Roadmap to Army Utilization of Microreactors

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Executive Summary

Our review of the current microreactor landscape indicates that successful deployment of a microreactor at an Army installation can be accomplished by 2023. From the review, we have also concluded that the best path towards that goal is through the DoD Strategic Capabilities Office (SCO); the Under Secretary of Defense for Research and Engineering can complete and successfully demonstrate a prototype reactor design appropriate to military needs. The Army should have a key role in that process to ensure that the design, or close variant, developed by the SCO can be sited at an Army installation. The selected reactor design and installation must be able to provide energy at prices comparable to alternative prices at the installation location, taking into account other relevant considerations such as reliability and resiliency.

For further progress beyond the initial installation, fuel production and supply limitations must be addressed, and commercial development should be encouraged to advance fundamental permitting, licensing and other regulatory requirements related to the construction and operation of microreactors.

Content of This Report

The roadmap in this report outlines a path for a prototype microreactor development and potential deployment at a domestic US Army installation by 2023. It specifies a direct, expeditious, and least risky strategy for such development and deployment by minimizing potential regulatory and development hurdles. The roadmap reflects an approach that matches the licensing, construction and operating needs of the Army, emphasizing coordination by interested parties to leverage technical expertise and resources.

The bulk of the report focuses on the key challenges that need to be addressed and overcome for the successful development of the prototype and the subsequent deployment of similar models for the energy needs of both fixed military bases and tactical military operations.

The roadmap was compiled after discussions with several dozen public and private experts who possess extensive knowledge of the current state of play regarding licensing, technology development, fuel acquisition, siting, transportability, power sales, public relations and other matters relevant to successful deployment of a microreactor on an Army installation by 2023. Documentation of the insights provided by these experts without attribution is provided in the Appendix to this report.

Introduction

From the period starting when he was Combatant Commander of the 1st Marine Division during the 2003 invasion of Iraq, former Secretary of Defense James Mattis has drawn attention to the fact that up to half of American casualties in forward-deployed scenarios occur due to supply chain operations, including supplying fuel oil for tactical needs. Nuclear energy has the potential to reduce greatly such casualties by minimizing the need for diesel fueled electricity in support of military operations.

In addition, domestic military bases continue to rely almost exclusively on the commercial power grid and, thus, have only limited ability to “island” electrical power in the event of blackouts. Should such a blackout be caused by a systemic attack on the US grid, cyber or otherwise, the country’s ability to maintain operations in defense of the homeland could be substantially compromised.

With Congressional support, the Department of Defense (DoD) has made previous efforts to develop nuclear technology for an array of military purposes. In 1954, the Army established the Army Nuclear Power Program (ANPP) to develop small pressurized water and boiling water reactors primarily at remote, hard-to-reach sites. However, due to escalating costs of operations, maintenance, and fuel, the program was terminated in 1977.

Recently, there has been renewed interest by both Congress and the Executive Branch in developing advanced nuclear reactors. Fueling that interest, private-sector designers are now working on advanced reactors with ratings of 2-10 MWe which can be used effectively to support military operations at home and abroad.

Congress recently enacted new legislation relevant to the renewed governmental interest and industry developments. The Nuclear Energy Innovation Capabilities Act (NEICA), signed into law on September 28, 2018, provides important new authorities for partnership of the Department of Energy (DOE), Nuclear Regulatory Commission (NRC), and the National Laboratories. It enables increased technology and information sharing between the leading nuclear technology developers and the NRC to support research, development, and demonstration of advanced nuclear reactor technologies. In addition to NEICA, the Senate is currently debating several additional bills that could have implications for microreactors and other advanced nuclear reactor technologies. They include the Nuclear Energy Leadership Act (NELA) and the Advanced Nuclear Energy Technologies Act. Congress also presented the Nuclear Energy Innovation Modernization Act (NEIMA) to the President for signature on January 2, 2019. This bill directs the NRC to update its regulatory requirements for small modular and non-light water nuclear reactors.

Moreover, The National Defense Authorization Act for Fiscal Year 2019 (NDAA) directs the DOE to produce a report on a pilot program for microreactors to “provide resilience for critical national security infrastructure… by contracting with a commercial entity to site, construct, and operate at least one licensed microreactor at a facility identified under the report by December 31, 2027.” For its part, the DOE released a Request for Information (RFI) on September 13, 2018 on the various nuclear technology options for successful demonstration of a microreactor on a DOE or DoD facility to satisfy congressional requirements within the NDAA section 4701. In addition, the DOE appropriations for Research, Development, Test, and Evaluation provide annual increases in the budgets for primary assessment technologies, dynamic materials properties, secondary assessment technologies, and enhanced capabilities for subcritical experiments, and advanced manufacturing.

Over the past several years, DoD has increased its focus on microreactors. Studies such as the 2016 report by the DoD Defense Science Board entitled "Energy Systems for Forward/Remote Operating

Bases," and the recently released report (October 26, 2018) from the Deputy Chief of Staff entitled “Study on the Use of Mobile Nuclear Power Plants for Ground Operations” reflect that interest. Both reports provide extensive analyses of the feasibility of mobile nuclear power plants within current technology limitations. Most significantly, on July 30, 2018 the Under Secretary of Defense for Research and Engineering, Dr. Mike Griffin, wrote a letter to the DOE Deputy Secretary which stated: “I have tasked the Department of Defense Strategic Capabilities Office (SCO) to begin…the development…of an operational demonstration of a prototype small modular reactor.”

On the commercial side, there has been heightened interest and activity in developing safe and dependable power sources at appropriate sizes for military applications. However, greater progress by these private-sector entities would benefit from a well-defined future market and financial support to give them an incentive for further investments in development work; something that can be provided by military applications as suggested in this report.

What are Microreactors?

A microreactor is a small self-contained nuclear reactor that has the ability to generate and provide off-grid electric power reliably and securely to support mission readiness. In addition to supplying power during normal operations, microreactors can support critical loads in emergency situations that result from the loss of grid services. Some designs can also be used to replace combined heat and power (CHP) units by utilizing the by-product heat for hot water or steam that can be used in community structures and facilities.

Currently, there is no widely accepted consistent taxonomy to categorize different microreactor power ratings. The NDAA, for example, defines microreactors as those providing less than 50 MWe of power output. The DOE commonly uses a range of 2-5 MWe to define microreactors. Other authorities define microreactors as having power outputs as low as 0.5 MWe. For military applications, the most generally accepted range for microreactor power output is 2-10 MWe. There is general consensus that microreactors at the lower end of these ranges can be made transportable. In the period 2015-2018, the National Aeronautics and Space Administration (NASA), in conjunction with the DOE’s National Nuclear Security Administration (NNSA), developed a reactor in the kilowatt range for its “Mission to Mars” Program. That reactor, built and tested at Los Alamos National Laboratory (LANL) test site in Nevada, was developed in the short time period of 18 months.

