MILESTONES

Cruise missiles post World War II

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THE BASIC TECHNOLOGY AND OPERATIONAL CONCEPT OF MODERN CRUISE MISSILES EMERGED DURING THE LATE 1960S, at the peak of the Cold War era. This type of weapon was exemplified by the RGM-109 Tomahawk series, the AGM-86C/D CALCM, the AGM-158 JASSM, and the Russian Kh-55SM Granat. Much less known is the generation of cruise missile technology that supplanted the 1940s era FZG-76/V-1 and its Russian and American clone variants. A good number of the former Soviet weapons of this generation remain in use, some still in production.

The aim of all cruise missile designs is to provide a weapon that can strike at a target while not exposing the launch platform to attack by enemy defences, whether the launch platform is an aircraft, surface warship, submarine or ground vehicle.

Key parameters in the design of any cruise missile are its standoff range, its accuracy and its survivability against target defences. Increasing standoff range reduces risk to the launch platform while increasing accuracy and survivability reduces the number of launches required to achieve desired effect. The economics of bombardment are simple: the more expensive the weapon employed, the smaller the war stock available for combat at any time, and the longer it takes to replenish this war stock once expended.

The ideal cruise missile is long range, virtually undetectable to all defences, is pinpoint accurate, dirt cheap, and available in large numbers. To date all attempts to produce such a weapon have been unsuccessful.

Northrop SM-62 Snark strategic cruise missile. This enormous 50,000 lb plus GLCM was built to directly attack the Soviet Union from US basing. It introduced the first stellar-inertial guidance system in a cruise missile.

EARLY COLD WAR IMPERATIVES

As the Cold War escalated through the early 1950s the primary strategic imperative of both sides was to develop the capability to bombard their opponents into oblivion using nuclear weapons. Ballistic missiles were simply not capable of achieving strategic ranges, a capability that did not mature until the 1960s. As a result, the primary platform to deliver nuclear weapons over strategic ranges was the heavy bomber.

At the end of World War II the US had a large fleet of the innovative B-29 Superfortress, and were developing the improved B-50, the larger and longer ranging B-36 Peacemaker. The jet powered Boeing YB-47 and YB-52, and Northrop YB-49 were in the development pipeline. The British were developing the three V-bomber designs, Valiant, Victor and Vulcan, to replace the piston engine Lincoln bomber, itself an evolution of the Lancaster. The Soviets were busily reverse engineering the B-29 into the Tupolev Tu-4 Bull, a solid achievement given the retarded Soviet industrial base of that period.

By the mid 1950s the US deployed fleets of the B-36 and B-47, and developed the early B-52 Stratofortress variants. The Soviets, via the interim Tu-85, evolved the B-29 technology into the turboprop powered Tu-95 Bear and turbojet powered Tu-16 Badger, and the latter remains in production today in China. The British at that stage were deploying the Valiant, used for numerous nuclear weapons tests in this region.

In parallel with the strategic bomber arms of these key Cold War players, naval arms were developing the capability to use nuclear weapons, primarily for theatre applications. The US Navy developed the A-3 Skywarrior for this purpose.

This was the environment which spawned the two generations of cruise missiles, which followed the FZG-76/V-1 design into operational service.

