Defining Iranian Nuclear Programs in a Comprehensive Solution under the Joint Plan of Action

Drawn from Institute for Science and International Security (ISIS) Sponsored Workshops and Discussions[1]

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This report discusses the necessary provisions of a comprehensive solution regarding Iran's nuclear program that the P5+1 and Iran will seek to conclude over the coming months as outlined in the Joint Plan of Action. In particular, this discussion seeks to define Iran's enrichment and heavy water reactor programs and their associated parameters, and the duration of long-term provisions.

The provisions discussed in this report require intrusive verification of Iran's nuclear program aimed at ensuring that Iran's declarations are correct and complete and developing confidence in the absence of undeclared nuclear facilities and materials. The latter condition must include sufficient verification measures to detect the construction and operation of secret gas centrifuge plants, a daunting task in the best of circumstances. This report does not address in detail the necessary verification steps; those steps will be the subject of subsequent ISIS workshops and reports.

Nonetheless, certain key aspects of the verification arrangements are already clear. One overriding condition that will need to be accepted by Iran is what is commonly called the "Additional Protocol Plus" or "AP Plus." This condition recognizes that, despite its central importance, the Additional Protocol (AP) by itself is necessary but not sufficient to verify any comprehensive solution. The other elements that would comprise the "Plus" need to be further developed, but some have been identified in general. One element is the verification of centrifuge manufacturing, including the declaration and verification of key raw materials and components. The declaration needs to include the origin and amounts of key raw materials and the total number of major components, including the number held in stock, the number manufactured or procured, and their fate. Another element is the verification of uranium obtained abroad and produced domestically, e.g. in uranium mines and mills. A third area is the verification of any key facilities, materials, and components associated with the former military dimensions of Iran's nuclear programs. This step, once put in place, would depend on Iran already having satisfied the International Atomic Energy Agency's (IAEA's) concerns about the military dimensions of its nuclear programs.[2] A fourth step is that Iran would agree to provide the IAEA with details of past and future imports, exports, and uses of key items listed under INFCIRC 254 part 1 and 2 and other critical goods that are used in Iran's nuclear programs.

[1] This report reflects the analysis of ISIS and not necessarily the positions of those who attended the workshops.

[2] The Joint Plan of Action is structured to require Iran to satisfy the IAEA's concerns about the possible military dimensions of its nuclear programs prior to achieving a comprehensive solution. If Iran does not, then U.N. Security Council (UNSC) and U.S. economic sanctions are unlikely to be removed. In the case of UNSC sanctions, only one member of the P5 need veto a resolution to prevent removing them and this state would be justified since the IAEA's concerns about possible Iranian weaponization activities are central to resolutions.

The over-riding goal of the negotiations of a comprehensive solution is to establish a set of provisions, and associated verification measures, which if Iran agreed to them would in our view protect the national security interests of the United States and its allies. The resulting limited nuclear programs and extensive verification measures would eliminate the risk of Iran breaking out to nuclear weapons at declared or covert nuclear sites without that effort being detected in a timely manner and without adequate time for U.S. and international responses that would prevent Iran from succeeding in that effort. This approach depends on the United States remaining ready for many years to take the steps necessary to prevent Iran from obtaining nuclear weapons.

In return, the United Nations Security Council, the United States, and allied countries should in a phased and reversible manner lift the economic sanctions currently in place against Iran, except those related to the procurement of nuclear and nuclear-related goods, which are typically called counterproliferation sanctions.

Below, this report outlines a set of provisions that would form the basis of a comprehensive solution able to protect adequately national security interests. By their nature, these provisions are highly technical. For background information, the reader is referred to the main ISIS website and its Iran-specific website. ISIS will return to the associated verification measures in later reports.

Conditions without a defined duration

- The Arak reactor complex will be upgraded to a light water reactor using low enriched uranium (LEU) fuel. The enrichment of the fuel should be less than 5 percent in the isotope uranium 235. The spent or irradiated fuel should be sent overseas, as is the case with the irradiated fuel from the Bushehr reactor.
- Iran will not reprocess any irradiated fuel or build a facility capable of reprocessing. Any irradiation positions in the reactor, fuel and target handling arrangements, and hot cells will be designed to produce isotopes for medical and industrial uses only.
- Iran will not enrich above 5 percent in the isotope uranium 235, and will not produce stocks of enriched uranium that exceed in quantity the needs of its civilian program, noting that it has long term LEU fuel delivery agreements with Russia and would be expected to have additional ones with foreign reactor vendors after the conclusion of a comprehensive solution.
- Iran will commit not to procure goods for its nuclear programs abroad in a manner that is considered illicit ("illicit nuclear trafficking or trade"). Such trafficking is illicit if such trade is not authorized:
    - by the state in which goods originate;
    - by the United Nations Security Council or regional authorities, such as the European Union;
    - by the states through which the goods transit; or
    - for import into the buying state or for use in an Iranian nuclear program.

