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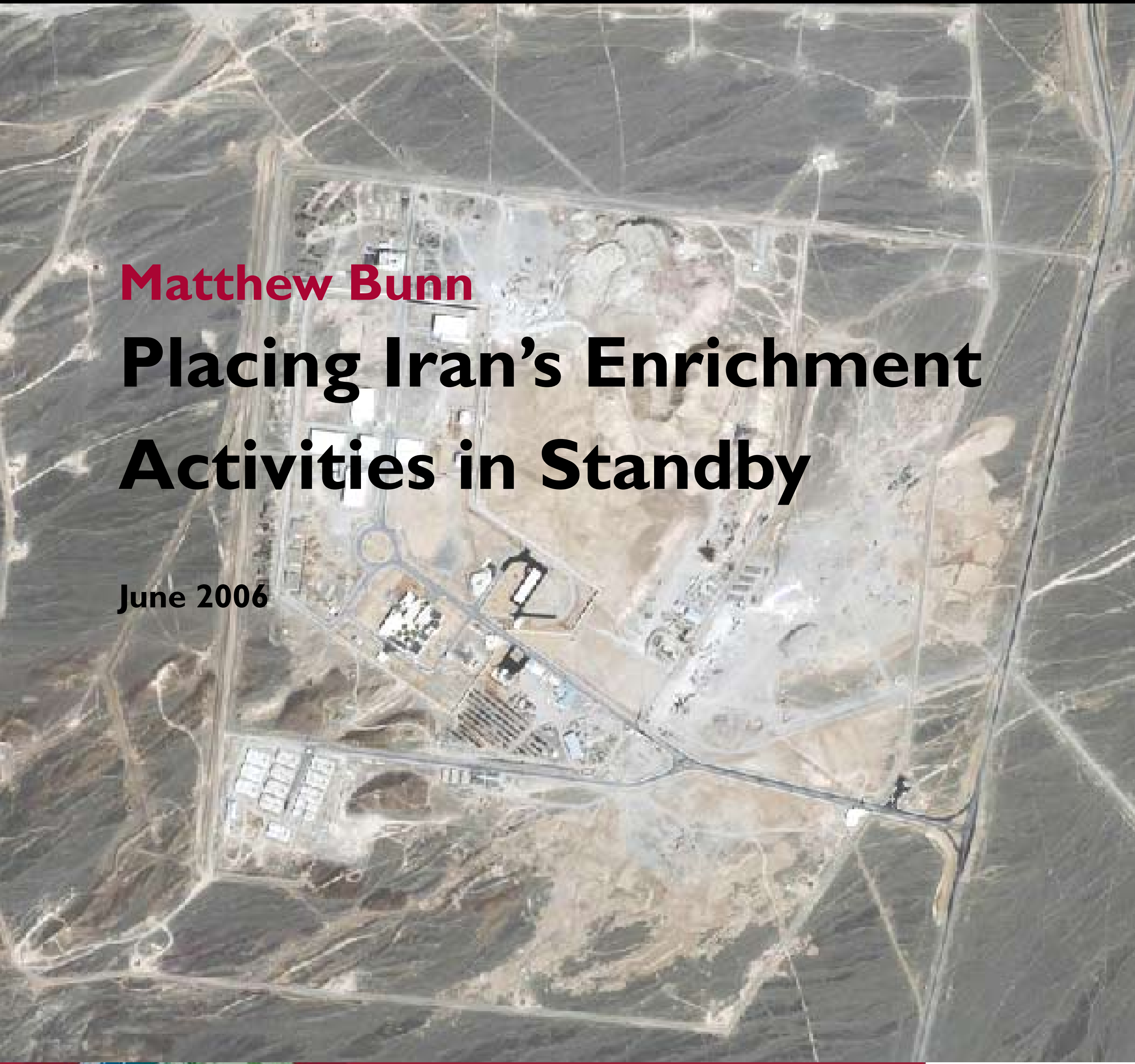

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Placing Iran's Enrichment Activities in Standby

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The Pilot Fuel Enrichment Plant near Natanz, Iran, is a small facility (noted by the box) with a cascade of 164 centrifuges housed in a small room...

