

## THE MK 92 FIRE CONTROL SYSTEM

The Navy has selected the MK 92 Fire Control System to fulfill antiair warfare needs for several classes of smaller ships. The system controls the ship's gun and missile rounds for delivery onto the target. APL initially managed and conducted the MK 92 environmental test program and provided technical support to the Navy. More recently, the role of Technical Direction Agent was assigned to the Laboratory by the Medium Range Weapon Systems Program Manager, Naval Sea Systems Command.

The MK 92 Fire Control System<sup>1</sup> (FCS) provides independent, quick-reaction surveillance, acquisition, tracking, and designation of air and surface targets, and it controls the shipboard gun and missile systems. The system has a number of configurations that fulfill the fire control requirements of various classes of ships. Each configuration is capable of independent (stand-alone) operation. The Mod 1 configuration is used for gun control on U.S. Coast Guard medium-endurance cutters and U.S. Navy hydrofoil patrol ships. The Mod 2 is integrated with the shipboard combat system to provide both gun and missile fire control for the guided missile frigates of the U.S. and Royal Australian Navies. The Mod 5, similar to the Mod 1 configuration, is used on two classes of ships of the Royal Saudi Arabian Navy.

### SYSTEM DESCRIPTION

The MK 92 FCS consists of integrated, modular units. The full system is the Mod 2 configuration shown in Fig. 1, which contains the following:

1. A Combined Antenna System, consisting of a search antenna and a track antenna, that uses a single X band pulse transmitter for (a) a search radar that provides air and surface target detection, surface target track-while-scan, and a navigation mode; and (b) a monopulse tracking radar (which derives angle and range information from a single return pulse) that provides tracking of an air or surface target. In addition, it provides target illumination for missile guidance;
2. A second monopulse tracking radar that provides long-range air and surface target tracking. This radar, designated the Separate Tracking and Illuminating Radar, also provides target illumination for missile guidance;
3. Two weapon-control consoles and a standard Navy data-display console that provide integrated controls and displays for surveillance, detection, designation, tracking, engagement, and evaluation;

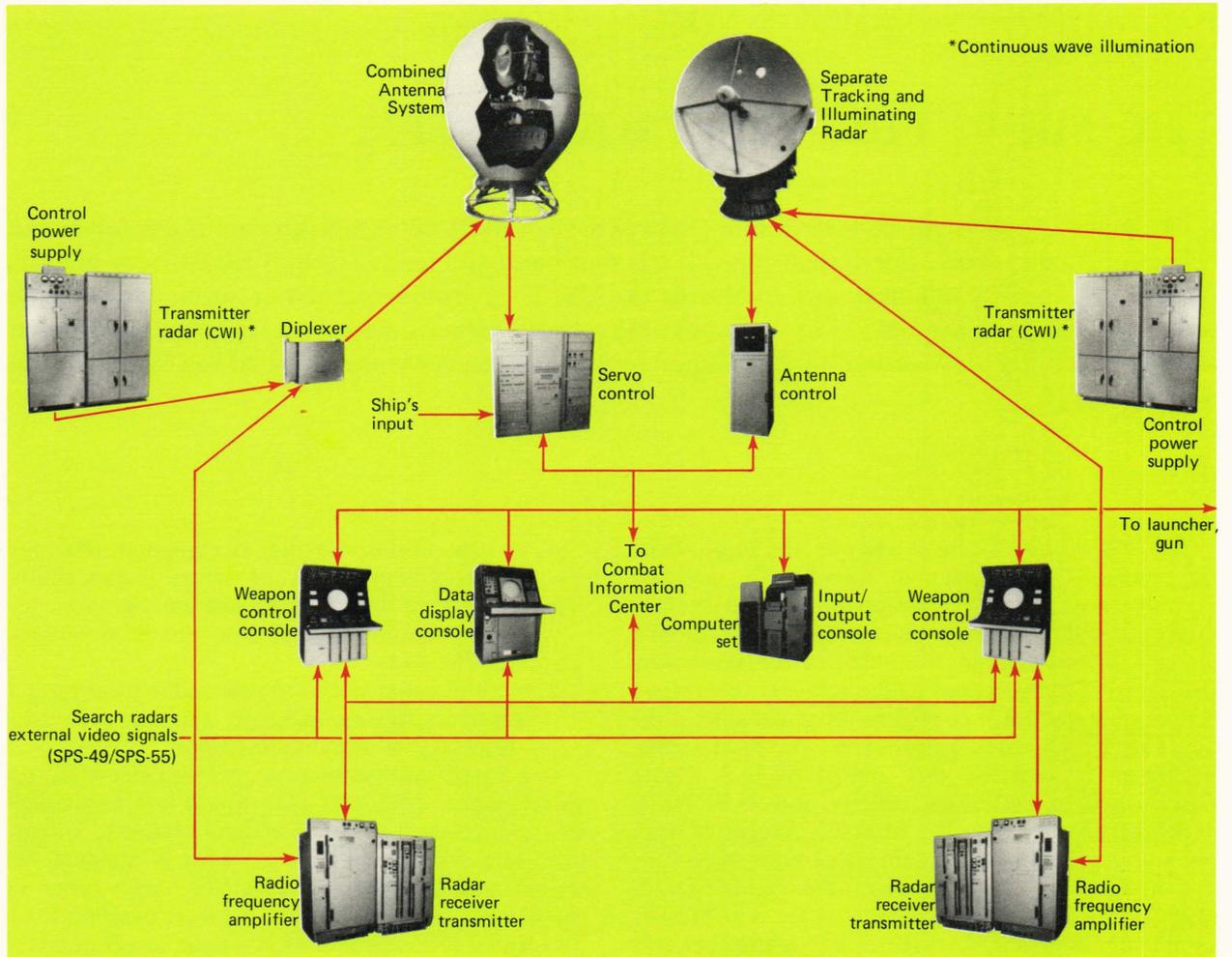
4. A general-purpose digital computer that performs computations of target engageability, aim points for the gun and missile launcher, and prelaunch orders for the STANDARD Missile; and
5. Several cabinets that house radar transmitters, receivers, power supplies, and servo controls necessary for system operations.

