

GRADES
9-12

NAVIGATING™ NUCLEAR



Energizing Our World

Virtual Field Trip EDUCATOR GUIDE

NUCLEAR REIMAGINED

Overview

This Virtual Field Trip (VFT) showcases the varied, multifaceted applications for nuclear science in areas like energy, medicine, space exploration, agriculture, archeology and more—while highlighting the broad spectrum of rewarding career opportunities available to students in the nuclear sector. Hosted by the U.S. Department of Energy’s Idaho National Laboratory (INL), the VFT gives students the opportunity to explore a place usually off limits to the public: the inside of the most powerful research reactor on Earth, as well as experience other key operations of INL. The companion activities help engage students prior to and during the Virtual Field Trip, and extend the learning from the Virtual Field Trip to the classroom.

Objectives

Students will:

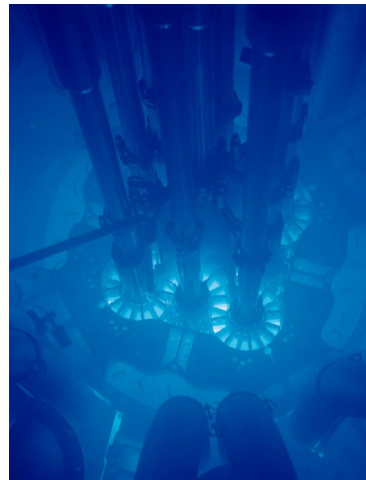
- Investigate the multifaceted applications of nuclear science.
- Explore the broad spectrum of career opportunities available in the nuclear sector.
- Align their skills and interests with a career in the nuclear sector.
- Compare and contrast large-scale and small-scale nuclear reactors.
- Employ computer science to strengthen coding abilities

Materials

- Devices connected to the Internet
- Image of Cerenkov/Cherenkov radiation
- Copies of *Applications of Nuclear Science Brainstorm Web*
- Copies of *Reimagining Nuclear Careers* infographic template
- Copies of *Career Profiles* Research handout
- Copies of *Venn Diagram: ATR vs. SMR* compare and contrast activity sheet

Engage

1. Display the image of Cherenkov radiation (but do not tell students what the image is). Ask students to write down their observations of what they are seeing in the image. Next, ask students to write down questions they may have about what they are observing. Finally, ask students what their interpretation of the image might be. Based on their observations and some of their questions, what is the best guess of what is happening in the image. Explain to students that they will find out what is creating this glow during their Virtual Field Trip!



2. Distribute a copy of the *Applications of Nuclear Science Brainstorm Web* and ask students to think of as many different applications of nuclear science that they can.

Alternatively, students can use <https://bubbl.us/> to create and add to a digital web and bring in media resource to illustrate their thinking.

3. Instruct students that they will be given approximately two minutes to fill in the web circles around the topic. At 30-second intervals you can ask students to consider “food” “medicine” “energy” and “agriculture” to help them with their web circles.
4. Tell students that they will be given a cue after two minutes, at which time they need to seek a partner and share their completed web.

- After approximately three more minutes of sharing with a partner, call the students back and introduce the *Nuclear Reimagined Virtual Field Trip*. Inform students that they will revisit their brainstorm webs at the end of the virtual field trip (See Optional Closing Activity).

During the Virtual Field Trip

- Distribute the *Reimagining Nuclear Careers* infographic template to students and review the background information.
- Direct students to watch the *American Nuclear Society Virtual Field Trip: Nuclear Reimagined*. While they watch, they should complete the infographic by listing the roles and responsibilities of each professional and the science behind the projects they are pursuing (Note: If some of the professionals don't mention these explicitly, tell students they will have an opportunity after the VFT to research important education/training for each career.)
- Then, students should look to match some of their personal background, schooling, and hobbies with the roles and responsibilities of careers featured in the presentation. They should also answer the other questions on the last page of the infographic.
- Following the VFT, use equitable strategies to call on students to volunteer to share their infographic

After the Virtual Field Trip

Explaining Cherenkov radiation

First, let's explain the image from the start of the activity. Students were making observations of a "blue glow". Even though this may have looked like a special effect, it's actually an effect in physics! When light travels in a transparent medium (such as water), particles can move faster than the speed of light. The electromagnetic radiation emitted is an effect called Cherenkov radiation.