Microreactors are not new. Universities and research laboratories have used small scale reactors for research purposes for many years. Both the Massachusetts Institute of Technology (MIT) and the Oak Ridge National Laboratory (ORNL) have operated microreactors on a continual basis since the 1950s. However, in contrast to the “older” technology, the new designs do not require operator or computer actions, or AC/DC power, or water to keep the reactor safe for an unlimited period. They can start from cold conditions without grid connections. They are extremely reliable (e.g., for a 50 MWe model, 99.98% reliability over a 60-year lifetime). They can be buried since they are “solid-state machines” and can be factory-fabricated, modularized and shipped to location for assembly. They are transportable by truck, shipping vessel, airplane or railcar. They are self-regulating with no need for special operators and they utilize passive safety systems that prevent any potential for overheating or reactor meltdown. Microreactor technology principles have been pursued elsewhere around the world, with some proven successes in Germany, South Africa, China, Russia, and Canada.

Benefits of Microreactors to the Army

Microreactors have the capability to provide energy for a wide range of Army installation needs, particularly for providing power and by-product heat to remote domestic military bases. Many of these remote bases are critical for national security and currently face challenges where grid services may be inadequate for future energy needs. These remote bases typically have substantial energy demands and high electricity costs.

Microreactors offer many advantages to Army installations. In addition to providing resilient and secure power in a manner that offers the potential to reduce dramatically the casualty rate from fuel delivery to forward operations, they also offer operational flexibility to support mission readiness in applications such as desalination, advanced weapons support, and critical infrastructure resilience. The latest designs are much simpler than reactor designs of the past with user interfaces that can be autonomously controlled. They should be quickly and easily licensed, and can have operating intervals as long as 20 years between refueling events. For multiple deployments in a region, a single monitoring room can oversee multiple reactors. That option might not be necessary for the simplest emerging designs. In addition to these benefits, microreactors are virtually invulnerable to grid outages and diesel generator malfunctions. As for safety, microreactors are capable of withstanding a large array of catastrophic natural events such as hurricanes, tornados, floods and seismic events. In addition, microreactors have much smaller "emergency planning zones" than light water reactors, mostly comprising just the building that houses the reactor.

These advantages stand in stark contrast to the many difficulties with current uses of fossil fuel to provide power to military applications, such as operations in extreme weather, the extremely high cost of generation in remote locations, and the reliability of fuel supplies and generators.

Challenge 1 – Design and Manufacturing

While the private-sector has made much progress in microreactor design in the past few years, many actions still need to be taken by the government to move the newly emerging technologies from design to prototype development and deployment on a military installation.

Simultaneous development of private sector microreactor technology will be necessary for the eventual deployment of multiple microreactors on military installations. To facilitate that outcome, coordination among DoD, DOE, and other relevant components of the Executive Branch and Congress is needed to promote corresponding parallel developments in both DoD and the private-sector. Such coordinated developments can be induced through legislative action in tandem with public promotion of the need for more secure, reliable and resilient power supply systems that enhance national security.

To advance a parallel development of advanced microreactors, Congress should continue to provide steady funding, and the DoD and DOE should increase the availability of competitive grants and cost-share funding to private-sector companies pursuing reactor and fuel supply development. Congress also should continue to provide additional legal authorities that expeditiously enable such development of advanced reactor technologies. This could include legislation that aligns the economics of small-scale nuclear power generation with increased private access to government research resources, or that further mandates interagency coordination of nuclear technology research and development.

An important aspect that currently limits the ability to design and develop novel reactors is the lack of domestic testing facilities for advanced reactor technologies. Providing a fast neutron test reactor, aka Versatile Test Reactor (VTR) would greatly address that limitation. Currently, three VTRs exist globally, none of which are in the United States or otherwise accessible to American developers. Both Russia and China currently operate VTRs.

The lack of a VTR places limits on our ability to test and use advanced nuclear fuels. Thermal flux reactors are the only reactors now available to test fuels, a situation that results in limited options. VTRs sustain nuclear reactions by utilizing fast neutrons, as contrasted with thermal-neutron reactors that employ neutron moderators. VTRs provide high energy neutrons needed to sustain chain reactions for many types of non-light-water-cooled reactor designs. Some of the advantages of these non-light water reactors include increased fuel efficiency and lower radiotoxicity of spent fuels. Having a domestic VTR is not just advantageous but necessary to ensure the future of advanced nuclear technologies in the U.S. because the NRC requires experimental validation for licensing decisions. The Idaho National Laboratory (INL) currently is establishing the Nuclear Reactor Innovation Center (NRIC) focused on developing and sustaining nuclear energy. The NRIC is intended for both a High-Assay Low Enriched Uranium (HALEU) fuel production facility and a VTR.

Having access to a VTR could substantially reduce costs and development times of future microreactors, resulting in significantly reduced NRC licensing times for new fuels that support commercialization. Other actions that could be taken in the design and manufacturing area would include enhanced programs to support DOE-private sector cooperation such as cost-sharing of grant programs and expansion of existing memoranda of understanding to facilitate the deployment of reactors at LANL.

Other possibilities for accelerating manufacturing processes include the use of advanced manufacturing technologies such as three dimensional printing of reactor parts, being pursued at ORNL. In addition to these focus areas; it will be necessary to address other concerns such as cybersecurity and protection of reactors from electromagnetic pulses.

Challenge 2 – Fuel Infrastructure

Another important area limiting the ability to design and develop novel reactors is the current lack of available fuel and fuel production infrastructure. Light water reactors operate on low enriched uranium with uranium-235 at a roughly 4-5% concentration. For uranium at this level of enrichment, there are well defined supply chain options and regulations in the United States. However, many of the advanced reactors under development, including most microreactors, require high-assay LEU or HALEU. This type of fuel contains uranium-235 concentrations greater than typical LEU fuel but less than 20%, above which fuel is deemed as highly enriched (i.e., HEU fuel). At present, the United States does not have a domestic commercial supplier of HALEU. While there are limited quantities of HALEU available for fuel testing and development of initial reactors, eventually additional sources will be needed to ensure a dependable and available commercial supply. Regulatory and transportation infrastructure for HALEU also needs to be developed.

An important element for developing both a fuel supply infrastructure and domestic testing facilities is the active support from Congress through appropriations and authorizations such as the recently enacted Nuclear Energy Innovation Capabilities Act (NEICA). NEICA directed DOE to "provide research infrastructure to promote scientific progress" of nuclear energy and to "enable the private sector to partner with the National Laboratories to demonstrate novel reactor concepts." While NEICA took significant steps to promote coordination among the NRC, DOE and private industry, further legislation may be necessary to increase interagency cooperation that allows for the development of microreactors. One such bill, Senator Murkowski's Nuclear Energy Leadership Act, would establish an interim supply of HALEU for both prototype and commercial advanced reactors, including microreactors.

DOE is the primary candidate to alleviate fuel supply concerns through the production of HALEU at the INL. The current version of the 2019 Energy and Water Development Appropriations bill contains $20 million for the purpose of developing a HALEU fuel facility on the site of the Experimental Breeder Reactor-II (EBR-II) that ceased operations in 1994. Used fuel from EBR-II could be reprocessed to create HALEU fuel. While DOE HALEU fuel production facilities are subject to NRC review, market demand is not necessary for the DOE to develop such a facility. The NNSA has stockpiles of highly enriched spent fuel used by Navy nuclear submarines at INL. INL is currently down-blending high enriched uranium from spent fuel and dismantled nuclear weapons to just below 20%.

In addition to the short term needs that can be addressed using leftover fuel, the DOE is looking to address long term HALEU needs. On January 7, 2019, the DOE announced a contract with Centrus Energy to develop a HALEU enrichment demonstration in Ohio by 2020.