In a typical engagement, targets are detected by the search radar, evaluated as to threat and engageability, and assigned to a fire control channel. The appropriate weapon (missile or gun) is assigned for engagement and then is fired at the hostile target by the weapon control operator. A postfire evaluation is performed to determine whether the target survived the engagement and, if so, whether the weapon should be fired again.

Approximately half of the MK 92 FCS's to be built are planned for guided missile frigates of the FFG-7 (*Oliver Hazard Perry*) class shown in Fig. 2. These ships are intended primarily for escort protection of merchant, amphibious force, and underway replenishment ships. In addition to protection provided by the MK 92 FCS against aircraft and antiship missile attacks, other systems provide the capability to detect and attack hostile submarines.

### THE ROLE OF APL

As Technical Direction Agent, APL assists the Navy Program Manager in establishing initial program concepts, development of performance specifications, engineering assessment of program progress, implementation of improvements, and conduction of test and evaluation programs. The Laboratory reviews Engineering Change Proposals for their impact on system performance; participates as a member of the Computer Program Steering Group, which makes recommendations with respect to design and performance of the system; serves as a member of a Special Task Group that addresses immediate operational problems; and participates in monthly meetings concerned with system reliability, main-



**Fig. 1—Equipment constituting the Mod 2 configuration of the MK 92 Fire Control System. It provides two tracking and illuminating radars for missile or gunfire control, a surveillance radar, and the necessary consoles for control of the system.**



**Fig. 2—USS *Oliver Hazard Perry* (FFG-7), commissioned in December, 1977, was the first ship of a class of about 50 to be built. This 3600-ton ship, with a complement of 11 officers and 153 enlisted men, provides protection for underway replenishment groups, amphibious forces, and military and mercantile shipping.**

tainability, and quality. In order to improve reliability, trouble and failure reports are investigated to determine the causes of failure and to provide methods for correcting or ameliorating the conditions. System performance capability against various threats is also assessed and operational guidance is developed for more effective use of the system in tactical situations.

Several tasks involving lead responsibility by the Laboratory are discussed below.

### Environmental Test Program

The MK 92 FCS has undergone a series of environmental tests conducted by APL. The tests were performed in accordance with military standards to verify that the system performs satisfactorily when exposed to the effects of natural shipboard climates and wartime conditions.

The emphasis of the environmental test program was to ensure that the equipment can withstand the extremes of temperature, humidity, water spray, shock, and vibration that might be encountered during Fleet use. All tests were directed by APL, but some were conducted at the Naval Research Laboratory, at NASA's Goddard Space Flight Center in Greenbelt, Md., and at the Norfolk Naval Shipyard in Portsmouth, Va.