Ask students if they remember if higher frequency light creates shorter or longer wavelengths. (shorter)

Then, ask students what color of visible light shorter waves creates. (Blue!)

Blue light has one of the shortest wavelengths of visible light, so the Cherenkov light is usually blue.

The blue glow effect is related to frequency. The higher the frequency, the higher the energy, and the higher the effect of the radiation. In a pool-type reactor students saw in the VFT, the amount of blue glow can be used to gauge the radioactivity of spent fuel rods.

Additional explanation can be found here:

<https://www.youtube.com/watch?v=Yjx0BSXa0Ks>

Three activity options are available for students to apply and summarize their learning from the VFT.

Activity #1 (Career Investigation)

- Remind students that during the VFT, they met many professionals representing the broad spectrum of rewarding career opportunities available in the nuclear sector, as well as multifaceted applications for nuclear science in areas like energy, medicine, space exploration, agriculture, archeology and more. From cutting-edge nuclear fuel researchers and engineers, to artists like glass blowers, each career plays a unique role in innovating for the energy needs of the future by identifying problems, creating solutions, thinking critically, communicating effectively as part of a team, and applying new technologies and skills.
- The VFT highlighted several of these careers. Ask students to share what they remember about these jobs:
 - Advanced Test Reactor Engineer
 - Director of Post-Irradiation Examination & Research Operator (TRISO nuclear fuel)
 - Glass Blower supporting scientists
 - Nuclear Scientist supporting space exploration
- Then, challenge students to learn more about one of the careers listed on the *Reimagining Nuclear Careers* infographic. Pass out the *Career Profile*, direct them to conduct a web search, and instruct them to record their research.

- Once research is completed, invite students to identify a gap in their school's course offerings. Encourage students to write a persuasive letter to the principal or guidance counselor asking that the school offer more opportunities in this area. This may be by offering specific courses or topics at their school or through partnerships with nearby community colleges or other high schools in their state.

Students may also want to formally present their recommendation using presentation software (Prezi, Google Slides, or PowerPoint).

Activity #2 Advanced Testing Reactors (ATR) vs. Small Modular Reactors (SMR)

- Begin by passing out the *Venn diagram: ATR vs. SMR* comparison sheet. Break students into pairs or small groups.
- Instruct students to complete the Venn diagram comparing the Advanced Testing Reactor students observed at the U.S. Department of Energy's Idaho National Laboratory to a Small Modular Reactor. The ATR they observed in the VFT is a research reactor used to test fuels and materials. In contrast, an SMR is used for power generation. Why does this matter? What is unique about each reactor? What characteristics do they share? Encourage each pair/group to come up for at least three facts for each section of the Venn diagram using what they remember from the VFT and the resources listed at the bottom of the handout.

Consider posting research links to an easy-to-access online space. Students may want to use an online Venn diagram (such as <https://www.canva.com/graphs/venn-diagrams/>) so they can insert media.

- After students have worked for about 10–15 minutes, review and help students complete their Venn diagram using the Answer Key provided. Ask students to summarize as a class what uses each of these reactors has to solving problems in our world and why they are both uniquely important.

Activity #3 Powering Exploration

- Explain to students that nuclear fission is used in power plants to produce large amounts of energy to power communities. But it may be used to power larger spacecrafts in the future! Nuclear energy doesn't need sunlight or wind and doesn't rely on an outlet or gas station for power. Traveling to Mars and colonization are both endeavors that will likely require nuclear energy. Along with an energy source, programmers will need to design and execute unmanned or manned missions. Invite students to explore some of the exciting missions nuclear may help power using [NASA Moon to Mars](#). This platform allows students to use block coding to learn about real-life NASA missions while strengthening their coding abilities.

