NAVAL RESEARCH REVIEWS

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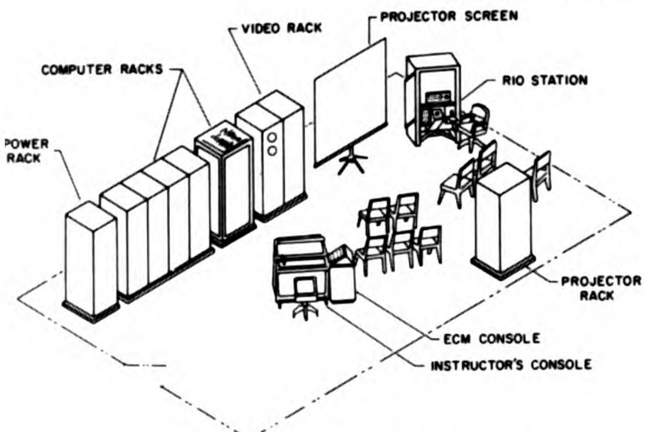
DEPARTMENT OF THE NAVY · OFFICE OF NAVAL RESEARCH

SPECIAL ISSUE Military Training Devices

Military Training Devices

Hit-indicator system; permits training with real weapons against live targets.

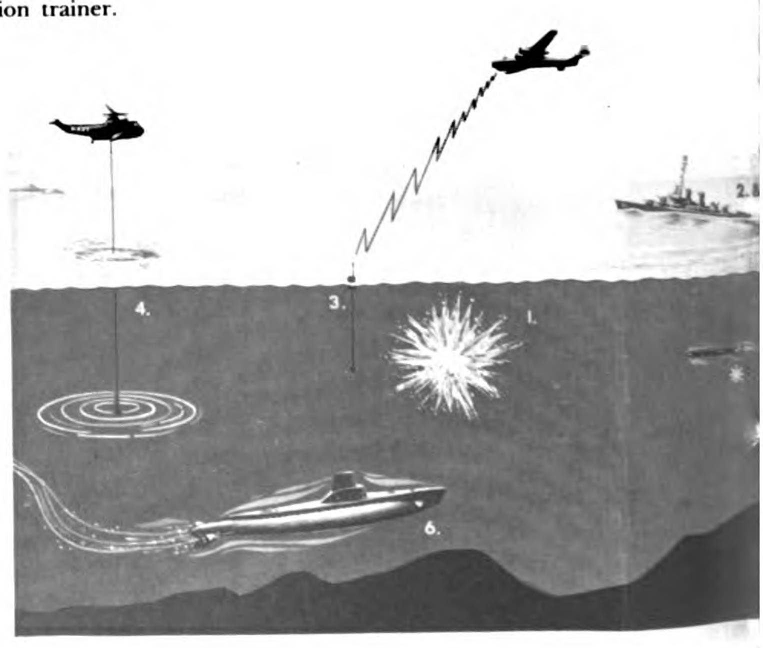
Polaris submarine control trainer



Layout of radar-scope interpretation trainer.

ASW Target Trainer

1. Explosive echo-ranging equipment.
2. Active and Passive sonar equipment.
3. Sonobuoy
4. Dip sonar
5. Variable depth sonar
6. Submarine decoying.
* ASW submarine target.



PREFACE

CAPT John K. Sloatman, Jr., USN
Commanding Officer
Naval Training Device Center

A force of dedicated men with modern weapons ready to perform ny task in any place at any time describes in simple terms our Navy day. Maintaining such all-encompassing readiness is not easy nd not simple. It is a complicated, expensive business, with many, any contributing factors. All of us could agree, however, that the aining and the retraining of our Naval personnel is the most nportant of these factors.

With the great technical advances and technological sophistication our Naval weapons, vehicles, and other equipment being introuced into the Fleet daily, our training techniques and training quipments become correspondingly complex and sophisticated. It the mission of the Naval Training Device Center to provide these aining techniques and training equipments to aid our Naval ersonnel in realizing the maximum potential effectiveness of their eapons and material and in achieving and maintaining maximum mbat readiness.

In this special issue of NAVAL RESEARCH REVIEWS, *you will ad of the Center's history, of how NTDC contributes to the Navy's erational readiness, and of the procedures it follows to provide aining equipment to all of the services as well as to an increasing umber of Government agencies.*

NTDC is located at Sands Point, near Port Washington, New York, 162 acres of land overlooking Long Island Sound. The total ilitary and civilian personnel complement is 815, of which 764 re civilians. Forty-three Naval officers, eight Army officers, and aval enlisted personnel make up the remainder. The budget for scal year 1964, consisting of RDT&E, operations and mainnance, and procurement funds, totalled almost 100 million dollars.

While the Center's prime concern is aiding the operational readiness the Fleet by developing, procuring, and delivering training devices, TDC is also concerned with other types of training and peacetime pplications. For example, the Center built the first human cenifuge—a device used later to check out and train astronauts. hortly afterward, the Center developed a human disorientation evice, a mechanism that can provide disorientation in three degrees freedom. In addition, studies performed by the Center's humanctors personnel contribute to the design and development of many pes of operational equipment as well as simulators.

The Center is the only activity in Government that is concerned cclusively with the unique field of simulation as applied to training quipment of various types. This training equipment not only ntributes strongly to the combat readiness of the Armed Forces, ut saves the U. S. taxpayer millions of dollars in the cost of training.

Parachute emergency-release trainer.

TV-controlled model tank; an element of the tank platoon-leader trainer.

History and Mission of the Naval Training Device Center

Charles T. Gabriele
Public Information Officer
Naval Training Device Center

The Naval Training Device Center provides equipment to improve the effectiveness of training, primarily in the Navy, but also in the other services and in other Government agencies. To accomplish this task, it has been given responsibility for research, development, production, installation, maintenance, and modification of air, sea, subsurface, land, and space trainers applicable to all types of military situations. These devices vary in design and use from the very simple to the very complex, and from those intended for mass training to those intended for individual training. They include jet-plane simulators, submarine simulators, space-environment trainers, missile trainers, Fleet tactical trainers, and innumerable radar, sonar, and electronic devices.

Although some prototype research and development work is done in the Center's own shops and laboratories, a large portion of its work is completed through contracts with private industry, colleges and universities, other research groups, and through extensive testing and evaluation of training equipment aboard Navy ships and at shore installations and other Department of Defense activities.

As a result of this work, which has now been underway for almost 25 years, the Nation's military personnel have been prepared to carry out their assignments more quickly, cheaply, safely, and effectively than would have been possible otherwise.

The first step in developing and adapting special training methods and devices in the United States was taken April 30, 1941, when RADM J. H. Towers, USN, the Chief of the Bureau of Aeronautics, issued a memorandum creating a Special Devices Desk in the Engineering Division. The purpose and function of this desk were to supervise the development of training devices for such applications as primary training, navigation training, and gunnery training.

No money was appropriated for the work. Planning, training, procurement, and maintenance services required in connection with the devices were to be rendered by the regular bureau organization. The first officer placed in charge of this desk was CDM Luis de Florez, USNR.

Comparatively little progress in the development of special training devices was made until June 3, 1941, when the Special Devices Desk was transferred to the Training Division proper and the sum of $50,000 was allocated for preliminary development work.

In October 1941, CDR Luis de Florez made a trip to the United Kingdom to study synthetic training methods of the British Air Training Command. After making a thorough investigation, he returned and reported the following findings:

- Synthetic training increased the quality and quantity of the usual training by teaching procedure and familiarization with operational equipment to the point where its use became instinctive.
- By means of synthetic training devices, instructors could handle large groups of students simultaneously and at any instant could "freeze" the operational problem, explain it, and immediately point out a student's error and apply the correction while the conditions were fresh in the student's mind.
- After thorough ground training had been given in theory and techniques and after instinctive reactions were developed through constant practice on training devices, crews could be sent aloft to put their knowledge and skill to use through actual practice.
- Special devices provided training in combat and operational situations which would not have been possible to achieve otherwise, except by tying up valuable combat equipment for unduly long periods.

As a result of a better understanding of the needs for synthetic training and because of the increasing pace of the Naval training program, it was decided to expand the work of the Special Devices Section. An appropriation of $1,000,000 was made at the beginning of 1942, and an additional $10,000,000 was allocated in March of that year. By the end of 1942, total funds made available amounted to approximately $36,200,000. Personnel in the Section increased from three in July 1941 to 125 by the end of 1942.

During the early part of 1942, a small shop and a laboratory were established at Anacostia, in Washington, D.C. As the Naval training program gathered momentum, additional space was provided by remodeling a garage building at 610 H Street, N.E., Washington. All office, shop, and laboratory facilities soon were centered there, and "610" became the trade name of the Special Devices Section throughout the war.

By the end of 1942, approximately 390 different training projects were in various stages of development, and 125 training devices were in production through contracts negotiated by the Section with civilian manufacturers. Among the many devices produced were training turrets, gunners deflection trainers, line trainers, and navigation trainers. They were distributed to Naval, Marine Corps, and Coast Guard aviation units, as well as to certain Fleet units, particularly aircraft carriers.

Realizing the importance of close liaison with other military and Governmental agencies, the Section made available plans and devices for use in the Army Air Corps Training Command. Also, in conjunction with the U.S. Office of Education, the Section initiated a project for building in the Nation's schools hundreds of thousands of recognition models of aircraft. These models were distributed to Navy, Army, and Civil Aeronautics activities, as well as to air training commands in Great Britain, Canada, and Latin America. This period also brought to light the importance of the human element in training and in fighting. Increased stress was placed upon time-and-motion study and task analysis to determine and standardize the best methods of training on the various devices being created.

On August 24, 1943, RADM Ralph Davison, USN, then acting Chief of the Bureau of Aeronautics, transformed the Special Devices Section into a division. CDR Luis de Florez was designated its director. An appropriation of $35,116,-000 was granted for the fiscal year 1944. The complement of the Division at this time was approximately 290 military and civilian personnel divided among four branches of activity—engineering, production, field service, and administration.

With its new status and increased appropriation, the Division expanded. By the end of 1943, it had worked on more than 500 different projects, all of which involved invention, research, engineering, and construction in such diverse fields as aviation, navigation, ballistics, optics, mechanics, radio electronics, photography, hydraulics, and, at times, even medicine and psychology. More than 200 different devices and aids were being mass-produced through some 250 manufacturers under contractual obligations amounting to approximately $45,000,000. By this time, more than 230 Naval officers were devoting full time to the training program, and the entire personnel of the Special Devices Division numbered over 400.

As old weapons were altered and new weapons were produced, and as the flow of battle reports from Fleet activities began to pin-point specific requirements for additional training, the problems of the Special Devices Division mounted. To indicate how some of these training problems were solved, a brief case history of one device completed in 1943 is presented in the following paragraph.

Until February 1943 there existed no practical synthetic training device for teaching anti-aircraft gunnery. However, there did exist an aerial free gunnery trainer which could be adapted for anti-aircraft training. Conversion of this trainer into the Dual Projection Trainer (3-A-2) for anti-aircraft use was made possible by projecting (upon an inclined screen placed above the student's head) motion pictures depicting dive-bombing, strafing, and torpedo attacks. Even greater reality was created by dubbing in actual sound tracks to simulate battle noises, and subsequent research led to modification of the device to give training in the use of lead computing sights. Thus, through the continued application of technical skill, the training device was changed constantly to keep pace with the introduction of new weapons.

By 1944 more than 2,860,000 devices were manufactured and delivered. They ranged in quantity and size from three mobile low-pressure units for aeromedical training to 1,750,000 Navy-Army pictorial manuals for aircraft recognition training.

A new Office of Research and Inventions was established by the Secretary of the Navy on May 14, 1945. It was created by merging the Naval Research Laboratory, the Special Devices Division of the Bureau of Aeronautics, the Office of Research Development, and the Office of Patents and Inventions. The new office was to report directly to the Secretary of the Navy and to the Chief of Naval Operations.

