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Profit-Minded Suppliers: The WMD Pathways and Combating Convergence

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Knowledge, materials, infrastructure, personnel, finances, and lines of communications are all components of both a weapons of mass destruction (WMD) proliferation network and an improvised explosive device (IED) facilitation network. Convergence describes occasions when profit-minded suppliers of an IED facilitation network use their transnational linkages to proliferate the critical components for WMD development and facilitate their employment by non-state actors. Convergence, however, does not necessarily lead immediately to a non-state actor possessing a WMD. There are several gaps that must be overcome that are dependent on the type of WMD involved and its delivery mechanism. Upon examining the risk associated with convergence of nuclear, biological, and chemical weapons networks, it is unlikely that profit-minded suppliers will be able to overcome the acquisition hurdles for obtaining the special nuclear material required to make a nuclear device. Convergence will, however, assist non-state actors in developing and employing biological and chemical weapons of minimal complexity, with its biggest contribution likely in propagating raw materials and knowledge similar to current IED proliferation. Combating the convergence of WMD and IED networks is difficult because much of the critical material and information required for the development of a WMD is not illegal.

Convergence in this article refers to profit-minded suppliers[a] of an improvised explosive device (IED) facilitation network using their transnational linkages to proliferate the critical components—whether material, knowledge, or a technically skilled individual—required for weapon of mass destruction (WMD) proliferation.[b] There is a multitude of transnational networks, such as narcotics trafficking or human smuggling networks, that could support convergence for WMD proliferation; IED employment has been

a The concept of 'profit-minded suppliers' in relation to IED/WMD network convergence was first described by John Caves. See John Caves, "Globalization and WMD Proliferation Networks: The PolicyLandscape," *Strategic Insights* 5:6 (2006).

b Weapons of mass destruction are commonly characterized as nuclear, chemical, and biological, and can provide "states or sub-national groups the ability to inflict damage that is wholly disproportionate to their conventional military capabilities." Even within the WMD realm, both destructive capability and the requirements to develop and employ the weapons differ greatly. Randall Forsberg, William Driscoll, Gregory Webb, and Jonathon Dean, *Nonproliferation Primer: Preventing the Spread of Nuclear, Chemical, and Biological Weapons* (Cambridge, MA: MIT Press, 1999).

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growing and expanding, with incidents occurring in 48 countries and territories in 2016 alone.[1] This prevalence and possibility for convergence is directly related to the wider "dissemination of [the] knowledge, technology, and material required to manufacture and employ an IED worldwide."[2]

In terms of IED facilitation, the U.K.-based non-governmental organization Action on Armed Violence (AOAV) examined the transnational dissemination of material, knowledge, and funding supporting actions by groups such as the Islamic State, Boko Haram, al-Qa`ida, the Taliban, and al-Shabaab. The following examples from AOAV's findings highlight the depth and breadth of these networks. For material, in one example, the Islamic State was able to "rapidly obtain chemicals, detonators, and other precursor materials in an often entirely legal manner."[3] For one specific IED precursor, the report found that the Islamic State used "three different companies in Brazil, Romania, and China, and [the material] was later imported by three different Turkish companies."[4] Additionally, while some knowledge was self-taught, according to AOAV, there was an exchange of information between terrorist groups regarding manufacturing and employment of IEDs.[5] Financial support was vast, derived from such sources as simple donations, kidnapping for ransom, extortion, and taxation on goods, such as cocaine smuggled through West Africa. One estimate in the report states that AQIM's taxation on drugs traveling through West Africa from Colombia, Peru, and Bolivia to Europe generated $800 million annually.[6] While these are just a few examples of components of an IED facilitation network, they demonstrate the scope and scale of the networks that could potentially converge for WMD proliferation.

The threshold for development and employment of both chemical and biological weapons agents has been lowered over time, as illustrated by chemical weapon agent use by both Aum Shinrikyo in 1995 and more recently by the Islamic State and when it comes to biological weapons, the higher number of ricin incidents worldwide.[7] The proliferation of the knowledge, material precursors, and technology to develop and employ a WMD is, consequently, a concern. This article, which builds upon an article on profit-minded suppliers published recently in this journal, examines the critical nodes required for non-state actors to develop nuclear, biological, and chemical (NBC) weapons. It also highlights the risk associated with IED facilitation networks providing the necessary support to lower the threshold for WMD proliferation.

