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THE TALOS SHIP SYSTEM

The Long Range Talos missile placed requirements on the ship system that were beyond the state of the art during the entire lifetime of the Talos Weapon System. However, valuable lessons were learned that affected the development of later systems. The evolution of the ship system proved that patchwork techniques could not be used to satisfy tactical needs.

The initial concept of the Talos Weapon System was established in 1952 and included antiair, antiship, and shore bombardment capabilities. There were two types of missile, each having intercept ranges up to 50 nautical miles. One missile carried a command-detonated nuclear warhead, and the other, a proximity-fuze-detonated continuous-rod warhead. The nuclear warhead missile rode a programmed guidance radar beam to the vicinity of the target, where it was detonated by a command from the ship. The missile with the continuous-rod warhead employed midcourse beamriding and terminal semiactive homing.

As would be expected, the Talos fire control system was directed from the ship's weapon control center. That center processed search radar data, provided selected coordinate data to the fire control radar, ordered loading of the missile launcher, and controlled missile firing.

To control the missile in flight, a continuous measure of target and missile position was necessary. There were three major subsystems: a target tracking radar to measure target position and to illuminate the target, a guidance radar for beamriding and missile range measurements, and a computer to generate angle-rate signals for positioning the guidance beam and activating the terminal homing system. Three types of trajectory were employed by Talos (Fig. 1).

Talos was constantly improved during the course of the Program. Improvements in missile capabilities became a primary driving force in establishing ship system requirements. Extending the maximum missile range, for example, forced the use of a new generation of search and target acquisition radars. The shift to continuous wave (CW) homing required the installation of CW illuminators. The state of the art was constantly being applied to improve the weapon system. A detailed description of the Talos ship system depended on the ship and the date.

The typical Talos system (Fig. 2) contained:

- Search radars that were used to detect targets and provide position data to the weapon control system;
- A weapon control system that made target assignments to the fire control system, ordered loading of missile launchers, fired missiles, and linked defense responses with Fleet units;
- A fire control computer that interfaced all elements of Talos to control the missile in flight;
- A fire control radar that accurately tracked the designated target and provided illumination for semiactive homing;
- A missile guidance radar that acted as a command link to the missile.

TALOS SHIP INSTALLATIONS

USS *Galveston* (CLG-3) was designated as the first ship to receive Talos missiles and underwent an austere conversion to accommodate the missile. The aft main gun battery and seaplane catapults were removed. A dual-rail missile launcher was installed. The ship's structure was modified to include a missile magazine, a missile handling area, and barbettes for the target tracking and missile guidance radars. Spaces for the radar consoles, the fire control computers, and a weapon control system were included. Missiles were loaded on the launcher by extendable and retractable overhead rails. The fire control system was a functional copy of the ground system used during development testing at White Sands Missile Range. Two fire control channels, consisting of

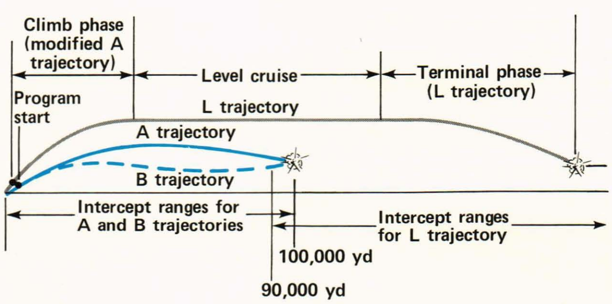

Figure 1 — Talos flight trajectory types depended on the range to the target and the electronic countermeasures environment. The A trajectory was medium range and approximated a circular arc. The B trajectory, also medium range, closed the beams earlier to reduce susceptibility to enemy countermeasures. The long-range L trajectory was used for intercepts at greater than 90,000 yards.