Appointed as Chief of ORI was RADM Harold G. Bowen, USN, former director of the Office of Patents and Inventions. The Assistant Chief was CAPT Luis de Florez, USNR, former Director of the Special Devices Division. The new Director of Special Devices under the ORI merger was CDR D. L. Hibbard, USNR, who helped CAPT de Florez develop the Navy's special-devices program.

Now, for the first time, all research activity was coordinated and was given a position of greater importance in the Naval Establishment. In creating ORI, the Secretary of the Navy indicated an awareness of the value of Naval research, not only as it applied to World War II but also to preparations for future wars. The Special Devices Division was a logical addition to the ORI, for it had already been shown that wars could not be won by a preponderance of weapons alone; efficient utilization of these weapons often was the determining factor. Since efficient utilization is the result of adequate training, it was apparent that all the problems and complexities of training must be solved at the same rate of speed that new techniques and weapons for warfare are produced.

Another reason for combining the Special Devices Division with other research activities was that many of the special devices developed for training often embodied features more practical than those on existing weapons. As the result of constant research and analysis, especially in the field of time-and-motion study, the Special Devices Division often developed alterations to make existing weapons more effective. In many instances, special-device research influenced the design of weapons still in the blueprint stage.

Soon after the creation of ORI, the war ended. Personnel of the Special Devices Division then numbered approximately 600, more than 500 of whom were employed by the military services. Since its establishment as a desk in BuAer, the organization had processed approximately 1100 separate training projects and had perfected more than 700 different training aids and devices. There was not a person in the Navy who at one time or another did not receive some benefit from one or more of these devices. And almost the same is true of the Army, Marine Corps, and Coast Guard, as well as various civilian defense organizations—all of which had access to the materials developed.

Special-device development also took on an international complexion during the war. England, Canada, Australia, New Zealand, Brazil, Peru, Chile, France, South Africa, Nicaragua, and various military commands, including Southeast Asia and China-Burma-India, received some training through the Navy's special-devices program.

Upon being accepted as an integral part of the Navy's research program, it was logical that the Division be given a permanent site for its activities. A special committee appointed for this purpose by the Secretary of the Navy selected the former Guggenheim Estate at Sands Point, Long Island, New York. On May 1, 1946, the Division moved to the new location. Here, for the first time, adequate space was available to house the personnel of the many branches of the Division, and ample room existed for laboratories and shops for construction and testing of training devices.

A new kind of problem now confronted the Division. The continuing release of military personnel to inactive duty created a replacement deficiency. New peacetime complements were established to consist mainly of civilian employees of the Navy Department. This readjustment, plus the physical consolidation of division activities that were being "rolled-up," retarded progress in the field of development. However, once these obstacles were surmounted, the normal flow of activity was resumed to keep in step with the over-all program of Naval research. During this period, a program was developed which was aimed at keeping the Navy well advanced, not only in the development of new weapons but also in the creation of the most modern methods for training its personnel to use them.

In March 1946, RADM Luis de Florez reported that the Special Devices Division, in its four and one-half years of operation, had handled close to 1500 separate projects. The efficiency with which the Division operated is revealed by the fact that only five percent of the money spent during this period was used on unsuccessful devices.

On August 1, 1946, by Act of Congress (Public Law 588), the Office of Naval Research was established. In effect, this act amounted only to a change of name of the Office of Research and Inventions to the Office of Naval Research. Tasks, functions, and organization remained substantially the same as those established under the old ORI. At this time, the name "Special Devices Division" was changed to "Special Devices Center." However, the activities of the division continued uninterrupted. In subsequent months, the balance of military and civilian personnel was readjusted, former Naval officers in many instances continuing their work as civilian employees of the Navy Department.

Now, no longer pressed by the urgency of war, the Center devoted more time to fundamental research into the relationship between man and the technical machines he must operate. In addition, new synthetic training devices were developed and produced.

—Continued on page 48

Fair Attraction

A training device named Cine-Globe, developed during World War II to sharpen the aim of aerial gunners, is part of the Navy exhibit at the New York World's Fair. Through Cine-Globe's three-dimensional movies, viewers see bigger-than-life views of the Navy and Marines in action. The special lens of this device, used in both the camera and the trainer, covers the extremely wide angle of 142 degrees, almost matching the field of vision of the human eye. The hemispheric screen curves around the audience, placing it right in the midst of the action.

Cine-Globe was contributed to the exhibit by the Naval Training Device Center.

Organizing for Research

CDR Eugene C. Moss, USN
Assistant Director for
Supporting Research

Joseph Mehr
Research Administrator
Naval Training Device Center

As in many scientific and technical organizations, both in government and industry, it has become clear at the Naval Training Device Center that its inventory of technical knowledge cannot be permitted to remain constant while the scope of training-device requirements continues to broaden. At the same time, it is also clear that limits must be set as to the level of research we will conduct.

The term "supporting research," unless carefully defined, can be a catchall descriptor meaning many things to many people. One way of depicting it is to point out what it is *not* as well as what it is. For example, it is not basic research. At NTDC, we do not try to expand man's fundamental knowledge for its own sake. Nor is supporting research engineering development. As applied at NTDC, it is that effort which draws from basic research the tools, materials, techniques, and methodologies that can be directed toward the development of training devices and, then, through selective study and experiment, demonstrates their applicability.

To best accomplish this purpose, NTDC's supporting-research laboratories are divided according to scientific disciplines rather than by operational objectives, as the engineering departments are divided. The Supporting Research Directorate consists of five laboratories (Physical Sciences, Computer, Visual Simulation, Electronics, and Human Factors) and a Laboratory Services Department. The laboratories conduct a variety of supporting-research projects, and they provide consulting services to the developmental-engineering segment of the Center.

More specifically, the functions of each of the laboratories and the Laboratory Services Department are as follows:

Physical Sciences Laboratory

- Fields of study include optics, photo-optics, photochemistry, mechanics, photogrammetry and cartography, geophysics, oceanography and meteorology, and materials and components for training devices.
- Provides for the synthesis of displays representing the environment as observed from any earth-related position by instrumental or visual sensors (photo, radar, infrared, sonar). For this purpose, the laboratory operates photographic and optical experimental test facilities and executes research in pictorial

and symbolic displays and in techniques and components required to generate, transmit, modulate, display, and record appropriate images.

• Conducts research in the detection and transmission of visual information.

Electronics Laboratory

• Concerned with simulation components and techniques of (1) electromagnetic detection and transmission equipment (such as radar, ECM, and radio); (2) sonar detection and transmission equipment (for example, transducers and sonobuoys): and (3) magnetic detection and transmission equipment (such as anomaly detection instruments).

• Conducts research in equipment and methods used to obtain information on student performance to use as a basis for scoring or evaluating students during gunnery training periods.

Visual Simulation Laboratory

• Conducts research in and evaluates real-world simulation systems and techniques.

• Establishes criteria for the degree of fidelity of presentation needed for various levels of training and for various operational situations.

Computer Laboratory

• Directs and operates the Center's Computer Laboratory facilities.

• Conducts research in computer mathematics and programming and the development of mathematical models for simulation purposes.

• Studies computer applications, analog and digital simulation, computer components, computing systems, and computational techniques.

• Provides consulting services in computer, computational, and mathematical technology and applications.

Human Factors Laboratory

• Defines, develops, conducts research on, and incorporates a human-factors input for a support program for present and future training-device development.

• Operates and maintains specialized psychological research equipment and conducts research in and evaluates human-factors problems.

• Provides, on a consulting basis, human-factors data relating to the analysis of training-device problems, man-machine-system-environment interrelationships, and training-device designs.

Laboratory Services Department

• Plans, operates, and maintains research-oriented shop facilities required to fabricate, repair, or modify experimental electronic and electro-mechanical devices for use in research projects.

• Maintains measuring equipment used to determine and analyze basic electrical and electronic values, frequencies, stabilities, and waveforms.

• Provides other specialized services not available in the laboratories.

• Provides consulting services regarding instrumentation for in-house projects.

As part of an expanded research program proposed for the Center, a number of new projects have been planned. Some of this work is outlined in the following paragraphs:

Physical Sciences Laboratory

The Use of Fiber Optics for Multi-image Transmission. Fiber optics appear to offer an opportunity to transmit images to multiple training stations while at the same time minimizing the complexity of the display—in other words, eliminating the need for television receivers.

Space Frequency Filtering. There are many presentations which are unclear because of interfering phenomena. The scan lines on a television screen are an example. By the development of techniques presently under investigation, it is believed that these phenomena can be eliminated by appropriate optical filtering.

Electronics Laboratory

Target Generation and Electronic Counter Measures (ECM) Simulation for Radar Training. We plan to develop a technique whereby radar and ECM training can be provided on operational equipment without physical coupling. This technique will make use of a transmitter and a measuring device which will inject radio-frequency energy into the operational antenna at the appropriate times.

Visual Simulation Laboratory

ASW Real-World Displays. There are several, as yet undefined, areas wherein real-world displays may be useful in ASW training. An example is infrared detection. It is intended to conduct a supporting-research program to develop the ASW-display requirements and to define a specific development program.

Computer Laboratory

Hybrid Facility. A facility is presently being implemented which will be used to study ways of improving training-device mechanization by means of suitable mathematical models. The equipment will include a MH 290 digital computer, a 100-amplifier computer, and, eventually, appropriate A-to-D and D-to-A converters.

New UDOFTT. The present Universal Digital Operational Flight Trainer Tool was developed in the mid 1950's. It includes the first computer capable

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of providing real-time simulation, which could be achieved because of its "fantastically short" access and adding times. Because of its age and mechanization (it utilizes vacuum tubes, is of large size and small capacity, and is expensive to maintian) the time has come to consider replacing it with an advanced, commercially available computer having a memory large enough to control multiple weapons systems trainers.

Simplification of Simulation Equations. A program is proposed whereby various classes of simulation equations will be examined and tested to determine which terms can be eliminated. Simplified equations can be translated into simpler and less expensive devices, because they do not call for as many unnecessary refinements to be made of simulation equipment.

Human Factors Laboratory

Programmed Teaching with Adaptive Systems. In conjunction with the Computer Laboratory, the Human Factors Laboratory will examine, develop, and evaluate criteria and provide design information for the development of self-adaptive training devices (trainers that reprogram themselves on the basis of the responses of the trainee). The Computer Laboratory will study the reprogramming of the computer used in such devices having both verbal and motor applications.

Evaluation of the Effectiveness of Training Devices. It is planned to conduct a systematic examination of those factors which can furnish a measure of training device effectiveness. A consequence of this effort will be the testing and evaluation of these factors in the field and validation of them for use as criteria for future training-device developments.

Improvement in Laboratory Facilities. The development of a sophisticated psychological laboratory is underway. In this laboratory, it is planned to investigate biopotential phenomena. For example, we know that certain measurable electrical characteristics are associated with eye motion; thus we plan to explore fully this activity to establish viewing criteria for training devices.

Study of Alternate Approaches to Weapons Systems Trainers. For the most part we have been trying to train pilots in weapons systems trainers that provide an environment similar to that which exists under actual operating conditions. We plan to develop approaches to weapons systems trainers which are pilot oriented rather than equipment oriented. Emphasis will be placed on obtaining desired responses rather than the simulation of the operational environment.

Important advantages will be gained through these efforts. For example, the optimization of simulation equations should result in less complex, more easily maintained, less expensive training devices. The radar target generation program will provide an "on the job" training capability. And the determination of effectiveness criteria will result eventually in the maximum dollar return for training device investment. To summarize, all of the proposed programs have been considered with an eye to their cost-effectiveness relationship and with a goal of maximum efficiency and economy.

A Submarine Simulator

William Levine
ASW Systems Trainers Branch
Naval Training Device Center

The Anti-Submarine Warfare (ASW) Submarine Target (Device 21B12) is a simulator which can be used in place of a real submarine for training in detection and tracking. The device provides surface, air, and subsurface ASW units with a realistic target for the active (pinging) or passive (listening) sonar equipment used by the Navy.

