The Next Generation of Iranian Ballistic Missiles:

Technical Advances, Strategic Objectives, and Potential Western Responses

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In-Depth Reports

Amid revived nuclear talks with the United States, Iran finally debuted its vaunted Fattah "hypersonic missile"—just after test-launching an improved large-payload MRBM—in a clear bid to demonstrate conventional military deterrence capability.

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On May 25, 2023, Iran's minister of defense, Gen. Mohammad Reza Qaraei Ashtiani, unveiled the so-called fourth generation of the Khoramshahr liquid-fuel ballistic missile—aka Kheibar—amid heightened tensions with Israel and the West regarding Tehran's nuclear program and renewed talk of preventive strikes against Iran's key nuclear sites. Ashtiani spoke at the Hakimiyeh Aerospace Industries Organization complex, east of Tehran, against a backdrop with the new missile and a large model of Jerusalem's Dome of the Rock.

(/sites/default/files/2023-07/Khoramshahr4unveiling.jpg)

The name Kheibar comes from a fortified oasis settlement north of Medina, Saudi Arabia, inhabited by Jewish tribes before the Islamic era. In AD 628, the Jews there were defeated by Muslim armies led by Ali ibn Abi Talib, who has become a legendary figure in Shia Islam. The message to Israel implicit in the Kheibar announcement was therefore unmistakable.

The Khoramshahr is Iran's most advanced liquid-fuel ballistic missile and probably the first using storable liquid fuel, with its first version having been introduced at a military parade on September 22, 2017. The missile is believed to have much in common technically with the **North Korean Hwasong-10 (https://www.washingtoninstitute.org/policy-analysis/irans-new-ballistic-missile-may-have-north-korean-icbm-links)**—itself based on the retired Russian R-27 submarine-launched ballistic missile. Iran is thought to have received several Hwasong-10 missiles from North Korea in 2005 for reverse engineering purposes. The Khoramshahr is also Iran's first departure from the Russian Scud and scaled Scud-generation propulsion systems.

Background and Technical Features of the Khoramshahr

Reports between 2016 and 2018 indicated Iran was test-launching the Khoramshahr, and the missile immediately prompted international **concerns (https://www.washingtoninstitute.org/policy-analysis/irans-continued-push-nuclear-ready-missile-capability)** because of its new design and propulsion system and substantial range-and-payload potential.

The propulsion system Arvand, named for the river marking the southern border between Iran and Iraq, consists of a main engine and two smaller thrust vector control (TVC) engines and is said to incorporate hypergolic propulsion—meaning that it uses storable fuel and oxidizers that ignite spontaneously upon contact with each other, without the need for a complex, failure-prone ignition system.

While Iran did not publish further details about the fuel/oxidizer combination, the most common oxidizer is dinitrogen tetroxide (N_2O_4), and the most common fuel types are unsymmetrical dimethylhydrazine (UDMH), monomethylhydrazine (MMH), hydrazine, or a mixture of hydrazine and UDMH. North Korea's Hwasong-10 uses a hypergolic combination of UDMH as fuel and either N_2O_4 or red-fuming nitric acid (RFNA) as oxidizer to an estimated maximum range of 4,000 km for both conventional and nuclear warheads. Arvand could be incorporated into a future intercontinental ballistic missile (ICBM) most likely employing a two-stage design, with two engines powering the first stage.

(/sites/default/files/2023-07/Khoramshahrdebut2017.jpg)

The Khoramshahr-1 debuts at a September 22, 2017, military parade in Tehran.

Other advantages of hypergolic fuels and oxidizers are that they are simple—although highly toxic; produce higher specific impulse (propulsive energy); and are denser and thus storable in smaller tanks. Most important, they remain stable for years at ambient temperatures while stored in the missile's fuel and oxidizer tanks, which are made from special corrosion-resistant materials. This makes it unnecessary to fuel the missiles before launch, substantially reducing preparation times, reportedly to about fifteen minutes. (A typical Scud B–class missile with non-hypergolic fuel and oxidizer, by contrast, takes approximately sixty to ninety minutes to finish a launch sequence.) The shelf life for a fueled Khoramshahr-4 is said to be three years, the point at which missiles are defueled and their propulsion tanks washed before refueling. In theory, this period is extendable to ten years, on par with Iranian solid-propellant missiles.

