



Can military strikes destroy Iran's gas centrifuge program? Probably not.

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Recent discussions of attacking Iran's nuclear facilities militarily often liken the destruction of Iran's uranium enrichment program to Israel's surgical strikes on Syria's clandestine nuclear reactor in September 2007, or Iraq's Osirak reactor in June 1981. In each case a single attack with fewer than ten aircraft destroyed a key facility that could have produced plutonium for nuclear weapons, setting back that country's ability to produce a plutonium-bomb by several years. In the case of Iran, the analogy goes, an attack on just two facilities, the Natanz enrichment plants (Figure 1) and the Esfahan uranium conversion facility (Figures 2 and 3) would likewise significantly delay Iran's ability to produce weapon-grade uranium for nuclear weapons.

This analogy is grossly misleading. It neglects the important differences between a gas centrifuge uranium enrichment program and a reactor-based program, and fails to account for the dispersed, relatively advanced, and hardened nature of Iran's gas centrifuge facilities. It also ignores the years Iran has had to acquire centrifuge items abroad, often illicitly, allowing it to create reserve stocks of critical equipment and raw materials, such as high strength aluminum, unmagnetized ring magnets, and special steels.

This report examines the difficulties of a military strike on Iran's enrichment facilities. It explores what is known about Iran's complex of facilities to make centrifuges and related equipment, noting that current knowledge of that complex is lacking. Without such information, an attack is unlikely to significantly delay Iran's mastery of enrichment with gas centrifuges.

Surgical Strike Not Possible

An attack on Iran's enrichment program could not just rely on a single strike. It would need multiple strikes against many sites. Destroying Natanz and Esfahan would require far more military ordinance than that used on either reactor attacked by Israel. After such strikes, the attacker might still have little confidence that it had denied Iran the ability to

produce weapon-grade uranium. It might not even have confidence that its strikes set back its enrichment program by several years, a minimum criterion often used to judge whether military strikes are a success.

Military strikes could prompt Iran to hasten its efforts to acquire nuclear weapons, embarking on a crash program. They would almost certainly lead to Iran's expulsion of IAEA inspectors and its withdrawal from the Nuclear Non-Proliferation Treaty (NPT). Iran could then build a small centrifuge plant at a secret location capable of producing enough weapon-grade uranium for one or two nuclear weapons per year. Because gas centrifuge plants can have few tell-tale signatures, they can be very difficult to detect.

Given sufficient suspicion of an impending military strike, Iran could quickly remove key centrifuge components, equipment and materials from its existing sites. (It may have already done so with certain items as part of a strategy to protect its centrifuge program.) Several of these sites have well-protected tunnel complexes in near-by mountains that can receive these strategic items in an emergency. Or Iran could move these items to other hiding places, waiting for the attack to end before reconstituting its program. This strategy was followed by Iraq during the 1991 Persian Gulf War. It was thwarted only by the intrusive on-the-ground inspections instituted by the UN Security Council after a war that involved weeks of aerial bombardment followed by a large-scale ground invasion. Few of those advocating military strikes envision such a scenario being repeated in Iran.

Where to attack?

The use of military strikes to try to cripple Iran's enrichment efforts assumes that the attacker knows what to attack. Gaps reportedly exist in U.S. and foreign intelligence on the precise location and vulnerabilities of Iran's nuclear facilities. U.S. participants reportedly left recent meetings between senior U.S. and Israeli military commanders "unconvinced that the Israelis have enough intelligence on where to strike, and with little confidence that they will be able to destroy the nuclear program."¹

The IAEA has considerable knowledge of Iran's centrifuge activities at the Natanz enrichment facilities and the Esfahan uranium conversion plant. However, it lacks information about where P1, IR-2, and IR-3 centrifuge components are currently made. In addition, Iran might have facilities containing centrifuge cascades unknown to the IAEA.

Iran formally halted its voluntary adherence to the Additional Protocol in early February 2006. This advanced inspection agreement required Iran to provide the IAEA broader declarations of its nuclear activities and to allow inspectors greater access to its centrifuge facilities. Iran ended its suspension of its enrichment program in January 2006, which included IAEA access to a wider range of centrifuge manufacturing facilities than allowed under the Additional Protocol, which provides information and access to a limited, albeit important, portion of a country's centrifuge manufacturing complex. Iran also announced that it would no longer provide the IAEA design information prior to the construction of nuclear facilities such as enrichment plants. It reverted back to an out-

¹ Tim Shipman, "U.S. Pentagon Doubts Israeli Intelligence Over Iran's Nuclear Program," *Telegraph*, July 5, 2008.

dated safeguards condition that requires notification about a new nuclear facility 180 days before nuclear material is introduced. This condition allows Iran to construct and start undeclared centrifuge cascades as long as it intends to give sufficient notice of when it introduces any nuclear material into the facility. But following a military strike, such a facility could replace the Natanz fuel enrichment plant.

Without these various inspection arrangements, the IAEA has limited means to inspect Iran's centrifuge manufacturing operations and already assembled centrifuges, or to determine if Iran is indeed building undeclared centrifuge plants. Based on interviews with knowledgeable government officials, intelligence agencies simply lack reliable information on the full-scope of Iran's centrifuge facilities and activities.

