Institute for Science and International Security
Report

Going for the Bomb: Part II, Tasks to Make a Crude Nuclear Weapon

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We have often been asked to describe timelines and unfinished tasks for Iran to build a nuclear weapon. Many of our publications have discussed these issues in detail.[1] This two-part report series discusses these issues. This report, Part II of the series, evaluates the tasks necessary to build a nuclear weapon, in particular a crude one, and adds some new thinking on those tasks. Part I discusses Iran's pathways to nuclear weapons.

The Iranian leadership has reportedly not made a formal decision to build nuclear weapons. But it is advancing its ability to weaponize nuclear material into a nuclear weapon, according to a recent Iran threat assessment by the U.S. Office of the Director of National Intelligence.[2]

A complicating factor is whether Iranian scientists and engineers are already working on aspects of nuclear weapons development without the formal approval of senior leadership, in essence getting ready, or even shortening timelines to build a nuclear weapon. This suspicion can be seen in part in our recent report that some former members of the 2000s production-scale nuclear weapons program, the Amad Plan, were working at former Amad nuclear weapons development sites on high explosive tests and technical research and development of a sensitive nature, without the approval of the senior leadership.[3]

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[1] David Albright with Sarah Burkhard and the Good ISIS Team, *Iran's Perilous Pursuit of Nuclear Weapons* (Washington, D.C.: Institute for Science and International Security Press, 2021) and Institute reports on Iran's nuclear archive (www.isis-online.org); David Albright, "How Quickly Could Iran Make Nuclear Weapons Today?" *Institute for Science and International Security,* January 8, 2024, https://isis-online.org/isis-reports/detail/how-quickly-could-iran-make-nuclear-weapons-today/8; and David Albright, "Iran Building Nuclear Weapons," *Institute for Science and International Security,* December 5, 2022, https://isis-online.org/isis-reports/detail/iran-building-nuclear-weapons/8.

[2] Office of the Director of National Intelligence, "Iran's Nuclear Weapons Capability and Terrorism Monitoring Act of 2022," July 23, 2024, https://www.dni.gov/files/ODNI/documents/assessments/ODNI-Unclassified-Irans-Nuclear-Weapons-Capability-and-Terrorism-Monitoring-Act-of-2022-202407.pdf.

[3] David Albright, Spencer Faragasso, and the Good ISIS Team, "Renewed Activity at the Sanjarian and Golab Dareh Amad Sites," *Institute for Science and International Security,* September 12, 2024, https://isis-online.org/isis-reports/detail/renewed-activity-at-the-sanjarian-and-golab-dareh-amad-sites.

Regardless of the potential muddiness of determining "time equal zero" of the start of a timeline of an Iranian effort to build a nuclear weapon, Iran will need to take a series of concrete steps to build its first and subsequent nuclear weapons.

As described in Part I of this report series, Iran has many pathways to building nuclear weapons using weapon-grade uranium (WGU), some of which require Iran to finish those tasks quickly, while others do not. Figure 1 summarizes the main pathways considered in Part I.

