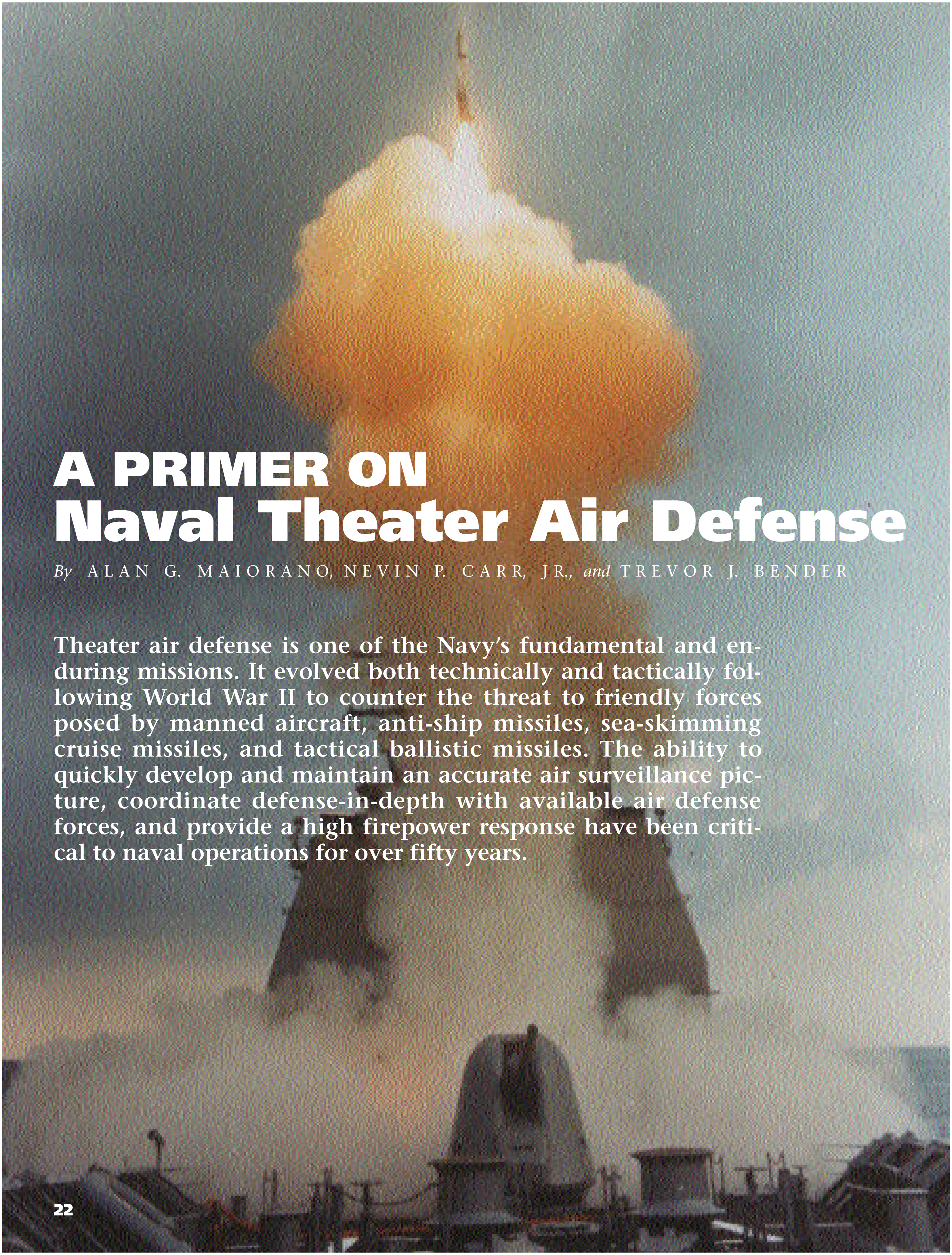

A PRIMER ON Naval Theater Air Defense

By ALAN G. MAIORANO, NEVIN P. CARR, JR., and TREVOR J. BENDER

Theater air defense is one of the Navy's fundamental and enduring missions. It evolved both technically and tactically following World War II to counter the threat to friendly forces posed by manned aircraft, anti-ship missiles, sea-skimming cruise missiles, and tactical ballistic missiles. The ability to quickly develop and maintain an accurate air surveillance picture, coordinate defense-in-depth with available air defense forces, and provide a high firepower response have been critical to naval operations for over fifty years.

