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A Report of the CSIS Missile Defense Project

CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

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Methodology

The foundation of this study is the CSIS Missile Defense Project's running effort to track and classify missile and missile defense-related incidents in the Yemen conflict. CSIS has continuously monitored these events since the Arab coalition's intervention in March 2015.[1]

The CSIS data set for The Missile War in Yemen is primarily curated from open-source media reports. The most common sources include the Saudi Press Agency, Kuwait News Agency, Emirates News Agency, and Al-Arabiya as well as Houthi sources such as Al-Masirah and Saba News. These sources are subject to biases and distortions, requiring the research team's judgment for classification.

International news outlets such as Reuters, the New York Times, and the Wall Street Journal occasionally report on missile activity in Yemen. In general, these reports rely on coalition statements rather than independent field reporters.

The research team has drawn data from other institutions that track events in Yemen. The United Nations Panel of Experts on Yemen was given access to Saudi radar data in 2017 that helped confirm some (but not all) missile events up to and including that year. The American Enterprise Institute's Critical Threats Project provides compilations of Yemen news updates, and their analysis often includes missile events gathered from local media. Figures 5, 6, 7, and 8 were produced using SMARTset, a modeling and simulations tool for air and missile defense analysis.

Terminology

This study generally classifies missile events in two ways: strikes and intercepts. Strikes include incidents in which a rocket, ballistic missile, cruise missile, or unmanned aerial vehicle completes its flight and lands on or in the vicinity of its apparent target. These include incidents that may not have resulted in a loss of life or property damage. Intercepts refer to events in which a defensive system prevents an enemy missile from completing its flight. In some cases, an intercepted missile can still cause damage due to falling debris. Failed launches of projectiles are not included in the data set.

This report uses the term "engagement" to refer to when a defense system acts against an enemy projectile, regardless of whether that action resulted in a successful intercept.

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Summary

The civil war in Yemen between the government of President Abdrabbuh Mansour Hadi and the Houthi movement is a conflict deeply rooted in the country's decades-old political divides. Yet since the Saudi-led intervention in 2015 to support the Hadi government, the war has broadened to become an arena of competition between Saudi Arabia and the Islamic Republic of Iran. The involvement of these parties has protracted the fighting and prompted a major humanitarian crisis. The influx of foreign involvement has also evolved the conflict into a modern war, one that may portend aspects of future wars.

One such aspect has been the extensive use of ballistic missiles, far more than any other conflict in recent history. With the assistance of Iran, Yemen's Houthi rebels have fired hundreds of ballistic missiles to strike Arab coalition bases, population centers, and infrastructure. They have also launched nearly a dozen antiship cruise missiles against coalition and U.S. Navy warships as well as nearby shipping vessels and oil tankers. The Houthis have furthermore struck scores of targets with unguided artillery rockets. They have used armed unmanned aerial vehicles (UAVs) to harass and assassinate coalition forces and attack economic targets in Saudi Arabia. Their increasingly capable surface-to-air missiles, furthermore, have downed a number of coalition aircraft and at least three U.S. drones.

The Saudi-led Arab coalition has countered the missile campaign with a three-pronged strategy. The coalition has launched hundreds of airstrikes to destroy Houthi missiles on the ground "left of launch." The coalition has also imposed strict air and sea restrictions to block the flow of weaponry from Iran into Yemen and set up numerous checkpoints to interdict shipments over land. Finally, the coalition has relied on active air and missile defenses—primarily the Patriot system—to defend against Houthi launches. The conflict in Yemen has the unique distinction of featuring by far the greatest use of ballistic missile defenses of any conflict in history.

While parties have taken some steps toward ending the violence, continued Houthi possession and use of long-range missiles and drones complicates prospects for restoring stability. The presence of a hostile actor on its southern flank with long-range projectiles significantly raises the stakes for Saudi Arabia, making Riyadh less willing to accept a robust Houthi role in a future Yemeni government. If unchecked, moreover, Houthi missile activity could inadvertently widen the conflict, possibly pulling in the United States or bringing the United States into direct conflict with Iran. Mitigating the Houthi missile threat, as such, will be a necessary component of any lasting peace.

Key Findings

- Iranian support has enabled the Houthi movement to field a diverse arsenal of ballistic missiles, cruise missiles, and drones despite the Houthis' lack of either a stable political base or significant industrial capacity.
- The Houthis have used missile and drone attacks as part of a strategy to raise the military, economic, and political costs of the Arab coalition's intervention. Its missile forces have also become a valuable propaganda tool.
- Houthi ballistic missile attacks have had limited military impact, primarily due to the inconsistent accuracy of Houthi ballistic missiles and the actions of coalition missile defenses. From hundreds of launches, only seven resulted in significant coalition losses.
- Missile attacks against economic targets, including petroleum facilities and oil tankers, have likewise failed to significantly disrupt Saudi Arabia's economy.
- The Arab coalition's initial air campaign in early 2015 reduced the number of ballistic missiles on the battlefield, but significant quantities under Houthi control remained operational.
- The frequency of coalition airstrikes against Houthi missile targets left-of-launch has declined significantly since 2016 (see Figure 9). Houthi missile forces have likely become more adept at evading detection from the air.
- International efforts to block transfers of Iranian arms to Yemen have been unable to consistently stem the flow of missiles and other weapons to Houthi forces. Interdictions of weapons shipments at sea have nonetheless provided substantial evidence of Iran's direct military aid to the Houthi movement.
- Restrictions on air and sea traffic have worsened Yemen's humanitarian crisis.
- The decline of left-of-launch air operations and the failure to stop Iranian arms transfers has made missile defenses an indispensable element of the Arab coalition's effort to limit the impact of Houthi missile fires.
- Between March 2015 and April 2020, coalition air and missile defense forces reported more than 162 intercepts of Houthi ballistic missiles. This total represents the greatest use of ballistic missile defenses of any conflict in history.
- Coalition defenses have been responsible for significant damage limitation from Houthi ballistic missile attacks.
- Coalition defenses have not proven perfect and have, on at least one occasion, failed against more complex ballistic missiles with separating warheads. Lower-flying threats such as cruise missiles and drones have also challenged coalition defenses.
- Publicly available information on coalition engagements lacks sufficient detail to assess the technical performance of the Patriot system.

Introduction

Yemen is no stranger to internal strife, having suffered through six civil wars since the 1960s. Yet the present war, ongoing since 2015, has expanded beyond sectarian strife to become an arena for the broader contest for regional hegemony between Saudi Arabia and Iran. This influx of foreign involvement has evolved the conflict into modern war, one that may portend aspects of future wars. The Saudi-led coalition has brought its modern air and ground forces to bear in support of the exiled government of Abdrabbuh Mansur Hadi. Iran, for its part, has supplied Yemen's Houthis with missiles, drones, small arms, and advisers to support their fight against the Hadi loyalists and the Saudi-led coalition. To date, it is unclear what these foreign interventions have achieved except to intensify and prolong the suffering of the Yemeni people.

Indeed, the war in Yemen has become a protracted stalemate, instigating a humanitarian crisis that has cut short the lives of more than 100,000 people, one of the world's most egregious humanitarian crises. More than 50,000 children have died of starvation from war-related famine. The United Nations has accused both sides of war crimes and crimes against humanity, including the targeting of civilians and civilian infrastructure. Non-governmental watchdogs have accused the Saudi-led coalition of more than 90 unlawful airstrikes, which killed scores of innocent men, women, and children.[2] Observers have also condemned the Houthi militants for confiscating food aid from the Yemeni people and indiscriminately targeting civilians with ballistic missiles and artillery.[3]

The Houthis' use of missiles and drones in their fight against pro-Hadi forces has, on its own, spawned another facet of this conflict worthy of attention. The war in Yemen has seen the most extensive uses of ballistic missiles and other asymmetric aerial weapons of any conflict in recent history. Through seizures of Yemeni munition stocks and substantial assistance from Iran, the Houthis have acquired a diverse arsenal of missiles and other aerial weapons. They have fired hundreds of ballistic missiles to strike Arab coalition bases, camps, and civilian infrastructure.[4] They have also launched nearly a dozen antiship missiles against coalition and U.S. Navy warships as well as nearby shipping vessels and oil tankers. They have furthermore struck scores of targets with unguided artillery rockets.

Consequently, the war in Yemen has also featured the most combat uses of modern air and missile defenses of any conflict in history. Saudi and Emirati Patriot batteries are largely responsible for these actions, reportedly intercepting over 162 ballistic

missiles since 2015.[5] Indeed, the other 13 countries that operate the Patriot system have watched this activity with keen interest.

This ongoing duel between Houthi missiles and coalition defenses—this missile war in Yemen—deserves more attention from the broader international security community. It has offered a rare glimpse of the utility and limitations of ballistic missiles as a military tool. The conflict has also illustrated the kinds of difficulties that missile defense faces on the modern battlefield. Since the intervention began in 2015, the Houthis have incorporated new weapons and tactics, such as armed UAVs and cruise missiles, to avoid or even target the coalition's missile defense elements. Events in Yemen since 2015 have also reinforced lessons about the difficulties of aerial "Scud-hunting" operations and the challenges of preventing the flow of missiles and other weapons from determined proliferators.

This report lays out the first comprehensive review of the Yemen missile war. It begins by reviewing the events and trends that have shaped this part of the conflict. It explores the strategy behind Houthi missile attacks and how Houthi militants have acquired their missiles. It furthermore examines the ways the Arab coalition has countered the Houthi missile campaign, including its employment of missile defenses, efforts to close these proliferation networks, and the efficacy and consequences of its attempts to destroy Houthi missile capabilities from the air.

The Missile War in Yemen: A Brief History

Origins of the Yemen Conflict

The Houthis are a Yemeni political group and rebel militia rooted in the Zaydi sect of Shi'a Islam. Also known as Ansar Allah ("Helpers of God"), the group was initially founded by Hussein Badr Eddin al-Houthi in the mid-1990s as a peaceful movement advocating for religious and political tolerance. However, following years of political discontent, the Houthis first turned to arms against the Yemeni government in 2004. A series of civil wars followed, destroying much of the Houthi-controlled Sa'ada governorate until ending in a 2010 ceasefire agreement.

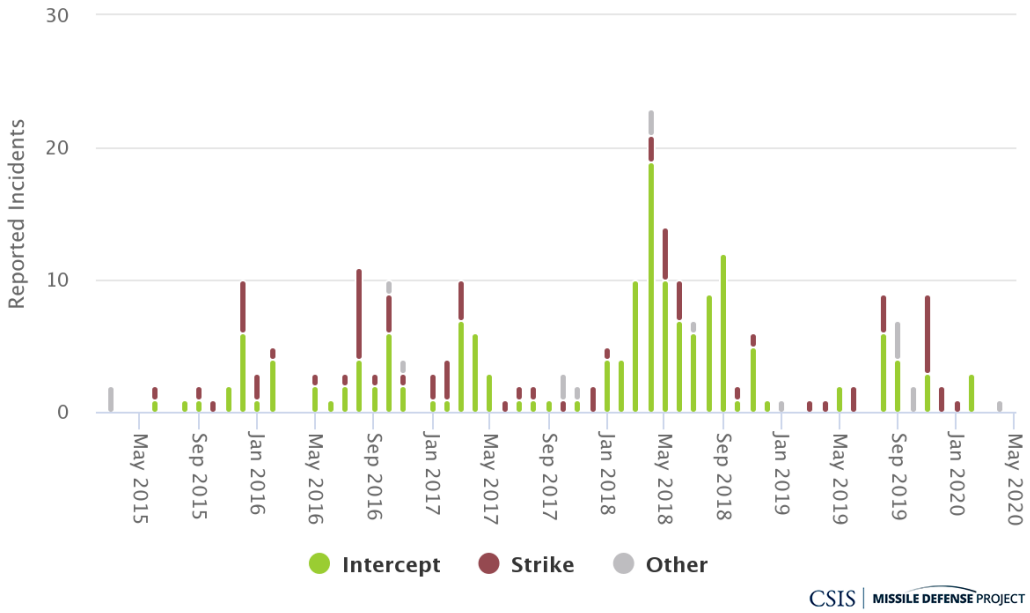
The 2011 Arab Spring arrived in Yemen shortly after. At this time, the Houthis joined tens of thousands of Yemenis protesting against the government over poor economic conditions, the lack of essential services, and government corruption. While Yemen's former president, Ali Abdullah Saleh, would eventually step down in February 2012, he remained a dominant political player. With his tacit support, the Houthis were able to march south and conquer large swaths of territory. By September, the Houthis took the capital city of Sana'a; by January 2015, they forced Yemen's new president, Abdrabbuh Mansour Hadi, to resign.

President Hadi sought and was granted refuge in Saudi Arabia, where the Saudi leadership had been watching the Houthis' rise to power with much unease, given the group's revolutionary outlook and potential ties to Iran. These factors, along with the Houthis' rapid successes, soon pushed Saudi Arabia to intervene on behalf of Hadi. Saudi Arabia gathered nine regional allies to form an "Arab coalition" and launched its Yemen intervention in March 2015.

The Coalition Intervenes: Initial Campaign (2015–2016)

On March 25, 2015, Saudi Arabia and its allies began an intervention in the Yemen conflict with airstrikes against ballistic missile depots and launchers, among other military targets. The coalition's air campaign was expansive and included over 2,000 sorties by coalition aircraft. Other targets not publicly acknowledged included air and seaports, food production and distribution, and public infrastructure.[6] At the start of the campaign, coalition estimates indicated that Yemen possessed around 300 Scud missiles. Yemen also

Figure 2: Timeline: The Missile War in Yemen



held SS-21 "Tochka" ballistic missiles, which it acquired during the Yemeni civil war of the 1990s. While shorter in range, SS-21s are significantly more accurate than Scud missiles.

Within days of the campaign's commencement, the coalition announced that its airstrikes had destroyed "most" of the Houthi forces' missile capabilities.[7] This statement would prove premature. On June 6, 2015, the coalition reported that it had intercepted a Scud missile fired by Houthi forces toward a Saudi air base near Khamis Mushait. This incident was the first known shot of the Yemen missile war. In late August, coalition Patriot batteries intercepted another Scud missile reportedly targeting an electrical station in Jizan. From that time until a brief ceasefire in April 2016, the coalition would publicly claim to intercept at least 12 ballistic missiles fired by Houthi forces.

Despite this performance by Saudi and United Arab Emirates (UAE) air and missile defenses, two incidents during this period would sober the coalition to the danger of these launches. In September 2015, a single SS-21 Tochka missile struck a military base in Marib province in Yemen, killing 60 coalition personnel. In December 2015, another Tochka strike in Yemen's Taiz province killed at least 100 Saudi and Sudanese military personnel, including the head of Saudi special forces.

No End in Sight (2016–2017)

After a short UN-backed ceasefire in April 2016, Houthi ballistic missile launches resumed with renewed intensity. The focus of Houthi missile attacks also seemed to shift to include more frequent targeting of Saudi and UAE civilian and economic targets in addition to military facilities. Reports of missile intercepts and strikes became a regular occurrence, with often conflicting messages from the coalition and Houthi sides. Most of these launches targeted parts of Saudi Arabia near the border, notably Jizan, Najran, Abha, and Khamis Mushait. One of the largest raids took place in November 2016, when Houthi forces fired a salvo of ballistic projectiles toward the border town of Al-Tuwail. Despite the raid's size, there was no reported damage or loss of life.