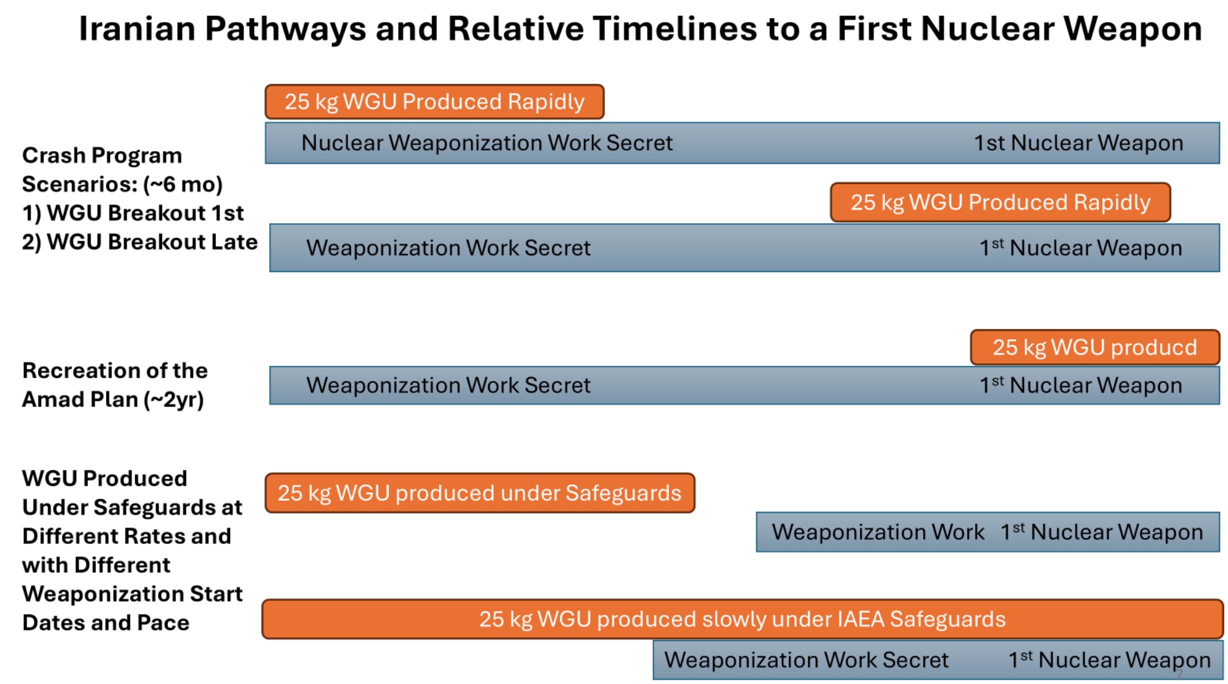

Figure 1. Iranian pathways to building nuclear weapons, where the orange bars represent the relative effort to make 25 kilograms of weapon-grade uranium (WGU), conservatively estimated as enough for a nuclear weapon, and the blue bars are the relative timelines to weaponize that weapon-grade uranium. Only the production of Iran's first nuclear weapon is considered here, but given Iran's capability to produce far larger amounts of weapon-grade uranium quickly, subsequent nuclear weapons could follow soon afterwards. It should be noted that the length of the bars is not proportional to the time to complete that task, either in an absolute or relative sense.

Iran faces two fundamental tasks in building a nuclear weapon. They are (1) acquiring the requisite amount of weapon-grade uranium for a nuclear weapon, conservatively taken here as 25 kilograms of WGU, and (2) building the nuclear weapon itself, commonly called nuclear weaponization, which in essence weaponizes the WGU. The nuclear weapon may be suitable for a nuclear test or crude delivery, a "crude" nuclear weapon, or able to be launched on a ballistic missile, a nuclear warhead.

Task 1: Nuclear Explosive Material: Weapon-Grade Uranium

Nuclear explosive material, sometimes referred to as fissile material, is the nuclear ingredient in nuclear weapons creating the atomic explosion. In the case of Iran, this material is weapon-grade uranium. Iran can rapidly produce weapon-grade uranium in what we refer to as breakout, by further enriching its safeguarded stocks of 20 and 60 percent enriched uranium to 90 percent or weapon-grade. As of September 2024, it could produce enough weapon-grade uranium for a nuclear weapon in seven days and have enough for six to nine nuclear weapons in a month, where the range depends on whether Iran uses only the deeply buried Fordow enrichment plant or both the Fordow and Natanz enrichment plants, respectively.[4] After more than twenty years of effort, Iran has mastered the process of making weapon-grade uranium—and of doing so quickly. That effort to develop the means to make weapon-grade uranium was started in the Al Ghadir project of the Amad Plan in the early 2000s, the project which launched the underground enrichment facility which we now know as the Fordow enrichment plant.

In a breakout, Iran would likely rely on its IAEA-safeguarded stocks of enriched uranium to make weapon-grade uranium in safeguarded centrifuges, triggering IAEA detection. However, Iran may delay the diversion's detection by a few to several weeks by denying inspectors access to these sites, such as Fordow, perhaps by falsely declaring a fire, an accident, or a security incident. In Fordow, less than two weeks would be enough time to produce sufficient WGU for four nuclear weapons,[5] and, as discussed above, a month would be long enough to make enough WGU for six. After producing WGU, Iran would likely move it to a secret site which may not be known to Western intelligence agencies.

In a breakout, the enrichment plants would produce WGU in the form of hexafluoride, or WGU hexafluoride ($WGUF_6$). It must be converted into WGU metal before being used in a nuclear weapon. To address this task, according to Nuclear Archive documentation, the Amad Plan had a material production project that started in June 1999. In early 2002, it was expected to finish in March 2003. The IAEA found that Iran had produced some 200 kilograms of natural uranium metal. Iran has demonstrated a more recent capability to make uranium metal via its ability to make both natural uranium metal and near 20 percent enriched uranium metal at IAEA-safeguarded uranium metal production lines at the Esfahan nuclear center. It produced small quantities of the latter during several months in 2021.[6] The production of 20 percent enriched uranium metal is nearly equivalent to making WGU metal instead. As a result of Iran's long development of the means to make uranium metal, as well as the experience it has gained in making it, converting WGU hexafluoride into metal form is not a bottleneck in Iran's nuclear weapons program. It is likely able to produce WGU metal.

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[4] David Albright, Spencer Faragasso, and Andrea Stricker, "Analysis of IAEA Iran Verification and Monitoring Report — August 2024," *Institute for Science and International Security,* September 9, 2024, https://isis-online.org/isis-reports/detail/analysis-of-iaea-iran-verification-and-monitoring-report-august-2024/8#fn3.

[5] "Analysis of IAEA Iran Verification and Monitoring Report — August 2024."

[6] "Analysis of IAEA Iran Verification and Monitoring Report — August 2024."

Task 2: Nuclear Weaponization Tasks

Iran accomplished so much on nuclear weaponization during the Amad Plan and afterwards, as documented by the Iran Nuclear Archive, the IAEA, and the media, that its timeline to building a nuclear weapon has been drastically shortened. Although the actual construction of the nuclear weapon, or "weaponization," typically poses less formidable challenges than acquiring the means to make plutonium or weapon-grade uranium, it requires overcoming many technical hurdles. Because Iran accomplished so much in the weaponization portion of the Amad Plan, it has only a few unfinished developmental tasks to complete before building a crude nuclear weapon.