The simulator can be launched or retrieved from surface vessels, helicopters, or submarines. Since it is 132 inches long, 10 inches in diameter, and weighs approximately 344 pounds, it is comparatively easy to handle with equipment already aboard Navy vessels. The "submarine" operates at eight knots for a two-hour running period and changes course and depth according to preprogrammed instructions which it carries on a 35 mm film strip. At the same time, it generates and transmits noises in the frequency range of 100 cycles to 10 kilocycles (kc), which is characteristic of a submarine. It can also receive sonar pulses as it passes through the sound beam of active sonar equipments. These pulses are amplified and retransmitted at an amplitude such that the echo appears to the sonar operator to come from a real submarine. This echo-repeat system operates at frequencies ranging from 8 to 30 kc.

At the end of its run, the "submarine" surfaces and ejects a highly visible green dye to mark its location. In addition, it transmits a sound signal through the water for sonar detection; this signal is emitted until the battery runs down, in about 48 hours.

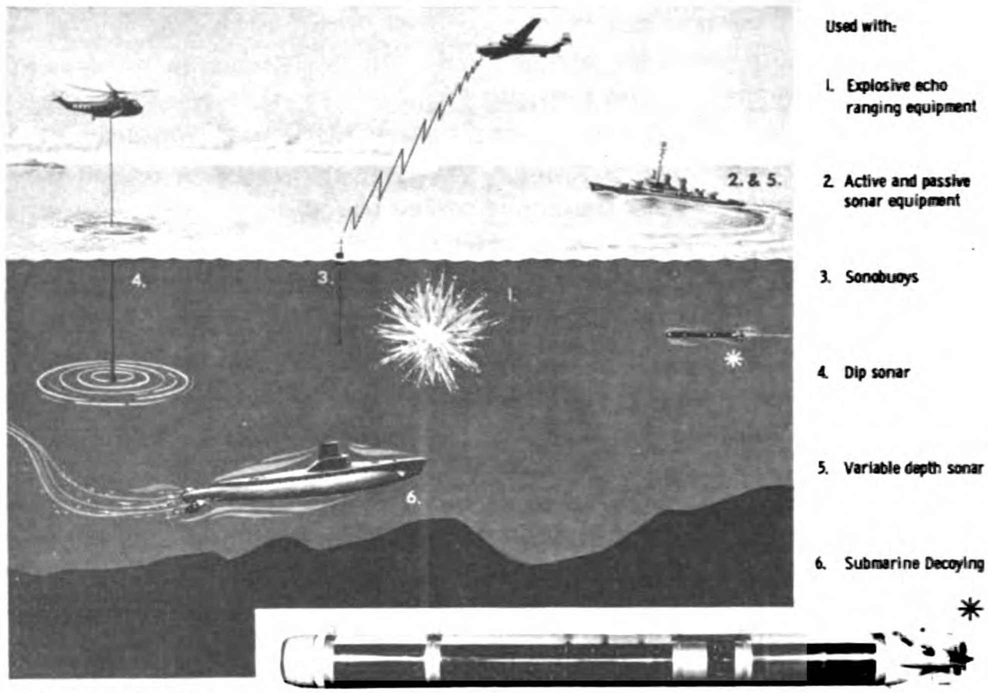
After retrieval, the simulator is cleaned and inspected, and repaired if necessary, the batteries are recharged, and the program tape is recycled. The device is then ready for use again. When properly maintained, the simulator can be reused many times.

Development and Delivery to Fleet

The development of Device 21B12 was begun in the early 1950's and carried out for several years by the Naval Training Device Center and Clevite Ordnance, a division of the Clevite Corporation. In 1958, the prototypes were evaluated and accepted by the Fleet; and by 1962, 154 production units were procured for Naval surface, subsurface, and air units operating in both the Atlantic and Pacific Oceans. The simulators have now been used successfully for team training of sonar operators in many ASW exercises at sea. Approximately 130 of the units are still on hand. Of the remainder, 15 were lost because of operational failures, and 9 because of misuse of the equipment.

A quantity of these simulators has also been procured by various foreign navies under our Military Aid Program. In addition, the Canadian Department

ASW SUBMARINE TARGET—DEVICE 21B12



General Characteristics:

Speed	8 Knots	Submarine Noise	100 to 10,000 C/S
Running time	2 hours	Echo repeating frequencies	3 to 30 kcs
Depth	Surface to 400 feet	Target Size	20 DB

Representation of an antisubmarine warfare training exercise in which the "enemy" being tracked down is Device 21B12.

of Defense Production purchased 65 units direct from the manufacturer, Clevite Ordnance, for the Canadian, United Kingdom, Australian, and Royal Netherlands navies.

The cost of using Device 21B12 for training as compared to that of using a submarine (whose services for this purpose are not generally available) is negligible. This is explained by the fact that the total expenditure for development and all production of the device to date has been less than the cost of procuring one conventional submarine. Furthermore, the approximate cost of operating a conventional submarine for a one-day training exercise is $20,000, as compared with only about $50 for the simulator.

Recent Improvements

To keep up with the rapidly changing art of sonar and to make Device 21B12 more useful, the Naval Training Device Center has carried out a continuous development and retrofit program. Some of the efforts now underway are listed below:

- *Extended frequency echo repeat.* With the rapid extension of sonars to continually lower frequencies, it has been necessary to extend the lower frequency range of the echo-repeat feature. This has been done by redesigning the electronic circuitry. The echo-repeat feature is now available over the full frequency range of 3 to 30 kc.

- *Elimination of blind spot.* Because of the physical location of the receiving transducer at the nose of the simulator, it was found that any vessel "pinging" on the device in the area approximately 20 degrees either side of the stern would not receive any echo repeat. This condition has caused some difficulties in training situations as well as the loss of acoustic contact with the device. The difficulty was overcome by eliminating the nose transducer and, in substitution, attaching a 1-inch-diameter, omnidirectional transducer to a small-diameter, 60-foot-long cable that trails behind the device.

- *Miniaturization.* In order to make the unit lighter and smaller, it was redesigned to include all solid-state (transistor) circuitry instead of vacuum tubes. Also eliminated were the high-voltage dynamotors, which are no longer needed. A bonus obtained by this miniaturization was a significant increase in reliability and a decrease in the current drain on the batteries.

- *Complete frequency coverage.* When the device was originally developed, it was found necessary, for technical reasons, to use two projectors (transmitting transducers) to cover the complete frequency range. To change from low to high frequencies, or vice versa, a switch had to be made to the appropriate transducer. To aid in combined ASW exercises and to simplify operation of the device, a technique was developed, analagous to the use of a woofer and tweeter coupled through cross-over networks in high-fi systems, that permits both transducers to be operated simultaneously. Greater utilization of the device is achieved, since it can now be applied to exercises in which both low- and high-frequency sonars are operated at the same time.

- *Electronic countermeasures (ECM) and improved recovery.* A project is now underway to develop and construct an ECM radio-beacon kit suitable for installation in the simulator. The models have been delivered and successfully tested at sea. The radio beacon is constructed so that it transmits whenever Device 21B12 is on the surface. Under this mode of operation, the radio beacon can provide training for ECM operators. It also provides a means for locating the device when it surfaces, since the radio waves can be detected at much greater distances than those at which the green dye is visible.

The Nuclear Submarine Simulator

Device 21B12 was developed in the decade following World War II to simulate the submarines of that period. Upon the introduction of the nuclear submarine as an enemy threat, it became necessary to develop a successor to Device 21B12—one that had greater speed, depth capability, and maneuverability, and that was designed to activate modern detection systems. A series of study programs has been underway at NTDC for a number of years to develop the techniques and technology required to produce such a simulator. Some of these programs are described below:

- *Hull and propulsion system.* This study, which was completed recently, involved analysis of the state-of-the-art of hull types and propulsion systems of such underwater vehicles as submarines and high-performance torpedoes.

Included in the investigation were faired hulls and straight cylindrical hulls. The propulsion study covered thermal and electric systems as well as some nonconventional systems, such as fuel cells and heat-storage engines. The thermal systems analyzed included turbine and reciprocating (internal and external combustion) engines. In addition, various combinations of engines and fuels were examined. The survey was made with the aid of a digital computer program so devised that any of the various parameters of the hull or propulsion system could be varied and the effects of the changes computed rapidly and automatically.

- *Wake generator.* With the aim of developing a method of producing a wake having the acoustic properties of that of a submerged submarine, a cylindrical generator package 40 pounds in weight, 10 inches in diameter, and about 30 inches long was designed. When viewed on operational sonar, the wake produced by this generator has the same appearance as that of a real submarine. The unit is now being given the proper configuration for incorporation into Device 21B12 and its successor.

- *Low-frequency transducer.* A serious need exists for the submarine simulator to be capable of producing realistic submarine sounds that can activate all types of passive ASW detection equipment employed by the Navy. While Device 21B12 does produce such sounds, they are very primitive—basically only prop-beat noises. To provide increased capability, a rugged, light-weight, low-frequency, broadband transducer 19 inches in diameter and 64 inches in length was developed. The unit effectively transmits low-frequency sounds (down to 10 cycles per second) to receivers many hundreds of miles away.

- *Guidance and control.* The purpose of this design study, which was begun only recently, is to develop a device capable of guiding and controlling the submarine simulator through its preprogrammed maneuvers while overcoming any unprogrammed maneuvers, such as drift. If the unprogrammed maneuvers are not compensated for, it becomes difficult or practically impossible to locate the device when its run is completed. Although to a large extent ways of achieving such control will be sought through the study of technologies related to underwater torpedo control, some original design and development work will be required.

- *Magnetic anomaly detection (MAD).* In order to simulate the magnetic anomalies created by full-scale submarines, various approaches will be taken toward the design of a unit capable of providing a signal that will activate an airborne MAD or simulated MAD at a range of 1500 feet. The signal will be similar to that produced by a 2000-ton, 300-foot-long submarine.

- *Electronics and transducers.* The objective of this investigation, which has not been started as yet, is to develop an electronic circuit and transducers capable of handling all frequencies that are used now or that may be used in the future in active and passive submarine detection. The equipment must be light in weight, so as to conserve propulsion power, and less than 21 inches in diameter, so that it can be launched via a standard submarine torpedo tube. Power drain must be kept to an absolute minumum so that battery size and weight can also be minimized.

- *Utilization concept.* Another study that has been planned will concern the most economical and practical utilization of the submarine simulator. Ideally,

—Continued on Page 24

Human Factors Research

K. F. Thomson and Staff
Human Factors Laboratory
Naval Training Device Center

The central position of man and his limitations and potentialities in the design of training devices led to the establishment, in 1947, of a human-engineering group as an integral element of the Naval Training Device Center.

One of the cornerstones of training-device design is simulation. Used broadly, simulation in training devices ranges from computer simulation of aerodynamic equations to the simulation of the auditory properties of a sonar return. Just as mathematical models constructed to simulate the physical world permit the investigator to indulge in calculated simplification, amplification, or manipulation to fit a set of circumstances, so does simulation of the operational world permit manipulation of a trainee's environment for specific purposes.

In effecting this simulation, two requirements must be met.

- The first is to obtain more complete and sophisticated knowledge of how the real world behaves. We know, for example, that a clumsy model is not nearly as often the result of inept mathematics as it is the result of a deficient knowledge of the phenomena it is constructed to represent.
- The second requirement is to produce more and better data from the manipulation of the properties of the models to learn how to provide the simplest and most useful approximations of the world to suit the economics of the situation at hand.

Transfer of training—the carryover of the results of training from school to the Fleet—is a major concern of the human-factors effort of the Center. It is important, for one reason, because of the very human tendency to learn to apply "right" responses to "wrong" situations. For example, the electronics technician who has been accustomed to pulling vacuum tubes from a live circuit will have some surprises if he attempts to do the same thing with a transistor circuit!

It is the purpose of this article to identify and describe briefly some of the more important areas of research being pursued by what is now titled the Human Factors Laboratory.