One lesson learned from both Iraq wars is the difficulty facing intelligence agencies in identifying and targeting correctly sites associated with a clandestine weapons program, in particular a gas centrifuge program. Few if any of Iraq's key centrifuge facilities were actually targeted in the first Gulf War. Only intrusive inspections identified them correctly later. Numerous reports have shown that assessments prior to the second Gulf War were mistaken about a reconstituted Iraqi gas centrifuge program and suspected associated sites.

The difficulty in achieving irreversible or long-term damage to Iran's nuclear program is not limited to the diffuse or unknown nature of its centrifuge program. Iran's uranium conversion facility at Esfahan, which produces the natural uranium gas that is introduced into centrifuges for enrichment, has already produced many years worth of uranium hexafluoride that is under safeguards. Destroying the facility would not eliminate this stockpile, now over 300 tonnes of uranium hexafluoride, or enough to produce weapon-grade uranium for over 30 nuclear weapons, if it were moved prior to a strike. In any case, an attacker would be hard pressed to destroy all of the uranium hexafluoride at Esfahan, since it is stored in many, relatively small, thick metal canisters designed to withstand sabotage and severe transportation accidents. The bombs or missiles would likely need to hit close to the canisters to ensure their destruction. Yet, the attackers might not know their precise location within Esfahan. Similarly, attackers would be hard pressed to destroy the low enriched uranium at the Natanz site. Iran could use this material to speed up the production of weapon-grade uranium in a clandestine plant.

Iran has also had ample time to accumulate large stocks of complete centrifuges and related equipment and materials. If they are not already in storage at interim locations or in underground or protected sites, they could be moved to such sites relatively quickly.

Iran's Pre-Suspension Centrifuge Manufacturing Complex

Crippling a centrifuge program requires the destruction of the equipment and materials in its manufacturing complex. Proliferant states such as Iran and Pakistan had to seek such a manufacturing capability to build their centrifuge plants. These plants contain thousands of individual, relatively small centrifuges, which could not be acquired in sufficient numbers from foreign suppliers. Iran's manufacturing complex is able to replicate centrifuges relatively quickly and in large numbers. Iran's centrifuges at Natanz can thus be replaced if the manufacturing equipment and raw materials are protected

against attack. Neither Iraq nor Syria was in a position to replace its reactor. Each depended on a foreign supplier to provide the reactor components and did not in the process develop an indigenous capability to make major reactor components, something difficult to justify in the case of a reactor in any case.

Iran has complicated any attack by following a strategy of dispersing its centrifuge manufacturing sites. The dispersed and somewhat ad hoc nature of this complex can be better understood by examining what is known of Iran's pre-suspension centrifuge program, which lasted until late 2003. This program is relatively well known because, as part of the suspension agreements, Iran agreed to allow the IAEA to monitor centrifuge components and manufacturing equipment to lessen the chance that Iran could make additional centrifuges during the suspension. In the process, the IAEA developed considerable information about Iran's facilities that had been dedicated to making the many centrifuge components that comprise the P1 centrifuge deployed at the Natanz site. Until the suspension, the centrifuge program made many components in its own facilities. To make many other components, it contracted with several small private companies and at least three facilities that are part of, or associated with, the Defense Industries Organization (DIO).

Although several of these sites have been referenced in previous IAEA safeguards reports, a few are being disclosed here for the first time. It is uncertain which of these sites are currently engaged in making P1, IR-2, and IR-3 centrifuge components and equipment. After the suspension ended, Iran might have resumed centrifuge production at these sites or moved equipment to other locations to make additional centrifuge components.

Iran's declarations to the IAEA in 2003 and 2004 reportedly contain the full list of facilities involved in the manufacture of P1 centrifuges prior to the suspension. The following discusses several of those sites and one facility involved in making parts for the IR-2 centrifuge. Unfortunately, we are unable to develop a complete list from publicly available information.

Kalaye Electric

Iran's centrifuge program falls under the Atomic Energy Organization of Iran (AEOI) and is operated by the Kalaye Electric Company. In Persian, "Kalaye" means "Goods." In the 1990s, the AEOI bought this company, which originally was a clock factory. It kept the company's generic, non-descript name, "Electric Goods Company" to help hide its centrifuge program from the IAEA and foreign intelligence services. Until operations moved to Natanz starting in 2002, the centrifuge program was centered in the facility known as Kalaye Electric in Tehran. This site conducted essential centrifuge research and development and handled the assembly of centrifuges. Figure 4 is a commercial satellite image of this facility. Its buildings are unremarkable and located among other industrial buildings to better hide their purpose. Earlier, secret centrifuge research took place at the Tehran Nuclear Research Center, according to IAEA safeguards reports, but Iran's concern about its discovery is believed to have prompted Iran to shift the work to the Kalaye Electric site, which would draw less unwanted attention. Currently, the Kalaye Electric facility is involved in the development of more advanced centrifuge

designs, including the IR-2 and IR-3, centrifuge components, measuring equipment, and vacuum pumps, according to IAEA safeguards reports.