TABLE 1

BALLISTIC MISSILE ATTACKS ON RIYADH AREA		
DATE	*CLAIMED TARGET*	*NOTES*
3/28/2020	Riyadh	Saudi Patriot air defenses reportedly intercepted an unknown ballistic missile.
6/24/2018	Information Center of the Saudi Ministry of Defense	Saudi Patriot air defenses intercepted two Burkan-2H missiles. The United Nations verified this claim.
12/19/2017	Yamama Palace	A Burkan-2H missile flew over 1,000 km. The coalition claimed to have intercepted it, which the United Nations has neither verified nor disputed.
11/4/2017	King Khalid International Airport	A Burkan-2H missile flew over 820 km and nearly struck the airport. The coalition said it intercepted the missile, but a New York Times investigation disputed this claim.
5/19/2017	Riyadh	A Burkan-1 missile flew 825 km before landing 68 km southwest of Riyadh. The coalition initially claimed to intercept the missile, which a UN report later disputed.
2/5/2017	Al-Muzahmiyah military camp	A Burkan-2 missile close to the Saudi-Yemen border flew 852 km before striking the military outpost. It did not have a warhead, and the Houthis claimed this was merely a show of their capabilities.

NEW MISSILES APPEAR

By mid-2016, Houthi forces had begun employing new missile variants that did not exist in the Yemeni stockpile before the conflict. In September 2016, the Houthis fired a new Scud-variant for the first time, which they dubbed the Burkan-1 ("Volcano-1"), targeting a Saudi air base in Taif. One of these new missiles struck the Saudi-UAE military base on Zuqar Island in the Red Sea in January 2017, killing around 80 coalition soldiers.

A month later, the Houthis unveiled an upgraded version, the Burkan-2H, distinguished by a shuttlecock-style nose common on Iranian ballistic missiles. Burkan-2H also features a separating warhead. The first confirmed use of this missile was an attack on a Saudi Aramco facility in Yanbu in late July 2017.

The extended range of these new ballistic missiles allowed Houthi militias to attack areas deeper into Saudi Arabia. These attacks included a series of launches against Saudi Arabia's capital, Riyadh, and its surroundings between February 2017 and July 2018. Other longer-range targets have included Jeddah, Taif, Yanbu, and King Fahad air base near Taif. Saudi Arabia has reported some attacks in this region as targeting the holy city of Mecca, although the Houthis have rejected this characterization.

Debris from these new missiles gave international observers hard evidence of what many had long suspected—that Iran had supplied the previously unseen ballistic missiles in the Houthi arsenal. Throughout 2017, UN investigators traveled to Saudi Arabia to examine the wreckage of Houthi missiles. The United Nations concluded that Iran

had manufactured the Burkan-2H missiles, smuggled them into Yemen in pieces, and reassembled them.[8] In December 2017, U.S. Ambassador to the United Nations Nikki Haley held a press conference and presented the findings as "undeniable" evidence that Iran was directly supplying ballistic missiles to the Houthis in violation of UN Security Council resolutions.[9]

THE MISSILE WAR AT SEA

In October 2016, the conflict took on another dimension when Houthi militias began employing antiship missiles against ships traveling near Yemen's coast. This expansion into the maritime domain intensified during a week-long duel between Houthi coastal missile batteries and the U.S. Navy. This engagement resulted in the most combat uses of U.S. Navy air and missile defenses in recent history.

The first shots at sea happened on October 1, 2016, when Houthi fighters fired a ground-based antiship missile at the *HSV-2 Swift*, a UAE logistics ship traveling through the Bab-el Mandab strait. The ship, reportedly carrying aid supplies, sustained major damage, although the UAE reported no loss of life.[10] The Houthis most likely fired a radar-guided C-801 or C-802 antiship missile from along the coastline.

The attack prompted the U.S. Navy to send warships to patrol the area to ensure freedom of navigation through the strait.[11] On October 9, the USS *Mason* (DDG-87), cruising with the USS *Ponce* (AFSB(I)-15), detected two incoming missiles, likely also C-801 or C-802s. The destroyer reportedly engaged the threats with two Standard Missile-2 Block III interceptors, an Evolved Sea Sparrow Missile, and two Nulka radar decoys.[12] Public reports are inconclusive as to whether the first missile was intercepted by the USS *Mason's* missiles, lured into the water by the decoys, or missed its target. The second missile hit open water about 14.5 km from the ship.[13]

On October 12, the *Mason* again came under missile fire and engaged a single antiship cruise missile with an SM-2 interceptor. The target splashed down about 13 km from the ship. Some media reports indicate that the SM-2 intercepted the missile, quoting an observer from the *Mason* saying, "We actually saw an explosion."[14] Following this attack, the USS *Nitze* (DDG-94) fired Tomahawk cruise missiles at Houthi forces along the coast, destroying radar stations identified as having supported the prior attacks. This strike remains the only time the U.S. military has engaged in direct military action against Houthi forces in the conflict.

In a third engagement on October 15, Houthi batteries again targeted the *Mason* and *Nitze* with five antiship missiles. The *Mason* reportedly responded with a Nulka radar decoy, an infrared decoy, and several SM-2 missiles, neutralizing four of the five missiles. The *Mason* alerted the *Nitze* of the remaining threat, which used a Nulka decoy to lure the missile away from the ship.[15]

Houthi leadership has denied involvement in the attacks on U.S. Navy ships, possibly fearing further U.S. involvement in the war.[16] Despite this concern, the Houthis have continued sporadic attacks on military and civilian vessels in the Bab el-Mandab strait. In June 2017, an antiship missile struck a UAE naval vessel, injuring one sailor.[17] In May 2018, a Houthi missile damaged a Turkish freighter bringing wheat to Yemen.[18] Houthi forces have also taken credit for attacks on at least three Saudi oil tankers in mid-2018 that caused minor

A picture taken on June 19, 2018, in Abu Dhabi shows Iranian-made Ababil drones which Emirati armed forces say were used by Houthi rebels in Yemen in battles against the coalition forces led by the UAE and Saudi Arabia.

Karim Sahib/AFP/Getty Images

damage to each ship.[19] These attacks resulted in some disruption of commerce, with Saudi Arabia halting oil shipments through the strait for 10 days following the tanker attacks.[20]

The Evolving Battle (2017–Present)

As the Arab coalition's intervention entered its third year, Houthi tactics and weapons began to take on new forms. Longer-range ballistic missile attacks, such as those against Riyadh, became less frequent around mid-2018. In its place came an increase in the Houthi's use of armed drones and an apparent uptick in rocket artillery fired along the border. Houthi-controlled drones have attacked military bases, coalition air defenses, and individual leaders as well as civilian targets such as airports and petroleum infrastructure. Houthi fighters also use these systems for battlefield reconnaissance and targeting intelligence.[21] Many Houthi drone operations have involved Qasef series UAVs. These small, remotely piloted devices closely resemble Iran's Ababil family of drones and can be equipped with up to a 30 kg explosive warhead.[22] The Houthis direct the drones using satellite navigation, with coordinates obtained from open sources. Qasef drones have been used in more than a dozen attacks since their earliest appearances in 2016.[23]

One of the deadliest Houthi drone attacks took place in January 2019, when Houthi militants detonated a bomb-laden UAV over coalition-backed Yemeni forces during a parade at the al-Anad military base. The attack killed at least six soldiers and wounded a dozen others.[24] Another high-profile attack occurred in August 2019, when Houthi forces struck a military graduation ceremony in Aden with a barrage of drones and missiles. The

attack killed dozens, including Brigadier General Munir Mahmoud Ahmad al-Mashali, a commander of the UAE-backed Security Belt Forces.[25]

Houthi forces have also employed drones against civilian and economic targets. A Houthi drone caused minor damage to a Saudi Aramco facility just outside of Riyadh in July 2018.[26] Another UAV attack in August 2019 caused a fire in Saudi Arabia's Shayban oil field. Airports have also been a frequent target for Houthi drone attacks. Saudi Arabia's Abha airport came under attack in the summer of 2019, with one person killed and more than 30 injured in two separate attacks with explosive-laden Qasef-2K drones.[27] In September 2019, the Houthis attacked the Shuqayq desalination plant in Saudi Arabia with an Iranian-designed Quds-1 cruise missile.[28]

In one puzzling incident in July 2018, Houthi media claimed to have struck Abu Dhabi International Airport with a long-range Sammad-3 UAV, which UAE officials denied. Instead, amid reported flight delays, the airport stated that a truck accident had caused some disruption to operations. Ten months later, however, Houthi media released a video showing a UAV crashing into and destroying a parked catering truck next to what appears to be the airport's Terminal 1. How such an attack could have gone unnoticed and unreported by transiting international passengers raises many questions, however. Houthi media claims similar attacks against the Dubai International Airport took place on August 27 and September 30, 2018. U.S. and Emirati officials neither confirmed nor denied the attacks.

Yet even as the Houthis have employed a greater variety of aerial weapons, ballistic missiles remain a potent, if unpredictable, threat. In February 2020, a Houthi ballistic missile struck a military base in Marib. This attack killed 116 pro-Hadi fighters and injured over 100 others, the second-highest death toll of any Houthi air attack of the war.[29] Two weeks later, Saudi Arabia reported incepting several ballistic missiles fired from Sana'a headed toward targets within Saudi Arabia, despite several months of relative calm.[30]

Looking Ahead

Saudi Arabia and the Houthis have taken steps toward a potential peace process. While the two sides have reportedly maintained an "open channel" for talks since 2016, several external factors have raised pressure on both to resolve their conflict diplomatically.

For Saudi leadership, the first major catalyst came in July 2019, when the UAE announced it would withdraw its military forces from Yemen.[31] The UAE's departure left Saudi Arabia with fewer military, financial, and political resources to continue the war. In September, Iran struck Saudi oil facilities in Abqaiq and Khurais with a barrage of drones and cruise missiles. The strike may have pressured Saudi Arabia to find a way to draw down its Yemen intervention to redirect its military focus against Iran while also removing a dangerous flashpoint with Tehran.[32]

Political events have likewise pushed the Houthis to the negotiating table. Starting in October 2019, large protests swept across Iraq, Lebanon, and later Iran, forcing Houthi allies in these countries to focus more on issues at home than in Yemen. This shift in priorities may decrease Houthi access to weapons, training, and money.

Saudi Arabia and the Houthis have since engaged in several de-escalatory measures, with mixed results. In September 2019, the Houthis announced they would cease attacks on Saudi territory in return for a suspension of airstrikes. This cessation of cross-border attacks lasted until December 2019.[33] While Saudi Arabia never stopped conducting airstrikes, it did significantly reduce their number in some areas.[34] Ground fighting, however, escalated again in January 2020, and subsequent Saudi airstrikes have resulted in dozens of civilian casualties.[35]

Some momentum toward peace may be building, however. After nearly a year delay, Saudi Arabia and the Houthis oversaw prisoner swaps of hundreds of combatants, as agreed to in the December 2018 Stockholm agreement.[36] In February 2020, Saudi Arabia began allowing flights from Houthi-held Sana'a for Yemenis who require outside medical care.[37] Perhaps most importantly, Crown Prince Muhammad bin Salman has tasked his brother, Prince Khalid bin Salman, to direct the peace talks with the Houthis in Oman.[38] Khalid bin Salman's involvement in these talks elevates their status and demonstrates prioritization by Saudi policymakers. Still, the shift from de-escalation to peace implementation will be difficult. Negotiations will need to cover several contentious issues, such as Iranian influence and activities in Yemen, border security and demilitarized zones, and the Houthi missile and UAV arsenal. To make progress on these fronts, Riyadh may need to recognize Houthi governance over larger swaths of Yemen than it would otherwise wish to see. Time is not on Riyadh's side. The longer the war goes on, the more permanently entrenched Iranian influence will likely become.

Figure 3: Geographic Distribution of Missile Activity, March 2015-April 2020

Houthi Missiles: A Military, Economic, and Political Tool

The Houthis' most pressing objective has been to force an end to the Arab coalition's military intervention and survive as the de facto governing power in Yemen. The Houthis have used missile and drone attacks to serve these goals by raising the military and economic costs for the coalition to continue its intervention. They have also used missile attacks as a political and propaganda tool to shore up domestic support and weaken the morale of the Saudi civilian populace.

Military Costs

The Houthis have attempted to use rockets and missiles to stymie the Arab coalition's intervention by disrupting its military operations and inflicting causalities. Missile attacks have killed over 400 Arab coalition military personnel since 2015. Ballistic missile attacks in 2015 included two high-casualty incidents, but the Houthis have achieved similar results only sporadically since then. One likely reason for this is that Houthi militants

The aftermath of a joint Houthi ballistic missile and suicide bomber attack on Aden, Yemen, on August 1, 2019.

Nabil Hasan/AFP via Getty Images

expended their more accurate missiles early in the conflict, such as the Soviet-made OTR-21 Tochka, the likely culprit for both high-casualty strikes in 2015. Second, Saudi Arabia and the UAE have likely adjusted their missile defense posture to better counter Houthi attacks. For example, after suffering 45 casualties from the Houthi's September 2015 strike on Marib, the UAE forward-deployed Patriot PAC-3 batteries into Yemen itself.[39]

The Houthis have also employed antiship missiles to put warships and shipping vessels at risk along the Red Sea and the Gulf of Aden since at least October 2015. They have successfully fired antiship missiles on Saudi, UAE, Turkish, and U.S. ships.

Nevertheless, the Houthi's lack of permanent radar since October 2016 has decreased the operational effectiveness of these weapons. The Houthis have instead had to deploy small boats to relay approximate target locations.[40]

The Houthis also have antiair missile capabilities that they have used to down several aircraft. They have used these weapons to shoot down at least three U.S. UAVs, in October 2017 and June and August 2019. Earlier, in May 2015, the Houthis also reportedly shot down a Moroccan F-16 over Yemen's Sa'ada province.[41] In February 2020, Houthi forces shot down a Saudi Tornado fighter aircraft in northern al-Jawf province.[42]

Several coalition aircraft have also fallen near Houthi-controlled territory, supposedly due to mechanical or human error. However, the proximity of these incidents to Houthi territory raises the possibility that hostile fire was to blame. In March 2015, a Saudi F-15 crashed into the Gulf of Aden, reportedly due to mechanical failure.[43] The same month, Houthi fighters claimed to have shot down a Sudanese warplane in northern Sana'a,

Table 2

HIGH-CASUALTY MISSILE STRIKES (20+ CASUALTIES)

DATE	*DESCRIPTION*
01/20/2020	A ballistic missile hit a military base in Marib, killing 116 pro-Hadi fighters and injuring around 100 others.
08/01/2019	A ballistic missile struck a military parade in Aden, killing 40 and wounding dozens.
03/17/2017	Two Zelzal-1 ballistic missiles strike a mosque in Sirwah in Marib Province, Yemen, killing 22 pro-Hadi fighters, likely Yemeni.
01/31/2017	Burkan-1 short-ranged ballistic missile (SRBM) strikes a Saudi-UAE military base on Zuqar Island in the Red Sea, killing 80 coalition soldiers.
01/16/2016	Unknown projectile strikes a small village in Taiz Province, Yemen, killing 10 civilians and injuring 14.
12/13/2015	OTR-21 Tochka SRBM strikes a coalition base in Taiz province, Yemen, killing 120+ coalition soldiers.
09/04/2015	OTR-21 Tochka SRBM strikes a weapons depot at a coalition military base in Marib, killing 60 coalition soldiers. The reported deaths included 45 UAE, 10 Saudi, and 5 Bahraini coalition soldiers. The UAE forward deployed Patriots in Yemen as a direct result of this strike.

although Sudanese officials denied the incident.[44] In December 2015, a Bahraini F-16 crashed in Saudi Arabia's southern Jizan province.[45] In February 2017, a Jordanian F-16 crashed in Najran, Saudi Arabia.[46] In November 2019, a coalition AH-64 Apache helicopter and Wing Loong UAV went down along the Saudi-Yemen border.[47]

Arguably the most effective missiles the Houthis possess, however, are shoulder-fired and antitank guided missiles (ATGMs), among the smallest and least discussed weapons in their arsenal. These weapons are widespread in Yemen. Propaganda videos going back to August 2015 show fighters using ATGMs against Saudi tanks to great effect. A 2016 report suggests Saudi Arabia lost at least 20 Abrams tanks in a little over a year of fighting in Yemen.[48] Houthi forces had previously gained experience with antitank weapons in their wars with the Yemeni government between 2004 and 2010. Still, they have since gained even greater lethality due to continued practice and acquisition of more advanced ATGMs.[49]

Economic Costs

As part of their strategy, the Houthis have sought to "shake" or "disrupt" the Saudi and UAE economies.[50] Houthi forces have used missiles to target Saudi oil facilities and tankers. Several of these strikes have landed successfully, and even failed attacks have increased the perceived risk to production lines and vessels, disrupting oil markets and raising shipping insurance costs.[51] In July 2018, for instance, Saudi Arabia suspended shipments in the Red Sea following Houthi attacks on two tankers in the area.[52] In August 2019, Houthi fighters launched "Operation Economic Deterrence," targeting Saudi Arabia's

Table 3

HOUTHI MISSILE ATTACKS ON PETROLEUM FACILITIES AND TANKER SHIPS

DATE	*DESCRIPTION*
7/25/2018	Antiship cruise missile targets a Saudi oil tanker in the Red Sea, causing slight damage.
5/14/2018	Badr-1 SRBM targets the Saudi Aramco distribution center in Jizan but reportedly misses.
5/11/2018	An unknown missile struck a Turkish vessel delivering wheat to the Yemeni port of Saleef.
4/23/2018	Two Badr-1 SRBM target Saudi Aramco in Jizan but are both reportedly intercepted.
4/04/2018	An unknown missile targeting the Saudi Aramco storage tanks is reportedly intercepted.
4/03/2018	Unknown projectile strikes a Saudi oil tanker in the Red Sea, causing damage.
7/22/2017	Burkan-2H MRBM targets the Saudi Aramco oil refinery in Yanbu, flying 965 km before landing within 5 km of the refinery. Marked the first reported use of the Burkan-2H missile.
8/26/2016	Unknown projectile strikes a Saudi Aramco power relay facility in Najran, starting a small fire.
12/21/2015	Qaher-1 SRBM targets Saudi Aramco in Jizan but is reportedly intercepted.

