# Nuclear Energy: Should DoD Lead or Follow?

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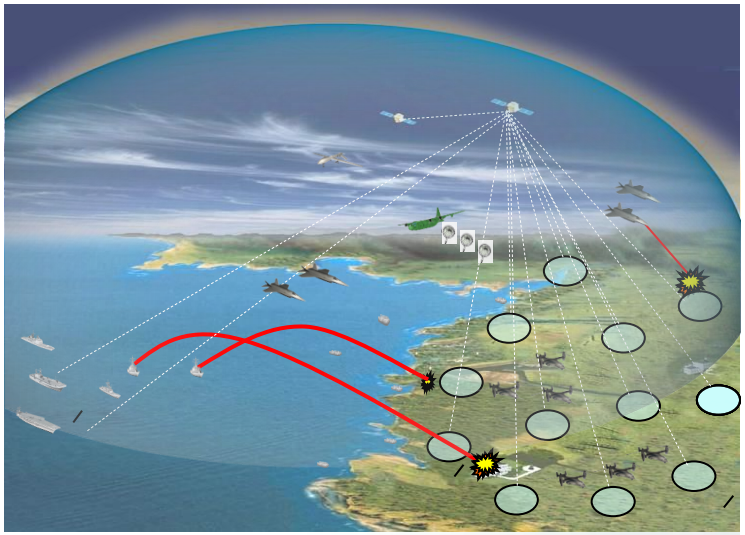
# We need energy to win the fight

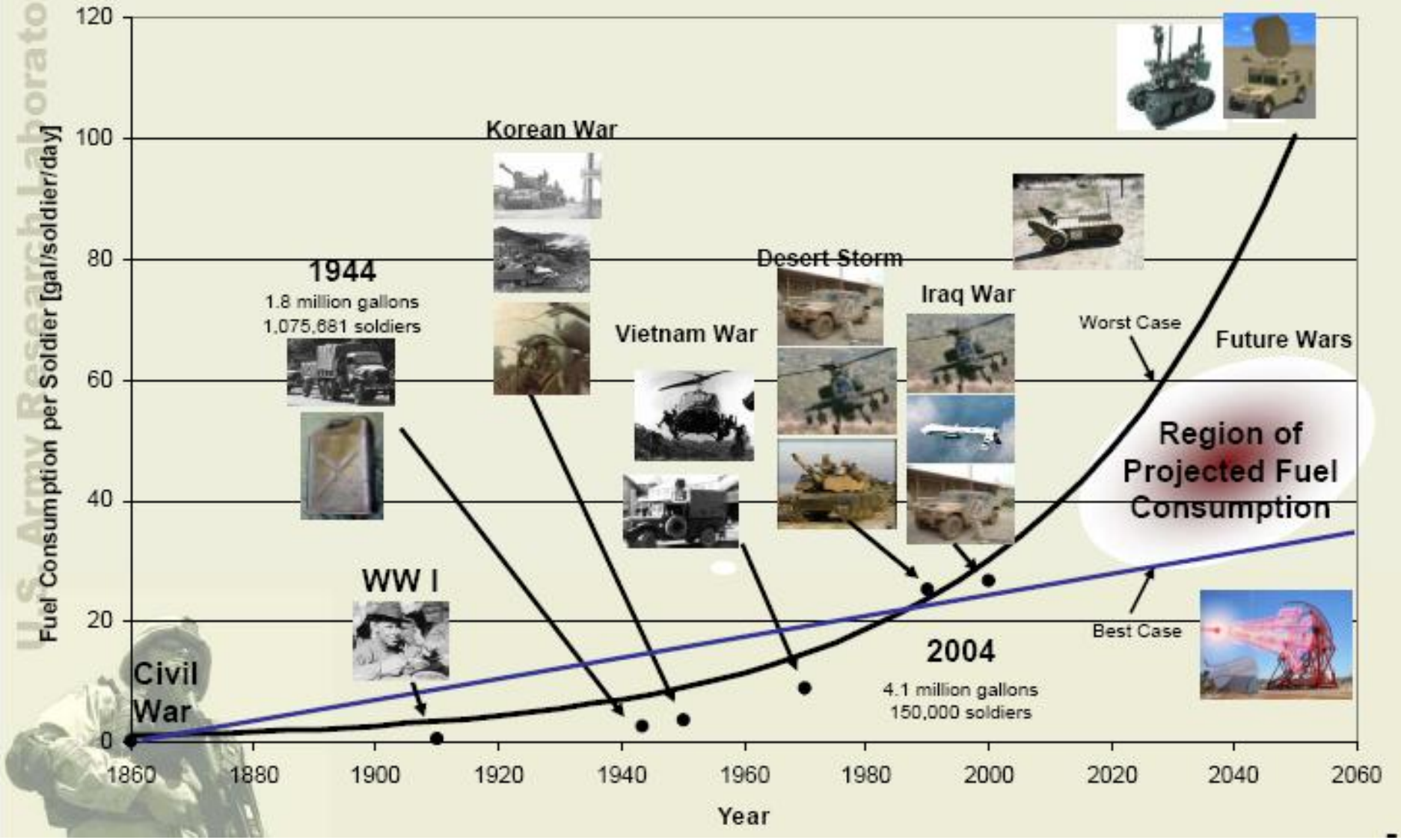
***How can we sustain the force in the face of uncertain oil supply and asymmetric threats?***