Proliferation Networks

The scope and depth of assistance required to develop and employ an NBC weapon are significant. Convergence with an IED facilitation network is one mechanism to overcome the complexities of WMD proliferation, and the scope of convergence is dependent on three key factors. The first factor is the type of WMD: nuclear, biological, or chemical. Even within these overarching categories, there are varying levels of complexity, as seen in Figure 1. The second critical factor is the starting point for the weapon that a non-state actor may be able to access. This starting point, ranging from raw materials to a nearly assembled device, is heavily dependent on the financial resources available to the non-state actor and access to the materials. And the third factor is the delivery system. Non-state actors, for example, do not have access to intercontinental ballistic missiles (ICBM) for long-range delivery of a nuclear weapon, consequently a device must be smuggled to the target location.[c]

Nuclear Weapons

The critical obstacle for a nuclear weapon is not the warhead design

c Some might argue that SpaceX is a non-state actor and that its ability to deliver goods to the international space station demonstrates the ability of a non-state actor to possess an ICBM. Nevertheless, rocket development by companies like SpaceX have, thus far, proceeded with support from the U.S. government (in the form of approval and contracts in support of the International Space Station) and do not represent a terrorist threat.

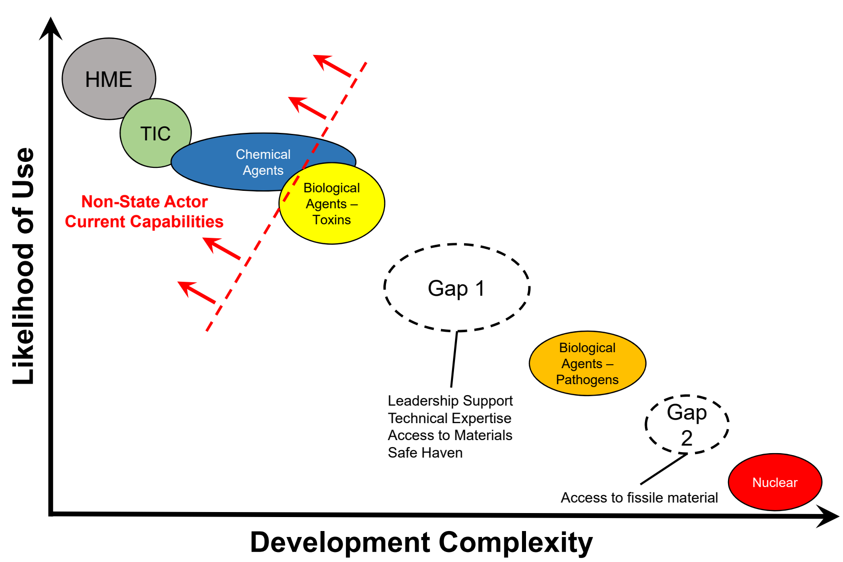

Figure 1. The relative complexity for weaponization and likelihood of use for nuclear, biological, or chemical weapons. The red dotted line highlights that space in which non-state actors currently operate. HME refers to homemade explosives and TIC refers to toxic industrial chemicals, such as chlorine. (Hummel)

but acquisition of special nuclear material (SNM), which is either Uranium-235 (U-235) or Plutonium-239 (Pu-239). To produce a weapon, a terrorist needs a significant quantity of SNM, which the International Atomic Energy Commission (IAEA) has described as 25 kg of U-235 and 8 kg of Pu-239.[8] There are two general pathways to gain possession of a significant quantity of SNM: production or acquisition.

Production of either U-235 or Pu239 is extremely difficult. Uranium naturally exists in two forms, or isotopes, with the predominant isotope being U-238 at 99.3% as compared to U-235 at 0.7%. Consequently, the uranium must undergo a separation process, known as enrichment, to produce a sufficiently significant quantity of U-235. Under ideal enrichment conditions, it takes a little over 3,500 kg of natural uranium to make a single weapon.[d] No enrichment process is perfectly ideal, however, and so more uranium is required in reality. There are several methods for achieving enrichment, but all require tremendous amounts of time, infrastructure, raw material, and knowledge in the fields of chemistry, chemical engineering, and physics.