Shaybah oilfield with 10 armed UAVs. Although the attack resulted in only limited damage, it demonstrated that the Houthis could strike targets over 1,000 km away.[53]

Thus far, however, these attacks have not raised much investor concern. As one oil analyst argued, "What the market thinks is that although these incidents are important and noteworthy, they have so far not had any impact on actual production or exports."[54]

Lastly, and while perhaps not directly intended, the Houthi missile arsenal has forced the Arab coalition to conduct resource-intensive interdiction operations. These efforts include routine naval inspections and patrol routes across Yemeni ports and manning land-based checkpoints along Saudi Arabia-Yemen and Oman-Yemen smuggling routes. The missile threat has also tied up the coalition air force in left-of-launch "Scud hunting" operations that entail aerial surveillance of Houthi missile launchers and air sorties to target missile launchers and depots across northern Yemen. There are no figures for how much these ventures cost, but more generally, Saudi Arabia spends an estimated $5-6 billion a month on Yemen operations.[55]

Political: Raising Discontent in Saudi Arabia

Houthis have also used missile attacks to raise political discontent is Saudi Arabia. These attacks have killed at least 100 Saudi civilians and wounded at least 800 others, and have displaced thousands from southern towns along the Saudi Arabia-Yemen border.[56] Yet Houthi targeting of civilian areas seems to have had little effect on Saudi Arabia's political calculus. Reports indicate the Saudi public has largely ignored the war.[57]

There is some evidence that the Houthi reliance upon missile attacks has been ineffective and may have even backfired. Rather than dissuade Saudi Arabia from continuing to prosecute the conflict, Riyadh has used Saudi civilian deaths as justification for its intervention. Some Houthi leaders recognize this issue. As one member of the Houthis' Political Bureau explained, "After we started using missile attacks and we started to target Saudi forces near the border, Saudi Arabia is now portraying its aggression on Yemen as if it's just a response to our missile and border attacks. Therefore, today's step aims to once again clarify our position."[58]

Domestic Propaganda

Since the start of the conflict in 2015, the Houthis have made their missile capabilities a centerpiece of their public messaging and propaganda videos. The Houthis have frequently released videos of ballistic missile launches, often emphasizing new systems and capabilities. One video released in July 2018, for example, shows the launch of a ballistic missile from an underground erector-launcher.[59] In February 2020, the Houthis released a music video with a compilation of surface-to-air missile launches.[60] Houthi-run websites such as al-Masirah and Saba News publish stories daily about rocket launches against coalition fighters and frequently report on older missiles under new names and fresh paint to create a sense of technical progress.[61]

The Impact of Houthi Missiles on the Yemen Conflict

The Houthis have used their missile capabilities as part of a layered strategy with military, economic, and political objectives. Given the complexity of the Yemen conflict, it is difficult to explicitly differentiate the impact that specific weapon systems have had on the course of the

war from the many other trends and forces at play. Yet the frequent use of ballistic, cruise, and other aerial weapons has been a hallmark of the conflict and has by all accounts shaped events on the ground.

Objectively, the Houthi use of its longer-range ballistic missiles, such as the Burkan series, has produced limited military success. Of hundreds of launches, only seven resulted in significant coalition losses. Missile and drone attacks against Saudi economic targets have also failed to meaningfully impact Saudi oil production or rattle oil markets in a lasting way.[62]

Yet the Houthis' determined use of ballistic missiles has had secondary effects. Attacks into Saudi Arabia have tied-up coalition airpower into extensive "Scud-hunting" efforts, resources it could have employed elsewhere. While limited in kinetic impact, Houthi missile attacks against civilian areas deep in Saudi Arabia have been a source of political embarrassment for the Saudi government and raised the stakes for it to find a speedy resolution to the conflict. As Houthi attacks on oil infrastructure have become more precise, the potential for them to cause greater havoc on production may have also increased the urgency for Saudi Arabia to find an off-ramp from the conflict.

A screenshot from a July 2018 Houthi video showing an underground missile launcher designed to conceal it from aerial reconnaissance.

Houthi media

On the other hand, Houthi access to small arms, such as antitank missiles and MANPADS, has boosted the Houthis' ability to resist pro-Hadi and Arab coalition ground forces. Among the Houthi air and missile arsenal, these weapons have most directly helped the Houthis maintain their territorial gains and create a quagmire for coalition ground forces in Yemen. This success on the ground ultimately led to the UAE's 2019 withdrawal of most of its troops from Yemen, arguably the Houthis' most significant strategic success thus far.

Houthi Missile Sources

Since the start of the conflict, the Houthis have employed a diverse inventory of ballistic missiles and other projectiles, which they have acquired from three primary sources: (1) Yemeni government stockpiles, with most equipment initially purchased from the Soviet Union; (2) Iran, through various land- and sea-based smuggling routes; and (3) battlefield capture of Arab coalition stocks, though this is the least significant source.

Yemeni Government Stockpiles

The Yemeni military has long maintained stockpiles of ballistic, antiship, antitank, and surface-to-air missiles. Yemen acquired its first Scud missiles from the USSR in the 1970s. The Yemeni civil war in 1994 featured ballistic missile exchanges between the South and the North using Scud missiles and OTR-21 Tochka missiles, respectively.[63] Yemen has also received missiles since then from Iran, North Korea, Saudi Arabia, and the United States.[64]

Entrance to the headquarters of the 19th Infantry Brigade in Bayhan, Yemen. According to a 2016 UN report, Houthi forces plundered this depot and faced "almost no resistance." The brigade carried a missile arsenal of 104 RPGs and 270 antitank missiles.

United Nations

Yemen's Houthi movement has benefitted from Sana'a's weak control over its weaponry. UN experts noted that even before the current Yemeni civil war, Houthi forces "frequently looted" government weapons caches between 2004 and 2010.[65] Illicit seizures increased substantially, however, following the fall of Yemen's President Muhammad Saleh, as the political turnover from Saleh to Abdrabbuh Mansur Hadi was fractious and large pockets of the military and political establishments remained loyal to Saleh. Only an estimated 60 percent of the Yemeni military remained with Saleh and joined him as he transitioned to support the Houthis.[66]

As Saleh and his military loyalists aligned with the Houthis, they brought their arms with them. One UN report notes that the internationally recognized Yemeni military may have lost control of nearly 70 percent of its weapons cache.[67] A 2018 UN report finds that in early 2015, "the 5th and 6th missile brigades aligned themselves with the Houthi-Saleh forces."[68] While initial coalition airstrikes destroyed a significant number of these government depots, various missiles and associated infrastructure remained. Houthi forces very likely obtained most of their first ballistic missiles from government inventories, which included legacy Scud-type and OTR-21 Tochka ballistic missiles.

BATTLEFIELD CAPTURE

Houthi forces have also acquired military equipment and arms, including rockets, through battlefield capture from coalition forces and allied militias. A 2016 report provides a prime example of this issue, finding that Houthi troops had captured at least 16 C-90C rocket launchers from either Saudi forces or local pro-Hadi fighters that Saudi Arabia had equipped. Simple accidents also fuel rocket proliferation. In April 2015, for example, Houthi fighters seized RPG-26 variants accidentally airdropped by the coalition into Houthi-controlled territory. A Houthi leader took a picture of the shipment holding a thank-you note addressed to King Salman (See Image 5).

RPG-26 variant inadvertently airdropped by the Arab coalition to Houthi forces. The note reads, "Thank you [King] Salman, Peace Mekhlafi."

United Nations

Iran

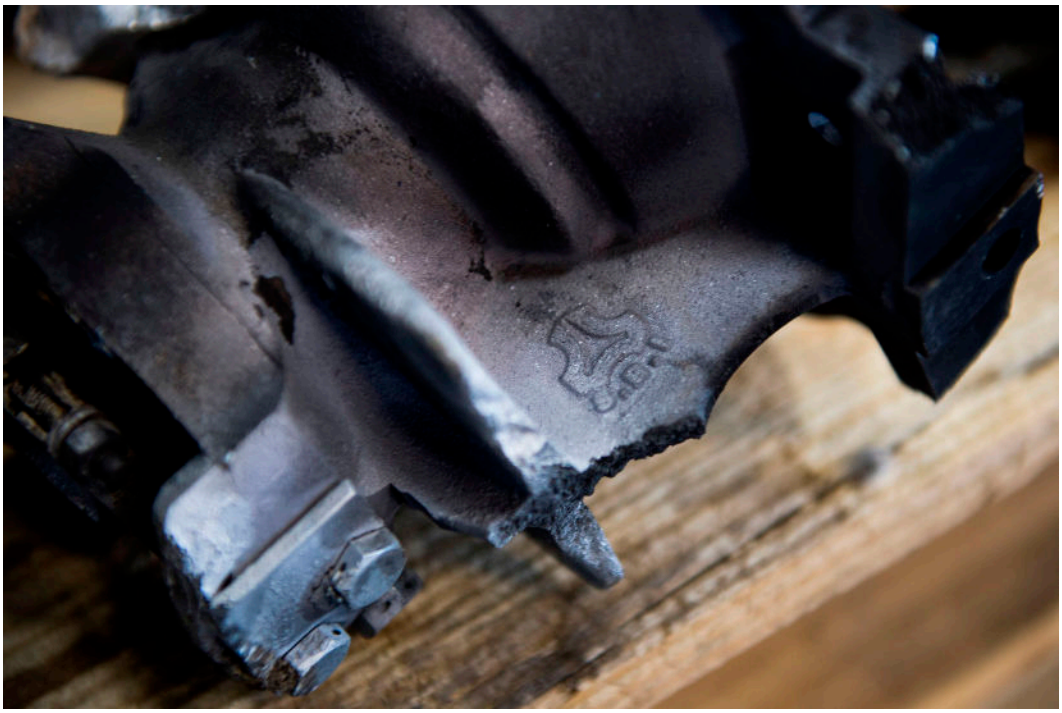
Over the past four years, U.S. and Arab coalition officials have collected and publicized evidence of Iranian missile smuggling to the Houthis. This evidence includes missile debris with Iranian manufacturing labels, naval interdictions of missile smuggling dhows originating from Iran, and missile-related training and equipment materials in Farsi seized from Houthi-controlled territory. Missiles such as the Burkan series ballistic missiles, the Quds-1 cruise missile, the al-Mandab-1 antiship missile, and the Sayyad-2C surface-to-air missile all bear Iranian fingerprints in design and manufacturing (See Appendix).

At a press conference at Joint Base Anacostia on December 14, 2017, U.S. Ambassador to the United Nations Nikki Haley unveiled previously classified information indicating that Iran violated UNSCR 2231 by providing Houthi rebels in Yemen with arms.

Jim Watson/AFP/Getty Images

Iran supports the Houthis as a cheap and effective way to challenge Saudi Arabia and other rivals. Similar to Lebanese Hezbollah and various militias in Iraq, the Houthis could serve to project Iranian power across the Middle East in ways its regular military cannot.[69] An empowered, Iranian-friendly Houthi force could control critical territory. One scholar explained that Houthi proxies "would effectively put the Quds force on the Saudi border and potentially give Iran a naval and air presence near the Bab-el-Mandeb, and the exit from the Red Sea to the Indian Ocean — a key trade route for petroleum and all trade and U.S. naval movements through the Suez Canal."[70]

Iran demonstrated a close linkage with the Houthis in June 2019, following rising tensions with the United States. During this time, Houthi forces launched two cruise missiles and 15 bomb-laden UAVs. The Houthis also intercepted a U.S. MQ-9 in a shootdown reportedly "enabled by Iranian assistance."[71] Earlier in May, the Houthis claimed to have launched seven drones over 800 km from the Yemen border to strike two Saudi oil pumping stations.[72] The attacks forced Saudi Arabia to shut down the connecting pipeline for a day.[73] However, U.S. intelligence found that the drones



A missile component recovered in Saudi Arabia reveals the logo of Iranian manufacturer Shahid Bagheri Industries.

Jim Watson/AFP via Getty Images

originated from Iran-backed militias in southern Iraq.[74] Similarly, the Houthis claimed responsibility for Iran's September 2019 drone and cruise missile attacks on the Abqaiq and Khurais oil facilities. These false claims of responsibility demonstrate close coordination with Iran, both in military activity and messaging.

Iran has transferred rocket and missile supplies over several routes to the Houthis. One is overland—namely, smuggling weapons into Yemen through bordering Oman into al-Mahra province. A senior Yemeni military source told reporters that one smuggling route runs through Shehen, an unpoliced zone along the Yemeni-Omani border.[75] Drug smugglers had previously used these passages to run illicit narcotics into Saudi Arabia.[76] Iran also delivers rocket and missile parts through smaller seaports over various points along the Red Sea, Arabian Sea, and the Gulf of Aden.[77] As one UN report importantly notes, "Weapon smuggling to, from, and through Yemen—in some cases with the collusion of security officials and businesspeople—predates the beginning of the current conflict."[78]

Coalition forces reportedly started seizing Iranian-sourced shipments of antitank missiles traveling overland from Oman to Ma'rib in mid-2016.[79] UN experts contend that Iran uses land routes primarily for ATGM smuggling.[80] However, Iran may have also used these routes to transfer ballistic missile components for assembly in Yemen. Debris from at least 10 Burkan-1 missiles, for example, show evidence of being smuggled and reassembled, which opens the possibility of overland transfer.[81] One U.S. official also claimed that Iran was transferring antiship missiles across the Omani border.[82]

The shift toward greater use of drones by the Houthis has, in some ways, simplified the transfer of firepower from Iran to Yemen. UAVs are smaller and more transportable than ballistic missiles and can be assembled locally. A 2019 UN report noted:

> Whereas in 2015 and 2016, complete or partially assembled weapons systems such as extended-range short-range ballistic missiles were supplied to the Houthi forces from abroad, they are now increasingly relying on the import of high-value components, which are then integrated into locally assembled systems such as extended-range unmanned aerial vehicles.[83]

In more than one respect, the Yemen missile war is evolving into a conflict characterized by a complex mix of air and missile attack.

