Appendix

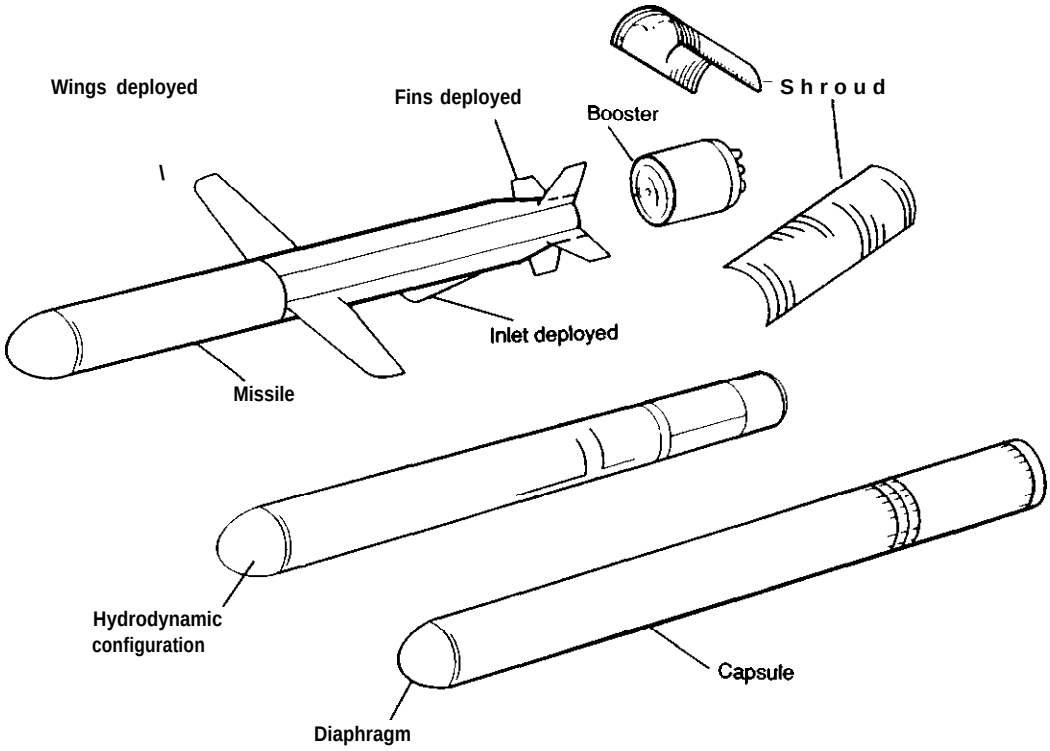
A cruise missile, sometimes referred to as a pilotless jet aircraft, is an unmanned, aerodynamic vehicle powered by some form of jet engine. Guidance for the missile can be programmed autonomous ("launch and leave"); command (i.e., remotely piloted); or semi-autonomous. Arriving at an agreed definition of a sea-launched cruise missile would be the first step in any future arms control treaty and would have important implications for treaty monitoring. For example, a treaty could distinguish among cruise missiles by their maximum range, maximum speed, type of propulsion, or type of warhead.

Typically, the warhead and guidance system for a cruise missile are contained in the front part of the missile; the engine is in the rear and fuel occupies most of the midbody. Most currently deployed cruise missiles fall into one of two categories: long-range systems powered by highly efficient, miniature turbofan engines, and short-range systems powered by less efficient, and presently less expensive, turbojet engines. Long-range cruise missiles fly at subsonic speeds in order to conserve fuel (a notably exception was the experimental Soviet SLCM, the SS-NX-24, which used an air-turbo rocket engine and flew at very high altitudes to reduce drag).

Cruise missiles initially evolved for two distinct missions-long-range attack of strategic targets on land and short-range attack of targets at sea or on the battlefield. These missions can now be accomplished by outwardly similar missiles. The latest development in cruise missile technology has been to design, in effect, a single weapon, which can be armed with a nuclear or a conventional warhead and adapted for launch from the ground, aircraft, surface ship, or submarine.

