

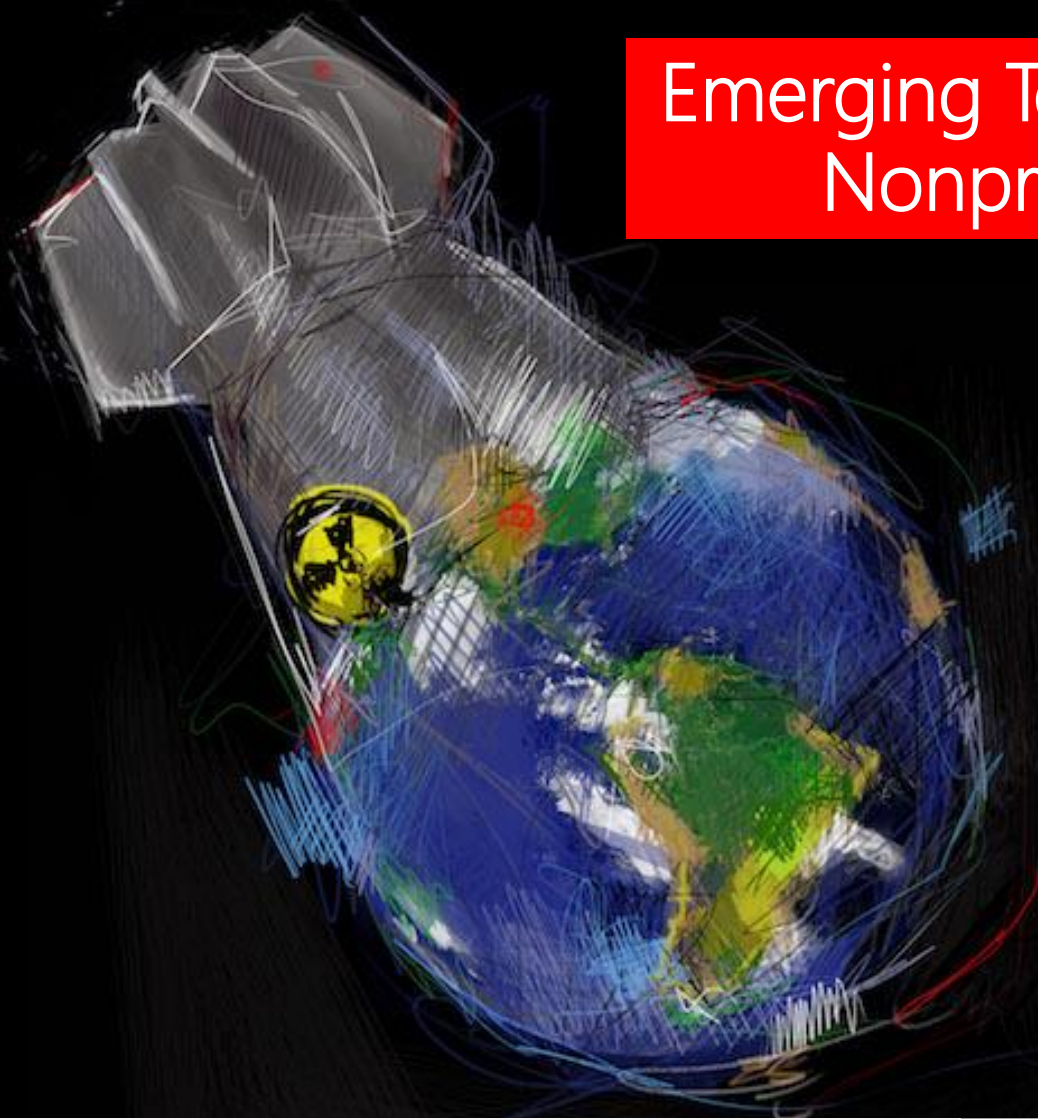
Emerging Technology
and Nonproliferation