Plutonium does not occur naturally and is only produced during a nuclear reaction. When U-238 absorbs a neutron and undergoes fission, one of the potential decay products is Pu-239. The most common place for this reaction to occur is in a nuclear fuel rod. When extracted from a reactor core, these rods are radioactive and require time in a spent fuel pool for the hot, short-lived isotopes to decay. Only after a cooling period, typically over 90 days, is it possible to extract the Pu-239 through reprocessing.

The infrastructure footprint and technical requirements for reprocessing are less difficult than enrichment but hardly insignificant. If not conducted in a radiation-shielded room (commonly referred to as a hot-cell), reprocessing exposes personnel handling the rods to lethal doses of radiation. A hot-cell requires feet of concrete, leaded glass, and remote-control manipulators to move the rods to protect the handlers. This infrastructure would also emit a radiation signature that could be identified with remote sensors. Reprocessing also requires large quantities of commercially available chemicals such as nitric acid and tributyl phosphate. These chemicals would impose specific handling requirements due to their corrosive and reactive nature. Production of a significant quantity of Pu-239 via reprocessing would also require detailed knowledge in chemistry, chemical engineering, and metallurgy.

Regardless of the skill and depth of the proliferation network, it is not likely that a non-state actor would be able produce special nuclear material undetected by the international community. The infrastructure, technical, and economic requirements are too significant for non-state actors. Many states, such as Libya, Iraq, and Egypt, have attempted to develop their own nuclear weapons program and were unsuccessful for a variety of reasons.[9]

Subsequently, a non-state actor would, in all likelihood, attempt to acquire the SNM via theft or purchase it from a nuclear weapons state. While SNM is heavily secured, there have been 21 incidents of attempted theft, acquisition, and diversion of highly enriched uranium (13), plutonium (3), and plutonium beryllium (5) from 1993 to 2015.[10] One such incident occurred in November 2007, when intruders breached a 10,000-volt security fence and stormed the emergency control center at the Pelindaba facility in South Africa where "supplies of weapons-grade uranium are stored" from the country's former nuclear weapons program.[11] This group of men accessed an electrical box and "circumvented a magnetic anti-tampering mechanism, disabled the alarms, cut the communications cable, and shut down power to a portion of the fence and to alarms on a gate just 250 feet away—opening a path for a vehicle to exit," while a second group of men breached the facility.[12] The men were unable to reach the uranium storage area, however, having run into an on-site firefighter who was able to keep the intruders at bay while calling for help. No one was ever arrested, and no terrorist organization ever claimed responsibility for the incident. If the material had been stolen, however, it could have been smuggled, like IED precursors, out of the country. And while SNM is the critical obstacle, a non-state actor would still face several knowledge and material hurdles, if the material were acquired.

The alternative acquisition option for non-state actors, therefore, would be via transfer from a state actor. There are not many states that currently possess nuclear weapons, so the threat of this option is low. Additionally, the scarcity of SNM makes attribution unavoidable. The 2018 U.S. Nuclear Posture Review highlights the nuclear forensics attribution program as a critical component of U.S. national strategy for deterrence.[13] Attribution uses the chemical and radiological isotope fingerprints that become embedded in the SNM through its production method. These fingerprints are traceable back to the material's origin regardless of whether or not it is highly enriched uranium or plutonium. The ability to trace material back to a state makes it unlikely that a state would willingly provide a non-state actor with a nuclear weapon since the consequences of attribution back to the state are too high.

In summary, the requirements to develop a nuclear weapon are currently so great that a non-state actor would not be able to develop one on his/her own. It is also not probable that a state would provide a significant quantity of special nuclear material, let alone a weapon, to a non-state actor. The risk of attribution to both the non-state actor and the supplying state is too high.