For a reliable nuclear warhead for a ballistic missile, Iran faces more challenges in finishing this task. Estimating the time to finish this task is complicated because Iran faced many challenges at the end of the Amad Plan in finishing a warhead to fit inside the Shahab 3 ballistic missile. For more advanced missiles and reentry vehicles, Iran may also need to further miniaturize its warhead. For the pathway involving building a nuclear weapon production complex (see Part I), which is estimated as needing two years, Iran would have sufficient time to finish a missile-deliverable nuclear warhead.

In terms of the crash nuclear weapons pathway, the time to finish the remaining steps largely determines how quickly Iran could produce its first nuclear weapon, albeit not deliverable by missile.

The crash program requires Iran to finish its nuclear weapons development steps rapidly and in parallel to build the necessary components, although some of those may already be in storage. So, what are the essential tasks and how fast Iran could finish these tasks and have a completed nuclear weapon?

In earlier Institute studies this question was evaluated carefully.[7] A good starting point is to consider Iran's basic levitated nuclear weapons design. Figure 2 shows a schematic of this design from the Nuclear Archive, which at the end of the Amad Plan, was 55 centimeters in diameter.

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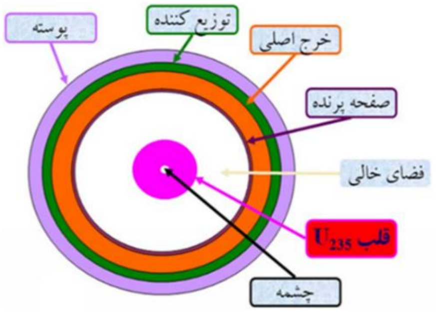
[7] David Albright with Sarah Burkhard and the Good ISIS Team, *Iran's Perilous Pursuit of Nuclear Weapons* (Washington, D.C.: Institute for Science and International Security Press, 2021) and Institute reports on Iran's nuclear archive (www.isis-online.org); David Albright, "How Quickly Could Iran Make Nuclear Weapons Today?" *Institute for Science and International Security,* January 8, 2024, https://isis-online.org/isis-reports/detail/how-quickly-could-iran-make-nuclear-weapons-today/8; and David Albright, "Iran Building Nuclear Weapons," *Institute for Science and International Security,* December 5, 2022, https://isis-online.org/isis-reports/detail/iran-building-nuclear-weapons/8.



From the bottom, and proceeding counterclockwise, the Farsi terms are:
- Neutron source
- Uranium 235 core
- Air gap
- Flyer plate
- Main charge
- "Detonation distributor" or shock wave generator, and
- Outer casing

Figure 2. Schematic from the Iran Nuclear Archive, with translated text, of Iran's design for a miniaturized nuclear weapon, resting on a levitated implosion arrangement with weapon-grade uranium in its core, a specialized multipoint initiation system, called "shock wave generator," and a long-life uranium deuteride neutron initiator at its center.

Figure 3 summarizes the weaponization tasks already accomplished and remaining to do for the crash program discussed in the rest of this report.

