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Ballistic missiles are central to the Islamic Republic of Iran's defense and deterrence strategy, and will remain so for the foreseeable future. The size and scope of its arsenal – the largest and most diverse in the Middle East – reflects the priority the country assigns to ballistic missiles. Iran is therefore highly unlikely to surrender its current systems. Ballistic missiles will continue to play a prominent role in its force structure, even as it begins procuring advanced military aircraft.

Background

Tehran's pursuit of missiles and long-range artillery rockets began soon after Iraq's invasion of Iran in 1980. During the Iran–Iraq War, Iraq repeatedly attacked Iranian cities, petroleum facilities and other strategic assets with Soviet-supplied aircraft and *Scud*-B missiles. Lacking reliable access to the skilled technicians and spare parts needed to maintain and operate its Western-supplied aircraft, Tehran had limited capacity to respond to the increasing pace of Iraqi assaults on its population centers.

The need for enhanced counter-strike capabilities therefore drove Iran's post-revolution regime to acquire missiles and rockets from willing suppliers. In 1985, in response to yet another barrage of Iraqi missiles, Iran retaliated with *Scud*-B attacks, which shocked the Iraqi regime and large portions of its populace. Saddam Hussein promptly agreed to suspend his missile attacks against Iranian cities if Tehran demonstrated similar restraint. Although the ceasefire did not last, Iran's firing of *Scud*-Bs fundamentally altered Saddam's strategic calculus and demonstrated that ballistic missiles are a powerful deterrent and vital to the defense of the Islamic Republic. Missiles have remained a cornerstone of Iran's deterrence and defense posture ever since.

After the war ended in 1988, missile acquisition remained a regime priority. Tehran turned primarily to North Korea for its more immediate needs, but also to China in order to support its longer-term requirement of self-sufficiency. It purchased 200–300 *Scud*-B and -C missiles, the latter having a long enough range to threaten the Gulf's Arab monarchies and the US forces stationed in the region. In the mid-to-late 1990s, Tehran began purchasing medium-range *Nodong*s from Pyongyang, allowing it to target Israel, Turkey and western Saudi Arabia. Flight tests of the missile (rebranded the *Shahab*-3) revealed that its range was limited to about 1,000 kilometers and it could therefore only reach Israel when fired from positions near Iran's western border, leaving launch crews vulnerable to interdiction by US forces stationed in Iraq. Iranian engineers overhauled the *Nodong*/*Shahab*-3 in the mid-2000s, replacing the original steel airframe with a lighter-weight aluminum alloy, lengthening the propellant tanks and incorporating other minor modifications. The modifications increased the range to about 1,600km. Iran completed testing of the modified *Shahab*-3, now called the *Ghadr*, by around 2007, and deployed the missiles, which can be used to threaten, intimidate, deter and retaliate against any of its regional adversaries, including Israel.

The Islamic Republic also operates an ambitious space program, which in 2009 lofted a small satellite into orbit using the two-stage *Safir* rocket. Iran has attempted at least eight launches since 2009, with only three or possibly four successful. A second-generation launcher, the *Simorgh*, is designed to boost larger satellites into space. The *Simorgh* may have been launched unsuccessfully on two occasions, once in 2016 and again in 2017. The *Safir* and *Simorgh* could, in principle, be altered for use as ballistic missiles, though flight testing as a missile would be needed to confirm the viability of the necessary modifications. No country has converted a satellite launcher into a missile, though ballistic missiles have often been used to launch satellites into orbit.

Iran's (and North Korea's) capacity to independently produce the engines that power the liquid-fueled *Scud* and *Nodong/Shahab-3/Ghadr* missiles is a hotly debated issue among analysts of ballistic-missile proliferation. Evidence indicates that Iran must import the liquid-propellant engines that power its missiles, leaving it vulnerable to the whims of potential suppliers. Creating an indigenous missile-production capacity, therefore, has long been an aim of the Islamic Republic.

Tehran procured industrial infrastructure and technical know-how from China in the 1990s and 2000s for the manufacture of solid-propellant artillery rockets in an attempt to achieve greater self-sufficiency. It leveraged the experience accrued while producing large artillery rockets to develop and manufacture bigger solid-propellant rocket motors. In 2008, Iran began flight testing a two-stage, medium-range ballistic missile based on solid fuel. The *Sajjil*-2 missile remains under development, though its existence illustrates Iran's resolve to become less reliant on imported technologies for its key strategic capabilities. Iran is the only country to have developed a missile with a 2,000-km range without having first acquired a nuclear weapon.