Biological Weapons

Similar to nuclear weapons, which require fissile material, biological weapons require an agent. The agent can be a toxin, virus, or bacterium.[e] Unlike nuclear weapons, however, acquisition of a biological agent is not the most difficult or time-consuming issue. The truly difficult hurdle for biological weapon production is developing large quantities of the desired agent at a sufficiently high

d Calculation for amount of natural uranium: (25 kg U235)(1 kg natural uranium / 0.007 kg U235) = 3,571 kg natural uranium.

e The U.S. Centers for Disease Control and Prevention delineates biological weapons agents into three categories, or levels, based on the risk they pose to national security. Level A agents make up the highest level and are agents that can be easily disseminated or transmitted person to person, have a high mortality rate, and present the greatest possible impact to public health. These agents include but not limited to Anthrax, Ebola, Smallpox, and Botulism. Level B agents are moderately easy to disseminate, have what are considered moderate morbidity rates, and low mortality rates Level B agents include Ricin toxin, Glanders, and Q fever. Finally, Level C agents are characterized as emerging pathogens that could be engineered for use as a WMD and are categorized based on their availability and ease of production and dissemination, along with high potential for mortality. This includes Nipah virus and Hantavirus. "Bioterrorism Agents / Diseases," Centers for Disease Control and Prevention.

purity threshold for the resulting weapon to be employed. Both viruses and bacteria are pathogenic, and the required complexity to weaponize these agents is greater than toxins. Weaponization of any biological agent, however, takes knowledge, technical skill, and specific infrastructure.

Each agent has its own advantages and disadvantages. A toxin, such as ricin, is easy to extract from castor beans; however, to do so at sufficient purity and at a large scale is difficult. Additionally, it is not easy to disseminate this toxin across a large population, and consequently, it is better 'suited' for targeted assassination by a terrorist organization. Furthermore, the potential agent dictates the possible employment methods since some agents cannot be aerosolized so ingestion is required.

All biological agents are naturally occurring.[f] While it is not necessarily difficult to acquire a biological weapon agent, employment is difficult. Anthrax, for example, can be found in soil worldwide and particularly in agricultural areas. These rod-shaped, gram-positive bacteria, however, are in its spore, or dormant, form. Anthrax spores become "activated" once ingested by an animal where it begins to grow using surrounding nutrients.[14]

A terrorist might easily obtain Anthrax spores from a soil sample, but a single sample is not enough to be effective. Anthrax is not contagious like the flu virus where it is passed via human-to-human contact. A single Anthrax spore if inhaled or ingested can be fatal, but the probability of inhaling that single spore is extremely low. Consequently, the density of spores in the air needs to be dramatically increased in order for it to be used as a weapon. Scientific knowledge and a laboratory are required to activate the Anthrax, allow it to replicate, and then return the bacteria to its spore form in order to disseminate it.

Infrastructure is critical for developing a biological weapon agent, particularly in terms of controlling the environment, as are personal protective measures such as supplied air and hoods. Unlike Anthrax, most viable weapons agents do not have a dormant phase and will die outside of a host for a variety of reasons, including temperature variation, ultraviolet light (sun) exposure, oxygen/carbon dioxide concentrations, and lack of access to nutrients. At a bare minimum, a lab requires incubators, containment hoods, refrigeration and freezer capabilities, pipettes, benchtop centrifuges, growth medium, and glass/plastic flasks. The specific quantities and capabilities of the equipment are all dependent on the scale of production as well as the agent itself. That said, a graduate-level microbiology lab would have all of the necessary equipment.

The knowledge and technical skill required to manipulate and grow an agent is just as important as infrastructure. Simply reading a few scientific articles would not suffice. The procedure outlined in a scientific journal, for example, would fail to highlight the nuances that can affect the efficiency of reagents—such ambient environmental factors as pressure and humidity—that a trained professional would understand. Direct knowledge of and experience with the laboratory equipment are critical; bacteria and viruses are living organisms that can quickly degrade if not maintained properly.

Figure 1 highlights the gap between toxin and pathogenic agents that non-state actors encounter. As demonstrated by the abundance of incidents worldwide, ricin is perhaps the easiest biological toxin for non-state actors to acquire. A few notable ricin producers that demonstrate the ease of production and the minimum amount of technical skill required for weaponization include Shannon Richardson, a part-time actress from Texas in 2013, and James Dutschke, a karate instructor from Tupelo, Mississippi, in 2014.[15] Additionally, Sief Allah H. was arrested by German officials in June 2018 on suspicion of planning an "Islamic-motivated attack" after he tested ricin on a hamster.[16] Pathogenic biological agents have rarely been employed by non-state actors—the two notable exceptions being the 1984 Rajneeshee attack in Dalles, Oregon, and the Aum Shinrikyo's 1993 Anthrax release in Tokyo. While the Rajneeshee attack hospitalized hundreds for "food poisoning," the Anthrax attack failed to injure anyone due to the strain of Anthrax the group aerosolized.[17]

In summary, due to the technical skill, knowledge, and infrastructure required to develop pathogenic biological weapons agents, there remains a hurdle that non-state actors, such as the Islamic State, are not able to overcome. This gap, however, is not insurmountable, particularly if proliferation of these agents is assisted by profit-minded suppliers.