**Nuclear energy is a compact, sustainable energy source that could dramatically improve US military sustainability.**

*It is the only currently available technology that could displace a significant amount of oil-derived fuels in the field.*

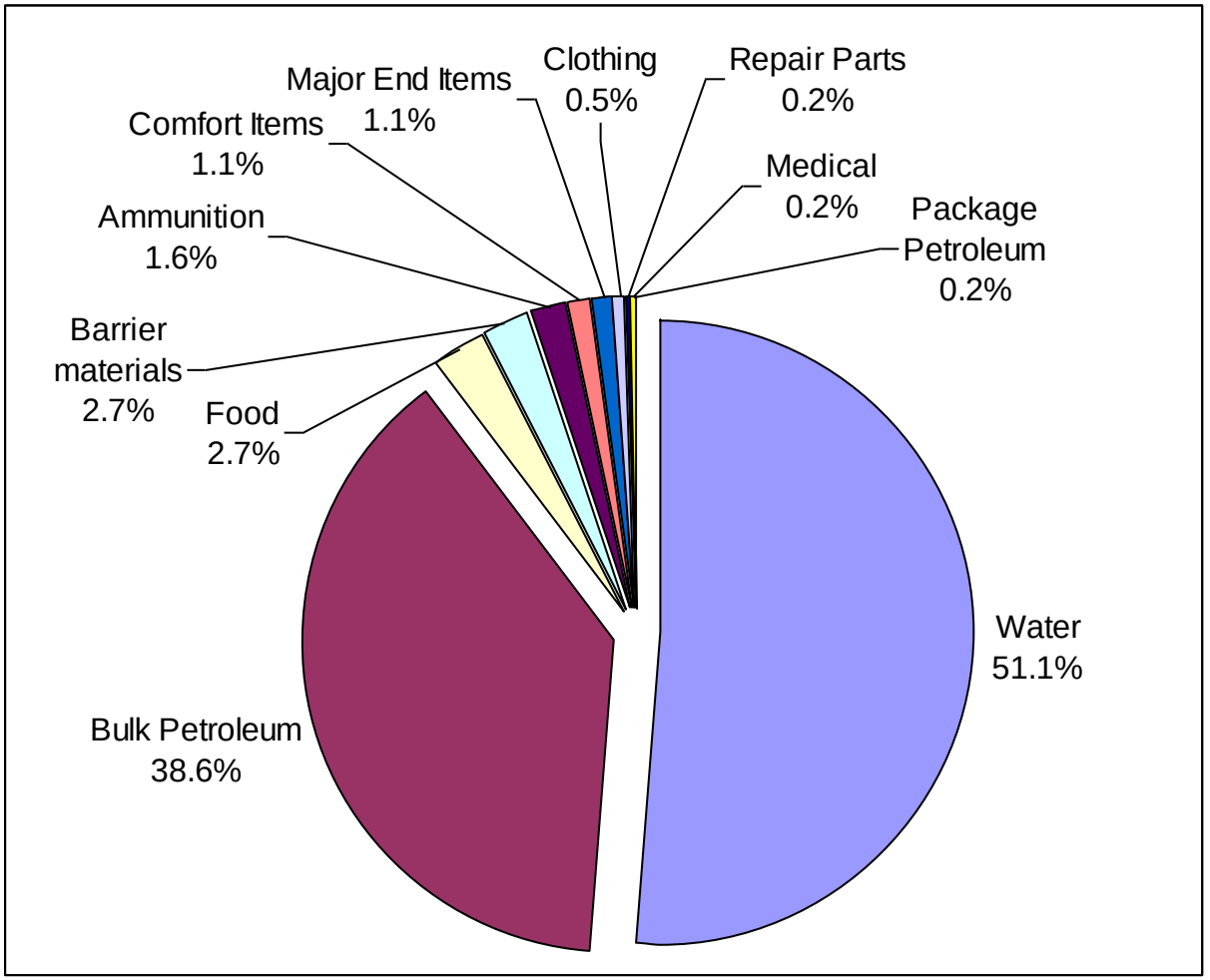
# Fuel Consumption Per Soldier Over Time



# Combat Logistics

- Extended supply lines, intermodal transfer are complex & vulnerable
- Liquids displace spare parts and ordnance
- Transportation costs can be prohibitive
- Storage and distribution challenges
- Local sources can be inconsistent

