INL/EXT-19-56554-Revision-0

# Demonstration Reactor Infrastructure

Nicholas Vise Smith

November 2019


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operated by Battelle Energy Alliance

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**Nicholas Vise Smith**

**November 2019**

**Idaho National Laboratory**
**Idaho Falls, Idaho 83415**

**http://www.inl.gov**

**Prepared for the**
**U.S. Department of Energy**

**Under DOE Idaho Operations Office**
**Contract DE-AC07-05ID14517**

# Demonstration Reactor Infrastructure

***Nicholas V. Smith, Deputy Director***
***National Reactor Innovation Center (NRIC)***

***November 12, 2019***


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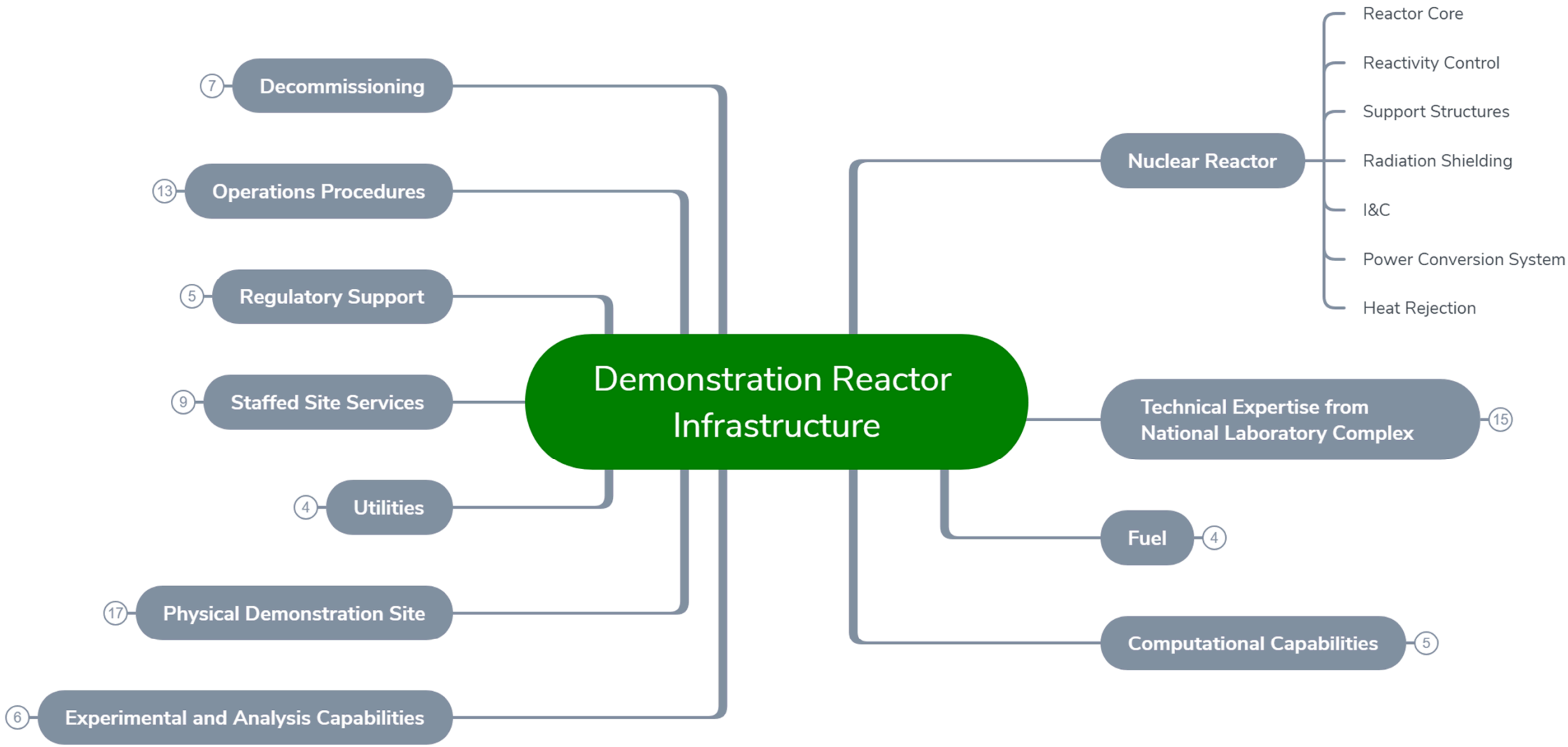
Idaho National Laboratory

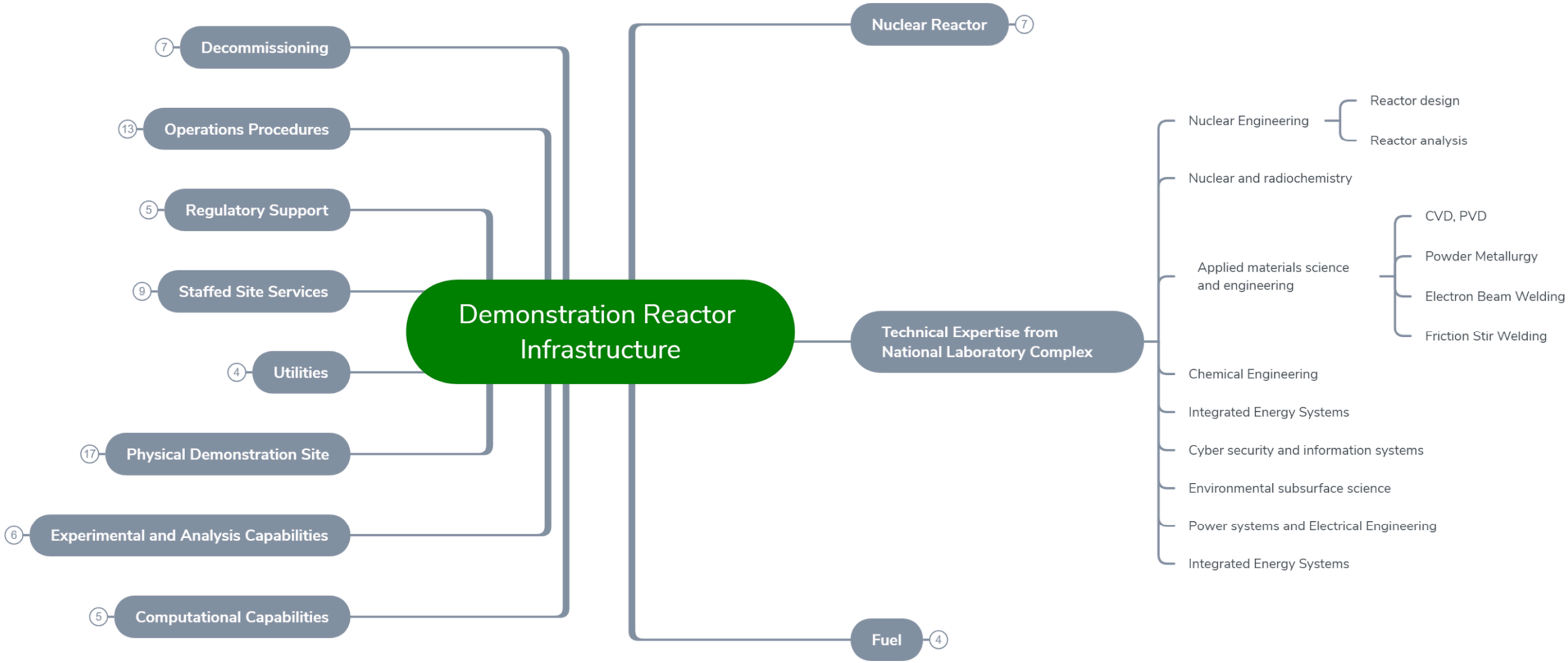
# National Reactor Innovation Center (NRIC) authorized by Nuclear Energy Innovation Capabilities Act (NEICA)