Laboratory Facilities

The Human Factors Laboratory operates and maintains a behavioral research facility for conducting a broad program of perceptual-motor, psychophysiological, and human-factors research. Emphasis in the program is given both to long-term experiments in the area of human perceptual and response characteristics and to the rapid construction or modification of training components for human-engineering feasibility testing and verification.

Physically, the research facility is composed of three main parts:

- A general-purpose laboratory equipped to conduct studies of such phenomena as vision, audition, and tracking. One project now underway involves the utilization of electronic biopotential pickup, amplification, and data processing to measure and record eye movements (see Figure 1). The ultimate goal is to utilize eye movement for such purposes as the direct guidance of vehicles. Another objective of the biopotential-signal data-processing research is the determination of the basic psychomotor character of human performance and its applications to training problems and devices. This work is expected to lead ultimately to the improvement of motor-conditioning techniques, high-g exoskeleton development, and a host of other potential applications. In cooperation with the Computer Laboratory of the Center, a general-purpose hybrid computer is being assembled to conduct the necessary computations for the biopotential-signal system as well as for other experimental projects.
- The second part of the facility consists of a cine-dome equipped for the collection of data concerning human visual perception. Apart from the real world, this installation supplies one of the best available demonstrations of the empty or unstructured visual field, which is of interest in so many military surveillance situations.
- The third part of the facility, which is located at a nearby college, utilizes Navy equipment and college subjects in the investigation of pitch-discrimination training, tracking performance, simulated air-to-ground detection, and other problems which require many human subjects.

Fidelity of Simulation

To the psychologist concerned with transfer of training, optimum simulation is measured not in terms of physical realism, but rather in the extent that training in an artificial environment will enhance performance on the operational task.

Interest in flight simulation is marked by five current projects dealing with such problems as reducing fidelity of simulation without loss of training effectiveness, the importance of cockpit motion in flight simulation, the potential for training time-sharing skills, target recognition and identification, and empty-field myopia.

Pilot Performance as a Function of flight Simulation. The question of total simulation versus selective simulation raises a number of practical and theoretical problems, two of which this project was designed to answer:

- Does high-fidelity simulation increase a pilot's performance sufficiently to justify its high cost?
- What elements can be deleted from the simulation equations so that equivalence of training is achieved?

The vehicle used in this study is the Universal Digital Operational Flight Trainer Tool (UDOFTT) located at the Center's Garden City facility. The computer is providing generalized jet-flighter characteristics to an F-100 cockpit. The purpose of the present work is to develop the computer programs and to pretest the flight maneuvers and performance measures prior to engaging in full-scale experimentation.

The Use of Motion Cues in Flight Simulation. The purpose of this study is to assess the value of cockpit motion in alerting pilots to emergent conditions and in improving corrective responses. The study will also attempt to assess how motion helps and if this help is related to the amount of motion.

A motion platform at the Grumman Aircraft Engineering Corporation is being used as the vehicle for this study. The platform provides pitch, roll, and heave, with yaw and forward translation being provided by a visual display. The visual display uses a point light source for the rear-screen projection of a seascape and carrier. This projection is then picked up by a TV camera and displayed on a monitor in the cockpit (see Figure 2).

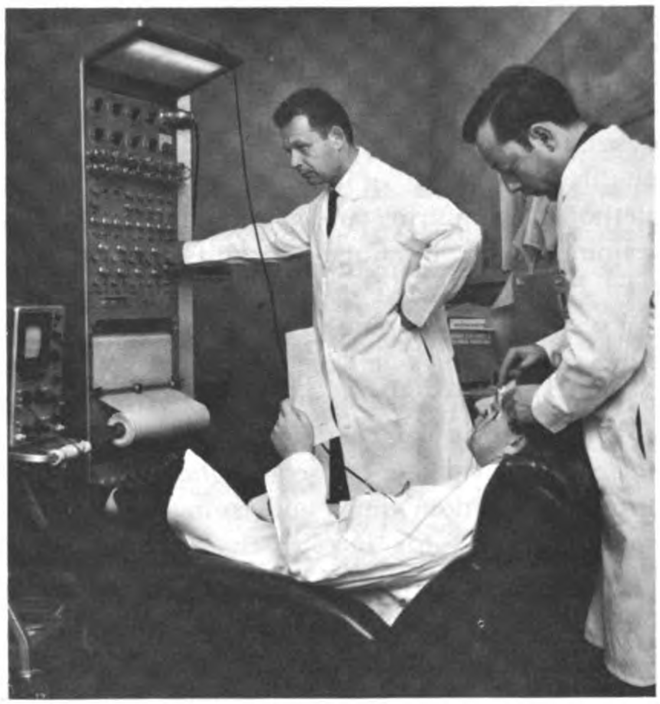


Figure 1 – Biopotential recording equipment. Electrodes have been placed on subject's head for study of lateral eye movement.

2 – The value of t motion in alerting to emergent conditions ı improving corrective ıses is studied by means ;imulated pilot cockpit notion platform. Shown re the cockpit, controls, ıual display.

The computer is programed to provide general fighter characteristics in a simulated carrier landing approach. In the experiment, two groups of jet pilots experienced in carrier landings are being tested—one having training with motion and the other with no motion. As emergent conditions are initiated by various control malfunctions during the training period, a number of measurements are recorded, including errors in glide angle and heading, time taken to respond to malfunctions, and respiration rate.

Results of preliminary experimentation indicate that control errors tend to be much greater under the no-motion condition, which would appear to favor the inclusion of cockpit motion in the trainers.

Time Sharing Training. Pilot success in landing, collision avoidance, aerial surveillance, and aerial refueling depends on confident, efficient, and correct time-sharing between inside- and outside-cockpit information. While many pilots develop appropriate time-sharing patterns in the course of their training and operational flying, the increasing speed of Navy aircraft and the growing congestion of airspace have pointed up the need for investigating more thoroughly the nature of time-sharing behavior. Our aims include systematic methods of acquiring and retaining such skills, as well as the formulation of training devices to afford appropriate practice cheaply and without danger to pilot and aircraft.

To test whether time-sharing skills are susceptible to training, one "more experienced" and one "less experienced" group of A4 Marine pilots are being given eight hours of training (spread over eight weeks) in a simplified device with a visual display that simulates the ground plane, the sky plane, and the horizon in navigation-cruise and glide-bombing maneuvers. Intruder aircraft appear at random times and from random directions. Cockpit instruments can be shut off for successively longer intervals of time, and aircraft malfunctions can be introduced. Equivalent groups of control subjects are *not* given this generalized training.

At the end of the training period, both the experimental groups and the control groups will be tested for performance in the A4D-2N operational flight trainer. This device will be equipped so as to be capable of simulating the outside world as it appeared during the two maneuvers of the training session, as well as simulating conditions of other maneuvers. Pilot performance will be measured in terms of adherence to the prescribed flight path, awareness of emergencies, and detection of intruder aircraft.

The need and significance of such a study can be gauged by two factors: (1)Visual displays for specific extra-cockpit simulation are about 10 to 20 times as costly as generalized attachments, and (2) only the generalized trainers are small and sturdy enough to be used routinely on aircraft carriers.

Target Recognition as a Function of Viewing Mode. For a long time, target recognition and identification have been recognized as difficult perceptual tasks.

The akinescope device used in this research was developed initially to determine the feasibility of an optical system to stop apparent motion in a continuously moving visual field. One of its applications would be to present a subject with successive, adjoining, static views of the terrain beneath his aircraft. One of the hypotheses leading to the development of the device was that the stop-action mode might facilitate detection of ground targets. An experiment was designed to test this hypothesis in a simulated aerial target-detection task. The design of the experiment also permitted assessment of the effects of aircraft speed, location of targets, practice, and transfer from continuous- to stop-action modes.

The following results were obtained:

- The stop-action mode does not facilitate target detection; the subjects in the experiment consistently were able to detect more targets in the continuous-action mode, apparently because the stop-action mode disrupts visual scanning patterns.
- As aircraft speed increases, target detection becomes more difficult; this finding was expected.
- Targets in the center of the viewing aperture are detected more easily than those near the periphery, which indicates, probably, that the subjects did not scan systematically.

The next steps are to repeat the experiment, making simultaneous recordings, and to conduct research on training in systematic visual scanning procedures.

Visual Performance in a Homogeneous Environment. In achieving successful rendezvous during flight at high altitudes, many judgments must be made involving visual orientation, visual acuity, depth perception, relative motion, and similar factors. If the background in which the pilot is flying is homogeneous, that is, devoid of details upon which he can focus, several of these visual tasks may be very difficult to carry out. For this reason, experiments concerned with the effects of homogeneous environments on visual performance have been and are being conducted in the Human Factors Laboratory.

This work has served, first, to increase our awareness of the complexity of the problem, and second, to indicate that the wearing of sunglasses or goggles during flight may have a significant bearing on visual performance.

In one of our studies, subjects were required to detect targets in a highly structured environment and in a homogeneous environment while wearing one of a variety of lenses. They also wore a pair of goggles having neutral-density filters. No differences were noted in the effects of the lenses; however, a significant decrement in target detection occurred in both the homogeneous and structured fields while the subjects wore the goggles.

With regard to the accuracy of visual orientation in the homogeneous environment, an experiment was conducted in which subjects were required to reposition to geometric center various size targets located at different positions in the homogeneous field. Our results suggest that accuracy of adjustment is affected both by the size of the target and the direction from which the target originates.

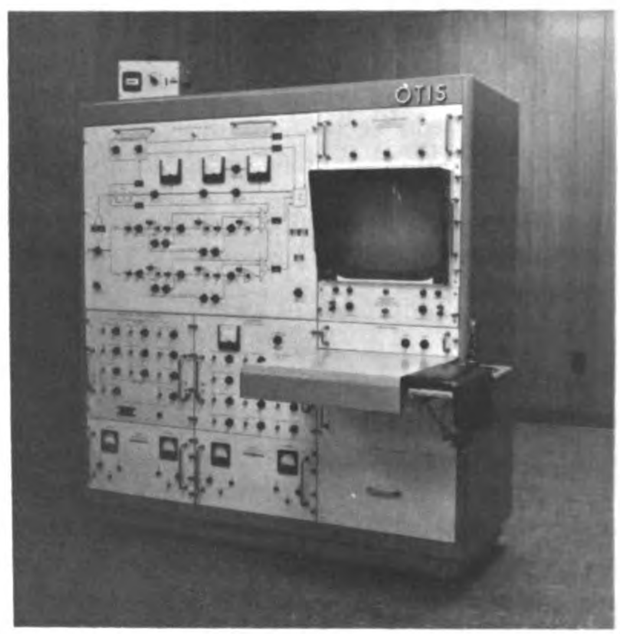
Training for Transfer

Transfer of training may be conceived of broadly as the change in performance on one task as a result of practice upon another. Classical and theoretical concepts of this phenomenon have been shown to be suspect. It is becoming increasingly more evident that the relationship between simulation and transfer is complex and variable for tasks of different types. A representative study in this area of fundamental concern is described below.

Tracking and Adaptive Learning. Complex training devices which have either digital or analog features, or both, can be viewed from two different aspects. The traditional view is to consider training devices as static, designed to demonstrate a concept or to provide a synthetic situation in which human skills and techniques are developed or improved. A more recent concept is to think of these devices as dynamic, capable of changing their mode of operation as a function of the level of the trainee's performance. Such devices may be thought of as being adaptive, because the level of task difficulty is always matched to the level of the trainee's ability.

Experiments were conducted in which an adaptive tracking simulator was used as the research apparatus. This device has the basic characteristics of many vehicles. The operator is given an assigned task, such as keeping a blip on the cathode ray tube for a certain number of minutes. Any deviation from this task, such as losing the blip from the face of the scope, is an error. The errors are fed back into the system in various ways to modify one or more characteristics of the machine or the level of difficulty until the trainee can perform the task at a specified level. **Figure 3 shows the adaptive tracking** simulator.

Figure 3 – Otis Adaptive Trainer.



For the practice sessions, three levels of difficulty were established—easy, moderate, and hard. According to the level, the machine gave much, little, or a moderate amount of help to the subject in keeping the blip on target. Each group of subjects was required to practice an hour a day for ten days on an assigned level of difficulty.