Figure 4: Weapons Smuggling and Weapon Seizures Over Land

The Arab Coalition's Strategy to Counter Houthi Missiles

The Arab coalition has undertaken significant efforts to prevent and minimize the impact of Houthi launched missiles. This strategy has included three distinct activities: (1) active missile defenses, (2) air and ground operations against Houthi missile launchers and depots, and (3) interdiction activities to prevent arms transfers into Yemen.

Air and Missile Defenses

The Arab coalition has employed missile defenses extensively in the Yemen conflict, reporting at least 162 intercepts of Houthi-launched missiles between March 2015 and April 2020. Saudi Arabia initially deployed its active defenses to protect military installations. Yet as the conflict progressed, Riyadh has had to increasingly disperse its air defense to protect population centers and economic assets as Houthi forces diversified their targets and fielded increasingly longer-range missiles.

Although coalition defenses have not proven perfect, the available data show they have meaningfully limited damage from Houthi missile attacks and curtailed the value of Houthi missiles as a strategic tool. An illustrative data point is that at least four of the seven deadliest Houthi missile strikes likely took place in areas that lacked ballistic missile protection at the time of the strike.[84] Given the damage seen in these unprotected areas, it seems likely that hard-hit areas such as Khamis Mushait and Jizan would have experienced greater loss of life had they too lacked defenses.

The experience of the Yemen conflict nevertheless has highlighted several challenges to existing air and missile defense systems. These include the greater challenge posed by complex targets and difficulties that drones and cruise missiles pose to defensive systems that, for years, have been optimized for ballistic missile defense.

HOW PATRIOT WORKS

Like all air and missile defense systems, Patriot operations center on three essential functions: detect, control, and engage. A ground-based radar performs the detect function, locating and tracking an enemy missile or aircraft. The radar sends this information to a manned mobile control station, which plans the optimal engagement solution across a battery's multiple launchers. The operators within the manned mobile command station

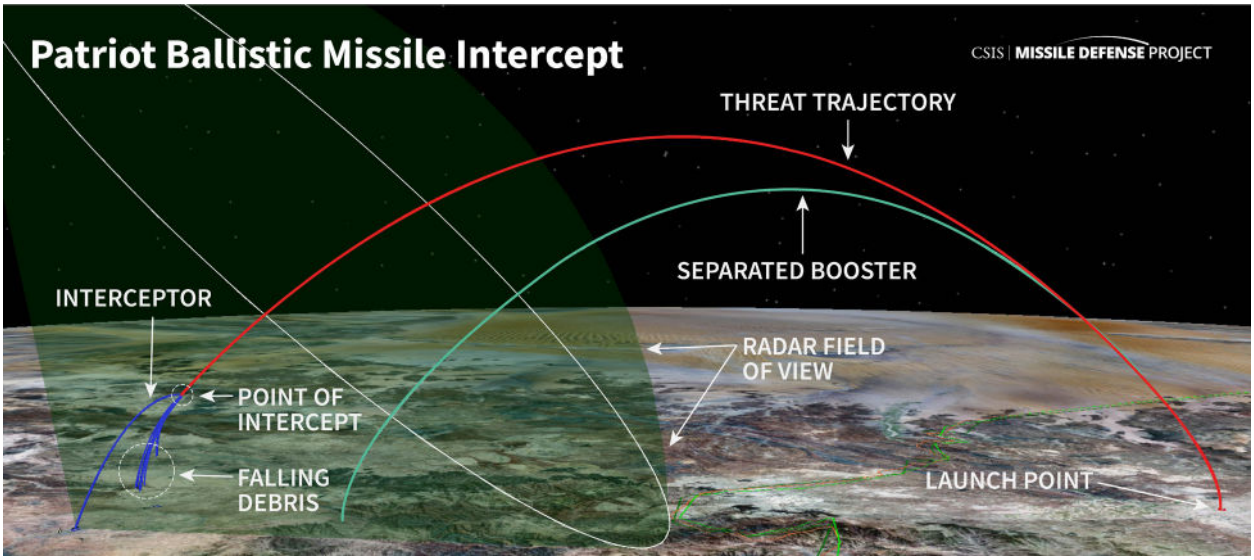
then engage the target with a salvo of interceptors.

As a point defense system specialized at engaging short-range ballistic missiles, a Patriot's defended area is relatively limited when compared to longer-range ballistic missile defense systems such as Aegis or the Terminal High Altitude Area Defense (THAAD) system. Patriots can also provide a wider area defense against air-breathing threats (e.g., aircraft or cruise missiles), but its radar's field of view still limits its reach. Patriot operators most often deploy them to defend high-value military assets such as air bases and command centers. Some countries such as Saudi Arabia and Japan also use them to protect civilian population centers. In some cases, these missions can overlap.

The Patriot launcher employs two families of interceptors. The first family uses semi-active radar guidance and a proximity fuse to explode near a target to destroy it. This group of interceptors includes variants such as the Patriot Advanced Capability-2 (PAC-2), Guided Enhanced Missile (GEM), GEM+, GEM/T (optimized for ballistic missile defense), and GEM/C (optimized for cruise missile defense). The other family of interceptors uses hit-to-kill technology, employing an active radar seeker while en route to destroying a target by physically colliding with it. This group includes the PAC-3 interceptors and the newer PAC-3 Missile Segment Enhancement (MSE).

A Patriot unit will typically engage a ballistic missile with two interceptors, a number known as "shot doctrine." Shot doctrine is principally meant to increase the probability of a kill. But other circumstances may force a battery to expend more interceptors against a given threat. One crucial factor is the ability to discriminate a ballistic missile's warhead from other parts of the missile. Against a non-separating missile, such as a Tochka, discrimination is less

Figure 5: Notional Patriot Engagement



A picture taken March 26, 2018 in Um Al-Hammam district in Riyadh shows a man looking at a hole in a household ceiling caused by falling shrapnel from Yemeni rebel missiles that were intercepted over the Saudi capital.

Fayez Nureldine/AFP via Getty Images

challenging since the missile will remain a unitary body throughout its flight. A missile such as a Burkan-2H, on the other hand, has a warhead that will separate from the main body during flight. A Patriot radar will detect two or more objects and must discriminate the warhead from the booster. If it cannot, the Patriot system may engage both warhead and booster, expending additional interceptors.

Unlike other missile defense systems such as Aegis BMD, which intercepts missiles in the vacuum of space, Patriot intercepts occur within the atmosphere at relatively lower altitudes. A Patriot interceptor aims to strike the warhead of the missile to neutralize its explosive element. This action can create significant debris, both from the enemy missile and the interceptor. Although far less destructive than an intact ballistic missile warhead, falling debris can still result in damage and even loss of life.

COALITION AIR AND MISSILE DEFENSE DEPLOYMENTS

Saudi Arabia deploys six Patriot battalions as part of the ~16,000-person strong Royal Saudi Air Defense Forces (RSADF). In the U.S. Army, a Patriot battalion typically consists of four batteries, which themselves includes 4-6 individual launchers, although organization can vary across different militaries. Each battery also contains an MPQ-53 or MPQ-65 radar, a command station, and other support equipment. The bulk of interceptors the RSADF has used in the Yemen conflict are PAC-2 GEM/T interceptors, but Saudi Arabia began receiving PAC-3 interceptors in 2017.[85] Until Saudi Arabia takes receipt of the THAAD system, Patriot will remain its only nationally-controlled ballistic missile defense capability.[86]

Saudi Arabia also possesses 80 standalone air defense radars. Many of these are older systems dating back several decades, such as the AN/TPS-43 and AN/FPS-117. Saudi Arabia

does deploy some more modern systems, such as the AN/TPS-59, which could provide earlier detection of ballistic missiles and cueing for its Patriot firing units.[87]

The RSADF also possesses 16 batteries of the MIM-23B Improved-HAWK medium-range air defense system, and 17 batteries of the French-made Shahine short-range air defense missiles, plus over 70 static units equipped with Shahine missiles for the defense of fixed installations.[88] The readiness and operational status of these forces is unclear, however.

Saudi Arabia does not publicly comment on the disposition of its Patriot units. Yet inferring from reported intercepts, its defenses are distributed across numerous locations in Saudi Arabia and Yemen (Figure 6). These include some of the areas hit hardest by missile attacks, such as Khamis Mushait, Jizan, and Najran, all near the Saudi-Yemeni border. The coalition has also reported intercepts in areas further north, such as Jeddah, Mecca, Taif, Yanbu, and Riyadh. The UAE possesses as many as three Patriot battalions that use the PAC-3 configuration.[89] The UAE also possesses two THAAD batteries, but these forces are presumably oriented northward against the Iranian missile threat, and there is no indication these have taken part in the Yemen conflict. While the bulk of UAE Patriots remained stationed in its territory, the UAE military had several Patriot units operating in Yemen as well until mid-2019.

These have included in Marib province and the al-Anad air base on the southern coast. Reports have credited UAE Patriots with intercepts around the port city of al-Mohka, along Yemen's southwest coast.[90] Analysis of commercial satellite imagery suggests the UAE Patriot forces have realigned at least once during the conflict, so it is difficult to ascertain how many Patriot units the UAE has had in Yemen at any given time.[91] All UAE Patriot forces likely departed Yemen, however, along with the broader UAE withdrawal in mid-

Figure 6: Notional Disposition of Saudi Patriots Based on Reported Intercepts

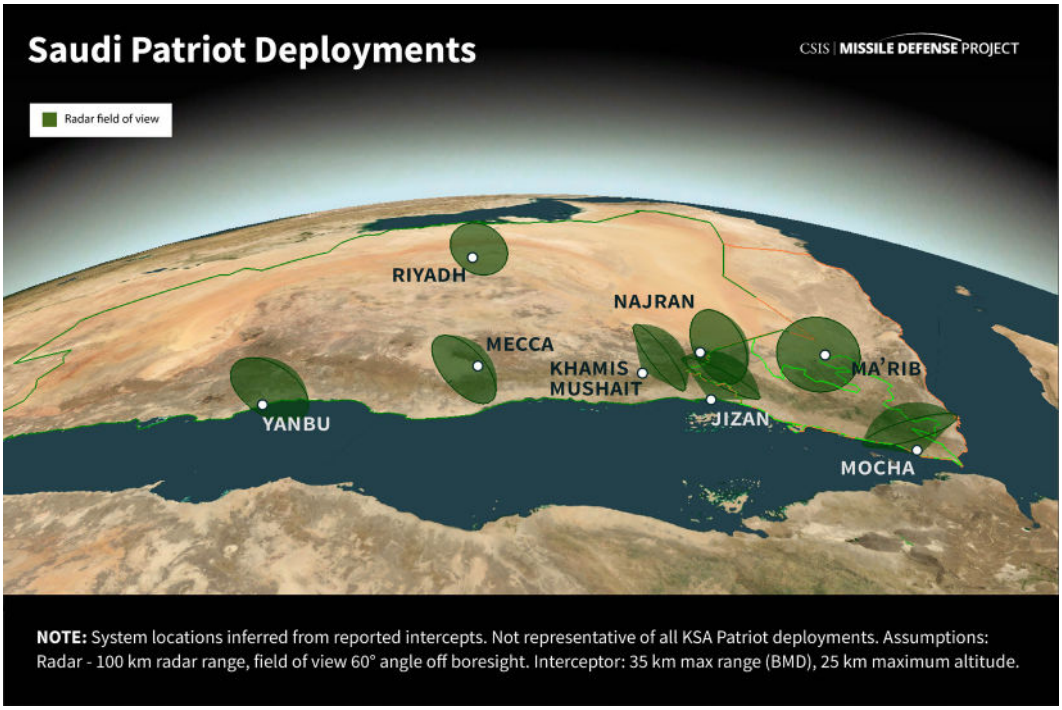
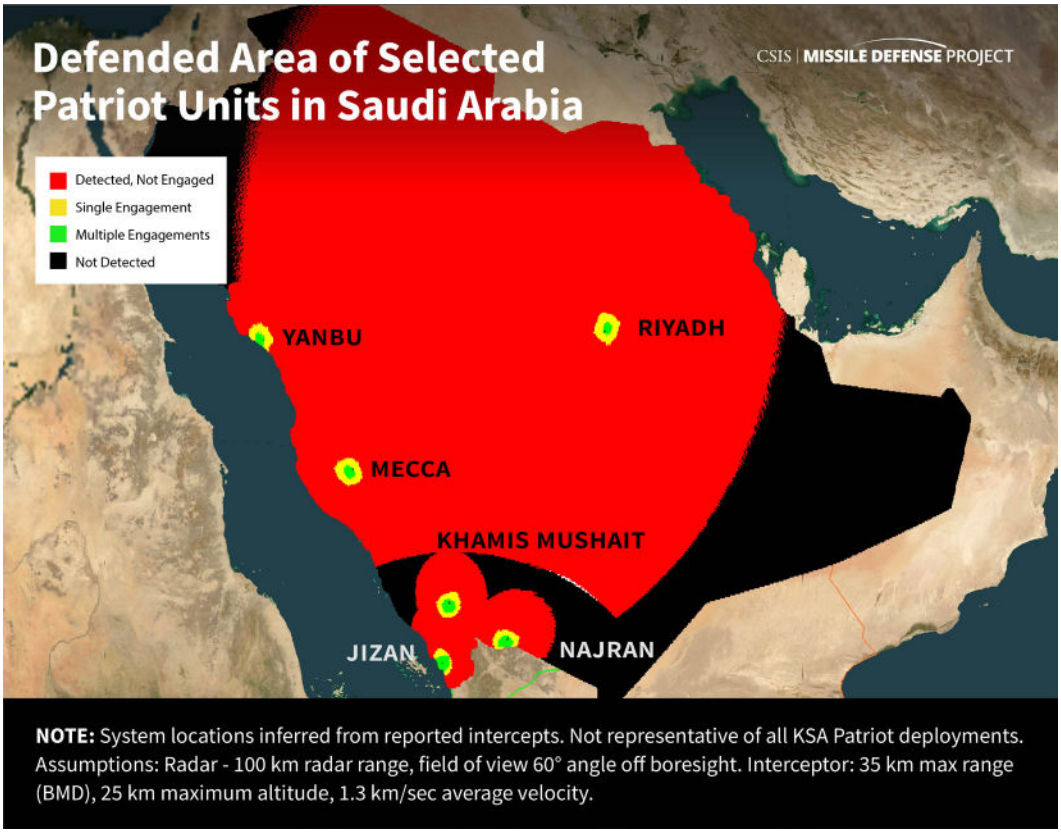


Figure 7: Notional Patriot Defended Area against SRBM/MRBM in Saudi Arabia



2019. Reports of intercepts by Saudi Patriots in the al-Mokha region in November 2019 suggest that the RSADF has moved in to continue the defense of al-Mokha. Conversely, a deadly ballistic missile attack in November 2019 and the February 2020 strike in Marib that killed over 100 Yemeni soldiers raise the possibility that the UAE withdrawal has left Marib without ballistic missile defenses.