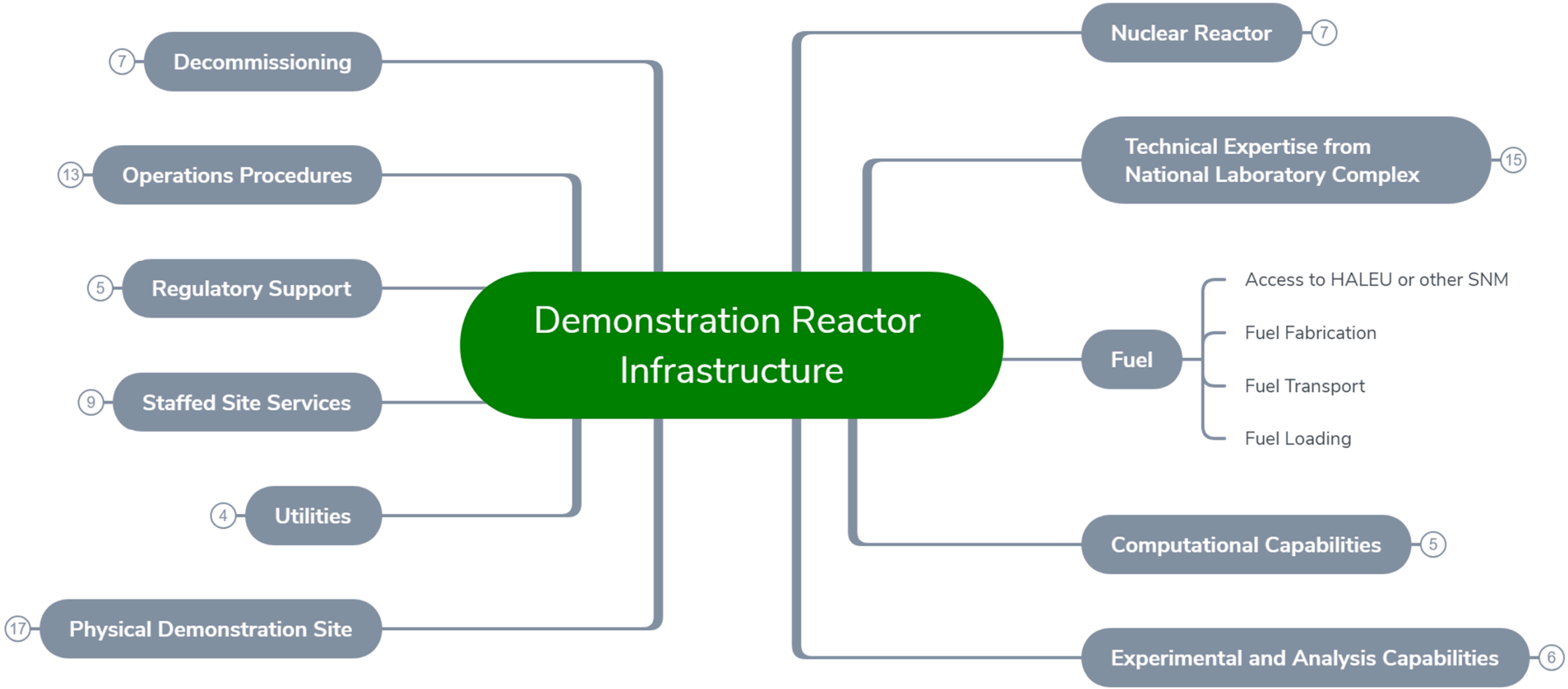
- DOE Launched NRIC on August 15, 2019
- The National Reactor Innovation Center is intended to:
  - Enable testing and *demonstration of reactor* concepts
  - Access to *infrastructure*
  - Led by INL, coordinating with other national labs

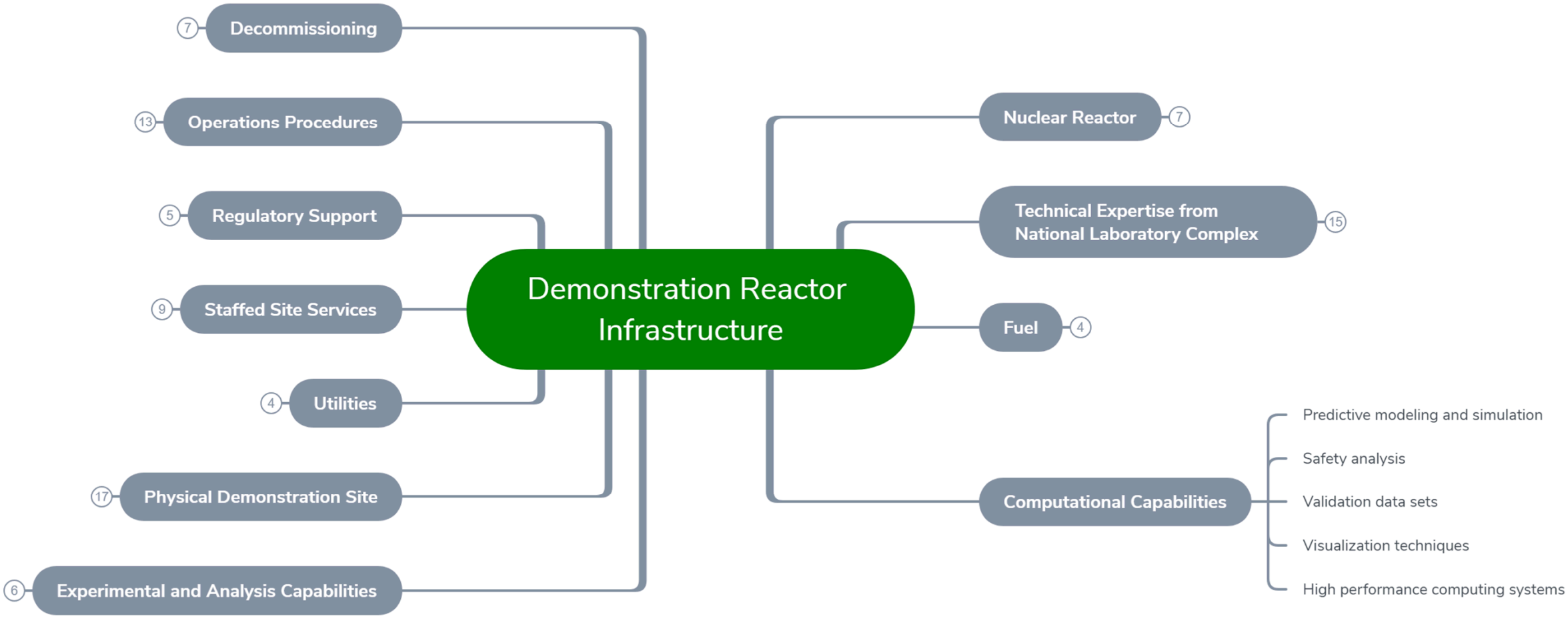
Sen. James Risch, R-Idaho, left, and Sen. Mike Crapo, R-Idaho, speak to audience members during the announcement of the launch of the National Reactor Innovation Center (NRIC) at Idaho National Laboratory on Wednesday, Aug. 14, 2019. NRIC will support private sector nuclear developers in their work to develop concepts and assess their performance according to a INL news release.