Even today, the centrifuge program still acquires vacuum pumps and much of its measuring equipment via illicit trade with foreign suppliers. Work at Kalaye Electric is aimed at creating an indigenous capability to make this equipment and reduce its dependence on smuggling, which has become more difficult under increased economic sanctions. However, it is unknown which Iranian facilities would make vacuum or measuring equipment.

7th of Tir Industries

The most important DIO contractor was located at a large industrial compound south of Esfahan called 7th of Tir Industries, or the 7th of Tir Steel Alloy Complex, identified in UN Security Council Resolution 1737 as subject to targeted sanctions. Figure 5 is a commercial satellite image of what is likely this large missile production site, also known as Hafte Tir or Haftom-e-Tir. The site is surrounded by perimeter fencing with guard checkpoints and several security gates, and it has a number of manufacturing buildings and what appear to be underground facilities. IAEA safeguards reports have not referred to this facility by name.

Centrifuge components were manufactured in a relatively small, unidentified facility within this large site. Under contract, DIO specialists made about twenty critical rotating components of the P1 centrifuge rotor. In total, this facility contracted originally to make 10,000 sets of these centrifuge components, according to Vienna diplomats present at technical briefings by IAEA officials, but it had not finished making all of them prior to the suspension. To prevent IAEA monitoring at this sensitive military site, Iran moved the key centrifuge manufacturing equipment and components to Natanz and other AEOI sites. It is unknown if after the suspension, Iran returned the centrifuge manufacturing equipment to this site and resumed the manufacture of these components.

This site manufactured one of the centrifuge's most sensitive parts, its bellows—a thin-walled cylindrical part—made from maraging steel. Iran secretly purchased 67 tonnes of this super strong steel in the United Kingdom, enough for approximately 100,000 bellows. Each centrifuge requires three bellows, giving Iran approximately enough steel for some 33,000 centrifuges. Iran may have purchased such a large quantity at one time, fearing that it would become only harder to procure should its centrifuge research and development become public. Apparently Iran was not able to buy the steel in tubes, which is the normal starting point for making a hollow bellows, so it bought metal rods.

Maraging steel is a sensitive commodity, whose purchase is controlled by suppliers. Iran may have found it easier to obtain if asking for rods. But the rod shape complicates the production of bellows. Iranian technicians had to first use a hot lance to pierce the rod and then cut out the center into a tube. This tube is then thinned to a wall thickness of only one millimeter on a specialized, precision flow-forming machine. Iran obtained this machine from the now defunct German firm Leifeld in 1985 and later obtained several more from this and another firm. The location of these flow-forming machines is unknown, more than one of which can be used to make bellows.

Farayand Technique

An important subsidiary of Kalaye Electric is Farayand Technique, located in a valley near the 7th of Tir site, likely in an industrial park (Figure 6). Prior to the suspension, this facility had multiple responsibilities, including making and assembling parts of the centrifuge's bottom bearing. This part of the centrifuge is designed to hold a thin pin with a ball at its end that is attached to the bottom of the rotor assembly. The ball fits inside a cup, which allows the rotor to spin rapidly with little friction. It also performed quality testing on components manufactured in the Esfahan area and had facilities for assembling and testing centrifuges. According to IAEA reports, Farayand was also initially envisioned as a site for assembling Iran's centrifuges but authorities decided it was too far from Natanz. IAEA inspectors suspected that this site could have been intended as a back-up to the Kalaye Electric facility.

Pars Trash

Pars Trash, a small company employing about ten people, is located in Tehran among many warehouses and light industrial buildings within a kilometer west of the Kalaye Electric facility. It made the centrifuge's outer casings. These are the thick aluminum tubes that house the centrifuge rotor assembly and, in the case of an accident, prevent broken pieces of the thin-walled rotor assembly, which can act like shrapnel, from injuring or even killing bystanders. Pars Trash was originally a small private factory involved in making automobile parts. It went bankrupt and was bought by the Kalaye Electric Company, or its subsidiary Farayand, for the three expensive computer-operated machine tools it owned, which could be adapted to the manufacture of centrifuge components. An engineer married to the plant manager is believed to have been the backbone of the operation. She programmed and set up the machines to make centrifuge components and ensured their quality, before turning the operation over to a technician who subsequently operated the automated machines to produce thousands of components.

Pars Trash also played a bit part in an IAEA inspection drama, when in February of 2003 the facility stored equipment that Iran had hastily disassembled from the Kalaye Electric site in an attempt to keep it out of sight of IAEA inspectors.

P1 Motor Workshop

A small workshop in Tehran made the P1 motor. This motor is a relatively easy part to manufacture, similar to a vacuum cleaner motor. A father and son team assembled about ten motors a day using materials sent from the Tehran Nuclear Research Center, which had obtained them from German companies. The workshop, which was not much more than a garage operation, is located in an area of Tehran with many similar workshops.

Other DIO Workshops

Kaveh Cutting Tools Complex, a part of Khorasan Metallurgy Industries, northeast of Tehran near the city of Mashhad, made scoops, molecular pumps and other components. These are all stationary components in a centrifuge and easier to make than the rotating ones. Figure 7 shows this facility. **Sanam Electronic Industry Group** in Tehran was the third DIO-associated facility involved in making centrifuge components. Figure 8 shows the area of Tehran where this facility and its headquarters are located.