ASSESSING PATRIOT PERFORMANCE

Incomplete access to information makes it difficult to have a clear picture of Patriot performance during the Yemen missile war. There is a significant amount of false information surrounding missile and missile defense activity. Saudi Arabia and the UAE have, at times, prematurely or falsely claimed successful intercepts. The Houthis have furthermore falsely claimed successful missile attacks and frequently mischaracterize artillery rocket fire as ballistic missile launches.

Various groups have provided different data and assessments. In July 2016, an official from Raytheon, the U.S. defense firm that manufactures Patriot, claimed Saudi Patriots had a "100 percent success rate" in intercepting "well over a couple dozen" Houthi missile attacks.[92] Just over a year later, in November 2017, Raytheon said that Patriot had had "over 100 successful engagements" during the conflict.[93] The 2018 UN Panel of Experts report cites 55 "confirmed or reported" intercepts of Houthi missiles between 2015-2017.[94] The CSIS database tracked reports of 57 reported intercepts during the 2015-2017 period and over 162 reported intercepts as of April 2020.

Despite the large discrepancy in sources and methodology, these figures are not necessarily contradictory. There is likely a significant amount of Patriot activity that goes unreported or is otherwise unconfirmable by independent observers. A successful Houthi missile strike, moreover, does not necessarily equate to a failed intercept attempt. The nature of Patriot as a point defense system limits its defended area. Missiles attacking outside these areas would not be engageable. Even within a defended area, Patriot operators may deem a target to be on a non-threatening trajectory and choose to let it go rather than expending valuable interceptors. Even in the event of a genuinely failed intercept, the root cause could be either operator error or mechanical failure. Absent a complete data set that can account for these variables, any effort to quantify Patriot's reliability using its performance in the Yemen conflict will remain questionable.

CHALLENGES TO COALITION AIR AND MISSILE DEFENSES

The Yemen conflict has highlighted the strategic value of active air and missile defenses. It has also, however, exposed the limitations of currently deployed systems and brought to light how adversaries may adapt tactics and equipment to exploit those limitations.

The Houthis' increasing use of drones, for instance, has complicated coalition air defense operations. Drones' small radar cross-section profiles can be difficult to distinguish from normal radar clutter. Their low-altitude flight paths also present a problem for traditionally configured air and missile defense radars, which are often calibrated to search for faster, higher-altitude missiles and aircraft. They also challenge air defense systems with sectored radars such as Patriot, as drones can approach from any direction. Iran's drone and cruise missile attack on the Abqaiq and Khurais highlighted these limitations.[95]

SUPPRESSION OF COALITION AIR DEFENSES

Drones have also posed a threat to the air and missile defenses themselves. Some of the Houthis' earliest known uses of drones were attacks on Saudi and UAE Patriot air and missile defense units. A 2017 report, for example, cited UAE military personnel who had experienced Houthi-operated drones crashing into Patriot radars to blind the batteries against follow-on missile salvos.[96]

Reports of Houthi drone attacks against air defense assets continued throughout 2018. In February 2018, the Houthis claimed successful drone attacks against coalition Patriot batteries in al-Mokha and Marib in Yemen. In May 2019, the Houthis claimed to have struck a Patriot battery stationed at Najran airport in Saudi Arabia. Saudi Arabia disputed the claim, saying it had shot down the drone.[97]

The success of such attempts to suppress coalition air defenses is unclear. Yet even if unsuccessful, the use of UAVs diversifies the types of threats coalition air defenses must contend with, complicating their mission. Their use may, for example, force Saudi Patriots to expend valuable interceptors on comparatively inexpensive drones.[98] Alternatively, they may impose costs on the coalition, forcing the deployment of other short-range air defenses to defend the defenders.

COMPLEX TARGETS

Detailed information on individual Patriot engagements has been sparse. Still, evidence suggests that the RSADF has, on at least one occasion, struggled to intercept a longer-ranged

ballistic missile with a separating warhead. In a November 2017 attack, Houthis fired a Burkan-2H ballistic missile at the Riyadh International Airport, one of the most audacious Houthi efforts of the conflict. Saudi Patriots engaged, firing at least four interceptors at the missile.[99] Debris from the missile littered downtown Riyadh, and the Saudi government reported that it had successfully intercepted it.

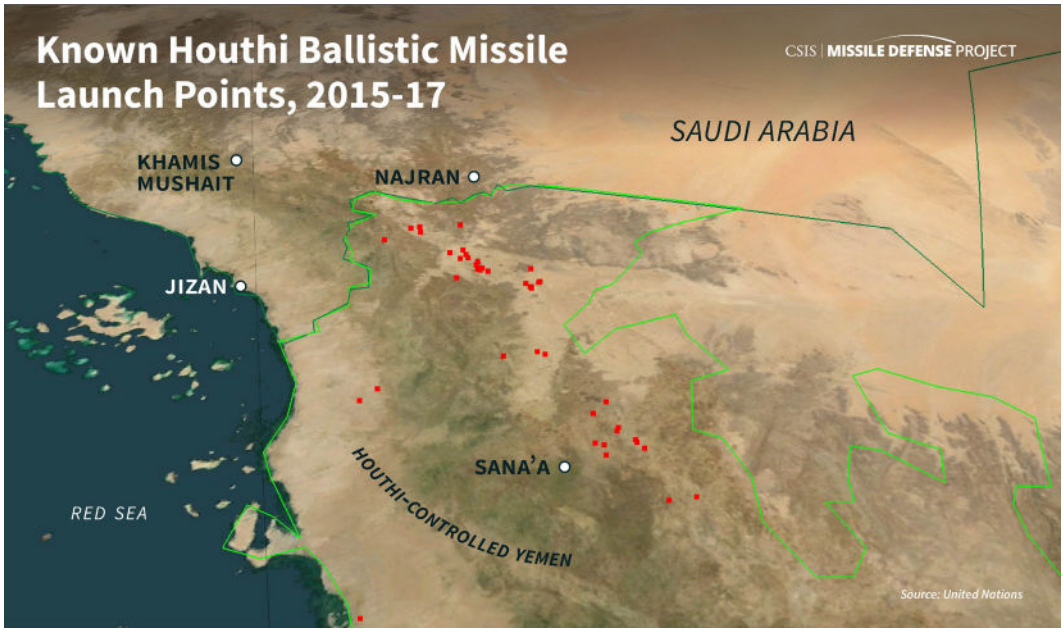
Analysis of commercial satellite imagery and evidence from social media, however, indicate that the Patriots most likely engaged the missile's separated booster but missed the warhead, which detonated harmlessly in an empty area near the Riyadh International Airport's main terminal.[100]

There are many reasons the intercept may have failed. One possibility is that the system was unable to correctly discriminate between the warhead and the booster and only engaged the booster. Another possibility is that the system engaged both targets, but the interceptors failed to destroy the warhead. Both

On March 25, 2018, Houthi militants fired seven ballistic missiles into Saudi Arabia. This screenshot from a video taken by Dhafer Alduhayim shows the debris of one missile that fell along a Riyadh highway.

"438888," [Unlisted] Dhafer Alduhayim, YouTube, March 25, 2018, https://www.youtube.com/watch?v=gb6YaLm9K5I&-feature=youtu.be

Figure 8: Known Houthi Ballistic Missile Launch Points, 2015-2017



scenarios could be the result of system or human error. Without more information, it is difficult to draw firm conclusions from this incident. Yet in future conflicts, complex ballistic missiles will likely become the norm rather than the exception, and continual efforts to improve performance against them will be key.

The Air Campaign

Another component of the Arab coalition's counter-missile strategy has been its campaign to destroy the Houthi's missiles and supporting infrastructure with air power. Over the Arab coalition's opening campaign, designated Operation Decisive Storm (March 26–April 21, 2015), coalition forces conducted 2,415 sorties with a reported 185 aircraft, dropping at least 1,000 air-to-ground bombs.[101] While remaining outside the coalition, the United States and the United Kingdom have provided it significant targeting, logistical, and intelligence support. On April 22, 2015, Arab coalition spokesperson Brigadier General Ahmed Asiri announced the successful completion of Decisive Storm, saying the operation "had completed its objectives in Yemen by destroying the ballistic missile capabilities of the Houthi movement and Houthi-allied military units."[102] Yemeni army sources maintained, however, that the Houthis and their allies still maintained 60 to 70 ballistic missiles.[103]

Events on the ground would soon prove that, while perhaps degraded, the Houthis retained a ballistic missile capability. On June 6, Houthi forces fired a ballistic missile targeting the southern Saudi town of Khamis Mushait, arguably the first shot of the Yemen "missile war." Yet while the Arab coalition failed to destroy the Houthi ballistic missile

Figure 9: Coalition Airstrikes on Houthi Missile Capabilities

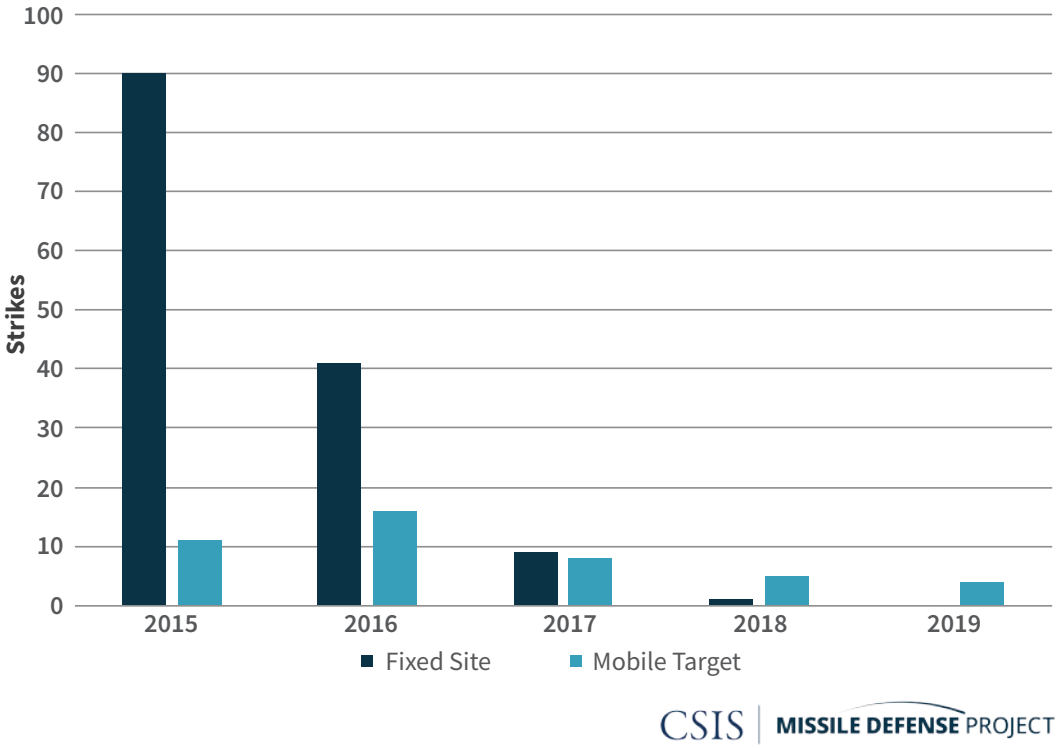
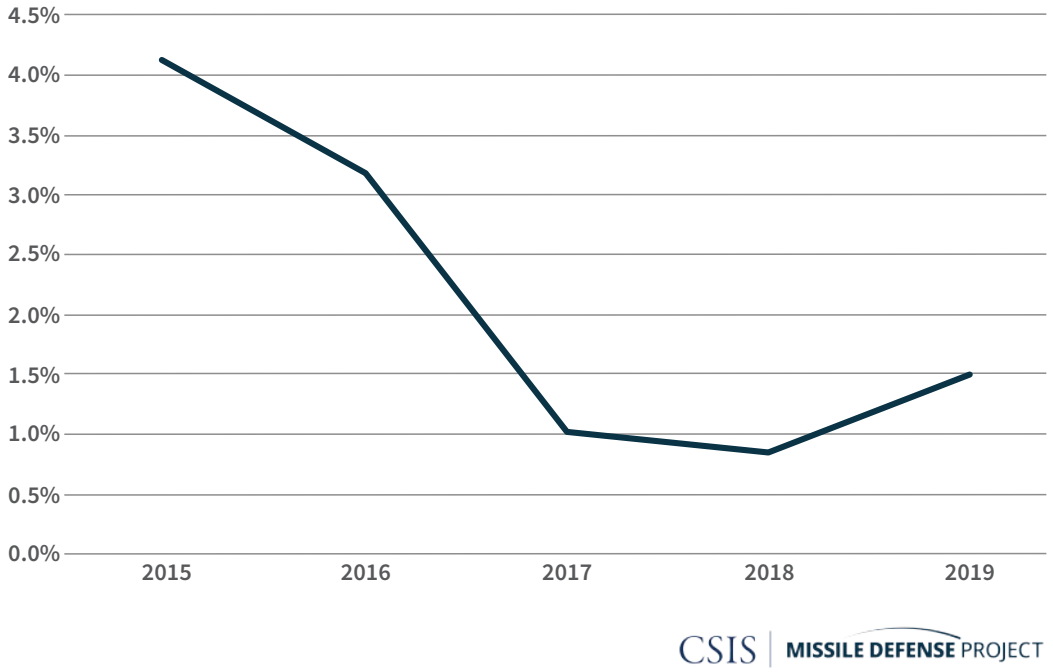


Figure 10: Portion of Total Coalition Airstrikes Targeting Houthi Missile Capabilities



arsenal in detail, its air campaign very likely reduced the number of missiles and related equipment available for the Houthis to seize.

Operation Decisive Storm was immediately followed by Operation Restoring Hope (April 22, 2015–present), which was supposed to focus more on reestablishing Yemen's politics and providing humanitarian assistance than continued military intervention. Nevertheless, Operation Restoring Hope has continued to rely heavily on coalition airpower and military force. The coalition has conducted nearly 20,000 sorties throughout its second Yemen campaign.[104] Only a small portion of these have targeted Houthi missile capabilities, however (Figure 10).