Supplying HALEU commercially has many challenges including ones dealing with fuel design, fabrication, and transportation on public highways (e.g., individual states through which HALEU fuel would be routed can disrupt or obstruct such transportation). For example, to upgrade an existing license for producing 5% enriched to one for producing up to but just less than 20% enriched uranium would take about two years. It would then take about a year to develop data on criticality. Then, packages for shipping HALEU hexafluoride would need to be developed and certified. Finally, it also would take government assistance to license such a commercial production facility. So, under the NRC rules, the time lapse for fuel design, fabrication, and development of a transportation package can extend to a period of five to six years.

Clearly then, it is advantageous for the first prototype to be developed under DoD authority on a DoD or DOE installation that provides the requisite fuel from on-site sources and thereby avoids the NRC time consuming process. The overarching goal for the first DoD microreactor project should be to demonstrate a working model to the DoD hierarchy who can then promote with conviction the further commercial development. Assuming that all goes well, it would take a minimum of seven years to develop the fuel cycle infrastructure required for the commercial supply of HALEU fuel. If the first DoD prototype is located on a DOE site, down-blended high enriched uranium can supply the HALEU needed on an interim basis. In this case, the HALEU can be made available in less than three years by avoiding the NRC commercial supply licensing requirements mandated under *10 CFR Part 70, Domestic Licensing of Special Nuclear Material*.

Another issue relevant to the design and manufacture of microreactors concerns the International Atomic Energy Agency (IAEA) classification of fuel enrichment. By definition, enrichment levels of less than 20% are considered to be low enriched. Microreactor development and use would benefit by a reclassification of fuel enrichment to promote reactor efficiency and reduce operating cost. Higher levels of fuel enrichment would allow for smaller and more efficient reactors without added safety risks. For example, compared to 20% enriched uranium, a 27% enrichment could reduce the cost of microreactor generated electricity by half according to the experts we interviewed. According to these same experts, the relative risk of weaponizing 20% and 40% enriched uranium is virtually identical.

Challenge 3 – Licensing

In recent years, private industry has made tremendous strides in designing advanced reactors. However, concerns arise around the cost and time needed to satisfy the requirements of the NRC licensing review process, especially for novel reactor designs. The current NRC review process was designed for light water reactors. It has not been updated to meet the needs of advanced nuclear reactors. While the NRC recognizes this situation and is working to make changes through licensing modernization efforts, the agency is oriented to following existing procedures based on familiar past experience.

Currently, the NRC review process for new reactor designs ranges from 36 to 48 months. While the NRC is considering streamlining the application process and currently is working with stakeholders to produce consensus changes, the private sector remains concerned about the pace of development of new procedures for non-light water advanced reactors.

There is general agreement within the commercial nuclear industry on the need for an improved regulatory path that promotes clarity and speed. More specifically, there is substantial opinion within the industry that making modifications to parts 50 and 52 of the NRC regulations could be more expeditious than developing a new licensing pathway. It is industry belief, for example, that parts 50 and 52 could be used to license advanced microreactor technologies more efficiently if changes were made to the licensing process to accommodate self-contained units that also feature smaller security and emergency planning zones. This might involve fundamental decisions on the basic regulatory processes that are most relevant to advanced reactors, such as the utilization of advanced mathematical modeling approaches instead of heavy reliance on demonstration reactors for the generation of safety test data.

The NRC also is now considering streamlining application requirements that could reduce the number of pages and volume of data necessary for license applications. The agency has a project entitled “The Licensing Modernization Project” to develop recommendations for regulatory changes. Personnel from the DoD and the private sector are involved in that project with the expectation that some such modified regulations could be promulgated within 18 months.

Important among the considerations relevant to the licensing efficiency issue are the inherent safety features of advanced reactors. There is substantial industry opinion that significant changes must be made to ensure that the “adequate protection” provisions of the rules are more compatible with modern-day safety features of advanced reactors. On a positive note, the NRC already is considering an expedited safety review process focused on the concept of “Safety Sufficiency Review.” Industry representatives believe that the process could be made more efficient by the adoption of a technology “type approval” approach, where safety processes associated with specific technology groups are evaluated on a generic basis, allowing the safety review process for specific applications to be evaluated in shorter time compared to individual design-by-design approvals.
A related area of needed reform concerns the NRC’s Advisory Committee for Reactor Safeguards. This “secondary look” approach is a relic of the Atomic Energy Commission, which made sense before the NRC developed its current commitment to safety and, therefore, might no longer be necessary. There appear to be two options to obviate this unnecessary impediment: (1) eliminate the Advisory Committee on Reactor Safeguards as redundant to the current regulatory framework governing microreactors, or (2) allow the NRC to incorporate within its mission an additional responsibility to promote nuclear power.

Regarding microreactor development technology by the DoD, Section 110, Part b of the 1954 Atomic Energy Act provides that microreactor technology developed by DoD and located on DoD property is not subject to NRC review. Therefore, DoD can potentially develop microreactor technology faster than is the case with the private sector. That said, the NRC currently is working with the DoD, through the SCO, to assist with its microreactor development technology activities. It is expected that, after the first unit is licensed by DoD, later units will then go through the NRC licensing process.

Within the Federal government, intra-departmental and interagency cooperation are essential to microreactor development. While DoD can develop microreactor technologies without being subject to review by the NRC, DoD should engage with the NRC to gain from its experience during design and testing to monitor and verify reactor performance and safety specifications. The NRC currently has such an agreement with the Navy to do “secondary” reviews after the Navy has completed primary design requirements. A similar agreement should be considered between the NRC and the broader DoD. A bilateral flow of expertise and information between the NRC and DoD could expedite both technology development and NRC rulemaking changes. Lessons learned from reactor development and testing would be shared with the NRC to help reshape the licensing pathway of advanced microreactors.

Over the longer term, there are substantial reasons why the Army, the Air Force and other DoD components have a strong interest in the commercialization of microreactor technologies developed by the DoD. Unlike the conditions that prevailed when the Navy started its nuclear program, a strong nuclear technology capability exists today in the private sector. Because of existing commercial capacity, many of the challenges previously faced by the Navy will not need to be addressed by the Army, the Air Force, and the other military components. A partnership of the interested military services could work for the benefit of all. Issues such as the lack of fuel and other necessary elements of a supply chain to support construction and operation of microreactors, the lack of operational expertise at levels necessary for such construction and operation, and past history of nuclear reactor difficulties and associated negative public perceptions could be effectively addressed by such a partnership to better guide and promote development through private commercialization.

Challenge 4 – Siting

While siting a microreactor on a DoD facility would not require an NRC license, it is prudent to follow all the steps otherwise required for such a license for all parties to gain the experience and to generate relevant data for subsequent NRC licensing for a commercial facility. Site preparation includes excavation, grading, site mobilization, and other activities, which altogether can take up to 24 months to execute. Site characteristics that can affect safety include earthquakes, geotechnical phenomena, volcanism, flooding, meteorological events, human-induced events, dispersion of radioactivity, and feasibility of site emergency plans. These are considered safety-related characteristics. There are also non-safety-related factors: nuclear security considerations, technology, economics, topography, and the availability of transport. A site evaluation is necessary to confirm that the site is suitable and to define the design basis of external hazards; for every external event, parameters are chosen so they can be used easily in the nuclear installation's design and in its safety assessment, see *10 CFR Part 100 – Reactor Site Criteria*. It is reasonable to anticipate that the inherent safety of the "solid-state" microreactor design and its small footprint will make site selection and preparation considerably easier than for the standard utility-sized reactors. A major difference is the fact that water availability, safety, and disposal is not a factor for microreactors. The long-term encasement of fuel with no need to refuel for up to 20 years is another major factor that will significantly simplify siting considerations.

