AIR-LAUNCHED BALLISTIC MISSILES

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Cover image: A Cape Canaveral Air Force Station B-52 conducts a test flight with four Skybolt (GAM-87), April, 1962. Air Force Space & Missile Museum, “Skybolt Photographs,” accessed November 5, 2019, http://www.afspacemuseum.org/missiles/Skybolt.

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ACRONYMS

ALBM	Air-launched ballistic missile	
ALCM	Air-launched cruise missile	
ASAT	Anti-satellite weapon	
ASM	Anti-ship missile	
ICBM	Intercontinental ballistic missile	(greater than 5,500 km)
IRBM	Intermediate-range ballistic missile	(3,000 – 5,500 km)
MRBM	Medium-range ballistic missile	(1,000 – 3,000 km)
NC3	Nuclear Command, Control, and Communications	
PLAAF	Peoples Liberation Army Air Force	
SEAD	Suppression of enemy air defenses	
SLBM	Sea-launched ballistic missile	
SRAM	Short-range attack missile	
SRBM	Short-range ballistic missile	(up to 1,000 km)
USAF	United States Air Force	

INTRODUCTION

In 2018, Russia and China both tested an uncommon type of missile that flew a ballistic trajectory but could be launched from an aircraft. Air-launched ballistic missiles (ALBM) are just one curiosity at a time when many countries are rapidly expanding and upgrading their missile inventories, but the tests raised some understandable questions: Is this a new capability? If a country has ground- and sea-launched ballistic missiles, or air-launched cruise missiles, why does it need an ALBM? What is it for?

In fact, ALBMs are not new. The United States, Russia, Israel, and now China all have considerable experience with ALBM technology. While the United States developed an ALBM option in the 1960s to supplement its strategic nuclear forces, the program did not survive the development of SLBMs, which provided similar capabilities. Subsequent ALBM programs have been developed as theater standoff weapons capable of rapidly striking targets that are mobile, defended, hardened, or some combination of the three.

The history of ALBM systems is instructive for understanding a range of emerging missile technologies. Like other categories of missile systems, it is difficult to develop a precise definition of an ALBM. The canonical definition of a ballistic missile is one that is powered in its boost phase by a rocket motor rather than an air-breathing engine and is subsequently unpowered as it follows a ballistic trajectory to its target. An air-launched ballistic missile is one such system that is launched from an aircraft.

In practice, especially in Russia, the development of ALBMs has been intertwined with efforts to modify ballistic trajectories by employing lifting surfaces, control surfaces, or thrust vectoring to allow the missile to maneuver when it is in the atmosphere, a category of systems known as "aero-ballistic missiles."[1] Several aero-ballistic systems

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[1] The trajectories exhibited by aero-ballistic missiles are sometimes referred to as "semi-ballistic," and the term "semi-ballistic missile" is sometimes used interchangeably.

blur the canonical definitions of "cruise" or "ballistic" missiles by exhibiting features typically associated with the other category. For example, multiple countries have possessed air-launched missiles that rely on rocket motors but exhibit flight profiles normally associated with air-breathing cruise missiles, including the Russian Kh-22 and U.S. SRAM, both of which possessed a capability to fly both ballistic and terrain-following trajectories.

Examining the phenomenon of air-launched ballistic missiles provides insight into not only the planning of the countries developing these systems, but also the diversity and complexity of missile systems.

The characteristics of ALBMs offer an advanced military several notable capabilities. The velocity of a ballistic missile provides a relatively simple means of creating a hypersonic strike option that can provide a prompt means of holding mobile or transient targets at risk, provided the aircraft that will launch it is within range. The ability to conceal delivery aircraft on the ground and to launch them in a crisis offers an added measure of survivability for air rather than ground-based ballistic missiles, compounding the challenge that even advanced military powers like the United States have in tracking strike platforms. Both the velocity and mobility together provide the system with an ability to defeat missile defenses by launching from an unexpected position, range, or angle and arriving at its target faster than an ALCM fired from the same point.

ALBMs also represent a cautionary tale for analysts concerned about the destabilizing effects of emerging technology. Amid widespread concern that hypersonic cruise missiles or boost-glide systems are threatening or destabilizing,[2] the history of ALBMs makes clear that this class of systems iterate on existing systems that could perform similar missions. It is difficult to see why new hypersonic weapons that rely on air-breathing engines or gliders are more threatening than ALBMs that have been in existence since the 1960s. In order to argue that emerging technologies are seriously destabilizing, analysts should explain how they provide strategic effects that are qualitatively distinct from existing systems.

[2] For analysis and information about hypersonic missiles, see Kelley M. Sayler, "Hypersonic Weapons: Background and Issues for Congress," Congressional Research Service, September 17, 2019, https://fas.org/sgp/crs/weapons/R45811.pdf and James M. Acton, "Hypersonic Boost-Glide Weapons," *Science and Global Security* 23, 2015, http://scienceandglobalsecurity.org/archive/sgs23acton.pdf.

HISTORICAL ALBM PROGRAMS

Air-launched ballistic missiles are not a recent innovation. For more than 60 years, countries with advanced missile programs have been developing, testing, and in some cases deploying, ALBMs and closely related systems.

The strategic and bureaucratic purposes of ALBM programs have varied. U.S. ALBM development programs carried were intended to perform a range of nuclear counterforce missions, including intercontinental second-strike weapons, theater damage limitation capabilities, and short-range air-to-ground strikes that could allow U.S. bombers to cut a path through Soviet air defenses. By contrast, Soviet and Russian programs developed short-range systems intended for use against theater military targets—especially U.S. carrier strike groups—while Israeli programs seem to be directed against hardened or defended targets on adversary territory.

The United States

In the 1950s, U.S. strategists grew concerned about the ability of U.S. nuclear-armed bombers to survive an initial Soviet strike against their forward air bases and then to penetrate Soviet air space to deliver unguided gravity bombs to their targets. Furthermore, the impending development of the Polaris SLBM led the Air Force to attempt to lock in its dominant share of the nuclear mission. General Maxwell D. Taylor, the Army Chief of Staff, believed a USAF ALBM program would result in a "prolonged dependence on aircraft."[3] Thus, inter-service rivalry helped to motivate the initial phase of ALBM research, which focused on developing what would later be classified as medium-range ballistic missiles (MRBM) that could be fired from bombers operating beyond the range of Soviet air defenses.

The United States began testing ALBMs in 1957 as part of the Weapons System 199 development program.[4] The program tested three new systems intended for delivery

[3] Charles G. Worman, "History of the GAM-87 Skybolt Air to Surface Ballistic Missile - ASFC Historical Publication Series 67-50-I" (Air Force Systems Command (AFSC), March 1967). Pg 30.

[4] Andreas Parsch, "WS-199," Directory of U.S. Military Rockets and Missiles, accessed August 10, 2019, http://

SKYBOLT (USA)

FIRST FLIGHT TEST:	APRIL 19,1962	LAUNCH AIRCRAFT:	B-52
MISSILE RANGE:	1,852 KM	AIRCRAFT RANGE:	14,080 KM
MISSILE LENGTH:	10.64 METERS	TWO STAGE, SOLID-FUEL MOTORS	

Source: Worman, "History of the GAM-87 Skybolt Air to Surface Ballistic Missile"; Air Force Global Strike Command.

of nuclear warheads—two air-launched and one ground-launched. The two air-launched systems were submitted to the development program as competitors: Martin's Bold Orion and Convair/Lockheed's High Virgo.[5] The program advanced even as the Army and the Navy expressed clear reservations about continued reliance on manned bombers.[6]

High Virgo proved a disappointment: its proprietary communication and guidance systems contributed to the failure of a number of tests. The rocket never achieved a range greater than 500 km.[7] Bold Orion performed better. Over the course of 1958-59, 11 of the system's 12 test launches were successful. After the rocket initially achieved a range of 463 km on 17 November 1958, the designers modified the rocket to accept a second stage, which extended the range of the Bold Orion to over 1,600 km, with an apogee of 193 km.[8]

The information gained from the WS-199 program went on to aid the production of the GAM-87 Skybolt,[9] which its program office asserted was "the most complex ballistic missile system ever to be developed by the United States" due to the difficulty of launching the missile from a moving platform, the need to integrate the missile with the aircraft to in order to know its launch position precisely, and the need to operate in environments that could subject the missile to shock, vibrations, and rapidly changing conditions.[10] President Kennedy himself even stated that the system was "the most sophisticated weapon imaginable," involving "the kind of engineering that's been beyond us."[11]

www.designation-systems.net/dusrm/app4/ws-199.html.