The specific impulse depends on several factors besides propellant combination, including the fuel/oxidizer mixing ratio, combustion chamber pressure, and nozzle expansion ratio. For the Khoramshahr-4, Iran's Defense Ministry claims a specific impulse of 280 seconds at sea level and 300 seconds in a vacuum, levels similar to those of the Hwasong-10. The specific impulse of the lighter, smaller Scud B missile is 220–260 seconds, depending on the altitude. For the Shahab-3, the specific impulse is estimated at 240 seconds. Moreover, the use of TVCs in place of

Scud-type moving control vanes and fixed winglets has apparently reduced drag and turbulence and improved the Khoramshahr's accuracy.

These features have potentially turned the Khoramshahr-4 into a tactical as well as a strategic missile. Along with a sturdier structure and lower lift-to-drag ratio thanks to the engine's placement inside the fuel tank—and a missile three meters shorter compared to earlier types like the Shahab-3 and Ghadr—this should offer a much better road-mobile capability and quicker launch times.

The configuration described here was pioneered by the Soviets in the 1960s in their submarine-launched R-27, but for the Khoramshahr, the priority was safe, land-based transportation—while fully fueled, to avoid time-consuming fueling at the exposed launch location. This requires great structural strength and the use of isogrid propellant tanks to minimize fuel sloshing. In the future, the Khoramshahr—of which no versions appear to be operational today—could conceivably be transported in more-mobile North Korean–style all-terrain transporter-launchers.

(/sites/default/files/2023-07/Khoramshahr4testlaunch.jpg)

(/sites/default/files/2023-07/Khoramshahr4fieldtest.jpg)

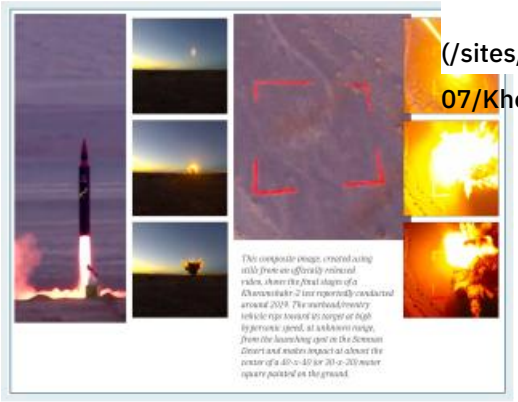
"Most Advanced" Iranian Ballistic Missile

In a May 26 interview with Iran's state television, Gen. Seyyed Mehdi Farahi—currently first deputy defense minister and previously director of two ministry arms, the Organization of Defense Innovation and Research (SPND) and the Aerospace Industries Organization (AIO)—stated that the Khoramshahr-4 is Iran's most advanced and survivable ballistic missile. He added that it combines resiliency and survivability ("mechanical" terminal phase, very high speed, small radar cross-section, cyberdefense capabilities) with "pinpoint" accuracy and artificial intelligence to decide the most effective evasive maneuvers.

A video of a successful test launch (date unspecified) complete with telemetry downlink animation, portrayed the launch from a Semnan site with a minimal exhaust plume and an exoatmospheric warhead/reentry vehicle (WH/RV) separation from the missile body at the completion of the midcourse phase before heading for its target in southeast Iran. An accompanying animated telemetry feed showed nine small vernier engines helping to stabilize the RV outside the atmosphere and maneuver it to an exact reentry position where it could initiate the terminal flight phase toward its target. The ability to tilt the nose tip earthward early during this phase reduces the RV's radar cross section. At the start of the terminal phase, four of the verniers were shown fired in pairs in opposite directions to initiate a fast roll aimed at ensuring stability during reentry. The RV was then intentionally

