INL/MIS-20-60889-Revision-0

Progress in Demonstration and Deployment of U.S. Advanced Nuclear Energy Technology

Ashley E Finan

December 2020

The INL is a U.S. Department of Energy National Laboratory
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NRIC

National Reactor Innovation Center

Progress in Demonstration and Deployment of U.S. Advanced Nuclear Energy Technologies

December 9, 2020

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Advanced Fission

- Categorized in terms of capacity
  - Microreactors: <10 MWe
  - Small reactors: 10 MWe – <300MWe (SMRs use modular construction)
  - Medium reactors: 300MWe - 700 MWe
  - Large reactors: > 700 MWe
- Variety of coolants (gas, sodium, salt, lead, water, etc.)
- Clean, high availability
- Diverse markets
- Improved safety, waste, security, and target economics
- 60+ private sector projects

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Image courtesy of GAIN and Third Way, inspired by the *Nuclear Energy Reimagined* concept led by INL. Learn more about these and other energy park concepts at thirdway.org/blog/nuclear-reimagined

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inspire

empower

deliver

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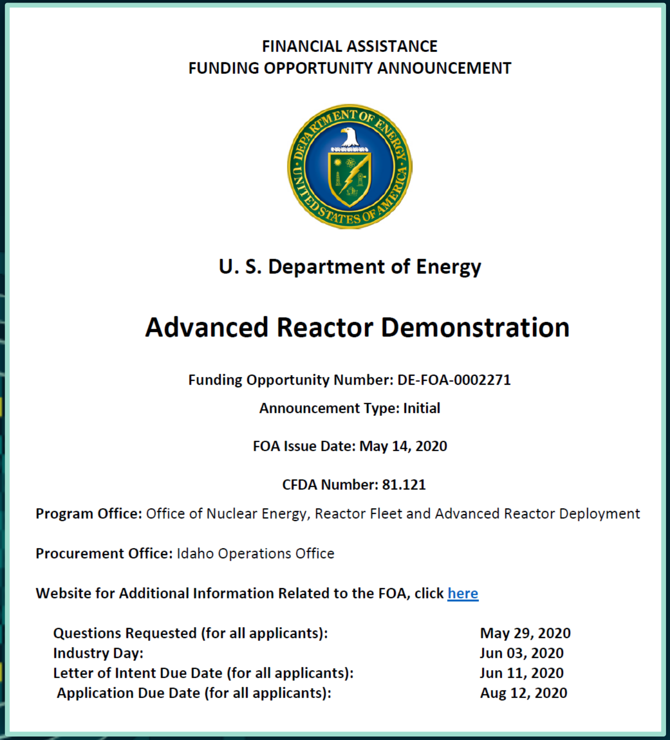
DE-FOA-0002271: Advanced Reactor Demonstration Program

- Initial funding of ~$210M for up to 9+ projects
- Cost-shared with industry
- The FOA has three separate award pathways:
  - Advanced Reactor Demonstrations (Demos)
    - 2 projects, $80M each in FY20, 5-7 years.
    - $400M - $4B
  - Risk Reduction for Future Demonstrations
    - 2-5 projects, $30M overall in FY20, up to 5-7 years
    - $40M - $400M
  - Advanced Reactor Concepts – 20 (ARC-20)
    - ~$20M for 2+ projects in FY20, up to 5 years
    - $10M - $40M



FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U. S. Department of Energy

Advanced Reactor Demonstration

Funding Opportunity Number: DE-FOA-0002271

Announcement Type: Initial

FOA Issue Date: May 14, 2020

CFDA Number: 81.121

Program Office: Office of Nuclear Energy, Reactor Fleet and Advanced Reactor Deployment

Procurement Office: Idaho Operations Office

Website for Additional Information Related to the FOA, click here

Questions Requested (for all applicants):	May 29, 2020
Industry Day:	Jun 03, 2020
Letter of Intent Due Date (for all applicants):	Jun 11, 2020
Application Due Date (for all applicants):	Aug 12, 2020

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TerraPower/GE Hitachi - Natrium

- Sodium-cooled fast reactor advanced fission technology
- 336 MWe, plus salt storage for up to 500 MWe for 5.5 hrs.
- Targeted power costs of $50-$55/MWh for first demonstrations and $40/MWh or less with storage system
- Ramp rate target of 8-15% per minute
- 80% reduction in nuclear concrete

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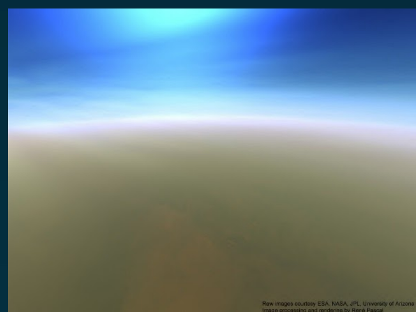
Space Nuclear Power and Propulsion for NASA

