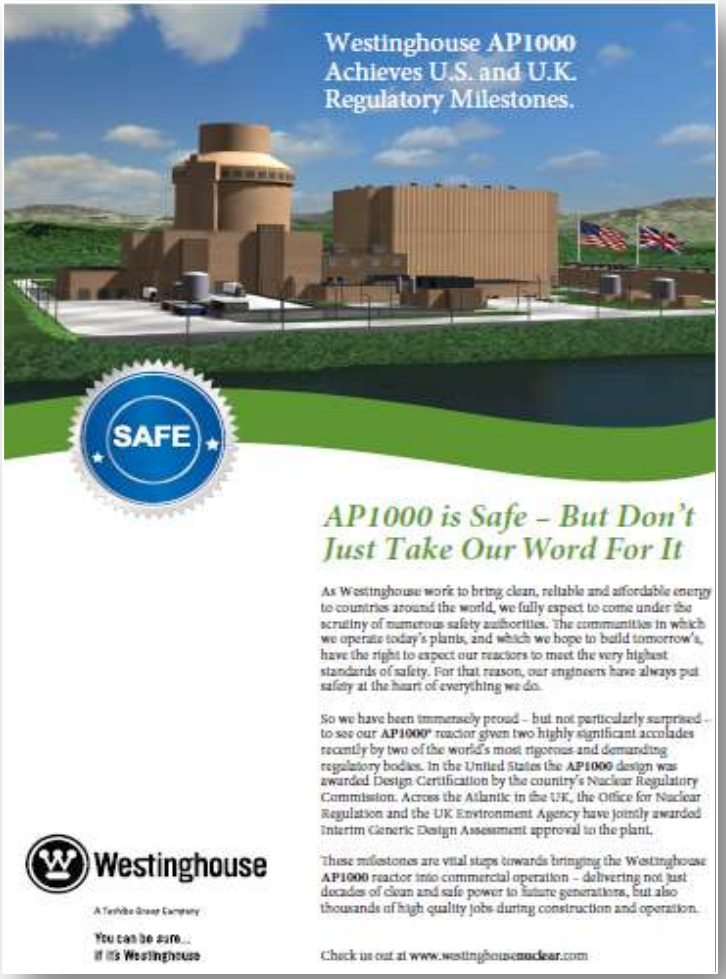
UR NRC Near Term Task Force Report

Questions ?



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