Small-scale nuclear reactors for remote military operations: opportunities and challenges

Bret Strogen, PE, PhD

August 25, 2015
NDIA Joint Service Power Exposition, Session 5, Talk #18004
Duke Energy Convention Center, Cincinnati, Ohio

DISCLAIMER: The views expressed are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government
The appeal of nuclear power for military applications

DoD’s previous research initiatives and expressions of interest regarding terrestrial small modular (nuclear) reactor R&D

- Army Nuclear Reactor Program (1950s-1970s)
- Recent DoD science board recommendations related to nuclear energy (2009 & 2012)
- DARPA RFI/Study on deployable SMRs (2010)
- Center for Naval Analyses Study on SMRs for installations (2011)

Remote and Forward Operating Bases (FOBs) lack infrastructure, and require significant quantities of energy and water.

Delivery of supplies entails significant mission risk, personnel risk, manpower and costs.
## Appeal of Nuclear: Energy Density

<table>
<thead>
<tr>
<th>Energy Sources</th>
<th>Energy Density (kilojoules per cubic centimeter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar, Wind</td>
<td>NA (diffuse), Clean and abundant, with diffuse, intermittent availability, Valuable supplemental sources</td>
</tr>
<tr>
<td>Electrochemical</td>
<td>3–5, Primary source for personal power, Development driven by commercial markets</td>
</tr>
<tr>
<td>Fossil fuels</td>
<td>20–35, Gasoline = 35, Primary source for vehicle propulsion and power, base power</td>
</tr>
<tr>
<td>Radioisotopes</td>
<td>&gt; 100,000, Significant untapped potential</td>
</tr>
<tr>
<td>Compact fission reactor</td>
<td>&gt; 10,000,000, Significant untapped potential</td>
</tr>
</tbody>
</table>

Recent DoD Science Board Recommendations

- USAF SAB Report 2009, Recommendation 4: Make nuclear energy part of AF energy planning
  - Evaluate a nuclear power generation option for selected bases, perform technical evaluation, engage Services/DOE/Industry for a concept demonstration.

- DSB 2012 Summer Study, Recommendation 8:
  - USD(AT&L) direct DARPA to fund applied research to develop and demonstrate safe, affordable, transportable, lightweight radioisotope batteries that provide ~5 W of power continuously for 3 to 5 years.
  - USD(AT&L) to convene a working group to address policy, regulatory, and related issues.


RFI on Deployable Reactor Technologies for Generating Power and Logistic Fuels (March 2010)

- Seeking technologies for generation of electrical power and military logistic fuels (using available indigenous feedstocks) in forward land based and maritime military operations.
  - inherently safe
  - do not produce waste products which would contribute to proliferation problems
  - total output of 5 to 10 MWe, and 15,000 gal/day fuel

https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=d0792af88a6a4484b3aa9d0dfeaaaf553&cview=0

DoD commissioned Center for Naval Analysis (CNA) to perform the study
- Report was published in March 2011

CNA study identified challenges to deploy small modular reactors (SMRs) at a base
- Identified First-of-a-Kind (FOAK) expenses for SMR deployment
- Recognized technology issues associated with plant size
- Addressed technical and licensing issues for development

DOE is targeting ~185 MWe and ~45 MWe designs for SMRs
  • Improved safety
  • Factory manufacture
  • Use as single, or group

90% of military installations require <40 MWe of power; ~50% require <10MWe

Required plant size to supply military installation average annual energy use FY 08-09

- Substantial FOAK expenses ~ $800 million (can be paid by some combination of USG and private sector funding)
- If FOAK expenses are excluded, estimated levelized cost of electricity ~$0.08 per kWh
- Potential benefits to DoD:
  - Increase energy assurance
  - Reduce carbon emissions
  - Viable price, if DoD does not pay FOAK expenses
- Issues requiring time & money:
  - Safety, certification, licensing, construction and operations

GAO: First SMR in United States unlikely to be operational before 2023

- 1st SMR application (NuScale) to NRC expected in 2016; operation expected 2023.
- No advanced (non-LW) reactors expected to submit NRC application before 2020.

Some experts believe that new reactor designs would require 20-25 years for development and approval through NRC (or through DoD, if the DoD’s authority to manage a nuclear energy program is exercised).

The committee continues to be concerned about the survivability, sustainability, and significant logistical costs of fuel and water associated with the support of deployed personnel at remote forward operating bases. The availability of deployable, cost-effective, regulated, and secure small modular reactors with a modest output electrical power (less than 10 megawatts) could improve combat capability and improve deployed conditions for the Department of Defense (DOD).

The committee understands the pursuit of such an endeavor invites ample concerns, not limited to: technical feasibility, policy oversight and regulation, robust safety and secure design features, logistics and resources, proliferation concerns, life cycle costs, deployment policies and transportability, personnel costs, and lessons learned from recent combat operations.

Therefore, the committee directs the DOD to submit a report to the congressional defense committees on the challenges, operational requirements, constraints, cost, and life cycle analysis for a small modular reactor of less than 10 megawatts no later than January 1, 2015.
Language from FY14 National Defense Authorization Act (NDAA), released in **June 2013**, was incorporated into Terms of Reference for a Defense Science Board (DSB) study to address energy challenges and potentially applicable technologies for remote and forward operating bases.

Terms of Reference were signed by the Under Secretary of Defense (AT&L) in **February 2014**.

Interim Letter to Congress in December 2014 stated an anticipated completion date of **November 2015**.
DSB Task Force Leadership

- **Sponsor**
  - The Honorable Frank Kendall, USD (AT&L)

- **Task Force Co-Chairs**
  - General Paul Kern, US Army (retired)
  - Dr. Michael Anastasio, Director Emeritus, Los Alamos National Lab

- **Task Force Members**
  - ADM (Ret.) Frank “Skip” Bowman
  - MGen (Ret.) Jan Edmunds
  - Dr. Jerry Galloway
  - Honorable William Schneider, Jr.
  - Dr. William Madia

- **Executive Secretary**
  - Dr. Bret Strogen, OUSD (AT&L) contractor

- **DSB Secretariat Representative**
  - LTCOL Michael Harvey, US Air Force
Objectively evaluate different mechanisms to provide energy to forward, remote operating bases.

- Identify relevant factors (e.g. survivability, supportability, suitability, force protection requirements, etc.) of energy sources.

Examine feasibility of deployable, cost-effective, regulated, secure small modular reactors (SMRs) with an output <10 MW, by addressing:

- technical feasibility,
- policy oversight and regulation,
- robust safety and secure design features,
- logistics and resources,
- proliferation concerns,
- life cycle costs,
- deployment policies and transportability,
- personnel costs, and
- lessons learned from recent combat operations.
Discussion: Potential KPPs for a FOB SMR

- **Size & Transportability**
  - 25-40 tonnes
  - Truck or C-17 compatible

- **Outputs**
  - 2-10 MWe
  - Heat, water, fuel, or other metrics?

- **Ultimate heat sink**
  - Air (vs. water)

- **Time to shutdown, cool down, disconnect, and remove**
  - 6 hours to 7 days

- **Time to install**
  - 12-72 hours

- **Health & Safety**
  - No net increase in risk to public, military personnel, environment
  - No net increase in consequences of adversary attack

- **Proliferation risk**
  - None

Photos Courtesy of Los Alamos National Laboratory
Bret Strogen, PE, PhD
bret.m.strogen.ctr@mail.mil
(703) 693-4228