U.S. and Soviet antiship SLCMs were first developed and deployed in the 1950s, but the military utility of these systems was limited by their large size, short range, and

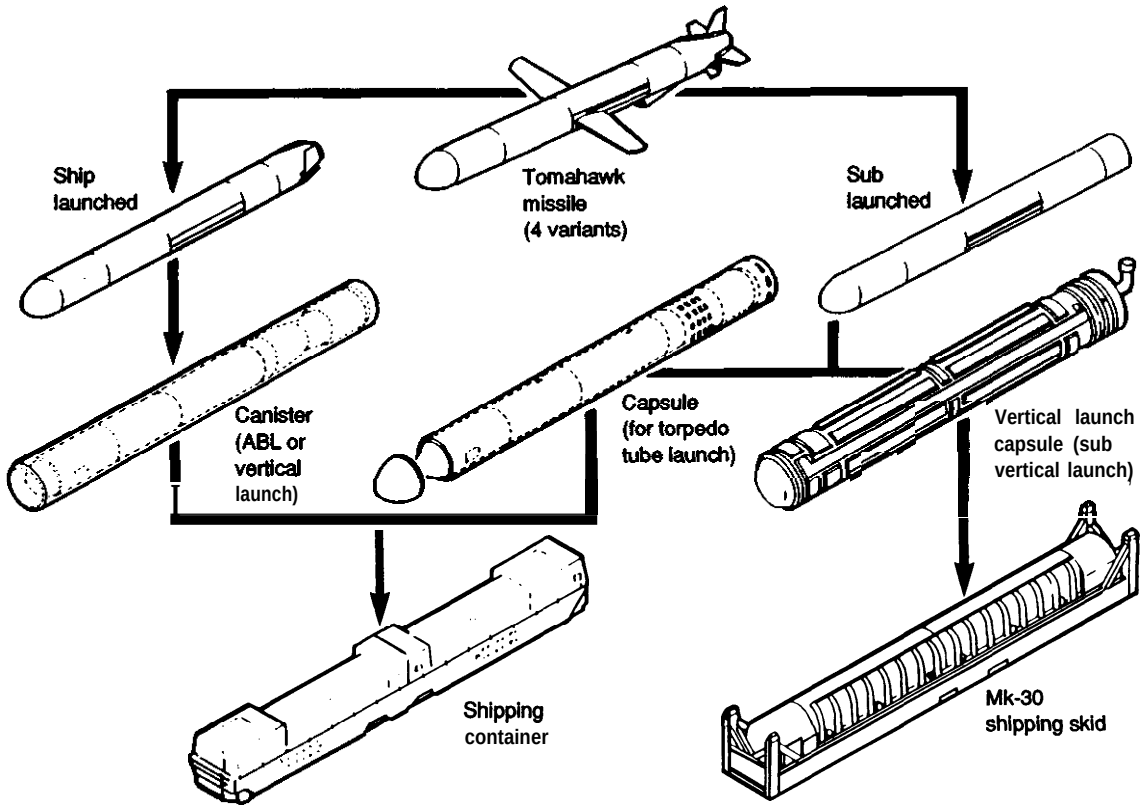
Figure A-l—Tomahawk Missile System is an All-Up Round



Each of the four Tomahawk SLCM variants-three for land-attack missions and one for antiship missions-is delivered to a ship or submarine as an all-up round (AU R), an encapsulated missile in a dry, gaseous nitrogen atmosphere. The Tomahawk AUR consists of the missile that flies the mission, the booster that starts its flight, and the container (canister for ships and capsule for submarines) that protects it during transportation, storage, and stowage. The container also acts as a Launch tube for the missile.

SOURCE: Department of Defense.