A number of locations are excellent candidates for the initial deployment of a stationary microreactor at a military installation. They include island locations (e.g., Guam), and western states with isolated locations and limited water resources. Notably, Fort Greely, Alaska is one option to consider for the deployment of a stationary microreactor following the successful demonstration of a DoD prototype.

Fort Greely is a suitable location for the first siting of a stationary microreactor due to its remote location, the criticality of its national security infrastructure assets, its electric load requirements, its current reliance on Jet 50A fuel, and the age of its existing power infrastructure. Fort Greely is a US Army launch site for anti-ballistic missiles located approximately 100 miles southeast of Fairbanks, Alaska. Because of its remote location, it was chosen years ago to house a "stationary, medium sized reactor" denoted as SM-1A and which provided 2 MWe of electricity. The SM-1A reactor was constructed between 1960 and 1962, initially reaching criticality on March 13, 1962. The reactor operated for 10 years but was shut down in 1972 due to high maintenance costs. This problem is not foreseen for the new microreactor technologies being developed, all of which feature much lower maintenance needs.

Presently, electric power for Fort Greely is supplied by a Golden Valley Electrical Association substation located next to the Fort Greely Central Heat and Power Plant (CHPP). The Fort Greely CHPP contains three boilers that were installed in 1954. The substation can provide 2.5 MWe of electric power. If the electrical load for Fort Greely exceeds 2.5 MWe, diesel generators can supply peak power loads (up to 5.5 MWe). Both the CHPP and backup diesel generator system use Jet 50A fuel.

The Departments of Defense and Energy have been working together on the challenge of identifying the first stationary microreactor site and Fort Greely is well-positioned for such consideration. Furthermore, arctic installations have increasing value to the rapidly improving navigability of the Arctic Ocean. The Request for Information (RFI) discussed above on page 2 contains a request to elicit interest in siting the first microreactor.

Challenge 5 – NEPA Compliance

The National Environmental Policy Act (NEPA) is most important of the many Federal environmental statutes, particularly for actions taken by the government, such as DoD. It is important to the deployment and use of microreactors because it sets forth a mandatory requirement for Federal agencies to take a hard look at the environmental impacts of all major actions significantly affecting the quality of the human environment, including alternatives to proposed actions. NEPA Sect 102 specifics are laid out in the regulations of the Council on Environmental Quality at 40 CFR 1500-1508.

There are three possibilities for compliance. The first would require a determination by the installing site that the proposed action qualifies for a categorical exclusion (CX). The second involves a determination by the installing site that the proposed action is a "major federal action significantly affecting the quality of the human environment," thus requiring the preparation of an Environmental Impact Statement (EIS). In the event the proposed action does not fit either of those two categories, an environmental assessment (EA) will need to be performed. The purpose of an EA is to make a determination regarding whether or not an EIS is required. Therefore, the only two possible outcomes of an environmental assessment are (1) a determination that an EIS is not required, in which case a finding of no significant impact (FONSI) is prepared, or (2) a determination that an EIS is required.

A major NEPA-related concern related to the proposed action discussed in this report is the time that NEPA compliance will take. A study of EIS preparation times conducted by Salisbury University found a range of 51 days to 18.4 years, with an average time of 3.4 years, for 2,095 final EISs conducted by Federal agencies. [deWitt & deWitt, 2008]. While several efforts have been undertaken within the Federal Executive Branch over the past several decades to streamline EIS processes, none has been notably successful in decreasing EIS preparation time frames.

Obviously there is a clear time frame distinction among the three NEPA compliance options listed above, with EISs taking the longest, EA/FONSIs typically taking much shorter times, and categorical exclusions taking very little time. Guidance on selection among these options is provided by Army Regulation 200-2, “Environmental Analysis of Army Actions,” codified at 32 CFR Part 651. A review of that guidance, including Appendix B “Categorical Exclusions,” indicates that, with regard to the proposed action discussed in this report, it is more likely that a determination will be made that either an EIS or EA will be deemed more appropriate than application of a CX.

With regard to the time requirements that would apply to NEPA compliance for the preparation of an EIS, there are multiple possibilities. These include preparation of a regional, site-wide or other type of programmatic EIS, or the preparation of a site-specific EIS. A programmatic EIS normally does not contain the level of detail on precise project footprints and impacts typical of site-specific EISs, and typically are followed by site-specific environmental analyses of project-specific impacts for projects proposed to be undertaken within the umbrella of the programmatic EIS. Subsequent site-specific environmental analyses typically are conducted through a process called “tiering,” frequently via a categorical exclusion or EA/FONSI. While preparation of programmatic EISs typically take several years to complete, subsequent analyses of project-specific impacts within the scope of the programmatic EIS can be completed in a shorter time period.

Therefore, if the intent of the planning process is to facilitate multiple microreactor deployments within the scope of a regional or area-wide programmatic EIS, the shortest time frame for NEPA compliance likely would be that associated with a programmatic EIS followed by EA/FONSI or CX determinations for individual deployments. On the other hand, if the intent of the planning process is to facilitate the deployment of a single pilot microreactor on an individual installation, then the simplest and quickest approach likely would be the preparation of a site-specific EIS.

In other words, from an overall program perspective, the least demanding approach, in terms of time requirements and expense, likely would be an area-wide or regional EIS that could provide NEPA coverage for multiple deployments of microreactors on installations throughout the United States.

There are a number of factors that should be considered when predicting the complexity, time requirements and expense associated with the three NEPA compliance possibilities mentioned above (CX, EA/FONSI or EIS). One such factor is the determination of the size of the emergency preparedness zone associated with the particular technology selected for implementation. (Smaller sizes of the emergency preparedness zone would support arguments in favor of less detailed environmental analyses.) For microreactors, that zone will be substantially smaller than commonly associated with light water reactors. A second factor concerns the nature of the initial installation. If the proposed Federal action were to involve multiple microreactor deployments within a region or on a single installation, an approach involving preparation of a programmatic EIS with NEPA compliance provided by site-specific EA/FONSIs or CXs tiered off the programmatic EIS could substantially expedite NEPA compliance. An example might be the concept of conducting all testing and prototype activities at the INL site.

Based on the foregoing logic, the best approach could be to conduct a regional or nationwide programmatic EIS addressing generic safety concerns that would then be utilized in subsequent site-specific environmental assessments for siting microreactors on individual bases. Under the approach set forth in the section below entitled "The Path Forward - Recommended Roadmap," both the DoD SCO and INL could be the co-proponents of the initiative for NEPA compliance purposes. After the process advances to siting on individual bases, the selected installation could enter into an Enhanced Use Lease arrangement with a private owner-operator. At that point, the private entity could conduct the NEPA analysis under installation oversight and support.

From its past experience in this area, the Army has a strong in-house capability to provide targeted data relevant to any NEPA approach through the Army Environmental Command's ISOCPP process. In years past that process has considerably reduced the time for NEPA reviews.