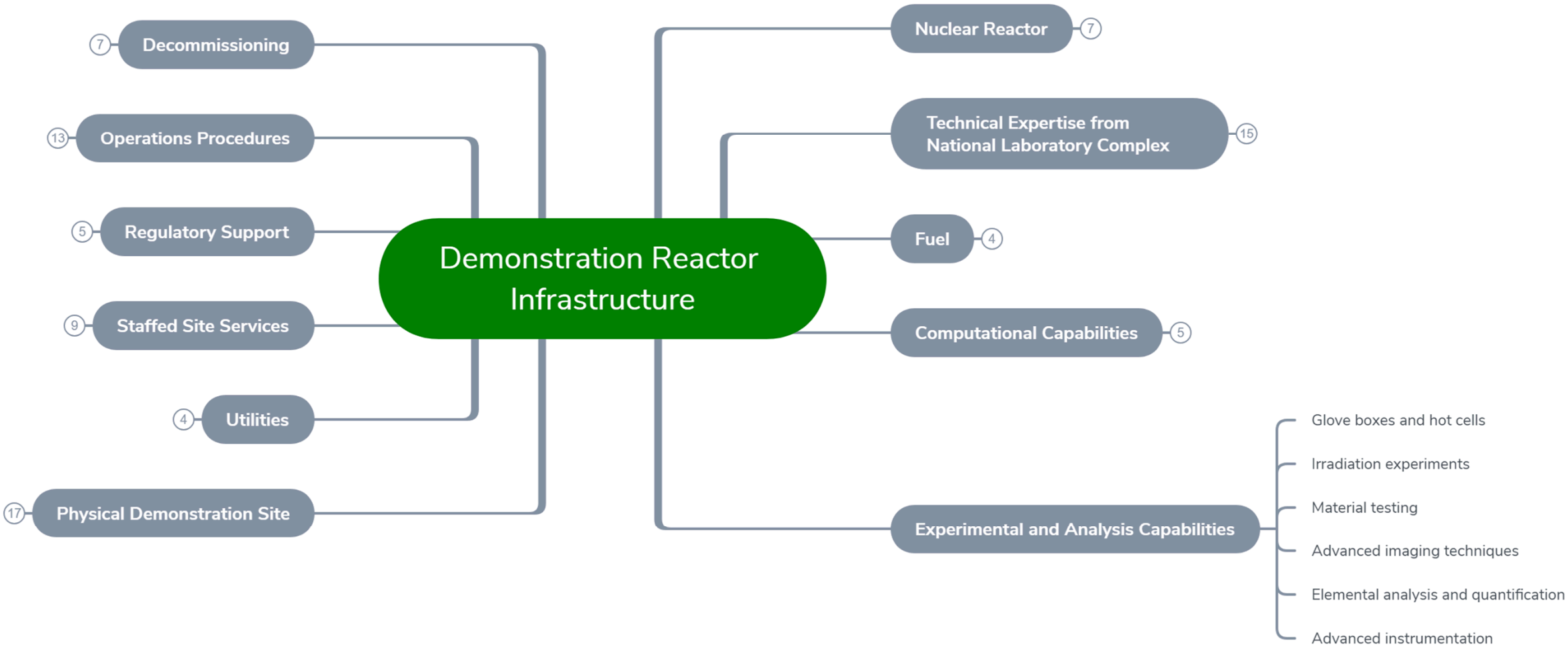
JOHN ROARK | jroark@postregister.com

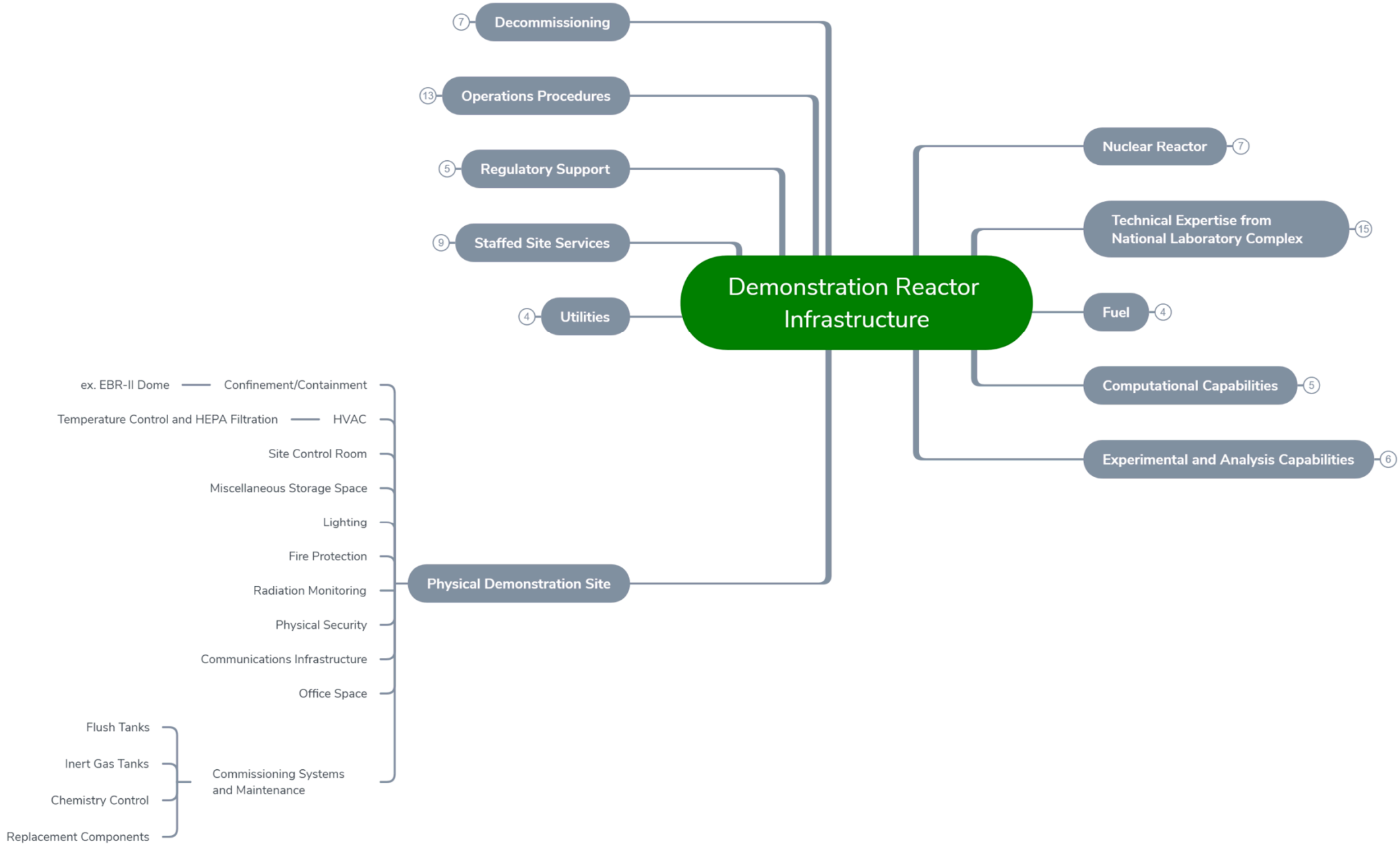

Demonstration Reactor Infrastructure
Nuclear Reactor
Reactor Core
Reactivity Control
Support Structures
Radiation Shielding
I&C
Power Conversion System
Heat Rejection
Technical Expertise from National Laboratory Complex
15
Fuel
4
Computational Capabilities
5
Decommissioning
7
Operations Procedures
13
Regulatory Support
5
Staffed Site Services
9
Utilities
4
Physical Demonstration Site
17
Experimental and Analysis Capabilities
6