[5] Bold Orion tests were carried out on B-47 Stratojet; High Virgo tests were conducted from a modified B-58 Hustler. Both of the systems relied on a Thiokol TX-20 (XM20) Sergeant solid-fuel rocket motor. Parsch.

[6] Charles G. Worman, "History of the GAM-87 Skybolt Air to Surface Ballistic Missile - ASFC Historical Publication Series 67-50-I" (Air Force Systems Command (AFSC), March 1967).

[7] Parsch, "WS-199."

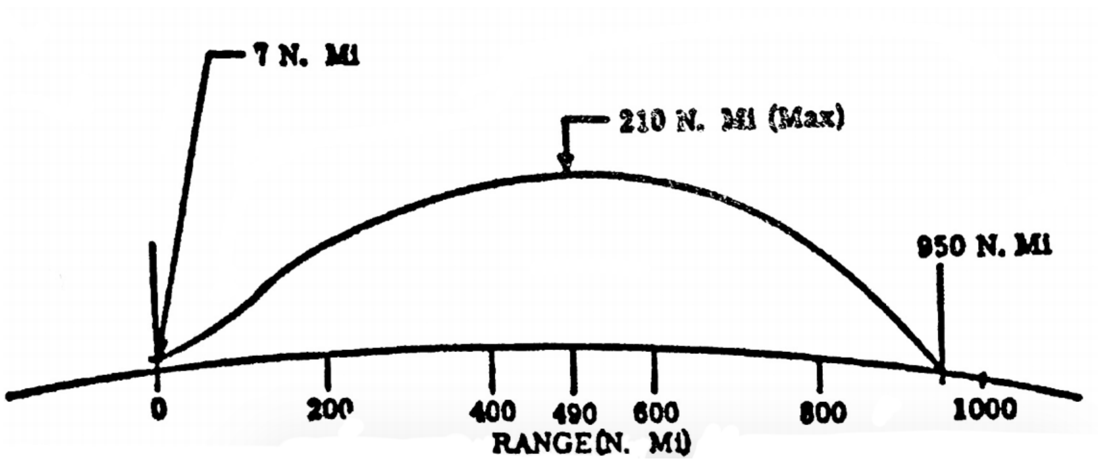
[8] Worman, "History of the GAM-87 Skybolt Air to Surface Ballistic Missile - ASFC Historical Publication Series 67-50-I"; Parsch, "WS-199."

[9] Philip. Birtles, *Missile Systems* (Shepperton, Surrey: I. Allan, 1985).

[10] Robert Strange McNamara, "Aide Memoire," File Unit, Records Relating to the Defense Program and Operations, ca. 1959 - ca. 1968 (National Archives and Records Administration, ca. - ca. 1969 1959).

[11] Worman, "History of the GAM-87 Skybolt Air to Surface Ballistic Missile - ASFC Historical Publication Series 67-50-I."

SKYBOLT FLIGHT PROFILE



Source: Charles G. Worman, "History of the GAM-87 Skybolt Air to Surface Ballistic Missile - ASFC Historical Publication Series 67-50-I" (Air Force Systems Command (AFSC), March 1967). pg 255.

Skybolt was powered by a two-stage solid-fuel rocket motor and employed an inertial navigation system. After release from its carrier aircraft, the missile ejected its aerodynamic tail cone, ignited its fixed nozzle motor, and relied on actuated flight surfaces for orientation. The second stage was equipped with a gimballed nozzle allowing it to maneuver in the upper reaches of the atmosphere and the vacuum of space where control surfaces cannot function. The missile was intended to carry a 1.2 MT W-59 thermonuclear warhead to a range of 1,852 km (1,000 nm), with an operational ceiling over 482 km. These performance objectives required a missile significantly larger than the WS-199 programs in both length and diameter.[12] Skybolt would achieve a top speed of Mach 15, arriving at its target just 12 minutes after launch, with a circular error probable (CEP) of 2.78 km.[13] Though the first five flight tests failed, on 22 December 1962, Skybolt successfully flew 800 miles after being launched from a USAF B-52 at 40,000 ft.[14] But the very same day, the Kennedy Administration cancelled Skybolt due to concerns that it duplicated the function of the Polaris SLBM. Secretary of Defense Robert McNamara viewed the intermediate-range ALBMs as offering "no unique capability."[15]

12 Andreas Parsch, "Douglas AGM-48 Skybolt," Directory of U.S. Military Rockets and Missiles, accessed August 30, 2019, http://www.designation-systems.net/dusrm/m-48.html.

13 Robert Strange McNamara, "Skybolt White Paper Draft 1/4/63," File Unit, Records Relating to the Defense Program and Operations, ca. 1959 - ca. 1968 (National Archives and Records Administration, ca. - ca. 1969 1959).

14 Robert Strange McNamara, "Analysis Of Air Force Press Release of the 6th Skybolt Test - Memo Item 4," File Unit, Records Relating to the Defense Program and Operations, ca. 1959 - ca. 1968 (National Archives and Records Administration, ca. - ca. 1969 1959).

15 Aerospace, "The Air Transportable Missile System (ATMS) Equipped with C-141 Aircraft/MGM-5200 Missile, December 11, 1964, 1–2BMC Document 02054507, File 13J-4-4-17" (Air Force Historical Research Agency, December 3, 1964); Cited in Steven A. Pomeroy, An Untaken Road: Strategy, Technology, and the Hidden History of America's Mobile ICBMs (Annapolis, Maryland: Naval Institute Press, 2016). Pg. 117.

The British, who had invested $23 million (1962 dollars) in the program by the time of its cancellation, were concerned about their ability to maintain a credible deterrent.[16] In 1960, the British had halted development of their own intermediate-range Blue Streak missile in favor of the Skybolt program and had already begun to phase out the Royal Air Force's Thor ballistic missiles.[17] This resulted in the entirety of the British's nuclear capability being devoted to the short-range Blue Steel air-to-ground missile. The so-called "Skybolt crisis" culminated in the Kennedy Administration's agreeing to sell the British the Polaris SLBM without warheads under the Nassau agreement.[18]

Skybolt's cancellation represented the end of the first phase of ALBM research. However, some inside the Air Force believed that an air-launched system offered unique capabilities, including mobility, speed, and throw-weight that could not be matched by SLBMs, ICBMs, or ALCMs then under development. In 1960, Aerospace Corporation proposed the development of a new aircraft that was capable of carrying and launching multiple intermediate-range ballistic missiles (IRBM).[19] This proposed aircraft would had been a gross weight of 600,000 pounds (a quarter more than a B-52), a payload capacity of 100,000 pounds, and the endurance to fly for two days while carrying its payload.[20] This program was envisioned as part of the continuous airborne bomber alerts that were occurring under Operation Chrome Dome. While this system never saw a prototype due to its outrageous requirements and the technological limitations of the time, the idea that an ICBM could be launched from nondescript transport aircraft in flight was appealing to strategists concerned that expanding Soviet ICBM forces could attempt a first strike against U.S. bomber airfields and silo-based missiles.

Concerns about the survivability of U.S. ICBMs led the Air Force to explore basing the Minuteman 1B ICBM on a U.S. Air Force C-5 Galaxy transport aircraft. This theory was tested on 24 October 1974 under the label "Air Mobility Feasibility Demonstration."[21] The test laid the ICBM horizontally on a cradle and sled that were to be

[16] Worman, "History of the GAM-87 Skybolt Air to Surface Ballistic Missile - ASFC Historical Publication Series 67-50-I."

[17] Ibid.

[18] Ken Young, "The Skybolt Crisis of 1962: Muddle or Mischief?," Journal of Strategic Studies, Vol. 27, No. 4 (December 2004), pp. 614–635, doi:10.1080/1362369042000314538.

[19] Pomeroy, Steven A. *An Untaken Road: Strategy, Technology, and the Hidden History of America's Mobile ICBMs*. Pg 117.

