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Statement of Mr. Michael Elleman
Iran's Ballistic Missile Program
Before the
U.S. Senate Committee on Banking, Housing, and Urban Affairs
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Introduction

Chairman Shelby, Ranking Member Brown, distinguished members of the Committee: I am pleased to testify before you today about Iran's Ballistic Missile Program and the role of sanctions under the Iran Deal.

My statement is informed by two decades of work as a missile scientist at Lockheed Martin's R&D laboratory, and more than 25 years observing and writing about ballistic-missile proliferation. I have participated in technical exchanges and visited missile production and testing facilities in at least seven countries, and have worked missile-related issues with technical experts from throughout the world. Over the past decade I have interviewed, formally and informally, Russian and Ukrainian missile experts who have worked in Iran and witnessed first-hand the status of its missile program and its indigenous capabilities. In 2010, I authored a dossier by the International Institute for Strategic Studies on *Iran's Ballistic Missile Capabilities,* which was a collaborative study supported by missile specialists from Russia, Germany, France, Israel and the U.S. I continue to monitor missile developments around the world.

My statement today reflects my views and not necessarily those of any organization to which I consult.

Iran's Ballistic Missile Doctrine and Capabilities

Ballistic missiles are central to Iran's deterrence posture and will remain so for the foreseeable future. The priority assigned to ballistic missiles is reflected by the size and scope of Iran's arsenal, the largest and most diverse in the region. Given this importance, Iran will not surrender its current systems, except, possibly, under the direst of circumstances. Even if Iran acquires advanced military aircraft in the near future, ballistic missiles will continue to play a prominent role in its force structure.

Iran's pursuit of ballistic missiles pre-dates the Islamic revolution. Ironically, the shah teamed with Israel to develop a short-range system after Washington denied his request for *Lance* missiles. Known as *Project Flower*, Iran supplied the funds and Israel provided the technology. The monarchy also pursued nuclear technologies, suggesting an interest in a delivery system for nuclear weapons. Both programs collapsed after the revolution.

Under the shah, Iran had the largest air force in the Gulf, including more than 400 combat aircraft. But Iran's deep-strike capability degraded rapidly after the Islamic Revolution and the break in ties with the West limited access to spare parts, maintenance, pilot training and advanced armaments. Consequently, Tehran turned to missiles to deal with an immediate war-time need after Iraq's 1980 invasion, and the subsequent air and missile attacks on Iranian cities. Iran acquired Soviet-made *Scud*-Bs, first from Libya, then from Syria and North Korea. It used these 300-km missiles against Iraq from 1985 until the war ended in 1988.

In Tehran's view, ballistic missiles played a critical role in responding to Iraqi missile attacks, and deterring future ones. The Iranian regime also witnessed how quickly the U.S-led coalition devastated the Iraqi army in 1991, the same army Iran battled to a standstill during an eight-year war. The only notable response from Iraq during *Operation Desert Storm* came in the form of ballistic-missile attacks against Israel, Saudi Arabia and other Gulf countries. The diversion of coalition aircraft to the '*Scud*-hunting' mission, and away from the assault on Iraqi troops and equipment, further informed Tehran's thinking.

Throughout the 1990s and beyond, Tehran steadily expanded its missile arsenal. It invested heavily in its own industries and infrastructure to lessen dependence on unreliable foreign sources, and is now able to produce its own missiles, although some key components still need to be imported. Iran has demonstrated that it can also significantly expand the range of acquired missiles, as it has done with *Nodong* missiles acquired from North Korea. Iran's missiles can already hit any part of the Middle East, including Israel. Tehran has established the capacity to create new missiles to address a most of its strategic objectives.

Iran's arsenal

The Islamic Republic's arsenal now includes several types of short-range and medium-range missiles. Estimates vary on specifics, and Iran has exaggerated its capabilities in the past. There is widespread consensus that Tehran has acquired and creatively adapted foreign technology to continuously increase the quality and quantity of its arsenal. It has also launched an ambitious space program that works on some of the same technology. The arsenal includes:

***Shahab* missiles:** Since the late 1980s, Iran has purchased additional short- and medium-range missiles from foreign suppliers and adapted them to its strategic needs. The *Shahabs*, Persian for "meteors," were long the core of Iran's program. They use liquid fuel, which involves a time-consuming launch. They include:

The ***Shahab*-1** is based on the *Scud*-B. (The Scud series was originally developed by the Soviet Union). It has a range of about 300 kms or 185 miles, and carries a one-ton warhead.