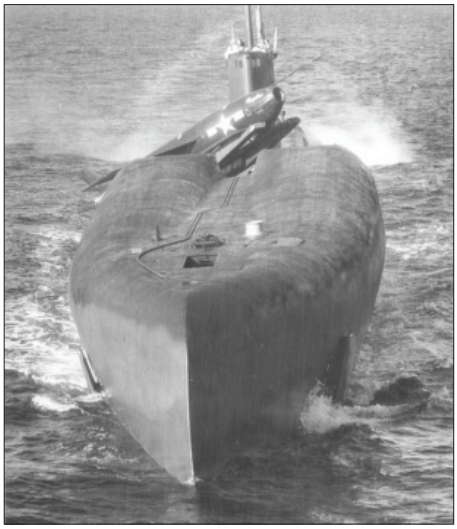
US NAVY CRUISE MISSILE DEVELOPMENTS

The US Navy first experimented with cruise missiles using the Loon, a reverse engineered FZG-76 design. In March 1946 funding was authorised and the USS Cusk SS-348 submarine converted with a launch ramp. The first Loon launch in February 1947 began a series which continued from the converted SS-337 Carbonero. Unlike the Luftwaffe's V-1s, the US Navy missiles had command links to guide the weapon to its target. The US Navy learned from these experiments that deployment presented technical problems, but also that surface warships had difficulty defending against a low flying missile that pops up over the horizon with little or no warning. That reality has changed little a half-century later.

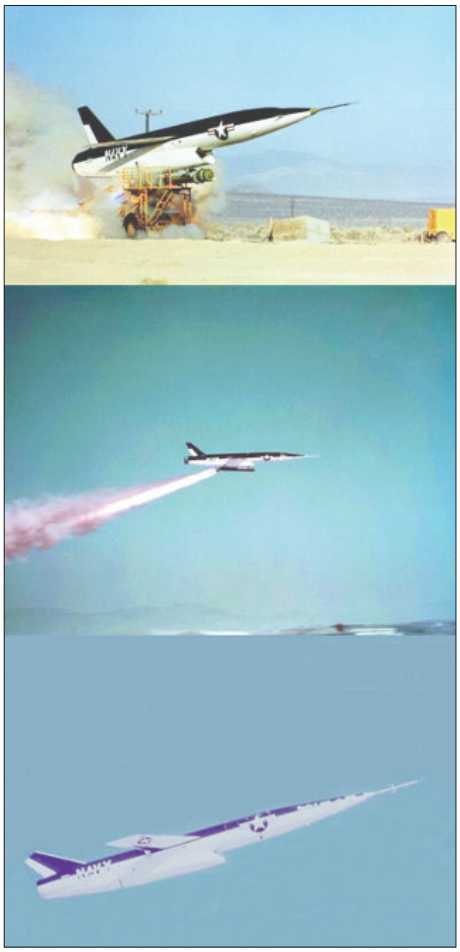
The success of the Loon trials led to ambitious plans to deploy the Mach 2 ramjet powered Rigel land attack cruise missile, and the even more ambitious Mach 3.5 Triton with up to 2,000 nautical miles range. The guidance and propulsion technology was simply not available at that time for such designs, and the result was the much less ambitious Regulus program.

The Chance-Vought SSM-N-8/RGM-6 Regulus program initiated during World War II progressed slowly until 1947 when a revised specification was issued for a turbojet powered missile with 500 nautical miles range, a 3,000 lb warhead and 2.5 nautical mile accuracy at maximum range. The resulting 12,000 lb weapon had folding wings for transport, a nuclear warhead and a J-33-18 engine. Solid rocket boosters thrust the missile airborne. The Regulus' complex radio command link guidance system, named TROUNCE, controlled the missile in flight, with control passed on from the launch submarine or warship, an aircraft, and other submarines. An engagement could see the launch submarine guide the missile until it crossed above the submarine's radio horizon, upon which

Launching a Regulus I from the cruiser USS Los Angeles. The Regulus was also deployed on aircraft carriers.



Deploying a Regulus I from the bulbous bow hangar of the SGG USS Growler. The Regulus was replaced by the Polaris ballistic missile in 1964.



The supersonic Regulus II did not enter production, but did become the template for the Soviet Shaddock and Sandbox cruise missiles.

terminal flight guidance control was assumed by another submarine within line of sight to the target, or an aircraft in proximity. This model was later adopted by the Soviets for a range of cruise missile designs.