The results showed that the level of difficulty during practice was the important factor. It did not matter how the experimenter varied the simplification parameters of the system's dynamics or whether the trainer aided the subject quickly or slowly. Moderate levels of difficulty during practice gave good results on all tasks, whether they were hard, moderate, or easy. Very difficult levels of practice gave poor training on all tasks, and easy practice gave poor to fair training.

Training for Tactical Decision Making

Training programs and training devices traditionally apply a positive approach of "training in" desirable behavior. A fundamentally different approach appears appropriate to decision-making training—namely, an emphasis on procedures designed to "train out" many of the undesirable behavioral characteristics which humans bring with them to tactical situations.

At present, the designs of command-control systems in many cases reflect the view that the most effective route to improved system performance involves the use of summary displays of computer processed data—that is, that the availability of precise numerical statements of the probabilities associated with tactical events will automatically result in "better" decisions. The fact is, however, that little is known regarding the basis upon which individuals make such decisions. Indeed, some experimental evidence was obtained which suggests that, unless individuals are suitably trained, they may exhibit various forms of undesirable behavior when responding on the basis of disembodied numbers. Moreover, experimental results reveal that decision makers often exhibit considerable uncertainty with regard to the resolution of situations in which they are at a disadvantage relative to an enemy. Practice with such situations should be given emphasis in tactical decision-making programs.

These results plus additional ones uncovered will be pursued for the next several years in order to improve decision-making performance. It is anticipated that the results derived from laboratory experimentation will be taken into field situations for refinement and determination of practicality.

Systems Approaches

The demands imposed upon designers of training devices increase as operational systems become more complex. In the interest of economy of time, effort, and costs, an attempt is being made to systematize information-gathering procedures in a manner consistent with the unique requirements of training. The problems of determining which tasks of a system are to be selected for training may be regarded as analagous to the strategy of giving precedence to one weapon system over another. The task and system analytical approaches being developed have the two-fold purpose of allowing data to be evaluated in precise and quantified units and of assuring that the recommended training approaches reflect the best possible payoff in terms of cost and improvement in performance.

A Cost-Effectiveness Approach to Operational Readiness

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In order to perform its assigned mission, the Navy must, at all times, strive to achieve and maintain a state of operational readiness. The key to operational readiness is training, and one of the keys to efficient training is cost effectiveness, which means receiving the most benefit from each training dollar expended.

Here is a typical problem: Train the pilot, co-pilot, and five-man crew of the Navy's Orion ASW Patrol plane (P-3A) to work as a smoothly functioning, well-coordinated team during anti-submarine warfare.

Here is the most obvious solution: Take one P-3A aircraft and crew; add fuel, sonobuoys, practice depth charges, smoke lights, flares, and dye markers. In addition, procure the services of one or two surface vessels and a submarine or two that just happen to have no operational commitments that day. Then mix well for the five or six hours that a typical ASW exercise may take.

By following these directions you have started to solve your problem—that is, if inclement weather or a faulty engine have not forced postponement of the exercise. However, even if the above items were available at all times, were in good working order, and their operation was not impeded by bad weather, the cost of conducting such training on a regular basis would be prohibitive.

A similar problem exists for each major Navy weapons system—airborne, surface, or sub-surface. What, then, do we substitute for the operational equipments to provide the many individual skills, team skills, and capacities for decision making needed by the men of today's complex electronic, computerized Navy?

NTDC's answer is to provide training devices designed to create a dynamic synthetic training environment as responsive to the actions and reactions of the trainee operator as is the operational equipment that it simulates.

The figures given in the table on page 23 make it apparent immediately that, from a cost-effectiveness standpoint, maximum possible use should be made of weapons-system trainers (WST) to supplement the operational flight curriculum. The concensus of users is that one hour of training in a weapons-system trainer is equivalent to one and one-half hours in the operational aircraft. This difference is explained by certain inherent advantages embodied in the trainer, such as, but not limited to, the following:

- *Training in emergency procedures.* Because of the extreme hazard to personnel and equipment, training in emergency procedures cannot even be attempted in the operational aircraft. In the trainer, however, they can be practiced safely until the pilot's and crew's reactions are instantaneous and positive.

OPERATIONAL AIRCRAFT	HOURLY TRAINING COST	RESULTANT SAVINGS PER HOUR (WST)	HOURLY TRAINING COST	ASSOCIATED WEAPONS-SYSTEM TRAINER
SP2E (P2V5FS)	$ 658	$ 495	$163	Device 2F70
F4B (F4H)	4,258	3,908	350	Device 2F55
SH3A (HSS-2)	1,255	1,120	135	Device 2F64
A4C (A4D)	648	418	230	Device 2F62
S2D (S2F)	629	479	150	Device 2F56
F8D (F8U)	1,324	1,164	160	Device 2F63

Comparison of training costs of operational aircraft and weapons-system trainers (WST), showing the per-hour dollar savings that can be realized when the WST is used instead of the operational weapons system to achieve an equivalent level of training.

Listed in the column at left is a representative, across-the-board selection of weapons systems, including fixed- and rotary-wing aircraft, that perform such missions as patrol, search, intercept, and attack. The elements making up the total hourly operating cost include the following: Fuel power, depreciation, overhaul, support personnel, and aircraft strike and damage costs. The figures for the operational weapons system were taken from a 1963 Bureau of Weapons report to the Chief of Naval Operations on training costs, while those on the weapons-system trainer were extracted from NTDC records.

- *"Freezing" of exercises.* In the trainer, an exercise can be stopped at any point to allow for discussion or correction. The exercise can then be resumed, or it can be re-started with initial conditions prevailing. In the operational aircraft, the exercise must be carried through to conclusion or be discontinued.
- *Over-the-shoulder coaching.* This kind of instruction, when needed, is much more feasible in the trainer than in the operational aircraft.
- *Monitoring of performance.* All instruction in the operation of single-place aircraft must be given during pre-flight briefings or by radio communication. No opportunity exists for close instructor monitoring of performance. This condition is obviated in the WST.
- *In-transit time savings.* All operational training in the aircraft must be on a real-time basis, little benefit being gained while the aircraft is traveling to and from the on-station area. In the WST, no time is lost getting on station or returning. In addition, training can be done at a real-time rate or slower or faster, as desired.
- *Trainer availability.* The availability of the WST for operation is more certain than that of operational aircraft; in addition, adverse weather conditions do not affect the scheduled utilization of the trainer.

In view of these many advantages of the trainer, an obvious question to ask at this point is, can the WST replace the operational aircraft for training purposes? The answer is that it cannot and is not intended to do so. But it can be a powerful tool when used to its fullest extent to supplement and complement operational training.

As indicated in the first advantage listed above, training is required not only to provide proficiency in performance of assigned tasks, but also to enable flight personnel to save their own lives should the necessity arise. It is not possible to calculate the actual dollar loss, both to the Navy and the country as a whole, resulting from aircraft fatalities that could have been prevented if adequate training had been given. Consider also the logistic expense occasioned by the reassignment and rescheduling of air crews due to flight fatalities and you begin to realize the need for repeated emphasis on flight safety and more thorough training.

Not all Naval activities have access to flight-physiology devices, such as ejection-seat trainers, ditching trainers, and high-altitude low-pressure chambers. As a result, a man stationed at an activity not so equipped may receive his first training session when he is confronted with the decision to eject or ride his plane down and ditch at sea. This is the moment of truth: He reacts correctly or doesn't live to tell the tale. By way of contrast, personnel stationed at activities where such devices are located can safely receive thorough survival training without danger to life or equipment.

Of 153 aircraft abandonments that occurred in fiscal year 1962, one-hundred and thirty-three were ejections and 20 were free bailouts. A total of 132 were successful, and 21 resulted in fatalities. Comment by the Aviation Safety Center, Norfolk, Virginia, was to the effect that most of the 21 lives were lost needlessly because of lack of a sure knowledge of ejection-seat and aircraft-abandonment procedures. Such knowledge could have been safely and economically acquired if ejection-seat trainers had been provided in sufficient numbers to be available to all flight personnel.

A further testimony to the value of survival trainers comes from a report by an A4D pilot who was forced to ditch. He stated, "I owe my life directly to the fact that a week prior to ditching I performed an abandonment drill in the Dilbert Dunker while wearing an anti-exposure suit and full parachute harness." This testimonial is but one of many that underscore the great savings to be realized through training devices designed for application to the aeromedical, flight-physiology field.

A Submarine Simulator—Continued from page 14

the simulator would be designed for repeated use at sea without reliance on a tender or shore base for overhaul and maintenance. This objective could probably best be met by building the simulator as a sealed unit. Such a unit would require only recharging, refueling, and resetting or replacing of the programer between repeated runs at sea. If at any time the simulator did not function properly, it would be abandoned and another one substituted for it.

The final step in the development of the new nuclear submarine simulator will be to combine and integrate all of the practical features revealed by these studies into a single unit. The Navy will then possess a simulator having the maneuverability and speed characteristics of a nuclear submarine and one that will respond realistically to all types of active and passive submarine detection devices. No longer will it be necessary, as it has been in the past, to divert nuclear submarines from their vital assigned missions in order to participate in ASW training exercises.

Radar Scope Interpretation Trainer

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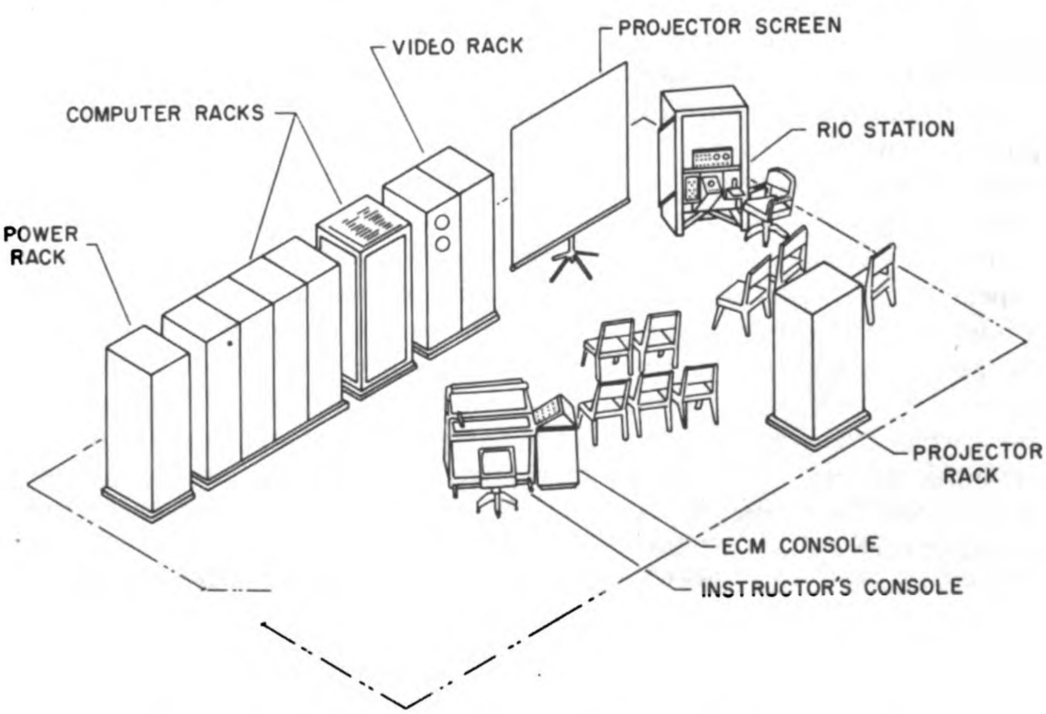
Naval Training Device Center

An airborne missile-control system is capable of locating a target in all weather conditions, launching the missile armament, and providing guidance signals which enable the missile to seek and intercept the target. Airborne radar sets are designed to be operated independently or in conjunction with other components in the airborne missile-control system.