Lavisian Shian Workshop

Prior to the suspension, Iranian technicians made carbon fiber rotor tubes for the IR-2 centrifuge in a military facility in the suburbs northeast of Tehran. This site appeared to be involved in manufacturing missile bodies from carbon fiber and had the requisite equipment and skills to make centrifuge rotor tubes out of carbon fiber. In the same area is the site called Lavisian Shian (Figure 9). The IAEA has investigated the Lavisian site because of its possible involvement in developing gas centrifuges in the 1990s. The area also contains several other high-tech military facilities, including Sanam Electronics and a Tehran office of 7th of Tir Industries.

Conclusion

From the time that Iran halted the suspension of its centrifuge manufacturing efforts and its adherence to the Additional Protocol, the IAEA's knowledge of Iran's centrifuge manufacturing complex has degraded dramatically. U.S. and other intelligence agencies appear to have only partial information about Iran's centrifuge complex and its ability to reconstitute its program following an attack. Iran's decision to disperse and keep secret several of its key sites further hinders the development of a full picture of its centrifuge complex. Considering the modular, replicable nature of centrifuge plants, we conclude that an attack on Iran's nuclear program is unlikely to significantly degrade Iran's ability to reconstitute its gas centrifuge program.

An emphasis on military responses to this conflict also has the effect of discouraging Iran from allowing more effective IAEA inspections, something necessary for the successful conclusion of a diplomatic solution to Iran's nuclear program. Iran is understandably concerned that more transparency on its part could lead to the U.S. and Israeli militaries gaining better targeting information on its nuclear program.

Finally, calls for military action against Iran may have the result of increasing pressure on Iran and hesitant allies to seek a meaningful diplomatic solution. If carried out, however, military strikes would likely fail to deliver on their promises and risk leading to a general war that could spill over throughout the region. It is time to set aside the military option and concentrate instead on credible diplomatic approaches to end Iran's growing nuclear weapons capabilities.