“bricked”—turned off electronically while still functioning in a mechanical mode—to protect it from electronic countermeasures and electromagnetic interference during the terminal phase. According to Iran’s Islamic Revolutionary Guard Corps (IRGC), the Khoramshahr-4 RV is made of composite material to even more effectively evade radar detection and tracking, and its midcourse velocity is Mach 16, with a reentry velocity eight times the speed of sound, two to three times faster than the Scud B. This combination of speed, maneuverability, and stealth is intended to make Khoramshahr survivable against an enemy’s antimissile defenses.

The targeting accuracy for the latest Khoramshahr iteration, according to unofficial Iranian sources, is better than a 30 meter circular error probable (CEP) at 2,000 km range. If true, this marks a significant improvement over what Gen. Mohammad Bagheri, chairman of the Armed Forces General Staff, **claimed (https://www.washingtoninstitute.org/policy-analysis/irans-ballistic-missile-arsenal-still-growing-size-reach-and-accuracy)** about an earlier version of the missile, which was “better than 60 meters at 1,300 km range.” A video released in 2019 showed a warhead making impact almost at the center of a 40-by-40-meter square—30-by-30 meters, according to another account—painted on the ground. So it can be assumed that the Khoramshahr missile family has quite good accuracy throughout its range.



(/sites/default/files/2023-07/Khoramshahr2testvideostills.jpg)

A Nuclear-Capable Missile

The Khoramshahr has been displayed carrying different types of warheads. The original 2017 version had a large conical nose, and the Khoramshahr-2 was shown in February 2019 having a smaller-diameter RV section with moving control fins similar to those of the Imad missile, a feature that would appear to promote limited endoatmospheric aerodynamic maneuvering.

A follow-up version was displayed seven months later carrying a reduced-diameter conical nose similar in size to the Shahab-3, attached to the body using a special adapter, while shedding the moving control fins. Whereas conical nose designs are generally used to achieve high reentry velocities for non-maneuvering warheads in order to evade antimissile defenses, different size options would allow wider targeting and range as well as more velocity options. A North Korean nuclear warhead of similar design is **estimated (https://www.38north.org/2015/02/jlewis020515/)** to weigh around 450–750 kg, with a diameter of 60–90 cm.

(/sites/default/files/2023-07/Khoramshahr1-3compare.jpg)

In the newest Khoramshahr, the original RV diameter has been restored, while the body has been lengthened slightly to accommodate either additional electronics or larger fuel and oxidizer tanks. Iranian military sources claim the missile can carry a cluster warhead capable of dispensing up to eighty submunitions of at least two anti-personnel and anti-runway types to cover wide-target areas like military depots, airfields, and cities. These submunitions are likely wind-corrected for improved target coverage and not individually guided, but one can expect a future individually guided version.

From the beginning, the Khoramshahr was clearly capable of carrying a nuclear warhead like that being designed by Iran during the early 2000s and perhaps later. According to documents from a hard drive smuggled out of Iran in 2004 by a nuclear scientist's wife and verified by the International Atomic Energy Agency (IAEA) and Western intelligence services—as well as the nuclear archive obtained by Israel during a clandestine mission in January 2018—Iran began designing a nuclear warhead and its associated electronics, detonator, and shockwave generator mechanisms under its Defense Ministry Projects 110 and 111 starting in early 2002. Project 111, for its part, dealt mainly with converting the internals of the nose cone of the Shahid Hemmat Industrial Group (SHIG) Shahab-3 ballistic missile to accommodate a 1,220 mm warhead with a 560 mm diameter. According to various IAEA reports, since the early 2000s, Iran has had sufficient expertise to design an implosion system small enough to fit a Shahab-3 nose. Therefore, a Khoramshahr missile with an even wider conical nose (1.5 meters in diameter, compared with 1.3 meters for Shahab-3) would have no problem accommodating an even larger device with higher yield if Iran managed to fabricate a working one. In theory, however, the smaller RV configuration in Khoramshahr-3 would also, with minimal changes, accommodate the original nuclear warhead developed for Shahab-3.