...while the U.S. Portsmouth Gaseous Diffusion Plant, as shown here, sprawls over hundreds of acres.

Despite differences in size and technology, however, the experience of developing options for keeping the Portsmouth facility on standby provides analogies to drawn upon in designing standby options for Natanz's centrifuges.

Cover Image: Overhead view of the Natanz Enrichment Facility in Iran.

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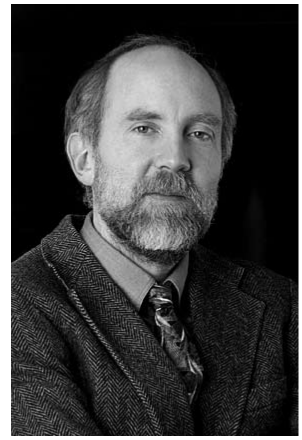
Placing Iran's Enrichment Activities in Standby

A central question in resolving the crisis over Iran's nuclear-related activities is what kind of enrichment-related activities will or will not continue in Iran. The current proposal from Europe, the United States, Russia, and China calls on Iran to suspend all enrichment-related activities while negotiations on a longer-term deal are underway; a moratorium on enrichment would be lifted only if approved by the United Nations Security Council, where the United States holds a veto.

For Iran, by contrast, maintaining its right to enrichment has become a point of national pride, on which it is difficult to compromise. Iran wants to continue "research and development" work with the 164 uranium enrichment centrifuges currently operating at its Natanz facility, and retain the right to expand to full-scale enrichment later. Iran's stated rationale is concern about being able to move rapidly to large-scale enrichment if foreign fuel supplies for its planned reactors are ever interrupted.

One option for Iran to suspend enrichment activities without compromising its future ability to resume enrichment is to place the 164 centrifuge cascade at Natanz in a standby mode. The United States considered "warm standby" and "cold standby" options for its Portsmouth enrichment plant several years ago. Despite the vast technical differences between a large gaseous diffusion plant and a small centrifuge facility, these approaches may provide analogies that the parties could draw on to forge an approach acceptable to all sides. An acceptable approach would have to assure the United States and Europe that the standby activities would not significantly increase Iran's capacity to manufacture nuclear weapons material; by the same token, accepting such an approach would require Iran to make a strategic decision not to pursue an option for rapid production of such material. At the same time, to be acceptable to Iran, an agreed approach would likely have to maintain Iran's ability to restart operations at Natanz.

If, in the future, states negotiate (or the United Nations Security Council imposes) requirements that states that violate their safeguards agreements suspend all sensitive nuclear activities and rely on foreign fuel supply until the violations have been corrected and international confidence restored, such standby approaches might be applied more broadly.[1]



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[1] See, for example, the proposals in Pierre Goldschmidt, "Addressing the Iranian Stalemate," paper presented at the Carnegie International Non-Proliferation Conference, Washington, D.C., 7-8 November 2005.

Goldschmidt is a former Deputy Director General for Safeguards of the International Atomic Energy Agency.

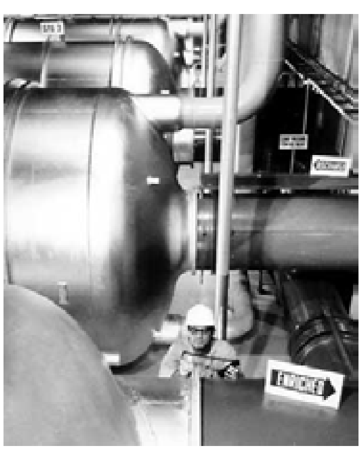
Warm & Cold Standby for the Portsmouth Enrichment Plant

In 2000, the recently-privatized U.S. Enrichment Corporation (USEC) announced plans to shut down the Portsmouth enrichment plant, one of the two U.S. gaseous diffusion enrichment plants, as there was not enough demand to run both plants profitably. The U.S. government, however, was concerned about the energy security implications of relying solely on the aging Paducah enrichment facility for five years or more until a new gas centrifuge enrichment plant was expected to open. What would happen in the event of a "significant disruption in America's supply of enriched uranium"?[2] The U.S. government also sought to "preserve jobs," especially among the "highly trained and qualified workforce" at the enrichment plant.[3] Although the political context is far different, these concerns are similar to those Iran has expressed as reasons to maintain some ability to restart enrichment operations at Natanz.

