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Iran's Work and Foreign Assistance on a Multipoint Initiation System for a Nuclear Weapon

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The November 8, 2011 International Atomic Energy Agency (IAEA) safeguards report on Iran identifies a foreign expert that may have been important to Iran's development of implosion detonation systems used in nuclear weapons. The Agency writes in the report that it has "strong indications that the development by Iran of the high explosives initiation system, and its development of the high speed diagnostic configuration used to monitor related experiments, were assisted by the work of a foreign expert who was not only knowledgeable in these technologies, but who, a Member State has informed the Agency, worked for much of his career with this technology in the nuclear weapon programme of the country of his origin."

Information in other IAEA documents reviewed by ISIS identifies this person as Vycheslav V. Danilenko.[1] Born in 1934, Danilenko worked in the nuclear weapon complex at VNIITF, Chelyabinsk-70 for three decades. At VNIITF in the early 1960s, he was a member of the gas dynamics group and became involved in the study of the manufacture of synthetic diamonds. He worked with leading explosives experts in the Soviet nuclear weapons program and developed understanding of the fundamentals of detonation, including shock compression. In 1960, the head of VNIIF, B. I. Zababakhin, launched the institute's research into the possibility of diamond synthesis by using the shock compression of graphite. Leading Soviet nuclear weapons experts were leaders in this effort in the early 1960s. In a recent book chapter Danilenko says that "experiments aimed at developing methods for synthesis were highly classified; for security reason, the results were initially contained only in secret reports from VNIITF."[2] According to IAEA officials, he likely had knowledge of the application of high explosives in the Soviet nuclear weapons program. Given his background and experience, this ex-Soviet nuclear weapons expert was well versed in key aspects of developing nuclear weapons.

Danilenko also has experience in the important area of the diagnostics of high explosions. His publications include work on high-speed photography and describe optical techniques by which fiber optic cables are used to capture the time of arrival of explosive shock waves.

[1] Paul-Anton Krueger was the first to identify Danilenko, although not by name, in an article in *Sueddeutsche Zeitung*, February 5, 2010. The article discussed among other topics the Iranian multipoint initiation system to which Danilenko is alleged to have contributed.
[2] Olga A. Shenderova and Dieter M. Gruen (editors), *Ultracrystalline Diamond: Synthesis, Properties and Applications* (Norwich, NY: William Andrew Publishing, 2006).

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After leaving VNIITF in either 1989 or 1991, Danilenko moved to Ukraine and established the company ALIT in Kiev, producing ultra-dispersed diamonds (UDD or nanodiamonds). He experienced economic difficulties by the mid-1990s. According to the IAEA, he contacted the Iranian embassy in mid-1995, offering his expertise on UDD. At the end of the year, he was contacted by Dr. Seyed Abbas Shahmoradi, who headed the Physics Research Center and also worked at the Sharif University of Technology.[3] Danilenko signed a contract with Shahmoradi, according to IAEA documents.

As head of Iran's secret nuclear sector involved in the development of nuclear weapons, Shahmoradi would have undoubtedly recognized Danilenko's value to an incipient nuclear weapons effort. Synthetic diamond production is unlikely to have been a priority, although it has obvious value as a cover story. In assessing the important contributions make by scientists and engineers to secret proliferant state nuclear programs, ISIS has not found any that did not initially offer other, more benign assistance that provided a plausible cover for their secret nuclear assistance. In some cases, their intention was originally benign but they were lured by money to assist in sensitive nuclear areas.

According to the recent IAEA safeguards report, Danilenko worked in Iran from about 1996 until about 2002, "ostensibly to assist Iran in the development of a facility and techniques for making UDD, where he also lectured on explosion physics and its applications." He told the IAEA that he lectured and constructed an explosive firing cylinder which was not designed for experiments on spherical systems. In 2002, he returned to Russia.

The IAEA has reviewed publications by Danilenko and has met with him. It has been able to verify through three separate sources, including the expert himself, that he was in Iran during that time. Danilenko told the IAEA that he does not exclude that his information was used for other purposes.