Figure A-2-SLCM Canisterization and Encapsulation Sequences



SOURCE: Department of Defense.

inaccuracy. In addition, early systems were not capable of underwater launch. Land-attack SLCMs from this period were similarly hampered by these limitations. The technologies that would make long-range, land-attack SLCMs practical did not reach maturity until the 1970s. The Soviet SS-N-21 "Sampson" and the U.S. "Tomahawk" nuclear land-attack missile (TLAM-N), first deployed in 1987 and 1983, respectively, exemplify these developments. Both fit into standard-size submarine torpedo tubes, have maximum ranges of approximately 2,500-3,000 km, and are capable of delivering a moderate yield nuclear weapon with an accuracy that maybe sufficient to destroy even hardened targets such as missile silos and launch control centers. SLCMs are relatively inexpensive weapons (if the cost of the weapon platform is neglected) —for example, the production cost of a nuclear Tomahawk, exclusive of the cost of the nuclear warhead, is about $1 million.

The United States also deploys conventional versions of its nuclear land-attack SLCM. Conventional land-attack Tomahawks can deliver 1,000 pounds of chemical high-explosive at ranges up to approximately 1,300 km. They can be armed with either a single 1,000-pound warhead (TLAM-C) or with a submunitions dispensing system (TLAM-D). The Tomahawk submunitions consist of 166 3.4-pound combined effects (armor piercing, fragmentation, and incendiary) "bomblets" that can be dispensed in 24 separate packages. Tomahawks are delivered to the Navy as "all-up" rounds. (See figure A-1 and A-2.) Planned "Block 3" upgrades to the unitary warhead of the Tomahawk include lighter weight and smaller volume warheads that will still be capable of producing the same explosive force as current models. Using the extra volume for fuel will extend the maximum range by approximately 50 percent. The Soviet Union has not developed a conventional variant of its long-range nuclear SLCM thus far. OTA believes that the "long pole" in the development of such a weapon would be the design of a guidance system accurate enough to allow target destruction using a chemical high-explosive warhead. (The United States accomplishes this with the DSMAC (Digital Scene Matching Area Correlator) guidance system. DSMAC is used on the TLAM-C and TLAM-D to update the inertial guidance system during missile final approach-to-target.)

U.S. antiship SLCMs are the short-range conventionally armed Harpoon and the long-range conventionally armed TASM (Tomahawk antiship missile).

Photo credit: Jane's Strategic Weapon Systems

A "Nanuchka" class corvette with two triple SS-N-9 "Siren" surface-to-surface missile canisters on deck.