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Brief Outline



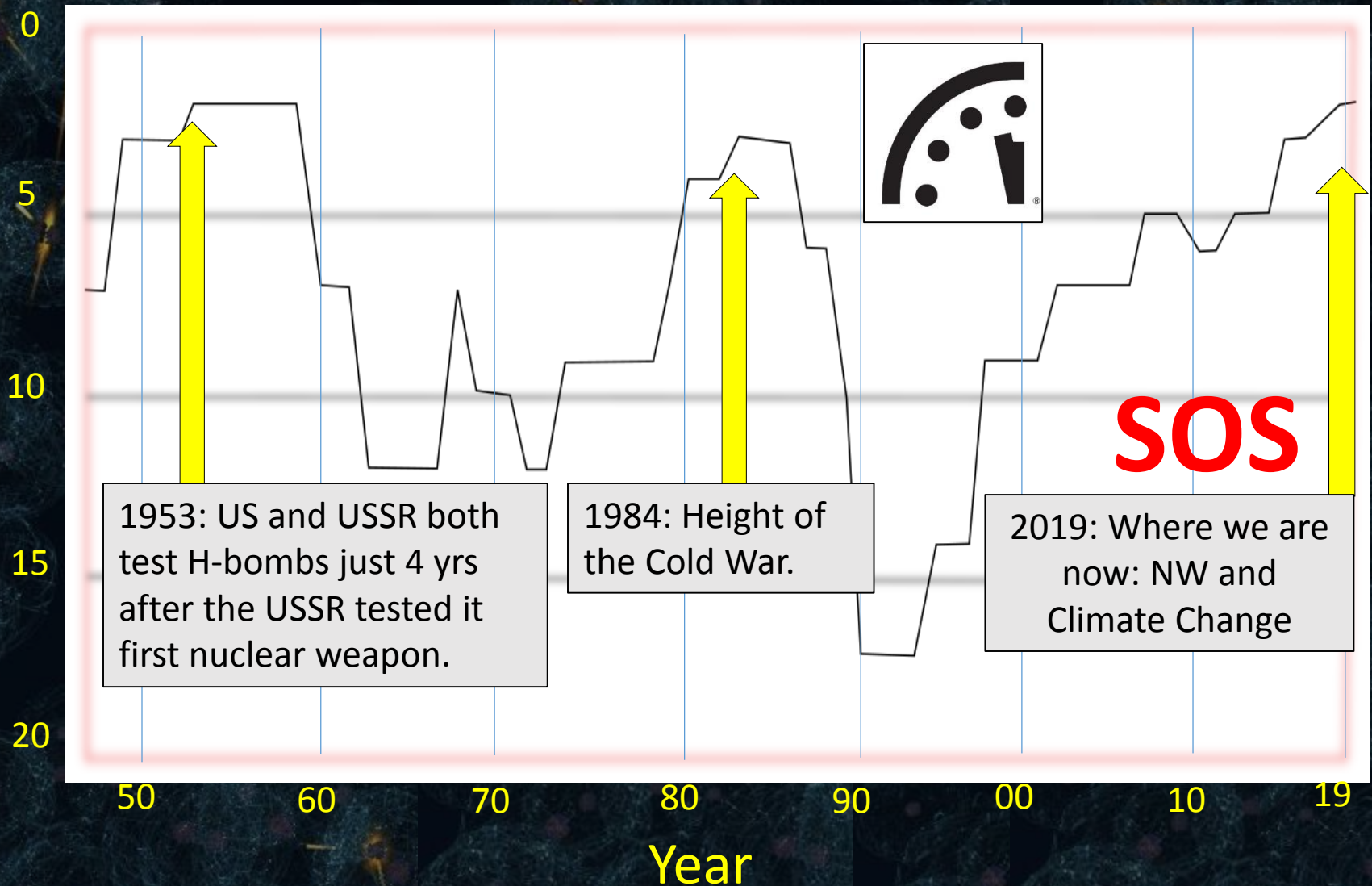
- Set context of the nonpro problem.
- How IC tackles the problem
- Emerging tech for support including neutrinos (and dual use concern).
- Other emerging technologies.