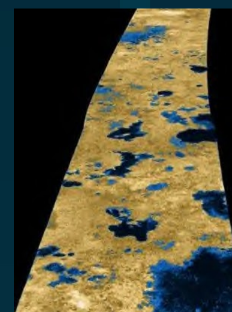
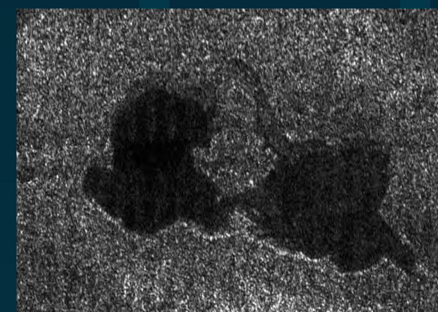
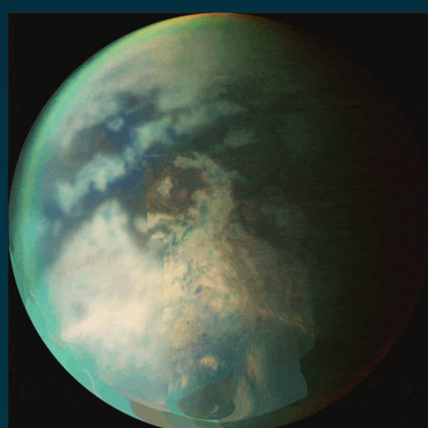
- For almost 60 years, nuclear power in the form of radioisotope power sources has enabled NASA’s leadership in solar system exploration. Missions such as New Horizons to study Pluto, its moons, and the Kuiper Belt beyond, Cassini to study Saturn and its moons, and the ongoing Voyager missions to the space between the stars, would not have been possible without on-board nuclear power systems.
- For approximately the same period of time, the US has looked to nuclear reactors to power and propel spacecraft and to provide power for crewed missions to the surfaces of the moon and Mars. In 1965, the US launched the first space reactor, the 500 watt SNAP 10A, into low Earth orbit. Although many reactor power systems have been studied since then, none have progressed to the ground testing of a prototype.
- It is well known that Nuclear Thermal Propulsion offers a substantial reduction in trip time for crewed missions to the moon or Mars, and for this reason the Rover/NERVA Program was conducted in the 1960’s. Over 20 reactors were tested leading up to a flight prototype test, before the program was cancelled.

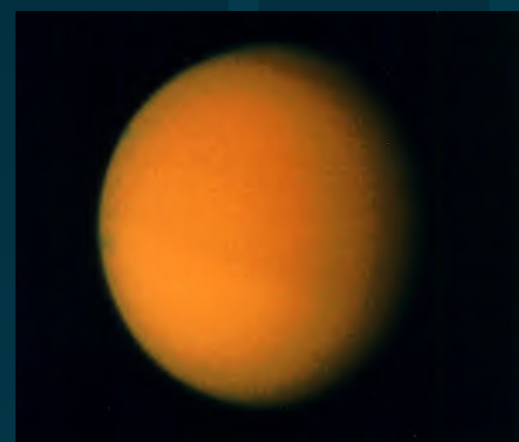
Voyager 1 and 2
150W(e) MHW-RTGs (3 each)

- **Spacecraft explored Jupiter, Saturn, Uranus and Neptune before starting their journey toward interstellar space.**
- **Now at very low power, but still transmitting data after over 40 years.**

CASSINI: MISSION TO SATURN
Three 275 W(e) GPHS-RTGs





NEW HORIZONS

Pluto / Kuiper Belt Encounters
One 245 W(e) GPHS-RTG

PLUTO & CHARON

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The Mars Science Laboratory (MSL) Mission

One 110 W(e) Multi-Mission RTG (MMRTG)

2012 Arrival Selfies

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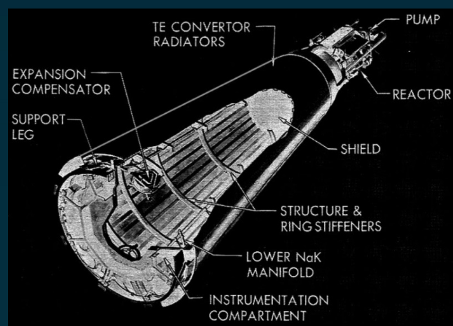
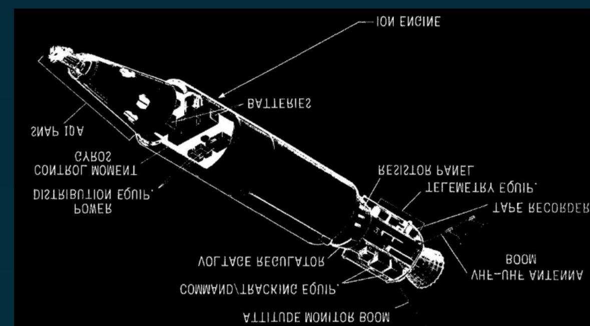
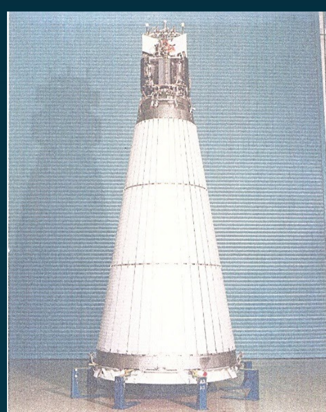
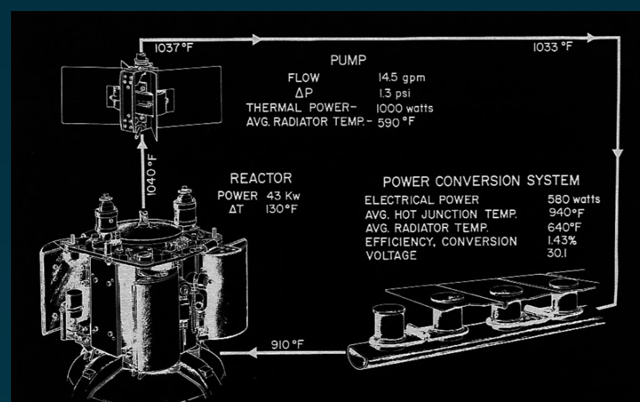
SNAPSHOT

