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Lessons Learned from the Approval of the NuScale SMR

SNETP Forum

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Dominick Claudio
Director of Sales

Acknowledgement and Disclaimer

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Who is NuScale Power?

- NuScale Power was formed in 2007 for the sole purpose of completing the design and commercializing a small modular reactor (SMR) – the NuScale Power Module™
- Initial concept was in development and testing since the 2000 U.S. Department of Energy (DOE) MASLWR program
- Fluor, global engineering and construction company, became lead investor in 2011
- In 2013, NuScale won a competitive U.S. DOE Funding Opportunity for matching funds, and has been awarded over $300M in DOE funding since then
- >530 patents granted or pending in nearly 20 countries
- >400 employees in 5 offices in the U.S. and 1 office in the U.K.
- Rigorous design review by the U.S. Nuclear Regulatory Commission (NRC)—NuScale received Design Approval in August 2020
- Total investment in NuScale to date is greater than US$1B

NuScale Engineering Offices Corvallis

One-third scale NIST-1 Test Facility

NuScale Control Room Simulator

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A Bold, New Energy Source

- **Smarter Energy** – Flexible design can support multiple applications, integrate with renewable resources, provide highly reliable power to mission critical facilities, and serve as clean baseload power.
- **Cleaner Energy** – 100% carbon-free energy – as clean as wind or solar – with a small land footprint.
- **Safer Energy** – Should it become necessary, NuScale's SMR shuts itself down and self-cools for an indefinite period of time, with no operator action required, no additional water, and no AC or DC power needed.
- **Cost Competitive** – The NuScale SMR is far less complex than other designs. Off-site fabrication and assembly reduce cost. Components are delivered to the site in ready-to-install form. All of this results in construction occurring in a shorter, more predicable period of time.

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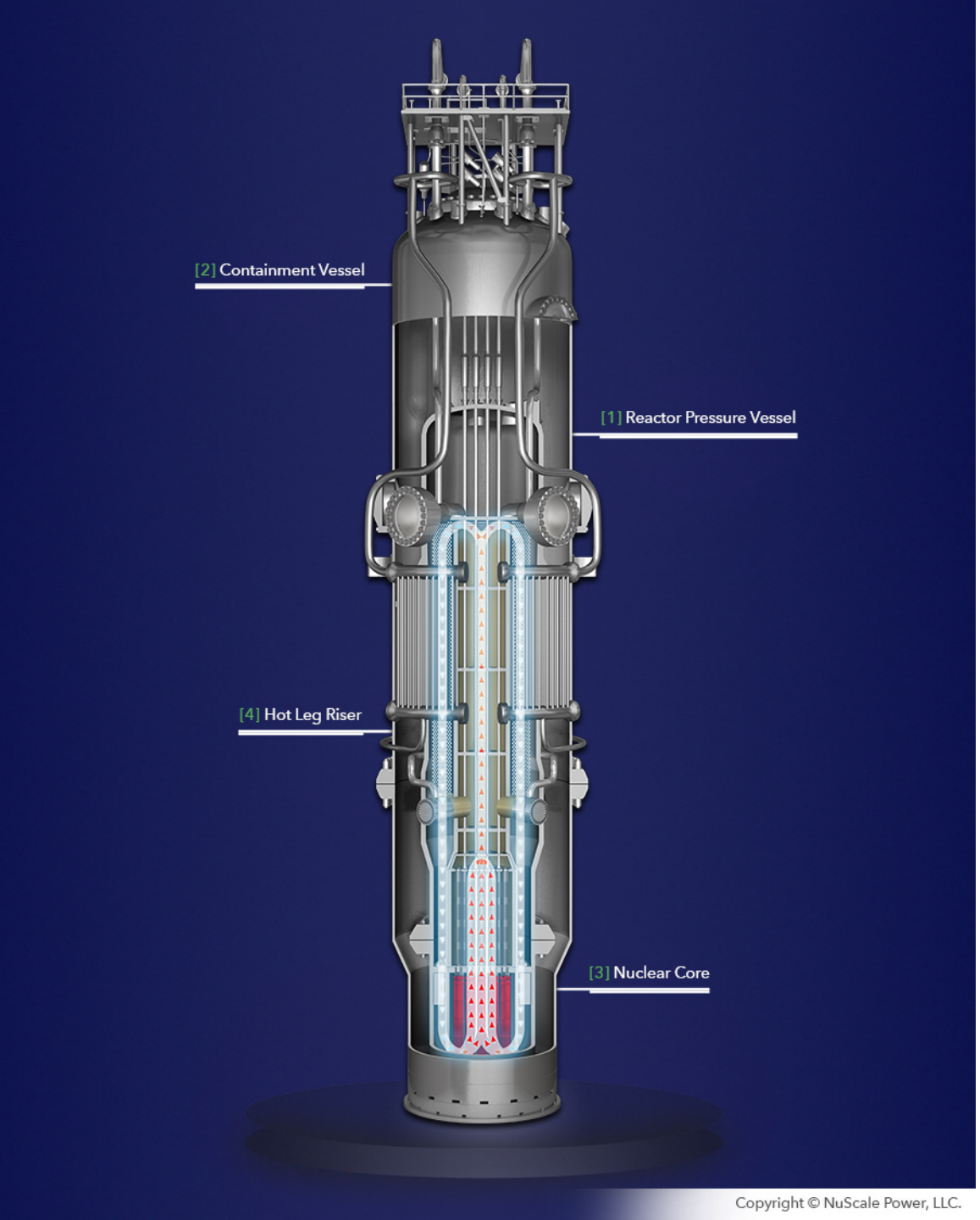