[20] Pomeroy, *An Untaken Road: Strategy, Technology, and the Hidden History of America's Mobile ICBMs.* These requirements were well in excess of any aircraft in the Air Force's inventory, then and now. The current iteration of the B-52 has a gross weight of 488,000 pounds, and a payload capacity of 70,000 pounds. Air Force Global Strike Command, Public Affairs Office, "B-52H Stratofortress," U.S. Air Force, accessed September 19, 2019, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104465/b-52h-stratofortress/.; The proposal also called for the use of thixotropic propellant and fiberglass casings and terminal area guidance which even current U.S. ICBMs and SLBMs do not possess.

[21] Periscope Films, *1974 Minuteman ICBM Air Launched Ballistic Missile Test Program 45154* (Periscope FIlms,

dragged out of the back of the C-5 by a set of parachutes. The second and third stages of this test missile were inert, and its first stage was programmed to ignite for a total of 10 seconds, simply to prove the feasibility of launching an already proven ICBM from the back of an aircraft. While this test was by all accounts a success, with the first stage burn beginning "at 8,000 ft and climbing to about 25,000 ft,"[22] the engineering difficulties of ensuring that a rocket designed to be stored vertically could maintain its structural integrity while stored for extended periods in a horizontal cradle generated concerns about its feasibility.

Minuteman was ultimately never deployed on an aircraft. It was offered by the U.S. as a negotiating point during the Strategic Arms Limitation Talks (SALT) in with the Soviet Union.[23] Aerojet Rocketdyne continues to use surplus SR19 solid rocket motors from retired Minuteman II missiles to construct ALBMs for the Missile Defense Agency's (MDA) Targets and Countermeasures (TC) program[24] to demonstrate the effectiveness of the U.S.'s Ballistic Missile Defense System.[25]

In 1972, the United States introduced the nuclear AGM-69 SRAM (short-range attack missile).[26] It was capable of adopting four different trajectories: semi-ballistic, terrain-following, terrain-following with a terminal-phase pullup from behind radar-screening terrain, and a combination of the first three.[27] These different trajectories allowed the missile to maximize its effect by choosing to enhance its kinetic penetrating force with the higher velocity of a ballistic trajectory or, alternatively, to reduce warning time for the target to react by following a depressed trajectory. SRAM's primary mission was to enhance the survivability of U.S. Strategic Air Command bombers by clearing a corridor through surface-to-air missile batteries. A secondary mission, to destroy strategic targets, was added later.[28] Carried by on USAF B-52G/H

2016), https://www.youtube.com/watch?v=8b8LLcdBaQc.

22 United States. Congress. Senate. Committee on Armed Services, *Fiscal Year 1977 Authorization for Military Procurement, Research and Development, and Active Duty, Selected Reserve and Civilian Personnel Strengths: Hearings before the Committee on Armed Services, United States Senate, Second Session, on S. 2965*., volumes (Washington: U.S. Govt. Print. Off, 1976), catalog.hathitrust.org/Record/009105793.

23 Syed Ramsey, *Tools of War: History of Weapons in Modern Times*.

24 MDA's TC program also uses ALBM test targets such as the MDA MRBM Type 1, Short Range Air Launched Target (SRALT), Long Range Air Launched Target, the Extended Long Range Air-Launched Target (eLRALT).

25 Missile Defense Agency, "Targets And Countermeasures Fact Sheet" (Missile Defense Agency, June 2016), https://www.mda.mil/global/documents/pdf/targets.pdf; Aerojet Rocketdyne, "Ballistic Missile Targets | Aerojet Rocketdyne," accessed September 2, 2019, https://www.rocket.com/defense/targets-decoys/ballistic-missile-targets.

26 James N. Gibson, *Nuclear Weapons of the United States: An Illustrated History*, Schiffer Military History (Atglen, PA: Schiffer Pub, 1996).

27 Norman Polmar and Robert S. Norris, *The U.S. Nuclear Arsenal: A History of Weapons and Delivery Systems Since 1945* (Annapolis, Md: Naval Institute Press, 2009).

28 Strategic Air Command, *From Snark to Peacekeeper: A Pictorial History of Strategic Air Command Missiles*., v, 123 p. (Offutt Air Force Base, Neb.: Office of the Historian, Headquarters, 1990), catalog.hathitrust.org/Re-

and FB-111 this system was powered by a solid-propellant rocket motor and had a range of 56 – 80 km at low-altitude and 160 – 217 km at high-altitude launch.[29]

Though the United States never deployed a canonical ALBM system, its development program would demonstrate the feasibility of the concept and inspire similar programs in other countries.

USSR/Russia

The Soviet Union developed air-launched missiles during the early years of the Cold War. Some programs (Kh-22 and AS-6) took the form of air-launched anti-ship missiles designed to target U.S. carrier groups from standoff ranges while others (AS-16 and the proposed R-13) were designed as land-attack ALBMs. Russia, lacking the geographical isolation of the United States, sought highly capable air-launched systems to threaten US force projection assets and land-based military targets relatively close to its borders.

In 1958, as the United States was testing precursors to Skybolt, the Soviet Union started a program that would result in the deployment of the Kh-22 Kitchen, a long-range anti-ship missile (ASM). Kitchen was designed to be launched from a Tu-22M Backfire bomber that had been modified to carry the missile in a special adaptor that recessed the weapon into the centerline of the aircraft's underside.[30] Propelled by a liquid-fueled rocket engine, Kitchen was designed to deliver either a conventional or nuclear warhead to a U.S. carrier battle groups before they could close to a range that would allow them to launch their air wings against Soviet targets. But unlike U.S. ALBMs and most other ballistic missiles, which rely on thrust and attitude control to orient the missile and the warhead toward the intended target, the Russian Kh-22 used lifting surfaces to control itself.[31] Lifting surfaces are common features on air-breathing cruise missiles, but relatively rare on systems with rocket motors. The Kh-22 uses lifting surfaces, combined with its initial post-launch altitude increase, to extend its range while keeping the launch vehicle below the radar horizon of its target. Once it reaches the target area, it enters a steep dive that is uncharacteristic of cruise missiles. This results in an unusual flight trajectory that includes an initially steep inclination, a powered "cruise" phase, and a terminal dive phase.

cord/002714030.

[29] Polmar and Norris, *The U.S. Nuclear Arsenal*.

[30] Carlo Kopp, "Soviet/Russian Cruise Missiles" (Air Power Australia, August 6, 2009), https://www.ausairpower.net/APA-Rus-Cruise-Missiles.html; Greg Goebel, "The Tupolev Tu-22 'Blinder' & Tu-22M 'Backfire,'" Air Vectors, accessed August 1, 2019, http://www.airvectors.net/avtu22.html.

[31] Sergei Moroz and Sergei Popsuevich, *Upravli͡aemye Rakety Dal'neĭ i Morskoĭ Aviat͡sii SSSR - Soviet Long Range and Naval Aviation Missiles.*

In 1970, the USSR deployed the AS-6 Kingfish, a smaller version of the Kitchen, powered by a two-stage solid-rocket motor.[32] Kingfish shared the design characteristics and flight profile of the Kitchen, but was a significant upgrade. Though smaller and lighter than its predecessor, Kingfish had a maximum range 200 km greater than that of the Kitchen at 700 km, even though its flight ceiling was almost 4 km lower.[33] In addition to the modified Backfire, Kingfish could also be carried by the Tu-16 Badger bomber. It also used an upgraded active radar or radiation-homing guidance system, depending on whether the intended mission was suppression of enemy air defenses (SEAD) or anti-ship targeting.[34] These upgrades gave it increased autonomous guidance capabilities and resistance to jamming.[35]

In the early 2000s, the Russian Federation began developing a further upgraded version of the Kitchen called Kh-32, which was deployed in October of 2018 and reportedly has a 1,000 km range.[36] With the same weight and size as the Kh-22, the system reportedly contains a new propulsion system,[37] though it is not publicly known whether this system featured the adoption of a solid-propellant motor like that seen on the AS-6 or an upgraded version of the liquid-propelled system used by the original Kh-22. It also incorporates a new radar targeting system that Russia believes makes it impervious to electronic jamming.[38]

Generally, ballistic missiles generate range by burning fuel and control themselves by vectoring their exhaust. Some ballistic missiles utilize fins or stabilizers to orient their payload. By contrast, cruise missiles generate range by supplementing the thrust generated from an air-breathing engine with lifting surfaces. Due to their rocket motors, parabolic trajectory, and aerial launch platform, the family of missiles derived from the Kitchen share many features of ALBMs. The inclusion of lifting surfaces makes these missiles a kind of hybrid. When flying on a ballistic trajectory, the surfaces

[32] John Pike et al., "AS-6 - Russian and Soviet Nuclear Forces," accessed August 30, 2019, https://fas.org/nuke/guide/russia/bomber/as-6.htm.

