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Editors' Note

This issue of *Science & Global Security* contains four articles that cover very diverse fields: nuclear disarmament verification, emerging weapon delivery systems, fissile material production for nuclear weapons, and repurposing of civilian nuclear facilities for fissile material production for weapons. Nonetheless, at one level these articles share a common theme – are things what they seem?

The first article "Ceci N'est Pas Une Bombe: Lessons from a Field Experiment Using Neutron and Gamma Measurements to Confirm the Absence of Nuclear Weapons" is by Eric Lepowsky, Manuel Kreutle, Christoph Wirz and Alexander Glaser. It reports and reflects on an effort to advance nuclear disarmament verification by working through a protocol for demonstrating the absence of nuclear weapons at declared sites or within demarcated areas on a site.

The exercise was organized by the UN Institute for Disarmament Research together with the Swiss Armed Forces, Spiez Laboratory, and Princeton University's Program on Science and Global Security (the home of this journal). It involved determining if closed containers of various sizes in a series of bunkers on a former military base at Menzingen, Switzerland did not contain nuclear weapons or their fissile material components. Key findings include that measurement hardware and software design must take into account expected field conditions, neutron as well as gamma radiation measurements may be needed to confirm the absence of nuclear weapons given the different signature of plutonium from that of uranium, and adequate background radiation measurements at the site are critical.

In their article "Hypersonic Weapons: Vulnerability to Missile Defenses and Comparison to MaRVs," David Wright and Cameron Tracy contest claims that hypersonic boost glide vehicles present significantly new military capabilities. One such claim is that these systems are better able to counter adversary endo-atmospheric missile defenses. The analysis determines that to evade the most capable current endo-atmospheric missile interceptor systems – assumed to be the enhanced version of the US Patriot Advanced Capability-3 (PAC-3) system deployed in 2016 – a boost glide vehicle needs to begin its dive toward its target from a glide speed of about Mach 10 or greater (the upper range of US hypersonic systems under development). This constraint also implies an initial glide speed significantly higher than Mach 10 since the vehicle will slow during its glide. These initial and final glide speeds may have to increase since countries are likely to develop faster endo-atmospheric interceptors to counter just such hypersonic boost glide systems.

The analysis also compares boost glide systems being developed by the United States with maneuverable reentry vehicles deployed on ballistic missiles flown on depressed trajectories to assess the respective mass, range, and delivery time – all of which may be relevant to military missions. It suggests there may be attacks where maneuverable reentry vehicles offer a combination of mass and delivery time that provide comparable or better options than hypersonic boost glide vehicles, especially if the maneuverable reentry vehicle can be made less massive than the hypersonic vehicle. Finally, the article challenges the claim that the maneuvering capacity of hypersonic boost glide vehicles is a key new attribute. It finds that midcourse maneuvering by a hypersonic boost glide vehicle increases drag, significantly reducing speed and range, limiting maneuvering capabilities and any advantages they might offer.

The third article is "Plutonium Production under Uranium Constraint" by Erik Branger, Peter Andersson, Vitaly Fedchenko, Sophie Grape, Cecilia Gustavsson, Robert Kelley, and Débora Trombetta. It explores options for a state aiming to produce plutonium in a heavy-water moderated CANDU-type reactor for its nuclear weapons program to overcome any shortfall in available natural uranium by using uranium separated from spent nuclear fuel and also by mixing this reprocessed uranium with enriched uranium. These options depend on the available fissile material production facilities and their capacities.

The analysis considers a base case with no enrichment and no use of reprocessed uranium, a case where uranium is recovered from spent natural uranium fuel and added to natural uranium for fabricating reactor fuel that contains slightly less than the 0.71 percent uranium-235 of natural uranium, and a third case where reprocessed uranium is mixed with enriched uranium (40–60 percent enriched) to make the blended material equivalent to fresh natural uranium fuel. This kind of comparison of possible fueling options allows for a more thorough assessment of the range of possible production rates of plutonium, weapon plutonium stockpiles, and possible number of nuclear warheads a nuclear-armed state may possess.

The final article in the issue is "Utilizing a Virtual Sodium-Cooled Fast Reactor Digital Twin to Aid in Diversion Pathway Analysis for International Safeguards Applications" by Ryan Stewart, Ashley Shields, Shaw Wen, Frederick Gleicher, Samuel Bays, Mark Schanfein, Gustavo Reyes, Jeren Browning, Kathrine Jesse, Christopher Ritter. It offers a case study of how a computer simulation (a virtual digital twin) constructed using actual reactor design information and continually updated with data from sensors in the operating reactor can enable a representation of the reactor over time "to model, predict, and analyze the behavior of a nuclear reactor to understand safeguards implications."

The case study involved a generic 300 MW sodium-cooled fast reactor, with LEU and reactor-grade plutonium fuel, with and without breeding blankets. The scenarios considered material being removed from an assembly before being loaded into the core and undeclared material being placed in the core to breed plutonium. The goal being to use the digital twin to find reactor operation signatures that could indicate such material diversion or misuse compared to normal reactor operations. The analysis finds that digital twins can offer an additional albeit limited tool for planning both improved safeguards by design at such reactors (assuming there is enough design information) and for monitoring such reactors when they are operational (assuming enough sensor data is available) to allow for more timely targeted safeguards inspections.