The complexity of airborne missile-control systems has made classroom lectures on air-intercept radar procedures and presentations inadequate. By this medium, instructors could not satisfactorily correlate the radar-scope presentation during the search, acquisition, and attack phases of a mission with what was happening in space between the interceptor and target aircraft. In addition, the high speeds achieved by modern aircraft and, therefore, the short time that is available to the pilot to interpret the radar scope and take appropriate action could not be demonstrated realistically by lectures. Also, actual target intercepts vary in range, elevation azimuth, and attack mode to such degrees that they could not be presented adequately on the blackboard.

The Radar Scope Interpretation Trainer, Device 15C4A, was developed to serve as a classroom demonstrator and trainer to familiarize pilots and radar-intercept officers (RIO) with two models of air-intercept radars before these officers made actual practice flights. The trainer was intended for use



Layout of Radar Scope Interpretation Trainer, Device 15C4A in conjunction with lectures to demonstrate to as many as ten students at a time the search, acquisition, and attack phases of operation of air-intercept radars. It assists the pilot in forming a mental picture of the spatial relationship of his aircraft to the target aircraft, and it demonstrates equipment limitations, including the effects of electronic countermeasures (ECM) on the radar displays and the countermeasures techniques to be utilized when ECM is employed by an enemy. The trainee also receives actual operational training at a simulated RIO station.

Briefly, interceptor, target, and electronic-countermeasure simulation are controlled from the instructor's and ECM consoles—the results being presented on the video rack, on a projection screen, and at the RIO station. The student is able to compare the presentations on an enlarged radar scope at the video rack (which are similar to what he sees on the radar scope in his aircraft) with the presentations on an adjacent projection screen. The information given on the projection screen includes the following:

- Intercept and target paths with increment time markers on each path.
- During the attack phase of a problem, silhouettes of the interceptor and target aircraft.

In controlling the displays at the RIO station and video rack, the instructor has the prerogative of activating either the radar set controls at the instructor's console or the RIO station. With a student at the RIO station, the instructor can evaluate actual trainee operational performance of air-intercept radar techniques. Operating from a control console, he can select the type of radar, course, and armament to be demonstrated and a maximum of six targets to be displayed on the radar scopes. The multiple targets are arranged in a basically rectangular formation with one target designated the master; the remaining five targets are slaved to the master. Controls are also provided to vary the spacing between the targets and to adjust the heading, airspeed, and altitude of the master target and, hence, of the formation. In addition, the airspeed, rate of turn, and rate of climb-dive of the interceptor can be adjusted.

Interceptor and target signals are introduced into a 400-cycle analog computer system, resolved into a computed range, relative elevation, and relative bearing of the targets to the interceptor, then presented to the projection system, video rack, and RIO station. The target and electronic-countermeasure signals are introduced at the video level into the radar system and are gated to appear on the radar scopes at the correct interceptor radar-antenna-beam azimuth and elevation angles. During the attack phase of a problem, the computer provides the correct lead angle and fire control data to the radar scopes. These data are required to enable the interceptor aircraft to pursue the correct attack course to achieve a successful strike with a particular type of missile or gun. In addition, appropriate radar displays, such as B sweep, horizon line, and range strokes, are generated and introduced to the radar scopes to correspond to the mode of operation of the radar.

The enlarged radar display at the video rack is accomplished by means of a five-inch cathode-ray tube and rear-projection system which provides a twofold magnification.

—Continued on page 47

Interservice Operations

B. L. Sechen
U.S. Army Participation Group
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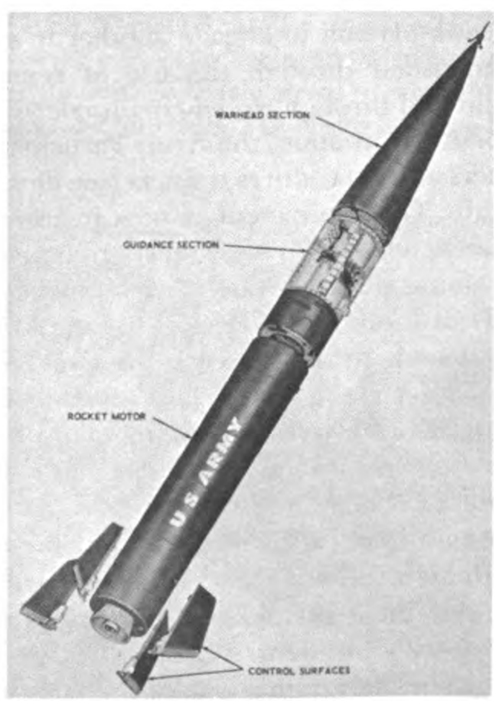
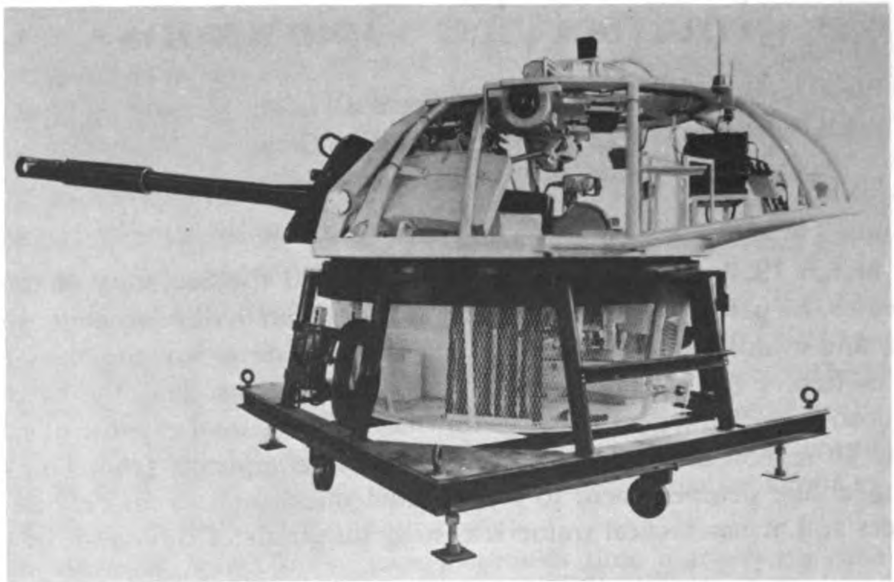
In March 1950, the Secretary of the Army and the Secretary of the Navy agreed to the participation of the Army in the research, development, procurement, and evaluation of certain training aids and devices at the Navy Special Devices Center (as NTDC was then called). Since that date, the Center has produced some 240 types of devices for the Army at a total expense of approximately 40 million dollars. The devices range in complexity from simple ones costing a few pennies each, to complicated ones, such as air-defense radar trainers and armor tactical trainers, costing hundreds of thousands of dollars each.

Initially, the Army contingent, called the Army Participation Group, was under the direction of the Continental Army Command, Fort Monroe, Virginia. Since the Army reorganization in 1962, the Group has been under the direction of the Army Materiel Command. COL James S. Greene, Jr., USA, is the Commanding Officer of the Army Participation Group as well as Associate Director of the Center. The Group has a complement of 10 officers representing all of the combat arms and several of the technical branches. These men serve as the project officers for Army training-device development work.

Army projects assigned to the Center are integrated into the overall program there. When they reach the engineering department, for example, they are handled right along with Navy tasks. Thus an engineer may work on several



Sergeant Missile Handling and Checkout Trainer, Device 3G52. This equipment is issued to artillery units for training of crews in assembly, loading, and checkout of the missile.



The M48A1 Tank Turret Trainer, Device 3A78. By means of this equipment, a tank crew learns to work together as a team in loading, turret maintenance, and operation of the M48A1 tank.

Navy and Army devices at the same time. The only separation between Army and Navy projects occurs early in their existence, at the times of planning and military-requirements determination.

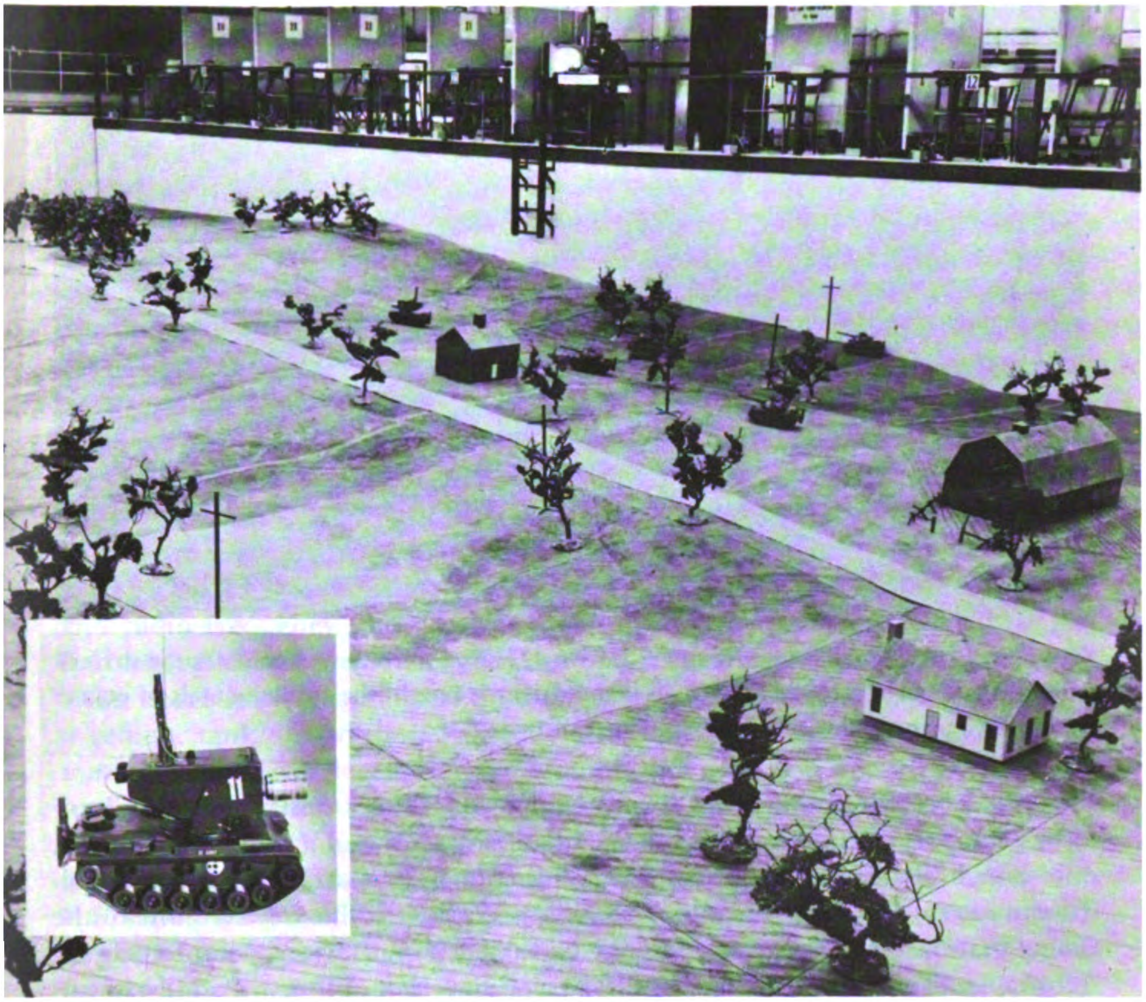
Training devices are under development or being produced for all of the Army's combat arms. The Sergeant trainer (Device 3G52; see illustration) is an example of a device prepared for the Artillery. The Tactical Platoon Leader Trainer (Device 17AR1) has been developed for Armor. It enables one tank platoon to engage another in simulated combat. The engagement is accomplished through the use of remote-controlled scale-model tanks and terrain and through closed-circuit television.

For Army aviation, the Army Participation Group has provided maintenance trainers and procedures trainers (see illustration of Device 2C9) for the Mohawk aircraft. This equipment is now in use at the Aviation School, Fort Rucker, Alabama, and the Army Transportation School, Fort Eustis, Virginia.