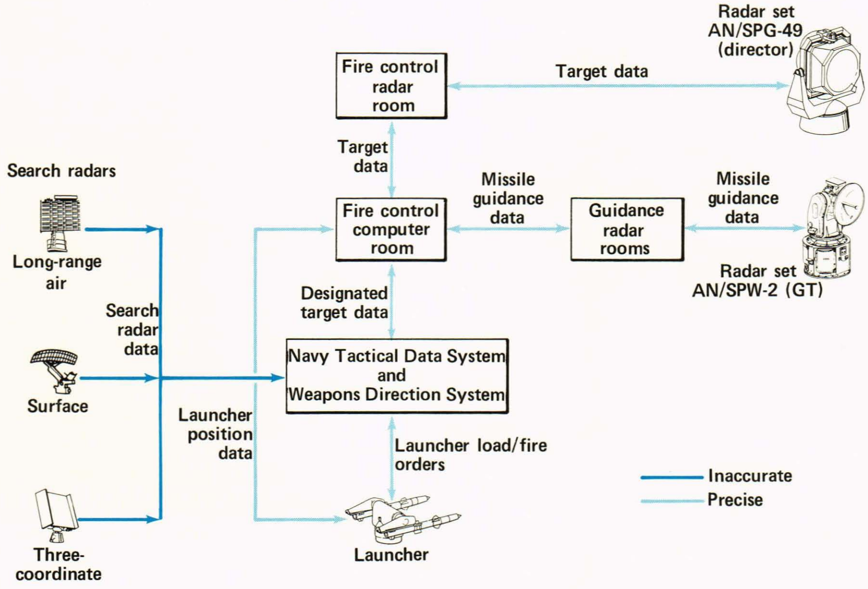

Figure 2 — Typical Talos Weapon System.

tracking radars, computer channels, and guidance radars, were required to support the dual-rail launcher (Fig. 3).

The Combat Information Center in *Galveston* was modified for mounting a television camera above a master plan position indicator and for the installation of two repeater displays. These formed the link between the Combat Information Center and Talos. Information could also be transferred by the use of grease pencils on the televised displays.

The Talos Weapon Control System provided manual tracking of up to six targets and the designation of any two of them to fire control channels. Little thought was given in the early days to a large number of targets, adverse environments (jamming), designation accuracies, and system reaction times.

Shortly after authorization of the *Galveston* conversion, two additional ships were authorized — USS *Little Rock* (CLG-4) and USS *Oklahoma City* (CLG-5). These ship systems were very nearly identical with the system on *Galveston*. The initial installation in these three light cruisers supported the short-range version of the missile (50 nautical miles).

Introduction of the long-range missile (100 nautical miles), and later the CW seeker, imposed changes in the ship system. These changes involved increasing the tracking range of the fire control radar, increasing the instrumented range of the fire control computer channels, and adding a low-noise-level, high-power CW target illuminator. Also required were a computation of the closing velocity between missile and target and the relaying of this information to the missile.

The long-range missiles focused attention on the need for long-range target detection and rapid handling of multiple targets in adverse sea, land, and weather clutter and heavy countermeasure environments. Threat studies showed that the search radars and weapon control system in the light cruisers were inadequate to support Talos in a heavy threat or jamming environment.

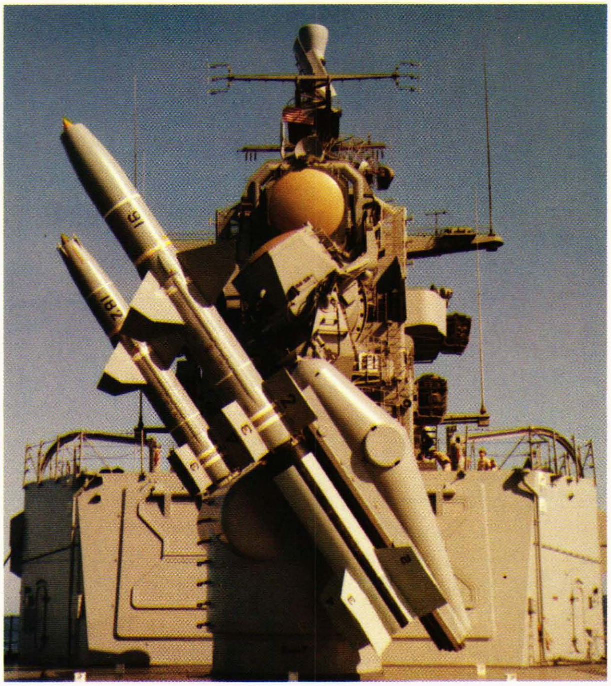

Figure 3 — USS *Galveston* (CLG-3) was designated as the first ship to receive Talos missiles. Two of the first tactical Talos missile types, SAM-N-6b and SAM-N-6bW, are shown on the launcher.