(/sites/default/files/2023-07/Khoramshahr1-4compare2_0.jpg)

Relatedly, an emerging cohort of nuclear deterrence advocates **(https://www.youtube.com/live/SukfWt4EQV0?feature=share)** in Iran has recently voiced support for an arsenal of plutonium-based tactical nuclear weapons. These advocates believe such weapons do not fall under the so-called anti-nuclear fatwa derived from the Supreme Leader's public statement **(https://farsi.khamenei.ir/others-dialog?id=9187)** read to a nonproliferation conference in Tehran on April 17, 2010, since they are basically used against military targets.

To Europe and Beyond

The Khoramshahr is not the only Iranian ballistic missile with a range exceeding 2,000 km, and it will not be the last, but it looks to be one of the most versatile and lethal given its payload-to-range capability. By maturing the Khoramshahr design, Iran is also demonstrating an intermediate-range ballistic missile (IRBM) potential that might soon enable it to reliably threaten the strategically vital U.S. air and naval bases at Diego Garcia in the Indian Ocean, which is about 3,800 km from the closest Iranian shoreline. More important, the technology developed for the Khoramshahr may represent a substantial advance toward developing an ICBM. Iran's missile industry should easily be able to extend the Khoramshahr's range to such distances if it has not already done so. Moreover, the possibility that Iran might save time by soliciting technical assistance from North Korea or even Russia should not be dismissed. Tehran has framed the Khoramshahr as a direct threat to NATO and Europe, ostensibly including the operational Aegis Ashore **(https://www.rand.org/pubs/research_reports/RR957.html)** missile defense sites in Romania and Poland, which were commissioned mainly to defend against Iran's ballistic missile threat.

Anticipating such Iranian threats, the George W. Bush administration in 2007 proposed deploying a ground-based midcourse missile defense system in Europe. Russia and Iran opposed deployment of the "phased adaptive approach missile defense system," which was first announced in September 2009, became operational in May 2016, and includes the Kurecik TPY-2 forward long-range radar station in southeast Turkey and a command, control, battle management, and communications (C2BMC) center at Ramstein Air Base, Germany. The distance between Ramstein and a major IRGC ballistic missile base, near Tabriz, is 3,300 km, while the Romanian site in Deveselu is 1,840 km from the Tabriz base. The Polish site in Redzikowo, which will soon be fully operational, is 2,860 km from the Tabriz base. Defenses at these distances would allow Western forces to intercept Iranian medium-range ballistic missiles (MRBMs) such as the Qadr, Sejjil, and Khoramshahr before they reach their targets in eastern and southern Europe. Aegis Ashore is designed to protect European NATO allies and U.S.

deployed forces in Europe against ballistic missile threats by detecting, tracking, engaging, and destroying ballistic missiles before they reenter the atmosphere, working in coordination with forward-deployed Aegis destroyers, such as those currently deployed to the region.

In a recent interview, IRGC Aerospace Force commander Gen. Amir Ali Hajizadeh stated that a self-imposed 2,000 km range limit—the range deemed sufficient to reach Israel from anywhere in Iran—was set "out of respect for the European countries, but it can be removed if they change their behavior." (See the author's essays from **March 2019 (https://www.washingtoninstitute.org/policy-analysis/irans-missile-defiance-potential-threats-europe-gulf-and-israel)** and **December 2019 (https://www.washingtoninstitute.org/policy-analysis/europe-pushing-back-irans-ballistic-missile-program)** for more on the potential ballistic missile threat to Europe). Hajizadeh suggested antimissile defenses were considered the main targets for the new Iranian missile, and the IRGC likely watched the Houthi-instigated missile duels over Saudi Arabia and is now watching the Russia-Ukraine clashes over Kyiv with keen interest.