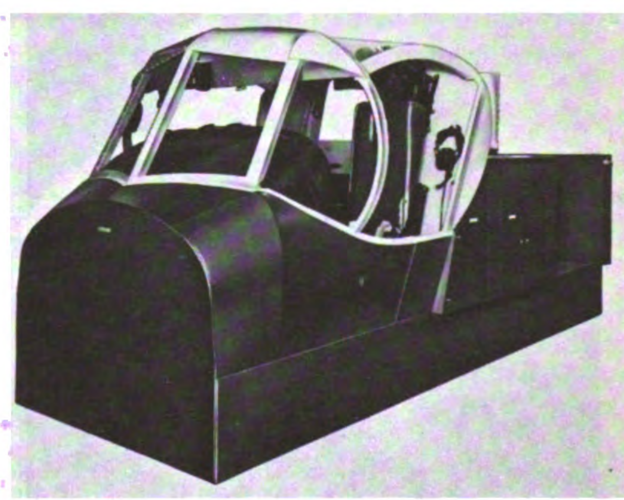
Training devices under development for the Infantry soldier consist of a family of hit-indicator devices for the M14 Rifle, 106mm Recoilless Rifle, and various tank guns (see article, "Simulated Operation of Real Weapons Against Live Targets," this issue). These devices, which depend upon a radio link with an infra-red source, enable gunners to be trained without the use of live ammunition. They can also be utilized in a simulated combat situation.

A device that will simulate the fall-out of a nuclear burst is under development for use in the nuclear biological and chemical field.

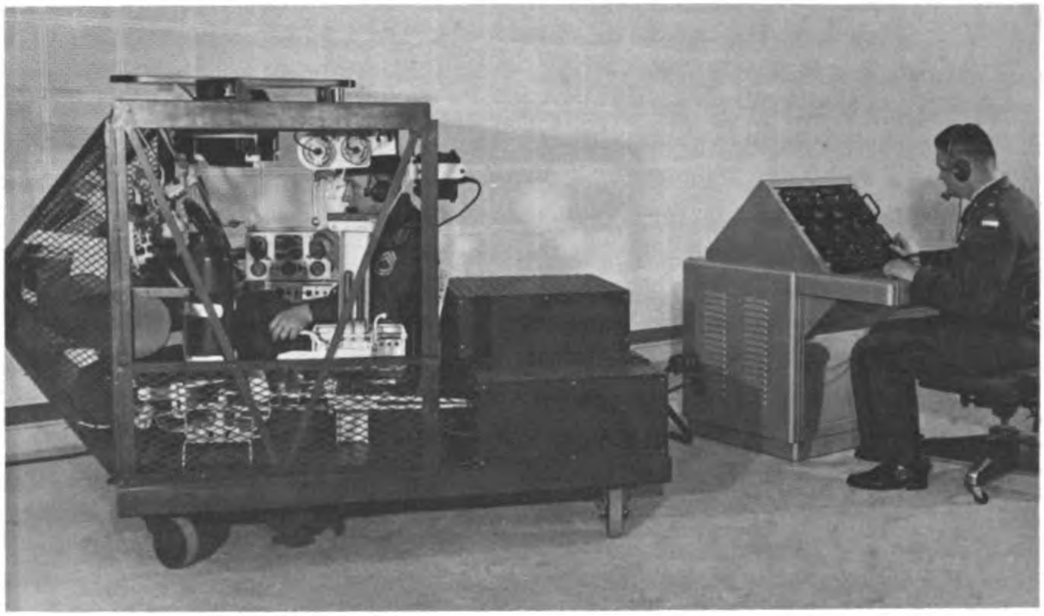
Although the Air Force does not have personnel stationed at the Center, it does rely on it occasionally for training-device development. At the present time, a weapon-system trainer is being designed for the Air Force at the Center. This trainer program is one of the largest ever undertaken.



'he Tactical Platoon Leader Trainer, Device X17AR1. Over a model terrain floor measuring about ? by 126 feet (equivalent to 83 acres at the scale of 1:20), 20 radio-controlled model tanks, operating two platoons, engage in simulated combat. Two of the vehicles are equipped with turret-mounted inch vidicon cameras and the necessary circuitry to transmit terrain scenes to remote television onitors serving platoon-leader trainees, instructors, and observers. The device has been installed Fort Knox, Kentucky.



Cockpit Procedures Trainer for the Mohawk A0-1, Device 2C9.



The Tracked Vehicle Driver Trainer, Device 11H20, shown here, simulates the driver's compartment of the M48A2 tank. In it the driver is taught the fundamentals of engine start, run-up, and reaction to various types of terrain.

A radar repair training set is an example of devices designed for still another category of users. It includes a small radar set and a radiation antenna, into which an instructor can insert malfunctions. By searching for these malfunctions, students learn trouble-shooting procedures. The device is one of the many that have been developed by the Naval Training Device Center to provide more effective training *throughout* the Armed Services.

The Honest John Handling and Checkout Trainer, Device 3G42, is identical to the actual missile in size and weight. It enables a crew to practice handling, loading, and checkout of the weapon.

Simulated Operation of Real Weapons Against Live Targets

Herbert Chaskin

Land Warfare and Missile Systems Trainers Division
Naval Training Device Center

The results of a number of research and development programs carried out for the Army Participation Group at the Naval Training Device Center are guiding the way to the simulation of combat situations in which operational weapons are used against live targets. The initial research resulted in the development of Hit Indicator Systems for the M14 Rifle, 106mm Recoilless Rifle, 90mm Tank Gun, and 105mm Tank Gun.

The operation of these systems is based on the use of an infrared (I.R.) link and radio frequency (R.F.) link between each target and weapon. The I.R. link consists of a photoelectric telescope or I.R. receiver mounted and collimated to an operational weapon and an omni-directional I.R. flashlamp mounted on a vehicle, tank, or personnel target. The R.F. link consists of an R.F. transmitter and receiver located at the weapon and a similar R.F. transmitter and receiver located at the target. Attached to the trigger mechanism of the weapon is a switch that causes the R.F. transmitter to send an interrogation pulse to all vulnerable targets at the time the weapon is fired. When this R.F. signal is received by the R.F. receiver of each target, the I.R. lamp of each target is caused to flash. Each target lamp is designed to transmit a coded flash within a specific interval measured from the time the weapon is fired, thereby indentifying the target and its location. The photoelectric telescope of the weapon detects the flash of the target over a narrow field of view in order to require the trainee to aim the telescope with an accuracy approximately the same as that of the real weapon. The detection of this flash initiates the transmission of a second R.F. pulse. The system is so designed that only the R.F. receiver of the target associated with the detected flash will receive this second R.F. pulse. This second R.F. pulse disables the weapon simulation equipment of the target and provides a visible and aural hit indication at the target by means of a flash lamp and emission of smoke and noise generated by a pyrotechnic device.

During the course of development of this I.R.-R.F. data link, two supporting-research programs were started. In addition to determining hit or miss information, the objectives of both programs included detection and display of a miss in units of angle of range and lead. In order to meet requirements for a 106mm Recoilless Rifle gunnery trainer, an electron optical tracker was developed in the first program. This tracker continuously measures the angle of miss between the gun line and the target and the range of the weapon to the target. In addition, a trajectory display of the round is simulated within the operational sight of the weapon.

Through another program that was based on a solid-state approach, a special photoelectric telescope containing a quadrant mosaic detector was developed.

A soldier squeezes the trigger of his rifle for a "kill." If his aim is good, radio-frequency and infrared links between the weapon and target will cause the lamp on the "enemy's" helmet to flash.

This telescope detects a miss within the quadrant area surrounding the area of the target. Continued development of a special lateral-type detector to be inserted within a similar photoelectric telescope will further improve the resolution of miss to satisfy the accuracy requirements of a gunnery trainer.

The simulation of combat involving realistic weapons and live targets will be planned so that full tactical flexibility can be applied safely and at relatively low cost. Under present training conditions, men have been wounded or killed accidentally while crawling through infiltration courses; when the simulation system is utilized, such accidents cannot occur. Economically, the new training system is advantageous because it does not require the costly expenditure of large amounts of munitions. Thus the use of synthetic hit indicators and gunnery trainers during maneuvers will very appropriately fill the gap between live fire instruction and actual combat.

Training devices are not designed for application to combat situations alone. Many of them are prepared for workers in a variety of other walks of military and civilian life. For example, NTDC has developed special training devices for oceanographers. They include three-dimensional demonstrator models of instruments used to measure ocean phenomena. Instruction in the operation of these devices is also produced in the form of animated transparencies, sound/slide programs and sound motion-picture films.

Simulation Engineering and Research

M. Aronson
Head, Visual Simulation Laboratory
Naval Training Device Center

The technical program of the Naval Training Device Center calls for extensive applied engineering design and development work. Generally, the end result of this work is a prototype device and a very limited production run. To provide the optimum simulation for the trainer, a prospective simulation technique can be explored either before development of the trainer begins or at the same time that the development is underway. The former approach is usually preferred, because, as a result of the prior research, the performance specifications can be made more firm and, therefore, the estimate of total costs and time of delivery of the device will be more realistic.

The project's simulation engineering and research phase generally begins when the project or research engineer participates in the Training Situation Analysis (TSA). The TSA considers potential training requirements and furnishes the basic information necessary to prescribe the most effective and efficient devices for such training.

Some of the steps an engineer takes to define the proposed training device in the form of specifications and some of the engineering decisions and compromises that he makes will be described for a representative project with which the writer was closely allied.

A complex device which has been used to train Naval aviators and air crewmen for the past 20 years in various aircraft is the Air Weapon System Trainer (AWST). This device consists of a special-purpose analog computer having about 250 amplifiers, a replica of a cockpit or crew station where the trainees work, and a monitoring station used by the instructor and device operators. In preparing the specification for the AWST, the project engineer recognized that, except for the specific aircraft and equipment to be simulated, the general functions of this type of trainer would remain the same; therefore, the building blocks (components, subassemblies, etc.) could be standardized to achieve lower initial costs, greater reliability, and lower support costs. The main simulation engineering and research effort would concern mathematical models, computation techniques, and the arrangement of the instructor's work station. The trainee's work area did not require much research because it had to resemble the aircraft cockpit and crew areas and thus would change only as the operational equipment changed.

Research in the area of aerodynamic mathematical models for application to the AWST was carried out by the Massachusetts Institute of Technology, beginning in 1955. Since the analytical results of this study were based on computer runs at one flight condition, a decision was made at NTDC to compare the M.I.T. optimized equations with those used in an operational flight trainer of current design. The comparison was to be made for a number of flight conditions. Both sets of equations were programed and run on the Universal Operational Flight Trainer Tool (UDOFTT) in 1963. The results showed that the M.I.T. equations and the trainer equations, derived by the trainer contractor over a period of years, yielded similar representations of the aircraft's performance and stability characteristics. At this stage in specification writing, the project engineer was able to state definitely that the M.I.T. mathematical model would be utilized for the trainer. The advantage of reaching this decision before development was started was that the contractor would not need to expend engineering effort to prove out a new mathematical model for simulation of the aircraft.

As the engineer continued to develop the specification, he noted that the document describing the proposed characteristics of the trainer, called "Military Characteristics," or "MC," states that the trainer will reproduce realistically the characteristics of the aircraft. In fulfilling this requirement for the AWST, another problem was encountered that was solved under a supporting-research program without burdening the training-device development with techniques research. It concerned the human element, which is important because the final evaluation of a new aircraft and its flight simulator is pilot opinion. It was necessary to (1) identify those aircraft parameters which influence pilot opinion and (2) describe a method for measuring them in the trainer which is consistent with the method used for measuring them in the aircraft. In a study performed by the Cornell Aeronautical Laboratory, a new method of trainer testing was evolved, called "dynamic performance measurement," which involved recording and analysis of the time histories of the simulator's response to step inputs. Previously, static testing of the trainer was required. In another study conducted by the Cornell Aeronautical Laboratory, uniform design criteria and tolerances were established for control forces, displacement, velocities, and accelerations based on comparisons of pilots' evaluations of aircraft and the corresponding simulators. Through this work, consistent tolerances and design values based on a pilot population and a comprehensive test program were obtained without taking more time than that required previously. In addition, differences between quantitative, recorded data and subjective pilot evaluations were reduced.