Optional Closing Activity: Revisit Your Brainstorm Web

- Ask students to pull out their *Applications of Nuclear Science Brainstorm Web* from the Engage part of the lesson.
- Using a random response strategy, ask for volunteers to share their ideas with the class, and encourage students to fill in their *Webs* with some of the Nuclear Reimagined ideas from the VFT. An example of a random response strategy is to ask students whose birthday is closest to Marie Curie's on November 7th. They will then kick off sharing. (Marie Curie is known for pioneering research on radioactivity)

Nuclear can:

- transform the way we travel,
- treat disease,
- protect crops,
- produce carbon free energy,
- study the past, and
- explore the universe.

HS National Standards Next Generation Science Standards

ETS1.B: Developing Possible Solutions

When evaluating solutions, it is important to consider a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

NGSS Crosscutting Concepts

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering and Technology on Society and the Natural World

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Standards for Technological Literacy– International Technology and Engineering Educators Association (ITEEA)

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.

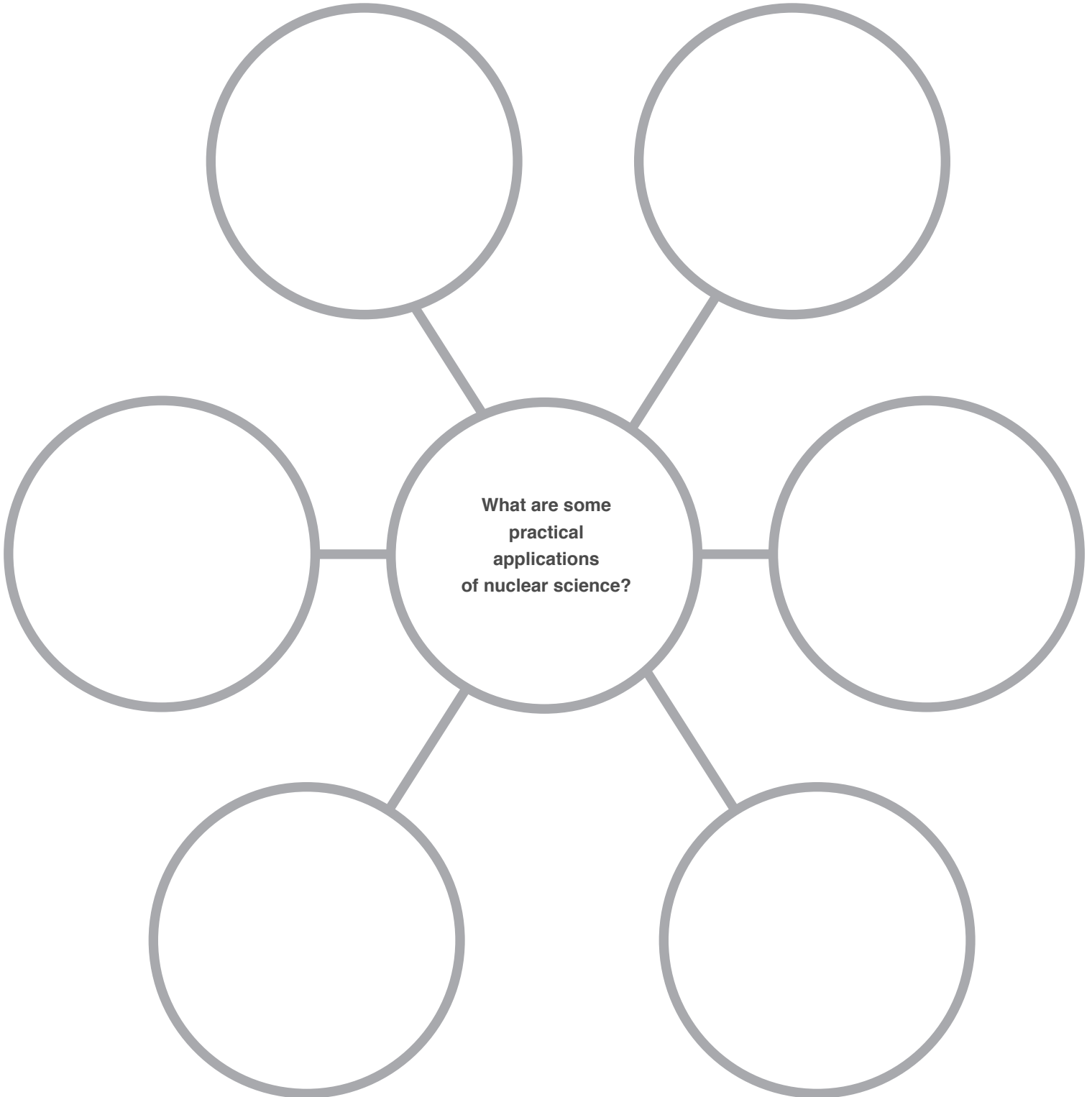
- I. Making decisions about the use of technology involved weighing the trade-offs between the positive and negative effects.

