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Innovations in Reactor Designs

OECD/NEA workshop on innovations in water-cooled reactor technologies, 11-12 Feb 2015

Julie Gorgemans

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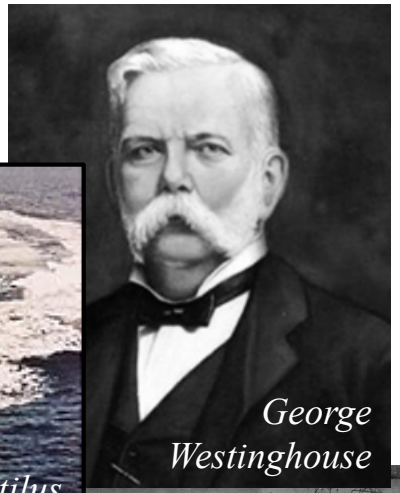
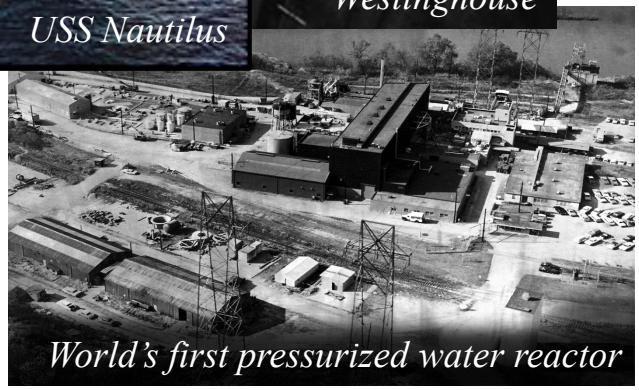
Westinghouse Electric Company

- Incorporated in 1886 by George Westinghouse
- Responsible for some of the world's most important achievements:
  - AC technology
  - 1st commercial radio broadcast
  - U.S.S. Nautilus
  - 1st camera on the moon
  - **Commercial nuclear power**
- Westinghouse Is Solely Focused on Commercial Nuclear Technology
- Nearly **50 percent** of the nuclear power plants in operation worldwide are based on Westinghouse technology


George Westinghouse


USS Nautilus


World's first pressurized water reactor

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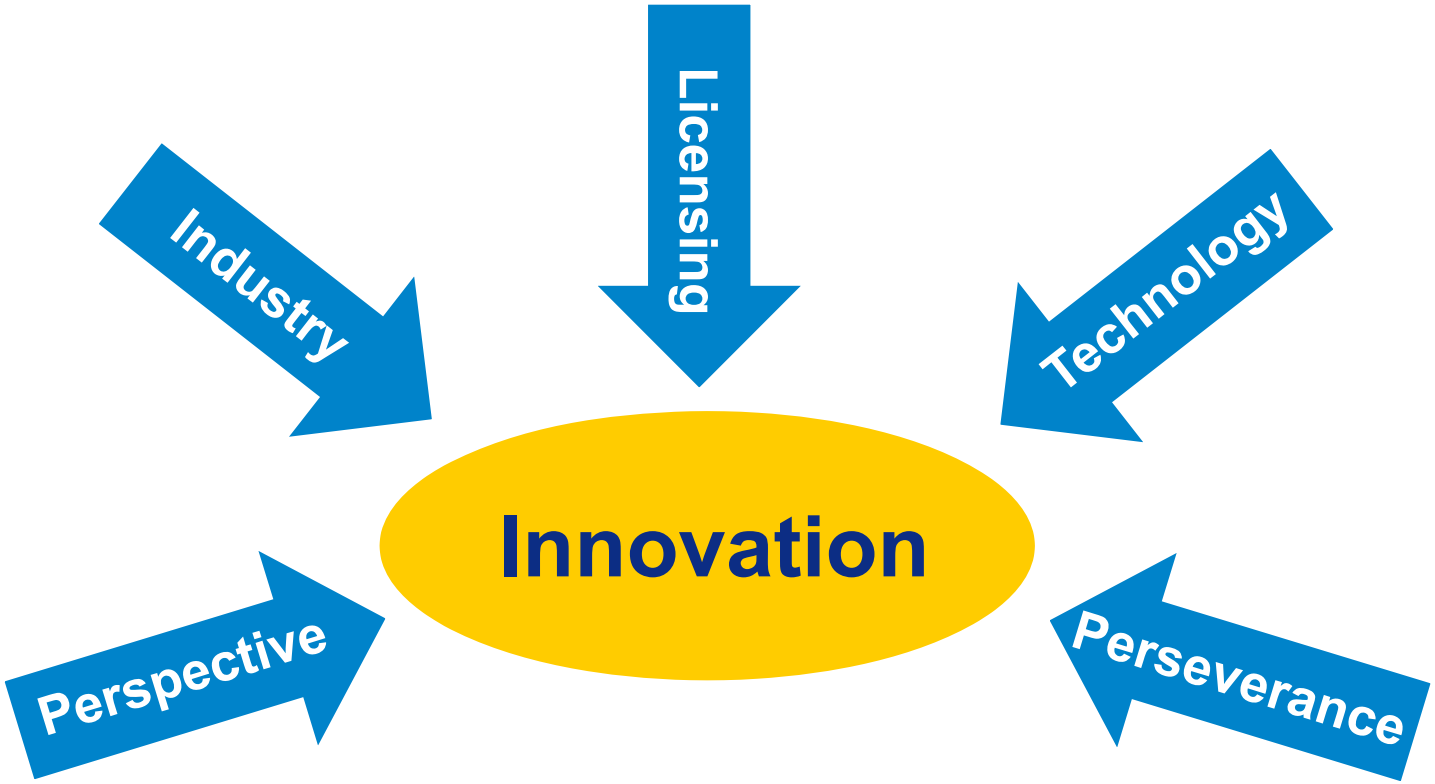
Factors that Influence the Development of a Nuclear Power Plant