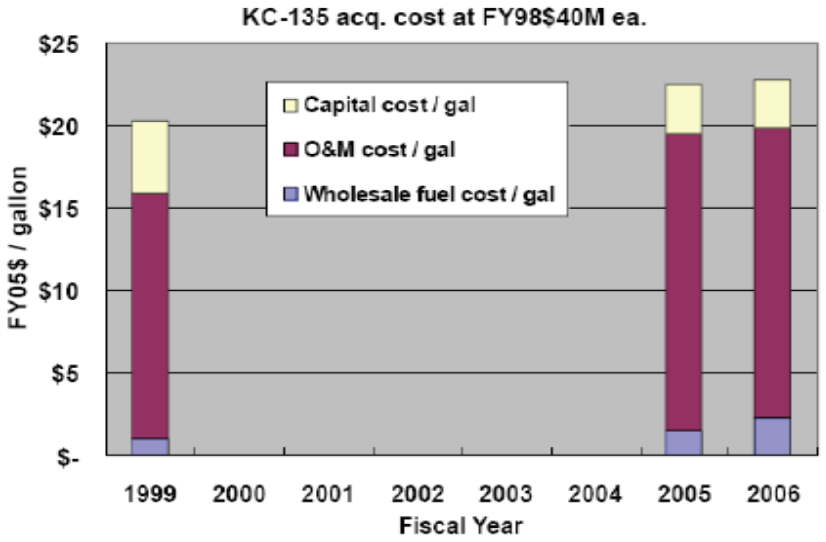
# US Army Battlefield Supply Volume




US Army Battlefield Logistical Demands adapted from James J. Valdes, “Biotechnology Executive Roundtable”presentation to GEN Paul Kern, Commander, US Army Material Command, undated.

# Logistics, supply costs, and other considerations

- Delivering fuel is costly in $s, infrastructure, and lives
- Fuel delivery costs
  - *Large multipliers*
    - It takes (a lot of) fuel to deliver fuel
    - Difficult to quantify
  - *Air-to-Air:* $20-25/gal
    - Some of this is fixed (not scaled by gallons) by prepositioned tankers around the globe
    - Assumes 40-year life for KC-135s
  - *Army theater:* $100-600/gal
    - Large cost range depends on "front line" to "back line" separation in distance, terrain, defense, etc.
- Infrastructure costs
  - *A large fraction of infrastructure costs and vulnerabilities scale with fuel volume that must be delivered*
- Cost in lives
  - *Changes in military doctrine*
  - *Present logistic supply designed at a time when "behind the front lines" denoted more-or-less safe terrain*




- JASON estimated cost/gal delivered in the air
  - *In* 2005, 6.5% (165 Mgal) *of USAF use*
  - *Gallons delivered also include non-USAF gallons*
  - *O&M costs dominate*
    - 1999 O&M costs back-calculated to match DSB2001 estimate
  - *JASON estimate adds acquisition cost/gal*

AF air-to-air data from L. Klapper [AF Cost Analysis Agency].

# A few statistics

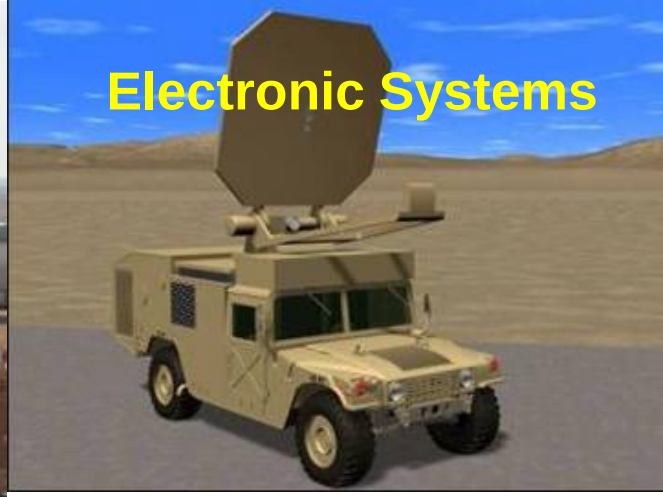
- 4th ID used 50,000 gallons/day of fuel in Iraq (7 times use in CONUS):
  - 20% for electric generation [~ 6 MW(e)]
  - 80% for ground and air vehicles
  - ~ 6 gallons per soldier per day (assuming 8000 troops)
- At $100 per gallon – estimated cost on the ground - this equates to:
  - $30 million/month for fuel for electric generation
  - $120 million/month for fuel for vehicles

