Safeguards for Fusion Energy Systems

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There are Potential Links between Fusion Energy and Nuclear Weapons

• DT and DD fusion reactions produce abundant neutrons that can be used to breed fuel for nuclear weapons.
  • One “significant quantity” of Pu or $^{233}$U = 8 kilograms, while a DT fusion system could produce up to ~ 3 kilograms / day / GWe.

• Tritium is used in advanced nuclear weapons.
  • U.S. weapons generally contain less than 20 grams of tritium, while a DT fusion system burns and breeds ~ 400 grams of tritium / day / GWe.

• Some of the science of inertial fusion energy is classified.
  • This is why the National Ignition Facility was constructed.

• These issues will need to be addressed for public acceptance, and worldwide impact, of fusion energy.

“…” ⇒ IAEA definition
Fusion Systems can Reduce Neutrons and Tritium, but at the Price of Lower Power Density

DT provides 3000x the power density of P-11B at 1/10 the temperature.
Breeding of Fissile Material can be Detected, but only if Safeguards are Implemented

• A fusion safeguards system could confirm:
  • No “source” material ($^{238}$U, $^{232}$Th) is introduced into the system.
  • No “special fissionable material” ($^{239}$Pu, $^{233}$U) is produced in the system.

• Fusion safeguards can draw on existing IAEA technologies for:
  • Sensitive “Environmental Sampling” for presence of nuclear materials.
  • On-Site Inspection (e.g., “Design Information Verification”).
  • Unattended Monitoring Systems (e.g., gamma spectra).
  • Containment and Surveillance (e.g., cameras, portal monitors).

• This is easier than for fission systems. No source material, no special fissionable material, and no fission products should be present.

• We should follow IAEA guidelines for “Safeguards by Design”
The Gamma Signature of Fission Products is Distinctive

Spectra are very different above 1 MeV, even with low-resolution detector.

No $^{238}\text{U}$ nor $^{232}\text{Th}$

$^{238}\text{U}$ for ~ 8 kilograms Pu per year

$^{232}\text{Th}$ for ~ 8 kilograms $^{233}\text{U}$ per year

Evan Leppink, MIT
Unpublished calculations
Tritium is a Challenge

- A DT system may have present kilograms of tritium / GWe.
  - The fuel system may recycle kilograms of tritium / day / GWe.
- Need to assure that grams of tritium are not diverted per year.
  - The technology for tritium accounting will need improvement.
  - How much is: burned, released, held up (and where)?
- Tritium technologies on the Nuclear Suppliers Group “Trigger List.”
  - Is this sufficient for limiting proliferation of tritium technology?
- Safeguards technologies for tritium inspection, “unattended monitoring,” and “containment & surveillance” need to be developed.
  - Tritium safeguards should be implemented “by Design.”
We Will Need to Control Information from Inertial Confinement Fusion R&D and Deployment

“In addition, information that could help countries develop more advanced boosted weapons or thermonuclear weapons could be gained from a thorough understanding of a fusion facility’s operation.” NAS, 2013
The Legal Framework is not Available for Safeguarding Fusion Energy Systems

- IAEA safeguards agreements are keyed to declared quantities of “source” or “special fissionable material.”
  - IAEA has limited authority through the “Additional Protocol” that allows “Complementary Access” to facilities to assure that all nuclear activities in a State are for exclusively peaceful purposes.
  - Environmental Sampling is permitted under Complementary Access.
- The Nuclear Suppliers Group Trigger List, Export Control, and 123 Agreements are additional tools that can be used.
  - But these do not affect fully domestic activities.
- The fusion community should be at the forefront of pushing for the development of a legal framework to support fusion safeguards, so fusion energy can have world-wide impact.
Next Steps

• **Technology R&D for fusion safeguards:**
  • Detecting production of special fissionable material.
  • Improving tritium accountancy, detection of tritium diversion.

• **Development of legal frameworks for:**
  • Safeguards at fusion power plants with no declared nuclear material.
  • Safeguards for tritium, and controls for tritium technology.
  • Protection of ICF-derived weapons information.

• **See also:**
  • R.J. Goldston, A. Glaser, “Inertial confinement fusion energy R&D and nuclear proliferation: the need for direct and transparent review,” Bulletin of the Atomic Scientists, **67**(3) (2011) 59
  • A. Glaser, R.J. Goldston, “Proliferation risks of magnetic fusion energy: clandestine production, covert production, and Breakout,” Nuclear Fusion **52** (2012) 043004