Moreover, coalition airstrikes on fixed and mobile missile targets have decreased significantly since the start of the conflict, both in terms of raw numbers of sorties and the percentage of airstrikes overall (Figures 9 and 10). There are two possible explanations for this decrease. The first is that the coalition targeted known missile launchers and depots at the start of the conflict. Once destroyed, there were fewer targets for the coalition to strike. A second reason may be that the Houthis have made their missile forces more resilient to coalition air attacks. The Houthis have developed underground storage facilities to protect their forces, conducting "shoot-and-scoot" operations to prevent counterattacks from destroying their launchers while limiting communications to avoid discovery (Image 3).[105]

SUPPORT FROM U.S. SPECIAL OPERATIONS FORCES

The Arab coalition has elicited direct U.S. counterproliferation support through the deployment of special operations forces. According to a New York Times report, U.S. Green Berets deployed to the Saudi-Yemen border in December 2017 to help the coalition "locate and destroy caches of ballistic missiles and launch sites." While U.S. Special Operations

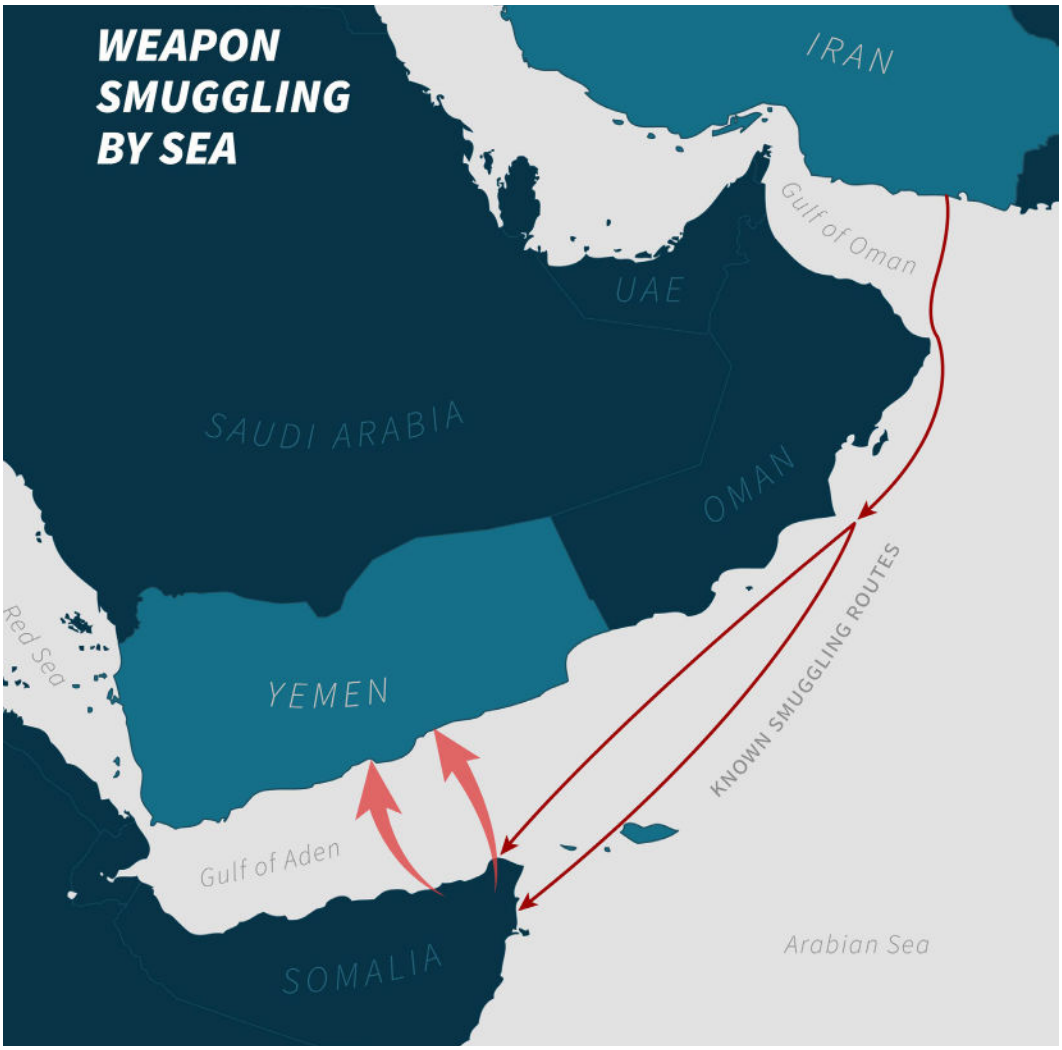
Command (USSOCOM) has operated in southern Yemen for years as part of the ongoing War on Terror, this expansion into the north represents a separate and significantly broader mission.

Maritime Restrictions and Interdictions

Another effort to degrade Houthi missile capabilities has been to restrict the overseas flow of weapons into Yemen. This naval activity has comprised two parallel lines of efforts: those of the Arab coalition naval forces and an international effort led by the United States and the Combined Maritime Forces (CMF).[106] Arab coalition patrols have largely been in coastal areas, monitoring traffic into Yemen's major ports. U.S. and CMF focus has primarily been on the interdiction of suspect vessels on the high seas.

At the onset of the intervention in March 2015, naval forces of the Arab coalition sought to take control of supply lines and enforce maritime restrictions.[107] Ports located around Aden, al-Mokha, and al-Hodeidah marked potential points for Iran to smuggle rocket parts and supplies into the country. The Arab coalition later asserted that UN Security

Figure 11: Weapon Smuggling Sea Routes



Council Resolution 2216, passed in April 2015, allowed it to take such measures as part of the "necessary measures to prevent the direct or indirect supply" of arms to Houthi forces.[108] The Arab coalition has not, as of April 2020, provided details of any interdictions of weapons at sea.[109] This lack of transparency makes it difficult to determine how effective its patrols have been.

The international effort has enjoyed greater public success, with seven known interdictions of ships carrying weapons to Yemen (Table 4). These interdictions were the work of U.S. ships operating as part of the U.S. Fifth Fleet or French and Australian ships operating under the CMF. Notably, these incidents all involved smaller dhows rather than the container ships or fuel tankers commonly searched and delayed by Arab coalition forces.[110]

Table 4: Interdictions at Sea

DATE	INTERDICTING SHIP	INTERDICTED VESSEL	WEAPONS SEIZED	ORIGIN	DESTINATION
9/25/2015	HMAS *Melbourne* (FFG-05)	Nasir	56 Toophan ATGM, 19 9M113 Kornet ATGMs, and associated launch equipment	Sirik, Iran	Hordio or Caluula, Somalia
2/27/2016	HMAS *Darwin* (FFG-04)	Samer	100 RPG-7 variant launchers, 1,989 AK-type assault rifles, 49 PKM light machine guns, 20 60-mm mortar tubes	Chababar, Iran	Caluula, Somalia
3/20/2016	FS *Provence* (D-652)	Unnamed dhow	9 9M133 Kornet ATGMs, 1,998 AK-type assault rifles, 64 Hoshdar-M sniper rifles, 6 PKM light machine guns	Chababar, Iran	Qandala, Somalia
3/28/2016	USS *Sirocco* (PC-6)	Adris	200 RPG-7 variant launchers,1,500 AK-type assault rifles, 21 heavy machine guns	Sirik, Iran	Caluula, Somalia
8/28/2018	USS *Jason Dunham* (DDG-109)	Ibrahim Dhibayn	3,000 Type 56-1 assault rifles	Unknown	Unknown
11/25/2019	USS *Forrest Sherman* (DDG-98)	Al Raheeb	21 Dehlavieh ATGMs, 2 SAMs, components for Quds-1 LACM, components for C-802 ASCM, and unidentified cruise missile	Unknown	Unknown
2/9/2020	USS *Normandy* (CG-60)	Al Qanas 1	150 Dehlavieh ATGMs, 3 SAMs	Unknown	Unknown

Despite these public successes, the continued use of Iranian-sourced weapons in Yemen raises doubts about the overall efficacy of the naval effort. A 2016 UN report noted that "several Member States commented during meetings that the coalition blockade could not realistically prevent all maritime smuggling using dhows."[111] Iranian smuggling dhows do not require large port facilities and can instead use the smaller, loosely policed ports that dot Yemen's 1,906-kilometer coastline. Subsequent UN reports in 2017 and 2018, however, assessed the ability to smuggle weapons into Yemen through the blockade as "unlikely," asserting that relevant waterways are "well patrolled by the Combined Maritime Forces, the United States Navy Fifth Fleet and the Royal Saudi Navy."[112]

While the effects of coalition maritime restrictions on weapons smuggling are unclear, their impact on Yemeni civilians has been plain. Since the Arab coalition's intervention, Yemen lacks access to food, water, medicine, and fuel, with the naval blockade marked as a central cause. These shortages have resulted in 1.8 million malnourished children, the worst cholera outbreak in history with over a million infected, and humanitarian aid held up for months.[113] These conditions have not prevented the coalition from expanding its restrictions, however. Following a Houthi missile launch targeting Riyadh in November 2017, Saudi Arabia imposed a full naval blockade on Yemen. The coalition eventually loosened this policy following a flood of media attention concerned about the potential for mass starvation.[114]

The Arab coalition employs various vessels to enforce its maritime restrictions over Yemen. On the top left: Egyptian Oliver Hazard Perry-class frigate, Sharm El-Sheikh (F-901); top right: Saudi Arabian Boraida-class replenishment oiler, Yanbu (904); bottom UAE Baynunah-class corvette, Al-Dhafra (P-173).

Wikimedia, KSA Ministry of Defense, US Navy

Airspace Restrictions

In addition to its maritime restrictions, the Arab coalition established an air blockade over Yemen in 2015 to cut the Houthi movement off from outside support. The coalition has since lifted its restrictions over Hadi-controlled airspace but kept them in place in areas controlled by the Houthis, with all flights requiring clearance by the Saudi Ministry of Defence.[115] The coalition has designed these restrictions primarily to prevent the Houthis from smuggling weapons into the country.[116]

Saudi Arabia's specific restrictions on flights have fluctuated over the past five years. For example, in August 2016, the coalition canceled commercial flights to Houthi-controlled Sana'a following the failure of peace talks.[117] The cancellation may have been retribution for the failed negotiations or a consequence of the coalition increasing the "scope and tempo" of their airstrikes in the region.[118] In November 2017, the coalition ordered a full closure of Yemeni airports following a Houthi missile attack on Riyadh. While those under coalition control reopened a few days later, those under Houthi control remained off-limits for several weeks. In November 2019, the coalition announced it would reopen Sana'a airport to allow sick Yemenis to seek treatment abroad.[119]

The coalition has also conducted airstrikes against Yemeni airports to degrade their facilities and prevent Houthi use. In 2016, the United Nations recorded nine coalition airstrikes on Yemeni airports.[120] Perhaps the most significant of these took place against Sana'a International Airport in April 2015, as the Iranian Red Crescent Society (IRCS) attempted to fly a passenger aircraft reportedly carrying humanitarian cargo. After the repeated warnings by air traffic controllers to turn back went unanswered, Saudi aircraft bombed the airport, killing 13 people and damaging the runway, airport facilities, and several commercial passenger airplanes. The IRCS plane then reversed course to return to Iran.[121]

Saudi Arabia's attack on a reportedly humanitarian convoy was extreme. Still, Iran has previously smuggled through weapons under the banner of humanitarian efforts, contrary to the international law of armed conflict. In December 2003, for example, Iranian aircraft shuttled between Syria and Iran, ostensibly to pick up aid for a devastating 6.6 magnitude earthquake that struck southeastern Iran. However, the convoy's primary mission was to smuggle in Zelzal missiles for Lebanese Hezbollah, which it accomplished.[122] According to Israeli sources, Iran similarly tried to transfer weapons to Hezbollah in convoys disguised as humanitarian aid following the 2006 Lebanon War.[123]

Like its maritime restrictions, the coalition's restrictions on Yemeni airports have had harmful consequences on Yemeni civilians. The bombing of Sana'a airport, for example, delayed humanitarian supplies for 10 days.[124] As one UN official explained, "Without access to the airports, aid agencies are unable to bring in staff, vital supplies of medicines and other critical life-saving assistance, or undertake medical evacuations of their personnel. Emergency relief and medical teams from abroad are likewise unable to fly in to scale up the humanitarian operation to address the needs of increasingly vulnerable Yemenis."

Final Thoughts

This study has focused on one strand of a complex and bloody war in which no side can claim the moral high ground. The Houthi movement's access to ballistic missiles, cruise missiles, and drones has enabled it to resist the Arab coalition but not defeat it. Despite extensive Arab coalition efforts to stop the flow of these weapons into Yemen, missiles and drones continue to appear on the battlefield in significant numbers. Widespread air attacks against missile launchers and supporting infrastructure have also not stopped the attacks. Active air and missile defenses have therefore proven to be a necessary element of the Arab coalition's strategy to blunt the impacts of the Houthi missile campaign.

The Arab coalition's experience in Yemen's missile war may contain some valuable lessons for the United States and its allies. It is difficult to imagine a future U.S.-involved war that would not be inundated with a wide variety of missiles. At this point, it seems unlikely that any combination of arms control, nonproliferation, and left-of-launch interdiction can negate the need for robust, right-of-launch missile defenses—even if the defenses themselves may be imperfect. Continued advancement in air and missile defense technology will also be critical, as future wars will likely feature aerial weapons that are more numerous, precise, and harder to detect than those wielded by the Houthis today.

Beyond this broader lesson, however, remains the geopolitical quagmire that Yemen has become. Observers fear that, if unchecked, Houthi missile activity could inadvertently widen the conflict, perhaps even pulling in the United States.[125] These weapons might also appear in other regional conflicts at some point. In May 2019, Hezbollah leader Hassan Nasrullah threatened that the Houthis could one day turn its missiles against Israel.[126] In the long run, a hostile, Iranian-backed force armed with long-range missiles on Saudi Arabia's southern flank would add even more urgency to Riyadh's deepening sense of insecurity, raising the instability of an already unpredictable region. Mitigating the Houthi missile threat will likely be a necessary component of any lasting peace.

Appendix: The Houthi Missile Arsenal

This appendix serves as a guide to the missiles and rockets employed by the Houthi movement in Yemen between 2015 and 2020. It surveys weapon characteristics, capabilities, and notable uses in combat. The information presented is derived entirely from publicly available sources and may not include all missiles and rockets possessed by the Houthis.

Antitank Rockets

Shoulder- and tripod-fired antitank rockets are ubiquitous in Yemen, and Houthi forces have ample experience with them from their wars with the Yemen government between 2004 and 2010.[127] Physical characteristics and evidence from naval interdictions point to Iran as a major supplier of these weapons. Since antitank ammunition is readily available in-country, Iranian transfers have mainly comprised launcher components.[128] Many of these weapons seized in Yemen show manufacturing dates in 2017, confirming these did not come from pre-war government stockpiles.[129] Houthi fighters have also captured quantities of antitank rockets from coalition forces.

Information from the battlefield suggests that antitank munitions have contributed significantly to the Houthis' ability to resist coalition ground forces. Reports from 2016 say Saudi Arabia lost at least 20 Abrams tanks in a little over a year of fighting in Yemen.[130] Antitank weapons have also featured in Houthi propaganda, with Houthi videos going back to August 2015 depicting fighters using antitank guided missiles (ATGMs) against coalition tanks to great effect.

RPG-7

The RPG-7 is an unguided, shoulder-fired rocket-propelled grenade launcher (RPG) developed by the Soviet Union in the 1950s. Since its inception, several countries, including Iran, China, and Slovakia, have manufactured a variety of ammunition to equip the launcher. The RPG-7 has an effective range of 200 m and fires a grenade weighing between 2 and 4.5 kg.[131] Warships have intercepted shipments of RPG-7s headed to Houthi fighters on at least two occasions. In February 2016, the Australian frigate HMAS *Darwin* (FFG-04) intercepted a dhow in the Arabian Sea carrying 100 Iranian-manufactured RPG-7-type launchers, among other arms.[132] A month later, in March 2016, the U.S. patrol craft USS *Sirocco* (PC-6) intercepted an arms shipment that included 200 RPG-7 launchers.[133] Houthi fighters have also captured a number of RPG-7s from Saudi and pro-Hadi troops.[134]

Several videos show Houthi fighters using the RPG-7 with both Russian- and Iranian-made ammunition against Saudi armored vehicles, military installations, and personnel.[135] A 2016 UN report also confirmed RPG-7 use by Houthi-Saleh forces in Taiz Province.[136]

RPG-7 variant seized from FV Samer (dhow).