At the very least, Danilenko had reason to know or should have known exactly why the Iranians were interested in his research and expertise. The IAEA information suggests he provided more than he has admitted.

Nature of Assistance

The IAEA obtained additional information that adds credibility to the conclusion that Danilenko used his technical and practical knowledge and expertise to provide assistance to Iran's program to develop a suitable initiation system for a nuclear explosive device. The IAEA assessed that a monitoring, or diagnostic, technique described in one of his papers had a remarkable similarity to one that the IAEA saw in material from a member state about a hemispherical initiation and explosives system developed in Iran (see below). This system is also described in the IAEA safeguards report as a multipoint initiation system used to start the detonation of a nuclear explosive.

The system that the IAEA says Iran was developing prior to 2004 was relatively sophisticated and small in diameter. Iran is unlikely to have been able to design it on its own. According to the November 2011 IAEA safeguards report, Iran is also believed to have obtained information from the A.Q. Khan network on nuclear weapons design. But the initiation and explosive system is sufficiently sophisticated that it points to a contribution from Danilenko.

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[3] Seyed Abbas Shahmoradi is currently associated with Malek Ashtar University.

The multipoint initiation system has a distributed array of explosive filled channels on an aluminum hemisphere which terminate at holes containing explosive pellets. The pellets simultaneously explode to initiate the entire outer surface of a high explosive component in hemispherical form. The experiments used a multitude of fiber optic cables and a high speed streak camera to measure the time of arrival of first light across the inner surface of an explosive component, thereby deducing the smoothness of the detonation front at this surface.

The IAEA also obtained from member states details of the design, development, and possible testing of what is called in IAEA information the R265 shock generator system, which is a round multipoint initiation system that would fit inside the payload chamber of the Shahab 3 missile tri-conic nose cone. This device involves a hemispherical aluminum shell with an inside radius of 265 mm and wall thickness of 10 mm thick. Outer channels are cut into the outer surface of the shell, each channel one by one millimeter, and contain explosive material. Each channel terminates in a cylindrical hole, 5 mm in diameter, that is drilled though the shell and contains an explosive pellet.[4] The geometrical pattern formed by channels and holes is arranged in quadrants on the outer hemispheric surface which allows a single central point of initiation and the simultaneous detonation of explosives in all the holes on the hemisphere. This in turn allows the simultaneous initiation of all the high explosives under the shell by one exploding bridgewire (EBW). If properly prepared, the R265 constitutes the outer part of an explosively driven implosion system for a nuclear device. The outer radius of the R265 system is 275 millimeters, or a diameter of 550 millimeters, less than the estimated diameter of about 600 millimeters available inside the payload chamber of a Shahab 3 (or the Sejjil-2 missile).[5]

In one of the slides of Project 111's presentational material in the possession of the IAEA, a photo shows an aluminum support plate with R288 written on it that is for a payload undergoing machining.[6] The implication is that the R265 system could be attached to this support plate that is fixed to the payload chamber.

According to information provided to the IAEA, the testing of the R265 system involved evaluating the uniformity of the time of arrival of the detonation front, which is measured at the inner surface of 50 kilograms of composition B hemispherical explosive charge located inside the aluminum hemisphere. Hundreds of fiber optic cables are placed in another thin hemispherical shell placed in proximity of the inner surface of the high explosive. The other end of the fiber cables go to a fixture for a rotating mirror that is part of a high speed streak camera.

When the EBW detonator is fired in the center of the hemispherical shock generator, the complex explosive distribution system initiates the high explosive charge. The detonation front travels through the composition B explosives and on exiting produces light, which is captured on film in the streak

[4] PETN-based explosives.
[5] *IISS Strategic Dossier: Iran's Ballistic Missile Capabilities: A Net Assessment* (London: International Institute for Strategic Studies, May 10, 2010).
[6] Project 111 was involved in 2003 with the design of the inner cone of the Shahab 3 missile re-entry vehicle and the production of an explosives operations control set (ECS) for a new payload. It is an engineering operation to accommodate a warhead into the Shabab 3 re-entry vehicle and understand flight dynamics and arming and fusing.

camera via the fiber optics cables, allowing a determination of smoothness of the converging shockwave.