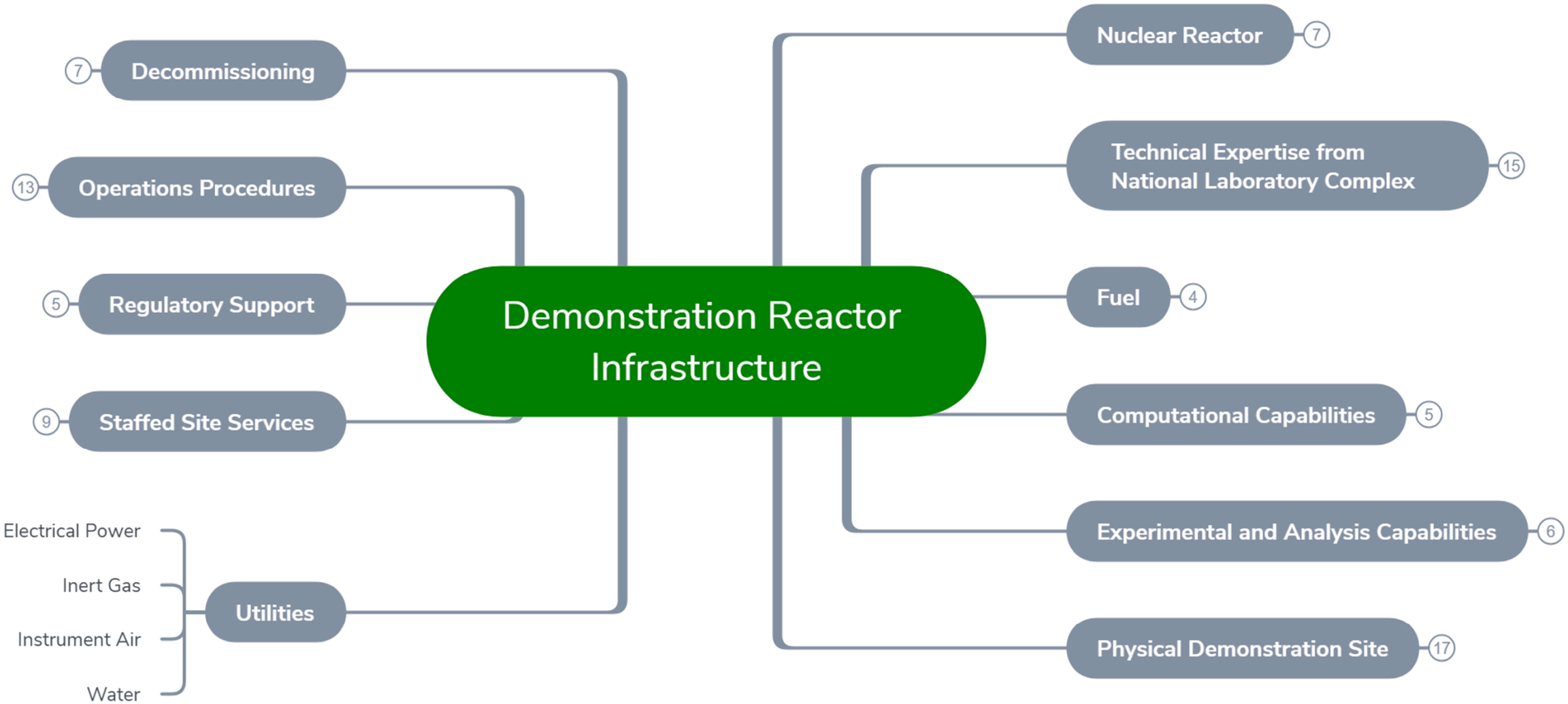

Demonstration Reactor Infrastructure
Nuclear Reactor
7
Technical Expertise from National Laboratory Complex
Nuclear Engineering
Reactor design
Reactor analysis
Nuclear and radiochemistry
Applied materials science and engineering
CVD, PVD
Powder Metallurgy
Electron Beam Welding
Friction Stir Welding
Chemical Engineering
Integrated Energy Systems
Cyber security and information systems
Environmental subsurface science
Power systems and Electrical Engineering
Integrated Energy Systems
Fuel
4
Decommissioning
7
Operations Procedures
13
Regulatory Support
5
Staffed Site Services
9
Utilities
4
Physical Demonstration Site
17
Experimental and Analysis Capabilities
6
Computational Capabilities
5