Innovation and ability to innovate have many factors

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AP1000® Plant Design Objectives

- Greatly simplified PWR
  - Construction, maintenance, inspection, operation, safety
- Increased operation and safety margins
  - Design basis accidents, Probabilistic Safety Assessment (core melt prevention & mitigation)
- Competitive cost of power, less than coal plant, other nuclear
- Short construction schedule; 3 years
- Licensing certainty – reviews by multiple different regulators
  - U.S. design certification, COL approvals, construction inspections
  - China preliminary/final safety analysis report reviews
  - UK generic design assessment and Canada pre-licensing review
- Proven design; proven components/systems
- Improved availability, maintenance, inspection, operational radiation exposure
- Pre-engineered/pre-licensed standard design
  - Fleet wide/multiple country standard with very limited differences
- Active participation from stakeholders in the **AP1000** plant design activities

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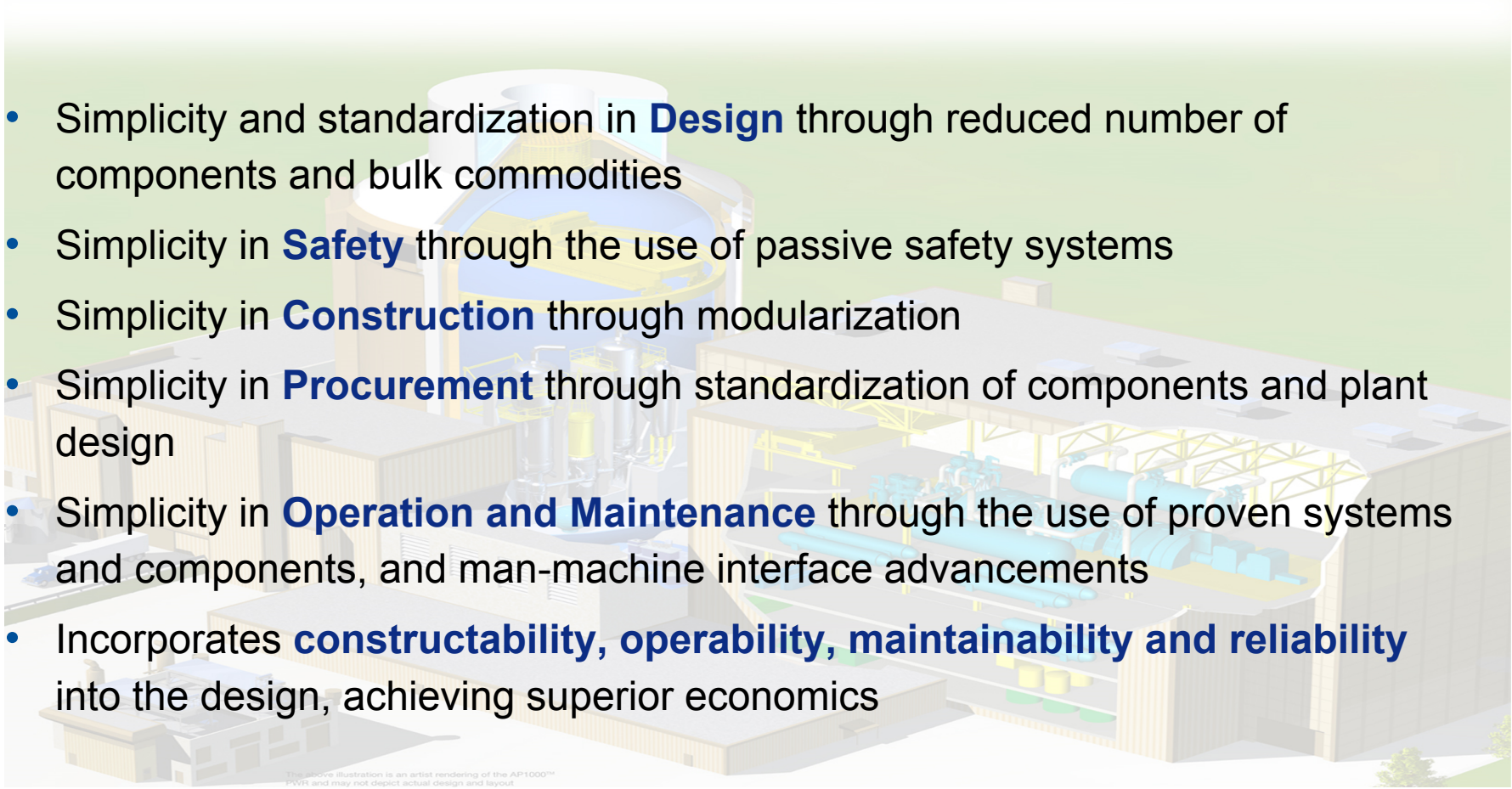
The AP1000 Nuclear Plant is a breakthrough in technology and design



- Simplicity and standardization in **Design** through reduced number of components and bulk commodities
- Simplicity in **Safety** through the 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 the use of proven systems and components, and man-machine interface advancements
- Incorporates **constructability, operability, maintainability and reliability** into the design, achieving superior economics

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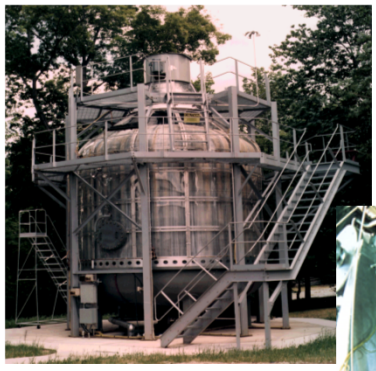
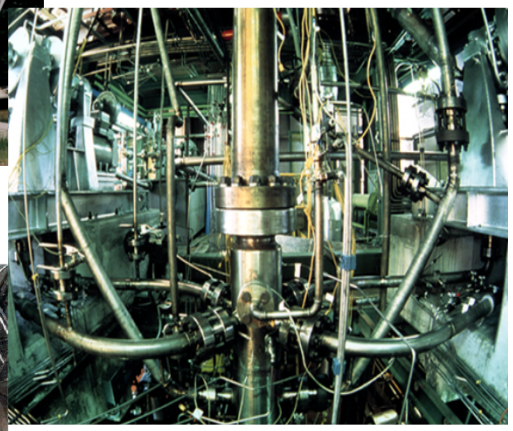
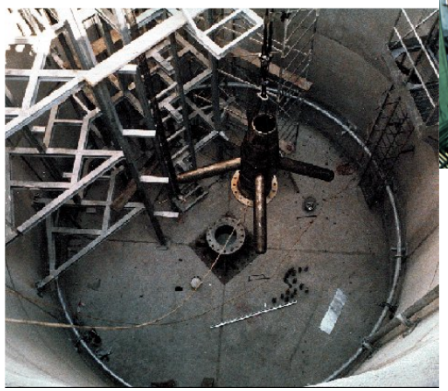
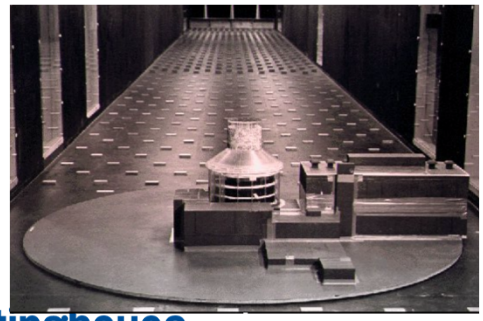
Advanced Passive Technology Testing