Limited military utility of Iran's missiles

The military utility of Iran's current missile stockpile is severely limited by the poor accuracy of its most-advanced systems. For instance, its *Shahab*-1 missiles (*Scud*-Bs) carry one-ton high-explosive warheads and have an estimated accuracy of around 800–1,000 meters circular error probable (CEP). CEP is defined as the radius of a circle, within which one-half of the warheads are expected to land. For the *Shahab*-1, this means the probability of mission success is between one in 100 and one in 1,000 for a soft target, such as unprotected humans or exposed aircraft. For hardened targets, the probability drops to as low as one in 10,000.[1] From the perspective of military planners, to destroy with moderate confidence a single, fixed-point military target, Iran would have to allocate a large percentage, if not all, of its missile inventory to one specific mission.

Against large-area military targets, such as an airfield or seaport, Iran could conduct harassment attacks aimed at disrupting operations or causing damage, but such missile attacks are not capable of halting critical military activities. Missile defenses arrayed across the Arabian Peninsula, Israel and Turkey, along with offensive operations designed to destroy missiles prior to launch and cyber operations, would further attenuate the disruptive effects of Iranian missile assaults against military bases and key logistics hubs.

Iran's ballistic missiles could be used to wage a terror campaign against adversary cities and industrial targets. Such attacks might trigger fear within the target population and erode the strategic resolve of some leaders, but the expected death toll, based on Germany's V-2 attacks on London during the Second World War, would likely be fewer than five per missile. Missile- and civil-defense measures would further minimize casualties.

Given the limited military utility of its missiles, Iran has historically viewed them as a tool for deterring attack by threatening to punish an adversary's population and civilian infrastructure, as it did during the war with Iraq.[2] Such threats extend to allies of the US in the Gulf region, particularly those that might support American military operations against Iran. Indeed, certain Iranian officials have been explicit about the role ballistic missiles play, such as Brigadier General Hossein Dehqan, who stated that 'Iran's missile capacity is defensive, conventional and deterrent.'[3]

Table 1 **Iran's rocket and ballistic-missile capability**

Missile	Range	Payload	Fuel	Mission	Note
***Zelzal*-2**	200 km	600 kg	Solid	Battlefield	Unguided
***Fateh*-110**	200-225 km	450 kg	Solid	Battlefield	Guided
Khalij Fars	200-225 km	450 kg	Solid	Anti-ship	Limited Capability
***Hormuz*-1/-2**	200-225 km	450 kg	Solid	Anti-radar	Limited Capability
***Fateh*-313**	300-325 km	350 kg	Solid	Battlefield?	Deployed??
Sajjil	2,000 km	700 kg	Solid	Strategic	Deployed??
***Shahab*-1**	300 km	1,000 kg	Liquid	Airfields, Military Bases	*Scud*-B
***Shahab*-2**	500 km	720 kg	Liquid	Airfields, Military Bases	*Scud*-C
Qiam	~700 km	500 kg	Liquid	Airfields, Military Bases	Modified *Scud*-C
***Shahab*-3**	800-1,000 km	~1,000 kg	Liquid	Strategic	*Nodong*
Ghadr	1,600 km	700 kg	Liquid	Strategic	Modified *Nodong*
Emad	1,600 km	700 kg	Liquid	Strategic	Modified *Ghadr*
Khorramshahr	2,000 km	~ 1,500 kg	Liquid	Strategic	*Development*

Table 1 - Iran has the largest, most diverse rocket and ballistic-missile arsenal in the Middle East. The missiles highlighted in red exceed the Missile Technology Control Regime's thresholds of 300-km range, 500-kg payload, and are generally considered to be capable of delivering a nuclear warhead. Iran does not currently possess nuclear weapons, and is verifiably prevented from acquiring them, per the Joint Comprehensive Plan of Action, or JCPOA.

In pursuit of greater precision

Iranian decision-makers also recognize that deterring attack by threatening to punish potential adversaries and their supporters may not be sufficient. The acquisition of missile defenses by Gulf states will undoubtedly amplify Tehran's worries. Consequently, Iran has spent the past decade refocusing its missile-development efforts away from increasing range to enhancing the precision and lethality of its missiles.

This pursuit of greater precision is best evidenced by the evolution of the *Zelzal* (Earthquake) artillery rocket. The first-generation *Zelzal* is unguided and terribly inaccurate, with half of the rockets missing their intended target by more than three kilometers. Spin-stabilizing the rocket only resulted in modest improvements to *Zelzal*'s accuracy.