U.S. Air Force SNAP-10A Reactor & Ion Propulsion Technology Demonstration
500W(e) SNAP-10A Reactor Power System









NASA-DOE Fission Surface Power Program

	Design	**Prototype**	**Flight Unit**
Milestones	1. Preliminary Design 2. Final Design	1. Manufacture Components 2. Construction 3. Operation & Validation	1. Leverage Prototype 2. Launch Ready by December 31, 2026 3. Deploy to Lunar Surface 4. Power Next Endeavor…

NASA-DOE Fission Surface Power Procurement Structure

	RFI *(3 weeks)*	**Contract 1** *(9 months, up to 3 contractors)*	**Contract 2** *(72 months + 12 months operations, 1 contractor)*
Tasks	1. Provide approach to identified goals 2. Potential teaming arrangements (nuclear + aerospace) 3. Identify technology gaps https://beta.sam.gov/opp/b92644af4767413c9e831e633c6e2888/view	1. Fission Surface Power System Preliminary Design 2. Cost estimate for Contract 2 3. Schedule estimate for Contract 2	1. Develop technologies 2. Demonstrate and test Engineering Design Unit (prototype reactor) 3. Develop and test subsequent flight system 4. Integration with lander 5. Ground support equipment 6. Safety & launch approval reviews 7. Operate 1 year on Moon

WE'VE DONE THIS BEFORE

WE'RE GOING TO DO IT AGAIN

WITH SOME *refinements*

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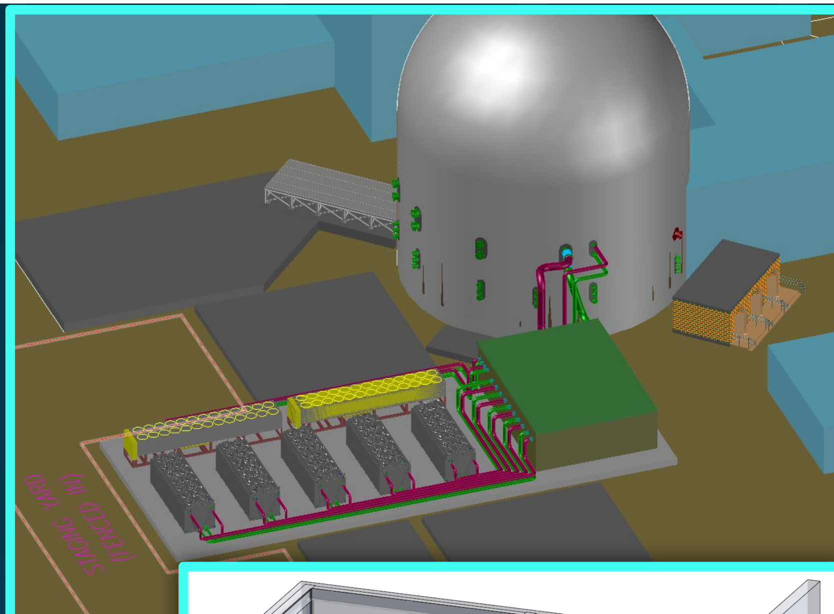
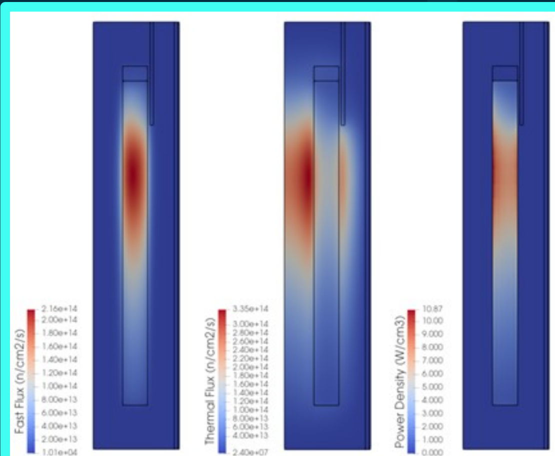
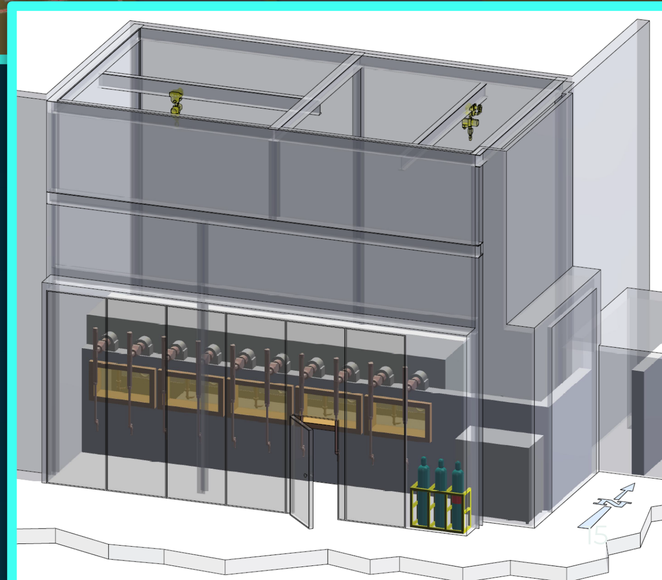
Mod. # 1 Empowering Innovators