The Department of Energy (DOE), which continued to own the Portsmouth and Paducah facilities while leasing them to USEC, developed a warm standby and a cold standby option for Portsmouth.[4]

Warm standby. In the warm standby option, DOE would have kept portions of the enrichment cascades operating in a "recycle mode." The product and waste from the cascade would be returned to the input, cycling material through to keep that part of the cascade running without enriching the uranium. DOE would have shut the rest of the plant down, but would have "fully buffered" it by pumping dry air into the cascades to ensure that damp air would not get in and cause corrosion. DOE projected that it might be possible to return to full production of three million separative work units (SWU) per year within two months. This option would have been expensive, however: DOE projected maintaining a staff of 1,100 people (nearly all of the plant's original staff) and continuing to use one-fourth as much power as before, at a cost of some $100 million to prepare the plant for this new status, followed by $120 million per year.

Cold standby. In the cold standby option, DOE would shut down the plant entirely, buffering all of the cells with dry air and conducting constant



Gaseous diffusion units, like the ones pictured here at the now decommissioned K-25 Gaseous Diffusion Plant at Oak Ridge, Tennessee, are much larger and consume more energy than centrifuges.

[2] U.S. Department of Energy, "Energy Secretary Richardson Announces Initiative to Secure Supply of Enriched Uranium in U.S.," press release, 6 October 2000.

[3] DOE, "Energy Secretary Richardson Announces Initiative."

[4] For a brief description of the warm and cold standby options, see U.S. Department of Energy, *Report to Congress on Maintenance of Viable Domestic Uranium, Conversion, and Enrichment Industries* (Washington, D.C.: December 2000), p. 9. Except where otherwise noted, the description of these options below is drawn from this report.

surveillance and maintenance. DOE planned to install buffer alarms on the cells to sound a warning in the event they detected any damp air leaks. DOE also planned to remove some uranium deposits, which had built up on parts of the cascades over years of operation, which might have blocked up the system as it moved to restart. DOE expected that restart in this case would take up to two years. The estimated cost of this option was far less, $210 million total over four years.

On October 6, 2000, then-Secretary of Energy Bill Richardson announced that DOE would keep Portsmouth in cold standby for five years, until a new centrifuge enrichment plant was built.[5]

[5] DOE, "Energy Secretary Richardson Announces Initiative."

In implementing this option, DOE found that it required a great deal of work to get the facility ready to survive the winter while shut down. During normal operations, the huge amount of waste heat from the diffusion operations heated the building (a very different circumstance from a centrifuge plant, which consumes little power and has only modest waste heat). Without that source of heat, DOE had to install various heaters to keep pipes and other equipment from freezing.

Though construction of a new centrifuge plant continues to be delayed, the cold standby contract ended in September 2005, and DOE transitioned the Portsmouth plant to final shutdown activities. In the end, the cold standby option proved to be more expensive than expected. The total life-cycle cost of the cold standby operation is estimated to have been $370 million (in 2006 dollars).[6] DOE's Inspector General criticized the management of the effort as ineffective.[7]

[6] U.S. Department of Energy, *Department of Energy FY 2007 Congressional Budget Request*, Vol. 5 (Washington, D.C.: DOE, February 2006), p. 219

[7] U.S. Department of Energy, Office of the Inspector General, *Audit Report: Cold Standby Program at the Portsmouth Diffusion Plant*, DOE/IG-0634 (Washington, D.C.: DOE, December 2003.

Warm & Cold Standby Options for Natanz

Currently, only 164 centrifuges are in operation in a small cascade at Natanz (*see below*). Spinning centrifuges, with their risk of vibrating themselves apart when they are turned off or turned on, are a markedly different technology from gaseous diffusion, with its massive pumps and membranes with the risk of clogging. Moreover, there is a vast difference in scale, with the operating centrifuges at Natanz in a single room requiring very little power, compared to the Portsmouth plant sprawling over hundreds of acres, using hundreds of megawatts of power. Nevertheless, warm standby and cold standby options that could be considered for Natanz are similar, in some respects, to those considered for Portsmouth.