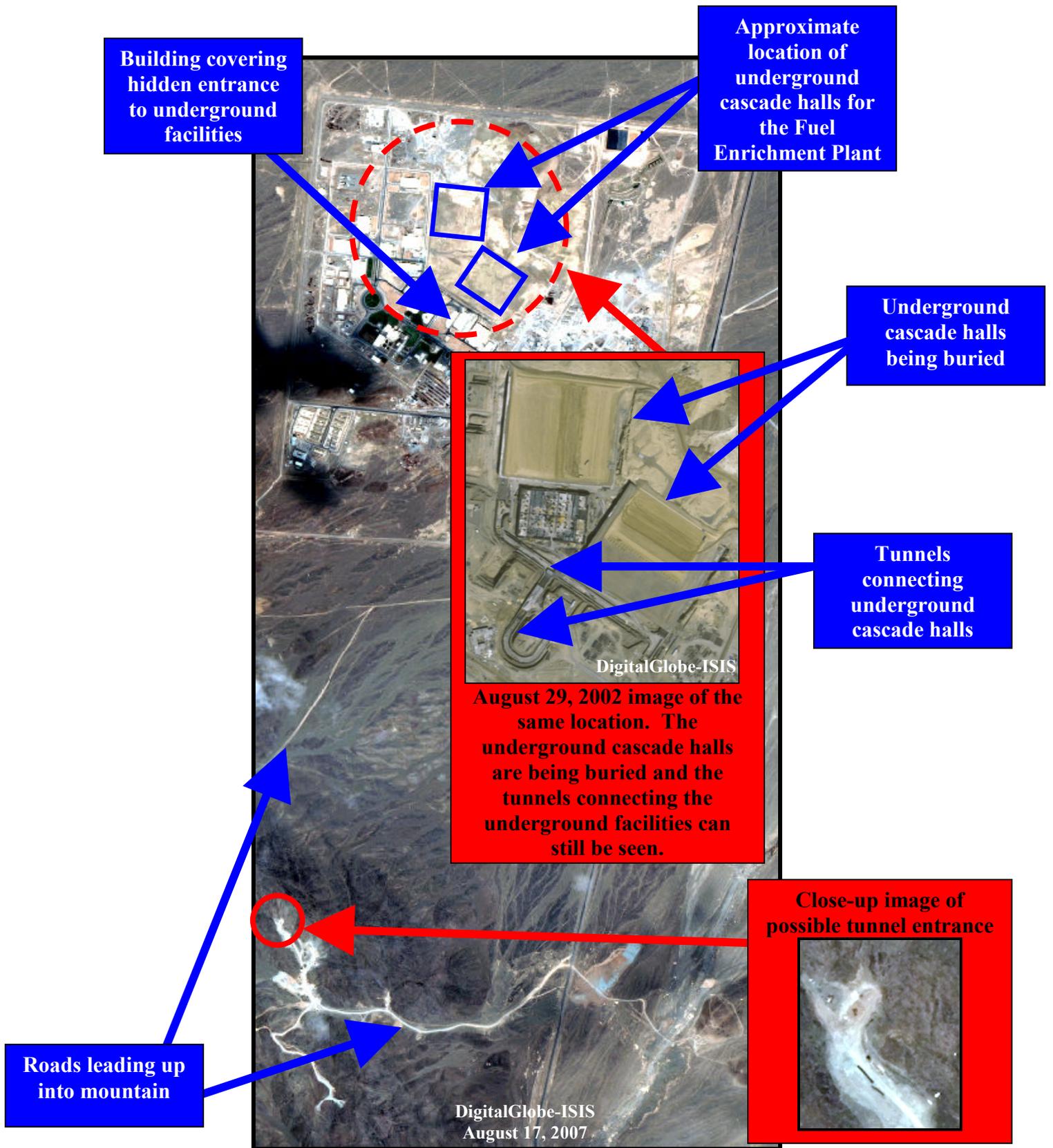


Figure 1. Natanz uranium enrichment facility. The cascade halls for the Fuel Enrichment Plant are buried with tunnels connecting the underground structures. In early to mid-2007, Iran began constructing a possible tunnel complex approximately two kilometers south of the uranium enrichment site. A tunnel facility would provide protection from an aerial attack and could be used to quickly store items such as centrifuge components and manufacturing equipment.

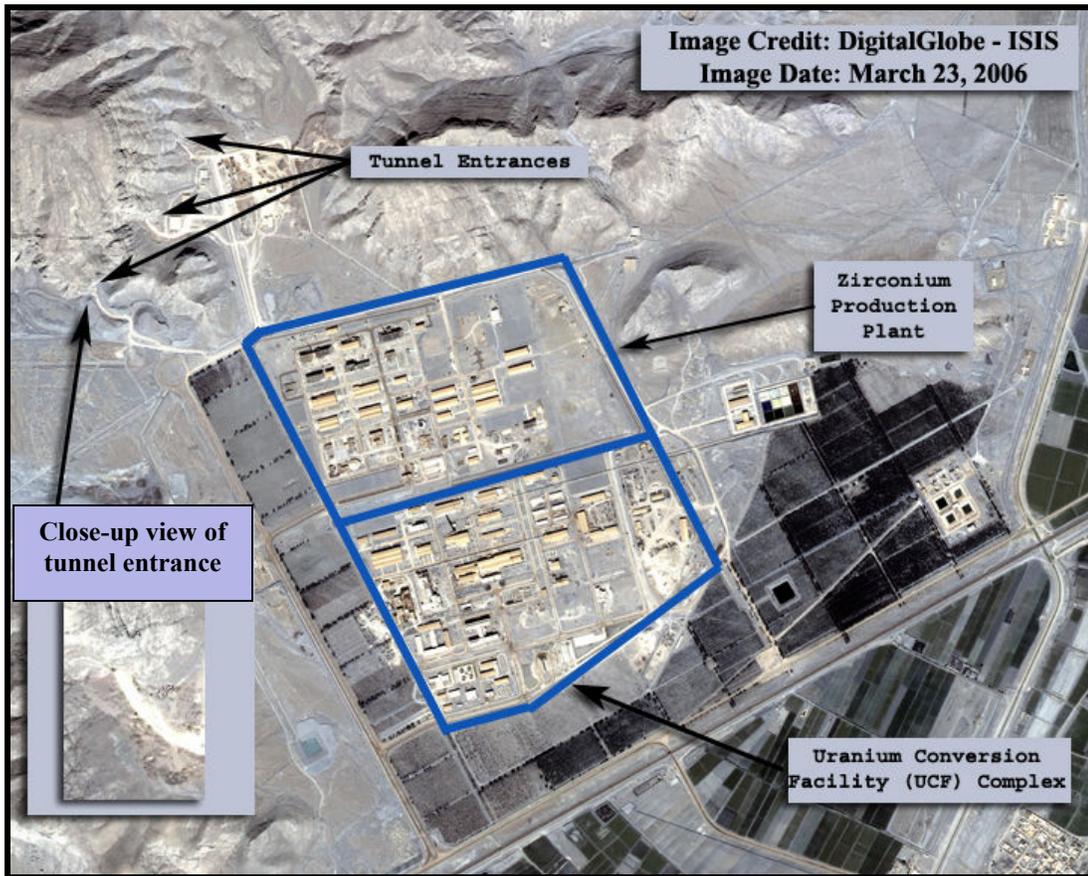


Figure 2. Esfahan uranium conversion facility.

