Experts say Iran nuclear agreement is sufficiently verifiable

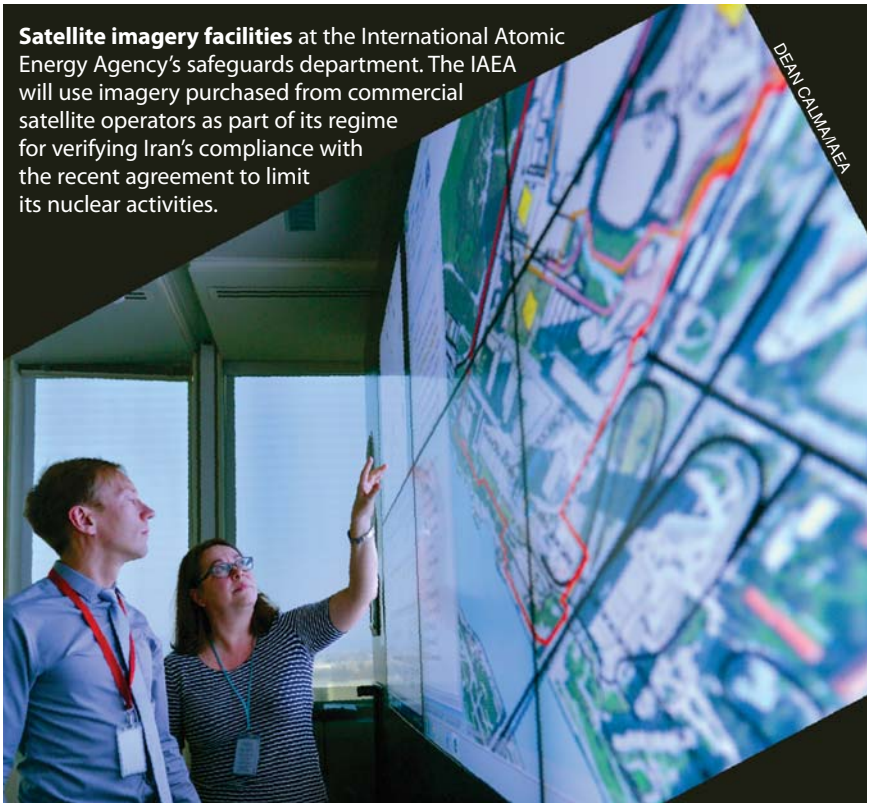
The International Atomic Energy Agency will use the latest surveillance technologies to ensure compliance.

As early as the end of this month, Iran says it will complete actions to dramatically scale back its nuclear program. Once those steps are completed and verified, the world's declared nuclear weapons states and Germany, collectively known as the P5+1, are to begin lifting the crippling economic sanctions that were imposed on Iran beginning in 2006.

Experts are confident the agreement, known as the Joint Comprehensive Plan of Action (JCPOA), is sound. In a statement released in August, 77 nonproliferation specialists wrote, "The JCPOA is effectively verifiable. The agreement will put in place a multilayered monitoring regime across Iran's entire nuclear supply chain, including centrifuge manufacturing sites for 20 years, uranium mining and milling for 25 years, and continuous monitoring of a larger number of nuclear and nuclear-related sites."

Secretary of Energy Ernest Moniz weighed in on the issue in a statement marking the official adoption of the accord on 18 October: "The JCPOA is based on hard science and unprecedented verification in order to assure the international community that Iran does not obtain a nuclear weapon and that its nuclear program is exclusively peaceful." An emeritus professor of physics at MIT, Moniz took part in the negotiations in the months leading up to the agreement, at the request of his counterpart, Ali Akbar Salehi, head of the Atomic Energy Organization of Iran.

The JCPOA effectively eliminates the plutonium pathway to a nuclear weapon by requiring Iran to remove the core of its heavy-water research reactor in Arak and to fill it with concrete. Iran has pledged to ship the spent fuel from all its research or power-generating reactors out of the country and not reprocess any of it. China and the US have announced they will lead an effort with Iran to design and build a reactor core that will produce little plutonium.



Satellite imagery facilities at the International Atomic Energy Agency's safeguards department. The IAEA will use imagery purchased from commercial satellite operators as part of its regime for verifying Iran's compliance with the recent agreement to limit its nuclear activities.