- Private Sector Driven Effort
- NRIC Resource Team
- Virtual Test Bed
- Demonstration Resource Network
  - Experimental facilities
  - Fuel facilities
  - Test beds
  - Demonstration sites







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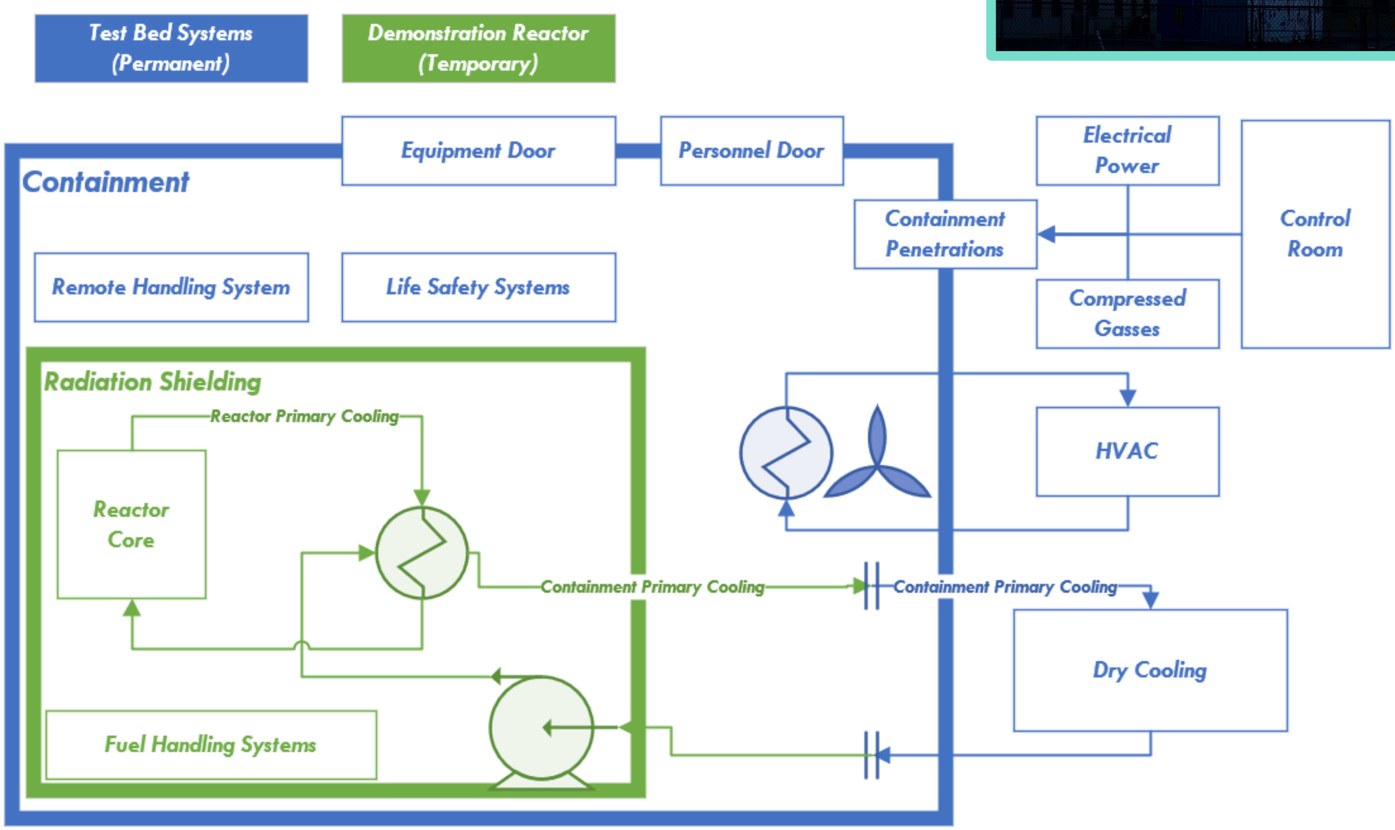
Demonstration Test Beds In Development



- User input received
- Functional and Operational Requirements Defined
- Concept of Operations Defined
- Digital engineering implemented
- Preconceptual design complete
- Request for Expressions of Interest released July 21 for A-E firm to complete design work in FY21

Pre-Conceptual Design
EBR-II Dome Demonstration Reactor Test Bed (ETB)

- Reactors producing less than 10MWt power
- Use of Safeguards Category IV fuels
- Modifications to equipment door to enable loading of Conex containers
- Cooling, electrical, ventilation, process fluid penetrations
- Ventilation system upgrades
- Electrical power system including safety class battery backup
- Control Room for ETB operations