The ***Shahab*-2** is based on the *Scud*-C. It has a range of about 500 kms, or 310 miles, but with a 720-kg warhead. In mid-2010, Iran is widely estimated to have between 200 and 300 *Shahab*-1 and *Shahab*-2 missiles capable of reaching targets across the Gulf. Iran began modifying its *Shahab*-2s in 2010 to create the ***Qiam*** missile. The *Qiam* can fly roughly 600 km and has a detachable warhead, making it more difficult to detect and track using missile-defense radars.

The ***Shahab*-3** is based on the *Nodong*, which is a North Korean missile. It has a range of about 900 km or 560 miles. It has a nominal payload of 1,000 kg. A modified version of the *Shahab*-3, renamed the **Ghadr-1**, began flight tests in 2004. It theoretically extends Iran's reach to about 1,600 km or 1,000 miles, which qualifies as a medium-range missile. It carries a smaller, 750-kg warhead.

Although the *Ghadr*-1 was built with key North Korean components, Defense Minister Ali Shamkhani boasted at the time it first appeared, "Today, by relying on our defense industry capabilities, we have been able to increase our deterrent capacity against the military expansion of our enemies."

A modified version of the *Ghadr*-1 missile, known as *Emad*, was tested in October 2015. *Emad* has four fins mounted at the base of the detachable warhead. In principle, the fins can steer the warhead toward the target as it descends through the atmosphere. In practice, however, full development of the *Emad* will a decade or more, and scores of flight tests. The *Emad*'s appearance indicates that Iran seeks to improve the accuracy of its missiles, a priority that supersedes the need to develop longer-range missiles. Iran has repeated said that it does not need missiles with a range of greater than 2,000 km, or 1,200 miles.

Sajjil means "baked clay" in Persian. The *Sajjil*-2s are medium-range missile that use solid fuel, which offers many strategic advantages. They are less vulnerable to preemption because the launch requires shorter preparation – minutes rather than hours. Iran is the only country to have developed missiles of this range without first having developed nuclear weapons.

The ***Sajjil*-2** is domestically produced. It has a range of about 2,000 km or 1,200 miles when carrying a 750-kg warhead. It was test fired in 2008 under the name, *Sajjil*. The *Sajjil*-2, which is probably a slightly modified version, began test flights in 2009. This missile would allow Iran to "target any place that threatens Iran," according to Brig. Gen. Abdollah Araghi, a Revolutionary Guard commander.

The ***Sajjil*-2** appears to have encountered technical issues and has not been fully developed. No flight tests have been conducted since 2011. If ***Sajjil*-2** flight testing resumes, the missile's performance and reliability could be proven within a year or two. The missile, which is unlikely to become operational before 2017, is the most probable nuclear delivery vehicle—if Iran decides to develop an atomic bomb.

Space program: Iran's ambitious space program provides engineers with critical experience developing powerful booster rockets and other skills that could be used in developing longer-range missiles, including ICBMs.

The ***Safir***, which means "messenger" or "ambassador" in Persian, is the name of the carrier rocket that launched Iran's first satellite into space in 2009. It demonstrated a new sophistication in multistage separation and propulsion systems.

The ***Simorgh***, which is the Persian name of a benevolent, mythical flying creature, is another carrier rocket to launch satellites. A mock-up was unveiled in 2010. The *Simorgh* may have been flight tested in April 2016, though it either failed, or only the first stage was launched. The first stage is powered by a cluster of four-*Nodong* engines.

Military and Strategic Utility of Iran's missiles

Iran's ballistic missiles have poor accuracy. The successful destruction of a single fixed military target, for example, would probably require Iran to use a significant percentage of its missile inventory. Against large military targets, such as an airfield or seaport, Iran could conduct harassment attacks aimed at disrupting operations or damaging fuel-storage depots. However, the missiles would probably be unable to shut down critical military activities. Missile defenses would further degrade the military utility of Iran's missiles.

Without a nuclear warhead, Iran's ballistic missiles are likely to be more effective as a political tool to intimidate or terrorize an adversary's urban areas, increasing pressure for resolution or concessions. Such attacks might trigger fear, but the casualties would probably be low – likely less than a few hundred, even if Iran unleashed its entire ballistic missile arsenal and a majority succeeded in penetrating missile defenses.