Challenge 6 – Public Relations

Critically important to timely progress towards the deployment of a microreactor on a military installation is providing a process to enable the public to understand this initiative. To avoid negative public reaction, it will be helpful to elicit understanding that the emerging microreactor technologies are significantly different from those of the past 60 years. Modern microreactor technology has evolved to the point where the reactors are as easy to operate as diesel generators. Human operators are needed only at the beginning of operations. New technologies do not require the security and emergency response requirements of light water reactors.

One potentially effective message would inform the public that reactors on college campuses have operated without much staff support for many years, relying simply on local safety and emergency response services that are employed to respond to common chemical and other health and safety risks. It seems likely that a number of case studies could be used to illustrate how small reactors have been used safely for decades, including MIT's 6 MWe reactor in downtown Cambridge, MA.

DOE's NNSA runs a program with academic institutions to promote the education of scientists and engineers in areas that are critical to stockpile stewardship. The Stewardship Science Academic Programs support U.S. research at universities that includes a goal to "ensure that there is a strong community of technical peers throughout the country, external to the NNSA national laboratories." It seems feasible that this program could be expanded to include a public educational mandate to address and mitigate exaggerated public fears and discomfort with nuclear technology.

Most encouraging, DOE is currently conducting public outreach through the Millennial Nuclear Caucus program. It focuses on the path forward for the nuclear industry and the role that innovative technologies will play. Microreactors could be a "poster child" for that program, given their many attractive features.

Other Army and DoD Considerations

The Army has been somewhat reluctant to own and operate nuclear power plants. It has had costly decommissioning and site cleanup of former nuclear sites, and it would prefer to avoid liabilities surrounding future programs. Additionally, the Army currently does not have personnel trained to operate nuclear reactors. The Army, however, has expressed interest in purchasing nuclear power through power purchase agreements, after the technology has been demonstrated and proven reliable.

There are several additional considerations that are relevant to the Army's longer term goals. One important concern is the issue of transportability. The Army is understandably interested in transportability as a means for reducing combat casualties associated with the transport of fuel supplies to forward operating bases. It is also considering locating a microreactor at one or more remote domestic military installations to capture the benefits herein discussed. Operational refinements and technology advances for tactical forward-base deployment will accrue from such dual pronged goals. This parallel process for the Army and the DoD is desirable and is also our recommended route for going forward.

Of particular note, the Army is very much interested in purchasing power generated by microreactors with proven reliable technology. This option is particularly attractive if the electricity and heating resources can be procured at prices competitive to local markets, taking into account appropriate premium allowances for considerations of reliability, resiliency and the cost of alternative power sources.

The other military services also are interested in the potential utilization of microreactors. The Air Force reportedly is involved in searching for a site for microreactor deployment; potential sites have been discussed, but are not yet ready to be publicly identified. Interest also has been expressed within the Marine Corps.

OSD (Under Secretary of Defense for Research and Engineering) is currently seeking DoD appropriated funding for FY 2020 for a transportable nuclear microreactor with development and beta testing assisted by DOE national labs (LANL in partnership with INL) by 2022. This approach would avoid NRC permitting and licensing, would benefit from DOE funding, and could expedite NEPA assessment while developing a model that could be successfully sited on a military installation.

The Roadmap

1. **DOD development** of a reactor design sufficient for military needs **without NRC licensing** review during microreactor technology development and demonstration
    - Development of reactor technology led by the Under Secretary of Defense for Research and Engineering in conjunction with assistance by the DOE national labs
    - Working Groups established by DoD to include representatives from the services and other appropriate agencies to monitor microreactor development
2. **Site selection** and deployment of first prototype
3. Development of a **fuel source**
4. **Concurrent** or subsequent **NRC licensing** of the technology (or variant) to enable construction, ownership and operations by defense contractors
5. **Commercialization** for marketing to non-military customers

The Path Forward

The most promising approach to facilitate development and deployment of a microreactor on an Army installation is to leverage the development capabilities of DoD and the willing assistance of DOE. That allows for first-of-a-kind technology demonstration, while applying the lessons learned to expedite the NRC licensing process. The optimal development and deployment strategy would suggest a process involving DoD development of a reactor design sufficient for military needs without NRC licensing review during microreactor prototype development and demonstration. The technology, or a variant, could then be licensed by the NRC, and built, owned and operated by third party contractors for military use. That design could then be commercialized and sold to domestic utilities or allied countries. Development of microreactor technology should be led by the DoD Under Secretary for Research and Engineering, specifically the SCO.

Both the Army and Air Force have expressed some level of interest in purchasing microreactor generated power. While the Navy has not expressed an interest in pursuing advanced reactor technologies within its program, its historical insights relating to risk management and technical expertise could be shared to benefit the other services.

If funding is procured and development of a demonstration transportable reactor started, the Secretary of Defense should then establish working groups to monitor progress and establish practices and procedures for the use of microreactor technology to support mission readiness broadly. The Secretary might consider authorizing two separate working groups to accomplish this task. The first would be an active intra-departmental working group among the services to share experiences and monitor progress specific to military needs. The group would determine reactor specifications and identify challenges in the design, development and construction of a prototype that meets the intended uses of microreactors by the military. This action would take advantage of the various areas of inter-service interest and expertise that could hasten development and reduce redundant inquiries. The second working group would be interagency to provide appropriate coordination between DoD, DOE, DHS, and NRC.

Activities of this first working group should include engagement by the services, especially the Army, on timely topics such as selection of siting locations, reactor parts manufacturers, fuel developers and suppliers, and contract operators. The working group could also collectively address areas of challenge such as regulatory requirements surrounding the siting, commissioning, and operation of nuclear reactors. Engaging in these activities while simultaneously monitoring reactor design could significantly reduce the time for the first operable microreactor on an Army installation.

A second working group should actively engage with all relevant governmental parties such as DOE, DHS, NASA, and the NRC to monitor developments that could impact the successful completion of a prototype design. This second working group would be wider in scope, perhaps meeting quarterly. The group should include representatives from each of the services, as well as representatives from any agency that may have an interest in the development of microreactors or related infrastructure including the DOE national labs. Critically, this working group would also actively engage with private industry to glean insights and support private reactor development. Additionally, the DoD should engage with relevant Congressional committees to champion the most pressing concerns of the nuclear industry which are relevant to microreactors.

In parallel with the design and construction through the SCO, LANL and INL, the Army additionally should pursue its chosen reactor design through the NRC in partnership with an approved contract operator. The design could be identical to, or largely based on, the prototype design created by SCO. Ideally, the NRC would use the lessons learned during the construction of the prototype reactor to update existing, or create new, licensing pathways for the reactor design. These two development efforts should be done in parallel to exploit synergies and efficiencies. Additionally, fuel and reactor test data from prototype construction could be used to hasten and satisfy NRC licensing reviews, further reducing licensing time and costs. Under this vision, the Army would enter into a long term power purchase agreement with the contract operator to ensure proper construction, operation and eventual deployment of the reactor.

Top Keys to Success

While certainly an oversimplification in light of the complexity of the challenges to rapid development and deployment of microreactors to support the Army's missions, the table below summarizes the top three keys to success on each of the six challenge categories discussed in this report.