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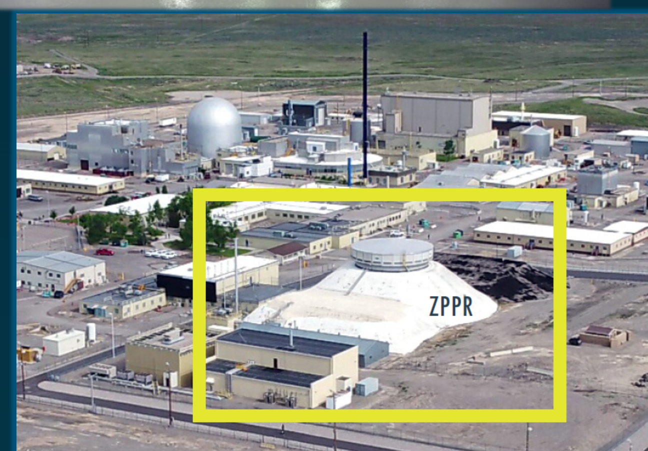
ZPPR Test Bed Pre-conceptual Design

- Built as Safeguards Category 1, Hazard Category 2 facility
- HEU and Pu fuel capable
- 500kW heat rejection system*
- Co-located with other MFC Capabilities:
  - Fuel production, hot cells, characterization, and machine shop
- Floor loading 3,000 psf or 500,000 lbs total
- 200 kVA, 480V electrical service
- Class 1E battery backup power and non-safety-related 100kW diesel generator*
- Compressed gas systems
- ~1,300 sqft floor space
- Co-located Control Room
- Roof entry point for installation of equipment and reactor packages*



*currently proposed in design

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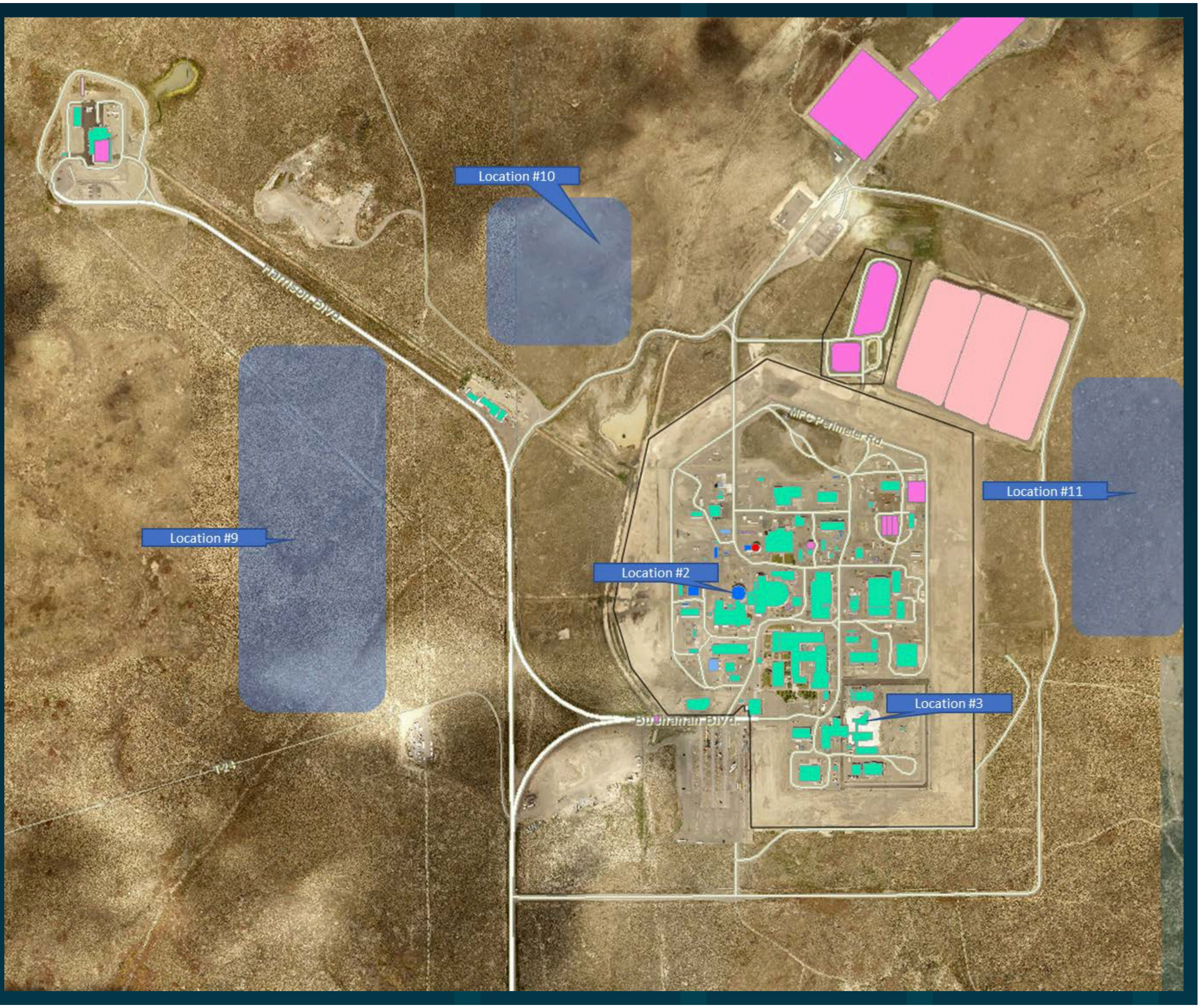
Siting Preparations Underway

- Completed Initial Siting Evaluation of 8 national sites with ANL, ORNL, U-Michigan
  - Additional sites in FY21
- Identified 9 candidate INL sites and initiated preparation for demonstration projects
  - Seismic; meteorological; grid access; water; environmental; regulatory; cost savings.