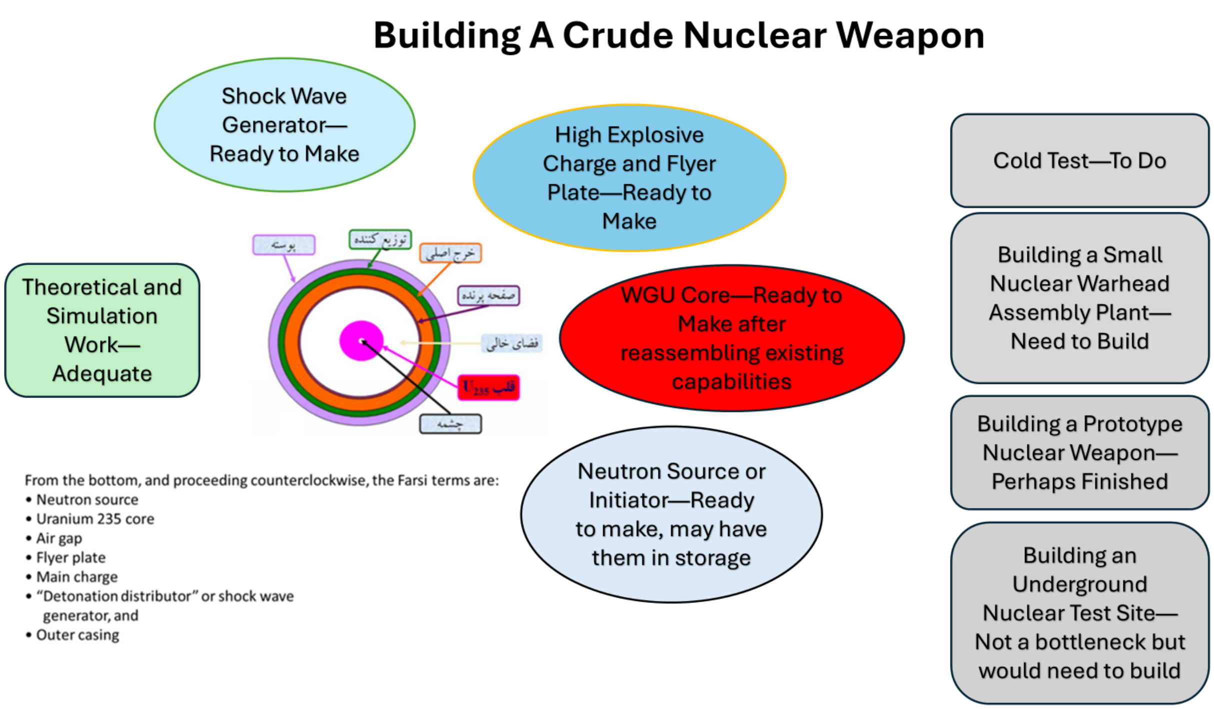


Figure 3. Summary of the tasks needed to build a crude nuclear weapon, marked finished, ready, and to do.

Theoretical and Simulation Efforts

The Amad Plan developed extensive theoretical models and carried out simulations of nuclear explosions. Ex-Amad Plan scientists continued their theoretical nuclear weapons work after the end of the Amad Plan, as documented by the IAEA. Some of that work is likely continuing today, under various guises.[8] Overall, these efforts are sufficient for building a crude nuclear weapon.

Operating System Project

During Amad, the construction of the main components of the nuclear weapon, their testing individually and as a whole, and their assembly into a nuclear weapon were the responsibility of the Operating System Project, a codeword for this project, which in turn was under Project 110 of the Amad Plan.

The Operating System Project created highly detailed Gantt diagrams of the tasks and schedules necessary to build a nuclear weapon. The Nuclear Archive contained a version from late 2001 or early 2002. It had six major sections with a total of well over 630 lines, where each line had a specific task and schedule for starting and finishing individual subtasks and listing the fraction completed so far. The Amad Plan continued for another 18 months, allowing for far more progress to be made. Some of this work, moreover, such as work on the neutron initiator, has been documented to have continued after the end of the Amad Plan

The six main sections of the Operating System Project from the Gantt diagram, which should be similar to those that would be used today, are discussed below.

1. Product System Engineering

This section involved the initial planning and design of the nuclear weapon, the facilities to test and build components, and assemble the finished nuclear device. As of late 2001 or early 2002, the project leaders said it was 83 percent completed and was expected to be finished soon afterwards. That planning documentation likely exists today and is available for use by all weaponization pathways.

2. Neutron Source Design and Production

The neutron source or initiator lies at the center of the nuclear weapon and is composed of a solid of uranium-deuteride (UD_3). Upon compression by the shock wave of the main high explosive charge, it creates a spurt of neutrons. The Nuclear Archive contains information about the production of the initiator at Amad's Lavisan Shian site and its testing at the Parchin site in a large high explosive chamber. Uranium, in the form of metal, came from drilling a

[8] Mark Gorwitz, Mohammadreza Giveh, and David Albright, "Iran's Likely Violations of Section T: Computer Modeling Relevant to Nuclear Weapons Development," *Institute for Science and International Security,* September 10, 2024, https://isis-online.org/isis-reports/detail/irans-likely-violations-of-section-t-computer-modeling-relevant-to-nuclear/8.

uranium disc in a glove box, producing uranium metal flakes which were processed with deuterium gas to make a solid uranium deuteride (see Figure 4). As of late 2002 or early 2003, the neutron source project was about 26 percent completed and slated for completion by early November 2003. Work continued during the rest of the Amad Plan and afterwards. The work is likely finished today, and Iran is likely capable of making such an initiator. It may have some of them in secret storage, since it is a long-life component.