The technology adopted for use on the new *Emad* indicates that Iran hopes to improve the precision of its larger missiles. Substantial improvements in missile accuracy will take years, if not a decade, to materialize.

Ballistic missiles no doubt would be the preferred delivery platform should Iran ever acquire an atomic weapon. There is no formal definition of what constitutes a "nuclear-capable missile," although the range-payload threshold established in the Missile Technology Control Regime (MTCR) offers a broadly accepted classification measure. The MTCR restricts the transfer of missiles capable of delivering a 500 kg payload to 300 km.

Iran's *Shahab*, *Qiam*, *Ghadr*, *Emad*, and developmental *Sajjil* missiles exceed the MTCR performance threshold. Under this definition, Iran possesses more than 300 nuclear-capable ballistic missiles.

Flight tests are an essential element of any missile program. Flight tests are used to:

- Validate the design, performance and reliability of a missile, under a variety of operational conditions;
- Verify the quality of indigenously produced missiles;
- Ensure reliability as the missiles as they age;
- Provide troop training and ensure readiness;
- Strengthen the credibility of a nation's deterrence capabilities;
- Threaten and coerce rivals.

Because Iran views ballistic missiles as a critical instrument of statecraft, deterrence and war-fighting, Tehran will very likely continue with missile testing. Sanctions are unlikely to deter Iran from testing its missiles.

The pace of missile testing by Iran last year and this year is consistent with past practices. Iran did not conduct a nuclear-capable missile launch in 2005, 2013 or 2014, when serious nuclear negotiations were underway. From 2006 to 2012, when talks were going nowhere, Iran averaged roughly five test launches per year. Three flight tests were performed in 2015, and five have occurred this year.

To place this in perspective, the U.S. and Soviet Union, on average, conducted more than 10 flight tests per year for each operational system throughout the Cold War. Given the number of systems deployed, each side conducted about one test a week.

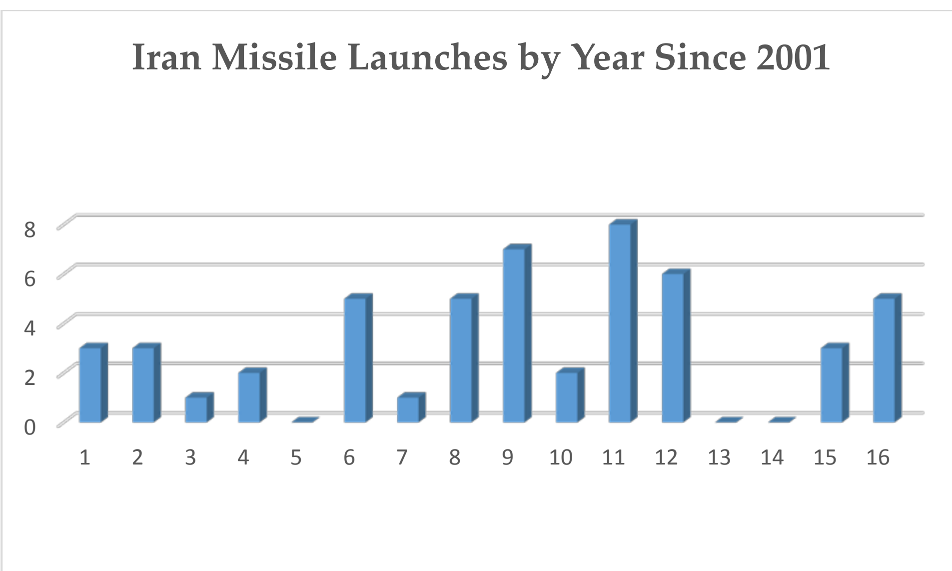

Figure 1 – The approximate number of nuclear-capable missile tests since 2001.

Long-Range Missiles

I have seen no evidence to suggest that Iran is actively developing an intermediate- or intercontinental-range ballistic missile (IRBM or ICBM, respectively). I cannot speak to a covert program. The need to flight test missiles before they are made operational provides advanced warning of new capabilities. Flight trials involve a dozen or more test launches, and historically require three to five years to complete, sometimes more.