“Fission”

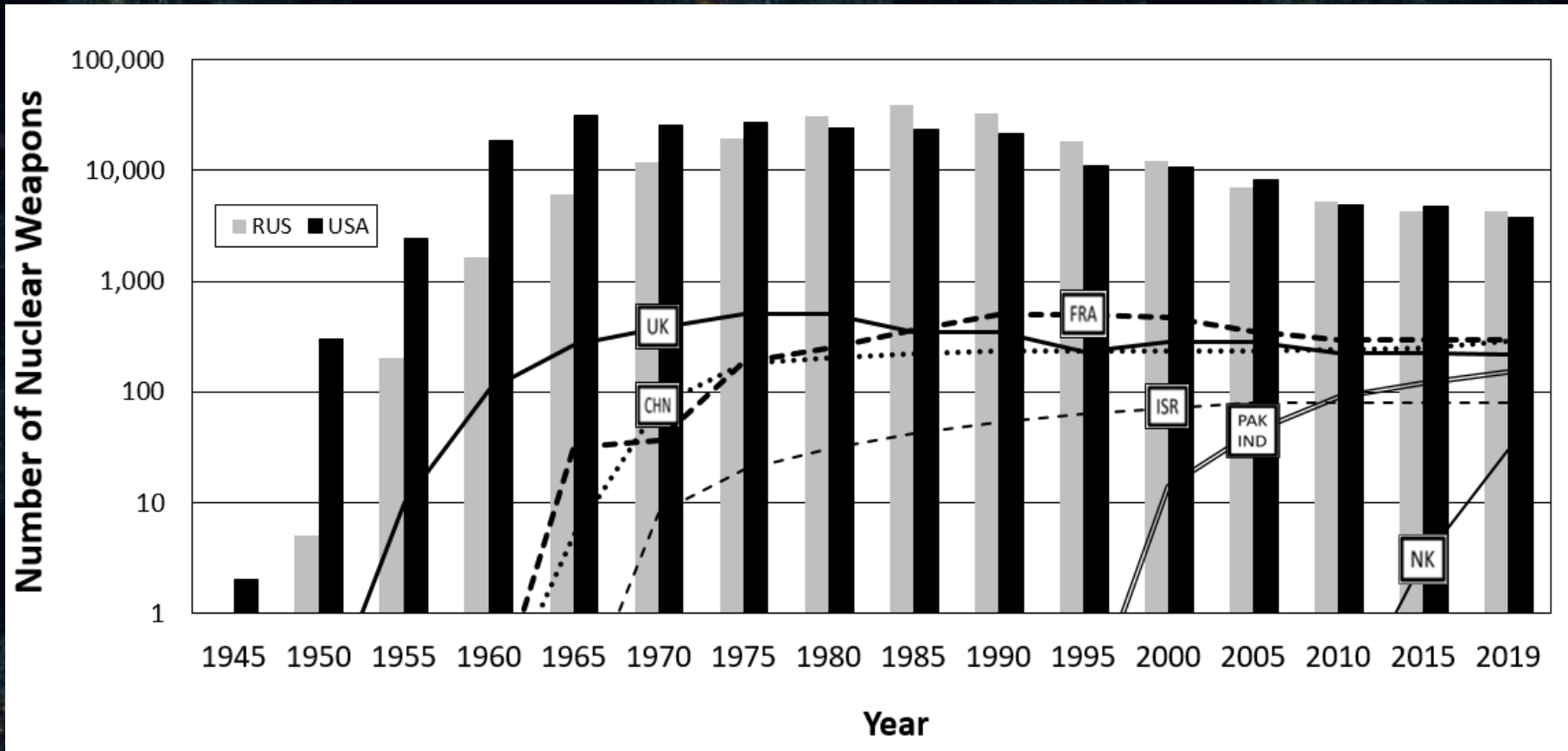
Used with Permission: Benoît Kloeckner
Institut Fourier, Université Joseph Fourier, Grenoble

Minutes to Midnight

Minutes to MN



Nuclear Weapons are Decreasing



Russia/US each have ~ 900 nuclear weapons on high alert. [For data see FAS website: nuclear notebook]