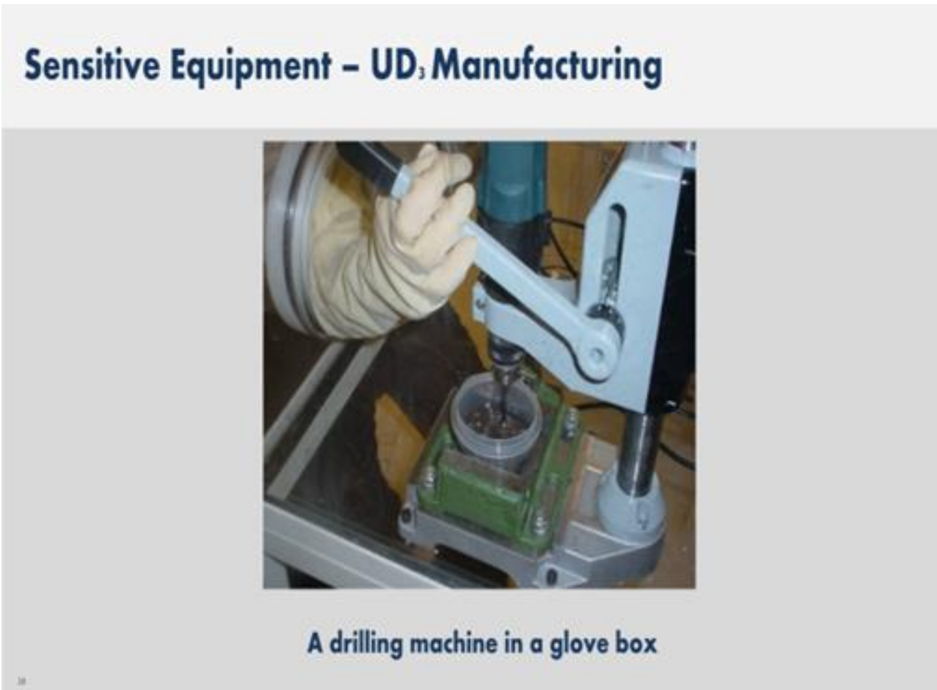


Figure 4. A photo from Iran's Nuclear Archive, obtained by the media and shared with the Institute, shows a glove box containing a drilling machine, with what appears to be a black object that is likely the uranium metal disc at Lavisan Shian.

3. Weapon-Grade Core Design and Production

The WGU core of the nuclear weapon, referred to in the archive by its most plentiful isotope, uranium 235, is a solid metal sphere, comprised of two hemispheres with a hole in the center for the neutron initiator. Iran's design required less than 25 kilograms of WGU. After producing weapon-grade uranium metal, the project would need to melt the uranium in a specialized furnace and then pour it into molds. Afterwards, it must be machined and finished into the two WGU metal hemispheres and then plated to protect against corrosion. Iran may also prepare other uranium metal components.

The Nuclear Archive contains documents and images showing extensive work during Amad on melting, molding, and finishing uranium metal using surrogate material. At the end of the Amad Plan, Iran was preparing to start working with natural uranium metal at its secret Amad sites as the last major step in practicing for subsequently making nuclear cores of WGU, when that material became available. Figure 5 shows pictures from the archive of a computer-controlled machine tool at the Amad Plan's pilot WGU core development and production site, Shahed Mahallati, and images of molten metal and cast metal hemispheres made with a surrogate material.

According to the Gantt diagram mentioned above, this section was 51 percent completed in late 2001 or early 2002 and projected to finish by June 15, 2003. By the time the Amad Plan was shut down in mid-to-late 2003, this section was largely finished. As a result, Iran is assessed as able to make WGU metal cores today.

Figure 5. The left image is a computer numerically controlled machine tool that was in Amad's Shahed Mahallati Uranium Metals Workshop and is likely still available to a crash program today. The right collection of three images shows molten material along with cast hemispheres in the pilot plant. Source: Nuclear Archive.

4. Multipoint initiation (MPI) system, the Shock Wave Generator, Design and Production

Iran's MPI requires two metallic, thin hemispherical shells containing a network of explosive-filled channels, which lie right outside the main high explosive charge (see Figure 2). This sophisticated MPI is called a shock wave generator, or a detonation distributor.

Each hemisphere is detonated by one exploding bridgewire (EBW). After igniting the EBW, the pentaerythritol tetranitrate (PETN) high explosives in an extensive network of channels uniformly detonate the high explosive charge, creating a uniform shock wave that compresses the core to achieve supercriticality, or fission, at an exponentially increasing rate. A former Soviet nuclear weapons expert provided key assistance in designing and testing the shock wave generator. See Figure 6.

As of late 2001 or early 2002, the Gantt diagram shows this section was 31 percent completed, with final completion expected by October 1, 2023. Based on archive documentation, the shock wave generator was likely finished. MPI work continued after the end of the Amad Plan, and Iran is likely ready to produce shock wave generators for nuclear weapons. It may have metal frames of the shock wave generator in storage, with the high explosive absent for safety reasons.

Figure 6. A model of an experimental system in the Nuclear Archive representing what appears to be a shock wave generator and high explosives, with a diagnostic system using fiber optic cables, to measure the time of arrival of a detonation front on the inside edge of the main charge. Such experiments were performed.

5. Construction and Equipping of Nuclear Weapons Assembly Workshop

A facility was planned to assemble the components into a nuclear weapon and securely store the completed or near-completed nuclear weapons. As of late 2001 or early 2002, the Operating System Project had made no progress on constructing and equipping a plant to assemble the weapons. This task was incomplete by the expected end date of September 2003.

Work on subprojects of this section was progressing as exemplified by an archive image of a device to assemble the central portion of the nuclear explosive, including the nuclear core and the flyer plate (Figure 7). In this case, the device appears to have been assembled as a model which would have used a surrogate metal for the core instead of weapon-grade uranium. The outer portion of the model is the flyer plate; the inner portion would contain the core. The positioning of the flyer plate in relation to the core in the overall nuclear weapon design can be seen in the Iranian nuclear weapons schematic in Figure 2. The device's operation was found in a simulation video from the archive. The animation shows the device in action, assembling the central part of a nuclear weapon. Two freeze-frames from the video are shown in Figure 7. The air gap between the flyer plate and nuclear core is also apparent in the video.

A crash nuclear weapons program would require only small, non-descript facilities to assemble nuclear weapons. Iran is seen as capable of accomplishing this goal in several months, although this task is likely unfinished.