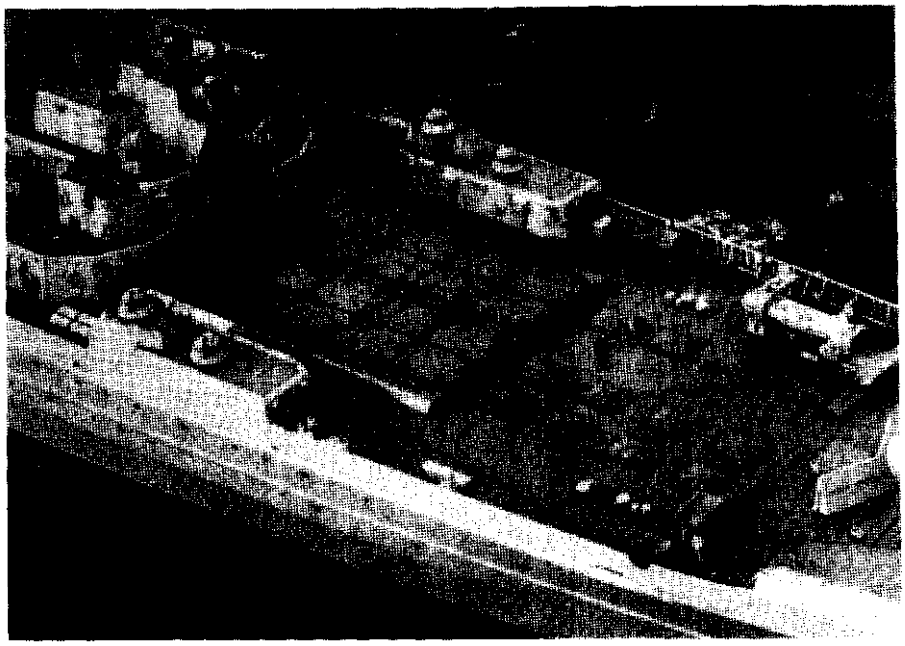


Photo credit: Jane's Strategic *Weapon Systems*

The Soviet battle cruiser Kirov, photographed in 1980, showing the 20 hatches on top of the vertical launch tubes for SS-N-19 "Shipwreck" missiles, with the smaller 12 hatches on the right of the picture for the SA-N-6"Grumbie."

Antiship SLCMs differ from land-attack SLCMs in their guidance and, in some cases, in their propulsion. Because some targets will beat relatively close range, an antiship SLCM can be designed to trade fuel efficiency for increased speed or a less fuel-efficient (but less expensive) engine. The Soviet Union has deployed several antiship SLCMs that have a supersonic capability; however, U.S. antiship SLCMs are designed to fly only at subsonic speeds.

The Soviet SS-N-21 and the U.S. Tomahawk are inherently stealthy. Their small size and small engines (600-pound thrust for Tomahawk) give them much

smaller radar, infrared, and acoustic signatures than manned bombers. In addition, these SLCMs can be programmed to fly sea-skimming flight profiles over water and low-altitude, terrain-following, flight paths over land.

On U.S. surface ships, Tomahawks are stored and launched from either an armored box launcher (ABL-four launch tubes protected by heavy armor and mounted on the ship's deck), or from an array of 32 or 64 vertical launchers (the vertical launch system, VLS) set into the deck. Vertical launchers can fire any missile adapted for vertical launch. For example, in addition to Tomahawk SLCMs, the United States currently deploys the Standard missile in VLS. The Standard missile is a conventionally armed solid-fuel rocket that could be used to defend against cruise missiles, aircraft, or ships. A foldable crane located in three VLS cells is used to reload Standard missiles from internal magazines, but it cannot be used to reload Tomahawks.

U.S. attack submarines (SSNs) can launch Tomahawk or Harpoon SLCMs through torpedo tubes. Some Los Angeles-class submarines have also been modified to allow vertical launch of Tomahawk from 12 dedicated launch tubes mounted outside the submarine's inner pressure hull (this particular vertical launch system is referred to as the "capsule launch system"). Soviet surface ships launch SLCMs with tube launchers similar to U.S. box launchers or below-deck launch systems that are similar to U.S. VLS systems. Currently, Soviet surface ships are capable of launching only antiship cruise missiles (i.e., they have not been deployed with SS-N-21s). In contrast, the U.S. launches both antiship and land-attack SLCMs from its surface launchers. The U.S. VLS system also differs from the Soviet system in that its launch tubes are perpendicular to the deck, while the Soviet launch tubes are inclined.

The former Soviet Union deployed numerous submarines dedicated to SLCM launch (SSG/SSGNs), but these submarines were loaded only with antiship SLCMs. Long-range, land-attack SS-N-21s could be adapted for launch from any vessel with a standard-size torpedo tube. The 1989 edition of the Pentagon's ***Soviet Military Power*** stated that the Soviet Union could deploy the SS-N-21 on "specific classes of properly equipped current-generation or reconfigured submarines." Among the candidate platforms listed for the SS-N-21 were Akula- and Victor-class attack submarines and "Yankee Notch" submarines. The Yankee Notch is a former Yankee nuclear-powered ballistic missile submarine (SSBN) modified to fire SS-N-21s (extensive changes have been made to the center section, thus the term Yankee Notch or Yankee Notch-Waist). The nuclear-powered Yankee, which first became operational in 1%8, is being replaced by more capable Delta and Typhoon-class SSBNs.