Iran began developing the *Fateh*-110, a semi-guided rocket, more than 12 years ago. The designers appear to have incorporated a simple navigation and guidance system, and four aerodynamic-control surfaces mounted just below the rocket's warhead section. The navigation unit, which senses deviations in the rocket's pitch and yaw, are likely used to maintain a preprogrammed orientation (i.e. angle of attack) during the boost and ascent phases of flight. If implemented effectively, the flight stabilization system should significantly reduce the *Fateh*-110's lateral dispersion; range dispersion, while improved, is still affected by inconsistencies in the rocket motor's performance. The first generation of the *Fateh*-110 still lacks the precision needed to reliably strike military targets despite representing a significant improvement in accuracy.

In principle, Iranian engineers could enhance the navigation, guidance and control system of the *Fateh*-110 so that it continuously corrects deviations along its full trajectory, including the final approach to the target. The missile would necessarily have to fly within the atmosphere to maintain positive aerodynamic control over its entire path to the target. Thus, the *Fateh*-110, like other missiles of this type, including Russia's *Tochka* (SS-21) and the US *ATACMS* systems, cannot exceed an altitude of 35–40km if it is to achieve a high level of accuracy, a constraint that limits its achievable range to 200–250km. Only Kuwait, portions of Iraq and the eastern emirates of the UAE are within the *Fateh*-110's range. Iran's later development, the *Fateh*-313, with a maximum range of about 300km, cannot reach most targets in Bahrain, Qatar, Saudi Arabia and western UAE, including Dubai and Abu Dhabi, unless launched from islands in the Gulf.

Despite working for more than a decade to improve the *Fateh*-110's accuracy, progress has been limited. During the *Great Prophet*-7 war games in 2012, for example, Iranian forces launched more than a dozen rockets and missiles towards a mock airfield. Most of the missiles fired were *Fateh*-110s, though a few were *Shahab*-1s (*Scud*-B). Iranian television showed the warheads impacting the intended target. A few months later, *Jane's Defence Weekly* published a report that included satellite imagery of craters distributed throughout a mock airfield and outside its imaginary boundaries.[4] The location of some of the craters in the satellite imagery corresponded with the impacts shown in the televised video, suggesting that the *Jane's* information accurately reflected events during the war game. Assuming the *Fateh*-110s were aiming for the center of the airfield, the spatial distribution of the impacts indicates a CEP of 800–1,100 meters, depending on the calculation method employed. Assuming an aim point at another location within the airfield boundaries does not improve the calculated CEP estimate. Not surprisingly, perhaps, the CEP value for the *Fateh*-110 is reasonably consistent with the theoretical predictions based on manufacturing deviations and other contributors to inaccuracy.

The *Fateh*-110's CEP of 800–1,000 meters is on a par with that of the *Shahab*-1 missile. The lethal effects of a missile warhead weighing 500–1,000 kilograms is limited to about 50 meters, making it easy to understand why the missile is not expected to land close enough to kill or destroy a specific target. As with the *Shahab*-1, the *Fateh*-110 is unlikely to succeed, unless the target is very large, like an airfield or military base. Iran will likely need many more years and scores of flight tests to reduce the CEP to below 200 meters, the minimum accuracy requirement for a missile to have a reasonable chance of destroying a specific military target.

Nonetheless, development of the *Fateh*-110 family of missiles, including the optically guided anti-ship *Khalij Fars* and the anti-radar *Hormuz* systems, as well as the *Fateh*-313, suggests that Iran seeks to produce and field highly accurate missiles capable of shaping the outcome of future military conflicts. The test launch of the medium-range *Emad* missile in 2015 provided additional evidence of Iran's desire to enhance missile accuracy. The *Emad*, which appears to be a *Ghadr* missile with a separating warhead capable of steering itself towards a target after it re-enters the atmosphere, is in its first phase of development. It will require very different technologies to the *Fateh*-110 to achieve the design objectives. Adding a Global Positioning System (GPS) receiver, or the Russian, French or Chinese equivalents, to the inertial navigation system to provide precise updates will only improve *Emad*'s accuracy by about 20–25%, not enough to alter its military utility. To achieve the precision needed to destroy military targets consistently and reliably, Iran must develop a post-boost control system and terminal guidance capabilities. With terminal guidance and control, missile warheads can be maneuvered to the target just before impact. Based on the time other countries took to develop precision-guided ballistic missiles with a range greater than 300km, Iran is not expected to possess an arsenal of accurate medium-range missiles before 2025. Extensive foreign assistance from China or Russia could shorten the timeline to a few years, however.