- 15 different test facilities used for Design Basis Accident (DBA) testing for the advanced passive technology:
  - Demonstrated passive core and containment cooling
  - Collected data for code validation
- U.S. NRC conducted extensive, independent testing in 5 test facilities:
  - Confirmed results obtained by Westinghouse for DBA as well as a significant number of beyond design basis accidents









Innovation in the nuclear industry requires analysis and test data

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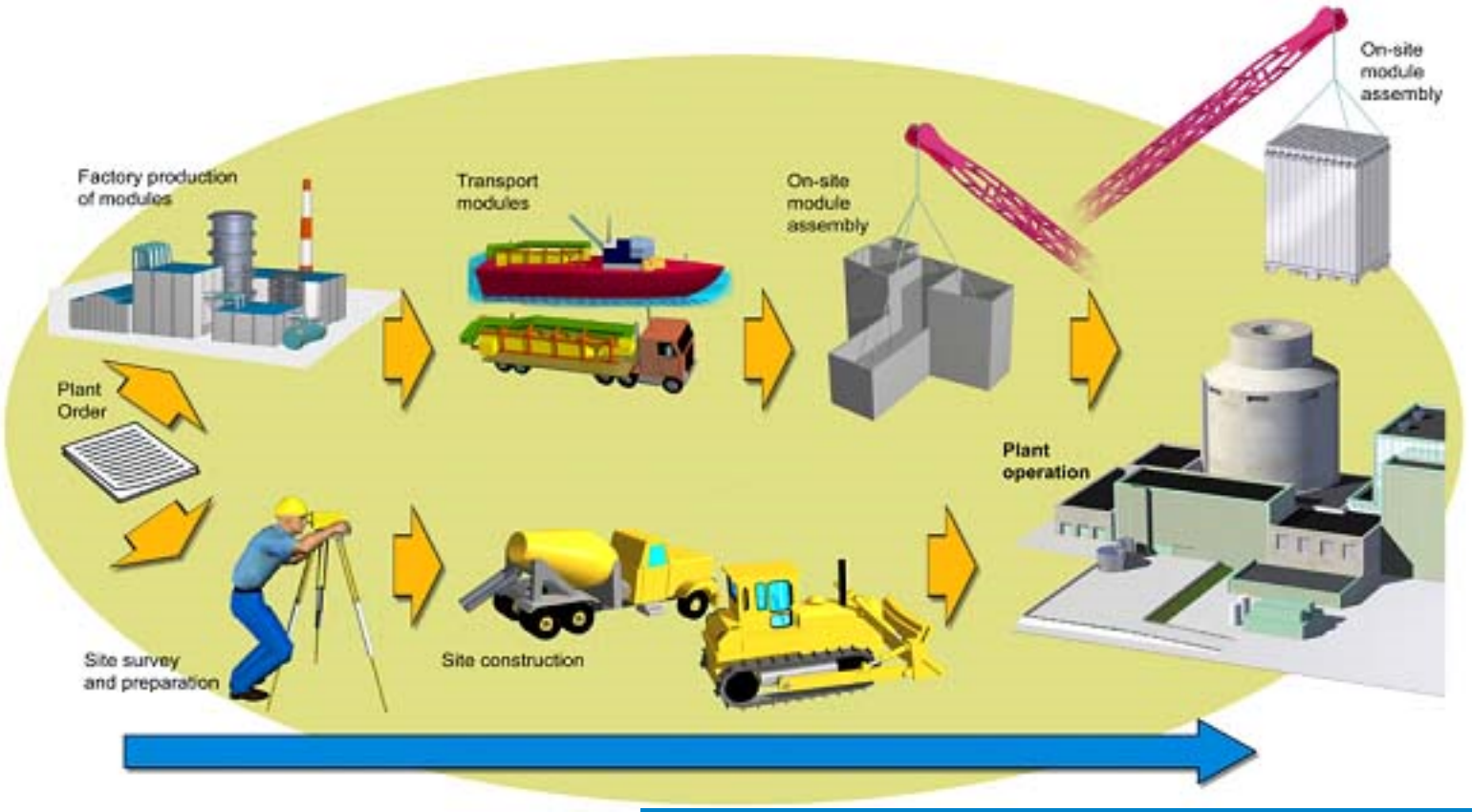
Modular Construction - Site Work Done in Parallel with Module Fabrication and Transportation