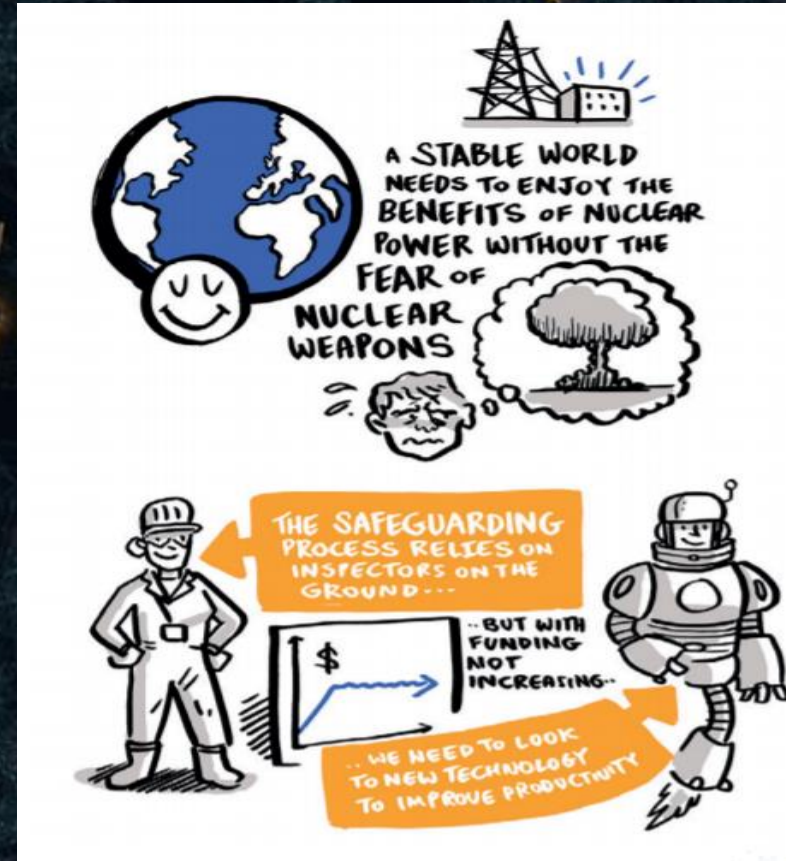
Why are we concerned in 2019?



Pres. Putin's Torpedo Announced in 2018

Multi-pronged to Tackle Problem

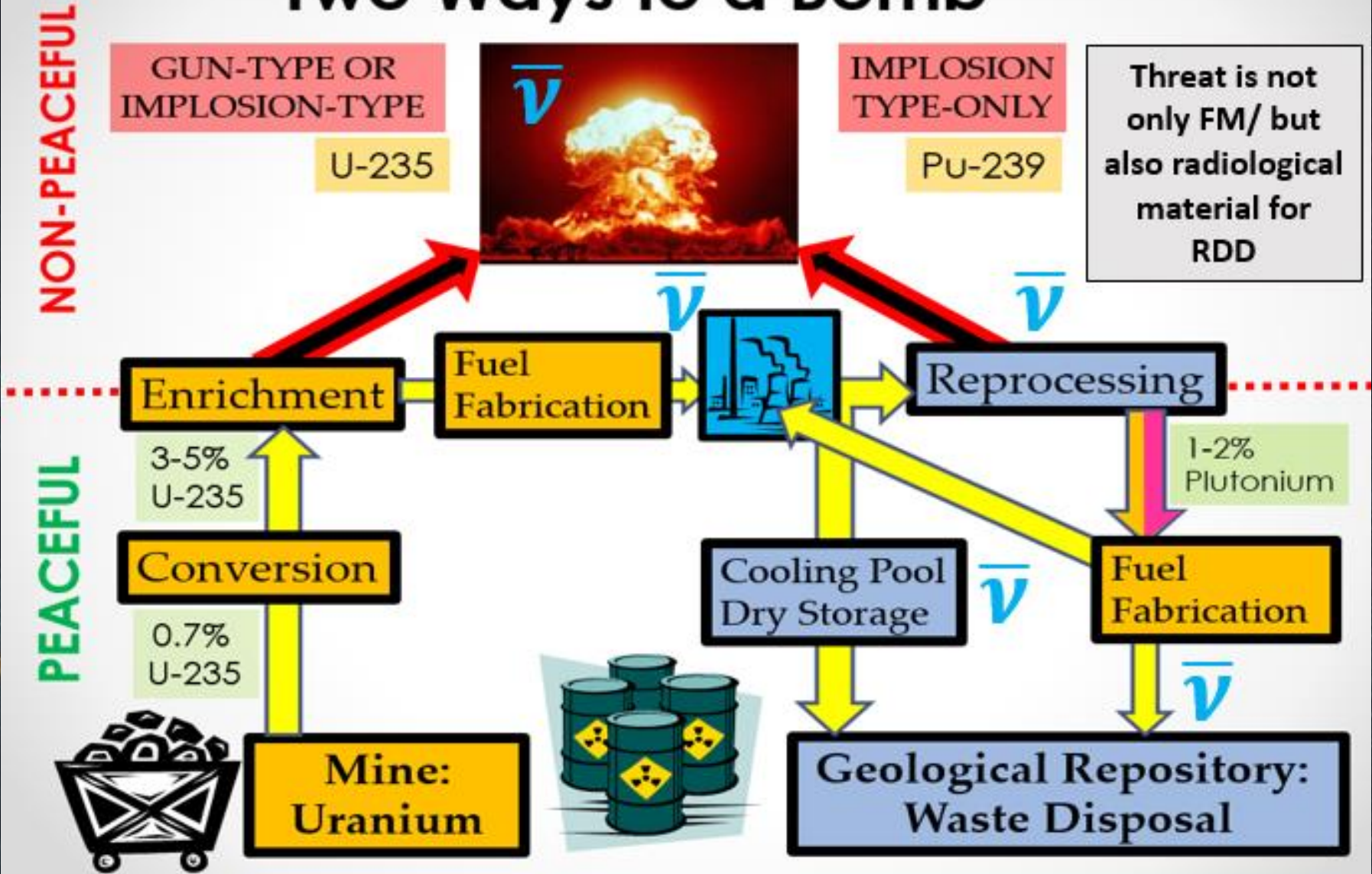
- Goal: Secure FM, radiological material, control delivery systems.
- Block all pathways while allowing peaceful use.
- Game-changing technology which can be of support to NP or help proliferator.