[33] Pike et al.

[34] Pike et al.

[35] In this period, Soviet Design bureaus also had several design proposals such as the R-13 (4K50) from MOM SKB-385 bureau and the R-210 project from the Yangel bureau however very little corroborated information regarding the history and purpose of these systems exists in the open-source space. This system is said to have a purported range of 600-700 km and a launch weight of 13,700 kg. Moroz and Popsuevich, *Upravli͡aemye Rakety Dal'neĭ i Morskoĭ Aviat͡sii SSSR - Soviet Long Range and Naval Aviation Missiles*.

[36] Gady Franz-Stefan, "Russia's Upgraded Tu-22M3M Long-Range Bomber Makes Maiden Flight | The Diplomat," https://thediplomat.com/2019/01/russias-upgraded-tu-22m3m-long-range-bomber-makes-maiden-flight/; TASS, "Russia's Upgraded Strategic Bomber to Join Aerospace Force in October," accessed September 19, 2019, https://tass.com/defense/1004329; Sivkov.

[37] Konstantin Sivkov, "Незамеченный Возмутитель Спокойствия 'Unnoticed Troublemaker,'" accessed September 1, 2019, https://vpk-news.ru/articles/41779.

[38] Sivkov, "New Kh-32 Antiship Missile Becomes Operational in Russia - Part 1."

allow the missile to prolong its midcourse phase and essentially stretch its range, after which it can nose down towards its target by using its control surfaces. When using a sea-skimming trajectory, it flies much as cruise missiles do.

The most canonical Soviet ALBM system, the AS-16, entered service in 1980. It served as a short-range ballistic missile with a range of 150 km.[39] Powered by a single-stage solid-rocket motor, it relied on an inertial guidance system and was capable of carrying either a conventional or a nuclear payload. This system shared characteristics with the American SRAM and probably was tasked for SEAD.[40] Designed to be launched from the Tu-22M bomber to target air defense systems, it would serve to permit larger, slower bombers in subsequent echelons to deliver munitions to strategic targets.[41]

Air-launched Space Vehicles

The requirements to launch a ballistic missile closely resemble those needed to insert a missile or space vehicle into orbit around the earth. Both the United States and Russia have explored air launched anti-satellite weapons (AL-ASAT) and air launched space launch vehicles (AL-SLV), and Russia has apparently deployed its system. Though there are few public indications that ALBMs and AL-ASAT weapons programs have been linked, AL-ASAT generally follow a minimum-energy trajectory (MET)[42] during boost phase to reach their target's altitude with the least amount of fuel possible. While an AL-ASAT will not have a reentry phase, the missile must conduct the same complicated calculation as an ALBM to understand where the missile is at launch, a calculation far more complex than receipt of a simple set of geographic coordinates like surface-launched systems. Progress on AL-ASAT weapons is therefore closely related to progress on ALBMs.

On October 13, 1959, Bold Orion demonstrated that ALBMs could serve as an Anti-Satellite (ASAT) weapon by detonating a nuclear warhead at a high altitude to destroy or damage satellites.[43] In 1985, President Reagan authorized a test of a new AL-ASAT named ASM-135 against an orbital target. ASM-135 was a modified AGM-69 SRAM, which had an added second stage to increase its range. Launched

[39] Moroz and Popsuevich, *Upravl͡iaemye Rakety Dal'neĭ i Morskoĭ Aviat͡sii SSSR - Soviet Long Range and Naval Aviation Missiles*.

[40] Boeing AGM-69 Short Range Attack Missile SRAM Nuclear Air to Surface Missile 62394, https://www.youtube.com/watch?v=is3NYchWTtQ.

[41] Moroz and Popsuevich, *Upravl͡iaemye Rakety Dal'neĭ i Morskoĭ Aviat͡sii SSSR - Soviet Long Range and Naval Aviation Missiles.*

[42] A MET maximizes a missile's range for a given amount of thrust.

[43] John Pike, "Bold Orion Weapons System 199 (WS-199B)," Global Security, accessed July 20, 2019, https://www.globalsecurity.org/space/systems/bold-orion.htm.

from modified a F-15A named Celestial Eagle in a 3.5 G zoom climb, the test system executed 68 seconds of powered flight before striking the target.[44] ASM-135's development process was halted when, concerned about the amount of debris created by the initial test, the U.S. Congress prohibited further tests against orbiting targets.[45]

The USSR initiated a reciprocal development program called Kontakt (30P6) two weeks after the U.S. test of the ASM-135 in 1985.[46] While little is known about the specific characteristics of this system, it was apparently never flight tested.[47] It is possible that the new Russian ALBM photographed in September 2018 being carried by a MiG-31 is a new AL-ASAT system derived from 30P6 technology.[48] In early 2019, CNBC reported that a U.S. intelligence report assessed that a new Russian ASAT weapon (PL-19 Nudol) will be deployed in 2022 and that its primary targets are expected to be communications and imagery satellites in low earth orbit, though early tests have been from mobile, ground-based missile launchers.[49]

An air-launched rocket booster is an attractive space launch platform because the aircraft can be aligned to the desired orbit, obviating the need for a ground-launched rocket to conduct a dogleg maneuver during its boost phase to align itself, saving fuel, weight, and therefore money. The aircraft's flight path can be modified to expand or shift an available launch window that would be more constrained for a fixed launch platform. Private space-launch companies, including Orbital ATK's (now Northrop Grumman) Pegasus, Generation Orbit and Stratolaunch, have adopted this technology to save costs on fuel, to employ an aircraft as a reusable first stage, and to simplify launch planning.

[44] Space and Missile Systems Center Los Angeles AFB, *ASM 135 ASAT*, https://www.youtube.com/watch?v=WA-hEdCCc9U4.

[45] David S F Portree and Joseph P Loftus, "Orbital Debris: A Chronology" (NASA Scientific and Technical Information (STI) Program Office, January 1999).

[46] Bart Hendrickx, "Naryad-V and the Soviet Anti-Satellite Fleet," *Space Chronicle*, Vol. 69 (2019), p. 22.

[47] Pavel Podvig, "Did Star Wars Help End the Cold War? Soviet Response to the SDI Program," *Science & Global Security*, Vol. 25, No. 1 (January 2017), pp. 3–27, doi:10.1080/08929882.2017.1273665.

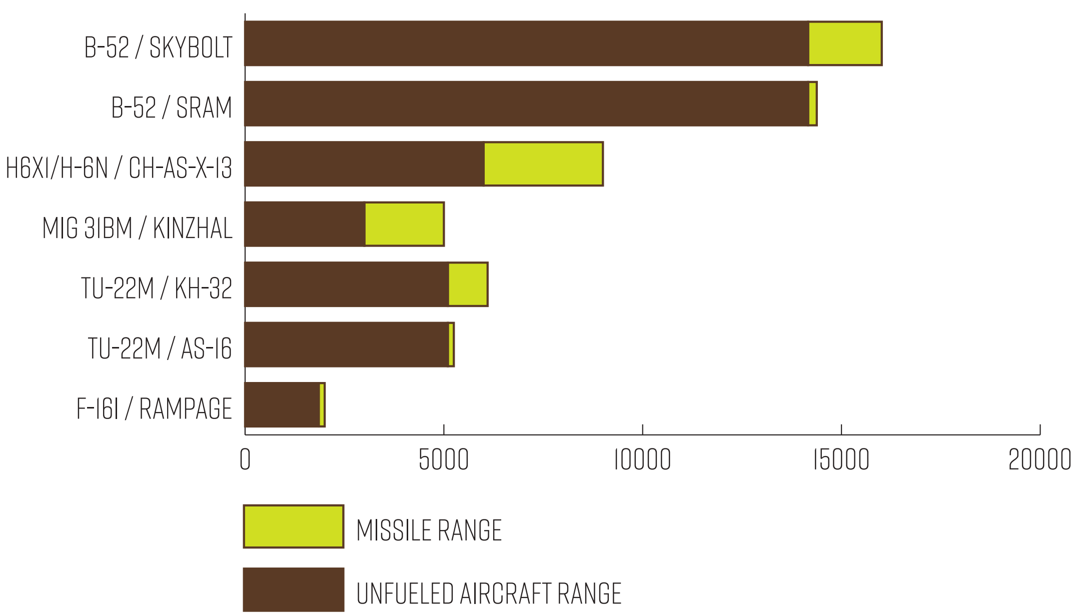
[48] Alex Lockie, "Russian Mig-31 Spotted with a Mystery Weapon That Could Be a Nightmare for the U.S. Military," *Business Insider*, accessed September 3, 2019, https://www.businessinsider.com/russian-mig-31s-mystery-weapon-possibly-anti-satellite-nightmare-for-us-2018-10.