# "Tooth to Tail"

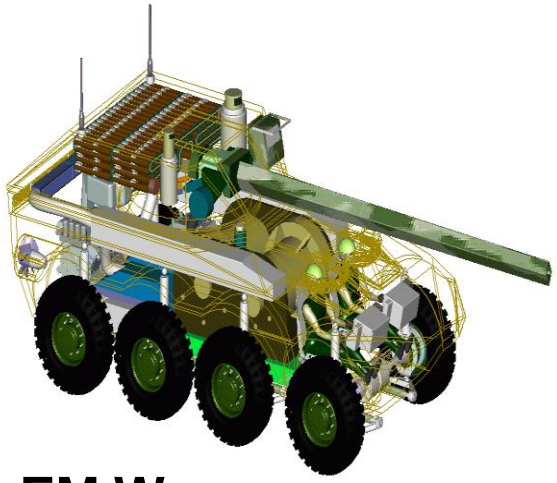
- Security forces diverted to secure convoys
- Combat activities limited by logistics capacity
- Support personnel required to transport, handle materials
- Contractor personnel and facilities required to support fuel and other logistics

Imagine

Fuel & Water

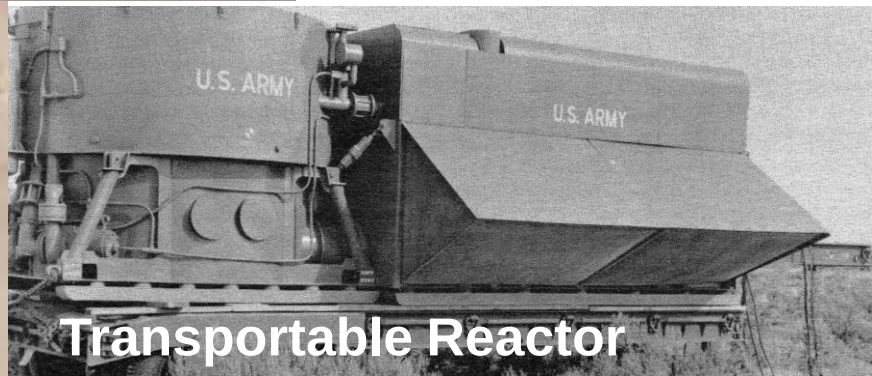






EM Weapons

Forward Operating Base



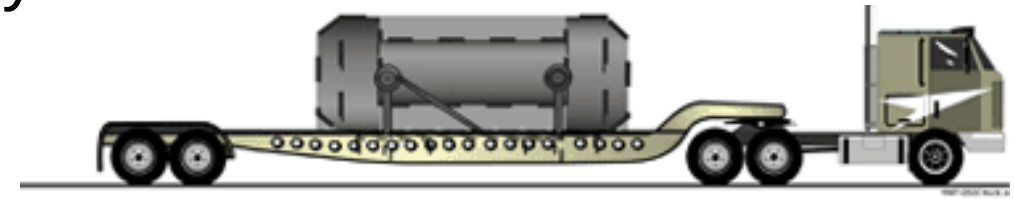

Transportable Reactor

# Why Nuclear?

- High energy density
- Fuel is self-contained
- Supports “more electric” force
- Low signature
- No “greenhouse” emissions
- Robust, domestic fuel source
- Proven technologies
- Leveraging opportunities
  - DOE and industry nuclear energy initiatives
  - Military systems could be available for domestic emergencies

# Why not nuclear?

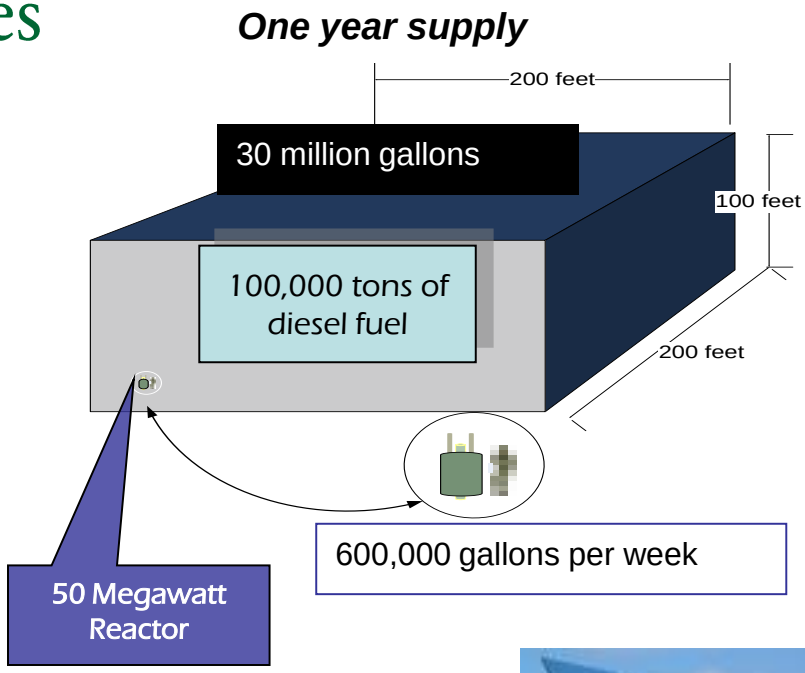
- Public opinion
- Proliferation concerns
- Investment challenges
- Safety concerns
- Need for simplicity
- Environmental concerns
- Treaties & politics
- Sheer complexity of the question