(/sites/default/files/2023-07/MapWithIranMissileRanges.jpg)

Iran is continuing to invest heavily in its missile programs, and the regime is confident it can safeguard its deterrence and boost its offensive capabilities. The Khoramshahr is Iran's most viable option for housing and delivering a nuclear warhead at medium to intermediate ranges—depending on the warhead weight—if and when it decides to weaponize its available fissile material. The missile incorporates a powerful, increasingly reliable engine, a resilient guidance system, very high payload-to-range performance, and a body reportedly sturdy enough to allow for quicker and rougher road transfers. Iranian defense officials and IRGC commanders claim the missile enjoys a very high degree of accuracy, which could also mean it can make impact at or near a specific building almost at its maximum range with a conventional warhead.

Also interesting, of course, is the timing of the unveiling, part of a series of high-profile announcements flaunting missiles, satellite launches, and hardened bases aimed at boosting Iran's deterrence. It comes not only at a time of heightened tension with Israel and the United States over Tehran's nuclear advances, regional behavior, and involvement in the Ukraine war, but also as reports emerge of secret "de-escalatory" talks between Washington and Tehran in Oman, with a new limited nuclear "understanding" possibly on the horizon. By showcasing its new missiles, the IRGC can claim credit for "Western capitulation" and demand more domestic funds and support for its programs.

The development and fielding of the Khoramshahr and similar Iranian missiles are a clear violation of UN Security

Council Resolution 2231, which gives legal standing to the 2015 Joint Comprehensive Plan of Action (JCPOA) and calls on Iran not to undertake activity related to ballistic missiles "designed to be capable of delivering nuclear weapons"—even if this phrasing is arguably meaningless—until October 2023. On June 28, European Union members and Great Britain told Iran of their decision to maintain EU ballistic missile sanctions set to expire October 18 under Resolution 2231. This move can be interpreted as a safer alternative to the JCPOA "snapback" mechanism, which can revive all previous UN sanctions if the current U.S.-led nuclear negotiations fail to produce tangible results.

Hypersonic Hype

In the current scene, Iran is relentlessly promoting its **deterrence (https://www.washingtoninstitute.org/policy-analysis/iran-seeks-strengthen-its-deterrence-showing-its-missile-force)** as well as its preemptive strike capability, for which a hypersonic missile has long been considered a silver bullet. In a handwritten **private letter (https://farsi.khamenei.ir/photo-album?id=38162)** to Supreme Leader Ali Khamenei dated December 12, 2005, Gen. Hassan Tehrani Moghaddam—then head of the IRGC's missile command and Self-Sufficiency Jihad Organization, who was killed in a work-related explosion in 2011—proudly reported that his organization had just started working on the "ultimate Israel-striker and deterrent rapid-reaction hypersonic missile." At that time, development of advanced Western and Israeli missile interceptors such as Arrow 3 had not yet begun.

Moghaddam's development program apparently dragged on for almost two decades until finally the IRGC, in a June 6, 2023, ceremony attended by Iran's President Ebrahim Raisi and top IRGC commanders, unveiled a "hypersonic ballistic missile" named Fattah, meaning "one who opens the door to victory." This followed a series of speeches and television interviews by Aerospace Force commander Hajizadeh, who boasted about the missile's features—such as a top speed of Mach 12–13, the ability to perform maneuvers and course corrections throughout its exoatmospheric midcourse and endoatmospheric terminal phases, and precision strike capability with total impunity from existing antimissile defenses.

The missile displayed at the public unveiling, which was painted black as opposed to the usual sand color, mirrored the main body of the **Kheibar Shekan (https://www.washingtoninstitute.org/policy-analysis/iran-takes-next-steps-rocket-technology)** solid-propellant missile unveiled in February 2022, just as the nuclear talks in Vienna were reaching a critical stage. Fattah, however, carries a new conical WH/RV with a dedicated thrust-vectoring solid-propellant motor that is said to activate somewhere between 900 km and 300 km from the intended target, depending on the flight profile, and effectively transforms the RV assembly into a second stage. The space-vacuum-optimized spherical-tank rocket motor is the same type as that used in 2020 and 2022 on the IRGC's Qased satellite launch rockets—as orbital maneuvering units to insert Nour-1 and 2 CubeSats into 425 and 500 km low earth orbits, respectively.