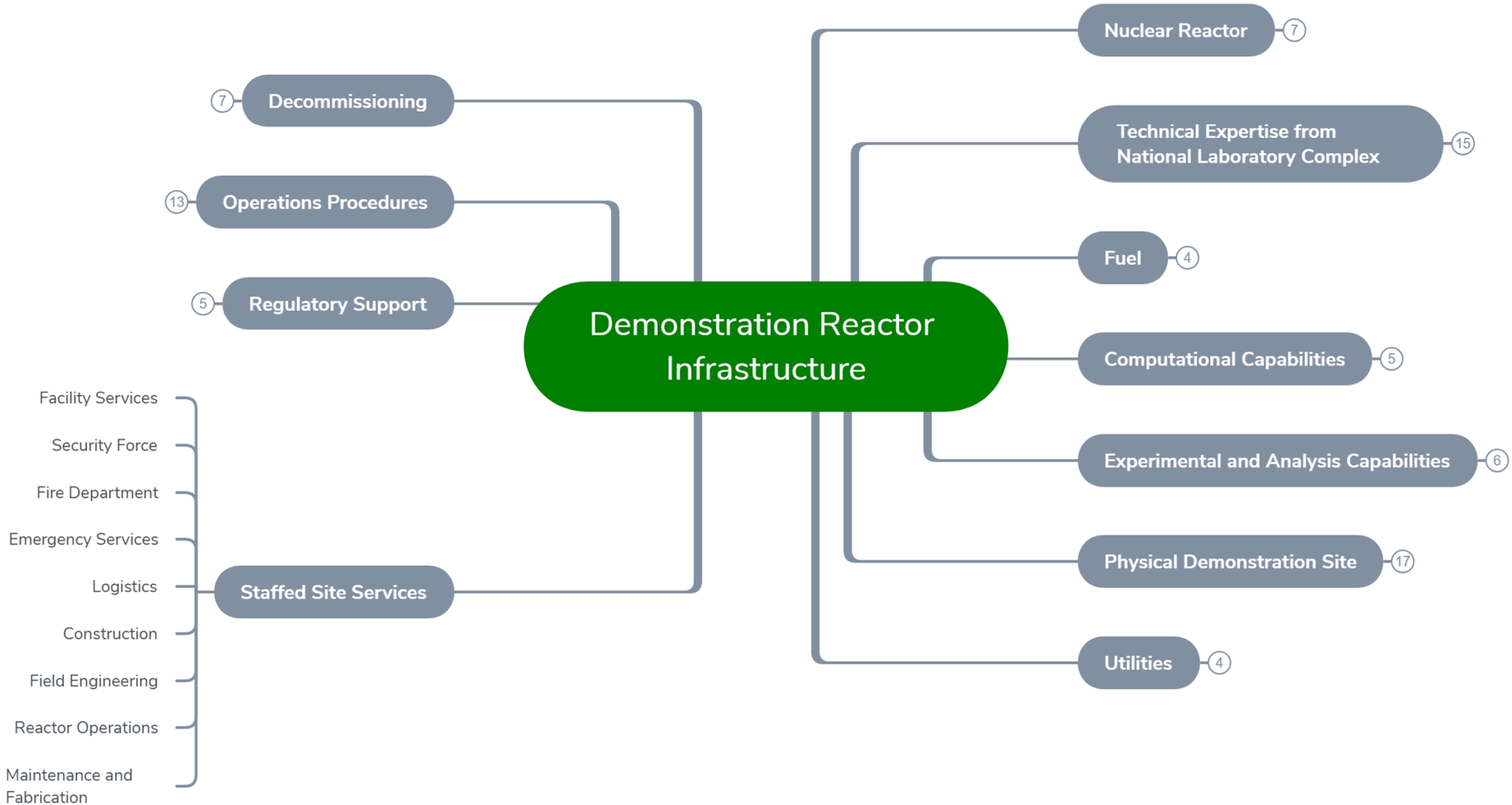

Demonstration Reactor Infrastructure
Nuclear Reactor
7
Technical Expertise from National Laboratory Complex
15
Fuel
Access to HALEU or other SNM
Fuel Fabrication
Fuel Transport
Fuel Loading
Computational Capabilities
5
Experimental and Analysis Capabilities
6
Decommissioning
7
Operations Procedures
13
Regulatory Support
5
Staffed Site Services
9
Utilities
4
Physical Demonstration Site
17

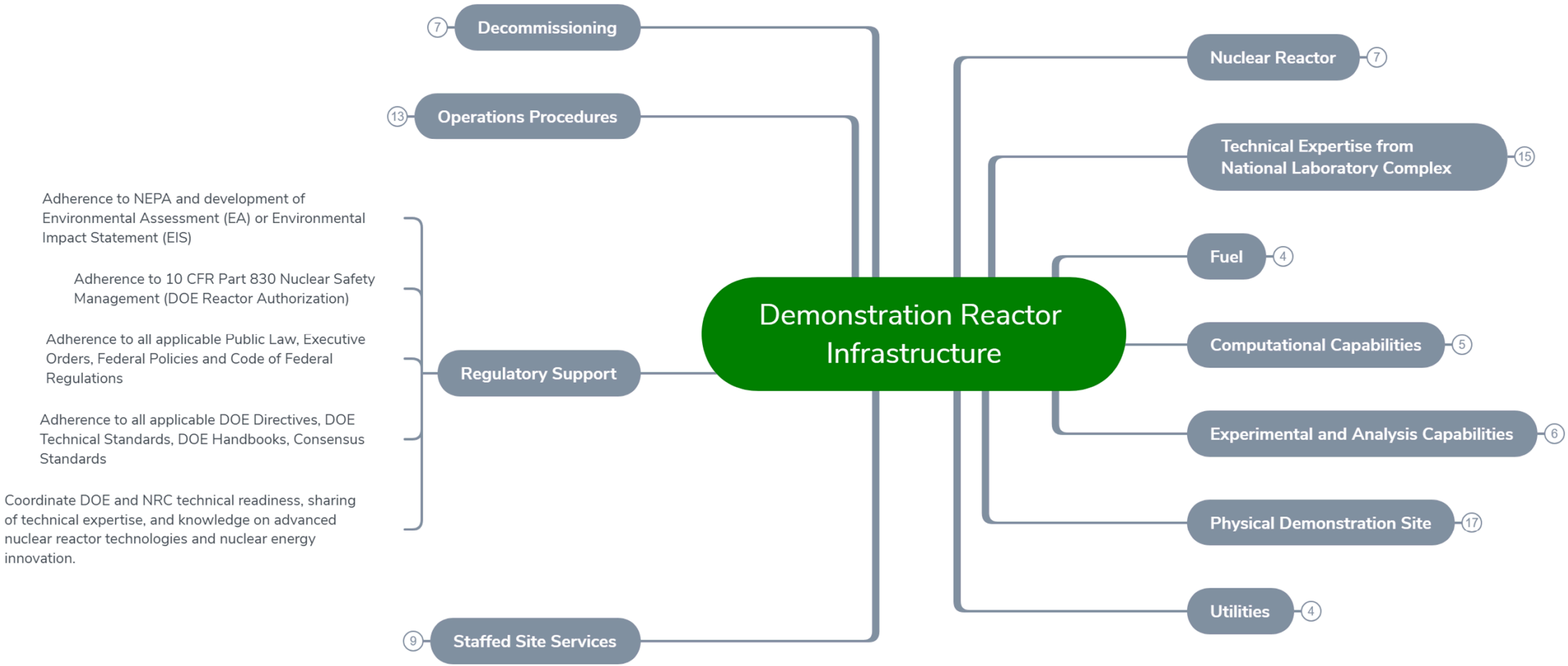

Demonstration Reactor Infrastructure
7 Decommissioning
13 Operations Procedures
5 Regulatory Support
9 Staffed Site Services
4 Utilities
17 Physical Demonstration Site
6 Experimental and Analysis Capabilities
Nuclear Reactor 7
Technical Expertise from National Laboratory Complex 15
Fuel 4
Computational Capabilities
Predictive modeling and simulation
Safety analysis
Validation data sets
Visualization techniques
High performance computing systems