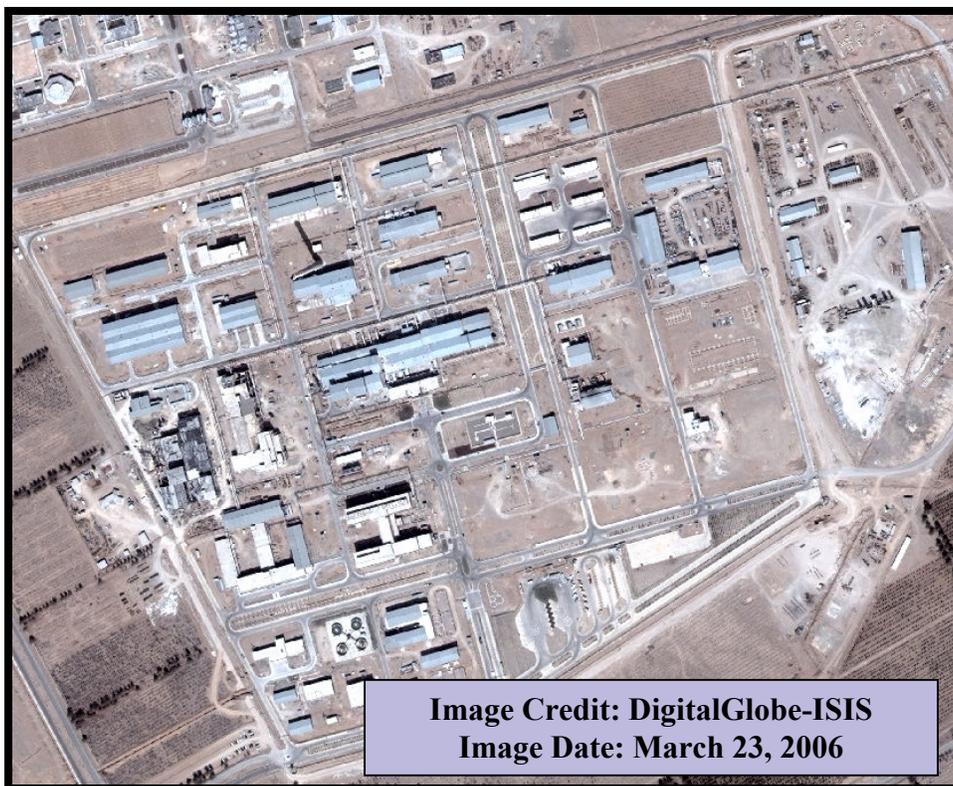


Figure 3. Uranium Conversion Facility (UCF) Complex at Esfahan.



Figure 4. The centrifuge assembly and research and development facility, Kalaye Electric, in Tehran, Iran.