U.S. Navy

Kamikaze attack on *USS Bunker Hill* off Okinawa, 1945.

In the 1970s and 1980s, system development, tactics, and training were largely driven by the threat of massed Soviet missile attacks far at sea from long-range bombers, missile ships, and submarines. The decline of the Soviet threat and simultaneous proliferation of offensive weaponry to littoral states prompted a reevaluation of the Navy's contributions to the new world order. First outlined in . . . *From the Sea*, and updated in *Forward . . . From the Sea*, the focus of the Navy has shifted from an open-ocean threat to near-land operations against increasingly capable regional powers. Now the global maritime threat has been replaced by regional challenges that are equally as demanding for theater air defense forces. This change in focus has altered the primary naval air defense mission from a blue-water, open-ocean defense to a more offensive extension of naval air defenses overland. Naval theater air defense objectives are clear:

kamikazes revealed shortfalls in air defenses and ushered in an era of systems development

- initiate and maintain control of airspace early in a crisis or conflict
- permit safe entry of follow-on U.S. and allied forces into a theater of operations
- protect and support forces and facilities ashore.

◀ *USS Bunker Hill* firing missile from vertical launching system.
U.S. Navy

Navy air defense capability is built on a solid foundation of leadership in combat systems integration, experience in combined arms warfare, and decentralized command and control. These are the key strengths on which to build a theater air defense capability in the 21st century.

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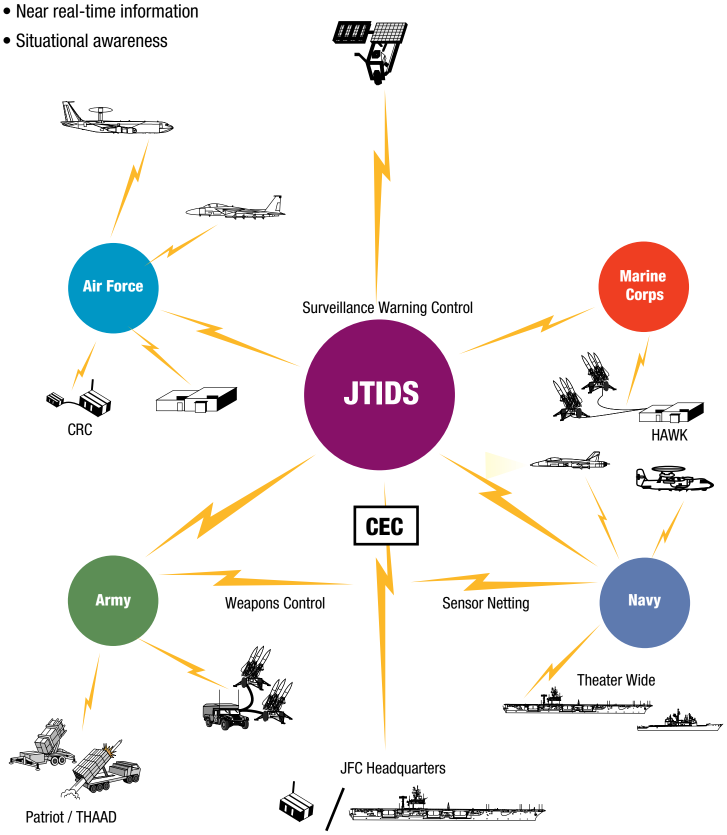
Evolution Based on Experience

In the 1920s, General Billy Mitchell introduced a new threat by sinking a target battleship, thereby demonstrating the vulnerability of ships to air attack. Early naval air defenses relied upon massive, uncoordinated fire from anti-aircraft artillery such as 20mm, 40mm, three-inch, and five-inch guns. In those days, the battlespace extended only to the visual horizon, normally less than 15 miles. Air defense was made up of a series of local anti-air battles fought close aboard, strictly in self defense. Ships counted on visual sightings and primitive, inaccurate voice communication. Subsequent advances in precision aerial bombing and torpedo bombing during World War II posed severe threats which demanded defensive capabilities.

