A VERY SHORT INTRODUCTION TO MAE’S NUCLEARFUTURES LAB

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Presentation to MAE Advisory Council
Department of Mechanical and Aerospace Engineering, April 20, 2017
CURRENT AREAS OF RESEARCH

nuclearfutures.princeton.edu/projects

NUCLEAR ENERGY AND CLIMATE CHANGE

Are there new reactor technologies that could be potential “game changers” for nuclear power?

NUCLEAR ENERGY AND PROLIFERATION

Can one safely expand the use of nuclear power without increasing the risk of nuclear proliferation?

VERIFICATION OF NUCLEAR ARMS CONTROL AGREEMENTS

Can one dismantle and atomic bomb without learning anything about its design?

Source: Author (bottom)
NUCLEAR ENERGY & CLIMATE CHANGE
Some Small Reactors Are Smaller Than Others

WHY CONSIDER SMALL MODULAR REACTORS?

• Substantially lower investment risks
  $1 billion vs $10 billion projects; combined with shorter construction times

• Better suited for electricity markets with low growth rates
  Modules can be added to existing facilities “on demand”

• Promise of meeting emerging (or niche) market needs
  Replacement of aging coal/oil-fired plants, non-electricity applications, etc.

• Promise of enhanced safety and security
  Almost all designs envision underground siting

• Potential nonproliferation benefits
  Long-lived cores

• BUT: Ultimately, most will hinge on the economics
SMRS WITH LIFETIME CORES CAN HAVE SIGNIFICANT INVENTORIES OF FISSION MATERIAL

(Neutronics calculations for a notional design, 200 MWe, 30-year core life, 300 days per year)

NUCLEAR POWER REACTORS IN THE WORLD, 2017

(449 operational reactors (5 more than in February 2011) in 31 countries currently provide ~10% of global electricity)

Source: IAEA PRIS
Data as of March 2017
SCENARIO FOR GLOBAL NUCLEAR CAPACITY, 2035–2060

GCAM policy scenario (450 ppm, stabilizes at ΔT = 2.25 °C by the end of the century)

Installed capacity in 2017; total 392 GWe
- Canada 18–26 GW
- United States 139–261 GW
- Latin America 15–74 GW
- Western Europe 129–163 GW
- Eastern Europe 18–45 GW
- Middle East 9–86 GW
- Africa 8–88 GW
- Southeast Asia 15–147 GW
- India 19–277 GW
- South Korea 32–47 GW
- Australia / NZ 0–11 GW

Installed capacity in 2035; total 610 GWe

Installed capacity in 2060; total 1910 GWe

Global Change Assessment Model, www.globalchange.umd.edu/models/gcam/
NUCLEAR ENERGY &
NUCLEAR PROLIFERATION
SHAPING THE IRAN NUCLEAR DEAL
ON THE POLICY SIDE, SPRING/SUMMER 2014
THE MODIFIED CORE IS MORE COMPACT

It has a much higher neutron flux, which compensates for usability

Original core
(40 MW with natural uranium fuel)

Modified core
(10 MW with 5%-enriched fuel)

IRAN AGREES TO DETAILED NUCLEAR OUTLINE

Clenched Fist Loosens a Bit
A Gamble by Obama
First Step Toward a Wider Deal by June
NUCLEAR VERIFICATION
CONSORTIUM FOR VERIFICATION TECHNOLOGY

Five-year project, funded by U.S. DOE, 13 U.S. universities and 9 national labs, led by U-MICH

Princeton participates in the research thrust on disarmament research (and leads the research thrust of the consortium on policy)
RELEVANT NUCLEAR ARMS CONTROL TREATIES

NUCLEAR NON-PROLIFERATION TREATY
Bans the acquisition of nuclear weapons by non-weapon states and commits the five weapon states to nuclear disarmament; verified by IAEA safeguards

COMPREHENSIVE TEST BAN TREATY
Bans all nuclear explosions in all environments and would be verified by extensive verification mechanisms (International Monitoring System, CTBTO)

FISSILE MATERIAL (CUTOFF) TREATY
At a minimum, treaty would ban fissile material production for weapons purposes; Issue about treaty scope: Would it also cover existing stocks?

NEXT-GENERATION NUCLEAR DISARMAMENT TREATIES
Agreements that place limits on total number of nuclear warheads in arsenals would pose qualitatively new verification challenges
THOUSANDS OF NUCLEAR WEAPONS
ARE CURRENTLY NON-DEPLOYED (i.e., IN RESERVE OR AWAITING DISMANTLEMENT)

W87/Mk-21 Reentry Vehicles in storage, Warren Air Force Base, Cheyenne, Wyoming
Photo courtesy of Paul Shambroom, www.paulshambroom.com
14 MeV neutron generator
(Thermo Scientific P 385)

Collimator slot

Test object

Detector array

Collimator

Zero-knowledge neutron radiography setup at PPPL
Simulated data from MCNP calculations; neutron detection energies > 10 MeV; N(max) = 5,000

A physical zero-knowledge object-comparison system for nuclear warhead verification

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OPEN

THE VIRTUES OF NUCLEAR IGNORANCE

By Alex Wellerstein

THE NEW YORKER

ELEMENTS SEPTEMBER 20, 2016
VIRTUAL REALITY FOR NUCLEAR ARMS CONTROL
(with full-motion capability, co-presence, and real-time virtual radiation fields)

TO ENGAGE THE PUBLIC AND INTERNATIONAL GOVERNMENT PARTNERS
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