Iran has also made substantial strides in developing the near-real-time targeting and prompt post-strike assessment capacities needed to support ballistic-missile operations. This nascent, but rapidly improving, capability was demonstrated in June 2017 when Tehran launched seven *Zolfaqar* missiles against the Islamic State, also known as ISIS or ISIL, in Syria. The attacks largely failed, with only two of the missiles landing within the suspected target area.[5] Despite the poor performance of the *Zolfaqar*, which is derived from the *Fateh*-110, Iran demonstrated its ability to fly surveillance drones above the suspected target and relay the information to launch crews hundreds of kilometers away. The targeting information for the missiles was presumably derived from the drone's surveillance of the area, though it is too soon to draw specific conclusions. Video from the drone shows at least one, if not two missiles striking buildings, indicating that Iran has the capacity to conduct real-time damage assessments under certain conditions.[6]

Iran's targeting and damage-assessment capabilities are limited, however. For now, Iran lacks the communications infrastructure needed to operate its drones more than a few hundred kilometers beyond the territory it occupies and controls. Ground-based controllers need to have line-of-sight access to the drones, as do the surveillance-data receivers. Operating beyond the line of sight requires communication linkages through high-flying aircraft or satellites.

Iran's evolving missile doctrine

A continuing pattern of prioritizing improved precision over increased range would mark a discernable shift in Iran's missile doctrine, from one that relies solely on punishing would-be attackers by striking highly valued targets, such as cities, to a strategy that strives also to deny potential foes their military objectives. Such a doctrinal evolution is consistent with Iran's overarching military strategy, which is primarily defensive.[7]

The 'mosaic defense' strategy, authored by Major-General Mohammad Ali Jafari, commander of Iran's Islamic Revolutionary Guard Corps (IRGC), establishes three asymmetric operational tactics to impede conventional military advances by an attacker: proxies provide a forward-based fighting force; guerrilla warfare at sea threatens enemies and impedes a navy-supported invasion; and the implicit threat of extraterritorial attacks with ballistic missiles deters adversaries.[8]

An arsenal of accurate, highly lethal ballistic missiles supports all three elements of this asymmetric approach to warfare. Heavy-artillery rockets and short-range missiles, if they can delivery ordnance precisely, are capable of denying an enemy access to territory along Iran's borders, or raise the cost of massing an invading army in a neighboring country. Short- and medium-range missiles threaten key ports that service the navies of the Arab Gulf states and external powers, including the US, UK and France, and can harass ships deployed within Gulf waters. Ballistic missiles striking airfields with precision could disrupt, if not halt, the sortie generation rate so vital to US and Arab Gulf state fighting strategies. Finally, missiles accurate enough to avoid potential collateral damage could be used to strike key military and civilian infrastructure with less risk of backlash from the international community. All these capabilities assume that Iran succeeds in developing highly accurate missiles.

Evidence to date suggests that Iran is improving the precision of its missiles, though not enough to generate the desired military outcomes. This will undoubtedly change as Tehran continues to master the technologies and operational tactics needed to achieve greater missile accuracy, as well as the critical enabling technologies, such as real-time targeting and damage-assessment capabilities. While it will take Iran a long time to establish an arsenal of militarily decisive missiles (at least five and perhaps ten years), the US and its Gulf partners must now begin identifying and developing a means to mitigate their impact.

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Notes

1 Michael Elleman, *Iran's Ballistic Missile Capabilities: A net assessment* (Abingdon: Routledge for the IISS, 2010), p. 122.

2 Michael Connell, 'Iran's Military Doctrine', United States Institute of Peace, http://iranprimer.usip.org/resource/irans-military-doctrine.

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4 Jeremy Binnie and Andy Dinville, 'Satellite imagery shows accuracy of Iran's ballistic missiles', *Jane's Defence Weekly*, 31 October 2012.

5 Russ Read, 'Iran's Missile Strike On ISIS Was A Massive Failure', *National Interest*, 20 June 2017, http://nationalinterest.org/blog/the-buzz/irans-missile-strike-isis-was-massive-failure-21253.

6 Artemis Moshtaghian, 'Iran launches missiles into eastern Syria, targets ISIS', CNN, 19 June 2017, http://www.cnn.com/2017/06/18/middleeast/iran-launches-missiles-into-syria/index.html.

7 For a more in-depth discussion, see Matthew McInnis and Michael Eisenstadt's papers in this collection.

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