# Theater Energy Alternatives

## Energy alternatives to produce 50 MW of power in theater

- 3600 gal/hr diesel fuel
- 5 million sq ft of solar array
- 35t/hr biomass (switchgrass)
- 50 t nuclear reactor




| Energy Source/Storage | Energy density (MJ/kg) |
|---|---|
| Mass-energy equivalence (E=mc2) | 89,876,000,000 |
| **Enriched uranium (3.5% U235)** | **3,456,000** |
| **Diesel fuel** | **46.2** |
| Household waste | 8.8-11 |
| Chemical propellants/explosives | 6.5-8.5 |
| Lithium ion battery | 0.54–0.72 |

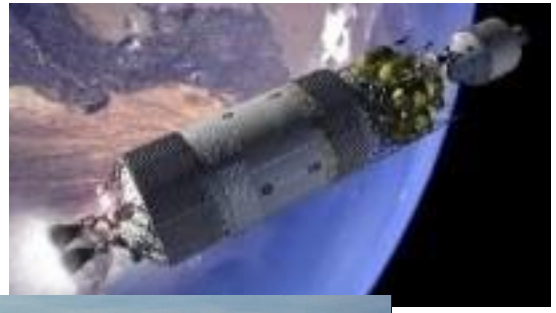
**~100,000x**

**Solar array**

**Wind Farm**

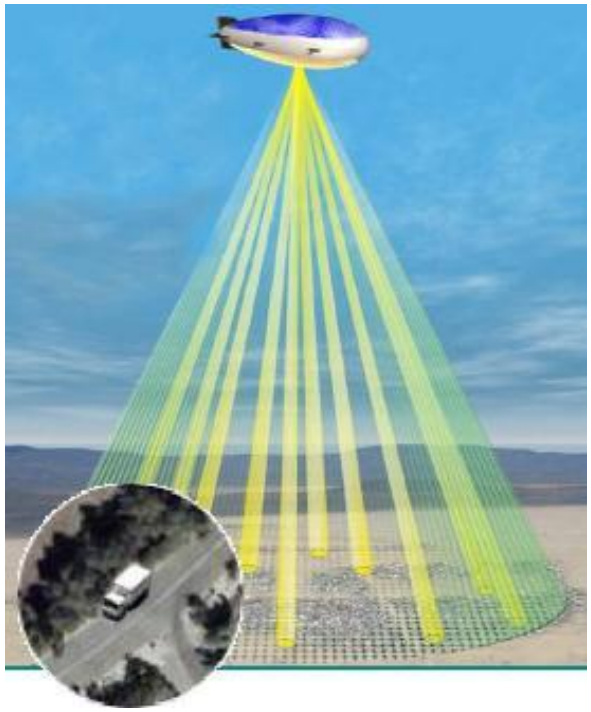
# Nuclear Energy Comes in Many Flavors

- Size – wide range
  - Radio-Thermal Generators used in deep space
  - Submarine/ship propulsion
  - 1000MW power reactors
- Coolant/moderator
  - Water
  - Graphite
  - Sodium
  - Helium
- Fuel
  - Pins/plates/balls
  - Uranium/plutonium
  - Metallic/ceramic



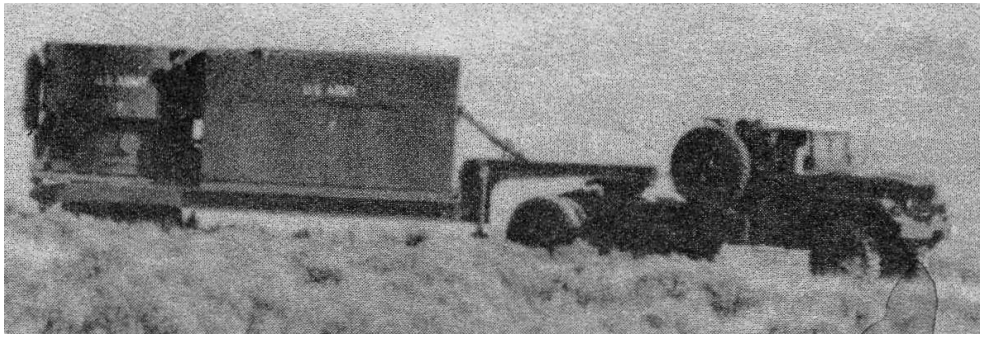
# Prospective Nuclear Application
## *Remote Package Systems*

- Small, self-contained systems for
  - remote sites
  - unmanned platforms
- Critical requirements
  - Extended endurance
  - High reliability
  - Rugged & proliferation resistant
  - Simple & safe to operate
- RTG systems already used on space missions