Conditions and parameters with a defined duration of 20 years

- Iran will have only one enrichment site, the one at Natanz. The Fordow site will be shut down or converted into a non-centrifuge-related site.
- Centrifuge research and development will only be conducted at the one enrichment site. All centrifuge testing, with or without nuclear material, will occur at this site. In particular, this

site will be the sole location to test rotors, whether tested in air, under vacuum, or with uranium hexafluoride.

- Centrifuge research and development will be limited to centrifuges with the theoretical equivalent enrichment output of no more than five separative work units in kilograms uranium (swu) per year.
- Major centrifuge component manufacturing and storage locations will be limited in number and identified. Moreover, Iran will fully inform the IAEA about these locations and any new locations well before starting centrifuge component manufacturing or storage at a new location.
- Centrifuge assembly will occur only at the one enrichment site.
- Steps will be taken at the enrichment plant to shorten detection times of a breakout through improved monitoring, such as remote camera monitoring and more unannounced inspections of the cascade areas.
- The number and type of centrifuges will be limited to ensure that breakout times are measured in many months and will be a minimum of six to twelve months at all times. In this report, to illustrate this method and make it concrete, we derive a cap on the number of centrifuges at the Natanz enrichment site based on a breakout time of six months. (The Fordow enrichment plant is assumed to close.) It should be noted that in addition to holding stocks of 3.5 percent LEU, Iran can be expected to hold sizeable stocks of near 20 percent LEU in the form of oxide powders, other solids, and solutions, and unirradiated and slightly irradiated oxide fuel elements and assemblies. Since most of these stocks of near 20 percent LEU oxide could be reconverted to hexafluoride form and used in a breakout, the amounts of these materials should be limited so as not to reduce the breakout times, in this case, below six months (see below).
- In order to define a cap in practical terms, it is necessary to first consider the case where only IR-1 centrifuges are enriching at the Natanz Fuel Enrichment Plant. In the case of a six month breakout time, a cap on total number of IR-1 centrifuges at the Natanz site is derived from the condition of the historical IR-1 centrifuge operations at the Natanz Fuel Enrichment Plant. Based on a set of calculations performed by University of Virginia centrifuge experts in support of ISIS, about 5,500 IR-1 centrifuges would lead to estimated breakout times of a minimum of about five to near seven months with a median of about six months, assuming that only 3.5 percent LEU is available to feed the cascades. However, because Iran is expected to hold a sizeable stock of near 20 percent LEU, which can be converted into hexafluoride form and fed into the cascades, this number of centrifuges is too large to result in a six month breakout estimate. In this calculation, it is assumed that Iran would retain a stock of unirradiated, or slightly irradiated, near 20 percent LEU oxide that is equivalent to only 100 kg of near 20 percent LEU hexafluoride (at the end of the interim period, Iran is estimated to hold the equivalent of over 300 kg of this material). In this case, during the first three months, using only 3.5 percent LEU, it could produce about 12.5 kilograms weapon-grade uranium (uranium mass). It could simultaneously build a conversion line and start reconverting the LEU oxide into hexafluoride form; three months should be sufficient for Iran to accomplish this task. At that point, it could feed both 3.5 percent and near 20 percent LEU into the cascades and in 1.75 months (range of 1.4-2.1 months) produce another 12.5 kg of weapon-grade uranium (uranium mass). So in a total of 4.75 months, it could produce 25 kg of weapon-grade uranium (uranium mass), or enough for a nuclear weapon. A stock equivalent to as low as 50 kg of near 20 percent LEU hexafluoride will not change this estimate. Getting this stock below 50 kg via significant irradiation in the Tehran Research Reactor will likely not occur for years. If Iran, as expected, maintains stocks of near 20 percent LEU, even in oxide form, then the number of centrifuges will need to be reduced below the above value of 5,500 IR-1 centrifuges to maintain a breakout time of six months. A reasonable value is 4,000 IR-1 centrifuges, which would give a breakout time of about eight months, assuming only 3.5 percent LEU is used, and one closer to six months if a limited stock of near 20 percent LEU is also available, as above. This

calculation also highlights that Iran will need to limit further its stock of near 20 percent LEU. Limits on Iran's stockpile of LEU are discussed in more detail below. In summary, in the case of a six month breakout time, Iran should have in total no more than 4,000 IR-1 centrifuges.