Accelerated construction time - three years from first concrete to fuel loading for Nth plant

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The **AP1000** Plant is the result of an evolution over three decades

1980 1990 2000 EUR Certification (2007) 2010

Advanced Passive Technology Development
AP600™ Plant (1985 - 1997)

AP600 Plant Review by US NRC
(1992 - 1998)

AP600 plant Approved
(1999)

AP1000 Plant Approved
DCD Rev 15 (2006)

Sanmen & Haiyang Construction Permits (March & Sept 2009)

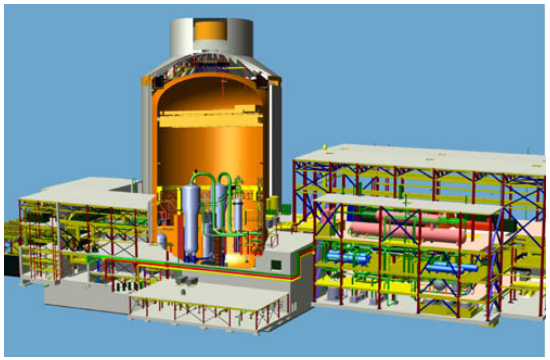
AP1000 Plant Approved
DCD Rev 19 (2011)

AP1000 Plant Design Development
(2000 - 2011)

AP1000 Plant Review by US NRC (2002 - 2011)

AP1000 Plant iDAC/iSODA
(UK, 2011)

- The **AP1000** plant builds on more than half a century of Westinghouse experience.
- More than $1 billion design and testing effort
- More than 200 man-years of review by the US NRC



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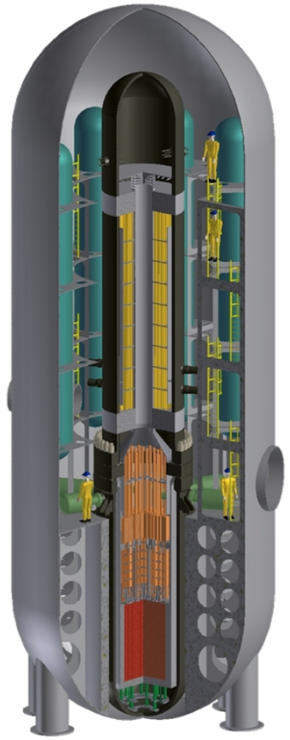
From the **AP1000** Plant towards the SMR

- Package existing technology developed for the AP600 and **AP1000** PWR to meet the demands of the SMR market
  - Less than 300MWe
  - Rail shippable components
  - Integral PWR
  - Containment vessel and reactor below grade
  - Extended coping for SBO – 7 days
  - Employ compact containment to address economy of scale challenge
  - Short development cycle/reduced licensing risk
  - Modular construction – 30-month construction schedule



SMR retains the same approach to Passive Safety as AP600 and AP1000 PWR

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Considerations for Advanced Reactor Designs