Deploying air search radar on naval ships dramatically altered the air defense environment. Long-range detection of the enemy enabled carrier-based fighters to attrite incoming raids a number of miles from the target task force. Early detection of distant raids provided defending ships with critical reaction time to initiate limited coordination of fire among friendly units under attack. Early detection and advance warning were essential to effective air defenses when kamikazes appeared in 1944 as the first true guided missiles. Tactics evolved quickly, including tightly grouped defensive ship formations and picket ships for early warning. Although primitive by current standards, the concept of effective, coordinated defense-in-depth took shape. But tactics were limited by stand-alone equipment, intermittent voice radio communications, primitive analog fire control computers, the inability to rapidly exchange accurate target position data, and the lack of a long range weapon. The war ended before an effective anti-aircraft defense was deployed. Nonetheless, the lethality of kamikazes revealed

Theater Air Defense Joint Architecture

- Theater CINC flexibility
- Seamless information transfer
- Interoperability with services / allies
- Weapon coordination
- Near real-time information
- Situational awareness



shortfalls in air defenses and ushered in an era of systems development.

The advent of unmanned missiles and long-range Soviet bombers led the Navy to develop defensive weapons and enhance ship-to-ship coordination. Transitioning from attacking aircraft to faster, smaller anti-ship missiles required cultural as well as technological changes in warfighting. Paradigms of air defense based on lookouts and shipboard guns were scrapped in favor of systems that integrated radar data, high speed fire control computation, and surface-to-air missiles (SAMs).

In the 1950s the Navy began deploying three guided SAM variants known as 3–T missiles: long-range Talos (65+ miles), medium-range Terrier (20 miles), and short-range Tartar (10 miles). Simultaneously, a large-scale program to convert previously non-missile ships to missile shooters was initiated with vessels capable of firing one of these missiles. A guided missile capability was incorporated in the designs and construction of several new classes of cruisers and destroyers by 1957, built from the keel up with air defense as a primary mission.

The combination of advancements in air search radars, deployment of 3–T SAMS, and shift to carrier-based fighter jets significantly improved air defense capabilities. The extension of target detection ranges, coupled with long-range fighters and missiles, expanded the battlespace of naval task forces to over 100 miles. Targets could now be engaged far beyond the visual horizon. New command, control, and coordination requirements were placed on naval air defense forces.

Despite significant advances in radar and SAM technology, performance shortfalls against an increasingly demanding threat highlighted weaknesses in stand-alone systems. Improvements in search radars, fire control radars, computers, launchers, missiles, and displays were piecemeal, built and supported individually with design and development agencies working independently. Search radars and display systems were managed in the Bureau of Ships while fire control radars, computers, guns, and missile launchers were handled by the Bureau of Ordnance. Often the first chance to test and operate multiple system components occurred after installation. Combat systems were wired together by shipbuilders, not system engineers. Lack of technical and organizational coordination created expensive and nearly insurmountable system interface problems. The reaction time gained by increased radar detection and target engagement range was offset by manual data evaluation, display, and dissemination. Continuous attention and action were required to deal with a growing volume of tactical data required by a disparate set of warfighting equipments.

The transition from guns to missile batteries was the first step in a series of initiatives to address high speed threats. In the late 1950s, the Navy recognized that technology would one day permit an enemy to develop weapon systems that could overwhelm first generation missile sensors and equipment. The flaw was in the speed and reliability of target information exchange between ships and aircraft. Voice communication was too slow and unreliable to be effective against large numbers of supersonic missiles launched by regiment-size Soviet bomber formations. As missiles could carry nuclear warheads, ship formations became more dispersed to minimize damage from single missile strikes, further aggravating air defense coordination. Faster and more reliable means of surveillance and identification data exchange were required.