[1] <https://www.iaea.org/sites/default/files/18/09/emerging-technologies-130217.pdf>

Focus on Detection of Noncompliance?

Two Ways to a Bomb



Focus on Detection of Noncompliance

- IAEA safeguard the process with shoestring budget!
- Variety of Emerging Technologies useful for safeguards. Including neutrinos.
- Big data, data analytics, AI to improve detection of proliferant behavior, shared ledger (block chain) to track nuclear materials.
- Key challenge: FNPP and new reactors.



[1] Lysenko, Bedenko, Dalnoki-Veress, *Moscow Journal of International Law*, Issue 3, Nov, 2019. <https://www.mjil.ru/jour/article/view/319/234#>

[2] Emerging Technologies Workshop., IAEA, Feb 13-16 2017.

Focus on Detection of Noncompliance

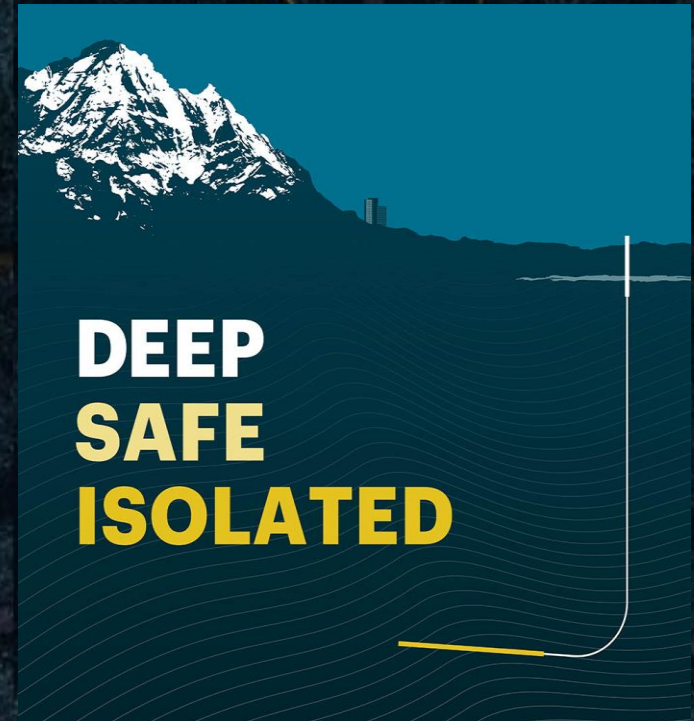
- Congress demands *Gold Standard* of **ENR**: “we shot ourselves in the foot,” : E. Moniz (NTI) [1]
- Alternative: Need strict verification protocol – ie. JCPOA. Use AI seek patterns. [1],[2]
- Dispose of Pu: Options too expensive, DBD. [3]