Challenge Categories	Top Three Keys to Success
Design and Manufacturing	1. Simultaneous public and private sector development microreactor technology 2. Continued Congressional funding, including increased availability of grants to private-sector companies pursuing reactor and fuel supply development by DoD & DOE 3. Accelerated development of an advanced fast neutron test reactor
Fuel Infrastructure	1. Development of a domestic commercial supplier of HALEU 2. Redefinition of fuel enrichment classifications 3. Resolution of fuel transportation barriers
Licensing	1. Licensing of first unit by DoD with later units going through NRC licensing 2. Streamlining NRC licensing process for microreactors 3. Rapid commercialization to address fuel, supply chain and operational expertise shortfalls
Siting	1. Specification of criteria for initial deployment 2. Screening of appropriate DoD and DOE installations 3. DoD/DOE cooperation on initial site selection
NEPA Compliance	1. Scoping of programmatic EIS 2. Tiering analysis of selected initial deployment(s) 3. Selection of key analytical factors
Public Relations	1. Coordinated process enabling public understanding 2. Development of key messaging points explaining differences between microreactors and LWRs 3. Utilization of existing outreach mechanisms such as Millennial Nuclear Caucus program

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<u>Appendix</u>: Expert Interviews, Affiliation and Major Points

Commercial Developers (11 individuals interviewed)

1. Air cooling works up to 15 MWe; after that it needs water cooling.
2. Nuclear power is expensive ($200/MWe-hour) so it is only practical for remote areas and special applications.
3. Microreactors have minimal moving parts.
4. Microreactors can easily run for more than 10 years without the need for refueling.
5. No need for supplemental power to start reactor.
6. They can be transported on a flat bed.
7. They do not need to be buried.
8. To compete with Russia and China will require U.S. Government support.
9. Having a clear regulatory path (clarity and speed) is very desirable. Theoretically, Part 50 could be used to license this technology. NRC (LPM) could provide focus to regulator on safety. “Security” and Emergency Plan Zone” are factors to design into the technology.
10. Unique permitting steps by NRC would be very detailed, very technical; and time consuming. Recommend working within parts 50/52; do not push part 53 for time being.
11. Important issues:
    - Technologies
    - DOE role
    - Supplying HALEU
    - Deploying in forward operating bases.
12. The National Nuclear Security Administration (NNSA) already is licensing Navy reactors.
13. DoD may want more control.
14. Prefer NRC to be the regulator, rather than NNSA. Who should regulate is important: e.g., NRC, NNSA, DoD orDOE?
15. DoD will can be critical for success.
16. Safety-related issues are mostly with fuel.
17. INL is a key partner, with Oakridge helping on “graphite” issues.
18. Technology has been proven in Germany and in South Africa.
19. Lack of fuel is a big challenge.
20. “We are developing an enclosed, long-life, self-contained, “intrinsically safe” reactor that will use 19.75% enriched uranium fuel (HALEU).”
21. Fuel availability is a key factor to actualizing technology. It will take three years to get HALEU.
22. Government involvement is the key to breaking the “chicken and egg” dilemma of development vs commercial demand.
23. HALEU transportation on public highways is a major issue; co-location with reactor might solve that problem.
24. The NRC procedures for light-water reactors need major modifications for micro-SMRs. “NRC needs to change its mindset.”
25. “We are working with INL because of existing infrastructure.”
26. Mobility presents many issues (e.g., need for heavy shielding).
27. Capacity for 2 MWe is seen as ideal (with power output less than 2 MWe).
28. Reliable fuel supply at 19.75% enriched HALEU is the big challenge; EPRI could be helpful in resolving the fuel issue.
29. “DoD should take the leadership from DOE to move this forward.”
30. Potential customers include Alaska, remote islands, Western states, state water agencies, and utilities.
31. NRC is amending processes and costs are coming down.
32. NEPA needs new rules for micros, as does NRC’s ‘Project Reactor Safeguards’ under the Advisory Committee.

33. The combination of NEPA and safeguard requirements could double the time needed to deploy a prototype, and increase the cost by 25% to 30%, with likely rise to 50% when we include company carrying costs.
34. 20% or less enriched is considered "low enriched." Classification criteria should be revisited to promote efficiency and reduce cost; 27% enriched would reduce cost of electricity by half and going over 20% would not cause added security exposure, given today's technology. "A desirable goal for enrichment is about 40%."
35. Transport and treatment of spent fuel needs to be addressed in order to go forward; these are political issues, not technical ones (e.g., Yucca Mountain).
36. There is some concern that DOE's development of the "Versatile Test Reactor" may take resources from other DOE efforts to contribute to the development of microreactors. "DOE will need additional funds if it wants to also pursue the VTR development goal."

Executive and Legislative Representatives (6 individuals interviewed)

1. Examine Fort Greely reactor experience (combined heat and power; 10% efficiency; promises were not realistic; now is being cleaned up).
2. Applications in Alaska (250 sites off grid, now use diesel power), can also satisfy remote mining and military installation needs; can also serve as a stabilizer for renewable energy generation.
3. There is a need to untangle regulatory, ownership, and installed location issues.
4. Nuclear Energy Innovation Capabilities Act (S.97: NEICA) signed into law; authorizes DOE to partner with private companies; and have MOU with NRC; it also authorizes fast reactors.
5. Nuclear Energy Leadership Act (S.3422: NELA) introduced 09/18, focuses on taking leadership in getting to market, allowing 40-year power purchase agreement, asks DOE and DoD to make plan to have a system in five years.
6. NDAA mandated a study on this issue for 2018.
7. Should DARPA take leadership of this issue for DoD?
8. DOE Labs held conference in Alaska in 2018 at University of Alaska in Fairbanks (UAF).
9. White House (NEC and NSC) are very interested in SMR.
10. DoD is looking at two paths: Stationary remote bases and transportable for forward operating bases (SCO).
11. The U.S. Navy is the gold standard on micro-reactors.
12. If DoD is serious, they should go to the Navy and replicate their approach.
13. Waste disposal is a challenge for micros. The waste would still be considered enriched and must be processed for disposal.
14. Decommissioning the waste can be complicated and costly. In France, the Government pays the costs of decommissioning waste.
15. Strategic Capabilities Office (SCO) can create the compelling case for micro reactors.
16. There is 34 tons of weapons-grade plutonium at Pantex that can be degraded or used in some way. Companies could make use of this fuel for hundreds of reactors. It would cost $15 billion to dispose of 34 tons of plutonium in New Mexico (WIPP).
17. Only DoD can get this off ground zero. DOE needs a very strong directive from JROC to mobilize effort for DoD.
18. New NEICA law orders DOE to develop prototypes. DOE (NNSA) has a very cautious attitude on plutonium. Nonproliferation NGOs have a lot of influence with NNSA – especially on plutonium.
19. DoD (Research & Engineering: SCO) is looking at mobile micro reactors.
20. The NDAA is the most promising vehicle for establishing commitments to use nuclear reactors.
21. The Navy is committed to light-water reactors. They focus on their TRIAD role and are reluctant to work with anyone else.