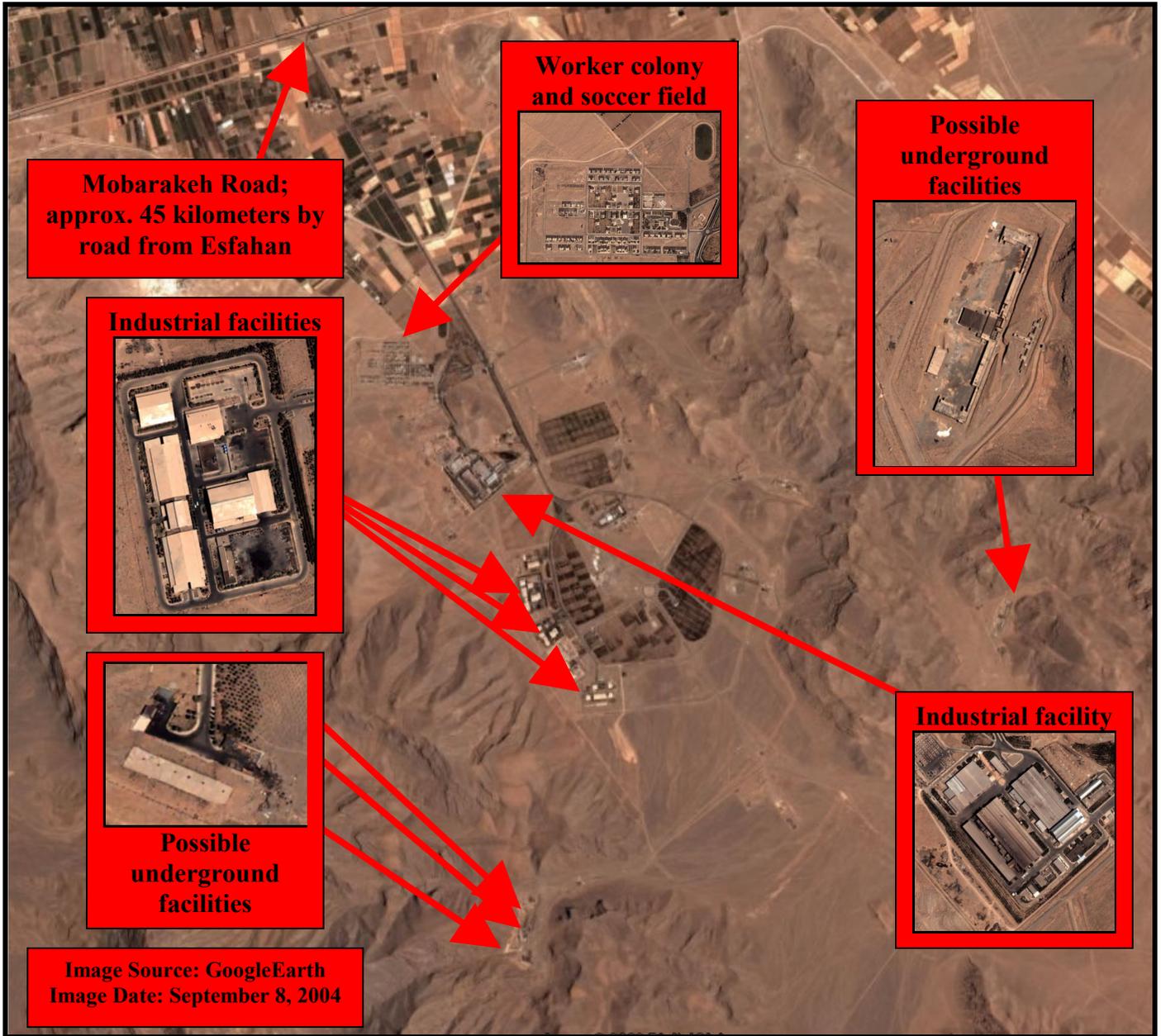


Figure 5. The likely site of 7th of Tir Industries (Haftom E Tir), a missile production and centrifuge component manufacturing facility along Mobarakeh Road south of Esfahan, Iran.



**Image Credit: GoogleEarth
Image Date: November 15, 2007**

Oshtorjan Industrial City

Figure 6. The likely site of Farayand Technique, located inside Oshtorjan Industrial City in Esfahan, Iran².

² The National Council of Resistance of Iran (NCRI) identified the address of Farayand Technique to be “Ashtarjan industrial city, Sixth Avenue, building of the board of trustees of the industrial city, number 59, Isfahan, Iran”



Image Credit: GoogleEarth
Image Date: July 7, 2006

Figure 7. The site of Kaveh Cutting Tools in Mashhad, Iran. Ground photographs on the Kaveh Cutting Tools company website match this compound located using the factory address also on the company's web site.