[1] Hoover Presentation on Nov 5 "Emerging Technology and Nuclear Non-Proliferation":

<https://www.youtube.com/watch?v=v2U-PuxNRV8>

[2] “The Race for AI,” Defense One, Feb 27, 2018, 12

Country that “leads in AI will get to rule the world.” V. Putin [2]

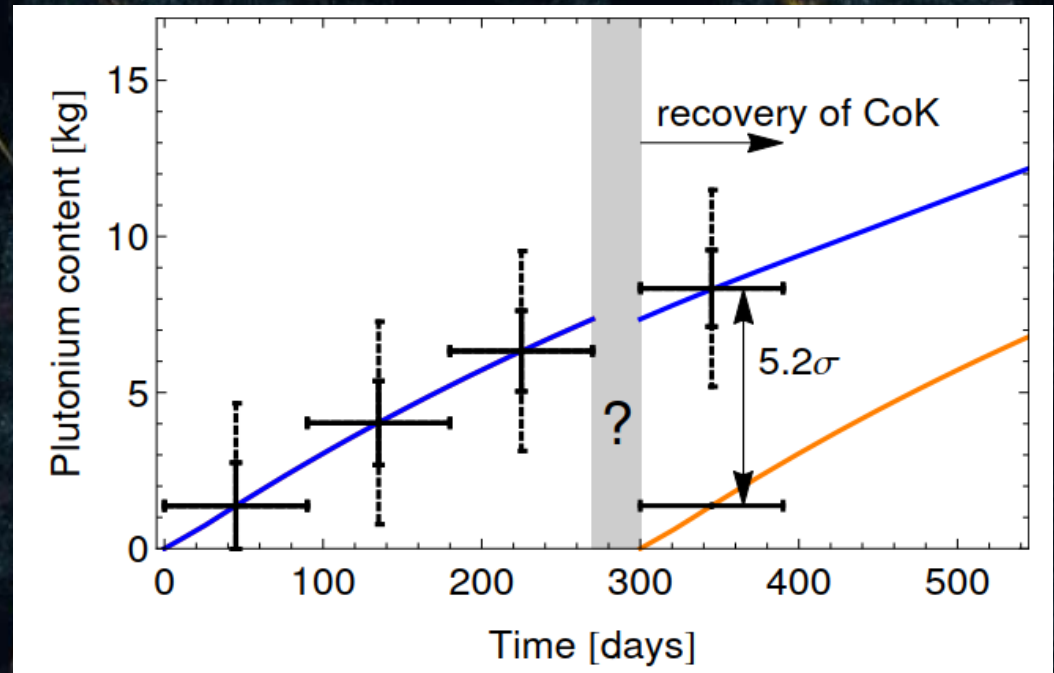


[3] <https://www.deepisolation.com/>

Horizontal Drilling Concept

NF Detector Reactor Deployment

- Diversion scenario: 40 MWth reactor has one month lost CoK. Has core been replaced?
- Assuming 5t detector at 20 m standoff. for 90 d counting times.
- Undeclared refueling easily detected within 1 week at 90% C.L.



Christensen, Eric, Patrick Huber, and Patrick Jaffke:

<https://www.tandfonline.com/doi/abs/10.1080/08929882.2015.996076?journalCode=gsgs20>
<https://arxiv.org/pdf/1403.7065.pdf>