Standard 7: Students will develop an understanding of the influence of technology on history

- G. Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

Applications of Nuclear Science Brainstorm Web

Instructions: As you watch the video, list features of the Palo Verde nuclear plant that make it unique and safer than the Fukushima plant.



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All the professionals you will hear from during the Virtual Field Trip will describe some of their roles and responsibilities and share the science behind projects they are working on.

List two background experiences/training opportunities that could be helpful for each career based on some of the information they shared about their work. (If none are mentioned, research after viewing the VFT).

Advanced Test Reactor Engineer:

- 1.
- 2.

Director of Post-Irradiation Examination & Research Operator (TRISO nuclear fuel):

- 1.
- 2.

Glass Blower supporting scientists:

- 1.
- 2.

Nuclear Engineer supporting space exploration:

- 1.
- 2.

Reimagining Nuclear Careers

Now, match your own background/opportunities to the careers highlighted:

Reflect	Which type of work or interests of yours mirror any that you heard during the video? List two or three below.
Connect	Are there any classes or clubs available at your school that would help in one of these careers? If yes, list them below.
Explore	If not, which courses or opportunities would you be interested in exploring further to see if they could be offered at your school or through an extension/partnership program? List one or two below:
Envision	List two careers from the Virtual Field Trip that are most interesting to you based on your background and the training opportunities available to you.
Share	Were you surprised by any of the careers at the Idaho National Laboratory? Why or why not?