- Successful commercialization of advanced reactor designs requires:
  - Sustained governmental nuclear policy (CO_2 reduction)
  - Focus on mission: Low-cost electricity
  - Regulators ready to license a new concept
  - Collaboration:
    - Multiple stakeholder cooperation (no single vendor)
    - Involvement from the industry, national laboratories and universities
  - Cost-share
  - Improve public perception for the advanced reactor
- Westinghouse has and will continue to explore a broad range of technologies
- Westinghouse recognizes the potential of salt-cooled reactors:
  - Do salt-cooled reactors truly have the potential to create a step change in economics and enhance safety?
  - Further investigation required to improve the technology readiness
  - Recommends industry collaborative effort

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Enhancing Safety: The Pursuit of Accident-tolerant Fuel

- The Westinghouse passive technology is a significant step forward in further enhancing the safety of what was already highly safe. What else can be done to enhance nuclear plant safety even further?
- The **Westinghouse accident-tolerant fuel (ATF) program** began in 2004, aimed at producing light water reactor fuel that provides a leap ahead in safety and performance, while also being economically attractive for nuclear power plant operators
- **International, multidisciplinary team, funded by the U.S. Department of Energy:** industry, national labs, universities
- Focus on new materials for both the cladding and the pellets to develop fuel that withstands and survives extreme events
- Manufacture of test fuel rods by 2016, six-year exposure in Test Reactors to develop the data required for licensing, lead test rods in commercial reactors in 2022

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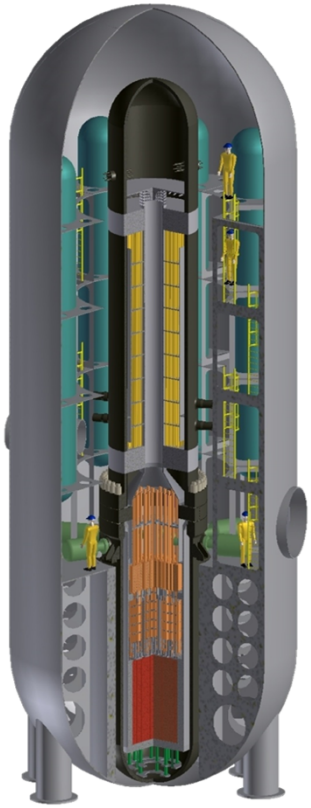
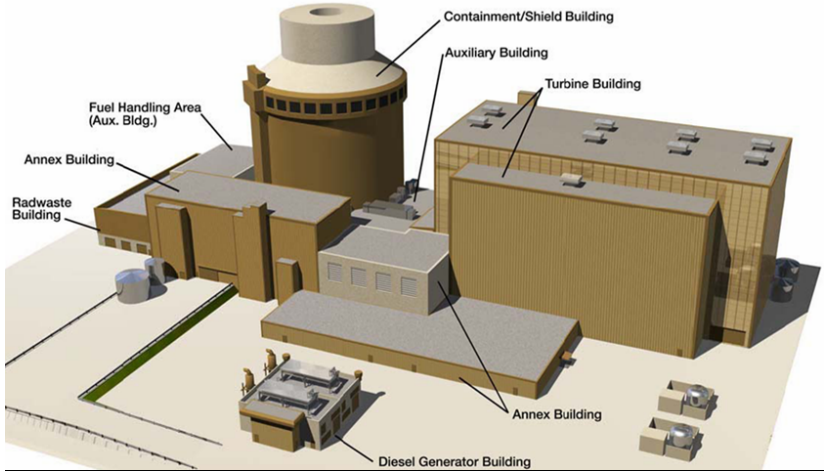
Conclusions





- The **AP1000** plant is a breakthrough in technology and design
  - Passive safety
  - Simplification
  - Modular construction
- The Westinghouse SMR builds on the existing technology developed for the AP600 and **AP1000** PWR to meet the demands of the SMR market
- Development of advanced reactor designs should be the result of a collaborative effort (industry, national labs, universities)
  - Potential of salt-cooled reactors
  - Need to mature the technology
- Westinghouse continues developing new technologies to improve the safety of light water reactors (accident-tolerant fuel)

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