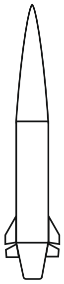
[49] Amanda Macias and Michael Sheetz, "Russia Conducted Another Successful Test of an Anti-Satellite Missile, According to a Classified U.S. Intelligence Report," *CNBC*, https://www.cnbc.com/2019/01/18/russia-succeeds-in-mobile-anti-satellite-missile-test-us-intelligence-report.html.

CURRENT ALBM PROGRAMS

Russia, China, and Israel are all actively engaged in development of ALBMs. The diverse programs of the Cold War have not led to a single class of ALBMs with a discrete role, as each country has developed an entirely distinct system. China has adapted a relatively large IRBM to be deliverable by legacy bomber aircraft. The Russian missile is adapted from an Iskander-M, barely at IRBM range. It is almost 3.5 times smaller than the Chinese system, its payload 120 kg lighter, and is fitted to be delivered by a supersonic fighter. Israel has invested in a smaller, highly accurate system to be delivered by tactical fighters. In short, existing ALBM programs have been tailored based on the missiles a country has available to adapt, the aircraft it has available to deliver the missile, and its country's strategic environment.

RANGES OF AIR-LAUNCHED BALLISTIC MISSILES





KINZHAL (RUSSIA)

FIRST FLIGHT TEST:	MARCH 11, 2018	LAUNCH AIRCRAFT:	UPGRADED MIG-31
MISSILE RANGE:	2,000 KM	AIRCRAFT RANGE:	3,000 KM
MISSILE LENGTH:	8 METERS	MOTOR UNKNOWN	

Source: TASS, "Russian Aerospace Forces Test Launch Kinzhal Hypersonic Missile"; "Russia's Upgraded MiG-31 Fighters Hold Dogfight in Stratosphere in Kamchatka Drills"; "Russian Aerospace Forces Test Launch Kinzhal Hypersonic Missile."

Russia

In March 2018, Russian President Vladimir Putin delivered a presentation that described four new nuclear-capable weapons systems. One of these weapon was Kinzhal, a nuclear-capable ALBM.[50] With a reported range of approximately 1,500 - 2,000+ km and launched from a modified MiG-31BM Foxhound with a range of 3,000 km, the pairing of these two systems provides Russia with a potential new option for delivery of tactical nuclear weapons.[51] In open-source reporting, Kinzhal has been labeled as a variant of the Iskander-M SRBM. However, given that little is known about the internal components of the missile, it is safer to state that the systems share a common appearance, pending further information.[52]

Kinzhal's capabilities provide an ability to reduce the time a target has available to relocate, shelter, or, if a missile, to fire; an increased ability to penetrate enemy missile defenses; and an additional margin of survivability for Russian theater nuclear forces. That the Iskander-M is capable of ranges approaching 500 km for conventional and nuclear theater strikes,[53] and given the Foxhound's lack of stealth characteristics, it is plausible that Kinzhal has been designed to allow Russia the ability to fire the missile from a position inside Russian airspace and far out of range from NATO air defense systems or aircraft.. If Foxhounds equipped with ALBMs could depart their bases before they were attacked, they could orbit over the Russian interior or transit to launch points in Russia's Western territory could provide an insurmountable challenge for allied planners attempting to target Russian tactical nuclear delivery vehicles. Furthermore, it may be difficult to track Kinzhal because the modified MiG-31s are likely difficult to distinguish from the standard variant using overhead imagery; the only ma-

[50] Vladamir Putin, *Presidential Address to the Federal Assembly*, vol. 2019, Aug 15, http://en.kremlin.ru/events/president/news/56957.

[51] Center for Strategic and International Studies, Kinzhal, vol. 2019, May 1, https://missilethreat.csis.org/missile/kinzhal/; Tom Demerly, *Russia Test Fires New Kh-47M2 Kinzhal Hypersonic Missile*, vol. 2019, April 30, https://theaviationist.com/2018/03/12/russia-test-fires-new-kh-47m2-kinzhal-hypersonic-missile/.

[52] Hans Kristensen and Matt Korda, *Russian Nuclear Forces, 2019*, vol. 2019, May 1, https://www.tandfonline.com/doi/pdf/10.1080/00963402.2019.1580891?needAccess=true.

[53] Center for Strategic International Studies, *SS-26 (Iskander)*, vol. 2019, May 1, https://missilethreat.csis.org/missile/ss-26/.

jor modification is a large hardpoint for mounting the missile underneath the aircraft. At long ranges, and especially in contested wartime conditions, it may be difficult for allied air-defense radars to distinguish modified Foxhounds carrying a nuclear-capable Kinzhal from standard variants conducting interception missions. Lastly, Kinzhal can be carried to its designated launch point faster than a mobile TEL, limiting the amount of time allied surveillance capabilities will have to detect it prior to launch.

Kinzhal offers a substantial range when fired using a MET but is also probably capable of performing aero-ballistic maneuvers for increased precision and evasion of missile defenses.[54] Iskander-M, for example, is reportedly capable of an independently maneuverable separating warhead, terrain-matching terminal guidance, radical in-flight maneuvers, and carriage of a wide variety of warheads. Even a small volley of missiles launched from unexpected angles that stay below the view of allied radar installations would limit warning time and would increase the missiles' effectiveness in a limited strike.

Recent information implies that Kinzhal is not Russia's only active air-launched missile development program. In September 2018, Tyler Rogoway and Ivan Voukadinov reported that Russian aviation watchers had spotted a modified MiG-31 carrying an ALBM significantly larger than Kinzhal. The authors noted that the missile "appears to feature a set of folding fins at its rear."[55] No additional information is currently available about this system.

China

In early 2018, Ankit Panda reported that since late 2016, China had undertaken five flight tests of a nuclear-capable ALBM. He reported that the ALBM is a modified variant of a DF-21 MRBM, possesses a 3,000 km range, and is designated CH-AS-X-13 by the U.S. intelligence community.[56]

The Department of Defense's 2019 annual report to Congress on Chinese military power stated that the Peoples Liberation Army Air Force (PLAAF) is developing "two new ALBMs, one of which may include a nuclear payload."[57] It is not known whether

[54] John Wood, *Russia, the Asymmetric Threat to the United States: A Potent Mixture of Energy and Missiles* (Santa Barbara, Calif: Praeger Security International, 2009).

[55] Tyler Rogoway and Ivan Voukadinov, "Exclusive: Russian MiG-31 Foxhound Carrying Huge Mystery Missile Emerges Near Moscow," *The Warzone*, September 29, 2018, https://www.thedrive.com/the-war-zone/23936/exclusive-russian-mig-31-foxhound-carrying-huge-mystery-missile-emerges-near-moscow.