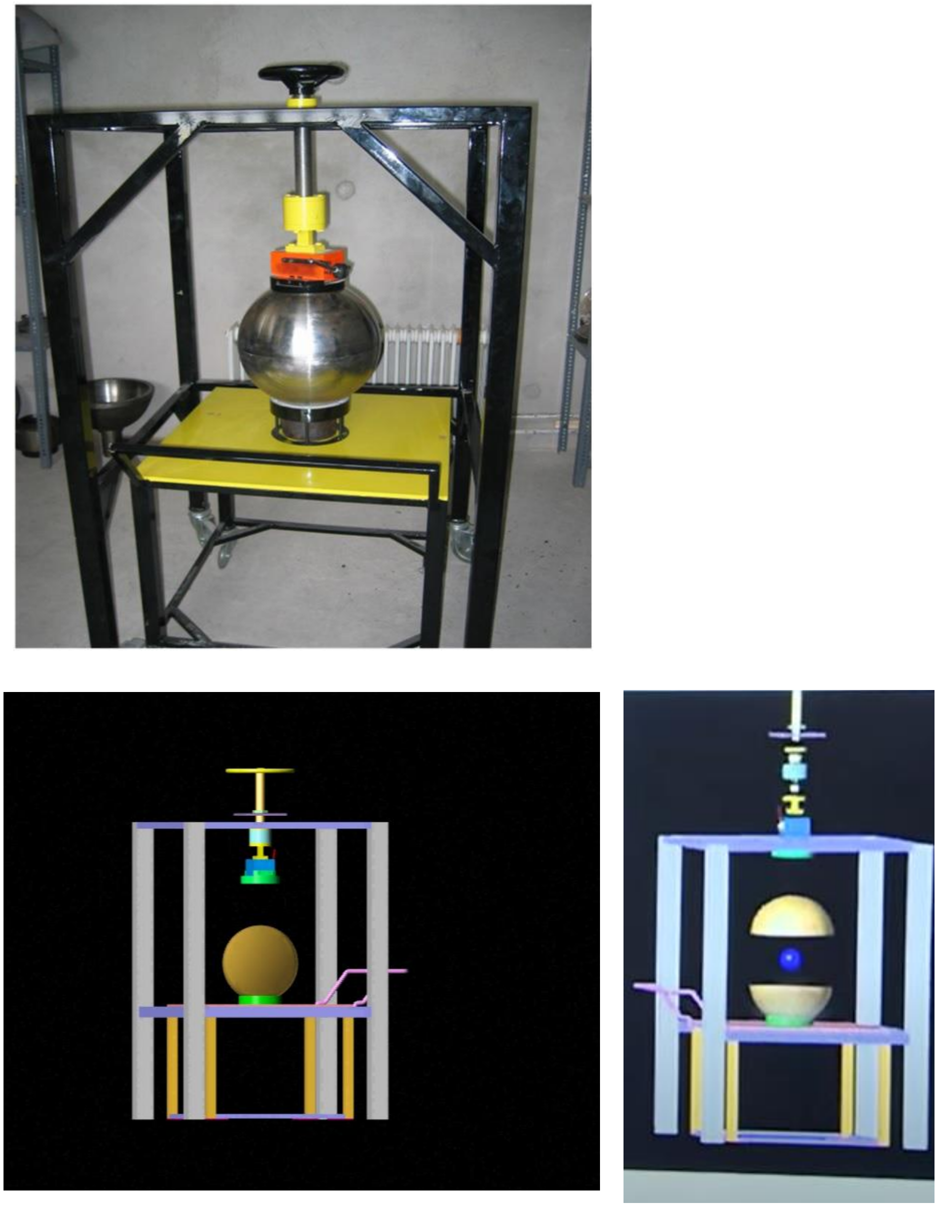


Figure 7. The upper image from the Nuclear Archive shows the assembly device, with flyer plate. The flyer plate itself is composed of two hemispheres: one can be seen in the background on the left. Below are two freeze-frames from a Nuclear Archive video simulating the working of the assembly equipment.

6. Product Engineering Prototype

An important step in the Amad Plan was the building of a prototype nuclear weapon. This would represent one of the final steps before manufacturing nuclear weapons. As of late 2001 or early 2002, this effort was 28 percent complete, with an expected completion date of November 23, 2003. This goal was not met, but archive documents show that the post-Amad planning placed a high priority on the production of an industrial prototype. Thus, a prototype nuclear weapon may have been finished, but this accomplishment is uncertain.

Other Significant Tasks

There were several more tasks included under the various sections in the Operating System Project that warrant discussion.

One of the most important final tasks is a **cold test**, which is one of the last tests of a nuclear explosive that entails detonating the entire device with a surrogate core material like natural uranium metal instead of weapon-grade uranium, thus the use of the term “cold.” The detonation and compression of the core would produce a spurt of neutrons from the neutron initiator. The neutrons escape the core and can be detected outside the device, providing a measure of how well the device performed.