Chemical Weapons

Akin to biological weapons agents, chemical weapons agents can be characterized by their weaponization complexity. Blister agents, such as sulfur mustard, are easier to develop and employ than nerve agents, like VX and sarin. While there are less requirements for chemical weapons development than nuclear and biological weapons, there are still the obstacles of leadership support, knowledge, technical skill, and materials. The Islamic State was able to manufacture and employ sulfur mustard, a blister agent, on multiple occasions from 2013 to 2017 against civilian and coalition targets.[18] Comparatively, Aum Shinrikyo was able to develop and employ sarin, a nerve agent, in the Tokyo subway in 1995.[19]

The attacks by the Islamic State and Aum Shinrikyo highlight the different levels of technical skill, knowledge, and infrastructure available to each group. In terms of technical skill, knowledge, and leadership, Aum Shinrikyo's primary personnel for its chemical weapons program were Seiichi Endo and Masami Tsuchiya. Seiichi Endo was the cult's "health and welfare minister." He was a virology graduate student at Kyoto University when he joined the cult and reportedly began working on its biological and chemical weapons program as early as 1990.[20] Masami Tsuchiya, the lead chemist for Aum Shinrikyo, received his master's degree in physical and organic chemistry from the University of Tsukaba in Japan. According to Judge Satoru Hattori, Masami Tsuchiya "made all of the chemical weapons used in the [sarin] attack."[21]

While it is clear that Aum Shinrikyo possessed the requisite personnel with both the knowledge and skill to development chemical weapons, the group also needed infrastructure, which in this case was a clandestine laboratory. Authorities discovered two such laboratories belonging to the cult: one on a farm in Australia and the other in a small village near Mount Fuji. At the Australian farm, chemicals were manufactured and then subsequently tested on sheep. The Organisation for the Prohibition of Chemical Weapons (OPCW) reported that "the South Australian Forensic Science

f There is one exception. Smallpox was eradicated through a World Health Organization vaccine program in the 1970s. The virus was declared eradicated in 1980 with the last known case to have occurred in 1977 in Somalia. Currently, the only two known samples of Smallpox are stored at the Center for Disease Control and Prevention in the United States and State Research Center for Virology and Biotechnology in Russia. "Smallpox," World Health Organization.

Laboratory detected sarin hydrolysis products from soils and sheep wool,"[22] meaning Aum Shinrikyo was testing its nerve agent on animals in preparation for use. The laboratory near Mount Fuji was found to have a network of thick pipes, three cooling towers, and the "ventilation system and fixtures ... said to be those of a modern laboratory, with computer-controlled systems."[23] The sophisticated environmental controls at the Mount Fuji laboratory enabled the facility to go unnoticed by the surrounding population, while the remoteness of the Australia lab itself provided that facility with its protection.

The Islamic State and its chemical weapons program faced different challenges that directly affected its access to infrastructure, raw materials, technical skill, and knowledge. It is these challenges that likely limited the Islamic State's chemical weapons program to producing sulfur mustard, which is less complex chemically than nerve agents. The Islamic State recruited those whom it could find on the battlefield. Suleiman al-Afari was a 49-year-old geologist for Iraq's Ministry of Industry and Minerals in Mosul when militants appeared.[24] According to reporting by *The Washington Post*, al-Afari had hoped to keep his regular job, but was instead offered the opportunity to "help us [the Islamic State] make chemical weapons."[25] While not a chemist, al-Afari did have a STEM[g] background and could contribute knowledge and some technical skill. His story is not unique. The Islamic State developed its chemical weapons program in "university laboratories and manufacturing facilities with a cadre of scientists and technicians."[26]

The different paths to chemical weapons for Aum Shinrikyo and the Islamic State highlight the level of support required. Aum Shinrikyo had skilled and knowledgeable personnel within its organization, whereas the Islamic State struggled in this regard. Aum Shinrikyo also had access to both money and infrastructure that enabled it to develop its sarin clandestinely in Japan and Australia. Even though the Islamic State had access to money, it lacked the ability to set up the requisite infrastructure in the towns and villages of Iraq and Syria in order to build an effective chemical weapon.[27] Consequently, the Islamic State's sulfur mustard, though deadly, was crude and contained impurities that degraded its effectiveness.[28]