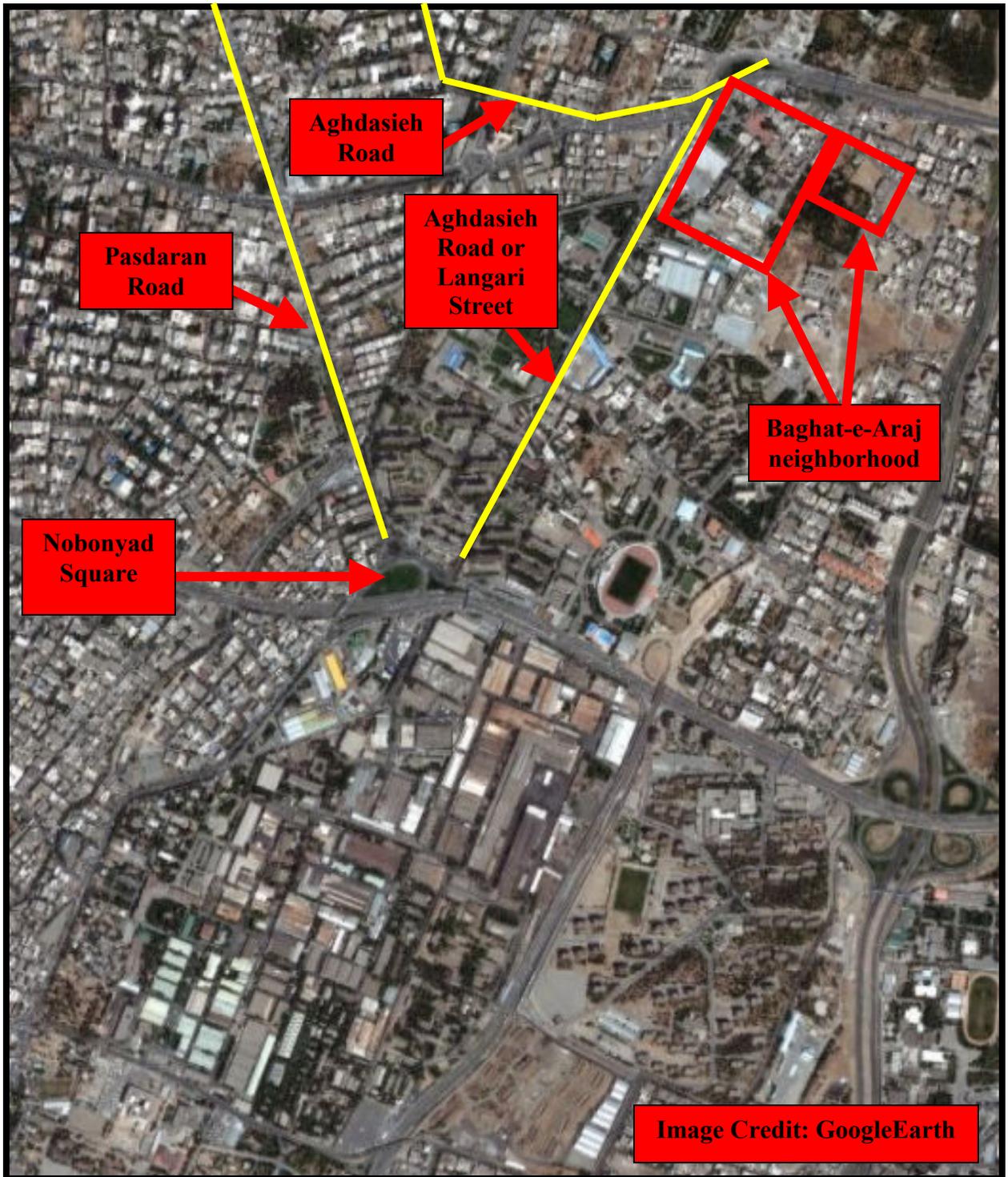


Figure 8. Sanam Industries Group is located near Aghdasieh Road/Langari Street, Pasdaran Road and Nobonyad Square. Sanam Electronic Industries, a subsidiary of Sanam Industries Group, is likely located in this area near Aghdasieh Road/Langari Street and the Baghat-e-Araj neighborhood. The exact location could not be determined by assessing Sanam company web sites or available web sites mentioning this company. Tehran offices of other Defense Industries Organizations, such as the 7th of Tir Industries and Parchin Chemical Industries, are located in the “Sanam Building” near Nobonyad Square.

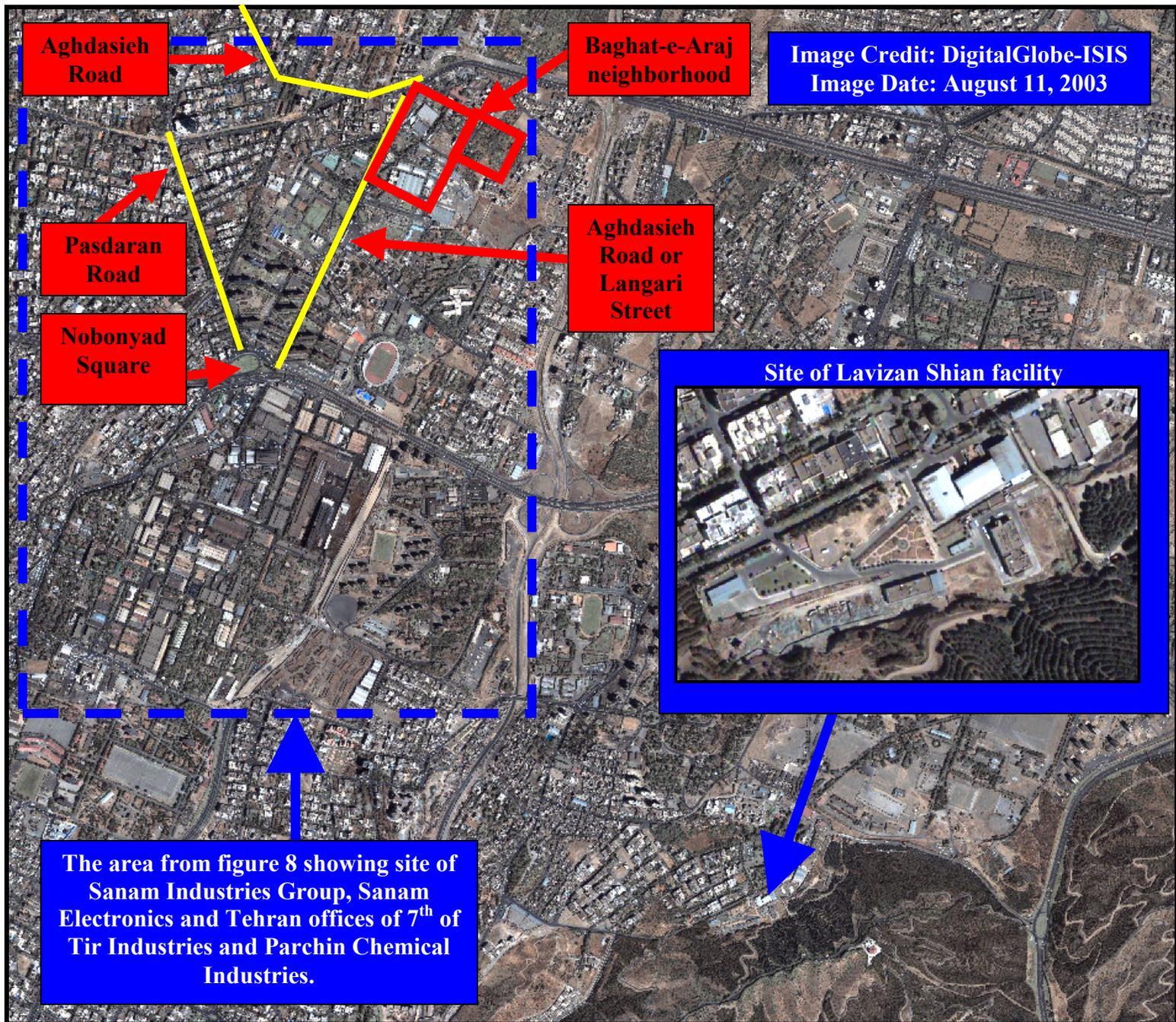


Figure 9. Prior to the suspension, Iranian technicians made carbon fiber rotor tubes for the IR-2 centrifuge in an unidentified military facility in an area near a site called Lavizan Shian in a suburb northeast of Tehran. The Lavizan Shian site is suspected of developing centrifuges. Iran removed the Lavizan Shian site by mid-2004. This area holds a number of other high-tech military industries.