22. There are three options for building a micro prototype: 1A, 1B(1), and 1B(2):
    - 1A: If project is for DoD only and not commercial, then NRC has no authority for licensing. NRC is willing to support DoD if they were asked to do so through an agreement; the authorization would remain with DoD. Currently NRC has such an agreement with the Navy to do 'secondary' reviews after the Navy has done design and other requirements to place a unit into service.
    - 1B(1): The reactor is built for commercial application. Only NRC has the licensing authority and would be involved in all stages.
    - 1B(2): The reactor is intended for both DoD and Commercial. Lawyers would parse authorities and responsibilities between NRC, DoD, DOE, and Commercial entity. [Currently, the NuScale reactor is being done under NRC authority.]
23. Commercial players are hoping for DoD to put money into design and development so they can then take it from there to commercialize the technology through NRC licensing.
24. NRC operates through standards and separately through procedures. The procedure for micros would be the same as for all reactors – companies can and do ask for exemptions and deviations, even for light-water reactors.
25. Companies are skittish about having NRC develop new procedures for micros; they're afraid it would complicate matters rather than simplify them. NRC itself would rather follow existing procedures and then later based on the experience with micros consider creating specific procedures for them.
26. NRC currently is reviewing what may need changing to better serve the needs of micros (e.g., the need and size of "emergency response zones" for micros. Such zones have been specified for light-water reactors. NRC expects that sometime soon it will issue a proposed rulemaking for micros on this topic). Also, NRC believes that there may not be a need for testing of a unit of similar previous design, or of one that can be accurately and reliably modeled.
27. NRC also is considering streamlining the application required (e.g., the number of pages and the volume of data). It currently has a project, "The Licensing Modernization Project," that will produce recommendations for regulatory changes. NRC hopes that modified regulations will be available in 18 months. [Congress is yet putting pressure on NRC to streamline their procedures.]
28. As for NEPA, there are no exemptions. The NEPA process is applied whether NRC does licensing (Part 51) or DoD or DOE do licensing. NRC currently has a working group looking at the specific application of NEPA requirements for micros. This working group is internal to NRC (e.g., no public comments per APA); however, NRC expects to hold public sessions on them to give NEI and other interested parties an opportunity for feedback.
29. NRC has strong interactions with DOE, not so much with the other players. Still, NRC has meetings every 4 to 6 weeks with all micro-interested parties. DoD recently began to attend these meetings. Meetings go for 6 to 8 hours and deal mostly with technical and policy issues.
30. NASA and Air Force have traditionally relied on DOE to represent their interests with NRC since it is DOE that usually builds the nuclear technology they seek.

DOE HQ and National Laboratories (12 individuals interviewed)

1. Light-water (1000 MWe) reactors have been the US workhorses. Their 40-year lifespan is now being extended by 20 years.
2. Renewables are getting subsidy benefits but creating an unregulated market w/o the benefit of a steady energy source.
3. Only the Navy, DoD or DOE can operate a reactor w/o an NRC license.
4. NRC is in a tough spot to regulate because they have not seen an operational SMR.
5. Investors are wary without customer commitments to use.
6. The US has a "prescriptive" rigid approach to nuclear energy generation.

7. HALEU has to come from a commercial source; diluting Navy spent fuel is “not an option.” The fuel for SMRs has to be managed by NRC licensed operators.
8. Currently, INL is decommissioning fuel from a previous INL unit.
9. DOE has an agreement with the State of Idaho to not bring nuclear waste into the State.
10. NRC follows Congressional mandates and reports to both Congress and the white House. Congress needs to give the NRC the flexibility to do what needs to be done.
11. SMRs now include micro-reactors that start at ½ MWe and can be made transportable; able to be built and demonstrated in less than five years, with fewer siting requirements and much smaller “safety zone” perhaps to include just the building that houses the micro.
12. INL is planning a National Innovation Center and working with a number of different companies.
13. DOE or DoD has the option to build an SMR w/o NRC license. For deployment outside the US, NRC would also have no role.
14. Developers need a “defined future” so they will invest in development; government support may not be helpful as it indicates there is no private sector support.
15. NRC is talking about modifying their processes. Companies could specify which processes are inapplicable. NEI report assumes NRC Parts 50/52 will be used; more realistically, there will be a new NRC process for micros. NRC will opt for a new micro process rather than a modified one for both micros and standard reactors. NRC licensing is likely to be the route taken.
16. DoDs posture will depend on whether they want to control the reactor or simply buy power.
17. Regulations for transporting reactors and fuel are very cumbersome as states can disrupt or obstruct.
18. Fuel needs can be bridged with “recovered” fuels at INL. Ten companies want such fuel.
19. Need to simultaneously resolve four items to speed process:
    1) Streamlining the NRC Reg. Parts 50/52 path w/o triggering rulemaking,
    2) Fabricating a prototype unit,
    3) Selecting an appropriate site, and
    4) Securing a fuel source.
20. DOE has considerable discretion in allocating funds to various initiatives. (The “versatile test reactor” was created to compete with fast neutron reactors in Russia and China.)
21. The immediate need for micros is in the U.S. Most other countries are not advanced on micros. Congressional support for microreactors is currently bipartisan.
22. Goal with micros is to make them as easy to turn on and operate as a diesel generator. We want to get rid of need for security and for emergency response (operators should only be needed at beginning). Reactors on college campuses already operate without a lot of staff support (they rely on local safety/response infrastructure) and can be examples of how safely they are used. Public fear may still be a factor in deployment. States will need to help address this public perception challenge.
23. DOE can do advocacy for micros; NRC cannot do this advocacy.
24. To build an SMR takes about $100 million investment; so they are relatively affordable.
25. Spent fuel less than 20% enriched is not a problem to dispose. The Nuclear Waste Policy Act provides for nuclear waste disposal.
26. SMRs are considered “low power density.”
27. DOE’s National Nuclear Security Administration (NNSA) currently has stockpiles of high-enriched fuel but it is not available. INL is now downgrading spent fuel to just below 20%. INL is hoping to process the Navy’s spent fuel. Currently, it is stored at the Navy area on the INL site.
28. The Navy has high-enriched fuel which is a non-starter (not a viable option) for civilian use.
29. INL has a close tie to Argonne Nat’l Lab and is the place in the U.S. to develop and test reactors. In 2005, INL’s mission changed to developing and sustaining nuclear energy; it is working to establish the Nuclear Reactor Innovation Center (NRIC).