With this system, Iran would need only two EBWs to initiate a nuclear explosion. This system may have been tested in 2003, which is discussed further below. In any case, the IAEA assessed that this information suggests Iran developed an effective high explosive implosion system which can fit within the payload container of the reentry vehicle of the Shabab 3. However, IAEA officials also assessed that this system was not finished when the program abruptly halted in 2003 (see below).

Recent IAEA Safeguards Report

The November 2011 IAEA report does not discuss the R265 system explicitly. However, it appears to discuss it in general terms. According to the recent IAEA safeguards report, the IAEA has shared with Iran information that indicates that Iran has had access to information on the design concept of a multipoint initiation system that can be "used to initiate effectively and simultaneously a high explosive charge over its surface." The IAEA has been able to confirm independently the existence of a multi-point initiation design concept and the country of origin of that design concept. Furthermore, nuclear-weapon states have informed the IAEA that the specific multipoint initiation concept is used in some known nuclear explosive devices.

The IAEA also received information from a member state that Iran tested this multipoint initiation concept in "at least one large-scale experiment in 2003 to initiate a high explosive charge in the form of a hemispherical shell." Further, "the internal hemispherical curved surface of the high explosive charge was monitored using a large number of optical fibre cables, and the light output of the explosive upon detonation was recorded with a high speed streak camera. It should be noted that the dimensions of the initiation system and the explosives used with it were consistent with the dimensions for the new payload which, according to the alleged studies documentation, were given to the engineers who were studying how to integrate the new payload into the chamber of the Shahab 3 missile re-entry vehicle (Project 111)." Further information provided to the IAEA by the same member state indicates that the large-scale high explosive experiments were conducted by Iran in the region of Marivan.

The IAEA has provided Iran with this information. However, in a 117-page submission to the IAEA in May 2008, Iran stated that it did not understand the subject and had not conducted any activities of the type referred to in the document.

Parchin

The IAEA also reported in its recent report that information from member states indicates that Iran constructed a large explosives containment vessel or chamber at the Parchin military complex in 2000 to conduct high explosive and hydrodynamic experiments. The latter are experiments conducted in which fissile and nuclear components may be replaced with surrogate materials. After constructing the chamber, Iran constructed a building around the large cylindrical object. According to the report, "a large earth berm was subsequently constructed between the building containing the cylinder and a neighboring building, indicating the probable use of high explosives in the chamber." The IAEA has obtained commercial satellite images that are consistent with this information. From independent evidence, including a publication by Danilenko, according to the report, "the IAEA has been able to confirm the date of construction of the cylinder and some of its design features (such as its dimensions), and that it was designed to contain the detonation of up to 70 kilograms of high explosives." This cylinder would be suitable for carrying out experiments containing the amount of explosive in the R265 system described above.

The IAEA report did not provide Danilenko's involvement, if any, in this chamber. On November 11, 2011, the Associated Press reported that his involvement may have extended to this chamber. Diplomats in Vienna at the IAEA told the Associated Press that Danilenko's son-in-law had told the IAEA Danilenko also helped Iran build a large steel chamber to contain the force of the blast set off by high explosives testing.[7] The son-in-law reportedly said that the container was built under Danilenko's direct supervision.

The IAEA became suspicious about Parchin in 2004 and investigated whether Iran was conducting high explosive testing there, possibly with nuclear materials. After at first resisting, Iran allowed the IAEA to make two partial, highly controlled inspections of a portion of the Parchin complex. The IAEA, along with ISIS, had used commercial satellite imagery to identify a number of areas of interest. None of the buildings visited by the IAEA, however, included the location now believed to contain the building which houses the explosives chamber. Consequently, the IAEA's visits did not reveal facilities or activities of relevance.

A Potential Test Site

The IAEA received a schematic diagram for an underground testing site that is 400 meters deep with a control unit 10 kilometers away. The diagram shows the placement of a high voltage power generator. The information shows the development of a remote system for firing an object in the 400 meter-deep shaft. Text accompanying the diagram calls for the simultaneous remote firing of two spark gap detonators. Although EBWs are safer, both methods would work. Is this related to the two EBWs needed to set off the two halves of the R265 system?