Available evidence, including the recent début of the *Emad* medium-range missile, indicates that enhancing missile accuracy supersedes Iran's quest for longer-range systems.

Iran could attempt to use *Sajjil* technologies to produce a three-stage missile capable of flying 3,700 km or 2,200 miles. But it is unlikely to be developed and actually fielded before the *Sajjil*-2 missile is fully developed.

Iran could elect to develop a "second-generation" intermediate-range missile of 4,000 km to 5,000 km, or 2,500 miles to 3,100 miles, using solid-fuel technology. This path would provide a basis for also developing an ICBM. However, Iran's engineers would need to design, develop and test a much larger rocket motor to support IRBM and ICBM projects. Large motor development typically requires two to three years, and involves many ground tests to validate design and production, as well as performance and reliability. Ground testing would necessarily be followed by at least three years of flight trials. Thus, there is little reason to believe that the Islamic Republic could field an IRBM before 2020. Moreover, Iran would still have to rely on imported technologies, production materials, components and technical assistance.

Iran's past missile and space-launcher efforts suggest that Tehran would probably develop and field an IRBM before trying to develop an intercontinental ballistic missile capable of reaching the United States more than 9,000 km or 5,600 miles away. If development of an intermediate- and intercontinental-missile are pursued in tandem, Iran could conceivably field an operational ICBM in 2022, at the earliest. If done sequentially, Iran will struggle to achieve a viable ICBM capability before 2025.

Iran could attempt a short-cut to an IRBM or ICBM capability. Satellite launch activity could, in principle, be used as a springboard to developing an IRBM or ICBM. However, no country has converted a satellite launcher into a long-range ballistic missile. There are sound reasons why such a conversion has not materialized.

Without question, rockets designed to boost a satellite into orbit and long-range ballistic missiles employ many of the same technologies, key components, and operational features. There are, however, key characteristics that differentiate satellite launchers from ballistic missiles, apart from the payload itself. Firstly, ballistic missile payloads must survive the rigors of re-entry into the earth's atmosphere. Protecting a long-range missile's payload from the extreme heat and structural loads experienced during re-entry requires the development and production of special materials, as well as testing and validation under real conditions.

Secondly, satellite-launch vehicles and long-range ballistic missiles employ distinctly different trajectories to fulfil their respective missions. The different trajectories call for different propulsion systems for optimal performance. One cannot simply swap out one engine for another and expect the missile to perform with high dependability. Multiple flight tests of the new configuration are needed to validate performance and reliability.

A third, less obvious difference lies with the operational requirements. Before flight, satellite launchers, unlike their ballistic missile counterparts, are prepared over a period of many days, if not weeks. Components and subsystems are checked and verified prior to launch. The mission commander has the flexibility to wait for ideal weather before initiating the countdown. If an anomaly emerges during the countdown, engineers can delay the launch, identify and fix the problem, and restart the process.

In contrast, ballistic missiles, like other military systems, must perform reliably under a variety of operational conditions with little or no warning. These operational requirements impose a more rigorous validation scheme, which includes an extensive flight-test program. Normally, only after successfully completing validation testing is a missile deemed to be combat ready. This latter requirement, and the need to ensure pre-launch survivability, explain why the Soviets and Americans never converted a satellite launcher into a ballistic missile, though the reverse process occurred frequently. China developed its early long-range missiles (*DF*-3, *DF*-4, and *DF*-5) and satellite launchers (*CZ*-2 and *CZ*-3) in parallel. However, running the developmental programs in tandem did not obviate the need to conduct a full set of flight trials over many years for the military missiles. Nor did the parallel programs shorten the development timeline significantly.

Iran's *Safir* and *Simorgh* rockets are optimized to lift a satellite into orbit. The second stages used by the *Safir* and *Simorgh* are powered by low-thrust, long-action time engines, which accelerate the satellite along a path that parallels the earth's surface. A ballistic missile trajectory must climb to higher altitudes to optimize its range capacity. An underpowered second stage would necessarily fight gravitational forces over a longer time, robbing the payload of velocity and thus range. Iran would likely modify the Simorgh by replacing the second stage's propulsion system with a Scud or Nodong engine.