An environmental qualification test plan, prepared and published by the Laboratory, organized the tests into separate events, each representing a specific environmental test of a specific piece of MK 92 FCS equipment. Before and after each test event, an operational test was conducted to determine if any degradation was caused by exposure to the test environment. The entire system was also operated during as many of the events as possible. This permitted a number of equipment deficiencies to be detected that otherwise would not have been noticed. When the entire system could not be operated (during shock tests, for example), the equipment was given a thorough post-test inspection for physical damage.

Existing and special instrumentation was used extensively during all test events to ensure that the equipment was subjected to the specified environment and to determine the effects of that environment at different locations on the equipment. Many of the subsystems performed well under the imposed environmental conditions; however, there were events during which difficulty was encountered. When a problem arose, its cause was isolated and corrective action was taken. Frequently, immediate redesign was required in order to allow the tests to continue. These changes were coordinated with the FCS contractor to ensure incorporation in production units.

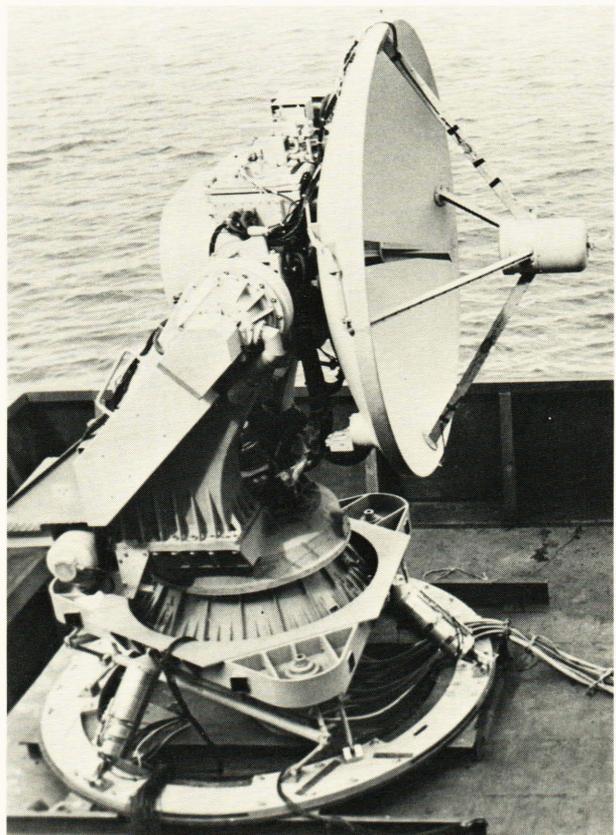
Of all equipment tested, the Separate Tracking and Illuminating Radar antenna has required the most extensive redesign as a result of the shock test. When the antenna failed to pass the high-impact shock tests, an antenna shock-reduction system was designed by APL and Sperry Corp. A prototype unit

was made and successfully tested on a special shock machine. A second prototype system was evaluated on a floating shock platform (shown in Fig. 3). Based on measurements obtained during the floating shock platform test, a revised design analysis was completed. Modifications were developed that will be included in the final design of the shock reduction system.

The overall result of the environmental test program has been to enhance the reliability of the MK 92 FCS. The correction of abnormalities discovered during the tests provides assurance that the system is ready to perform in combat and under adverse weather conditions.

### Antenna Pattern Improvement

The STANDARD Missile (Medium Range) uses a semiactive homing system for guidance to the target. (The term "semiactive" refers to the nonradiating or passive response of the missile to the actively radiating shipboard radar.) Specifically, the missile requires a continuous (nonpulsed) signal to both its forward-looking and its rearward-looking antennas. The MK 92 FCS radar provides target illumination by directing a narrow beam at the target. The missile