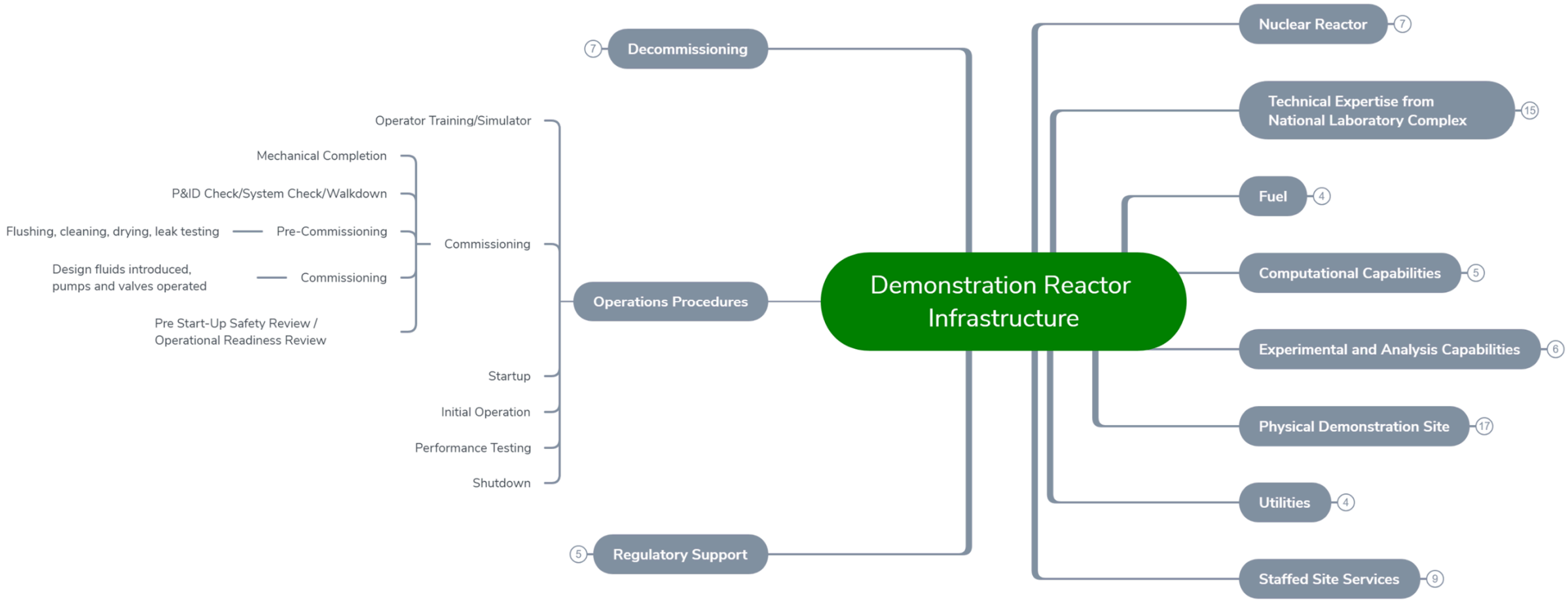

Demonstration Reactor Infrastructure
7 Decommissioning
13 Operations Procedures
5 Regulatory Support
9 Staffed Site Services
4 Utilities
17 Physical Demonstration Site
Nuclear Reactor 7
Technical Expertise from National Laboratory Complex 15
Fuel 4
Computational Capabilities 5
Experimental and Analysis Capabilities
Glove boxes and hot cells
Irradiation experiments
Material testing
Advanced imaging techniques
Elemental analysis and quantification
Advanced instrumentation

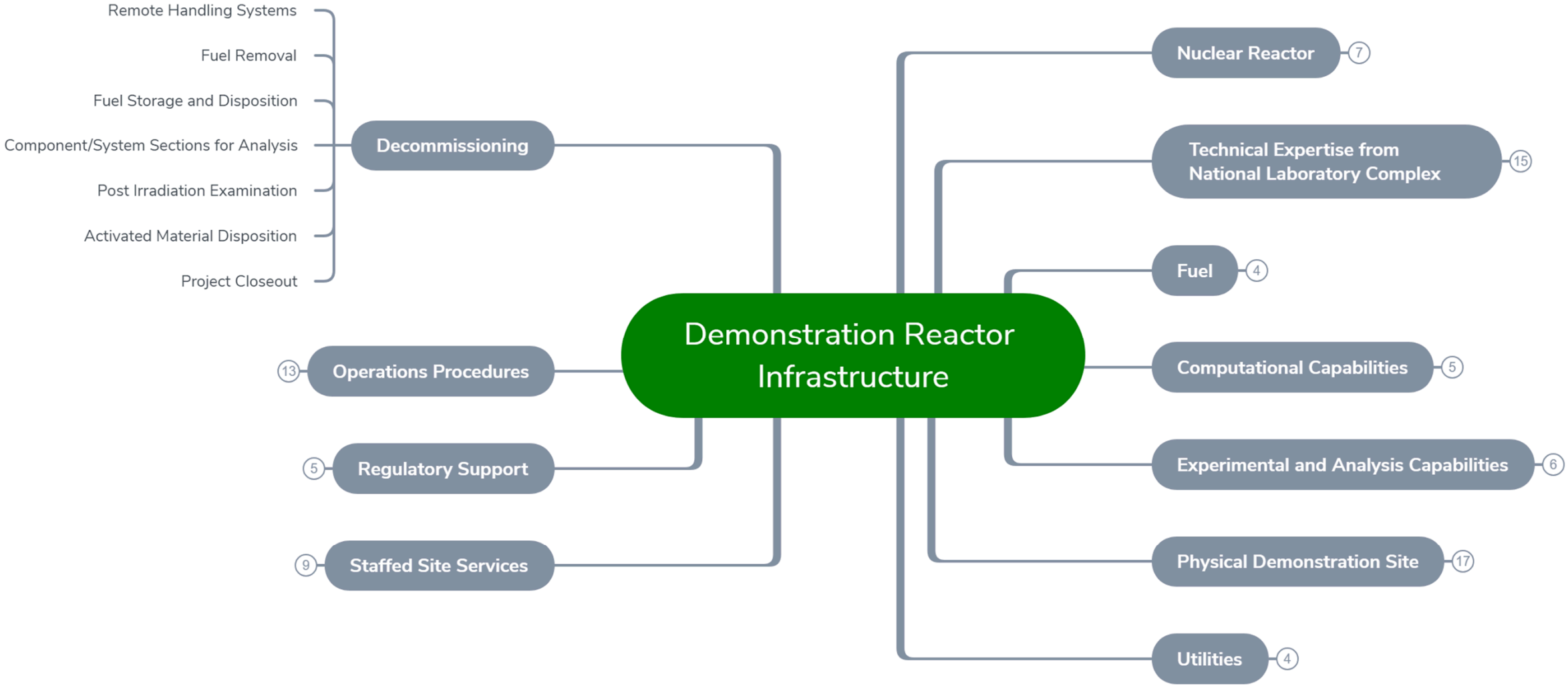

Demonstration Reactor Infrastructure
7 Decommissioning
13 Operations Procedures
5 Regulatory Support
9 Staffed Site Services
4 Utilities
Nuclear Reactor 7
Technical Expertise from National Laboratory Complex 15
Fuel 4
Computational Capabilities 5
Experimental and Analysis Capabilities 6
Physical Demonstration Site
ex. EBR-II Dome — Confinement/Containment
Temperature Control and HEPA Filtration — HVAC
Site Control Room
Miscellaneous Storage Space
Lighting
Fire Protection
Radiation Monitoring
Physical Security
Communications Infrastructure
Office Space
Commissioning Systems and Maintenance
Flush Tanks
Inert Gas Tanks
Chemistry Control
Replacement Components


Demonstration Reactor Infrastructure
Nuclear Reactor
7
Technical Expertise from National Laboratory Complex
15
Fuel
4
Computational Capabilities
5
Experimental and Analysis Capabilities
6
Physical Demonstration Site
17
Decommissioning
7
Operations Procedures
13
Regulatory Support
5
Staffed Site Services
9
Utilities
Electrical Power
Inert Gas
Instrument Air
Water


Demonstration Reactor Infrastructure
Nuclear Reactor
7
Technical Expertise from National Laboratory Complex
15
Fuel
4
Computational Capabilities
5
Experimental and Analysis Capabilities
6
Physical Demonstration Site
17
Utilities
4
Decommissioning
7
Operations Procedures
13
Regulatory Support
5
Staffed Site Services
Facility Services
Security Force
Fire Department
Emergency Services
Logistics
Construction
Field Engineering
Reactor Operations
Maintenance and Fabrication


Demonstration Reactor Infrastructure
Decommissioning
7
Operations Procedures
13
Regulatory Support
Staffed Site Services
9
Nuclear Reactor
7
Technical Expertise from National Laboratory Complex
15
Fuel
4
Computational Capabilities
5
Experimental and Analysis Capabilities
6
Physical Demonstration Site
17
Utilities
4
Adherence to NEPA and development of Environmental Assessment (EA) or Environmental Impact Statement (EIS)
Adherence to 10 CFR Part 830 Nuclear Safety Management (DOE Reactor Authorization)
Adherence to all applicable Public Law, Executive Orders, Federal Policies and Code of Federal Regulations
Adherence to all applicable DOE Directives, DOE Technical Standards, DOE Handbooks, Consensus Standards
Coordinate DOE and NRC technical readiness, sharing of technical expertise, and knowledge on advanced nuclear reactor technologies and nuclear energy innovation.