- Because Iran may seek to replace the IR-1 centrifuges with more capable ones, a more general enrichment cap is derived from the cap on IR-1 centrifuges developed above. For the case of IR-1 centrifuges at the Fuel Enrichment Plant, the above breakout calculations have used an average value in cascades of 0.9 swu per year per centrifuge. Using this average enrichment value and continuing to use the case of a six month breakout time, 4,000 IR-1 centrifuges would be equivalent to a total annual enrichment output of approximately 3,600 swu/year. This value serves as a general enrichment cap regardless of the actual enrichment capacity of any centrifuge that would replace the IR-1 centrifuge in the future. It would also serve in the case that the IR-1 centrifuges had an average enrichment value significantly different than 0.9 swu/yr/cent or if other types of centrifuges were installed at Natanz. If Iran deployed IR-2m centrifuges, for example, the parties would need to agree upon an average centrifuge enrichment value before deriving the number of IR-2m centrifuges needed to produce 3,600 swu/yr. For example, if an IR-2m centrifuge has an average enrichment output of 4 swu per year, then the cap would be 900 IR-2m centrifuges. If Iran deploys any other enrichment technology, such as laser enrichment, it and any centrifuge plant would need to have a total enrichment output at this cap or below.
- In the case of the IR-1 centrifuges, centrifuge manufacturing would be limited to the replacement of broken centrifuges, if no spares exist (see below). For example, in the case of IR-1 centrifuges, a stock of many thousands of uninstalled centrifuges would be stored and then drawn upon to replace broken ones. Thus, Iran would agree not to build any IR-1 centrifuges until this stock is exhausted.[3] Centrifuge manufacturing of new centrifuges in the case of the IR-2m centrifuge, if used for enrichment at the Natanz Fuel Enrichment Plant, would be unnecessary, at least initially, because any broken ones could be drawn from a surplus stock of them. In the case of new centrifuges, Iran will not build more centrifuges than allowed to be installed under the above enrichment cap of 3,600 swu/year and would build more only to replace broken ones.
- When the long term agreement takes effect, centrifuges and all associated cascade equipment in excess of the cap would be turned off, so that no centrifuges are operating and the cascades are not under vacuum. Centrifuges would be turned off in a controlled manner so as to limit centrifuge damage.
- Right after the comprehensive solution is implemented, excess centrifuges and the cascades containing them would be disabled in a manner so as to require at least one month to restart any disabled cascades. To achieve this goal, several disablement steps would likely be necessary, such as removing key equipment from the feed and withdrawal sections of the plant, removing key measuring equipment from individual centrifuges such as vibration detectors, fast-acting and other valves, pressure transducers from the cascades, and computer control equipment. [Some of the key equipment removed should be taken out of Iran.] The March 18, 2013 Almaty Confidence Building Proposal, Technical explanation of the E3/EU+3 Almaty proposal, describes several important disablement steps, but the steps in the Almaty proposal are unlikely to be sufficient to achieve the goal of one month reconstitution time.

[3] Broken centrifuges will be replaced with centrifuges of the same type. This should mean, for example, that an installed IR-1 centrifuge would be replaced with an IR-1 centrifuge of the same design and enrichment capability as the one removed. A broken centrifuge is defined as one that has a rotor assembly incapable of spinning under power and cannot be repaired.

(http://backchannel.al-monitor.com/index.php/2013/06/5444/p51-almaty-confidence-building-proposal-to-iran/#ixzz2nuw2GuAZ).