Core Technology: NuScale Power Module

- A **NuScale Power Module**™ (NPM) includes the reactor vessel, steam generators, pressurizer, and containment in an **integral package**

- Simple design that eliminates reactor coolant pumps, large bore piping and other systems and components found in large conventional reactors

- Each module produces up to 77 MWe
  - Small enough to be factory built for easy transport and installation
  - Dedicated power conversion system for flexible, independent operation
  - Incrementally added to match load growth
  - 12 module plant – up to 924 MWe gross
  - 6 module plant – up to 462 MWe gross
  - 4 module plant – up to 308 MWe gross

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Simplicity Enhances Safety

Natural Convection for Cooling

- Passively safe - cooling water circulates through the nuclear core by natural convection eliminating the need for pumps.

Seismically Robust

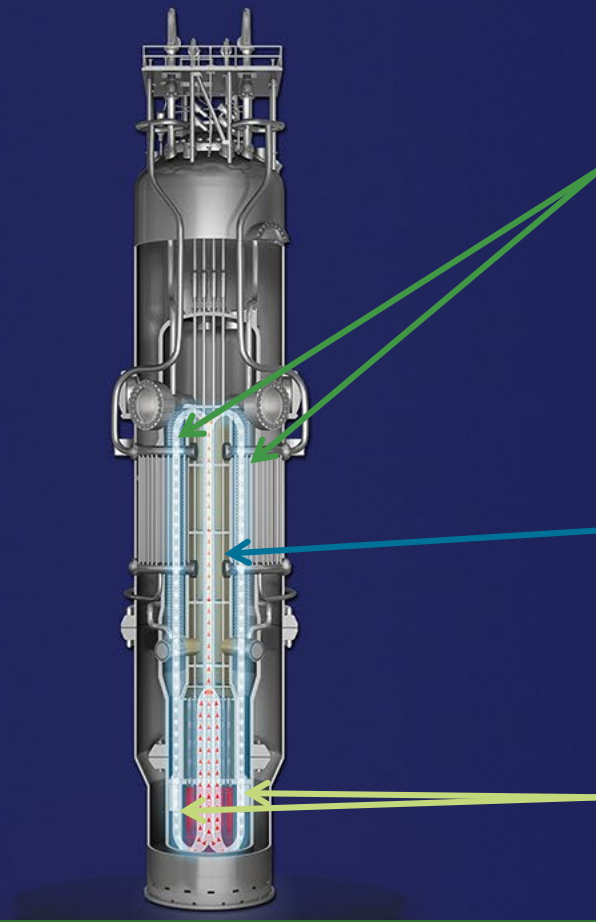
- System submerged in a below-grade pool of water in an earthquake and aircraft impact resistant building.