The first chance to install an improved ship system occurred with the authorization to convert USS *Long Beach* (CGN-9) to a Talos ship. This first nuclear-powered cruiser had powerful long-range search and acquisition radars that used state-of-the-art, fixed-array, electrically steerable beams and a new Weapon Control System capable of rate-aided manual tracking of up to 24 targets. Digital computer technology

Table 1 — The Talos ships.

Ship	*Commissioned*	*Armament*
USS *Galveston* (CLG-3)	May 1958	46 Talos missiles 6-inch triple-barrel gun 5-inch dual-purpose guns
USS *Little Rock* (CLG-4)	Jun 1960	Same as CLG-3 except for the number of guns
USS *Oklahoma City* (CLG-5)	Sep 1960	Same as CLG-3 except for the number of guns
USS *Long Beach* (CGN-9)	Sep 1961	52 Talos missiles 240 Terrier missiles 5-inch twin-barrel guns
USS *Albany* (CG-10)	Nov 1962	104 Talos missiles 80 Tartar missiles 5-inch twin-barrel guns
USS *Columbus* (CG-12)	Dec 1962	Same as CG-10
USS *Chicago* (CG-11)	May 1964	Same as CG-10

using hard-wired techniques was used for the first time in the Fleet. Solid-state devices were used in the analog fire control computers to improve their reliability. The nuclear-powered cruiser was the first Talos ship to employ the Naval Tactical Data System for ship-to-ship and ship-to-air communications.

The next chance to install an improved ship system came with the authorization for conversion of three heavy cruisers to carry Talos and Tartar. The seven Talos ships, their commissioning dates, and armaments are listed in Table 1.

SEARCH RADARS

Three basic types of search radar were used on the Talos light and heavy cruisers: a short-range surface search radar, a longer-range radar for range and bearing data, and a long-range air search radar for range, bearing, and target height data. Radar video and timing signals were sent to the Combat Information Center in all the ships and to the Weapon Control System in the heavy cruisers.

WEAPON CONTROL SYSTEM

The Talos Weapon Control System served several purposes: classification of targets based on search radar data, assignment of targets to fire-control channels, display of repeat-back data from the fire control radars, determination of open fire and intercept ranges, evaluation of the booster splash point and firing cutout zones, selection of the missile type to be used, assignment and loading of the missile launchers, and firing of the missiles.

The weapon direction equipment in the light cruisers contained two large displays of televised radar scopes and a bank of lights for indicating the status of the weapon system. Data written on the televised radar scopes would appear on the displays. Four smaller repeaters were installed — two in the Weapon Control Center and two in the Combat Information Center. Two target engagement consoles interfaced with the main displays via a symbol generator. Six targets could be processed simultaneously. One target could be designated to each of the two fire control channels and one to the gun system. A missile firing panel enabled missiles to be selected, loaded, and fired. It contained a display of surface radar data and superimposed booster splash point and firing cutout zones. A height storage console interfaced the system with three-dimensional search radars.

At the time that a weapon control system was selected for the nuclear and heavy cruisers, digital systems were being developed and more severe threats were being recognized. A hard-wired digital computer, representing the state of the art at that time, was selected for the Weapon Control System. Two target entry consoles were installed for assigning targets to track consoles and for monitoring the weapon systems (Talos and Terrier in the nuclear cruiser and Talos and Tartar in the three heavy cruisers). Six target tracking consoles were installed, each of which could process four targets. The program for processing data for as many as 24 targets was stored and handled in hard-wired magnetic core memory. Frequent manual entries were required to maintain accurate tracks. Two director assignment consoles interfaced the Weapon Direction System with the fire control systems. Four launcher assignment consoles interfaced the system with the missile launchers — two for Talos and two for Tartar.

The hard-wired digital computer proved to be inflexible and expensive to change. It had a high failure rate and long diagnostic and repair times. The solution of these problems appeared to be the replacement of the entire system with a general purpose digital computer and general purpose consoles. These equipments became available too late in the lifetime of the cruisers to warrant their installation.

FIRE CONTROL RADARS

The Talos missile required an automatic tracking radar that was powerful and accurate, with an acquisition capability to cope with target designation errors from search radar data. In 1949, a survey of available radars resulted in the selection of a gun-laying radar that could be adapted to Talos. It consisted of two integrated radars: a scanning acquisition radar and a monopulse tracking radar (Fig. 4). The antenna director had three degrees of freedom: train, elevation, and traverse. The traverse member permitted the tracking of high-speed crossing targets and gave the radar a track-overhead capability. All of the microwave equipment, antenna control electronics, and high-voltage power supplies were mounted within the director. This location made the radar difficult to service at night or during inclement weather. The directors were mounted on barbettes that extended to the keel of the ship for alignment stability. Two operator consoles were mounted below decks — an acquisition console having a unique five-plane display, which gave a synthetic three-dimensional display of the volume of space containing the target, and a tracking console with a range scope display and a plan position display.