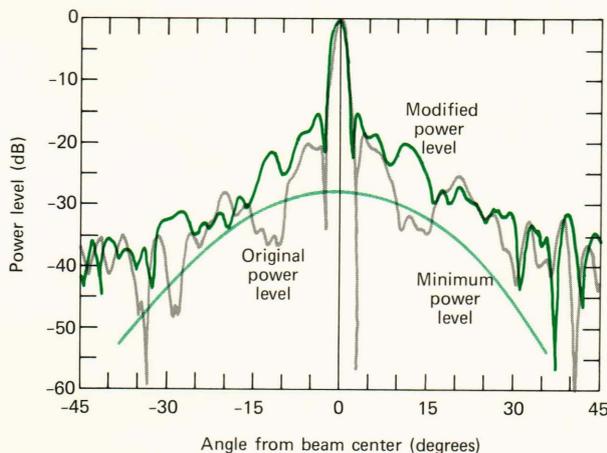
**Fig. 3—The Separate Tracking and Illuminating Radar antenna is shown mounted on the shock isolation system aboard a floating shock platform in Portsmouth, Va. This barge was towed to the test area, where a precisely placed underwater explosive charge was detonated to simulate the shock induced by a near-miss in wartime.**

forward-looking antenna receives this radiated energy after it is reflected from the target. The missile receiver compares this reflected signal with the reference signal entering the rear antenna directly from the FCS radar. Because the missile may not be in the narrow radar beam illuminating the target, the beam directly received by the missile must be sufficiently wide to ensure its reception. Target illumination is supplied either by the Combined Antenna System or by the Separate Tracking and Illuminating Radar.

Early firings conducted with the MK 92 FCS showed fluctuations in the direct reference signal that might occasionally degrade missile performance. It was suspected that the fluctuations were caused by nulls in the antenna pattern (areas in the wide beam where the signal power is low). APL was requested to investigate the antenna patterns of the MK 92 radars and make recommendations.

The Laboratory measured antenna patterns at two separate antenna-range facilities. The narrow- and broad-beam composite patterns of both illuminators were measured at high, medium, and low frequencies in the bandwidth. The results indicated the need to improve the illumination patterns. Modifications to both antennas were then developed, tested, and evaluated. The measured antenna patterns of several modified antenna configurations of the Combined Antenna System were compared with the specified power levels necessary to support STANDARD Missile flights. The configuration finally selected eliminated the nulls near the center of the beam and provided increased energy levels in the wide-angle portion of the beam (see Fig. 4). The changes to the Combined Antenna System developed by APL to improve the composite illumination antenna pattern are to be incorporated in all antennas in the Mod 2 configuration.

Although the original tests of the unmodified Separate Tracking and Illuminating Radar show



**Fig. 4—The composite illumination pattern in azimuth is shown for the Combined Antenna System before and after modification. The addition of several simple modifications to the antenna significantly improved off-axis portions of the pattern where low power levels existed.**

some low power levels, analyses of missile flight tests and measurements of antenna patterns indicate that the problem is minor. Also, the illumination modifications devised for this antenna were unable to improve performance enough to justify a change. Based on these pattern measurements, it has been concluded that the current design of this antenna precludes any significant improvement of the illumination pattern without an extensive redesign.

### Counter-Countermeasures Program

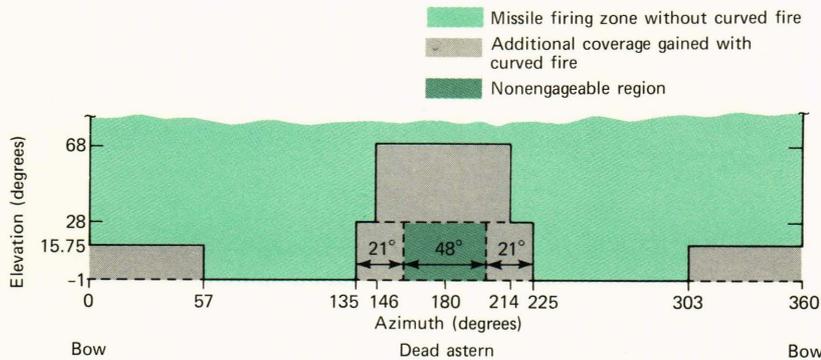
The electronic countermeasures threat continues to increase. Therefore, weapon systems require continual countermeasures assessments to determine future needs. Countermeasures tests were recently conducted with the MK 92 FCS. The Laboratory contributed significantly to the planning, instrumentation, and conduct of the tests. The jamming parameters to be employed were used for analyses prior to the tests in order to predict the performance of the system. After the tests, APL assisted in reduction and analysis of the test data presented in a report prepared by the Naval Ship Weapon Systems Engineering Station, Port Hueneme, Calif.

The test results reveal the need for improved system performance and establish the basis for a Counter-Countermeasures Improvement Plan, which is being prepared by APL. The results indicate that improvements should be made in the near future to maintain the system's capabilities in the presence of the anticipated electronic countermeasures threat during the 1980's. Further investigations will be required to establish long-term improvements.