At the end of the Amad Plan in 2003, Iran was preparing to conduct a cold test of a nuclear explosive with a surrogate nuclear core at the Marivan site. The Nuclear Archive contains a slide deck that includes a set of slides titled “Marivan Test Results,” serving to report on a test at Marivan aimed at determining the ability of neutron detectors to withstand the blast long enough to measure the neutron flux emitted from the neutron initiator at the center of a mock nuclear explosive device, e.g., during a cold test (see Figure 8). It is unknown if Iran conducted a cold test after the Amad Plan. Nonetheless, one is likely still required.

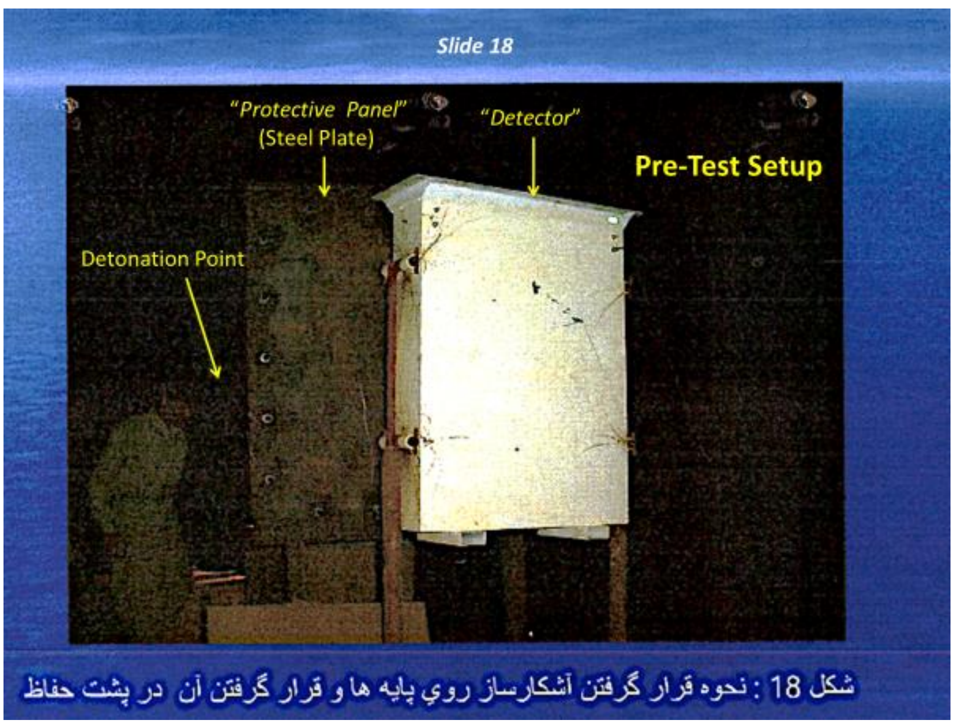


Figure 8. A slide from the archive slide presentation, “Marivan Test Results.” The caption reads, “Figure 18, The positioning of the detector on its base and its placement behind the shield.” The slide is part of a slide set from the Iranian Nuclear Archive, translated by the Institute. The white case in the foreground would contain a neutron detector. Annotations by the Institute.

Preparing the main high explosive charge is another key task. Iran's weapons design requires a high-quality explosive, machined into hemispherical shells placed around the flyer plate, air gap, core, and neutron initiator (see Figure 8). The explosive called Octol, composed of HMX and TNT, was used for its nuclear weapon design. Iran is ready to make the main high explosive charge for nuclear weapons.

Figure 9. Image from the Nuclear Archive that shows a high explosive casting mold at an unidentified location in Iran.

Nuclear Testing Project: Project Midan

After building its first nuclear weapons, Iran may conduct an underground nuclear test. However, the Amad Plan was designed so that Iran would have confidence that a nuclear device would work without a test, and Iran could reveal that it has nuclear weapons via ambiguous but credible statements. Nonetheless, Iran may seek to demonstrate its possession of a nuclear weapon through an underground nuclear test. Such a test would also lead to greater knowledge about nuclear weapons, useful in improving them or building more advanced ones.

Project Midan conducted extensive site selection and characterization for a vertical shaft to conduct an underground nuclear test. By 2003, Iran had already selected five candidate test sites (see Figure 9). However, by the end of 2003, it had not yet picked a site. Project Midan had also developed methods to estimate the yield from the underground explosion, including seismic methods which Iran likely continued to work on after the end of the Amad Plan.

Today, Iran is seen as capable of relatively quickly selecting a site and building an underground test shaft. Alternatively, it could use a horizontal tunnel inside a mountain, as North Korea does.