United Nations

RPG-26

The RPG-26 "Aglen" is an unguided, disposable, shoulder-fired rocket-propelled grenade launcher developed by the Soviet Union in the 1980s. The 72.5-mm caliber rocket weighs 2.9 kg, measures 77 cm in length, and has a range of 250 m.[137]

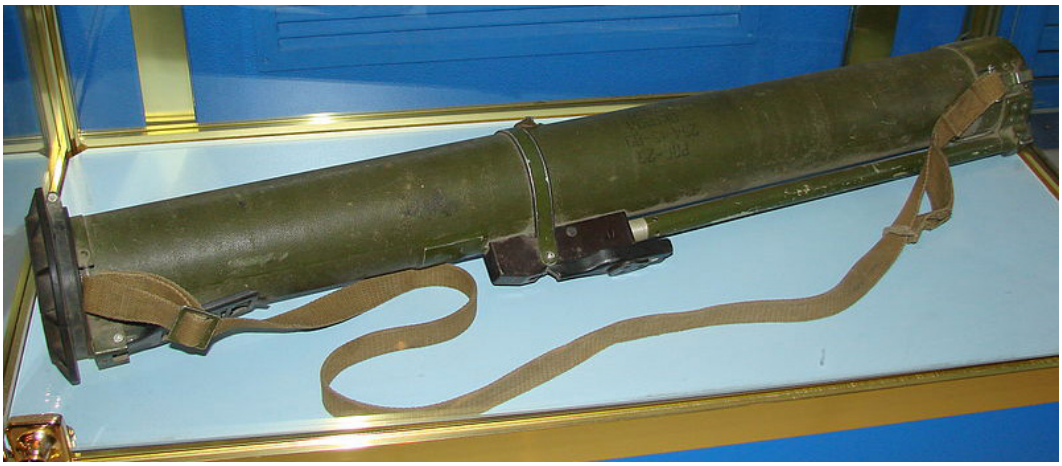
A 2016 UN report says that Arab coalition aircraft accidentally air-dropped weapons with "similar characteristics to [the] RPG-26" into Houthi-controlled territory, after which a Houthi leader took a picture of the shipment with a thank you note addressed to King Salman.[138]

RPG-26 variant inadvertently air-dropped by the Arab coalition to Houthi forces. The note reads "Thank you [King] Salman, Peace Mekhlafi."

United Nations

RPG-27

The RPG-27 "Tavolga" is an unguided, disposable, shoulder-fired rocket-propelled grenade launcher developed by the Soviet Union in the late-1980s. The RPG-27 weighs 8 kg, measures 1.135 m in length, and fires a 105-mm caliber tandem-charge warhead to an effective range of 200 m.[139] UAE troops reportedly seized one RPG-27 from a Houthi base in Safir, Marib Governorate, in September 2016.[140]



RPG-27 seized in Ma'rib Province, Yemen, in September 2016 while in transit to Houthi-Saleh-controlled territory.

United Nations

C90-CR ROCKET LAUNCHER

The C90-CR is a family of short-range, shoulder-fired rocket launchers produced by the Spanish company Instalaza SA in the late 1980s. Saudi Arabia purchased the weapon in the early-1990s. C90-CR models include antiarmor, antimaterial, antipersonnel, antifortification, and smoke/incendiary variants. All fire an 88.9-mm caliber rocket to

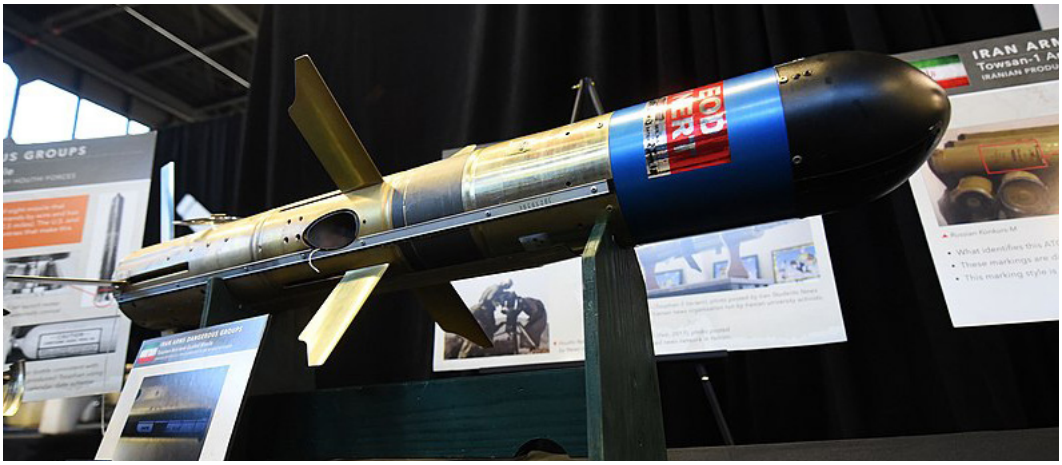
a range of approximately 300-350 m. A 2016 report found that Houthi fighters have captured at least 16 C-90CR from Saudi or Saudi-equipped pro-Hadi forces.[141]

Houthi fighter holding a captured C-90 series weapon near the Asir region along the Saudi-Yemeni border.

Houthi media

BGM-71 TOW ATGM (IRANIAN VARIANT: TOOPHAN)

The BGM-71 TOW ("Tube-launched, Optically-tracked, Wired-guided") is a U.S. antitank guided missile (ATGM) developed in the 1960s. There are currently eight variants of the weapon, measuring between 1.17 and 1.51 m in length and weighing between 18.9 and 22.6 kg, with a range of up to 4.5 km while carrying a 2.4-6.14 kg warhead. The United States sold 264 BGM-71 rockets and 12 launchers to North Yemen in 1979.[142] The United States also sold the BGM-71 to Iran before the 1979 Iranian Revolution and during the 1985-1987 Iran-Contra affair.[143] Iran subsequently developed a domestically-produced variant known as the Toophan.[144]



An Iranian Toophan antitank guided missile found in Yemen was shown at the Iranian Materiel Display at Joint Base Anacostia-Bolling, Washington, D.C.

Department of Defense

In September 2015, Arab coalition ships intercepted a stateless vessel carrying 54 Toophan/TOW ATGMs, 19 9M113 Konkurs ATGMs, and related equipment.[145] A 2016 UN report shows technical instruction in Farsi found in a box containing the TOW Missile Guidance System.[146] Inspectors also noted that "the TOW missiles, their associated equipment, and electronic components had markings bearing the names of Iranian industrial companies."[147] In November 2018, U.S. Ambassador Nikki Haley presented a Toophan ATGM seized by Saudi Arabia as one of four pieces of evidence showing Iran's military support to the Houthis.[148]

9M113 KONKURS (NATO: AT-5 SPANDREL; IRANIAN VARIANT: TOSAN)

The AT-5 Spandrel is a semi-automatic command to line of sight (SACLOS) wire-guided antitank guided missile (ATGM) developed by the Soviet Union in the late-1960s and early-1970s. The AT-5 has an effective range of 4 km and can penetrate more than 750 mm of armor.[149] Iran produces a domestic variant called the Tosan.

UAE troops seized one Tosan rocket from a Houthi base in Safir, Marib Governorate, in September 2016.[150] Multiple videos purportedly show Houthi militants using AT-5 ATGMs against Saudi armor in northern Yemen and southern Saudi Arabia.[151] In September 2015, Arab coalition ships intercepted a stateless vessel carrying 19 9M113 Konkurs ATGMs, 54 Toophon TOW ATGMs, and related equipment.[152] The 2016 UN report also notes video evidence of Houthi fighters using a Konkurs ATGM against a Saudi tank along the border with Saudi Arabia.[153] In November 2018, the United States presented a Tosan ATGM seized by Saudi forces in Yemen as one of four pieces of evidence proving Iran's military aid for the Houthis.[154]

9M113 Konkurs operated by a Houthi fighter.

United Nations

9M133 KORNET / DEHLAVIYEH / KORNET-E (NATO: AT-14 SPRIGGAN)

The AT-14 Spriggan is a laser-guided antitank guided missile (ATGM) developed by Russia in the 1990s. It is likely the Houthis' longest-range ATGM, with an effective range of about 5 km while carrying an antiarmor or bunker-busting thermobaric warhead. It can reportedly penetrate armor up to 120 cm thick.[155] The Dehlaviyeh is the Iranian-produced variant of the AT-14, which Iranian media publicly displayed for the first time in 2012.

Coalition and international maritime forces have interdicted hundreds of AT-14 missiles traveling to Yemen. In November 2015, UAE troops seized one 9M113 Kornet and one Dehlaviyeh from a Houthi fighting position in Taiz Province. The Dehlaviyeh's

serial number showed it was manufactured around July 2015, confirming the very recent transfer of the missile.[156] In March 2016, the French frigate FS *Provence* (D-652) intercepted a dhow carrying nine Kornet-type rockets off the coast of Oman.[157] In September 2016, pro-coalition forces seized 15 Kornet or Dehlaviyeh ATGMs in Ma'rib Province.[158] A Yemeni Army commander further reported seizing around 100 Kornet/Dehlahviyeh rockets in November 2016.[159] Several videos show Houthi militants using the AT-14 against Saudi tanks in Najran, Jizan, and elsewhere.[160]

Dehlaviyeh ATGMs seized from a dhow in November 2019.

United Nations

Unguided Rockets and Ballistic Missiles

QAHER-1 AND QAHER-M2

The Qaher ("Conquerer") is a family of re-engineered Soviet V-755 surface-to-air missiles (SAMs), modified for land-attack missions. The V-755 had equipped Yemen's S-75 SAM systems, which it first imported from the Soviet Union in the late-1970s and early-1980s.[161] North and South Yemen procured at least nine SA-2 SAM systems and 225 V-750 missiles during this time.[162] Yemen's S-75 SAM system had become obsolete against the coalition's aircraft, leading the Houthis to find alternative uses for the V-755s.[163]

In May 2015, the Houthis established a new missile force, which in turn created a missile research division. Known as the Missile Research and Development Center (MRDC), the researchers converted around 200 V-755 SAMs into unguided land-attack rockets. The Houthis renamed these missiles Qaher-1 and fielded them in late 2015. An improved variant was later designated the Qaher-M2.[164] These missiles became key to replenishing Houthi stocks of ballistic missiles, especially considering their declining supplies of Scud and Tochka missiles early in the conflict. The Houthis revealed and first fired the Qaher-1 in December 2015.[165] The missile can range 250 km while carrying a 200 kg payload. The Qaher-M2 has a reported range of 400 km with a 350 kg warhead. Houthis first fired this upgraded version in March 2017.[166]

Qaher-M2 missile on display.

Houthi media

BADR-1, BADR 1-P, AND BADR-F

The Badr-1 rocket was first unveiled in February 2017. Houthi militants have employed this projectile since at least March 2018. It is likely based on the Syrian 302-mm "Khaibar" rocket.

Badr-1P missile on display.

Houthi media

Although the Houthis refer to it as a short-range ballistic missile, it better fits the category of an unguided artillery rocket. UN inspectors noted that it is "produced locally from steel tubing very likely sourced from the oil industry."[167]

The Houthis unveiled an improved variant, the Badr 1-P, in October 2018.[168] It featured new guidance fins, with a reported range of 130 km.[169] It may be derived from Iran's Fateh-110 or Syria's 302-mm rocket.

The Badr-F is the latest variant, unveiled in April 2019.[170] It has a reported range of 160 km and

carries an air-burst warhead, exploding around 20 m above the ground, impacting an area 350 m in diameter.[171]

OTR-21 TOCHKA

The OTR-21 Tochka has proved the most accurate and reliable ballistic missile type the Houthis have employed. The solid-fueled, road-mobile missile has a range of 70-120 km while carrying a 480 kg payload.[172] A 2005 Congressional Research Service (CRS) report notes Yemen had an inventory of around 24 Tochka missiles.[173] According to SIPRI, North Yemen procured 115 OTR-21 Tochka missiles and four launchers in 1988.[174]

The Houthis first fired a Tochka missile in September 2015, targeting the coalition's Safer military base in Marib, Yemen. The strike hit a weapons storage depot and killed 60 coalition soldiers.[175] The Houthis fired another Tochka on December 14, 2015, targeting a coalition base southwest of Taiz city in Taiz, Yemen. The strike reportedly killed over 120 coalition soldiers.[176] The most recently recorded Tochka fire took place on November 19, 2016, landing in a desert in eastern Marib Province. The target was unclear but was likely the Arab coalition's al-Ruweik military camp.[177]

Considering the initially low numbers available to the Houthis and the lack of reported uses since 2016, it is highly unlikely that any OTR-21s remain on the battlefield.

Houthis training on OTR-21 Tochka in May 2015.

United Nations

SCUD-C

The Scud-C is a short-range ballistic missile developed by the Soviet Union and first deployed in the 1960s. It measures 11.25 m in length, 0.88 m in diameter, and 6,400 kg at launch. The missile features an increased range of 550 km while carrying a smaller payload of 600 kg.[178]

Reports differ on the number of Yemen's pre-war Scud-C stockpile, with estimates at 25, 45, or 90.[179] North Korea delivered 15 Scud-C missiles to Yemen in a highly publicized December 2002 transfer that was interdicted but then let go by the U.S. Navy.[180] According to a 2016 UN report, the first confirmed Scud-C launch occurred on June 29, 2015, although an earlier Scud-C launch likely took place on June 6, 2015.[181]

Iraqi Scud missile in Saudi Arabian desert during Operation Desert Storm.

Department of Defense

BURKAN-1

The Burkan-1 is likely a modified variant of Iran's Shahab-1 missile with a reduced payload for an extended range of 800 km. It measures 12.5 m in length, 0.88 m in diameter, and weighs approximately 7,250 kg. The Houthis unveiled the Burkan-1 in September 2016.

Burkan-1 displayed by the Houthis in September 2018.

Houthi media

BURKAN-2H

The Burkan-2H is a short-range ballistic missile derived from Iran's Qiam missile, itself a modified Scud-C. The Qiam-1 features a nominal range of 700 km while carrying a 750 kg payload. The Houthis have extended this range to 1,000 km by reducing warhead weight to around 250 kg.[182] It measures approximately 8 m in length. The Burkan-2H was first unveiled in February 2017.[183]

KNOWN BURKAN-1 LAUNCHES		
DATE	*LIKELY TARGET*	*SUMMARY*
October 2016	King Fahd air base	The Houthi's first Burkan-1 launch. Arab coalition claims successful intercept
October 2016	King Abdul Aziz International Airport	The Houthi's second Burkan-1 launch. The missile flew 667 km before falling 65 km north of Mecca.
January 2017	Coalition base on Zulqar Island in the Red Sea	The Houthi's third Burkan-1 launch. This strike reportedly killed 80 coalition soldiers, although the coalition neither confirmed nor denied the attack.

The Houthis claimed that they had derived the Burkan-2H from the Scud-C. However, UN experts assessed that "sufficient weight savings could not be made . . . nor could the power output be upgraded sufficiently" to extend the Scud-C's 600 km max range to 1,000 km.[184] In December 2018, Secretary-General Antonio Guterres said the debris of three Burkan-2H missiles fired over March-April 2018 showed "specific key design features consistent with those of the Iranian Qiam-1 short-range ballistic missile."[185]

Burkan-2H on display.

Houthi media

Several design features make this connection apparent. The Burkan-2H is finless, a unique characteristic that it shares with the Qiam. The missile is furthermore composed of aluminum alloy, unlike the steel airframes used in Scuds. Most definitively, however, the missile actuator shows the logo of Iran's Shahid Bagheri Industries, producer of the Qiam missile. Debris from a Burkan-2H fired in November 2017 also showed markings from Shahid Bagheri Industries.[186]

Iran delivered to the Houthis approximately 10 Qiam-1 SRBMs in 2017.[187] A 2018 UN report states that Iran likely smuggled Burkan-2H components overland following a ship-to-shore transfer to ports in Mahrah Province.[188]

KNOWN BURKAN-2 LAUNCHES		
DATE	*LIKELY TARGET*	*SUMMARY*
February 5, 2017	al-Muzahimiyah military camp or Riyadh	The first Burkan-2 launch. The missile flew 852 km before striking a military camp in al-Muzahimiyah, located 40 km west of Riyadh. The Houthis claimed they did not equip this missile with a warhead.[189]
July 22, 2017	Oil refinery plant in Yanbu	The Houthi's second Burkan-2 launch.[190]
November 4, 2017	King Khalid International Airport in Riyadh	The Houthi's third Burkan-2 launch. The strike nearly hit the airport. Saudi Arabia attributed this strike to Iran and called it an "act of war."[191]
December 19, 2017	Yamama Palace in Riyadh	The Houthi's fourth Burkan-2 launch. Saudi Arabia claimed to have successfully intercepted the missile.[192]

BURKAN-3

The Houthis unveiled their Burkan-3 medium-range ballistic missile in August 2019. It is the longest-range missile in the Houthi arsenal. Houthi forces employed it for the first time on August 1, 2019, to strike a Saudi military site in Dammam, located along the country's east coast around 1,200 km from Houthi-held territory in Yemen.[193]

While details on the Burkan-3 remain scarce, it appears to measure around 0.88 m in diameter, suggesting it is a further development upon Iran's Qiam missile and not derived from a new missile.