- Excess centrifuges and associated cascade piping and equipment will be scheduled for removal from Natanz and Fordow and stored under IAEA monitoring. These centrifuges and associated cascade items will be stored at an agreed-upon site under IAEA monitoring, pending their use as replacements of broken centrifuges and cascades or their destruction under monitoring.
- Iran will not build any conversion lines that can convert enriched uranium oxide into hexafluoride form.
- LEU stocks will be limited, based on a realistic civil justification.
    - With regard to near 20 percent LEU, Iran will not possess any such LEU in hexafluoride form and its total stock in unirradiated oxide form including in fresh fuel elements and assemblies, will be less than the equivalent of 100 kg of near 20 percent LEU hexafluoride soon after the start of the implementation of the comprehensive solution. This proposed cap will require Iran to further reduce its stocks of near 20 percent LEU through blending down to less than five percent enriched uranium, irradiation in the Tehran Research Reactor (TRR) which would make reconversion to hexafluoride form much more difficult, or transfer overseas for storage. Although Iran would commit to not building any conversion lines to reconvert the near 20 percent LEU oxide into hexafluoride form usable in centrifuges, it could build such a capability relatively rapidly if it reneged on its commitment not to do so. Thus, it is also necessary to limit further the near 20 percent LEU stocks. As of November 2013, Iran had approximately 195.3 kg near 20 percent LEU hexafluoride, according to the IAEA. Iran had also fed a total of 213.5 kg of 19.75 percent enriched uranium hexafluoride (or about 144 kg of near 20 percent LEU (uranium mass)) into the process lines at Esfahan and produced U_3O_8 containing about 88.4 kg of enriched uranium (uranium mass). The IAEA verified 28.7 kilograms of near 20 percent LEU (uranium mass) in liquid or solid scrap form. Thus, an estimated 26.9 kg of near 20 percent LEU (uranium mass) remained held up in the process or in different forms, as of this date. Since November Iran has produced more near 20 percent LEU hexafluoride and may have converted more into oxide form. Under the interim steps, Iran has agreed to blend down about half of its stock of 19.75 percent uranium hexafluoride and convert the rest into oxide form. Ignoring what Iran has produced or converted since early November 2013, 97.7 kg near 20 percent LEU hexafluoride is slated for conversion into oxide under the interim deal. That translates to about 65 kg near 20 percent LEU oxide (uranium mass). In total, at the end of the interim period Iran is expected to possess 209 kg of near 20 percent LEU (uranium mass) in various forms, although mostly in oxide form. This amount is the equivalent of approximately 310 kg near 20 percent LEU hexafluoride. Most of this LEU could be reconverted in a straightforward manner into near 20 percent LEU hexafluoride and further enriched in centrifuges, if Iran decided to renege on its agreements. If reconverted to hexafluoride form, Iran could dramatically reduce its breakout times, even with reduced numbers of centrifuges. However, some of the LEU will be in scrap and may not be readily convertible into hexafluoride form. Some will be irradiated in the TRR and unlikely to be recovered easily. But these amounts will amount to only a fraction of the total LEU. Iran would be expected to reduce the amount in scrap and the TRR, which is a small reactor, will take years to irradiate the equivalent of even 100 kilograms of near 20 percent LEU hexafluoride. Thus, well over half of the LEU fed into the process lines at Esfahan will likely be stored with no imminent use in a reactor. A priority is achieving a reduction of the stock soon after the start of the implementation of the comprehensive solution to no more than the equivalent of 100 kg of near 20 percent LEU hexafluoride. During the

implementation period, this stock will be reduced further to below the equivalent of 50 kg of near 20 percent LEU hexafluoride.
    - Iran will not possess more than the equivalent of 20 tonnes of unirradiated, less than five percent LEU hexafluoride, almost all of which should be in oxide form.[4] Of this total LEU inventory, Iran will possess no more than 1.5 tonnes LEU hexafluoride at any one time; in essence this cap requires Iran to convert LEU hexafluoride into oxide form.
    - LEU in excess of these caps will be blended down to natural uranium or shipped abroad for storage or fuel manufacturing. In practice, this step is likely to be necessary only if Iran does not find a way to use this LEU in reactors during the next decade. As of November 2013, Iran had 7,154 kg of 3.5 percent LEU hexafluoride. At a cap of 3,600 swu/yr, Iran could produce about 1.2-1.5 tonnes 3.5 percent LEU hexafluoride per year. Thus, it would reach the cap in about 8-10 years.
- Uranium mining, milling, and conversion facilities will be limited in throughput to the actual need for enrichment or other mutually agreed upon use. In the case of enrichment, the throughput limits would be defined by the cap on enrichment capacity.
- At the beginning of the period of the comprehensive solution, a procurement channel will be established for items needed in Iran's nuclear programs. The list of items will be established by mutual agreement and will include major nuclear facilities, nuclear components, nuclear and nuclear-related dual-use goods, and other sensitive items such as those on watch lists. The channel will be established in a United Nations Security Council resolution that will be binding on all states. The resolution will create a committee and a Panel of Experts to oversee the channel. Procurements of listed items outside this channel will be banned and considered illicit nuclear trade. This condition will also have the benefit of more clearly identifying procurements from North Korea to Iran as illicit. Iran will declare to the IAEA the key exports received and these items will be subject to IAEA verification.
- Iran will not export or otherwise transfer nuclear materials, reactors, centrifuges, reprocessing equipment, other nuclear facilities or equipment, or the means to make such equipment or facilities to any state, company, or other entity.[5]
- By the end of the period in which the comprehensive solution will be in force, Iran will implement an export control system in line with the requirements of the four main export control regimes (lists and guidance) and submit a comprehensive report to the 1540 Committee on Iran's implementation of the resolution. Iran will also commit not to export or otherwise transfer reprocessing or enrichment technologies or goods to any state or non-state actor after the comprehensive solution period ends.