Detecting Hidden Reactors

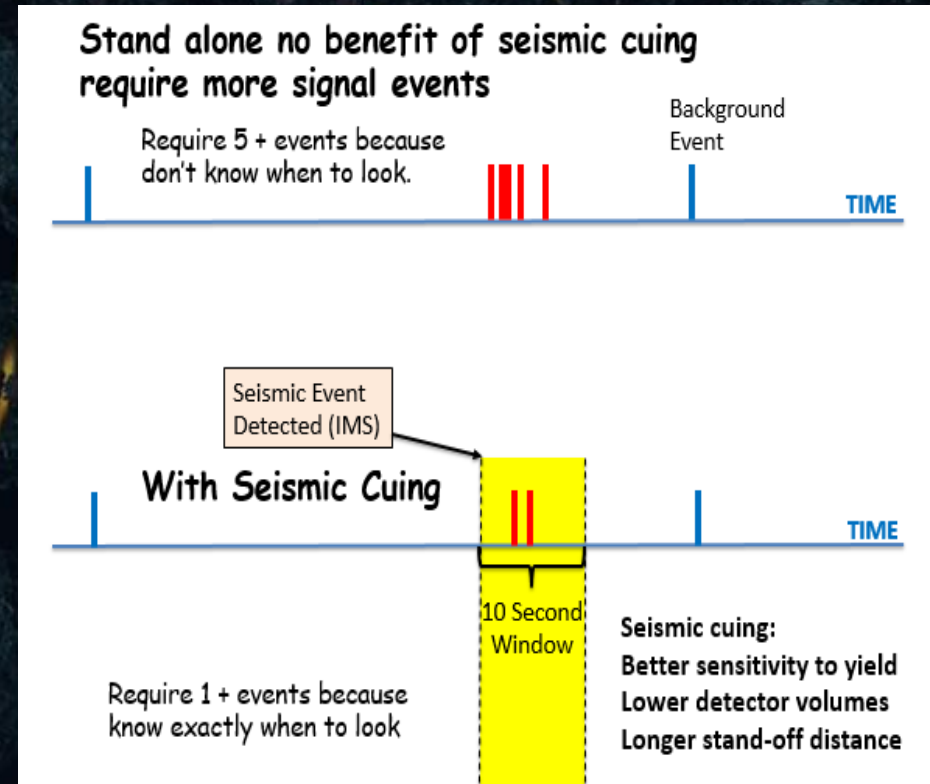
- $\bar{\nu}$ offers advantages (shielding) but challenges (IBD) as well. Multi-source data.
- Require large detectors.
- WATCHMAN program launched to demonstrate the viability of scalability of Gd-doped water Cherenkov detectors for nonprol. **Most viable path to a 100 kt – 1 Mt scale detector.**



C. Grant, AIT-WATCHMAN A Remote Reactor Monitor and Advanced Instrumentation Testbed, TAUP, 2019.

Detection of Nuclear Explosions

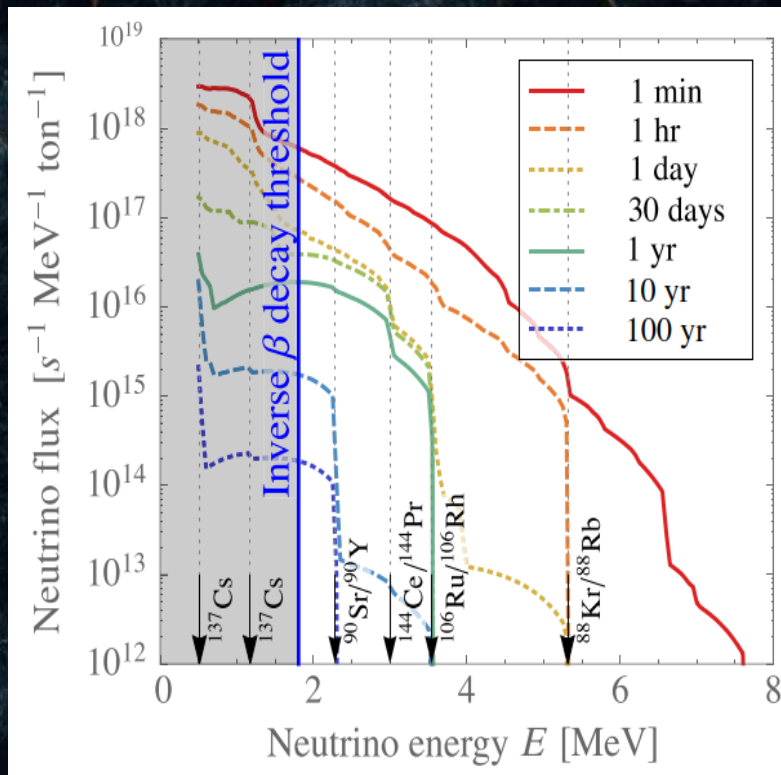
- Confirming nuclear fission nature of suspect nuclear explosion.
- Use seismic cueing
- Pay off high! But still requires $>Mt=B\text{\$}$ scale detectors to be valuable.
- Cooperative verification of former nuclear test sites. Co-located seismometer.



Carr, Dalnoki-Veress, Bernstein.
Phys. Rev. Applied 10,
024014 (2018).