Career Profile Research

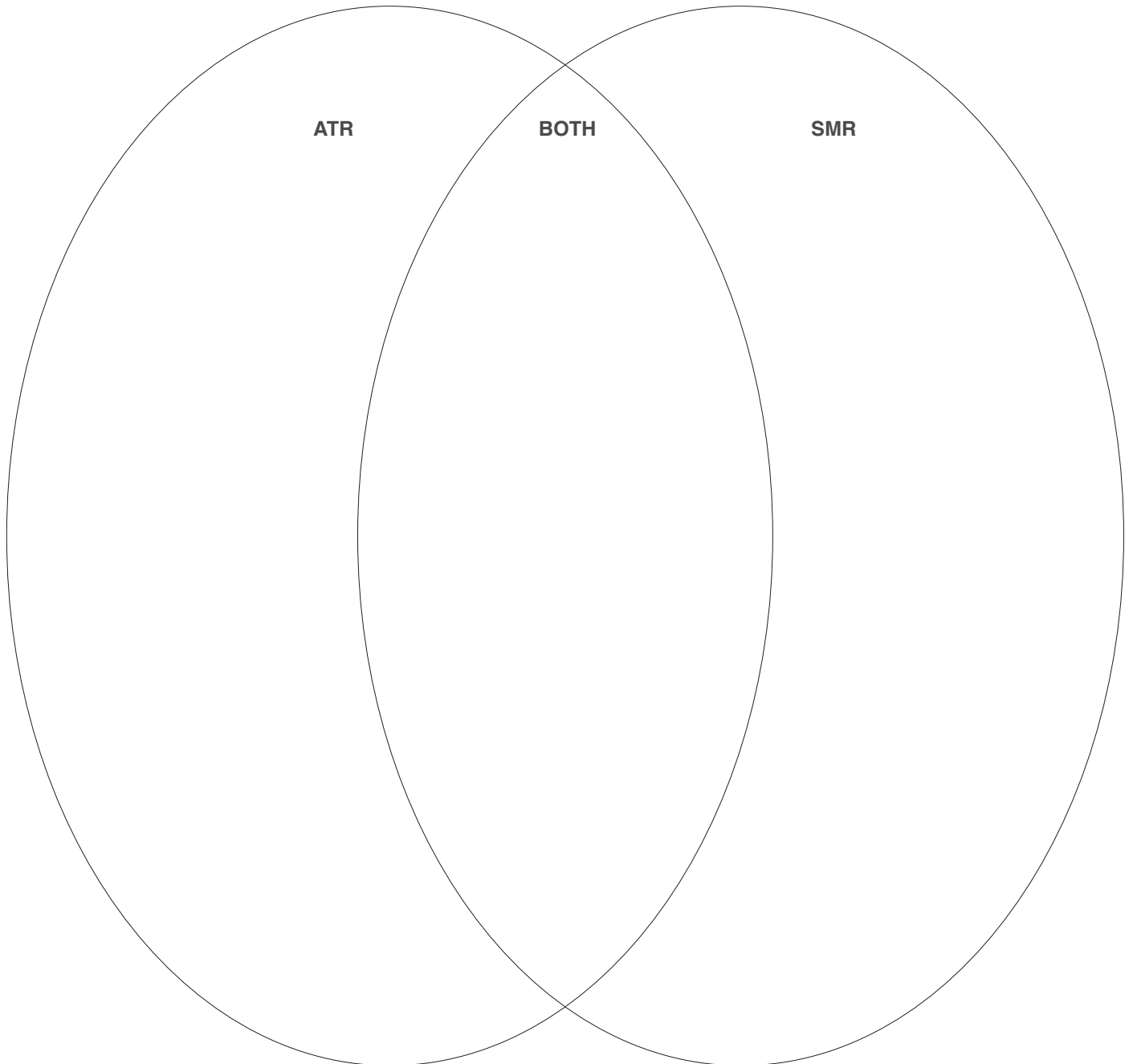
Directions: Conduct internet research to further explore a career that you learned about in the Virtual Field Trip. Record your notes below.

CAREER NAME: _____	
Brief Description	
Training & Skills Required	
Salary Range	
Related Careers	
Current Job openings, if available	
Current classes I am taking that impact this career	
How this career matches my interests/skills/strengths	
Training opportunities I would need in the future to pursue this career	

List of resources used:

Venn Diagram: ATR vs. SMR

Directions: Using what you remember from the VFT and what you learn from the resources below, complete the Venn diagram to compare and contrast the Advanced Testing Reactor (ATR) from the U.S. Department of Energy’s Idaho National Laboratory to a Small Modular Reactor.



Resources:

- <https://www.energy.gov/ne/articles/7-fast-facts-about-idaho-national-laboratorys-advanced-test-reactor>
- <https://factsheets.inl.gov/FactSheets/AdvancedTestReactorSafety.pdf>
- <https://www.energy.gov/ne/nuclear-reactor-technologies/small-modular-nuclear-reactors>

Venn Diagram: ATR vs. SMR | ANSWER KEY

ATR	Both	SMR
<p>“Advanced Test Reactor” the most powerful research reactor on the planet</p> <p>Assembled one at a time</p> <p>Only reactor in the U.S. that can produce huge amounts of high-flux neutron irradiation in a prototype environment</p> <p>Consists of a serpentine core with five nearly independent reactors in one (each of the 4 corner lobes can be controlled independently)</p>	<p>Rely on nuclear fission process of splitting the nucleus of an atom into two or more smaller nuclei</p> <p>Use the same concept of energy generation</p> <p>Require testing and prototyping to develop new technology that is safe for the planet</p>	<p>“Small Modular Reactors” (75% Smaller)</p> <p>Pre-built in a factor and require fewer resources (cheaper to build)</p> <p>Can be located in a lot more places, even remote ones, (easier to transport)</p> <p>Engineered for great fuel efficiency, resulting in less waste</p> <p>Generates cleaner electricity</p>