Example –INL Materials and Fuels Complex Sites

INL/EXT-20-57821, **Evaluation of Sites for Advanced Reactor Demonstrations at Idaho National Laboratory**



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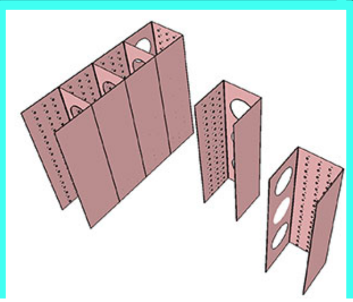
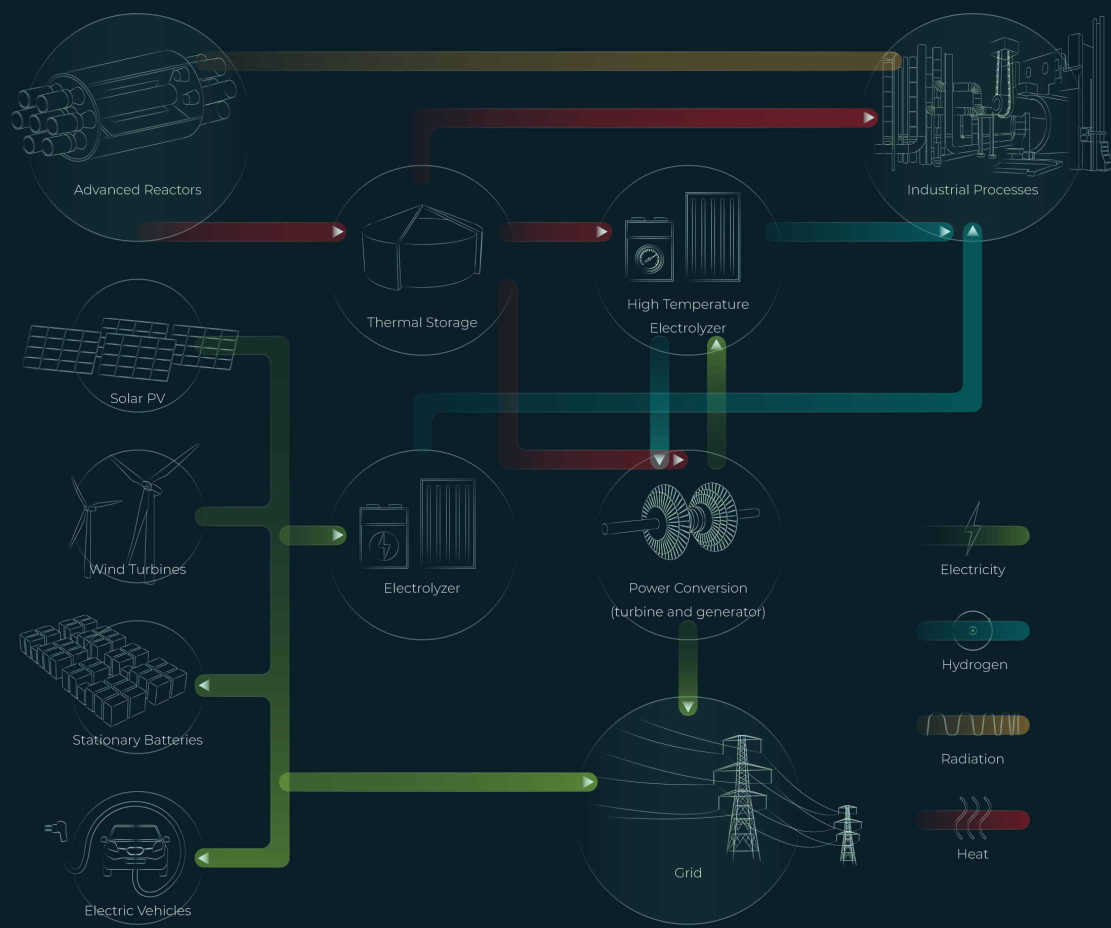
Mod. # 2
Addressing Cost and Markets

- Digital Engineering
- Advanced Construction Technologies
- Integrated Energy Systems





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Digital Engineering Opportunity

- Significant program impacts, for example published impacts at Mortenson Construction demonstrate
    - **600 cumulative day** direct **schedule reductions**
    - **25% productivity increase**
    - Use across 416 VDC programs
- 40% improvement in first-time quality through use of digital twins (Boeing)
- Expected $30M savings at NNSA
- Proven across engineering domains: Construction (Mortenson VDC), Aerospace (Boeing 777), Automotive (Bugatti)