Simple and Small

- Reactor core is 1/20th the size of large reactor cores.
- Integrated reactor design - no large-break loss-of-coolant accidents.

Defense-in-Depth

- Multiple additional barriers to protect against the release of radiation to the environment.



Conduction **– the water heated by the nuclear reaction (primary water) transfers its heat through the walls of the tubes in the steam generator, heating the water inside the tubes (secondary water) and turning it to steam. This heat transfer cools the primary water.**

Convection **– energy from the nuclear reaction heats the primary water causing it to rise by convection and buoyancy through the riser, much like a chimney effect**

Gravity / Buoyancy **– colder (denser) primary water "falls" to bottom of reactor pressure vessel, and the natural circulation cycle continues.**

Second-to-none safety case – site boundary Emergency Planning Zone capable

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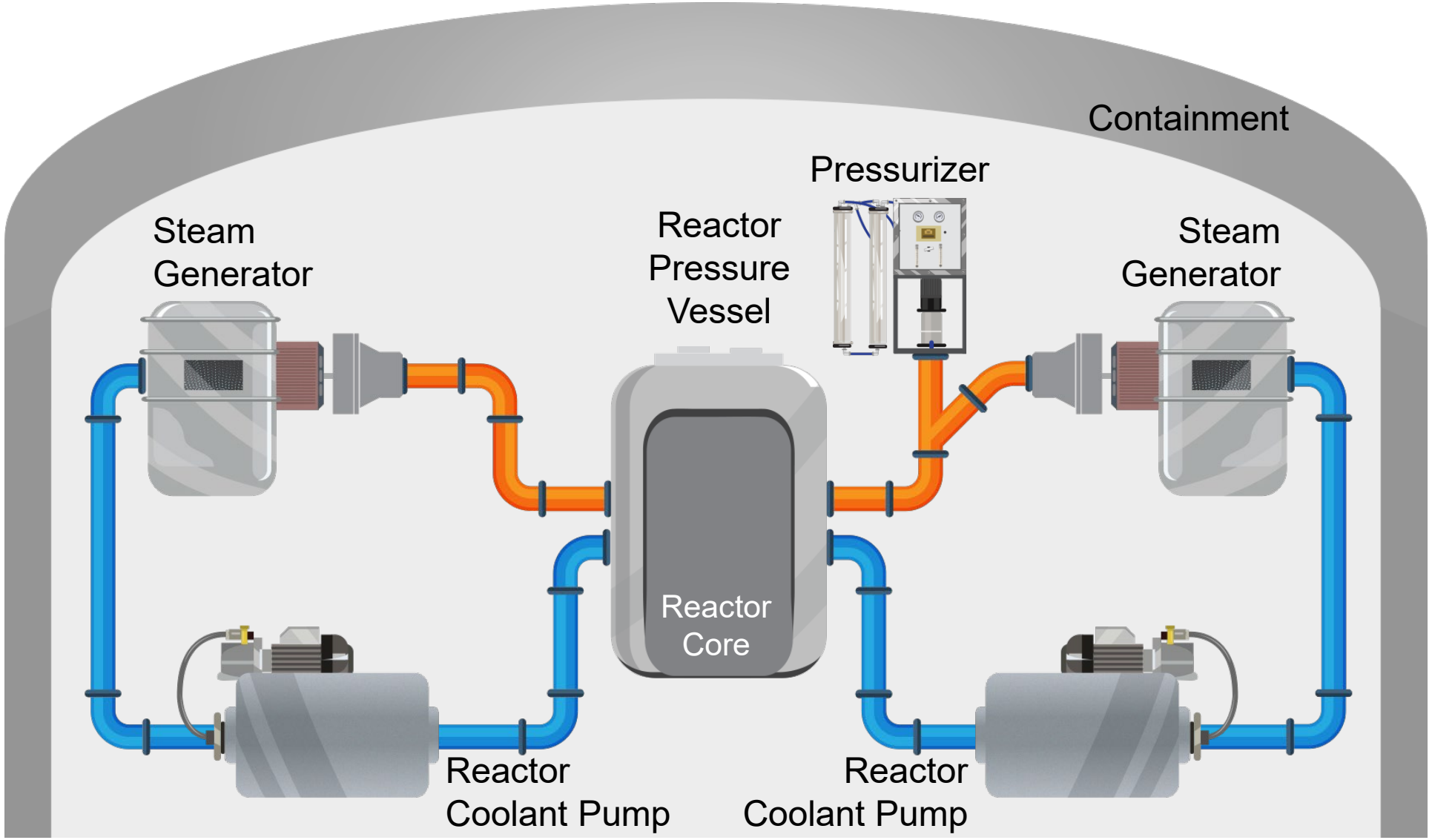
Typical Pressurized Water Reactor