The Navy tactical data system (NTDS) was introduced in 1958, the world's first shipboard tactical data system based on programmable computers. This was an initial step in the integration of multiship systems in a force-wide air defense system. Conceived as a means of exchanging air surveillance radar information throughout a task force, NTDS replaced and automated older manual displays and reduced dependence on voice communications for air defense. NTDS incorporated target position and identification information from a ship's sensors, as well as information inserted over an electronic data link by other ships in a task force, into one computer-managed track file. Data were exchanged and updated among ships several times per minute via an electronic data link known as Link-11. Early warning and reaction time, information exchange speed, and information reliability improved strikingly. Link-11 data standards and protocols were adopted by Britain and Canada and soon by NATO as a whole. The system's efficacy is reflected in the fact that NTDS, upgraded over the years to keep pace with threat and technology advances, remains at the heart of naval and joint air defense management systems today.

E–2A Hawkeye expanded air defense surveillance and battlespace beyond a ship's radar horizon

NTDS linked long-range surveillance sensors and surface-to-air weapons for the first time with an automated information management system to support the coordinated defense of widely distributed forces. Air defense tactics continued to evolve as individual ships became more potent defenders and anti-air warfare commanders (AAWCs), responsible for defending battle groups or task forces, became capable of monitoring battlespace beyond the range of their organic sensors. With more reaction time and reliable target identification and position data, further decentralization of air defense command and control became possible. Able to oversee numerous individual ship engagements, AAWC could quickly and reliably provide command by negation or direct specific target assignments when necessary. In response, a centralized control/decentralized execution anti-air warfare organization was implemented. Area defense provided from forces at sea or near land became a reality. With an information exchange system (NTDS) and the requisite firepower (3–T missiles) coordinated through an effective command and control mechanism, naval forces could regulate the air battlespace within a designated theater.

These tactical and technical advances came none too soon. The Soviets began deployment of a series of air and surface launched cruise missiles in the 1960s, including the subsonic Styx. The following year Badger C and Bear B/C long-range bombers were equipped to fire supersonic, nuclear-capable AS–2 Kipper and AS–3 Kangaroo air-to-surface missiles from ranges in excess of 100 miles. The launch range of some weapons extended beyond the surveillance range of radars aboard ships. Undetected missile launch and supersonic speeds combined to reduce reaction time, while increasing raid density threatened to saturate defenses.

The Navy recognized that stand-alone defense components would eventually not be capable of responding to air threats. Search and fire control radars were based on analog technology and first generation computers. SAM launchers depended upon hydraulic loading operations and large rotating magazines, restricting the rate of fire to one or two missiles a minute. High speed, low altitude cruise missiles stressed existing missile fuzing systems. In combination, the stand-alone components were manpower intensive and could not react in the required time.

The widespread introduction of digital and other electronic technologies initiated a period of combat system improvements that affected almost every aspect of sensor, weapon, and launcher design. This development included true combat system integration for the first time. In 1963, the 3–T missile effort transitioned into a dual-track Standard missile (SM) program which incorporated earlier designs. Though Talos was discontinued, Tartar became SM–1 (MR or medium range) and Terrier became SM–1 (ER or extended range). Responding to the threat of cruise missiles, SM had an improved autopilot, proximity fuzed target detecting device, greater range, jamming resistance, and inertial navigation to guide the missile from the launch ship to a designated homing basket.

Advancements in combat system capability were not limited to ships. In 1964, the E–2A Hawkeye airborne early warning aircraft entered the fleet. With an aircraft version of NTDS to exchange track data with other ships and aircraft, Hawkeye expanded air defense surveillance and battlespace beyond a ship's radar horizon, restoring costly reaction time for fleet air defense units. With the advance warning provided by E–2 airborne radar, carrier-based fighters and guided long-range SAMs became the first line of air defense for task forces as tactics stressed "shoot the archer" before an arrow was launched. Fighter and ship actions, target assignments, and the employment of weapons were initiated by preplanned operational orders and coordinated via

NTDS by AAWC. Together, missile ships, E–2s, and fighters exchanged data continuously via Link-11 to mutually reinforce defense-in-depth. This tactic focused on heavy attrition of incoming raids, forcing enemy aircraft and missiles to penetrate multiple, coordinated layers of defense.