# Prospective Nuclear Application
## *Transportable Power Generation*

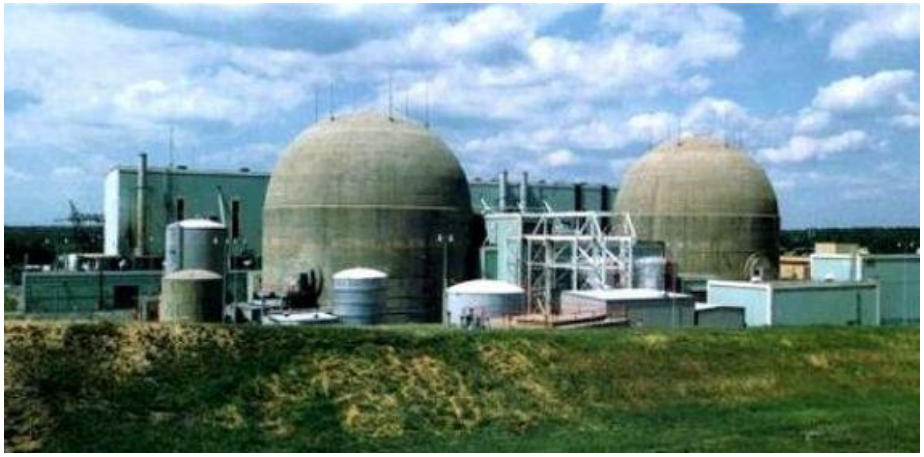
- Modular systems which can be deployed for contingency or emergency operations
  - War zone
  - Reconstruction
  - Natural disaster relief
- Critical Requirements
  - Limited resupply
  - Air transportable
  - Rugged & proliferation resistant
  - Simple & safe to operate
- US Army Corps of Engineers operated a series of prototypes during the 1950s and 60s.



US Army ML-1 Reactor, 1962

# Prospective Nuclear Application
## *Installation Power*

- Base load or backup power systems which assure power continue mission
  - Natural disaster
  - Terrorist attack
  - Fuel disruption
- Critical Requirements
  - Reliable operation
  - Assured fuel supply
  - Resistant to natural disaster or attack
  - Economical & safe to operate
- Commercial nuclear plants currently provide safe, reliable power worldwide

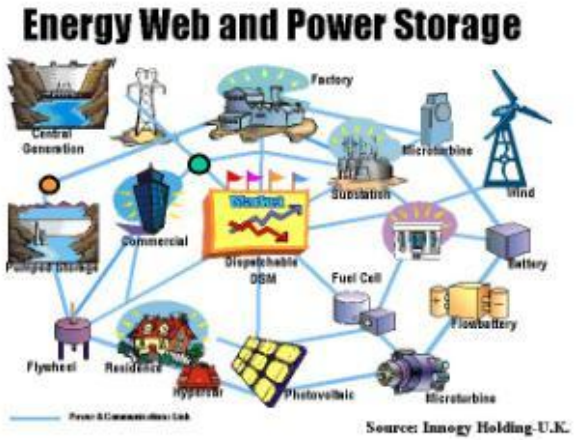


# Current DoD Efforts in Nuclear Energy

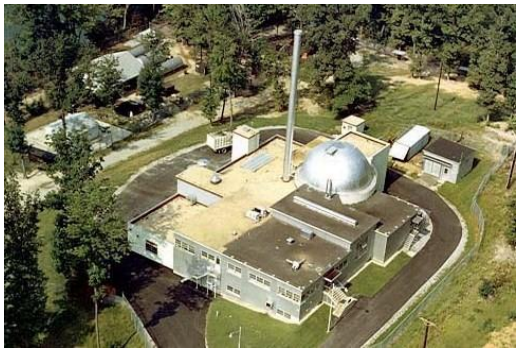
- Navy
  - Ongoing use of power for carriers & subs
  - Considering adaptation to power next generation cruiser
- Air Force
  - Considered commercial plant to be sited on Air Force Base for reduced vulnerability (2008/2009)
- Army
  - RDECOM/USMA studies of transportable reactor concepts for power, water, synfuel production

# Technology Opportunities

- Small/modular nuclear reactors
  - First generation military reactors
  - Next Generation reactor concepts being pursued
  - Toshiba 4S concept being marketed
  - Several transportable concepts currently proposed
- Process Integration
  - Water production
  - Synthetic Hydrocarbon
    - Fischer Tropsch process improvement
    - Catalytic conversion
    - Hydrogen, carbon collection
      - Gasification of coal, waste, other organics
      - Extraction from seawater
      - Extraction from air



# Prospective Long-Term Path

SM-1 Reactor, Fort Belvoir, VA


Conceptual nuclear/synfuel system (ARL/BTG)

- Analyze requirements, alternative concepts
- Build demonstration/testbed reactor(s)
- Expand deployment on domestic bases
- Diversify integration with other technologies (hybrid designs)
- Develop deployable reactors for military/contingency use
- Spin out safety and security improvements for global use.