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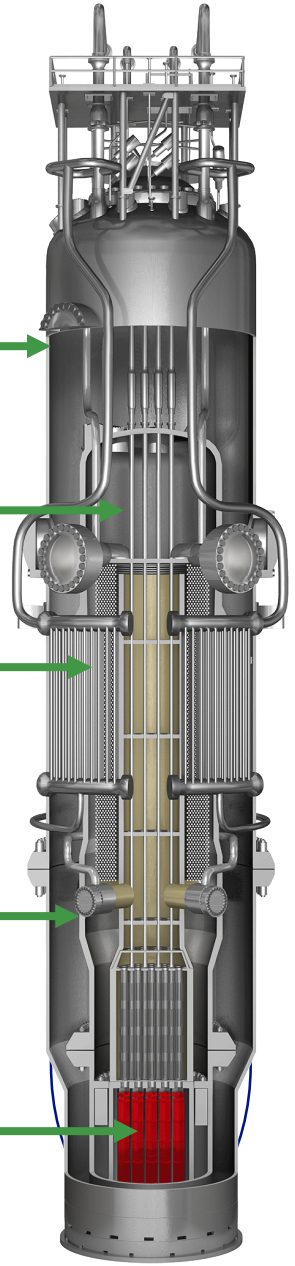
NuScale Power Module™ Components