56 Ankit Panda, Revealed: China's Nuclear-Capable Air-Launched Ballistic Missile.

57 United States Department of Defense, "Annual Report to Congress - Military and Security Developments Involving the People's Republic of China 2019" (Dept. of Defense, May 2, 2019), https://media.defense.gov/2019/

these two ALBMs are distinct systems or if it is one launch vehicle with two different payloads. The Chinese government has not acknowledged the existence of either system nor displayed them at any publicized military events or parades. On October 1, 2019 China displayed a variant of the H-6 bomber, the H-6N, that lacks bomb bay doors that is likely intended to serve as the launch platform for a new ALBM.[58]

In addition to a modified DF-21, Chinese publications have raised the possibility that the second ALBM could be either a DF-15 SRBM (which has a range of 600 km launched from land) or a DF-26 IRBM (3,000 – 4,000 km launched from land). The Sina news service asserted in September that "as everyone knows, China's "aircraft carrier killer" has two types of anti-ship ballistic missiles, the Dongfeng-21D and Dongfeng 26," which were also intended to hold at risk U.S. forces on Guam. The article asserts that the DF-21, when combined with the range of the H-6N "is effective against large warships, especially aircraft carriers, inside and outside the first island chain," even after the range of its carrier air wing is extended by the US MQ-25 unmanned refueling aircraft.[59] Eleven days later, Ta Kung Pao, a prominent newspaper, also speculated that the H-6N was capable of carrying the DF-26.[60] In late 2019, a Chinese trade magazine published by the China Shipbuilding Information Center, an office of the State Administration for Science, Technology and Industry for National Defense, published several drawings of an H-6N carrying a DF-15 SRBM.[61]

The DoD annual report states that deployment of the nuclear-capable ALBM "would, for the first time, provide China with a viable nuclear 'triad' of delivery systems dispersed across land, sea, and air forces," implying that the CJ-20 ALCM capable of being launched from the H-6 bomber is not nuclear-capable or is otherwise inviable.[62]

China's rapidly expanding ground-launched ballistic missiles forces are already capable of striking targets on U.S. or allied territory in a conflict. The volume of available missiles is probably able to saturate the missile defense systems of defended facilities or ships, but may require firing a quantity of missiles incompatible with escalation con-

May/02/2002127082/-1/-1/1/2019_CHINA_MILITARY_POWER_REPORT.pdf.

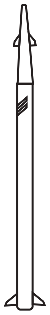
58 Ankit Panda, "Huh. Fascinating. On CH-AS-X-13, the nuclear-capable ALBM:" tweet, September 22, 2019, https://twitter.com/nktpnd/status/1175675375134937088. The modified bomber may also be capable of carrying the new WZ-8 supersonic reconnaissance UAV displayed at the same event.

59 Hong-6N ke gua zai shecheng 3 qian gongli fan jian dandao daodan [H-6N can mount 3,000 kilometer range ballistic missile], Xinlang junshi, September 28, 2019.

60 Cangqiong zhanshen hong-6N [H-6N: God of War], Ta Kung Pao, October 9, 2019.

61 Zhongcha: Xian-6N zhongxing hongzhaji [Center insert: H-6N mid-size bomber], Xiandai jian chuan [Modern Ships], No. 23, 2019, p.26-27.

62 United States Department of Defense, "Annual Report to Congress - Military and Security Developments Involving the People's Republic of China 2019"



RAMPAGE (ISRAEL)

FIRST FLIGHT TEST: UNVEILED JUNE 11, 2018 (FIRST FLIGHT UNKNOWN)
MISSILE RANGE: UNKNOWN
MISSILE LENGTH: ~4.7 METERS

LAUNCH PLATFORM: F-16I SUFA
AIRCRAFT RANGE: 1,852 KM
SINGLE-STAGE, SOLID-FUEL MOTOR

Source: I. M. I. Systems, *IMI and IAI Unveil the Rampage a Co-Developed Innovative Air-to-Ground Rocket*; Pike, "F-16I Sufa (Storm)"; IAI, "Rampage: Long Range Air-to-Ground Precise Strike Weapon"; Elbit Systems Land Ltd, *RAMPAGE Long-Range Precise Supersonic Missile*.

trol or other tasking requirements for the missile forces. In this context, an ALBM may provide an additional ability to fire on defended targets from unexpected directions, increasing the ability to destroy them while conserving missile magazines. It is unlikely that H-6 bombers that lack stealth characteristics are capable of surviving to come within 3,000 km of Hawaii, but the long range of the Chinese ALBM could permit new options against U.S. military installations on Guam, in Japan, and for mobile targets like carrier strike groups from launch points over the Chinese littoral, or within the first island chain, where the bombers can be better protected by land-based air defense systems and tactical aircraft. Against ships, there is limited utility to the ability to fire from unexpected angles: while the THAAD battery on Guam has a 120-degree field of view and could potentially be circumvented, the Aegis radars on U.S. and many allied ships provide 360-degree coverage.

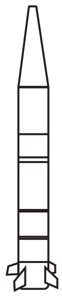
Israel

Israel has developed multiple conventional ALBMs, and may have employed one in combat. Israeli Military Industrial Systems (IMI) and Israeli Aerospace Industries (IAI) jointly developed an air-launched derivative of IMI Systems' ground-launched Extended Range Artillery (EXTRA) system, called Rampage. Unlike other ALBMs, Rampage is a tactical precision munition, weighing only 570 kg without its warhead ascompared to Kinzhal's 4,300 kg.[63] An Israeli F-16I can carry up to four,[64] and the system can also be fired from F-15s or any other aircraft with a pylon capable of carrying an Mk83 bomb.[65]

[63] IMI Systems, "EXTRA Advanced Long Range Fire Power System," http://www.imisystems.com/wp-content/uploads/2017/01/EXTRA-1.pdf. Rampage's full weight is unknown, but the EXTRA missile it is modified from carries a 120 kg warhead.

[64] Yoav Zitun, IMS, IAI Develop Missile Undetected by Enemy, vol. 2019, July 06, https://www.ynetnews.com/articles/0,7340,L-5283738,00.html; Elbit Systems Land, *Rampage - Long Range Supersonic Air to Ground Precision Weapon,* vol. 2019, June 01, https://www.youtube.com/watch?v=abWP3RfyR68; Strategic and Studies, Kinzhal.

[65] Robin Hughes, "IAI, IMI Unveil Rampage Stand-off Air-to-Surface Missile," Jane's 360, https://web.archive.org/web/20180818021343/.



ROCKS (ISRAEL)

FIRST FLIGHT TEST: UNKNOWN
MISSILE RANGE: UNKNOWN
MISSILE LENGTH: 4.85 METERS
LAUNCH PLATFORM: F-16I SUFA
AIRCRAFT RANGE: 1,852 KM
SINGLE STAGE, SOLID-FUEL MOTORS

Source: Rafael Advanced Defense Systems Ltd, *ROCKS: Autonomous Extended Stand-Off Range Air-to-Surface Missile*; Pike, "F-16I Sufa"; Rafael Advanced Defense Systems Ltd, *Sparrow Targets Air-Launched Ballistic Targets*.

Informational material from the manufacturer states that Rampage is capable of flying at altitudes between roughly 1 and 9 km with an impact angle of up to 90°, meaning that the missile is likely capable of complex aero-ballistic maneuvers to fly at depressed trajectories or to execute steep vertical dives in its terminal phase.[66] Boaz Levy, the General Manager and Executive Vice president of IAI's Rockets and Space Group stated that the system "does not have a pure ballistic trajectory."[67] Its sophisticated satellite navigation and inertial navigation guidance systems are said to give the missile a CEP of less than 10 meters.[68] IMI advertises the system as a "quantum leap in performance and extraordinary cost-effectiveness ratio."[69]

A single uncorroborated report has claimed that a Rampage was used to strike a suspected Iranian Islamic Revolutionary Guard Corps (IRGC) rocket production and storage facility in Masyaf, Syria on April, 13 2019.[70]

Rampage offers the Israeli Air Force a strike option with a higher velocity and potentially a larger warhead than the previously available Delilah cruise missile. The Rampage's high velocity decreases warning time available to the target's air defenses that might otherwise attempt to shoot down a slower cruise missile. Its aero-ballistic capabilities afford Rampage the ability to strike defended targets from unexpected angles.

Israel also operates an ALBM family named Sparrow as test targets for its Arrow ballistic missile defense system. The three variants of the Sparrow—the short-range Black Sparrow, medium-range Blue and Silver Sparrow missiles—provide an ability

[66] Elbit Systems Land Ltd, *RAMPAGE Long-Range Precise Supersonic Missile*, vol. 2019, July, 01, https://elbitsystems.com/landing/wp-content/uploads/2019/06/rampage.pdf. Like the SRAM or Kitchen, Rampage's rocket motor is nevertheless capable of operating as a simple ALBM.

[67] Hughes, "IAI, IMI Unveil Rampage Stand-off Air-to-Surface Missile."