### Digital Signal Processor Development

The MK 92 FCS search radar provides air and surface target detection capability. Two track-while-scan channels allow direct engagement of surface targets by using the search radar data. The search radar operates in various modes and has inherent radar parameters suited for that role. A fundamental limitation of the search radar processing, however, is that initial target detection and acquisition must be performed manually. In adverse environments, this can result in detectable targets being lost or unrecognized due either to interference on the display or to reduction of sensitivity initiated manually in order to reduce display interference.

The addition of a digital signal processor to the search radar permits adaptive threshold processing techniques to be used to eliminate clutter and interference from the radar display while essentially full target-detection capability is retained. The result is a significant increase in detection in clear, clutter, and countermeasures environments. The digital signal processor also allows full use of the radar's instrumented range. Both coherent (moving target indicator) video signals and noncoherent video signals are processed simultaneously, in contrast with the present system (which can use either but not both). In



**Fig. 5—Target intercept enhancement by means of curved fire technique for FFG-7 class ships.** The curved-fire technique allows firing at targets in many areas that would ordinarily require a change in the ship's heading to unmask the blind zones caused by the ship's structure. The technique was implemented by using software only.

addition, the processor provides an accurate estimate of the centroid position of each detected target. These centroids provide a convenient mechanism for increasing the number of surface and air track-while-scan channels, thereby permitting improved threat evaluation and system reaction.

The digital signal processor outputs centroid, status, and countermeasures data for use in a standard Naval Tactical Data System interface. This allows the search data to be input directly to any appropriate computer for automatic detection and tracking.

An advanced development model of the digital signal processor has been developed by APL. Its principal objectives were to demonstrate the feasibility of a digital signal processor for the search radar, to produce performance measures for verifying the expected effectiveness of the processor, and to provide a performance specification for an engineering development model integrated into the search radar. The advanced development model has successfully passed tests in the MK 92 FCS that were designed to determine centroid accuracy, to obtain radar elevation data, and to obtain data on performance in clear and countermeasures environments.

### Missile System Engageability Improvement

All U.S. Navy missile ships that use trainable launchers have nonpointing and nonfiring regions imposed to prevent possible launch into the ship's structure. These denied angles, or "launcher blind zones," impose significant tactical restrictions on target engagement. The nonpointing zone in the FFG-7 class ship represents some 29% of the possible hemispheric coverage of the missile system. When a computed launcher aimpoint falls within this area, the missile firing circuit is inhibited, and tactics require that the ship maneuver to provide a clear pointing zone to the target. To ameliorate this problem,

APL developed a curved-fire technique for the STANDARD Missile in FFG-7 class ships. This technique lessens the firing restrictions caused by the launcher blind zones by using the missile's maneuvering capability. Curved fire is especially attractive for the FFG-7 class because there is one target-tracking illuminator located forward and another located aft, permitting a target at any bearing to be illuminated by one of them. However, the single launcher, mounted forward, has a nonpointing zone aft that is 90° wide at low elevation angles; most targets in this region cannot be engaged without curved fire.

The curved-fire technique consists of logic in the fire control computer program that modifies the launcher orders when they would otherwise cause the launcher to go to a nonfiring zone. The missile can then be fired around the ship's superstructure. Because of modification of the launcher orders when in the curved-fire state, it flies a slightly less than optimum trajectory. The missile is directed to acquire the target off axis and, in effect, to maneuver around the obstruction to the target. APL conducted simulated missile flights with and without curved fire. The results indicated a negligible change in total time of flight and missile velocity and a slight increase in the minimum intercept range. The slight penalty paid for using suboptimal launcher orders is more than offset by the increased ability to engage targets without the requirement for the ship to maneuver in order to unmask the launcher. The potential improvement in missile coverage is shown in Fig. 5. Demonstration tests conducted aboard the USS *Oliver Hazard Perry*, using controlled aircraft, show that curved fire performs satisfactorily.

### NOTE

<sup>1</sup>The MK 92 Fire Control System is an Americanized version of the WM-25 family of fire control systems designed and produced by N. V. Hollandse Signaalapparaten B.V., the Netherlands. Sperry Corp. is producing the MK 92 for use by the U.S. Navy, the U.S. Coast Guard, and foreign customers.