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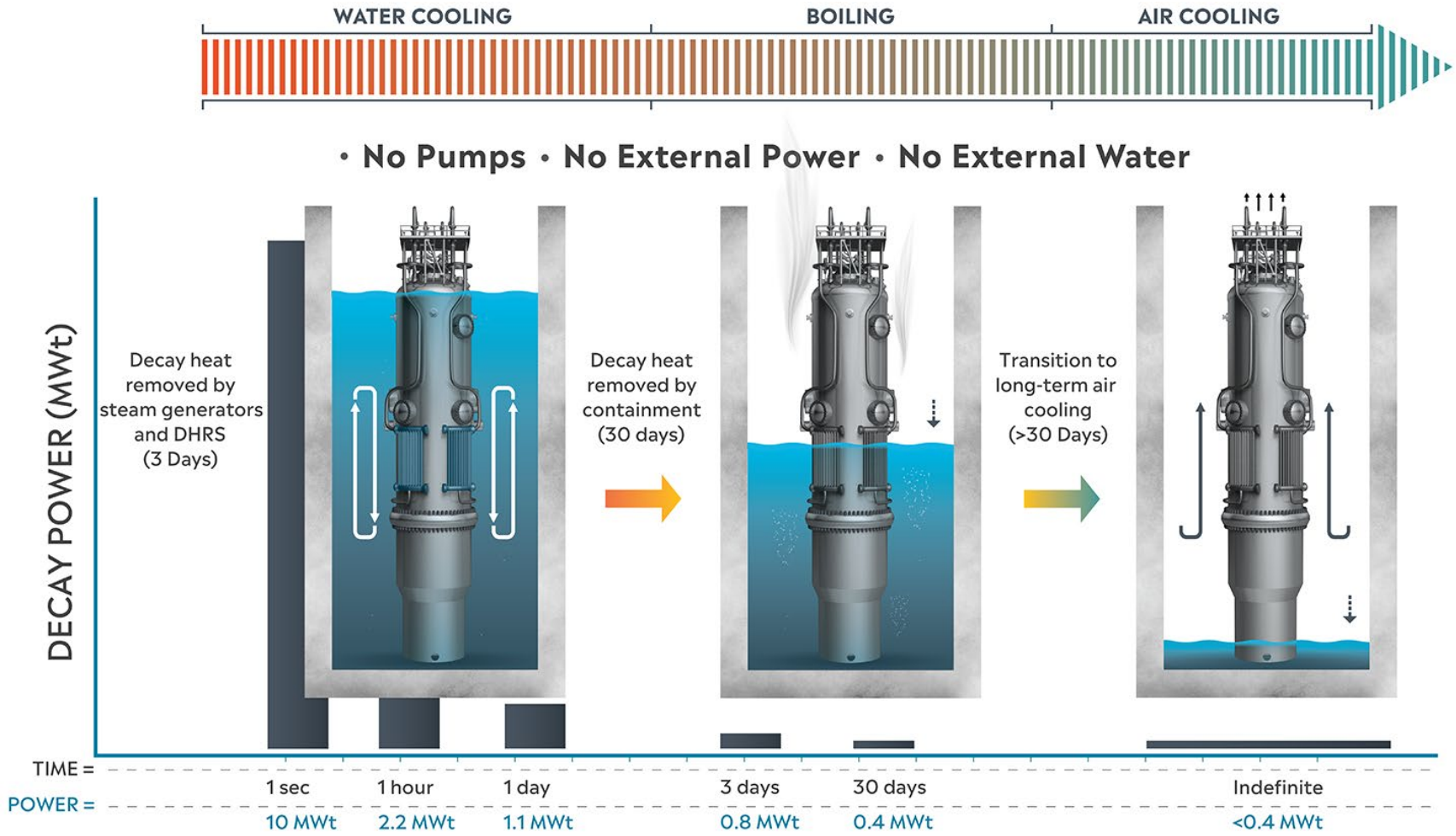
NuScale Safety Systems

Systems and Components Needed to Protect the Core:

- Reactor Pressure Vessel
- Containment Vessel
- Reactor Coolant System
- Decay Heat Removal System
- Emergency Core Cooling System
- Reactor Protection System
- Containment Isolation System
- Ultimate Heat Sink
- Residual Heat Removal System
- Safety Injection System
- Refueling Water Storage Tank
- Condensate Storage Tank
- Auxiliary Feedwater System
- Emergency Service Water System
- Hydrogen Recombiner or Ignition System
- Containment Spray System
- Reactor Coolant Pumps
- Safety Related Electrical Distribution Systems
- Alternative Off-site Power
- Emergency Diesel Generators
- Safety Related 1E Battery System
- Anticipated Transient without Scram (ATWS) System

Innovative Advancements to Reactor Safety

Nuclear fuel cooled indefinitely without AC or DC power*



**Alternate 1E power system design eliminates the need for 1E qualified batteries to perform ESFAS protective functions – Patent Pending*

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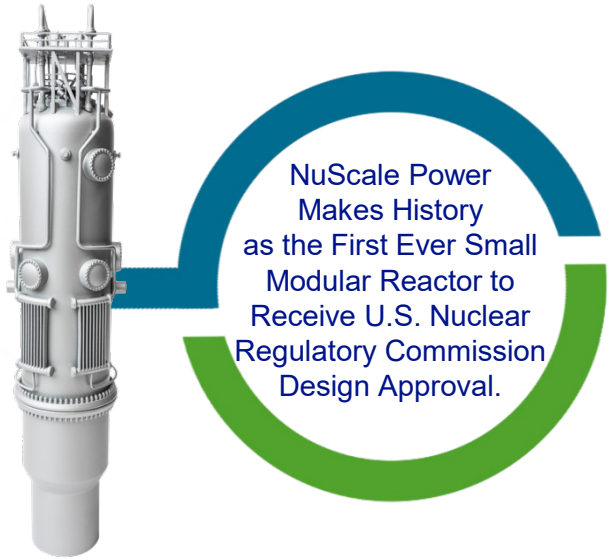
First SMR to Undergo Licensing in the U.S.