The uranium provisions of the agreement are more complicated. Iran will be allowed to continue enriching uranium to a maximum of 3.67% ^{235}U, sufficient for reactor fuel. But of its 12 000-kg stockpile of enriched uranium, it can keep only 300 kg enriched to that maximum; the remainder must be diluted to the natural uranium isotopic ratio of 0.7%, sold, or shipped abroad for storage. Iran hasn't announced which of those alternatives it will take.

Iran is also restricted to operating a maximum of 5000 of its 19 000 gas centrifuges for enrichment; the 5000 must be its oldest machines. Another 1000 are to be repurposed for isotope production. The remainder will be removed from enrichment facilities, disassembled, and placed in storage monitored by the International Atomic Energy Agency (IAEA).

Under the JCPOA, all 20%-enriched material must be blended down to the 3.67% ceiling, fashioned into fuel for the research reactor in Tehran, or shipped abroad. In an August open letter to President Obama, 29 prominent US scientists said that Iran had accumulated sufficient 20%-enriched ^{235}U that it would take just a few weeks of further enrichment to produce enough weapons-grade material (at least 90% ^{235}U) to make a nuclear weapon. The JCPOA, they said, will put Iran "many months" away from amassing that bomb fuel, should it decide to renege on the agreement.

The Obama administration maintains that the minimum time needed for Iran to produce a nuclear weapon will be pushed back to one year. In saying so, the administration implicitly acknowledged that Iran has been prevented from acquiring a bomb only by its lack of the necessary nuclear material, notes Frank von Hippel, a member of Princeton University's Program on Science and Global Security (PSGS).

A 27 August IAEA report said Iran has converted 337 kg of its 20%-enriched uranium hexafluoride into 162 kg of 20%-enriched uranium oxide, 69 kg of which has been used for the Tehran reactor fuel elements. The remaining 110 kg of 20%-enriched UF_6 has been downblended to a 5% or lower enrichment level. Since January 2014,

the report said, Iran has not enriched any material to more than 5%.

All the actions required of Iran must be completed before economic sanctions are lifted. US officials have said those steps will take many months, but Salehi and Iranian president Hassan Rouhani have both said that sanctions will be lifted by year-end, according to published reports.

"We'd be delighted if it happened that quickly," a senior US administration official told reporters on 17 October, while cautioning, "our focus remains on it being done correctly more than it being done quickly." The timetable for what is known as implementation day "really depends on [Iran's] will and on, frankly, the technical side of how long it takes to uninstall thousands of centrifuges or export or dilute 10 000 or 12 000 kilograms of uranium."

Modern verification methods

The IAEA has authorized more than 100 verification technologies, says Thomas Shea, a retired IAEA safeguards official living in Vienna who authored the report *Assuring Effective IAEA Verification of the Iran–P5+1 Agreement*. The study was commissioned by PSGS and two nonprofit institutions.

A Department of Energy official says that a key component of the JCPOA is the ability for the IAEA to use more modern, efficient, and timely safeguards technologies. Many of the new technologies have been developed in the US at Oak Ridge, Pacific Northwest, Sandia, and Los Alamos National Laboratories. A senior administration official said that Iran has agreed to implement "systems that don't exist anywhere else in the world."

As with all the IAEA's agreements with individual member states, the details of the agency's safeguards provisions for Iran are confidential. An IAEA spokesman declined to make an expert available for this article. About 50 IAEA inspectors and analysts are assigned to the Iran task force, says Shea.

At the heart of verifying the uranium provisions is a system for near-real-time monitoring of enrichment levels in gas centrifuge cascades. "It will be critical in monitoring the enrichment activities in Iran," Moniz said at a 21 October conference on the DOE labs. Developed at Oak Ridge and Los Alamos, the system uses gamma-ray spectrometry. "They are looking at the 186-keV emission line of uranium-235 and comparing that to a reference standard," says Charles Ferguson, president of the Federation of American Scientists. "From the emission line you can infer how much U-235 is in there proportional to the total." The system also extracts the pressure and temperature of UF_6 from the lines to estimate its concentration.

The same technology was used to check enrichment levels during the 20-year "megatons to megawatts" program that concluded in 2013, through which Russia blended down 500 tons of highly enriched uranium from Soviet-era weapons into US commercial reactor fuel. But that system required inspectors to physically collect data from the monitors periodically. The technology to be used in Iran was designed to meet IAEA requirements for unattended, remotely monitored instruments.