Level 7	automated design optimization	Artificial Intelligence
Level 6	analytics automation	Advanced Analytics
Level 5	connections across lifecycle	Digital Thread
Level 4	connections within in each domain	Digital Links
Level 3	data storage are centralized	Data Lake
Level 2	document storage are centralized	Content Management
Level 1	data and documents disconnected	Siloed Program

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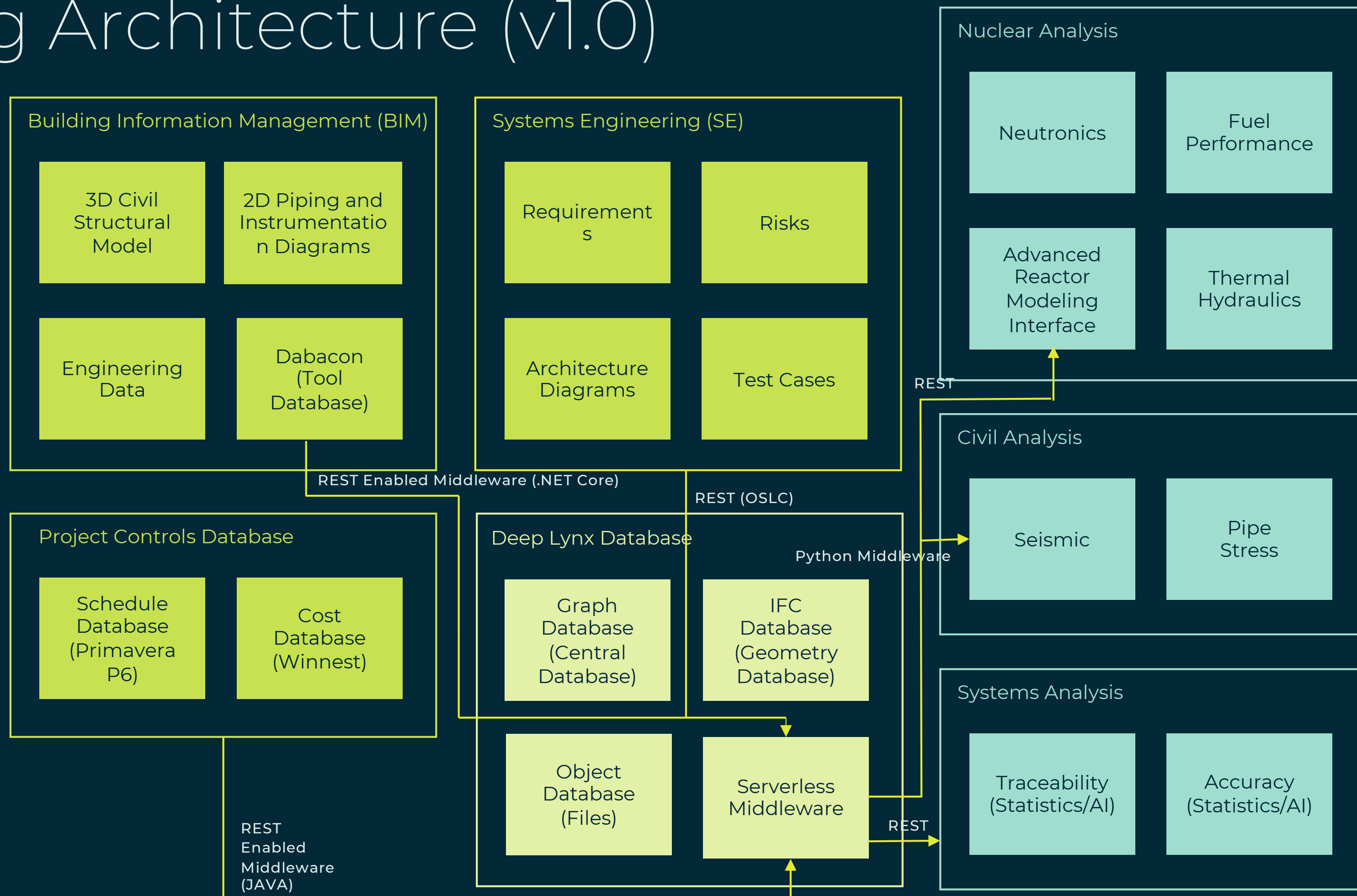
Example Derivative Solution: Plant Digital Engineering Architecture (v1.0)

- Cloud-based service of industry leading COTS tools
- Automation of design, modeling, & analysis integration
- Visualization of traceability between siloed tools
- Analysis of overall system traceability and accuracy