Demonstration Reactor Infrastructure
Decommissioning
7
Operations Procedures
Operator Training/Simulator
Commissioning
Mechanical Completion
P&ID Check/System Check/Walkdown
Pre-Commissioning
Flushing, cleaning, drying, leak testing
Commissioning
Design fluids introduced, pumps and valves operated
Pre Start-Up Safety Review / Operational Readiness Review
Startup
Initial Operation
Performance Testing
Shutdown
Regulatory Support
5
Nuclear Reactor
7
Technical Expertise from National Laboratory Complex
15
Fuel
4
Computational Capabilities
5
Experimental and Analysis Capabilities
6
Physical Demonstration Site
17
Utilities
4
Staffed Site Services
9


Demonstration Reactor Infrastructure
Decommissioning
Remote Handling Systems
Fuel Removal
Fuel Storage and Disposition
Component/System Sections for Analysis
Post Irradiation Examination
Activated Material Disposition
Project Closeout
Operations Procedures
13
Regulatory Support
5
Staffed Site Services
9
Nuclear Reactor
7
Technical Expertise from National Laboratory Complex
15
Fuel
4
Computational Capabilities
5
Experimental and Analysis Capabilities
6
Physical Demonstration Site
17
Utilities
4

# The EBR-II Dome has great potential as a demonstration reactor site

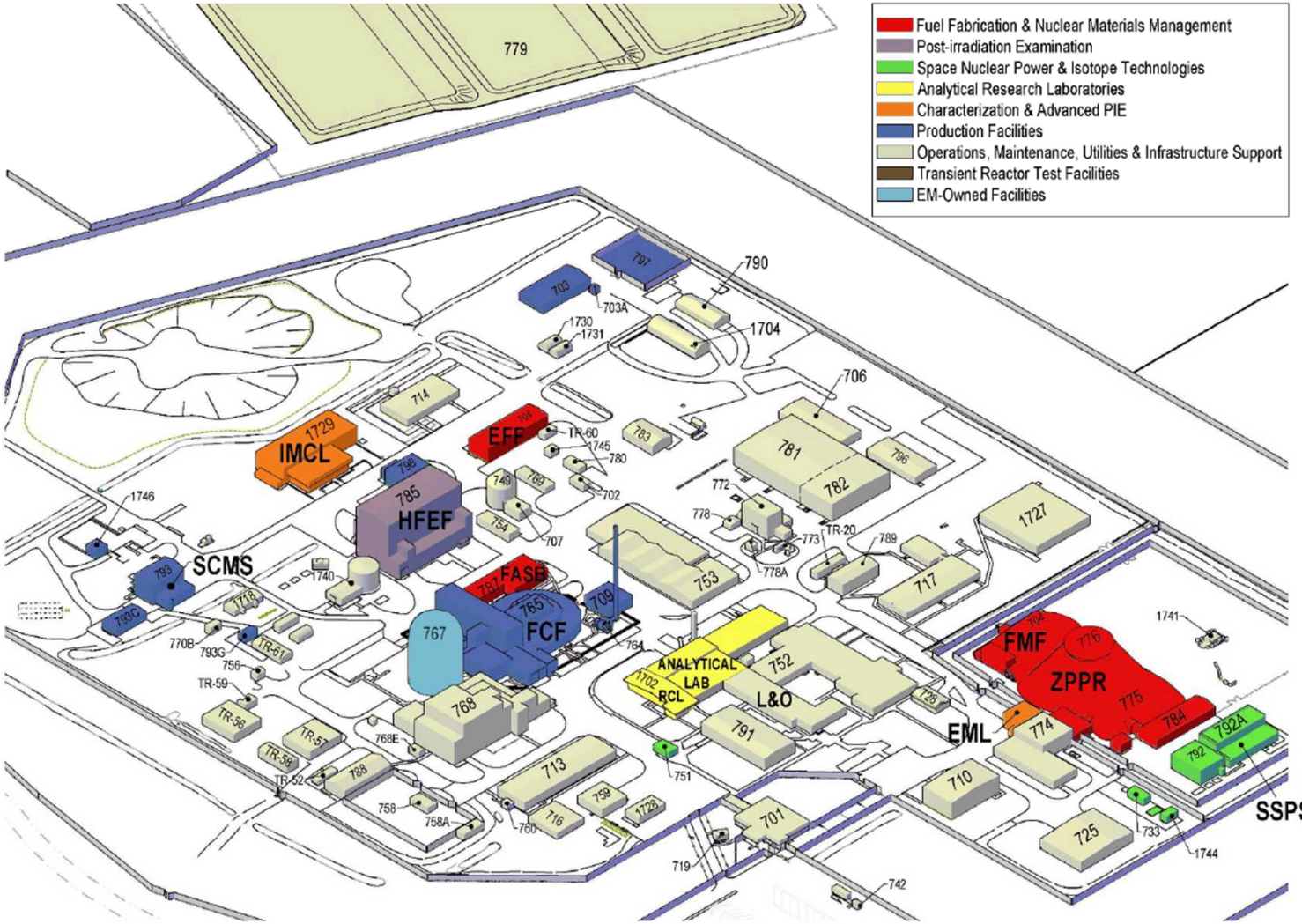
- Experimental Breeder Reactor-II Dome (EBR-II) MFC-767
- 78ft internal diameter, 87ft tall from ground level at highest point, walls are 1ft thick rebar reinforced concrete with 1inch of steel plating on outer side.  Leak tight to 24psi.
- Safeguards category 2, hazard category 2
- Floor loading capacity of 5,000 pounds per square foot
- Two lightly loaded 2MVA transformers.  13.8kV or 480V service could be supplied
- 75ton overhead crane was damaged during decommissioning, could be repaired (est. cost ~$3M)
- Has been seismically qualified in the past, (est. cost ~$300k to recertify)
- Upgrades needed:
  - Larger containment penetration needed for equipment (currently only 6ft x 6ft door)
  - Installation of cooling capacity needed
  - Electrical power, instrument air, argon, and nitrogen not currently installed
  - Repairs to overhead crane
- Excellent radiation protection, very large space, co-located with MFC for access to infrastructure

# Critical Infrastructure Test Range Complex (CITRC) Power Burst Facility (PBF) 612 and 613 as options for demonstration reactors

- PBF-612 and PBF-613 have very similar layouts and floor plans (PBF-612 basement floor plan is broken up with multi-level steel platforms, PBF-613 is open)
- 60ft x 90ft building with a 40ft x 90ft high bay on first floor and 44ft x 37ft x 22ft deep basement
- 10ft x 10 ft bay doors on opposite sides of the building to bring in equipment
- Plenty of open asphalt staging area
- Restrooms, breakroom, conference room, office space to accommodate 10 to 15 personnel
- Safeguards category 3, hazard category 2
- Floor loading in concrete basement estimated at 1,000 pounds per square foot, main floor ~10x less
- Fed from two 167kVA transformers providing ~300kVA at 480V
- Overhead crane with 10ton lift capacity
- Has been seismically qualified in the past, (est. cost ~$300k to recertify)
- Hall road connecting to MFC for access to infrastructure without public roads
- Upgrades needed:
  - Installation of cooling capacity needed
  - Instrument air, argon, and nitrogen not currently installed