The Islamic State was likely dependent on a transnational network that supplied components for its IEDs to also provide the disulfur dichloride, a precursor for sulfur mustard. This compound is used in the manufacture of synthetic rubbers and dyes and when reacted with ethlyene can produce sulfur mustard and equal quantities of sulfur impurities.[29] There is little difference in the requirements for moving chemical precursors for an IED and the precursors required to make a chemical weapon. Thus, potential for convergence between an IED facilitation network and the development of chemical weapons is high.

Risk of Convergence

While gaps currently exist for non-state actors to develop nuclear, biological, or chemical weapons, the threshold for some is being lowered. Convergence of an IED facilitation network supplying the personnel, material, infrastructure, and financial support is lowering that threshold. There are more opportunities for the profit-minded supplier via transnational networks to illicitly circumvent treaty and trade restrictions meant to stop the proliferation of WMDs. And as stated in the first profit-minded supplier article, "while the taboo associated with WMD may deter some suppliers, other are likely to remain focused on the profits."[30] Regardless of convergence, nuclear weapons will likely remain out of the hands of non-state actors. The requirements for producing SNM are too great for a non-state, nor is a state likely to part with its SNM.

Convergence, especially when driven by the opportunity for profit, can and will directly assist non-state actors in developing their own biological and chemical weapons. Certain types of weapons, such as nerve and pathogenic agents, will remain out of the grasp of non-state actors due to their manufacturing requirements and will remain beyond the grasp of all both the most sophisticated non-state actors. Other types such as toxins and blister agents can be easily developed and employed. Perhaps, the biggest limitation for development of nerve and pathogenic agents is not a lack of convergence but a willingness and understanding of the requirements of non-state actors. Convergence can lower the hurdles for the development of chemical and biological weapons and will continue to do so.

Conclusions

Knowledge, materials, infrastructure, personnel, finances, and lines of communications are all components of both a WMD proliferation and IED facilitation network. All of these components can be acquired for the right amount of money. And while convergence with transnational networks for WMD proliferation can help non-state actors overcome some of the hurdles required for WMD development and employment, it will not overcome all of them. There is a risk of exposure and potentially attribution from the international community that both the profit-minded supplier and the non-state actor consider when conducting business. To reduce the risk of exposure, it is likely that the non-state actor desiring the WMD will use multiple transnational networks in order to reduce the acquisition signature visible to the intelligence community.

Convergence will likely take the path of least resistance that maximizes the profits for the supplier. Specifically, the acquisition of special nuclear material required to make a nuclear weapon is too difficult to overcome, but the ease of moving chemical precursors is minimal, especially considering the dual-use nature of most chemicals. Convergence will assist non-state actors in developing and employing biological and chemical weapons with minimal complexity. Its biggest contribution is likely to be raw materials and knowledge similar to current IED proliferation.

Combating convergence of these two networks is difficult because much of the critical material and information required for development of a WMD is not illegal, such as knowledge of a chemical process or possession of precursors such as disulfur dichloride. No single entity within the U.S. government alone, for example, will be able to combat convergence and WMD proliferation single-handedly. There are programs, such as the Proliferation Security Initiative (PSI) and the Australia Group along with United Nations Security Council Resolution 1540, designed to fight WMD proliferation, yet proliferation has still occurred.[h] As technology progresses and information disseminates worldwide, the threshold limiting WMD

g Science, Technology, Engineering, and Mathematics.

h United Nation Security Council Resolution 1540, which was passed in 2004, states that "all States shall refrain from providing any form of support to non-State actors that attempt to develop, acquire, manufacture, possess, transport, transfer, or use nuclear, chemical, or biological weapons." This resolution also requires States to "adopt and enforce appropriate laws to this effect."

proliferation will be lowered. As stated in the authors' previous article, "there are strong arguments for expanding ongoing efforts that address IED facilitation networks, including applying lessons learned, to anticipate the potential for these same networks to proliferate the knowledge, material, financing, and access to infrastructure required for WMD development and employment."[31] CTC

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