- Design Certification Application (DCA) completed in December 2016
- Docketed and review commenced by U.S. Nuclear Regulatory Commission (NRC) in March 2017
- NuScale received standard design approval in September 2020



DCA Statistics

- **12,000+** pages
- **14** Topical Reports
- **>2 million** labor hours
- **>800** people
- **>50** supplier/partners
- Over **$500M**

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The Challenge of Innovation

- Innovation itself is not the issue; innovations can enhance safety
- The challenge arises from the extent that the innovations depart from what was contemplated in creating the regulatory framework
- Safety enhancement alone is not sufficient justification
- Lack of holistic approach in evaluating safety
  - An innovation perceived as positive by one discipline may be negative to another
  - Innovations in a design are interdependent
    - Complicates review
    - One innovation can have cascading effects
- Time and cost to achieve approval is a disincentive
  - Lack of acceptance criteria creates ambiguity on demonstration of proof
  - Uncertainty of ultimate approval creates business risk

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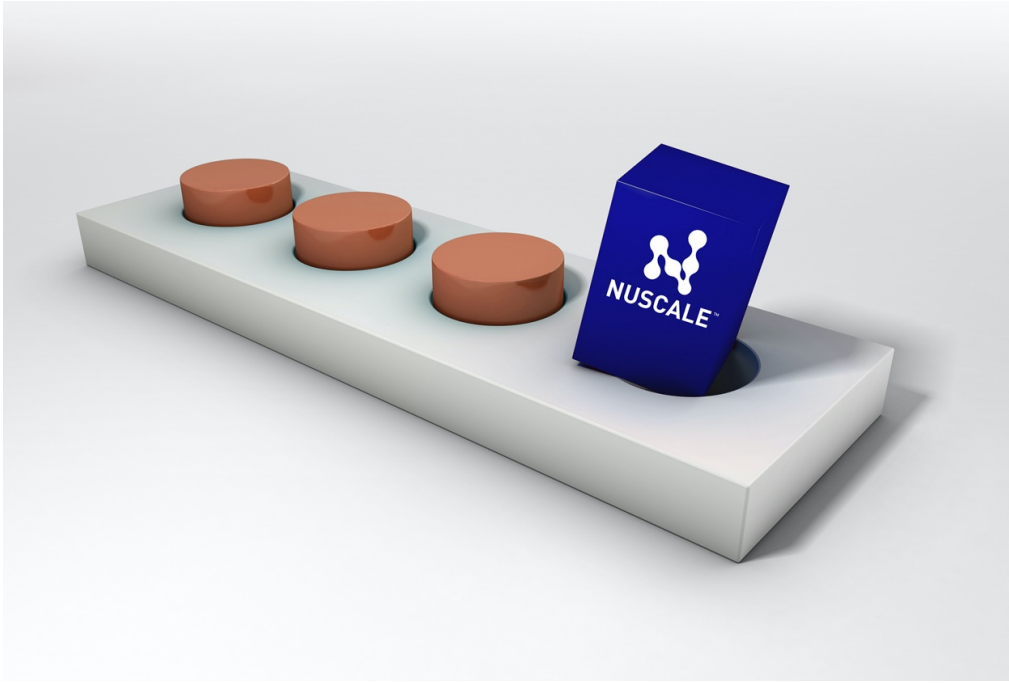
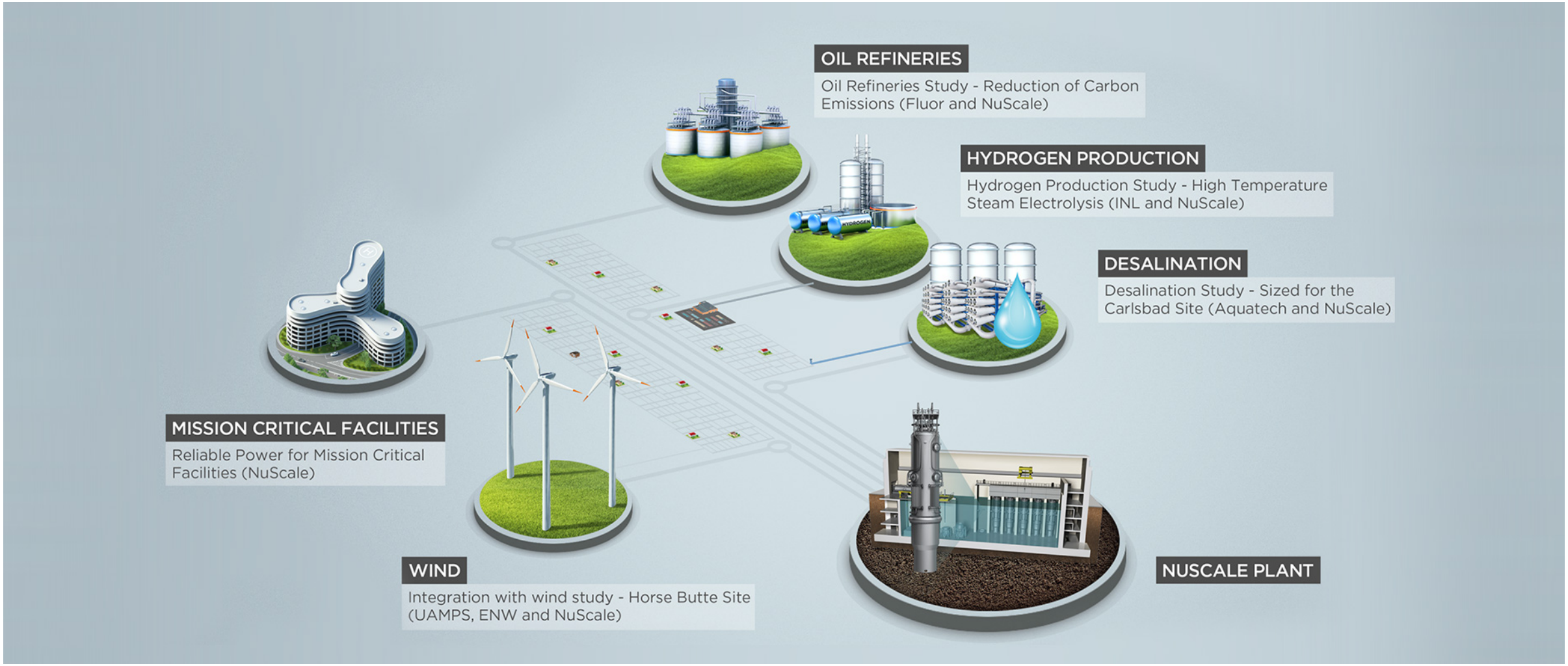
What did this mean for NuScale?

- Extensive preapplication effort over eight years
- Comprehensive test program
- Regulatory gap analysis provided four years before submittal
- Design-specific review standard developed
- Remaining challenge areas in review included:
  - Triple Crown for Nuclear Plant Safety™
  - All passive safety systems
  - Containment function
  - No credible core damage events



Beyond Baseload Electricity



Reports for associated technical studies are available at: www.nuscalepower.com/technology/technical-publications

Image courtesy of Third Way Nuclear Reimagined

The Challenge of Innovation

- NuScale's small core size and exceptional safety, defense-in-depth make the case for a reduced EPZ to the site boundary.
  - This means that NuScale Plants could be sited closer to population and industrial centers – where energy is needed most
- Tennessee Valley Authority (TVA) Demonstrates Site Boundary EPZ Possible for SMRs
  - TVA analysis adds information on Clinch River early site permit application using NuScale Plant design
  - Shows any accident radiological impact would be limited to within site boundary
  - Analysis provides basis for exemption from 10-mile EPZ in regulatory breakthrough
- NRC Emergency Preparedness Rule for SMRs is out for public comment

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dclaudio@nuscalepower.com