

# Learning to build the bomb

Alisa L. Carrigan

**Alisa Carrigan** (alisa.carrigan@gmail.com) holds a PhD in war studies from King's College London and was a visiting fellow at the Center for International Security and Cooperation at Stanford University in California. She currently works for FirstWatch International.

**At the end** of the cold war in 1991, the US and its allies realized that the former Soviet Union had thousands of unsecured nuclear weapons, tons of unguarded fissile material, and unemployed nuclear weapons scientists. The materials and expertise necessary for a so-called rogue state or terrorist group to build a nuclear weapon were readily accessible.

So the US set about helping the former Soviet states secure their weapons, materials, and scientists through various facets of the Cooperative Threat Reduction program. Several CTR projects were aimed specifically at preventing a mass exodus of former Soviet scientists to rogue states by reemploying them on peaceful projects—and thus taking away the temptation to sell their weapons expertise to any state that came recruiting.

But 15 years on, the reemployment programs have made slow progress in the former Soviet Union; official US government reports and various academic studies attest to that fact.<sup>1</sup> And yet the feared mass exodus of scientists to rogue states never happened (but plenty of former Soviet scientists emigrated to Western states), even though Libya, North Korea, and Pakistan were building nuclear weapons programs and were presumably in need of nuclear expertise. Now Iran is also building an enrichment program, and perhaps more. If those states were not recruiting unemployed former Soviet scientists with experience designing and building nuclear weapons, then where did they—and where would potential nuclear-weapons states—get their nuclear workforce?

## How do we learn?

Knowledge about anything—including nuclear weapons—can be disseminated either explicitly or tacitly. Graham Spinardi and Donald MacKenzie define explicit knowledge as “information or instructions that can be formulated in words or symbols and, therefore, can be stored, copied and transferred by impersonal means, such as in written documents or computer files.”<sup>2</sup> They define tacit knowledge, on the other hand, as

“knowledge that has not been (and perhaps cannot be) formulated explicitly and, therefore, cannot effectively be stored or transferred by entirely impersonal means.”

During World War II, when Soviet spies stole US blueprints and other documents that gave specifications for building an atomic weapon, the Soviet Union gained explicit knowledge that it used in early nuclear experiments. The spread of such explicit knowledge since then has been extraordinarily helpful to a number of national nuclear programs. For example, the centrifuge work of Iraqi scientists was aided by the specifications in a 1960 report by Gernot Zippe.<sup>3</sup>

Some scientists claim that when building a nuclear weapon, tacit knowledge is even more important than explicit knowledge. An individual can gain tacit knowledge either through his own experience and practice or by learning it from someone else who possesses it. Transmitting tacit knowledge can be difficult, so it is best done in person. Both the building of nuclear weapons and maintenance of the stockpile are facilitated by having individuals with tacit nuclear knowledge to teach others the processes. Tacit knowledge can accelerate the overall success of a program, may help a nation overcome potential safety issues, and may even help keep a program clandestine by reducing both the number of experiments and the need for extra materials.

The importance of tacit knowledge is exemplified by the Iranian centrifuge program. Although the Iranians had all the materials they needed to manufacture centrifuges, they encountered a problem that they initially had trouble diagnosing: A significant number of their centrifuges became unbalanced and were destroyed—“turned to powder,” as Gholam-Reza Aqazadeh, the head of the Atomic Energy Organization of Iran, put it.

The engineers had no idea what caused the imbalance. After some time and effort, the engineers discovered the explanation: The technicians who assembled the centrifuges' many parts weren't wearing fabric gloves during

the assembly phase. Because they used their bare hands, minute amounts of sweat and skin were transferred to the centrifuge assembly. Although a single drop of sweat may seem insignificant, it is more than enough to unbalance and destroy a centrifuge rotating at 60 000 to 80 000 RPMs—hence the necessity of gloves for assembly technicians.<sup>4</sup>

The Iranians had plenty of information about how to build centrifuges, but they still lacked some of the intangibles—the seemingly inconsequential information like the necessity of wearing gloves—that often separate a working nuclear program from one that never succeeds. They were able to discover this information themselves, through trial and error, though they lost a number of centrifuges and probably weeks of working time in the process.

What this example illustrates is the specialized knowledge—even more than what's available in open literature—required to build even a single stage in a homegrown nuclear weapons program. States must somehow recruit or train people to produce fissile materials, to make those into weapons packages, and to couple the weapon with a delivery system. Most of the explicit knowledge is available; but where do states turn to obtain the tacit knowledge that distinguishes a successful program?

## Where do we learn?

The answer is surprising, and in direct contravention to current US and international thought. Among states that successfully build nuclear weapons or make significant progress toward their construction, the necessary scientists and engineers almost always come from the state itself. And they are almost never recruited from abroad. But in many cases a significant number of a country's first generation of nuclear scientists are trained abroad, and then they return to work on their indigenous nuclear program.