Vietnam provided the first test of new air defense capabilities. Not only did systems prove to be reliable and effective for air defense of forces at sea; the Navy also found that it could extend the air defense envelope over land in support of forces operating near the coast. Various enemy air bases were within shipboard and E–2 radar range, allowing naval forces to monitor and respond to launch and recovery activities. In 1965, the guided missile cruiser *USS Long Beach* engaged two MiGs detected 60 miles inland with ship-launched SAMs. From offshore, naval forces showed that they could protect friendly forces operating in port facilities, beachheads, and coastal airfields.

Theater Air Defense Matures

Throughout the conflict in Vietnam, enemy aircraft frequently flew in the same battlespace as friendly air forces. Tactics and procedures proved sufficiently responsive and flexible to enable AAWC to manage the complex battlespace as well as adjust to various operating environments and threat conditions. Air defense tactics were tested and refined. Fleet air defense identification zone procedures were drafted to control the intense air surveillance and identification environment over the Gulf of Tonkin and to confirm the identity of returning friendly aircraft. Later, the procedures were used extensively to track, identify, and deconflict thousands of flights over land and water in the Persian Gulf War. Zero blue-on-blue engagements remains an essential air defense criterion.

In spite of advances, new dangers from high speed sea skimming cruise missiles required more than incremental improvements. Rotating radars updated data too slowly on targets travelling at supersonic speeds. A widespread reliance on stand-alone combat system components imposed manpower intensive and time consuming steps in the detect-track-engage sequence. A shipboard combat system was required to automate manpower intensive functions and to enable employment of on board weapon systems more rapidly. In response to these air defense challenges, the Navy began full scale development of the Aegis shipboard weapon system in 1973.

Aegis combined virtually every aspect of anti-air warfare management in a fully integrated, multi-sensor, computer-aided combat system. Introduced operationally in 1983, the heart of the Aegis weapon system is the SPY–1 phased array radar, which provides automatic detection and fire control quality tracking for hundreds of targets simultaneously. Since its radar also communicates directly with SMs in flight to provide midcourse guidance information, the demand to dedicate a separate fire control radar for the duration of a missile's flight is eliminated. Target illumination, required for semi-active homing missiles, is provided only for the final seconds of missile flight, or endgame. The result is a dramatic increase in the number of simultaneous engagements, since the ship is no longer limited by the availability of tracking fire control directors. The uniqueness of the fully integrated Aegis weapon system is not only in the increased number of actions completed automatically, but also in the ability of operators to alter the conditions under which actions can be performed using automated doctrine. This is accomplished by programmable "if-then" statements that associate track criteria such as speed, altitude, IFF (identification, friend or foe), and range with a specific automatic or semi-automatic action.

Throughout the Aegis design and development process, five performance factors were used to evaluate its capabilities: reaction time, firepower, electronic countermeasure and environmental resistance, continuous availability, and coverage. With design efforts focused, new initiatives and potential warfighting capabilities had to contribute to the improvement of one or more of these key performance factors. The era of stand-alone components and black boxes, which required added shipboard manpower and unique logistics tails, had ended. In the past twenty years, these factors successfully guided every modification or upgrade to the Aegis system.

Three other recent developments promise to have a dramatic impact on theater air defense: cooperative engagement capability (CEC), joint tactical information distribution system (JTIDS), and the proliferation of tactical ballistic missiles. CEC is a computer-based information exchange system that allows ships or aircraft to remotely share raw radar measurement data at near real-time exchange rates. Cooperative engagement is a natural result of tactical computer networking which captures major technological and reliability advancements in high speed computer processing and communications. With sensor netting fire control, quality sensor data can be exchanged among multiple cooperating units (CUs) including ships, aircraft, and ground forces, enabling participants to view the same tactical picture. The potential for force-wide automated doctrine to assist track evaluation, identification functions, and engagement decisions could optimize the speed,

Aegis cruiser launching multiple Standard missiles.

U.S. Navy

Combat information center aboard *USS Vincennes.*

U.S. Navy (Tim Masterson)

reliability, and utility of data exchange. Leaders can spend more time evaluating data than processing it.

CEC is being tested at sea today. Planned for operational introduction in 1996, it provides a quantum leap in data accuracy exchange between air defense forces. CEC-equipped forces will be able to engage hostile targets not seen on their sensors. The unparalleled accuracy of composite track data will allow missiles in flight to be handed off to other units better positioned to control the engagement endgame. The implications for coordination of air defense actions across the entire theater of operations are enormous.