Built from commercially available components, the gamma enrichment monitors are housed in a tamper-proof package attached to pipes along the enrichment pathway, the DOE official says. Algorithms were developed to estimate ambient background levels of ^{235}U, including deposits on pipe walls.

Seals, another verification method, have "evolved dramatically over the 50-odd years that they've been used," says Hugh Chalmers, a researcher at the

London-based Verification Research, Training and Information Centre. Early versions of seals attached to doors, containers, canisters, and other components consisted of small metal loops with caps marked by a random pattern of scratches and solder. Inspectors periodically removed the seals and took them back to IAEA headquarters in Vienna to determine if they matched that unique pattern.

More modern seals include fiber-optic cable loops through which encoded light pulses are sent. If the loop is broken, its control box will register the location of the break and record when and for how long the break occurred, Chalmers says. The control box has tamper-resistant technologies to prevent cheating. The method is versatile; the loops can run up to a kilometer in length.

"It may well be that a number of fairly sophisticated technologies are already being used in Iran," Chalmers says. Since the IAEA has been monitoring compliance with the Joint Plan of Action, a predecessor agreement signed in 2013 between Iran and the P5+1 nations, "the agency probably has a lot of knowledge from Iran," he notes.

The IAEA began environmental sampling in nuclear facilities after the first Gulf war in 1991, when Iraq's secret nuclear program was uncovered. Swabs of surfaces inside enrichment halls are examined for their isotopic content. "That is a remarkably powerful technology," notes Shea.

The JCPOA includes monitoring Iran's uranium mining, milling, and conversion to UF_6. Such monitoring is aimed at preventing diversion of uranium to any potential covert enrichment program, but it presents a difficult challenge, given the volumes involved. "You are talking about a lot of material to sift through to extract U-235," says Ferguson. "I can imagine the error bars being pretty big. They probably don't need really fine granularity. [Accuracy to] within tens of kilograms might be good for the purpose of monitoring."

Verification of bulk processing uses material-balance accounting, in which uranium stocks, records, and receipts are audited to detect shipper–receiver differences and unaccounted material that exceeds the limits for measurement uncertainties. Video surveillance is also used to prevent removal or alteration of nuclear materials containers.

IAEA

Cameras used in the International Atomic Energy Agency's verification process have covers that indicate tampering and record details of a breach.

Shea says Iran's known uranium ore reserves have increased considerably in recent years, and they could continue to do so. "Verifying something that is declared is a much easier job than finding out that it's not being submitted in the first place," he says.

Civilian technologies, particularly commercial imaging satellites, also will be a part of JCPOA verification. The IAEA has long purchased satellite imagery for its own analyses, and it culls other open sources of information, such as journals and trade databases. "They use quite sophisticated analysis tools to crunch huge amounts of free information to help paint a picture of a certain state," notes Chalmers.

Other nongovernmental organizations have access to the same imagery and other open information sources. That, says Christopher Bidwell, a senior fellow at the Federation of American Scientists, "can breed a mini-industry of proliferation experts" who may draw conclusions opposite those of the IAEA. An unofficial analysis "creates more opportunity to catch acts of cheating, but at the same time, it adds to the noise level," he says.

The IAEA and the signatories to the JCPOA may have to spend time and effort investigating such third-party assertions. And they will have to deal with potential accusations from other parties such as Israel or Iranian dissidents, says Bidwell. He recommends that the agency set up a rapid resolution process for allegations of noncompliance.

Possible military applications

Officials of the IAEA announced on 15 October that the agency had completed its investigation of the 10 or so issues it had raised on the "possible military dimensions" of Iran's program. Those included suspicions that the testing of high-explosive lenses needed for an implosion-type weapon had taken place at Iran's Parchin military site. The IAEA staff is to report to the director general its findings in mid-December.

Shea anticipates that the IAEA report will be less than definitive: "something along the lines that they now have a full picture of the activities that were carried out and that they are now prepared to implement the JCPOA as foreseen according to the schedule of events." The report's purpose, he says, is to determine whether an activity the IAEA may uncover in the years ahead had begun before or after the agreement took effect.

The US has independently assessed Iran's nuclear programs. In January 2014, James Clapper, director of national intelligence, testified that Iran "has the scientific, technical, and industrial capacity to eventually produce nuclear weapons." But whether it will do so is unknown, he added.

David Kramer