Iran could opt to modify the *Simorgh* satellite-launch platform for use as a ballistic missile, though the transformation would not be simple or quick. There would still be a need to flight test the transformed *Simorgh* in a ballistic missile mode. If Iran built a ballistic missile using the *Simorgh*'s first stage, and replaced the second stage with a *Nodong*, the notional missile might achieve a maximum range of 4,000 to 6,000 km, depending on configuration details and the payload. To reach the continental U.S., a powerful third stage would have to be developed and added to the first two stages of the *Simorgh*. The notional missile would remain poorly suited for use as a ballistic missile, because it would be too large and cumbersome to deploy on a mobile launcher. It would therefore have to be placed in a silo, making it an attractive target for adversaries possessing advance reconnaissance and strike capabilities.

Nonetheless, Iran could elect to upgrade and modify its *Simorgh*. The Soviet Union considered an analogous upgrade in 1957, when the *Yangel* Design Bureau suggested combining the main boosters of the *R*-12 and *R*-14 missiles to create the *R*-16 ICBM. The *R*-16 was successfully developed, but only after substantial redesign, including the development of new engines using more energetic propellants. The Soviet experience suggests that Iran would find it challenging and time consuming to build an operational ICBM derived mainly from *Simorgh* hardware. A new missile design seems more plausible.

Indigenous Capabilities

Iran possesses the technical, project-management and industrial capacity to develop and field the ballistic missiles it desires. But development of new systems will require sustained investment, years of patience and a tolerance for failed projects.

The modifications of the *Shahab*-2 and *Shahab*-3, to create the *Qiam* and *Ghadr* missiles, respectively, demonstrate Iran's technical prowess and ingenuity. North Korea has no equivalent, suggesting that Iran is slowly surpassing its original supplier of systems, components and technology. Iran has also leveraged *Shahab*-3 technology to develop the *Safir* and *Simorgh* satellite launchers. Finally, Iran has, over the course of three decades, mastered many key aspects of solid-propellant motor production.

However, Iran is not fully self-sufficient. Available evidence indicates that Iran cannot fabricate reliably the *Scud* and *Nodong* liquid-propellant engines that power its operation missiles. This may change in the future, although the history of "reverse-engineering" complex equipment suggests otherwise. The Soviet Union, for example, could not successfully clone the German *V*-2 missile after the war, despite have access to much of the original production line, the original blueprints and many of the key German specialists that developed the *V*-2. Similarly, the Soviet attempt to reverse-engineer the American *B*-29 bomber resulted in a *Tu*-4 which did not perform like the original. It seems much more likely than not that if Iran wishes to expand its arsenal of liquid-fueled missiles, it will have to import additional engines from North Korea. North Korea's liquid-fueled engines were very likely fabricated in the Soviet Union in the 1980s and 1990s.

Iran's development of the *Sajjil*-2 missile appears to have stalled, partly because it cannot indigenously produce some of the key ingredients used in the manufacture of solid-propellant motors. Iran has successfully imported key ingredients, though disruptions to the supply chain have forced it to use multiple providers. Relying on different suppliers, each of whom produces key ingredients to different standards, introduces many new variables to the solid-propellant production process, which is challenging enough under the best of circumstances. The challenges are amplified many fold as the size of the rocket motor to be produced grows. Iran's reliance on foreign suppliers creates opportunities for those countries that seek to slow the development of large missiles propelled by solid-propellant.

Iran – North Korea Missile Cooperation

North Korea supplied Iran with ballistic missiles and technology beginning in the mid-1980s and receding in the late-1990s. The relationship was highly transactional; missiles and missile technologies were exchanged for cash. Evidence over the past decade indicates that North Korea-Iran cooperation is limited in both scope and depth. Some testing data may have been exchanged in the early-2000s, as Iran began efforts to modernize the design of the *Nodong/Shahab*-3 to create the *Ghadr* missile. North Korea is not known to have tested an equivalent version of the *Nodong*, although imprecise mock-ups of a missiles having a nosecone geometry similar to the *Ghadr*'s were shown during a military parade in Pyongyang in late 2010.

Sharing of blueprints and other sensitive information seems unlikely, primarily because of security issues. Interviews with Russian and Ukrainian missile specialists who worked in Iran during the late-1990s, and early-2000s reveal that Tehran heavily compartmentalizes its most valued weapons programs. This was done to prevent foreigners from understanding the scope and status of Iran's missile endeavors, its indigenous capabilities, and its technology import requirements. It seems reasonable that the same security standards and practices are applied to the North Koreans who may continue to assist Iranian efforts. The barriers erected to preserve security would also, by definition, impede cooperation.