In addition to CEC, JTIDS is being fielded by all services. This system is a high speed, secure, jam-resistant, voice and tactical data communications system over Link-16. It provides users with real-time position, status, special purpose, and identification information on friendly, unknown, and hostile tracks. The associated command and control processor (C^2P) introduces the capability to exchange information between tactical links (such as Link-11, Link-16, and CEC) and conduct multiple simultaneous data link operations. JTIDS will be the joint surveillance, warning, and command and control coordination net of the next century.

Finally, the widespread proliferation of tactical ballistic missiles (TBMs) is the most recent and threatening challenge to effective air defense. The Gulf War clearly demonstrated the tactical and strategic impact of TBMs and stressed the political and military importance of TBM defense. Like anti-ship cruise missile defense at sea, TBM defense of forces ashore has become an essential to successful operations in regional conflicts. To achieve this capability quickly and affordably, the Navy is capitalizing on prior investments in SM and the Aegis weapon system, which are being

U.S. Navy (*Independence* Photo Lab)

Task Force 70 in western Pacific.

modified to incorporate a TBM capability. Defense against TBMs from ships at sea will permit a safe entry of joint forces into a hostile theater.

The real-time exchange of tactical information among the services is fundamental to joint operations along littorals. With multiservice track data exchange provided by JTIDS and planned CEC deployment with real time shooter-to-shooter coordination, the C[2] architecture to orchestrate theater air defense units at sea and ashore will be in place. Synergism among recent air defense advances—Aegis, CEC, JTIDS, and theater ballistic missile defense (TBMD)—makes them force multipliers and ensures robust air defense and seamless transition to a joint command structure on arrival of follow-on forces.

flexible and robust tactics are in place to support Navy, joint, and allied air defense requirements

Since Vietnam, air defense tactics and procedures have been developed to address specific requirements of near-land and amphibious operations, emphasizing early coordination with marine and joint forces ashore. The reorientation of the Navy toward littoral operations imposes added C[3] requirements on commanders ashore. Forces operating ashore or in an amphibious objective area require defenses against cruise missiles, hostile air, and tactical ballistic missiles. The increasing emphasis on joint operations in regional conflicts established a clear demand for theater air defense battle management procedures to quickly transition from an area air defense commander (AADC) afloat to a counterpart ashore without loss of continuity.

Navy theater air defense is a model of jointness and the product of technological evolution, training, and operational lessons. AAWC is normally stationed on board an Aegis cruiser. In the open ocean they control and coordinate air defense assets, including guided missile ships and early warning, combat air patrol, airborne tankers, and electronic warfare aircraft. Land-based aircraft are coordinated through AAWCs who are responsible for proper identification, check-in, and flight safety. Coordination among air defense units is accomplished via Link-11 (increasingly by JTIDS) and optimized by CEC among shooters. Flexible and robust tactics are in place to support Navy, joint, and allied air defense requirements, near-land or in open ocean, including operations from crisis prevention to regional conflict.

The Navy theater air defense capability is derived from equipment, computer programs, tactics, and training that have evolved over fifty years. Periodic validation in combat has proven the efficacy of these capabilities and demonstrated the Navy's essential contribution to air defense. Driven by a changing threat, tactical and technological improvements have ensured that the Navy maintained its air defense capabilities in every potential theater of operations. For the foreseeable future, the Navy role in air defense will include four key components:

- fleet and amphibious objective area air defense against cruise missiles, aircraft, and tactical ballistic missiles
- overland area tactical ballistic and cruise missile defense of joint and coalition forces
- tactical TBMD for defense-in-depth and reassurance of allies
- joint theater air defense battle management and C[3] prior to and during transition to AADC ashore.

Navy ships and aircraft are forward deployed 365 days a year in virtually every region of the world. They can establish an air defense umbrella at sea or overland, bring organic firepower for area and self defense, and provide doctrinal automation to help watchstanders remain vigilant for long periods of time under stressful conditions. CEC-equipped, TBMD-capable Aegis ships (with SM block IV variants) ensure that the Navy stays in the vanguard of joint theater air defense in the 21st century. JFQ