Take the case of South Africa: That country was a textbook example for how to build a national nuclear weapons program from the ground up. It is also a perfect illustration of how ca-

pable scientists with relevant training, often acquired abroad, can take a peaceful technology and divert it to a weapons program. (To this day, the South African nuclear energy and enrichment programs are at the core of the country's economy, but the government dismantled its nuclear weapons in the early 1990s.)

In the 1950s South Africa already had a core of scientists who had been educated in the country and understood the theoretical underpinnings of a peaceful nuclear program. But they didn't yet know how to build or run a nuclear program, either for peaceful purposes or for building weapons. As a result, South Africa looked to its Western nuclear counterparts for assistance, and through colonial links and the US's desire to spread the benefits of peaceful nuclear knowledge, South African scientists were exposed to the nuclear work going on in European and American laboratories. They even managed to work side by side with scientists from the Manhattan Project in some cases, though the bulk of their training was restricted to peaceful nuclear technologies. Ultimately, South Africa wanted to be able to produce fissile materials and weapons indigenously, but the government was initially forced to look abroad for the necessary nuclear training while it built up its own training programs.<sup>5</sup>

Waldo Stumpf, a former head of the South African Atomic Energy Board (AEB), told me, "In the early 1960s, a number of [students] were sent overseas for general postgraduate training. . . . A few were posted to overseas nuclear facilities as part of the Atoms for Peace Program sponsored by the US." Stumpf himself was sent by the AEB to Karlsruhe, Germany, where he worked on the German national fast breeder reactor program and then brought his knowledge back to use in South Africa. Five South African laboratory heads were trained in the US at Argonne National Laboratory, and at least one of those men, J. W. de Villiers, eventually became the head of the AEB.

The South African case illustrates the most prominent trend among states that successfully build their own nuclear programs: Although those states often educate their own scientists, while the program is maturing they send them abroad for specific training in nuclear laboratories whose work may be relevant to weapons. Then they bring the trained scientists back home to build up the national program, and thus lessen the need for foreign train-

ing over time. And successful nuclear states almost never recruit foreigners to work on any significant part of their programs.

In fact, the pattern of sending some scientists abroad to learn as much as possible about building a nuclear program (often under the guise of an energy program) during that program's early years is seen in almost every successful nuclear state, from the UK, France, and China in the 1950s to Pakistan, India, Iraq, and Iran at present. And yet the pattern has apparently been ignored as a potentially important piece of the proliferation puzzle.

## Knowledge proliferation

Iran is one of the highest-profile tests of the nuclear nonproliferation regime at the moment, and it conforms almost perfectly to the pattern laid out by successful nuclear states. Iran has a good educational system that produces capable graduates and a developing scientific complex. Additionally, Iran has been sending numerous scientists and engineers abroad—most often to Russia, but also to Pakistan—for training in nuclear-related areas.

In spite of this pattern being repeated over and over, policymakers don't seem to take it into account when designing nonproliferation programs that address the dissemination of nuclear expertise.

The US CTR program gave grants to some of Russia's senior weapons scientists so they could continue to work and wouldn't be tempted to migrate to a rogue state to help with its nuclear weapons program. Other CTR programs were aimed at opening up Russia's closed nuclear cities and building industrial partnerships between Russian scientists and Western corporations, again to keep scientists from migrating with their nuclear expertise.<sup>6</sup>

Unfortunately, the US and Russia were so concerned about weapons scientists leaving Russia that little was done to monitor who might be entering the country for training. As recently as 2003, the Russians had trained hundreds of Iranian scientists and engineers at their nuclear reactor sites.

Where else are would-be nuclear-weapons states sending their scientists for nuclear training? And might the international community be missing this proliferation of nuclear knowledge because the community is looking for scientists going out rather than scientists coming in?

Although the spread of nuclear knowledge—especially tacit knowl-

edge—seems to continue unabated, the international community can still do a few things to prevent its dissemination.

► Be aware that the spread of nuclear expertise is just as problematic for the nuclear nonproliferation regime as is the spread of nuclear materials. Even if the international community can cut off the supply of materials completely, people with nuclear weapons knowledge can make more materials. We don't ignore the spread of materials, so why do we turn a blind eye to the spread of the knowledge necessary to make and manipulate those materials?

► Involve more states in the international system of export controls, and tighten those controls to keep a more careful watch on the transfer of not only dual-use material, but dual-use technologies and knowledge as well.

► Member states of the International Atomic Energy Agency, the UN's nuclear watchdog, should supply it with more information on who is going where to work or train and what types of scientific collaboration are being carried out. The added details will help the IAEA paint a much clearer picture of nuclear proliferation activities around the world.

Taken together, these three steps will help strengthen the nonproliferation regime against the further spread of nuclear weapons knowledge. It is unlikely that the international community can stop the dissemination of nuclear weapons knowledge altogether. But we can have a much clearer picture of what potential nuclear states are really doing if we examine not only their material acquisitions but the foreign training they acquire for their scientific cadre as well.

## References

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