The Regulus was deployed initially on submarines SSG-282 USS Tunny and SSG-317 USS Barbero, equipped with a 50 kilotonne class Mark 5 nuclear device. From 1956 the weapon was rearmed with 1-2 Megatonne class W27 warhead. The US Navy deployed two specialised SSGs built for the Regulus with bulbous bow hangars, the SSG 574 USS Grayback and SSG 577 USS Growler – followed in 1960 by the nuclear powered SSGN 587 USS Halibut with a hangar for 4 to 5 rounds. The US Navy retained the submarine (and ship) launched Regulus until 1964 when ballistic missiles replaced them. The surface fleet also deployed the Regulus. Four Baltimore class cruisers, the US Ships Los Angeles, Macon, Toledo, and Helena, were armed with three missiles each. The Regulus was deployed also on a number of attack carriers to supplement the air wing.

Over 500 Regulus missiles were built, which is significant. It was the first US Navy nuclear armed missile, and it pioneered technologies that the Soviets were to use extensively in their cruise missiles. The larger supersonic RGM-15 Regulus II was cancelled, as were the Rigel and Triton. The US Navy did not deploy another cruise missile until the advent of the RGM-109 Tomahawk series during the 1970s.

US Air Force Cruise Missile Developments

The USAF also experimented with the Loon, including air launching the missile from a Superfortress. The imperative for the USAF was to increase bomber survivability, increasingly challenged as the Soviets initially deployed supersonic interceptors and later Surface to Air Missiles.

The first USAF cruise missile to be deployed in credible numbers was the Martin B-61 Matador, later redesignated the MGM-1A. Similar in size and concept to the Navy Regulus, the Matador shared the same engine design. Unlike the Regulus, the Matador was deployed from ground vehicles, qualifying it as a Ground Launched Cruise Missile (GLCM). A convoy of vehicles, including the semi-trailer Transporter Erector Launcher (TEL) for the Matador was required to deploy this weapon.

Like the Regulus, the Matador used a radio command link guidance scheme. Early variants employed a missile tracking system, the MSQ-1 radar to track missile location. Later variants used the Short Range Navigation Vehicle, or SHANICLE system, which employed phased microwave beacons and a time difference of arrival tracking scheme.

Matador missiles were deployed primarily in West Germany with the 38th Tactical Missile Wing at Bitburg AFB and Hahn AFB, and in Taiwan and South Korea with the 58th Tactical Missile Group. Around 1,200 Matadors were built, with the weapon withdrawn from service in 1962. The war load was a W5/Mark 5 device with a yield of up to 120 kilotonnes TNT.

Matadors were replaced by the more capable TM-76A/MGM-13/CGM-13 Mace, initially designated the Matador B. The Mace was longer ranging at 700 nautical miles but importantly introduced a more robust guidance package – the Goodyear ATRAN (Automatic Terrain Recognition And Navigation), an early implementation of an area correlator guidance scheme later used in the Tomahawk and a range of Soviet weapons. The later TM-76B Mace B introduced the first inertial guidance system, permitting higher flight altitudes and almost doubling range. The sensitive inertial guidance system required fixed basing, and the Mace B was deployed from shelters. The Mace was retired after 1965 with its role transferred to theatre ballistic missiles and airframes converted into target drones.

A contemporary of the Matador was the massive 50,000 lb Northrop SM-62 Snark. Initiated during the late 1940s, the Snark program did not yield a deployable weapon until a decade later. Unlike the Regulus, Matador and Mace, which were theatre weapons, the Snark was built to be a strategic weapon, with a intercontinental range of 6,000 nautical miles. The Snark went through a protracted development process, punctuated by repeated failures of components and systems. The weapon was powered by a 10,500lb Pratt & Whitney J57-P-1 turbojet, launched using a pair of solid rocket boosters. It would cruise at subsonic speed to its target, using a combination of inertial and stellar navigator guidance. The target was attacked with a 4 Megatonne W39 nuclear device.