[68] Elbit Systems Land Ltd, *RAMPAGE Long-Range Precise Supersonic Missile.*

[69] I. M. I. Systems, *IMI AND IAI UNVEIL THE RAMPAGE- A CO-DEVELOPED INNOVATIVE AIR-TO-GROUND ROCKET*, vol. 2019, June 15, http://www.imisystems.com/mediacenter/iai-and-imi-systems-unveil-innovative-co-development-the-rampage/; Anna Ahronheim, *Did Israel Use the Rampage to Strike Syria? IAF Allegedly Hit Iranian Missile Factory on Saturday*, https://www.jpost.com/Middle-East/Did-Israel-use-the-supersonic-Rampage-to-strike-Iranian-targets-in-Syria-587279.

[70] Babak Taghvaee, "#Israel Air Force Successfully Used #Rampage for First Time. Due to the Danger of #Syria Air Defense Force's S-300PM-2s, #Israel Air Force Had to Use the Rocket to Target a Rocket/ Ballistic Missile Factory + Weapon Warehouses of #IRGC Proxies in #Masyaf, #Syria on 13/04/2019:https://twitter.com/Babak-Taghvaee/status/1117474575955185664 …," Tweet, *@BabakTaghvaee.*

to test BMD radars and interceptors against a variety of targets that simulate Scud-B, Scud-C/D, and the Iranian Shahab-3 MRBM, respectively.[71] According to industry promotional material, the Sparrow (which Israel launches eastward from an F-15 over the Mediterranean) can adopt ballistic, maneuvering, and a downward-spiraling barrel-roll trajectory, as well as a number of unusual warhead types, including water (potentially to simulate a bulk-fill chemical warhead), inert, and high explosive.[72]

The Israeli defense firm Rafael has also developed and displayed a missile called ROCKS that shares the length and external characteristics of the Back Sparrow.[73] ROCKS is described as a highly accurate missile with a CEP of 3 m and offers either a ground-penetration or blast-fragmentation warhead.[74] If ROCKS shares its capabilities with Black Sparrow, it is capable of radical maneuvers in the last moments of flight, which would explain its advertised ability to enter the mouth of an underground facility that is facing away from the missile's original direction of travel.[75] In 2019, Rafael released images of ROCKS being tested from the IAF's F-16I.[76]

[71] Rafael Advanced Defense Systems Ltd, *Sparrow Targets Air-Launched Ballistic Targets*, vol. 2019, July 25, https://www.rafael.co.il/wp-content/uploads/2019/03/Silver-Sparrow.pdf; "Israel Test Fires Silver Sparrow Target Missile," Airforce Technology, https://www.airforce-technology.com/news/newsisrael-test-fires-silver-sparrow-target-missile/.

[72] Rafael Advanced Defense Systems Ltd, *Sparrow Targets Air-Launched Ballistic Targets*. It may be that the final designation is meant to simulate a "high explosive" payload, as is not clear why a country would run the risk of attaching an active high explosive warhead to a missile defense target being fired toward its territory and there is no public information to indicate that the missile is deployable.

[73] Calculated based on mensuration from available images using known lengths of aim-120s and the advertised length of the Black Sparrow in Rafael's brochure.

[74] Rafael Advanced Defense Systems Ltd, *ROCKS: Autonomous Extended Stand-Off Range Air-to-Surface Missile*, vol. 2019, August 01, https://www.rafael.co.il/wp-content/uploads/2019/03/rocks032019.pdf.

[75] Rafael Advanced Defense Systems Ltd.

[76] Ibid.

WHY BUILD AN ALBM?

Given the diversity of air-launched ballistic missiles and the strategic environments of the countries that pursue them, there can be no single explanation for these programs. Yet the capabilities of ALBMs suggest some strong hypotheses. Given the lack of publicly available information about the characteristics of existing ALBMs and the doctrine that governs their use, the evidence is not conclusive.

Promptness

The velocity of an ALBM is a major advantage over existing ALCMs, and enhances the ability of these systems to perform a distinct set of missions. As countries race to deploy hypersonic strike platforms with air breathing engines or gliders that skip off the atmosphere, an ALBM may represent a relatively near-term, low-risk pathway to development of air-launched hypersonic systems prior to the deployment of air-breathing hypersonic options.

To take one example using publicly-reported reported flight speeds, the current iteration of Russian long-range ALCMs, the KH-101, would take one hour and eight minutes to fly from Kaliningrad to Ramstein Air Base in Germany, while Kinzhal is said to be capable of striking targets at twice the distance roughly ten minutes after launch. Depending on the air-defense capabilities of the target country and the flight paths available to an ALCM, the range and speed of an ALBM may considerably increase the time between when a defending forces detect an incoming threat and when it arrives on target, limiting their ability to protect or move vulnerable targets or to attempt to down the aircraft delivering the missile. If an ALBM targets a missile, leaders will have very little decision time in which to choose to launch the missile before it is destroyed.

An ALBM's compressed flight time provides an option to strike targets that are only visible for short windows of time, namely ones that are highly mobile or concealable. Command and control and leadership assets are one example of this type of target.

That systems like Kinzhal and Rampage are deployed on tactical aircraft may also contribute to shortened decision time, because a defender is unlikely to gain a reliable radar or visual image of the aircraft that can determine whether it is carrying an ALBM. Most likely, a defender may not be able to determine whether a tactical fighter is on a strike mission and potentially carrying an aero-ballistic missile before the missile is fired. A defender facing these capabilities is presented with a battlespace in which any of dozens or hundreds of tactical fighters may be capable of precision attacks against defended targets from considerable standoff ranges. Defending forces hoping to limit damage may well go after bombers, but may have difficulty knowing which tactical aircraft pose a serious threat. This challenge is compounded for NATO forces, as Kinzhal possesses a nuclear capability.

The challenges of short decision times and discrimination are not unique to ALBMs, but they do present a quantitative increase in the severity of the challenge. In circumstances when a combatant's air defense capabilities cannot threaten the launching aircraft (for example, incomplete coverage due to attrition or because the missile is fired from uncontested airspace), ALBMs may represent a qualitatively unique capability.

Missile defense defeat

The deployment of Russian and Chinese ALBMs comes at a time when both are making substantial investments to defeat U.S. missile defense systems. Though most experts agree that Russian or Chinese missile inventories are sufficient to saturate U.S. theater and strategic missile defenses and both countries possess aero-ballistic capabilities to evade missile defenses, both are pursuing boost-glide capabilities that provide an additional method of evading interceptors. In addition to any aero-ballistic features they possess, ALBMs offer the option of firing at defended targets, including missile defense batteries themselves, from unexpected angles.

Survivability

Questions persist about the ability of U.S. adversaries to maintain a survivable second-strike capability given likely improvements in the ability of U.S. forces to locate, track, and hold at risk mobile launchers and submarines. The mobility of aircraft might offer an additional margin of survivability for aircraft over existing systems. Where the operations of land-based mobile missiles can be observed and tracked over time, an ALBM can be loaded onto a bomber or tactical aircraft in a crisis and dispersed to a different base or airfield. The challenge of hunting ALBMs is less like a years-long needle-in-a-haystack hunt and more of a shell game that plays out in minutes. Both challenges are considerable, but the challenge of hunting ALBMs will be particularly taxing in times of war when intelligence, surveillance, and reconnaissance capabilities are already stretched to the maximum. The consideration is particularly relevant for ALBMs if a country envisages strikes on its theater nuclear forces—against airfields or against short-range mobile missiles near the battlefield—that does not escalate to a general counterforce strike against strategic forces. An ALBM therefore provides a prompt, reliable, and survivable standoff nuclear capability for targets against which cruise missiles are judged to be ineffective.

Survivability is therefore only a decisive consideration to the extent that a nuclear power doubts the survivability or effectiveness of existing sea-based, land-based, or air-breathing standoff systems. Short of these doubts, ALBMs simply supplement the survivability of existing options.

Domestic factors

There is considerable evidence that historical ALBM programs were motivated by bureaucratic or organizational concerns rather than any deep strategic necessity. The U.S. Skybolt program, for example, was motivated in part by the Air Force's effort to preserve its share of the nuclear mission in advance of the introduction of SLBMs. These considerations are often bound up with arguments in favor of "inter-leg hedging," in which a country might choose to duplicate capabilities in multiple domains to hedge against the failure of a leg of the triad in any given domain.