P-1 centrifuges recovered in Libya, similar in design to Iran's centrifuges at Natanz. Note the difference in scale from the gaseous diffusion units.

Cold Standby. As with Portsmouth, cold standby would involve shutting down the cascade, with efforts to maintain as much ability to restart as possible. Iran shut down the centrifuges that were already in place during the previous suspension, but there is little public data concerning what efforts, if any, Iran took to maintain restart capabilities during that period.

For centrifuges that are not perfectly balanced, there is a risk that some of the machines will fail as they pass through vibration resonances as they slow down, and again as they are turned back on and come up to full speed. For well-balanced centrifuges, this is not a major problem: in Germany, for example, late last year URENCO reportedly turned off all the thousands of centrifuges in the Gronau plant and turned them all back on again, without experiencing significant failures.[8] Iran, with earlier-generation centrifuges and less experience in manufacturing them and balancing them accurately, might encounter more failures.

[8] Personal communication from Alexander Glaser, Princeton University, June 2006, based on discussions with Pat Upson, URENCO.

Therefore, the standby effort might include a monitored program to manufacture an agreed number of replacement centrifuges (to replace those that fail on shut-down and the fraction of the total that were expected to fail on restart); it might also include monitored manufacture of replacements for any components which surveillance indicated had degraded unacceptably during shut-down. It would also include regular maintenance and surveillance of the facility (perhaps carried out by an international team, to build confidence).

Because the time required to begin spinning centrifuges is small, it is very likely that a cold standby program could be designed that would allow restart within a matter of weeks or months. As only a modest number of personnel and almost no power would be needed, the cost of such an operation would be small, a tiny fraction of the Portsmouth cold standby costs. If the parties agreed, Iran could conduct monitored testing of one or a few centrifuges during this cold standby period. International Atomic Energy Agency (IAEA) inspections could readily confirm that only agreed activities were taking place at Natanz.

Warm standby. In a warm standby option, the centrifuges at Natanz would continue to spin with inert gases instead of uranium hexafluoride (UF6). (This appears to have been the approach Iran has been taking for part of the period since it restarted enrichment operations in February 2006.) The continued spinning of the centrifuges would allow Iran to make some further technical progress in its understanding of centrifuge operations during the standby period; for example, even without UF6, the continued high-speed spinning would help determine whether the centrifuge bearings (one of the more technically challenging elements of a centrifuge) were functioning reliably for years at a time. But without using UF6 or adding centrifuges, it would be difficult for Iran to substantially improve its centrifuge designs or its ability to build and operate centrifuges and centrifuge cascades.

If this standby mode was maintained for several years, some centrifuges would be likely to fail from normal wear and tear. As with cold standby, the parties might agree on a monitored program to manufacture replacements for centrifuges that failed. The warm standby option would probably be more expensive overall: it would have significantly higher operating costs, but, depending on the number of centrifuges that would fail on shut-down in the cold standby case and the number that would fail during operation in the warm standby case, the warm standby option might have lower equipment costs. Unlike the Portsmouth case, however, the costs of either option would likely be small enough to have little effect on decisions. Warm standby would allow very rapid restart of operations with uranium hexafluoride. As in the cold standby case, IAEA inspections could readily confirm that only agreed activities were taking place at Natanz.

Options for the Natanz centrifuges, shown here, could include a cold standby approach, in which the centrifuges would be turned off but maintained in a state ready to return to operation rapidly, or a warm standby approach, in which the centrifuges would be kept spinning but would be filled with inert gas rather than uranium hexafluoride.

Conclusions

In short, warm and cold standby approaches offer options for a verifiable pause in uranium enrichment operations, while maintaining Iran's capabilities for the future. Either option would effectively constrain Iran's ability to use activities at Natanz to increase its potential capability to produce material for nuclear weapons. The cold standby option's constraints would be somewhat stronger in this respect than those of the warm standby option, and the cold standby option would probably be cheaper for Iran to implement as well. Either option would allow a rapid restart of enrichment operations.

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