In conjunction with moving fins, the unique orbital maneuvering rocket motor is said to allow the Fattah RV to conduct significant preset course adjustment and missile defense avoidance maneuvers both outside and inside the atmosphere. It also could have contributed to the claimed high hypersonic speed at the start of the terminal phase. Moreover, right before reentry, the RV appears to pitch down to reorient itself and reduce its cross section to ground radars. The combination of these abilities, according to Hajizadeh, is designed to make course calculation and interception by antimissile defenses "very improbable for decades to come, if not totally impossible."

If one takes at face value the capabilities Iran claims for its hypersonic missile, then the Fattah, in its current configuration, could be seen to occupy its own subclass. This is because, while it evidently still cannot conduct significant, sustained atmospheric maneuvers besides minor course corrections, the relatively large solid-fuel rocket motor with thrust vectoring in its WH/RV section can allow significant maneuvers outside the atmosphere.

Separately, although a short video released on unveiling day attempted to indicate a successful test-firing, the video most likely showed a previous test for a similarly sized Kheibar Shekan missile, which suggests the Fattah might still be some time from its first live test and possibly several years from becoming operational. This could give more time to defense companies like Northrop Grumman and Rafael to hone their anti-hypersonic technology.

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Conclusion

Iran can be expected to continue devoting substantial money and manpower to developing more effective, longer-range ballistic and cruise missiles and drones, and to its militant policies in the region. It will do so not only to boost its deterrence and negotiating leverage, but also to gradually increase psychological and kinetic pressure on the United States and Israel. To create further complications for these adversaries and buy more time, Iran will likely keep up gestures toward regional de-escalation, as when it reestablished diplomatic ties with Saudi Arabia this past March.

For the Islamic Republic, a reliable hypersonic capability through the Fattah missile—enabling it to accurately, quickly, and unpredictably hit high-value targets hundreds, if not thousands, of kilometers away—could seriously challenge available or emerging missile warning and defense systems and would be a worrying development. It could eventually develop into an even more troubling orbital bombardment system capable of striking anywhere in the world on short notice. This is the case even though Fattah still appears to be several years away from full deployment.

Tehran is fully able, meanwhile, to manufacture and prepare for initial operational capability a missile, the Khoramshahr-4, that can deliver a nuclear warhead to MRBM and later IRBM ranges. It can be expected to have such a missile in its inventory soon, if it does not already have it in some limited way. While the Iranian regime is becoming increasingly confident of its conventional deterrent power, it also understands that when confronting

established nuclear powers, ultimate deterrence rests with a deployed nuclear weapon capability.

The question thus arises of what can be done to limit the risks of these growing Iranian capabilities alongside its perceived march toward a nuclear weapon capability. Already, the United States, several European countries, and Israel have been developing high-tech anti-hypersonic missile detectors and interceptors, but these efforts need to be given higher priority and be better integrated across national boundaries. Furthermore, Washington especially—by fielding a credible long-range conventional precision-strike capability in the region that incorporates hypersonic speeds and maneuverability, along with optional hardened-target penetration—could help discourage an increasingly emboldened Tehran. The U.S. Army's land-mobile Long-Range Hypersonic Weapon (LRHW), a ground-launched boost-glide missile system with a range of about 2,800 km, will soon enter operational service, and while the Indo-Pacific is often considered the theater of choice for deployment of such advanced systems, the Middle East should also be considered for any early deployment. This way, the United States could reassure Iran's neighbors and demonstrate its ability to quickly strike any number of military targets throughout Iran and the region with confidence and impunity.

(/sites/default/files/2023-07/HakimiyehwithTELsv2.jpg)

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