The SM-62 Snark entered operational service with the 702nd Strategic Missile Wing (SMW) at Presque Isle Air Force Base, Maine in March 1960, and was withdrawn from service in June, 1961, as the weapon was no longer considered survivable in combat. Only 51 production Snarks were built, with 30 rounds deployed by the 702nd SMW.

A far more strategically important weapon was the supersonic North American GAM-77 Hound Dog, later redesignated the AGM-28. Developed from 1956 and deployed in 1960, the AGM-28 remained in use until the early 1970s. North America made good use of numerous components developed for the SM-64 Navaho intercontinental cruise missile, cancelled in 1958.

The Navaho did not achieve operational status but is significant in illustrating the thinking of that period. It was to be a 3,500 nautical mile range Mach 3.5 ramjet GLCM powered by a pair of RLJ-47 engines, and using a vertical launch arrangement with a liquid oxygen and kerosene powered booster. Bedevilled by technical problems arising from its complexity and the immature technologies used, the high flying Navaho would have been an easy target for Soviet 1960s SAM systems.

The AGM-28 was a large 700 nautical mile range 10,000 lb cruise missile, powered by a single J52-P3 turbojet, capable of exceeding Mach 2 in cruise, and armed with a dial-a-yield W28 0.7 to 1.4 Megatonne nuclear device. The AGM-28 was also important in introducing stellar-inertial guidance into a mass production operational cruise missile.

The Hound Dog deployed operationally on the B-52 in late 1959, and more than 700 GAM-77 rounds were built for the USAF. It was superceded by an improved GAM-77A, with the Kollsman Instruments KS-140 stellar navigator integrated into the inertial guidance, and radar absorbent materials added to improve survivability. Around 430 GAM-77 rounds were upgraded to the GAM-77A/AGM-28B configuration, which remained in use until the missile's replacement after 1975.

No discussion of US Air Force cruise missiles of this period would be complete without the SLAM/Pluto nuclear powered ramjet project (Supersonic Low-Altitude Missile), work on which was well

Left: Launch of the massive 6,000 nm intercontinental range SM-62 Snark GLCM. This missile experienced numerous development problems with many test vehicles lost. One Snark, launched from the continental US, was found by a farmer in Brazil in 1982, having lost its way during a test flight.

Right: The nuclear ramjet propelled SLAM/Pluto project never reached production. The intent was to build a 60,000 lb missile which would penetrate at 1,000 ft AGL and Mach 3.5 speed, armed with more than two dozen nuclear warheads. The SLAM produced a radioactive exhaust plume in its wake.

advanced by the contractors, Ling-Temco-Vought and Marquardt, and Lawrence Livermore Labs, who were developing the powerplant when it was cancelled in 1964.

The SLAM/Pluto was a massive cruise missile by any standard, with a launch weight of the order of 60,000lb. It was to be powered by a 500 MegaWatt nuclear reactor, ingesting air and using the reactor to heat it and expel it to generate thrust. The concept of operations was that this GLCM would be rocket boosted from a hardened shelter, climb under rocket thrust until sufficient speed and altitude were reached to start the ramjet, the missile then cruising at Mach 4.2 until it reached the target area, upon which it would descend to 1,000ft and penetrate defences at Mach 3.5. Targets would be attacked by ejecting up to twenty-six individual nuclear warheads as the targets were overflown. Once the warheads were expended, the SLAM would terminate its sortie as a 'dirty bomb' scattering the reactor over the intended target.

With nuclear propulsion this missile had a high altitude range cited at 100,000 nautical miles and a low altitude range cited at 11,500 nautical miles, sufficient for the missile to loiter for considerable time before initiating its attack run. Byproducts of the missile's low altitude flight profile were a 150 deciBel acoustic shockwave footprint, and a radioactive dust trail, which presented a range of deployment and flight routing issues.

Ballistic missiles were deployed instead of the SLAM/Pluto missile.