Questions?

# Backup Slides

# Range of Power Applications

**COMMERCIAL**

Automotive

Heavy Vehicle

Marine

Industrial

Locomotive

Electronics

Residential

$10^1$ $10^2$ $10^3$ $10^4$ $10^5$ $10^6$ $10^7$ $10^8$

Power, Watts

Soldier Power

Sensors, Unmanned Vehicles

Vehicles, Mobile Generators

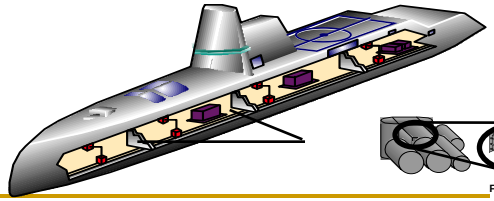
Ship Service

Ship Propulsion

*Future Force Warrior*

*FCS*

*USMC MEFFV*





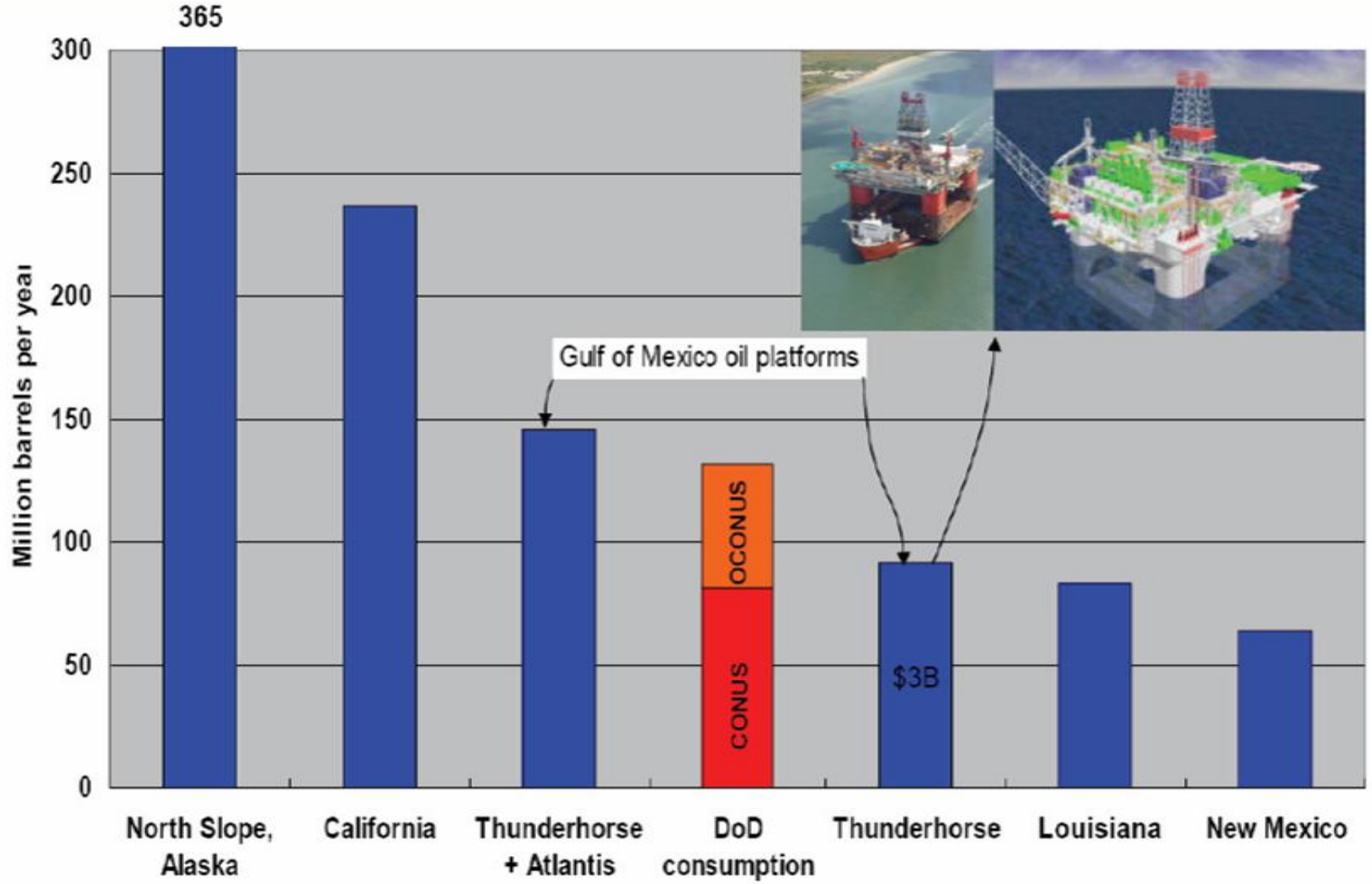
FUEL CELL

**MILITARY**

NAVSEA NAVAL SEA SYSTEMS COMMAND

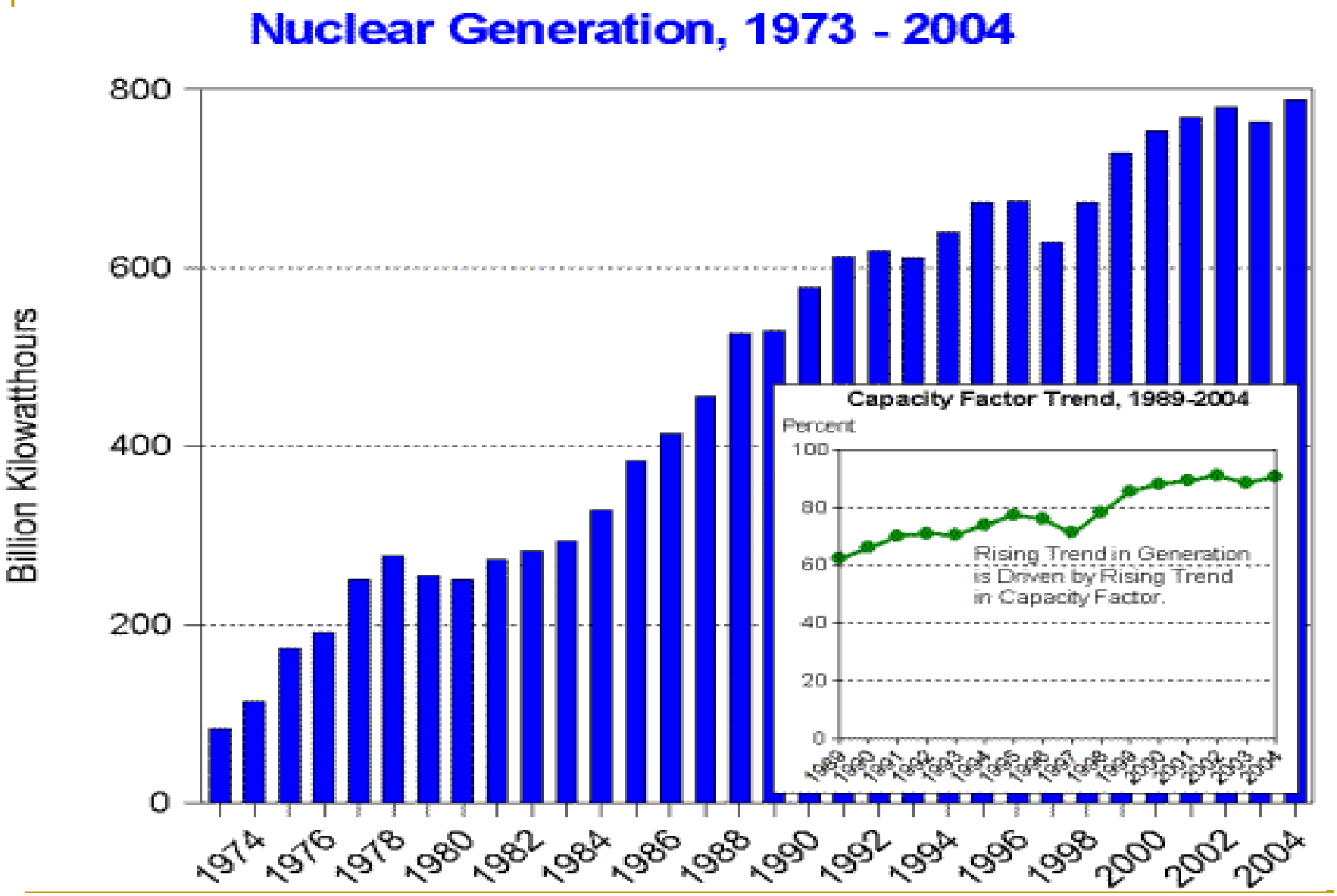
ONR Science & Technology

# Some U.S. production sites vs. DoD consumption




(2005) DoD consumption needs could be met by (2005) production capacity of a few U.S. production regions/sites

DoD consumption data from DESC FY05 Fact Book




**Growth of nuclear power generation (*Monthly Energy Review*, EIA/DOE).**

# How to Consider the Nuclear Option

- Conduct defense-wide assessment
  - Military requirements
  - Design/performance criteria
  - Issues/limitations
- Identify promising design concepts
- Construct technology roadmap
  - Key technologies
  - Research and development needs
- Develop program plan
  - Investment approach
  - Key decisions
  - Risk management strategy