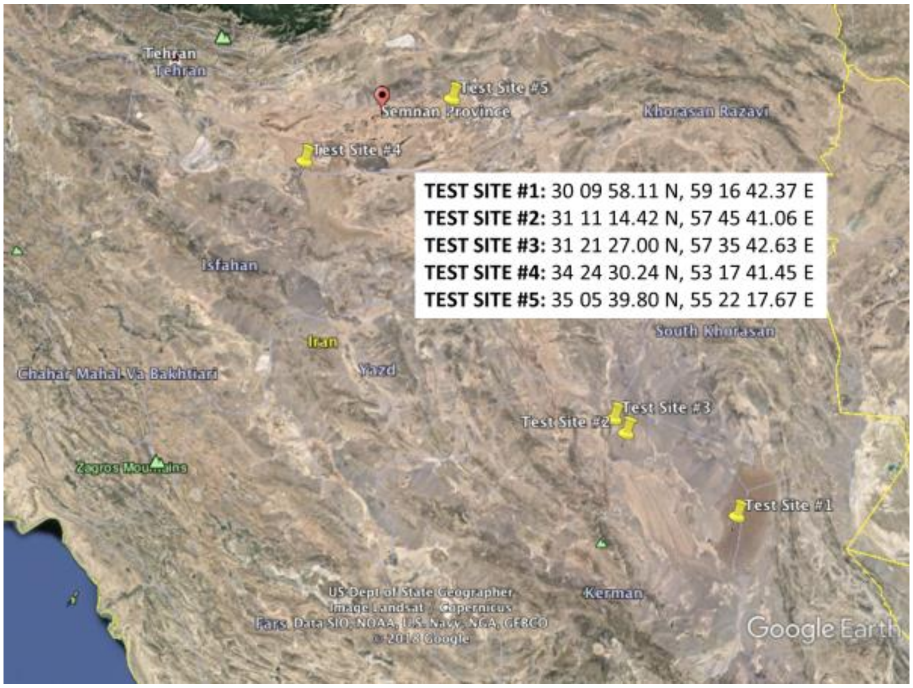


Figure 10. A map showing pins identifying the five specific locations identified by Project Midan as candidate sites for building a test shaft. An inset numbered 1 through 5 lists the coordinates of these five sites, from south to north on the map, geo-located by the Institute in Google Earth. Source: David Albright and Frank Pabian, "Iran's Investigation of Possible Underground Nuclear Test Sites in the AMAD Program prior to 2004," *Institute for Science and International Security,* May 1, 2018, http://isis-online.org/isis-reports/detail/irans-investigation-of-possible-underground-nuclear-test-sites-in-the-amad/8.

Nuclear Warhead Project: Mating a Nuclear Warhead to a Ballistic Missile

A critical task of the Amad Plan was to place a nuclear warhead on a Shahab 3 ballistic missile. Iran had made substantial progress on integrating a warhead into a reentry vehicle of a ballistic missile under the Amad Plan in a project called Project 111, aka Project 110's Warhead Project. However, this task was unfinished at the completion of the Amad Plan and faced several challenges. Figure 10 shows a schematic from the archive, with a warhead inside the reentry vehicle of the Shahab 3 missile. Today, Iran may opt to use a different, more advanced medium-range missile. It would likely need more than six months to finish mating a warhead to a ballistic missile.

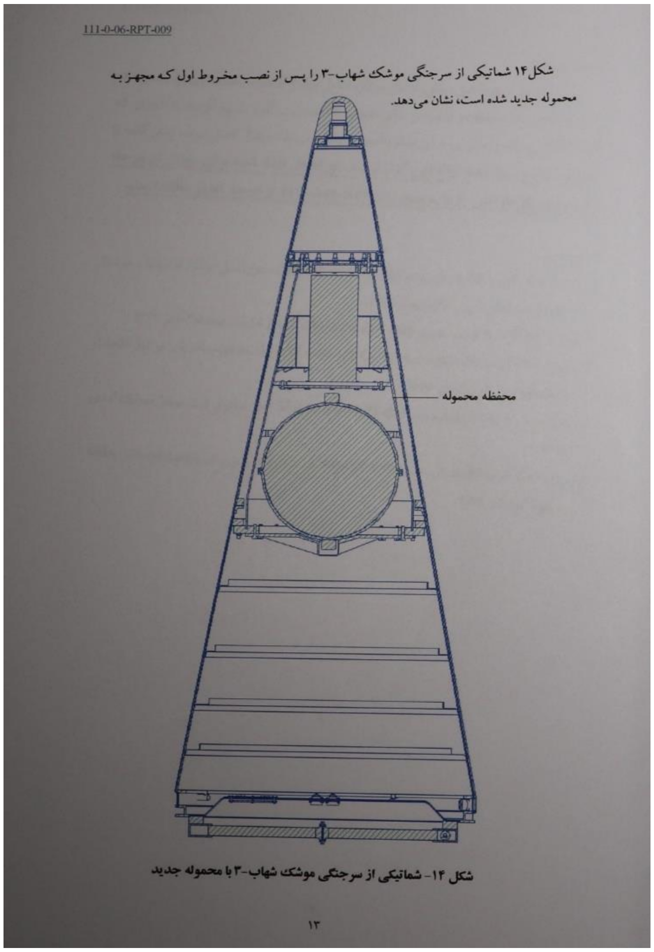


Figure 11. A schematic from the Nuclear Archive of a Shahab 3 re-entry vehicle with a payload inside. The top caption reads: "Figure 14 shows a schematic of the Shahab 3 missile warhead after the installation of the first cone, which is equipped with the new payload." The middle caption points to an inner structure which is labelled the "payload chamber," sometimes called case. The bottom caption reads "Figure 14--Schematic of the warhead of the Shahab 3 missile with the new payload."