The radar was modified at the same time the long-range missiles were introduced, to increase range and to include a high-power CW target illuminator operating through an indexed target-acquisition antenna system. It became the highest-powered, most accurate radar in the Fleet until the digitally controlled pulse Doppler fire control radar for Tartar was introduced in the late 1960's.

Over the years, numerous modifications were proposed and tested to improve radar performance at low elevation angles, for targets in clutter, for fading targets, and for targets screened by countermeasures. Some of these modifications included pulse compression, fade-coast mode, low-elevation-angle mode, track-on-jamming capability, alarm gate for chaff, and digital range gate processors.

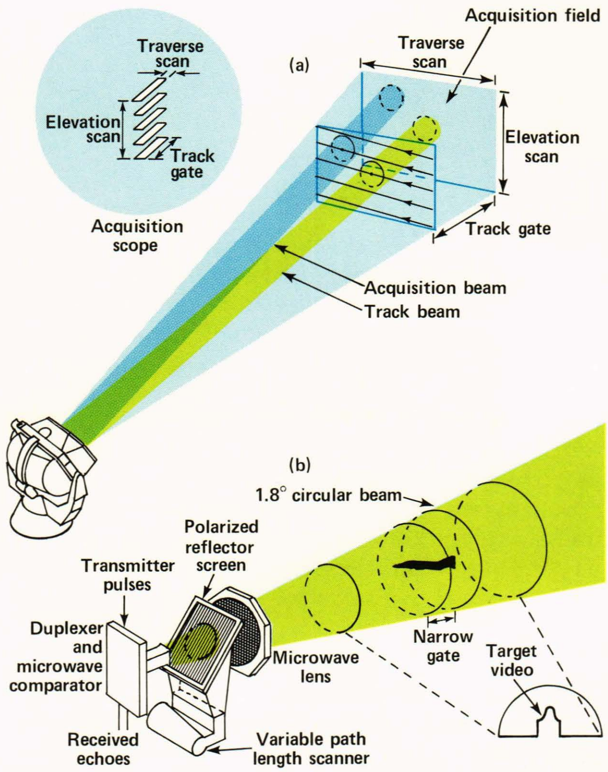

Figure 4 — The Talos fire control radar consisted of two integrated radar systems using a common microwave lens: (a) The acquisition system was scanned by a motor-driven polarized reflector grid and a scanning feed. (b) The tracking radar system, polarized at 90° from the acquisition system, operated through the transparent reflector grid.

FIRE CONTROL COMPUTERS

The fire control computers for Talos were an extension of gun fire control technology of the early 1950's. They were vacuum tube, electromechanical devices performing three-dimensional coordinate conversions in real time and solving both linear and nonlinear equations. These computers implemented the following tasks: target designation; target tracking; launcher assignment and guidance radar control; booster splash point and firing cutout zone calculations; and missile firing and beam programming for antiair, antiship, shore bombardment, and home-on-radiation missions. The computers were originally designed to support the short-range missiles and were later modified to support the long-range missiles.

The analog computers were subject to long settling times and inaccuracies caused by drifting. The drifts were not detectable without comprehensive tests and analysis. As a result, extensive test and adjustment procedures were developed. A high failure rate increased the maintenance burden and system downtime.

The fire control computers for the nuclear and heavy cruisers used solid-state analog technology in the 1958-59 era. However, they suffered from the same problems experienced with the earlier computers — long settling times and inaccuracies.

The problems with the analog computers led to the first studies of digital fire control systems in 1956. The studies, however, were aimed at two additional heavy cruisers and not at existing ships. Cancellation of the cruiser shipbuilding program halted the studies of digital systems until 1961, when APL-built analog-to-digital conversion equipment became available for interfacing with general purpose computers. The operational capability for digital control of guidance radars was demonstrated in 1964. These demonstrations led to evaluation of a digital fire control computer system in USS *Albany* (CG-10) in late 1964 and early 1965. A Univac Model 1218 computer was selected; it became known as the military Mk 152 digital computer.