Conclusion[6]

[4] Excluded are the many tonnes of LEU that ended up in dump tanks due to the need to evacuate the cascades unexpectedly. Typically, this material was enriched to about one percent or less. This quantity should be blended down to natural uranium or enriched further to 3.5-5 percent and counted in the above cap.

[5] A model condition developed by ISIS: The state of concern agrees not to transfer to any state or entity whatsoever, or in any way help a state or entity obtain, nuclear weapons or explosive devices, or components of such weapons; nuclear material; nuclear know-how or technology; or equipment, material, goods, technology designed for, prepared for, or that can contribute to the processing, use, or production of nuclear materials for nuclear weapons or in sanctioned nuclear programs.

[6] ISIS considered several other provisions but decided not to include them in the main text, which focuses on a minimal set of provisions. However, the following three provisions are worth further exploration:

- The fate of the heavy water production plant would be left to Iran but its continued operation would have conditions on production levels and the use and sale of the heavy water. At any given point in time, the heavy water inventory of Iran would not exceed 20 tons.

The above provisions collectively should represent a fundamental part of a final, comprehensive solution that can ensure that Iran will not obtain nuclear weapons. Once the necessary verification conditions are added, any Iranian attempt to seek nuclear weapons will be detected in a timely manner, providing enough time to allow an international response that would prevent Iran from succeeding in acquiring nuclear weapons. Critical to this approach is that the United States must remain ready for many years to prevent Iran from obtaining nuclear weapons.

The duration of the provisions, namely twenty years, is viewed as a minimum amount of time to develop confidence that Iran can be treated in the same manner as other non-nuclear weapon states in good standing with the Nuclear Nonproliferation Treaty. The twenty years would in particular allow the IAEA enough time to thoroughly verify that Iran is fully compliant with its safeguards and treaty obligations and that it has ceased any military nuclear-related activities. In particular, the IAEA would have the time to determine under the Additional Protocol a "broader conclusion" about Iran's nuclear programs and activities. Such a determination has taken many years in the case of states that have *not* violated their safeguards agreements, such as Japan, Canada, and South Africa. Iran has violated its safeguards agreement for more than 20 years, according to Olli Heinonen, the former Deputy Director General of the IAEA who is intimately familiar with the Iranian file in the 1990s and 2000s. So it would not be surprising if the IAEA needed two decades to ensure that Iran is fully compliant with all its non-proliferation obligations. It should be noted, however, that the removal of key economic sanctions would neither depend on the IAEA reaching this broader conclusion under the Additional Protocol nor eliminate the requirement for Iran to address the IAEA's concerns about the alleged military dimensions of Iran's nuclear programs prior to the finalization of a comprehensive solution.

An issue that is not addressed in the Joint Plan of Action is the following: what happens if 20 years, or any other duration agreed upon, is not enough time to achieve necessary confidence in the exclusively peaceful nature of Iran's nuclear programs? Currently, the Joint Plan of Action implies that the provisions outlined above would simply end after this time has passed. Thus, there is the need for a set of conditions that would be met before the above provisions are suspended after the 20 years.

Nonetheless, if Iran accepted these provisions outlined above, the duration period of 20 years, and the associated verification conditions, the major sanctions related to its nuclear programs should be removed.

- Iran should ratify the Comprehensive Test Ban Treaty (CTBT) as an additional means to demonstrate its commitment to nonproliferation.
- Iran could offer its centrifuge plants to the IAEA as facilities where new safeguards techniques and technologies could be tested, similar to some other states with centrifuge plants.