Royal Air Force Cruise Missile Developments

Britain, like the United States and the Soviets, invested heavily in a strategic bomber force for the delivery of nuclear weapons. Britain's three heavy bombers, the Valiant, Victor and Vulcan, were subsonic designs initially developed to penetrate high and fast, to the extent that nuclear anti-flash reflective white paint was employed early in the service life of these bombers. The difficulty the RAF recognised during the 1950s was that improving supersonic performance in Soviet fighters, and the emerging PVO SAM force, would take a heavy toll on these aircraft, blunting the deterrent effect they produced and thus challenging the bombers very purpose.

The Avro Blue Steel supersonic cruise missile was developed after 1954 under OR.1132 'stand off bomb' to allow the V-bombers to standoff and attack from 100 nautical miles range, putting the bomber out of the reach of even the best Soviet long range SAMs of that era.

Unlike US designs of that period, the Blue Steel was liquid rocket powered. The missile airframe had an unusually large diameter for its size, to accommodate the bulky UK designed thermo-nuclear warheads of the period, but production weapons were fitted with the more compact Red Snow, claimed to be based on the W28 used in the Hound Dog.

The powerplant for the Blue Steel was a two-chamber Armstrong Siddeley Stentor Mk.101 designed to deliver 6,000 lb cruise thrust and 24,000lb dash speed thrust. The Blue Steel was to cruise at Mach 1.5, and attack at Mach 3. The Stentor was fuelled with a mix of kerosene and hydrogen peroxide oxidiser.

Test trials of the Blue Steel were conducted at Woomera, and a missile airframe remains on display at RAAF Point Cook.

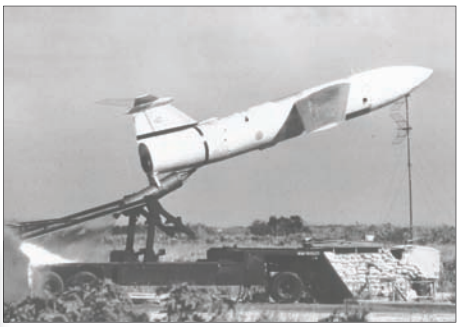
The Blue Steel entered RAF service in 1963 and was withdrawn in 1970, with 48 operational rounds built for the RAF. Planned extended range ramjet powered and low altitude variants were cancelled.

The Blue Steel makes an interesting comparison against its contemporary, the Hound Dog. The US missile was much longer ranging but slower and thus easier to intercept using SAMs.

Perhaps the greatest impact the Blue Steel produced was as the conceptual model for the Soviet Raduga Kh-22 Burya / SA-4 Kitchen, and KSR-5 / AS-6 Kingfish, of which thousands were built.

Early Cold War cruise missiles developed and deployed by the US and UK provided key nuclear deterrence capabilities until Soviet air defence advanced to the point that highly detectable high flying supersonic cruise missiles could not survive. The next evolutionary step were modern cruise missiles, represented by the US AGM-86, R/B/UGM-109 Tomahawk and their Soviet equivalent, the Kh-55 Granat family.

No less importantly, these US and UK designs provided conceptual templates for airframe, guidance and deployment designs which were aggressively copied by Soviet designers, resulting in two generations of weapons, many of which continue in production today.



The US Air Force Martin B-61 Matador was a contemporary of the Regulus I, a subsonic GLCM armed with a 1 Megatonne warhead. It, and its depicted successor, the CGM-13 Mace, were retired by the mid 1960s.

The cancelled N.A.A. Navaho was to be a 3,500 nautical mile intercontinental range nuclear armed Mach 3.5 ramjet GLCM.

The N.A.A. AGM-28 Hound Dog was a supersonic 700 nautical mile range class cruise missile, carried operationally by the B-52 fleet until 1975. Over 700 were built. It used a liquid propellant booster stage for launch and climb to cruise altitude.

Poor quality image of a Blue Steel being released from an RAF V-bomber. The Blue Steel became the technical template for the Soviet Kh-22 and KSR-5 missiles, of which thousands were built.