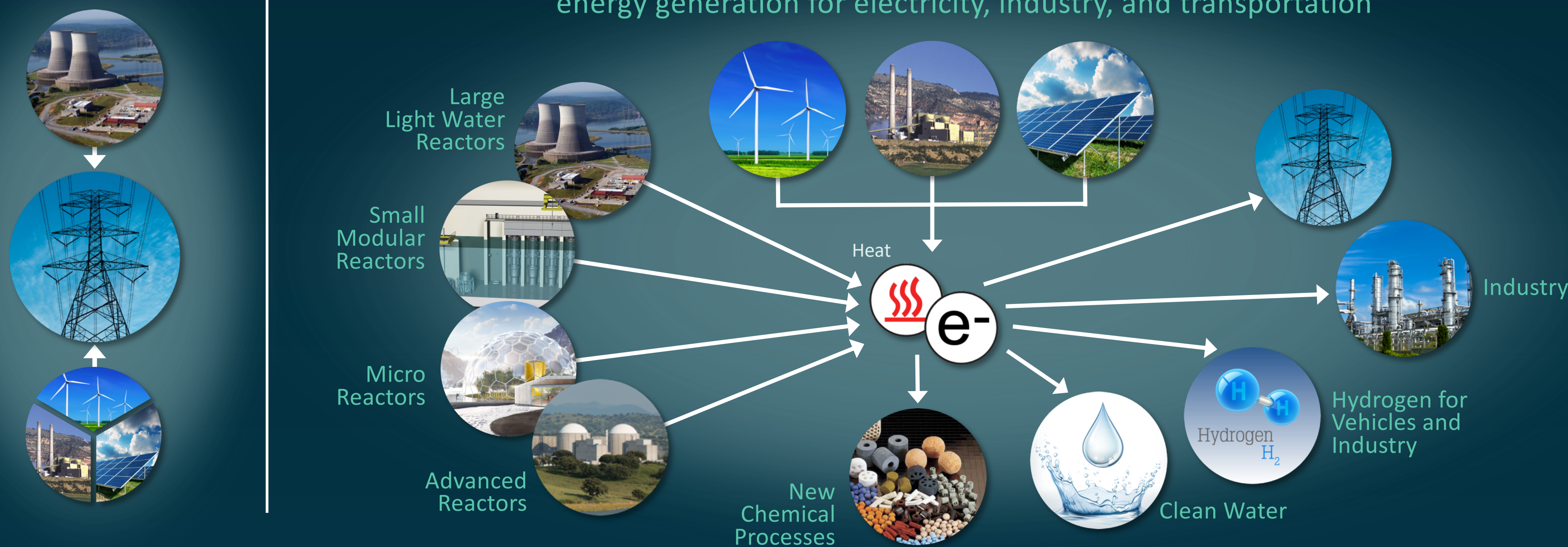
Maximizing energy utilization, generator profitability, and grid reliability and resilience through systems integration—while maintaining affordability

Today

Electricity-only focus

Potential Future Energy System

Enhanced energy system leverages contributions from low emission energy generation for electricity, industry, and transportation



Flexible Generators ❖ Advanced Processes ❖ Revolutionary Design

https://ies.inl.gov

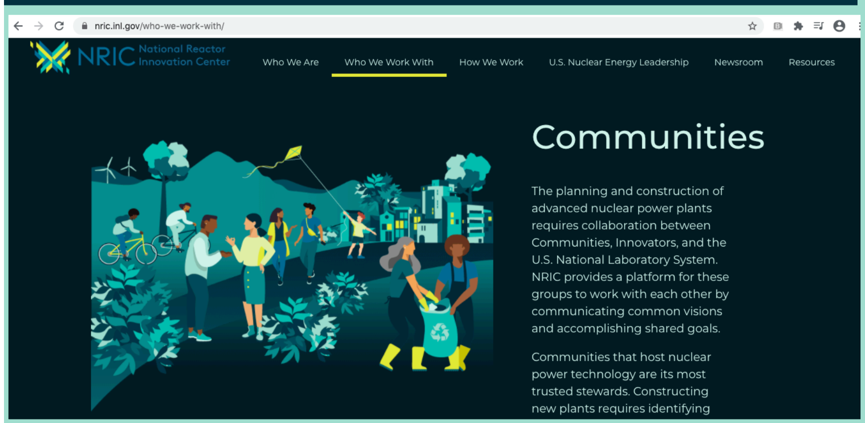
Slide by Dr. Shannon Bragg-Sitton

Mod. # 3
Proactive Impact Management

- Environmental impact assessment
  - Cultural and biological surveys
  - Plant parameter envelope
  - Water use
- Packaging, storage, transport, and disposition
- Safeguards & Security via ARDP Advanced Reactor Safeguards program

Mod. # 4 Engagement

- Tools
  - Web/Social
  - Flyover, Mapping, Videos
- Best practices development



NRIC Key Accomplishments FY20

- Established NRIC
- Demonstration Test Bed under development
- Siting preparations underway
- Advanced Construction Technology RFP issued
- Established Resource Team and Supported 18 ARDP proposal efforts

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Goals for FY21 – Maintain progress to support demonstrations by the end of 2025 and sustained innovation

- Prepare vital infrastructure
- Provide planning tools and resources
- Demonstrate cost-cutting technology
- Anticipate and address regulatory needs
- Build and develop the NRIC team
- Strengthen and expand partnerships and collaborations

National Reactor Innovation Center

NRIC is preparing to support space nuclear demonstrations with:

- Siting preparations and demonstration test bed
- Staff/consultants who participated in all previous DOD and NASA FSP programs and know lessons and technologies
- Digital engineering, modeling and simulation, experimental infrastructure
- Safety and environmental analysis, including DOE authorization
- Project planning & coordination of work among labs and private sector
- Outreach and communications

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Thank you
Questions?

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