Signs of minimal cooperation are also evidenced by the missiles and satellite-launch vehicles developed by the two countries. North Korea's *Taepo-dong* 1 satellite launcher, which overflew Japan in 1998, was a three stage system. Iran's *Safir* launch vehicle uses two stages. North Korea abandoned the *Taepo-dong* 1, in favor of the larger *Taepo-dong* 2 (*Unha*) launcher, after only one (unsuccessful) flight. The *Safir* has been used at least seven times since 2008, with just over half of the launches resulting in success.

Iran's *Simorgh* launch vehicle, like the *Safir*, is a two-stage rocket. North Korea's *Unha* is a three-stage system. And while it is true that the first stage of the *Unha* and *Simorgh* are powered by a cluster of four *Nodong* engines, the two designs are significantly different. South Korea recovered from the ocean two *Unha* first stages, the first from the December 2012 flight, the second from the February 2016 launch. After analyzing the recovered debris, the South Korean government concluded that in addition to the four main engines, four small ones were also used to steer the *Unha* during first-stage operation. Each of the steering engines received its fuel and oxidizer by tapping into the plumbing that feeds an adjacent main engine. This arrangement reduces slightly the thrust output of the main engines by depriving it of the propellant flow diverted to the steering engines. The small reduction in thrust is compensated, though not fully, by the thrust generated in the steering engines. The *Unha* configuration is a reasonable, low risk design.

Photographs of the *Simorgh*'s first stage show that it too employs four steering engines for flight control. However, a separate pump – scavenged from a *Scud* engine – is used to deliver fuel and oxidizer to the four steering engine. The Iranian design provides the *Simorgh*'s first stage with an extra 13 tons of thrust when compared to the *Unha*'s first stage. The different designs indicate that North Korea and Iran do not share blueprints for their respective satellite launchers. Given the more sensitive nature of ballistic missile designs, it is reasonably safe to conclude that the two countries do not co-develop military missiles.

Containing Iran's Ballistic Missile Program

Multilateral sanctions, most notably UN Resolution 1929, likely played a prominent role in retarding development of the *Sajjil* medium-range missile. Technical challenges and the deaths of several key personnel in late-2011 may also contributed to the delays. The apparent success of the sanctions, which disrupted the supply of critical ingredients used to produce solid-fuels, was facilitated by the UN Panel of Experts on Iran. The Panel was responsible for investigating potential violations. The investigations, and reporting to the Panel by governments interdicting proscribed shipments to Iran, raised international awareness of the sanctions. The Panel's work also identified illicit networks and pathways, which further underscored the international community's role in enforcing Resolution 1929.

However, the Panel does not exist under Resolution 2231. The U.S. should work with the Security Council to re-instate the Panel, with a focus on enforcing the trade restrictions contained in Resolution 2231.

The success of unilateral sanctions, especially those leveled against Iranian enterprises and individuals, is historically ambiguous. Iran creates new trading companies to replace those that have been sanctioned. As Iran renews international trade under the relief granted by the JCPOA, unilateral sanctions may or may not become more effective. It is difficult to predict.

The Proliferation Security Initiative – and international effort to disrupt the flow of WMDs and related technologies -- could be an effective tool for intercepting shipments from North Korea, Iran's principle, if not sole source for missile engines. Without a supply of additional engines from North Korea, Iran will find it difficult to expand its arsenal of liquid-fueled missiles. This may drive Iran to seek greater self-reliance, but the cost of developing and qualifying a production line for these engines will be high.

In response to the growing threats posed by Iran's ballistic-missile arsenal, the Pentagon has worked tirelessly with our Gulf partners, Israel and NATO to deploy regional-missile defenses for protection. Joint missile-defense exercises with our Gulf partners – and Israel -- offer a tangible counter narrative to Iran's missile tests, and possibly deter Iranian use of missiles. Joint-exercises will also serve to enhance the capabilities and effectiveness of the missile-defense systems deployed in the region.

Iran has said it does not need missiles with a range exceeding 2000 km. The U.S. should explore options that, at a minimum, would legally codify that range limit. Other limitations may be ripe for negotiation, including those that increase the transparency of Iran's space program.