30. There would not be on-site refueling of vSMRs; so that issue is not relevant. NRC licensing doesn't need an actual prototype to be built as long as data supports the design. SMRs need to be automatically controlled; it would be too costly to have a control room. A monitoring room to monitor a number of SMRs might be affordable.
31. Reactors at MIT and Oakridge Nat'l Lab run 24/7. INL does some testing on the MIT reactor.
32. SMRs are not likely to be eligible for CATX exclusion under NEPA. INL might go for a NEPA site-license to cover all related activities at INL. Conceivably, a private company could be permitted to build and operate a fuel (HALEU) production facility on site.
33. Funding may be available from DOE to kick start the program. There are MOUs with companies to build reactors on DOE sites.
34. NELA (S.3422) provides for 40 year PPA; DOE already has authority to do it, S.3422 gives it to other agencies. NELA also allows vendors to lease the reactor and then take it back at end of life; this makes it easier for government users to acquire, use, and then not worry about disposing of equipment and spent fuel.
35. We have yet to fully crystallized why we would pay more for nuclear energy (e.g., resiliency, security, reliability, flexibility).
36. Senate Bill authorizes 40 year PPA, and also payments above market.
37. Micros can be justified on basis of national security and reliability even if cost is higher.
38. DOE is leveraging Oakridge manufacturing capability. It also has a $1.3 billion budget with about 10% for micros, which also benefit from existing infrastructure. [$100M for SMRs; $112M for advanced reactor technologies; $20M for micro R&D; $30M for 3-D printing; $20M for HALEU work.]
39. DOE is doing outreach (e.g., Clean Energy Ministerial on international front)
40. NEI "Smart Start" looks at what needs to be done to promote SMRs and micros.
41. Army is doing a DoD report on "mobile nuclear power plant." Army had experience with nuclear reactors in Panama.
42. Someone needs to do a credible job of ranking the maturity of all prototype SMRs.
43. So far, no authority has issued a specification against which vendors can be compared, or progress measured. Vendors have been on auto-pilot. [Criteria for mobile reactors exist and DoD should issue an RFP to elicit vendor submissions.] There are many patents on SMRs, but none have been put into practice. Need to "smoke out" the technologies through a competitive process.
44. DoD continues to struggle with energy logistics, especially for forward operational bases.
45. NRC has been criticized by Congress for "slowness" of process.
46. The nuclear business is highly regulated and highly capitalized; this applies to SMRs too.
47. The Navy will not voluntarily get involved in current SMR arena. It will eventually be brought in to address the DoD needs.
48. Manufacturability is a big factor in the nuclear world, especially with SMRs.
49. If DoD took the leadership, a micro reactor could be done in five years; DOE and NRC would collaborate.
50. This Administration has shifted more support to industry. In 2017, DOE got $100 million for public-private partnerships. Only with government support will the nuclear agenda go forward.
51. Focus has recently shifted to micros for "islanding" and niche applications.
52. DOE and DoD are talking and planning on moving forward.
53. DOE issued an RFI with responses received on 10/15/18.
54. NRC rules for light-water reactors are inapplicable to micros.
55. HALEU development can be done in DOE labs.
56. DOE plans to do $19 million worth of research on micros in 2019.
57. The Atomic Energy Act gives DoD authority to license reactors.

58. The Navy uses high-enriched uranium (HEU) in their reactors, which is inapplicable to micros for other DoD needs.
59. NASA was first to approach DOE for a micro reactor in kilo-watt range for “Mission to Mars” needs. So a 1 KWe unit was built in 18 months and tested at LANL test site in Nevada.
60. This Office is now talking to SCO for a 2 MWe mobile unit that would cost about $100 million to develop.
61. NRC is monitoring the SCO initiative but will not issue license since DoD is doing it for the first unit. NRC will issue licenses for subsequent units.
62. Parties involved in the SCO project: SCO, DOE, LANL, INL, Sandia, and Y-12 (Part of Oakridge Lab in Tennessee for fuel).
63. The SCO unit will fit on a C-117 and hopefully on a C-130 in two 20-foot containers.
64. “Exclusion zone” specifies boundary where a “rad worker” can enter and a “non-rad worker” cannot enter.
65. Army facility at White Sands NM does testing, and would carry out bulk of testing for the SCO project.
66. Pantex plutonium waste (34 tons) is from weapons and not usable unless significantly downgraded.
67. Y-12 has an approved process to quickly ramp-up fuel production.
68. LANL also has infrastructure and climate modeling capabilities, as well as data analytics.
69. Priorities of DOE Nuclear Energy Office (NE):
    - Protect and extend the life of existing fleet of commercial nuclear reactors to 60 – 80 years (current average is 40),
    - Create and foster a pipeline of new advanced nuclear reactors,
    - Help to nurture the creation of a viable, commercial fuel cycle.
70. The major challenge is the market: there is a downward pressure on the existing nuclear reactor fleet – it is losing money. Seven reactors have shut down since 2013 (some 50% are in jeopardy of closing). DOE Nuclear Energy Office (NE) is working to find ways to support commercial units.
71. Revival of fleet needs to occur in the 2020s if we are going to be successful.
72. This lends additional impetus to support advanced reactors and the fuel cycle (currently, there are four options for advanced fuels that appear to be on track for 2026 time frame. HALEU is targeted mostly for micros. DOE expects industry to develop the commercial supply of HALEU).
73. DOE also is doing modeling of various options and scenarios.
74. There are strong demands for clean nuclear power, but challenges are many, including financing.
75. The micro market is small even with their design and operational advantages. SMRs do offer modular build up from 60 to 720 MWe (i.e., they can be made big).
76. Micros are going to be disruptive, like I-Phones and Web.
77. “If we don’t innovate, we die.” The U.S. fleet needs to be innovated; U.S. still get 20% of national power from nuclear.
78. We need resilient and secure power for the U.S. and most especially for the military (some 47% of casualties in forward operations are attributed to fuel supply activities).
79. NEPA requirements would either be applied by NRC or DoD/DOE depending under whose licensing authority the unit is developed and tested.
80. DoD has been speaking to DHS on the application of micros.
81. Two factors are needed to move needle forward: (1) Clear authority for power purchase agreements, and (2) clear authority to pay above market prices for power.

Department of Defense (2 individuals interviewed)

1. A DoD group is looking at putting a land-based 2-4 MWe reactor in place by 2023. Technology is proven and just needs integration and implementation – no need to spend DoD money on research.
2. Push for micro-grids have provided impetus for micro reactors.
3. DoD and DOE put out an RFI to elicit interest in siting a unit. The Army is sitting back and watching developments; Marines may be interested. Air Force ostensibly is active in searching for a site; potential sites have been discussed but are not yet releasable.
4. DoD is not interested in owning a reactor, just wants power (PPA) because manpower and training are very big investments. Still, there would be some need for NRC-trained operators to start.
5. DoD is on a fast track with NRC to improve licensing to promote commercial uses – NRC is talking about an expedited strictly safety review process: "Safety Sufficiency Review." Industry prefers a "type approval."
6. Biggest issues: licensing and fuel availability; lack of commercial interest has depressed potential fuel providers. DoD met with DOE to try to resolve the fuel issue. Other issues include cybersecurity and protection from electromagnetic pulses.
7. Though little interest exists in DoD for mobile reactors, R&E (SCO) is looking at them. Miniaturization is the challenge. The initiative originated in the White House (NSC).
8. SCO initiative on transportable micro reactors is complementary to initiative for a stationary micro for military bases.
9. SCO is in "CAPE" phase of budget process to receive money to go forward.
10. "The model being considered is based on a micro unit from LANL. It will be 2 to 4 MWe; capable of being dismantled and transported on a C-17 in less than one week."
11. DOE involvement is promoted by provision in latest NDAA. INL may be involved with "design and build" of the microreactor on site. Reportedly, the Air Force has volunteered to do prototype on one of their installations.
12. NASA may also be involved with the integration; they have just built a micro (1 KWe that can scale to 10 KWe) that was built in 18 months using the LANL model. Having someone from NASA on the project would be very helpful.
13. NRC is reportedly on board to assist on this project. First unit will be licensed by DoD; later units will need to go through the NRC process.
14. NEPA has to be brought into this process.
15. Services are watching but with a skeptical eye. They are likely to get on board when the prototype is deemed successful.
16. SCO trying to get budget approval for FY 2020 before end of 2018; wants to do critical test by 2022.
17. DoD expected to own the first unit, but would then prefer to simply buy power from units owned by vendors.
18. This reactor has to fit on a C-17, preferably in two 20-foot containers to satisfy Army and Marines.