The development of digital range data processors for the Talos target tracking and guidance radars was paced with the development of the digital fire control computers. The first conversion to a digital system took place in *Albany* in 1966. Conversion of the nuclear-powered *Long Beach* and of USS *Chicago* (CG-11) soon followed. The three light cruisers and USS *Columbus* (CG-12) were retired before conversion took place.

MISSILE GUIDANCE RADAR

By the end of World War II, several target-tracking fire control radars existed that used conical scanning antenna feeds and time-domain signal processing for tracking targets automatically. Beamriding missiles became an extension of that technology by relocating the radar receiver in the missile and using the output to control the missile.

The missile guidance radar selected for Talos employed a 4°-wide pencil beam that was offset 2° from boresight and nutated about it at a 30-hertz rate. The train and elevation angles in the guidance radar could be controlled manually during collimation testing or remotely by the fire control computer during beam programming. The pulse repetition rate of the radar was frequency modulated sinusoidally at a 30-hertz rate and with a phase related to a stable platform so as to remove the effects on missile attitude of ships' roll and pitch. The frequency modulation provided the missile with a phase reference with which to compare the phase of amplitude modulation resulting from being off boresight. The result of the phase comparison was used to steer the missile in the required direction to follow the boresight line during guidance beam programming.

Instead of a single pulse in conventional radars, the guidance radar used a group of pulses that could be time coded to identify a particular missile with a particular guidance radar and to convey commands to the missile. The coded pulse group also triggered a transponder in the missile to enhance missile tracking by the guidance radar.

The guidance radar for Talos used 1950's technology, and no major modifications were made until digital range data processors were developed in 1966. During its lifetime, several minor changes were made to decrease the receiver noise figure for longer range beacon tracking, improve the settling time of the range tracking output after beacon lock-on, and improve the guidance radar operability and maintainability.

MISSILE LAUNCHING AND HANDLING SYSTEM

Missile magazines and handling areas were installed in the aft end of the light cruisers and the nuclear-powered cruiser. Magazines and handling areas were installed in both ends of the heavy cruisers. A bookkeeping system was incorporated for locating and calling out missiles with continuous-rod or nuclear warheads. Later on, the bookkeeping system was modified to include the location of missiles configured for home-on-radiation missions. In the heavy cruisers, the launchers could be assigned to either the forward or aft fire control channels. Each handling area contained a battery charger and Talos tactical test equipment. The specialized test equipment could exercise the electronics and hydraulics of a missile for periodic tests to determine readiness. On-board repair of missiles could be accomplished by module replacement using on-board spares. At sea, resupply of missiles was accomplished by high-line transfer from ammunition ships. Few changes were made to the missile launching and handling systems during the lifetime of Talos.

EQUIPMENT AND SYSTEM DOCUMENTATION

The introduction of the complex Talos, Terrier, and Tartar Weapon Systems in the Fleet soon demonstrated the inadequacies of available documentation. Failure-reporting procedures were insufficient to highlight problem areas and give direction to the logistic system. Test and evaluation techniques were inadequate to determine the readiness of equipment to meet the needs of an exercise or a real engagement.

A System Operability Test was developed in 1962 to determine system capability to support a mission. This evolved into a Daily System Operability Test that included simulated missile firings and measurement of system parameters for a go/no-go condition. The Daily System Operability Test was also a training aid for maintaining the proficiency of weapon system personnel.

Signal flow diagrams known as pyramids were developed in 1963 to assist personnel in locating faults quickly. This resulted in a new type of documentation known as Improved Maintenance Plans, which evolved into a Planned Maintenance System for surface missile ships. A failure-reporting system was developed that permitted rapid determination of mean-time-between-maintenance events, mean time between failures, mean time to repair, system availability times, and demands on the logistic system.

CONCLUSION

The Talos Program motivated developments in many areas of weapon system technology. The existence of a guided missile having a tactical range in excess of 100 nautical miles most certainly advanced the state of the art in long-range target detection and target data handling. It pointed out the need for:

1. High firing rates for long-range missile systems;
2. Automatic evaluation and reaction to threats;
3. Improved counter countermeasures for radar systems; and
4. Digital computers in all areas for automation, accuracy, flexibility, and maintainability.

The Talos Weapon System provided seven cruisers with a wide-area air defense system unequaled at its time by any other guided missile system in the Navy inventory.