# INL's Materials and Fuels Complex (MFC) offers world class infrastructure to support demonstration reactors

- IMCL- Irradiated Materials Characterization Laboratory
- HFEF- Hot Fuels Examination Facility
- EML- Electron Microscopy Laboratory
- FASB- Fuel and Applied Science Building
- AL- Analytical Laboratory
- EFF- Experimental Fuels Facility
- FCF- Fuel Conditioning Facility
- RCL- Radiochemistry Laboratory
- MFC-767 (EBR-II) Experimental Breeder Reactor-II Dome



# Irradiated Materials Characterization Laboratory (IMCL) MFC-1729

- Irradiated Materials Characterization Laboratory (IMCL) MFC-1729
  - Recently installed thermophysical glovebox/hot cell
    - Thermophysical characterization of metallic and oxide nuclear fuels.
    - Allows for remote manipulation of highly radioactive samples via master/slave manipulators on the hot cell side of box
    - Part of National Science User Facility (NSUF)
  - Abundant microscopy resources
  - Differential Scanning Calorimetry (DSC) — Specific Heat
  - Thermogravimetric Analyzer (TGA) — *When combined with DSC*
    - melting temperature, crystallization temperature, phase changes, enthalpy, volatility
  - Laser Flash Analysis (LFA) — Thermal Conductivity, Thermal Diffusivity
  - Gas Chromatograph
  - Surface Morphology, Elemental Analysis, Grain Structure, Corrosion Rates, Lattice Defects
    - Focused Ion Beam (FIB)
    - Energy Dispersive X-Ray Spectroscopy (EDS)
    - Electron Backscatter Diffraction (EBSD)
    - Transmission Electron Microscopy (TEM)
  - Electron Probe Microanalyzer (EPMA) — Elemental Mapping
  - Optical Microscopy — Surface and Cross Section Imaging
  - Microindentation, Microhardness Testing System — Material Hardness and Ductility
  - X-ray Diffraction (XRD) — Crystal Structure, Phase Analysis, Interplanar Spacing
  - Sample Prep Equipment — Polishing, Cross Sectioning
  - Metrology Equipment — Analytical Balances, Micrometers, etc.

# Hot Fuels Examination Facility (HFEF) MFC-785
# Fuel and Applied Science Building (FASB) MFC-787

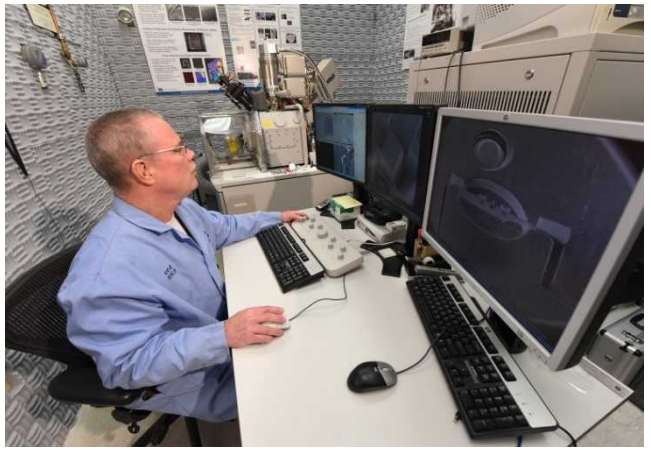

**Hot Fuels Examination Facility (HFEF) MFC-785**

- Large number of experiments ongoing, variable atmosphere quality
- Electrochemistry — Energies of formation, redox potentials, chemical activity,
- Bubbler — Surface Tension, Contact Angle, Interfacial Behavior ( Foaming, Wetting of Surfaces)
- Tensile Strength
- Creep Strength
- Fatigue
- Fracture Toughness
- Bending Strength
- Microindentation, Microhardness Testing System — Material Hardness and Ductility
- Sample Prep Equipment — Polishing, Cross Sectioning
- Metrology Equipment — Analytical Balances, Micrometers, etc.
- Neutron Radiography — NRAD (TRIGA)

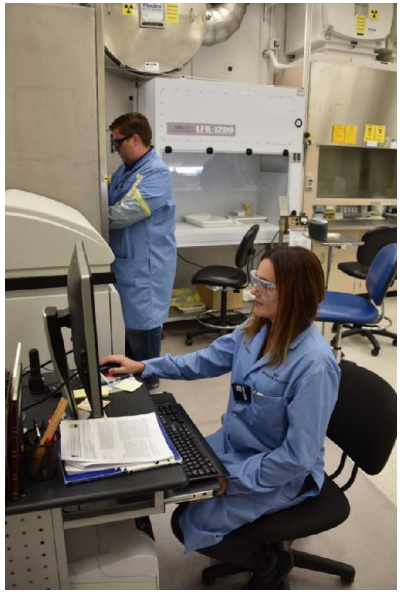
**Fuel and Applied Science Building ( FASB) MFC-787**

- Differential Scanning Calorimetry (DSC) — Specific Heat
- Thermogravimetric Analyzer (TGA) — *When combined with DSC* — melting temperature, crystallization temperature, phase changes, enthalpy, volatility
- Electrochemistry — Energies of formation, redox potentials, chemical activity,
- X-ray Diffraction (XRD) — Crystal Structure, Phase Analysis, Interplanar Spacing
- X-ray Fluorescence (XRF) — Elemental, Chemical Analysis
- Sample Prep Equipment — Polishing, Cross Sectioning
- Metrology Equipment — Analytical Balances, Micrometers, etc.

# Electron Microscopy Laboratory (EML) MFC-774
# Analytical Laboratory (AL) MFC-752



- Electron Microscopy Laboratory (EML) MFC-774
  - Abundant microscopy resources
  - Scanning Electron Microscopy (SEM)
  - Surface Morphology, Elemental Analysis, Grain Structure, Corrosion Rates, Lattice Defects
    - Focused Ion Beam (FIB)
    - Energy Dispersive X-Ray Spectroscopy (EDS)
    - Electron Backscatter Diffraction (EBSD)
    - Transmission Electron Microscopy (TEM)
  - Sample Prep Equipment — Polishing, Cross Sectioning
  - Metrology Equipment — Analytical Balances, Micrometers, etc.



- Analytical Laboratory (AL) MFC-752
  - Differential Scanning Calorimetry (DSC) — Specific Heat
  - Thermogravimetric Analyzer (TGA) — *When combined with DSC* — melting temperature, crystallization temperature, phase changes, enthalpy, volatility
  - Laser Flash Analysis (LFA) — Thermal Conductivity, Thermal Diffusivity
  - X-ray Fluorescence (XRF) — Elemental, Chemical Analysis
  - Alpha Spectroscopy — Identification and quantification of alpha emitting isotopes
  - Gamma Spectrometry with high purity germanium detectors — Identification and quantification of gamma emitting isotopes
  - Gas Pressurized Extraction Chromatography — Uses pressurized nitrogen to push solutions through media instead of liquid or gravity
  - Fourier-transform infrared spectroscopy (FTIR) — Vibrational spectroscopy
  - Laser Ablation Laser Induced Breakdown Spectrometry (LIBS) — Elemental analysis (ppm)
  - Inductively Coupled Plasma (ICP) Mass Spectroscopy ( MS) and Optical Emissions Spectroscopy (OES) — Elemental analysis (sub-ppm)
  - Thermal Ionization Mass Spectrometry (TIMS) — Elemental Analysis (sub-ppb) — time consuming, costly , ultra-accurate results
  - Liquid Scintillation Counting — Quantify the radioactivity of low energy radioisotopes, mostly beta-emitting and alpha-emitting
  - Ultraviolet/Visible Spectrometry — Speciation, Oxidation States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