According to the November 2011 safeguards report, the IAEA has been informed by another member state that these arrangements directly reflect those which have been used in nuclear tests conducted by nuclear-weapon states. IAEA officials assessed that this information is most likely related to testing a nuclear explosive device, although it reflects the conceptual development of a test rather than representing an engineering drawing or plan.

Post-2004 Work

Information available to the IAEA makes clear that Iran's nuclear weaponization effort stopped abruptly, without finishing work on developing a reliable warhead for the Shahab 3. Although the report does not discuss the reason for such a halt, Iran was under intense pressure at that time to halt all its secret nuclear activities. The IAEA in 2003 was exposing a wide range of secret Iranian nuclear sites and activities and showing Iran's flagrant violation of its verification requirements under the Nuclear Non-Proliferation Treaty, actions highly embarrassing internationally to the Iranian regime. The United States had also just invaded Iraq, and Iran must have worried it could be next. As

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[7] George Jahn, "IAEA shows Iran nuke program intel to 35 nations," Associated Press. November 11, 2011.

a result of all this pressure, Iran agreed to suspend its uranium enrichment program in late 2003 and allow more intrusive IAEA inspections. It apparently also decided to shut down and hide its nuclear weaponization effort, something which the program's leader Mohsen Fakhrizadeh is known to have opposed. U.S. intelligence learned of his opposition to a halt, according to a European source, and his outspokenness is one of the more compelling reasons to believe the conclusion that Fakhrizadeh's program was halted.

However, the IAEA report outlines how Fakhrizadeh was able later to reestablish some activities under his leadership. According to the report, he retained leadership, "first under a new organization known as the Section for Advanced Development Applications and Technologies (SADAT),[8] which continued to report to MODAFL [Ministry of Defense Armed Forces Logistics], and later, in mid-2008, as the head of the Malek Ashtar University of Technology (MUT) in Tehran. The Agency was advised by a Member State that, in February 2011, Mr. Fakhrizadeh moved his seat of operations from MUT to an adjacent location known as the Modjeh Site, and that he now leads the Organization of Defensive Innovation and Research. The Agency is concerned because some of the activities undertaken after 2003 "would be highly relevant to a nuclear weapon programme."

One of those activities could involve the multipoint initiation system and Iran's nanodiamond project could be a front for such work. According to the report, the IAEA "has received information from two Member States that, after 2003, Iran engaged in experimental research involving a scaled down version of the hemispherical initiation system and high explosive charge referred to [above], albeit in connection with non-nuclear applications. This work, together with other studies made known to the Agency in which the same initiation system is used in cylindrical geometry, could also be relevant to improving and optimizing the multipoint initiation design concept relevant to nuclear applications."

Iranian nanodiamond research is centered at Malek Ashtar University of Technology, and not Sharif University of Technology, which does most of the materials science related research. One of these researchers is Saeed (Saeid) Borji, who was named by the National Council of Resistance of Iran (NCRI) as being associated with Iran's nuclear program. If one leaves aside the NCRI allegation, it is still relevant that so much nanodiamond work is conducted at Malek Ashtar University.

Final Note

On November 10, 2011, Reuters reported on an interview with Danilenko by the Russian newspaper, *Kommersant*. He reportedly stated to *Kommersant*, "I am not a nuclear physicist and am not the founder of the Iranian nuclear program." He reportedly refused to provide any additional information. It is not clear what questions Kommersant asked Danilenko, but the November IAEA safeguards report does not allege that Danilenko is a "founder" of Iran's nuclear program, as the program pre-dates the start of his assistance to Iran in the mid-1990s. Similarly, the IAEA never alleges that Danilenko is a nuclear physicist, but rather that he may have assisted Iran in the development of a spherical high explosives multipoint initiation system. It remains for Danilenko to more fully explain his assistance to Iran.

[8] On the ISIS web site, the acronym used is FEDAT.