Screenshot of Burkan-3 missile launch.

Houthi media

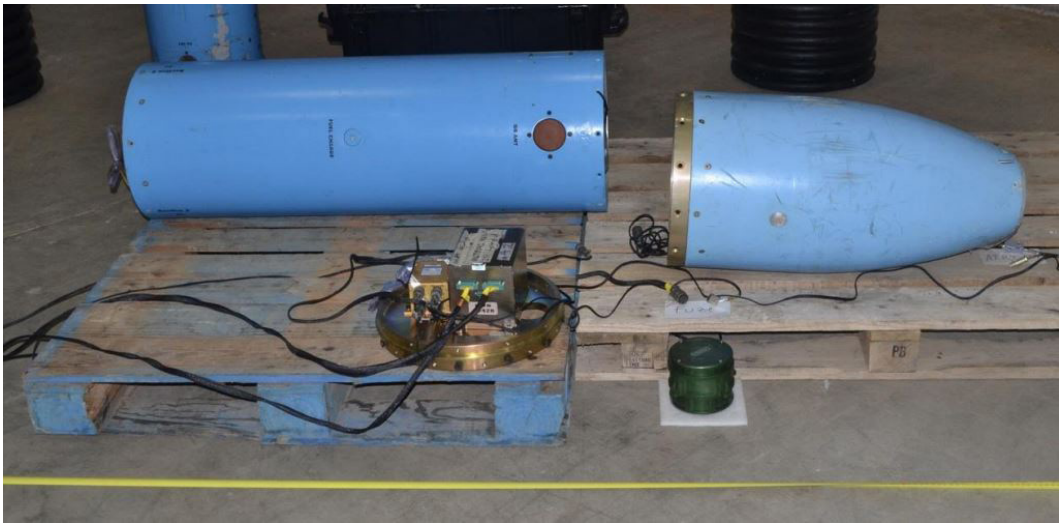
Land-attack Cruise Missiles

QUDS-1

The Quds-1 is a land-attack cruise missile first deployed in 2019.[194] It measures about 5.3 m in length and 35 cm in diameter, has a range of 700-800 km, and reportedly has a max speed of 735 km per hour.[195] The United States appears to have designated the weapon as the "351" land-attack cruise missile.[196]

The Houthis claim to have indigenously developed the Quds-1. Given the missile's sophistication, however, it was much more likely produced and supplied by Iran. The fact that the missile employs the Czech-designed TJ100 turbojet engine—a model previously displayed by Tehran in 2019—further implies Iranian involvement.[197]

The Houthis have used the Quds-1 missile in at least three attacks. The first reported launch took place in June 2019, striking Abha International Airport and injuring 26 civilians. The Houthis fired another Quds-1 missile a week later, targeting the water desalination plant in Shuqayq. In August 2019, the Houthis again targeted Abha airport with a Quds-1 missile.[198] Iran also used the Quds-1 missile in the September 2019 attack on Abqaiq and Khurais.



Quds-1 on display.

United Nations

Antiship Missiles

The Houthis have used antiship missiles to attack shipping vessels and warships along the Red Sea and Gulf of Aden since at least October 2015, firing them on Saudi, UAE, Turkish, and U.S. ships. However, the Houthi's lack of permanent radar since October 2016 has decreased the operational effectiveness of these weapons. The Houthis have instead used small boats to relay approximate target locations. Although the United Nations reports that the number of security incidents remains low, the "threat to commercial shipping increased, as Houthi forces developed and deployed sophisticated weapons."[199]

In addition to antiship missiles, the Houthis also threaten coalition warships and trade vessels with waterborne improvised explosive devices, sea mines, antitank missiles, and skiffs with armed militants.

C-801 AND C-802 (IRANIAN VARIANT: NOOR)

The C-801 is an antiship missile developed by China in the 1970s. It has a range of 42 km while carrying a 165 kg warhead. It measures 5.81 m in length, 0.36 in diameter, and 815 kg at launch.[200]

The C-802 is an improved version of the C-801, developed by China in the 1970s and 1980s. It has a range of 120-180 km while carrying a 165 kg warhead. It measures 6.39 m in length, 0.36 m in diameter, and 715-800 kg at launch. The missile is turbo-jet powered, high-speed subsonic, and sea-skimming capable.[201]

According to SIPRI, the pre-war Yemen government had procured from China 25 C-801 antiship missiles in 1995.[202] A 2017 UN report also says the Yemeni navy acquired additional C-801 missiles in 2006 or 2007 from an unnamed Arab coalition member state.[203] Several C-801 missiles fell into Houthi hands in 2015 upon the defection of three Yemeni navy Type 021 missile boats.[204]

The Houthis may have acquired the C-802 from indigenous inventories. Although China is not known to have supplied the Yemeni government with C-802 missiles directly, Yemen may have purchased these missiles second-hand. Alternatively, it is also possible that the Houthis acquired the Noor, an Iranian C-802 derivative first deployed in 2000. In November 2019, a U.S. warship seized a C-802 missile from a dhow traveling to Yemen.[205] The Houthis have employed C-801/802 missiles in attacks on military and civilian ships travelling near Yemen's coastline. These incidents include the 2016 attacks on the USS *Mason* (DDG-87).

In November 2017, the Houthis posted a video depicting their antiship missiles, designated al-Mandab-1.[206] Due to their physical similarity, it is unclear whether the al-Mandab-1 is the C-801 or C-802.

C-802 antiship cruise missile seized from a dhow in November 2019.

United Nations

P-15 TERMIT (NATO: STYX)

The Styx is an antiship missile developed by Russia in the 1950s. It has a range of 40 km while carrying a 454 kg warhead. The Styx measures 5.8 m in length, 0.76 m in diameter, and 2,125 kg at launch. It can reach speeds of up to 310 m/s.[207] In November 1990 and January 1991, an unnamed coalition member state "supplied the Yemeni Navy with two Tarantul (Molnya)-class corvettes, each armed with four P-21 (a P-15 variant with improved guidance) surface-to-surface missile launchers."[208]

Evidence indicates, however, that the Houthis have employed these in an atypical manner. In December 2017, U.S. officials publicly displayed parts of a weaponized motorboat seized by the UAE navy earlier in 2016. The drone boat was equipped with a warhead from a Styx missile.[209] The Houthis used an identical drone boat to attack a Saudi frigate in 2017. The decision to remove and repurpose the warhead was likely due to the complexities and hazards of operating the decades-old, liquid-fueled missile.[210]

P-15 missile on display at Steven F. Udvay-Hazy Center in Chantilly, Virginia.

Wikimedia

Surface-to-Air Missiles

Although the Houthis converted much of their obsolete surface-to-air missiles (SAMs) to land-attack weapons, they retain their relatively newer SAMs for the air defense mission. They have used these weapons to down at least three U.S. UAVs, in October 2017 and June and August 2019. There are also numerous reports of the Houthis targeting Arab coalition warplanes, although the coalition usually attributes issues to mechanical or human error.

"358" SURFACE-TO-AIR MISSILE

Designated the "358" by U.S. officials, this missile does not appear to have been identified in Houthi media. It is reportedly a surface-to-air missile, equipped with an electro-optical sensor and optical proximity fuse, allowing it to burst when near aircraft.

It measures approximately 2.7 meters in length and uses kerosene or diesel fuel, along with a solid-propellant booster.[211]

U.S. warships have interdicted at least two dhows in the Arabian Sea, ferrying 358 missiles bound for Yemen. In November 2019, the USS *Forrest Sherman* (DDG-98) stopped a dhow carrying two to three missiles.[212] In February 2020, the USS *Normandy* (DDG-60) interdicted a dhow transporting three to five more of these missiles.[213]

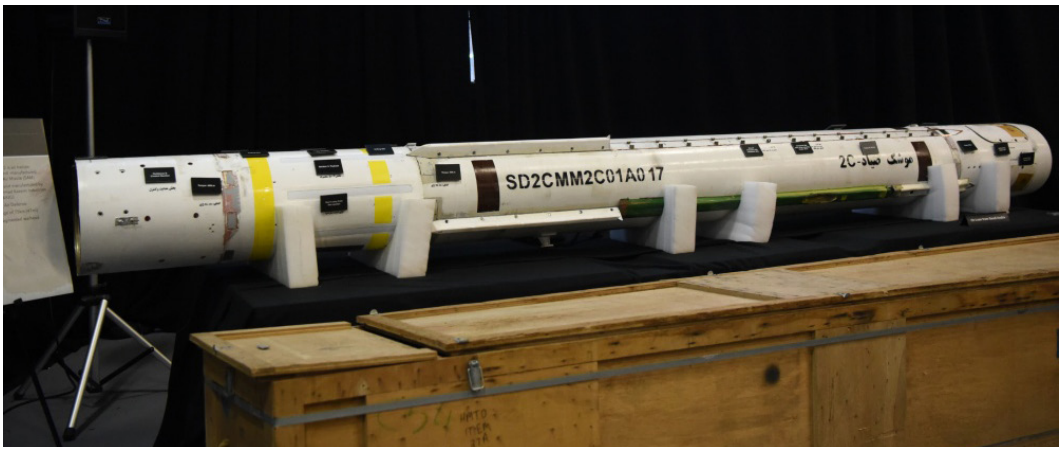
Unknown cruise missile, likely a surface-to-air missile, seized from a dhow in November 2019.

United Nations

SAYYAD 2C ("HUNTER")

The Sayyad-2C is an Iranian SAM first deployed in 2015. Iran derived the missile from the U.S. Standard Missile-1 (SM-1), which Iran acquired in the 1970s. It has a range of 74 km and a reported max altitude of 27 km. It can fit several SAM launchers, including the Talash, S-200, and the 3- and 15-Khordad systems.[214]

In November 2018, the United States publicly displayed a Sayyad-2C missile that was seized in Yemen by Saudi Arabia earlier that year.[215] In August 2019, Houthi fighters reportedly used a Sayyad-2C to shoot down a U.S. MQ-9 Reaper operating south of Sana'a.[216]



Sayyad-2C on display in Washington, D.C.

Lisa Ferdinando, Department of Defense

2K12 KUB/KVADVAT (NATO: SA-6 GAINFUL) / FATER-1 ("INNOVATOR-1")

The SA-6 is a SAM developed by the Soviet Union in the 1960s. The initial "Kub" interceptor can engage targets 6-22 km away, at a maximum altitude of 7 km.[217] Yemen procured at least 200 SA-6 missiles in 1979 from the Soviet Union.[218]

In June 2019, a Houthi-fired SA-6 missile shot down a U.S. MQ-9 Reaper reconnaissance drone flying over Yemen. The U.S. military said the Houthis had likely conducted the attack with Iranian assistance.[219]

In August 2019, the Houthis unveiled what they claimed to be a new and indigenously produced missile called the Fater-1 ("Innovator-1"). However, the missile appears to be a painted-over SA-6.[220]

Fater-1 on display in Yemen.

Houthi media

THAQIB-1/-2/-3 ("PIERCER")

The Thaqib missile series are Russian-made air-to-air missiles (AAM) configured to be fired from the ground. The Thaqib-1, -2, and -3 are modified Russian R-73, R-27, and R-77 AAMs, respectively. Yemen procured approximately 150 R-73 and 150 R-27 missiles from Russia between 2002 and 2005.[221]

The Houthis unveiled the Thaqib SAM family in February 2020.[222] A Houthi video purportedly shows a Thaqib-2 firing on and damaging a Saudi F-15 fighter aircraft.[223]

Thaqib-2 missile on display in Yemen.

Houthi media

Unmanned Aerial Vehicles

The Houthis have used unmanned aerial vehicles (UAVs) to target Saudi oil fields and refineries, air defense radars, and airports as well as to assassinate opposition leaders. Armed drones are cheaper to develop than ballistic missiles and easier for sources such as Iran to smuggle into the country given their smaller size. Although armed UAVs carry significantly smaller warheads than ballistic missiles, their relative precision augments their lethality. UAVs have become such a critical part of the Houthi aerial campaign that the group declared 2019 to be "the year of the drones."[224]

QASEF-1 ("STRIKER") / QASEF-2K

The Qasef series are armed drones designed to fly into their targets with a high explosive warhead. These drones are likely sourced from Iran, as they are nearly identical in all characteristics to the Iranian-manufactured Ababil-T drone.[225] The Ababil-T has a range of 150 km while carrying a payload of 30 kg, capabilities likely shared by the Qasef-1. The Qasef-1 measures 2.5 m in length with a wingspan of 3 m and has a flight time of 120 minutes.[226] It uses GPS guidance and reportedly flies autonomously along pre-programmed waypoints towards its target.[227]

The Houthis say they have developed an improved variant called the Qasef-2K. However, the new model looks nearly identical to the Qasef-1, and it is unclear how or if it is different.[228]

Qasef-1 missile on display in Washington, D.C.

Department of Defense

RASED

The Rased UAV is a commercially available RC plane drone known as the Skywalker X-8.[229] Houthi fighters use it for battlefield surveillance.[230] It measures 1 m in length and 2.2 m in wingspan, has a flight time of 120 minutes, and can range up to 35 km.[231]

Rased UAV on display in Yemen.

Houthi media

RAQIB

The Raqib is a reconnaissance UAV.[232] It measures 1 m in length and 1.4 m in wingspan, has a flight time of 90 minutes, and can range up to 15 km.[233]

Raqib UAV on display in Yemen.

Houthi media

HUDHUD-1

The Hudhud-1 is a reconnaissance UAV.[234] It measures 1.2 cm in length and 1.9 m in wingspan, has a flight time of 90 minutes, and can range up to 30 km.[235]

Hudhud-1 UAV on display in Yemen.

Houthi media

SAMAD-1/-2/-3

The Samad family of UAVs is named after Houthi leader Saleh al-Sammad, who the Arab coalition killed in an airstrike in April 2018.[236] The Houthis began deploying the UAV in mid-2018.[237] It was previously designated "UAV-X" in UN reports.

The Samad-1 has a range of 500 km.[238] Ostensibly built for reconnaissance missions, the Houthis have weaponized it on multiple occasions.[239]

The Samad-2 is an extended-range version of the first variant, capable of ranging 760-900 km.240 It is otherwise mostly similar to the Samad-1.[241] The Houthis reportedly deployed 10 Samad-2 UAVs in their August 2019 attack on Saudi Arabia's Shaybah oil field.[242]

The Samad-3 variant further extends the UAV's range to 1,200-1,500 km.[243] It measures 2.8 m in length, 4.5 m in wingspan, and 0.84 m in diameter.[244] It can carry a payload of 18 kg.[245]

The Houthis purportedly used the Samad-3 in an attack on Abu Dhabi International Airport in July 2018.[246] It was also reportedly used to target Riyadh but crashed 30 km short of the city after running out of fuel.[247] The Houthis also said they used Samad-3 drones in the Abqaiq and Khurais attacks in September 2019, although this claim has proven false.[248]

Sammad-3 on display in Yemen.

United Nations

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