Focus on Detection of Noncompliance

- Detection of reprocessing facilities and spent fuel facilities, geological repositories.



Realization by Brdar *et al*
Decades after spent fuel
release still produces
 $\bar{\nu}$ above IBD threshold.

Lower flux signal than
reactor but may have
applications.

Possible to detect large
diversion of material.

Brdar, Vedran, Patrick Huber, and Joachim Kopp. "Antineutrino monitoring of spent nuclear fuel." *Physical Review Applied* 8, no. 5 (2017): 054050.

Roll Back of North Korea's Program

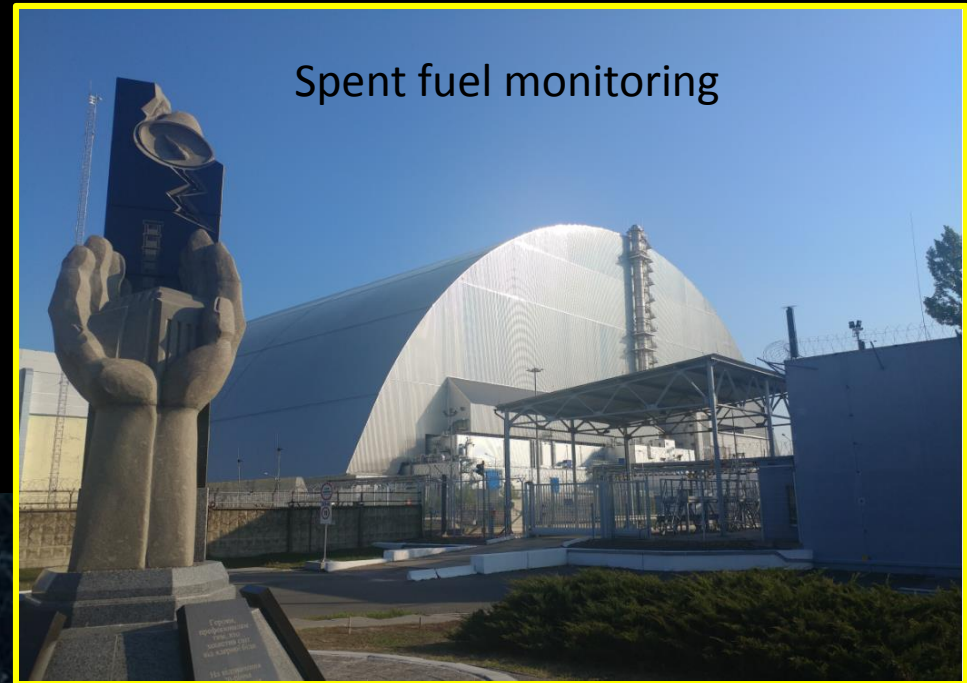
- Cooperative Threat Reduction (CTR) program for NK.
- Shut down production reactors, monitor facilities, secure WMD, deal with spent fuel & waste in future agreement.



Roll Back of North Korea's Program

- International collaboration looked at using antineutrinos for monitoring YB using segmented detectors. Access to facility or remote access.

CASE	5MWe/ 20 MW _{th}	ELWR/ 100 MW _{th}
Monitoring near reactor	<2 weeks	< 1 day
Remote Monitoring w/ Overburden (larger detector)	250 days	< 2 weeks



Unauthorized start up

Delayed dismantlement "concoon"

Carr, Rachel et al. "Neutrino-based tools for nuclear verification and diplomacy in North Korea." *Science & Global Security* (2019): 1-14.

Emerging Technology: Evolving Dual-Use Concern



See: <https://www.scientificamerican.com/article/3-d-printers-could-help-spread-weapons-of-mass-destruction/> and our detailed article referenced herein.

Trancending Traditional Manufacturing: Generative Design and AM Electronics



BLACK SWAN

- AM-centered military program: team of AM specialists.
- Specialists in AM but not in the WMD technology itself (AI for instance).
- Produce something new, never seen before.
- Below the radar without violating export controls / sanctions.
- Detected when it is too late.



Conclusion

- We are in precarious times!
- Prevent future use of NW while allowing nuclear technology to be used.
- Antineutrinos have a role, but challenging, and needs further demonstration.
- Emerging technology: promise or peril.



Children's Cold War toy in Pripyat (near Chernobyl)