However, given that the air forces of each country operating ALBMs retain cruise missiles and other capable conventional land attack options, bureaucratic explanations are less compelling for contemporary programs. The Russian, Chinese, or Israeli Air Forces are not at risk of going out of business for the conventional strike mission. Organizational advocates of ALBM programs will have to explain why they need multiple types of air-deliverable strike options. Given the distinctive capabilities of ALBM and the enthusiasm in several nuclear weapons states for additional investments in nuclear delivery systems, these arguments have apparently resonated.

However, components of the Russian and Chinese air forces could still understand ALBMs as a means of securing their place in the nuclear mission. China has never demonstrated an entirely credible ability to deliver nuclear payloads by air, as the H-6 lacks the ability to penetrate defended air space to deliver gravity bombs and the U.S. intelligence community assesses that its ALCMs are not part of the nuclear force.

A nuclear-capable ALBM provides a considerable upgrade in terms of operational capability.

Though there are no comparable doubts about the capabilities of Russian nuclear-capable cruise missiles,[77] Kinzhal is apparently compelling to Russia's tactical aviation community as a way of gaining a credible capability for theater nuclear attack. Previously, Russia's fighter-bombers carried only anti-ship missiles and gravity bombs.[78]

[77] Russia's bombers are slated to receive a new long-range nuclear-capable ALCM, Kh-102, to replace the aging Kh-55.

[78] Kristensen and Korda, ibid.

RECOMMENDATIONS

The emergence of multiple ALBM programs in other advanced military powers raises certain policy issues for the United States and its allies: should the U.S. pursue its own ALBM, should ALBMs be included in arms control agreements, and should U.S. missile defenses adjust to account for them?

Does the United States or its allies need ALBMs?

As the Trump Administration orders new weapons procurement programs with the aim of winning a new era of great-power competition, a number of analysts have returned to thinking of deterrence requirements as motivated by a concern for symmetry. Using this measure, some might argue that the United States or its allies should pursue ALBMs to "counter" "pressure," or "keep up" with adversary developments. LTG (ret.) David Deptula, Dean of the Mitchell Institute of Aerospace Power Studies, argued that the United States could "provide an air launched ballistic missile capability to enhance deterrence of Chinese military adventurism" as one option to enhance medium-range conventional missile forces in the Pacific.

The United States has little military requirement for ALBMs. Its long-range bombers, distributed basing, and refueling capabilities means that ALBMs would provide few new angles of attack for U.S. systems relative to ALCMs or SLCMs or land-based ballistic missiles. An ability to maintain armed unmanned aircraft loitering over potential targets, or target coverage from undersea platforms, will in most circumstances provide superior or comparable options for prompt attack. Though ALBMs could marginally enhance America's ability to strike mobile targets of opportunity during tight visibility windows, for example in counterterrorism operations, it is difficult to see why an ALBM would enhance an operation against a near-peer adversary. In most scenarios, U.S. forces would fire coordinated salvos of projectiles to achieve a military effect at multiple targets at once. ALBMs and other hypersonic weapons would have to delay their launch to synchronize the strikes, nullifying an ALBMs potential benefits from speed and ability to penetrate missile defenses. The United States also has less of a requirement to hold at risk targets like aircraft carriers because potential adversaries rely on them less, and their ability to protect similar targets is relatively weaker. Lastly, as analysts express concern over the volume of fires that the United States could apply to targets in the Pacific, given difficulties generating high sortie rates and limited available missile tubes, ALBMs with ranges beyond short-range would tend to be so large that they would limit the quantity of munitions that a bomber platform could carry.

U.S. allies also have little reason to seek ALBMs. Ground-launched ballistic missiles stationed on their territory and air-launched cruise missiles can hold targets at risk more efficiently than an ALBM could. For allies, an ALBM program would cost more than it would be worth.

Include ALBMs in arms control agreements

The ability to launch a ballistic missile from an aircraft instead of a ground launcher should not exempt these missiles from arms control agreements.

Carnegie Fellow and former State Department official Pranay Vaddi argues that Kinzhal is not accountable under New START because its MiG-31 delivery vehicle would not be classified under the treaty as a heavy bomber due to its short range and its inability to deliver long-range, nuclear-armed air-launched cruise missiles.[79] Vaddi argues that the combined range of an upgraded Tu-22M3 Backfire bomber and the Kinzhal could very well constitute a "new kind" of strategic offensive armament as defined by Article V of the treaty and could therefore be included under the treaty following negotiations in the Bilateral Consultative Commission.[80] Inclusion under the treaty would be contingent on the extension of New START and Russian assent following successful negotiations, but the case remains hypothetical for now.

Future arms-control agreements that intend to limit ballistic missiles of specific ranges or that limit nuclear-capable delivery platforms should account for the existence of ALBMs. Any replacement for the INF treaty should include a provision to hold intermediate-range ALBMs accountable under it (whether they fall under intermediate-range by virtue of the missile's range capacity or the combined range potential from the aircraft and missile together).

ALBMs are also a strong candidate for inclusion in an arms control regime that covers a range of emerging technologies with strategic stability implications. The move to arm tactical aircraft with nuclear-capable air-to-ground standoff systems, and ability

79 The Kinzhal may therefore have been developed as a way of circumventing restrictions in the INF Treaty that applied only to land-based launchers. That treaty is now inactive.

80 Vaddi Pranay, "Bringing Russia's New Nuclear Weapons Into New START," *Lawfare*, https://www.lawfareblog.com/bringing-russias-new-nuclear-weapons-new-start.

of ALBMs to strike defended targets with little warning, represents a significant concern for efforts to maintain strategic stability.

Missile defense

Missile defense advocates may claim ALBMs as an additional reason to expand investments in and deployments of theater missile defense systems. On the theory that theater missile defenses can deny an adversary the ability to carry out limited strikes against strategically important targets, advocates may argue that ALBMs require radars and interceptors that can provide 360° coverage. Yet undertaking costly efforts to defend against ALBMs would simply represent an additional step in the missile defense arms race that can never be won at acceptable cost.

The aero-ballistic features of existing ALBM systems means that they are likely to be able to penetrate existing U.S. missile defenses regardless of whether they could hypothetically defend against simple ballistic targets on those vectors. Furthermore, existing adversaries will retain the ability to saturate missile defense systems with large salvos, meaning that adversaries' ability to penetrate theater ballistic missile defenses is not seriously in doubt. ALBMs, like land-based ballistic missiles (including Russia's Iskander-M, China's DF-12, and North Korea's KN23)[81] may provide an option to reliably strike targets with small salvos of missiles in an attempt to improve the efficiency of strikes or limit the escalatory potential of an attack. Lastly, given the scarcity of ALBMs and the relative abundance of ground-launched ballistic missiles, it is probably an overreaction to undertake expensive renovations of missile defense posture on this basis.

For the foreseeable future, the capabilities and cost-effectiveness of missile technology will outpace missile defense technology. ALBMs are not unique in this regard but simply another iteration in an offense-defense arms race that cannot be won at an acceptable cost. Reconfigurations of theater ballistic missile defenses might marginally increase their ability to intercept ALBMs, but would not provide a significant ability to protect any given class of target.

[81] For more on the capabilities and strategic implications of the KN23, see Adam Mount, "Challenges Pile Up on U.S.-South Korea Alliance Agenda," *Council on Foreign Relations*, accessed October 24, 2019, https://www.cfr.org/blog/challenges-pile-us-south-korea-alliance-agenda.

CONCLUSION

The current period of rapid development in nuclear and conventional delivery systems is not only advancing programs based on new physical principles but also recovering and refining technologies that have been in existence for decades. Air-launched ballistic missiles are instructive for understanding the contemporary missile challenge. Though at first glance they appear to be an alarming new capability, ALBMs for the most part simply iterate in the ability of adversaries to hold at risk classes of targets that were previously vulnerable but have been protected with certain types of hardening, missile defenses, extensions in their ranges, or improved counterforce options. There are few instances in which ALBMs represent qualitatively new capabilities or represent an appreciable risk of destabilizing existing balances.

Reviewing the history of ALBM development shows that global missile arsenals are more diverse and capable than commonly understood. Managing the problems created by today's missile systems requires understanding that a range of capabilities that appear exotic or novel are empirically commonplace.

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