Another example of the application of supporting research to trainer engineering is the contribution of the UDOFTT operation to developing NTDC confidence and knowledge in real-time digital-computer operation. As a result of the research which has gone into the UDOFTT, technical proposals on trainers in which digital computers are to be used can be evaluated realistically and knowledgeably.

Next, the project engineer had to define the configuration of the instructor's station, or work area. The MC or the TSA report may identify the criteria the instructor will use in scoring the student, but not the exact form in which the data are to be presented. Human-factors studies on instructor-station arrangement and information readout and recording provided much of the knowledge needed to specify the appropriate configuration for the flight portion (pilot flight performance) of the AWST. With respect to mission simulation,

—Continued on Page 48

Sonar Operator's Target Classification Trainers

Arthur W. Menken
Land and Sea Systems Trainers Department
Naval Training Device Center

The sonar operator functions in a hostile underwater world which is capable of assuming an infinite number of disguises to thwart the discovery of its true identity. Through the maze of such interfering responses as those caused by reverberations, whales, old wrecks, underwater pinnacles, wakes, schools of fish, and intrinsic sea noises, actual submarine targets must be detected.

In recognition of the difficult problem encountered in training men to operate sonar equipment, the Naval Training Device Center, in 1952, instituted a research program concerned with the classification of the many interfering phenomena. It was considered impossible to duplicate electronically the complex visual and aural responses encountered by the sonar operator. Hence, the design effort of the initial research program was directed toward the development of a system based upon actual recordings made at sea. A suitable playback device was required so that a realistic sonar audio and video presentation would be made available to the trainee sonar operator.

In October 1953, NTDC contracted with the DGC Hare Company for the development of an experimental model of a Sonar Operator's Target Classification Trainer. From this development, the Government obtained the assignment of the rights to a patent application entitled "Training Aid System for Detection Equipment." The patentable features concerned the simultaneous preforming of the sonar beams and recording of a reference signal for use in correcting sound distortions carried by tape-speed variations or by stretching of the tape. Another desirable technical feature of the trainer was the use of sub-carriers to reduce the number of recorded channels and, hence, the required tape width.

A demonstration of the new trainer, called Device 15R5, was made on April 7, 1955, at the submarine base in New London. After witnessing the first major breakthrough in sonar recording, ADM Arleigh Burke, then Chief of Naval Operations, in a letter to the Commander in Chief of the U.S. Atlantic Fleet, stated: "The excellent training potential of this device in providing realistic training in target classification, maintenance of contact, and attack procedures is great, and the early exploitation of the device in operating ships should enhance the ability of sonarmen considerably...It is recommended that the playback unit of Device 15R5 be procured in sufficient quantity to equip all destroyer-type ships."

In July 1955, the Chief of Naval Operations stated in a letter to the Chief of Naval Research: "This trainer recently demonstrated the technique of tape recording the audio and video information received in a sonar during actual antisubmarine runs at sea, and subsequently reproducing that information in any like sonar by playback of the magnetic tape. That technique shows promise of providing the realism, heretofore unobtainable, for shipboard classification training."

At this time, NTDC began investigating the feasibility of recording the transducer, or preamplifier, output directly. This design was desirable because it would enable all console controls to be activated on playback and result in greatly enhanced operator training.

Device 15R5 was designed to operate in conjunction with the high-frequency scanner sonar set AN/SQS-1, which provides 180 degrees of display. It was subsequently rebuilt for operation with sonar set AN/SQS-11A. The display was expanded to provide for 360 degrees of audio and video presentation. In addition, ships' gyro information was recorded to provide a "true" bearing display. Additional accessory equipments—the Prototype Shorebased Playback Unit (Device 15R5D) and Tape Duplicator (Device 15R5F)—were accepted by NTDC in 1957.

A program for redesign of the 15R5A series was initiated in 1957 with the following objectives:

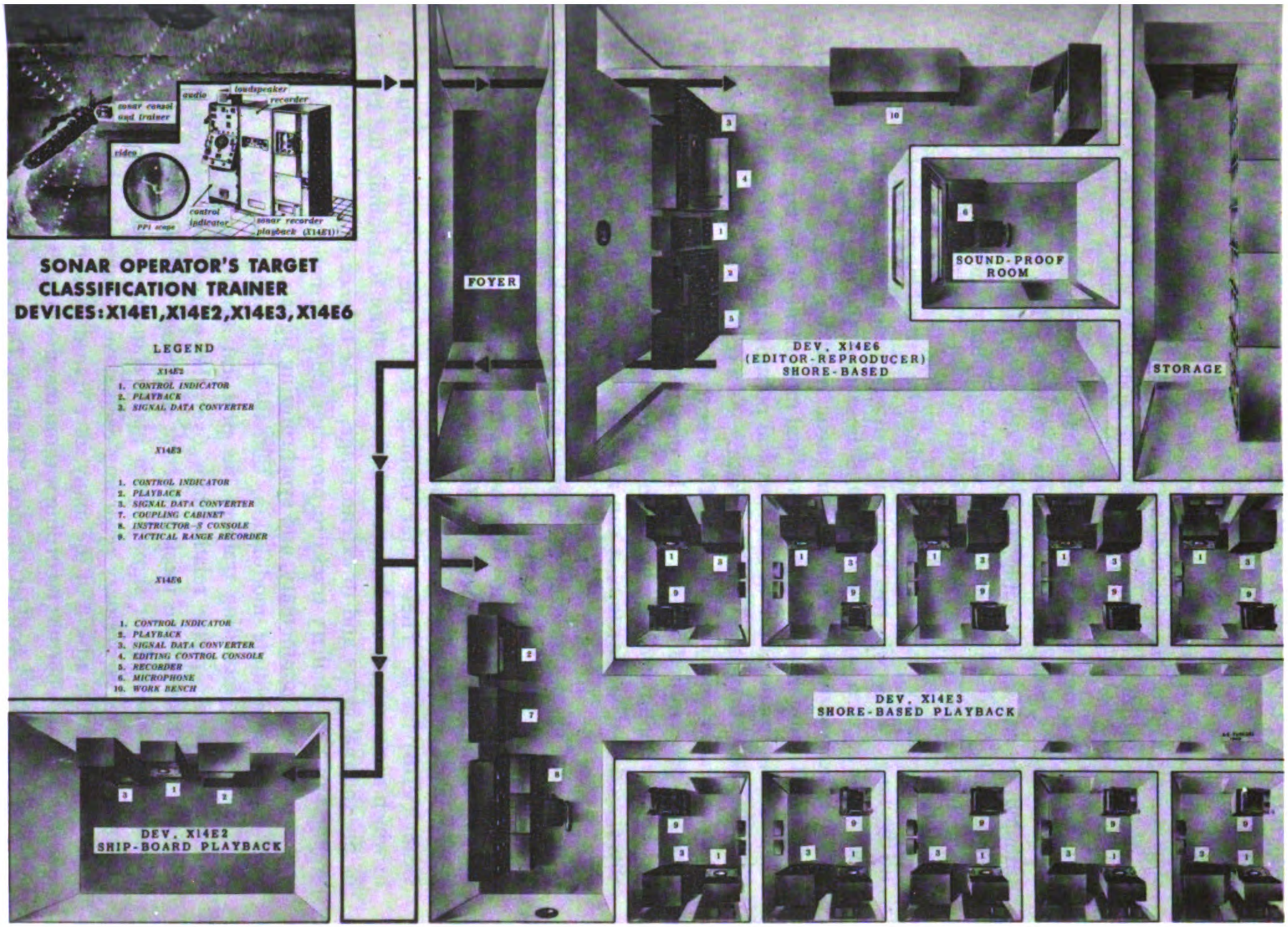
- Provide equipment compatible with all sonars in the low-to-high frequency range.
- Provide editing equipment for making training tapes from master tapes.
- Reduce equipment size and weight.
- Improve accuracy and stability.

The direct result of this program was the development of the 14E series of Sonar Operator's Target Classification Trainers.

One of these early devices—Device X14E1—is capable of recording training tapes, under actual operating conditions, carrying all of the information received by many AN/SQS-series operational scanning-type sonar equipments. This device utilizes a 1-inch, 14-track tape recorder to record a total of 66 signals—48 sonar signals, internal signals used for synchronization and control purposes, and a voice commentary. Narrow-band audio signals are recorded by means of pulse amplitude modulation, time-division multiplexing. Basically, this method involves a periodic sampling of the instantaneous amplitude of the signals to be combined, the sampling being done at discrete intervals and in a specific sequence to form a single pulse train. By this process, recorded information from all 48 staves of the sonar transducer are recorded in sequence on eight tracks of the magnetic tape.

The ship's course and sonar-sweep signals modulate FM channels which are recorded by means of frequency-division multiplexing. Video outputs, ship's commentary, and sonar synchronizing pulses are also recorded by this method. Frequency-division multiplexing combines simultaneously the signals of varying frequencies which do not coincide or overlap. Each signal may be a pure sine wave, an AM or FM modulated sine wave, or a band of frequencies. In the demodulation process, the multiplexed signals are simultaneously separated into their different frequency channels and restored to their original form before they are applied to the appropriate circuits in the sonar equipment.

Device X14E2 is a playback unit for tape recording on Device X14E1. It can be used with Device X14E1 as a recording reviewer to verify, while at sea, the training adequacy of tapes being made. Realistic sonar operator classification training can be provided in an actual shipboard environment by utilizing



Representation of Sonar Operator's Target Classification Trainer, Devices 14E-1, -2, -3, -6.

edited training tapes with DeviceX14E2 and an operational sonar unit. Device X14E3 is a shorebased playback unit capable of playing edited training tapes into a set of ten sonar equipments.

Device X14E6 (Tape-Editor Reproducer) provides the means of reviewing, editing, and duplicating the raw training tapes recorded by Device X14E1 in order to produce the finished training tapes used with Device X14E2 and Device X14E3.

Later NTDC developments in the sonar recording field include the Submarine Sonar Operator Trainer (Device 21B55). This equipment has been installed aboard several submarines for the recording of training tapes. It can be used with active and passive sonar equipment such as AN/BQS-4 and -4a and AN/BQR-2B and -7.

Good frequency response can be obtained by a rapid longitudinal movement of the tape. However, this results in a drastic reduction in available playing time from a given tape. To avert this limitation, the necessary head-to-tape speed is achieved by sweeping a magnetic head transversely at a relatively high speed compared with the longitudinal movement of the tape itself.

Recordings made at sea at this electrical position are not limited by any receiver adjustments made by the operator. As a result, the trainee is presented a pure recorded sonar signal. All of his controls are effective, and all playback functions are handled as they would be under real operating conditions. The device is of modular design and is completely transistorized. When used as a shorebased playback system, it can activate simultaneously up to four sonar sets.

Device 14E12, the latest sonar recording and playback trainer, was designed for use with the AN/SQS-26 sonar. In principle, it can be used with active or passive sonar equipment. It provides for 164 channels on two wideband tracks. Seventy-two channels are designated as the Zero Depression Beam (ZDB) track, and another 72 channels are known as the Variable Depression Beam (VDB) track. These latter channels record the operational situation in which sonar signals are bounced off the ocean floor to minimize the effects of the thermal layers and to extend range. The balance of the channels are assigned to two auxiliary tracks to provide such information as ship's course and speed, voice commentary, and synchronizing signals.

The basic amplitude modulation, time-division multiplex system utilized in NTDC sonar recording trainers has practical advantages in maintaining channel-to-channel phase relationships over the more obvious direct track recording. However, the most important advantage of the system is that it permits the recording of signals from many transducer staves on a single channel, whereas in ordinary recording each stave requires its own separate channel. With the advent of the many stave transducers, the pulse amplitude modulation system permits recording without massive duplication of equipment.

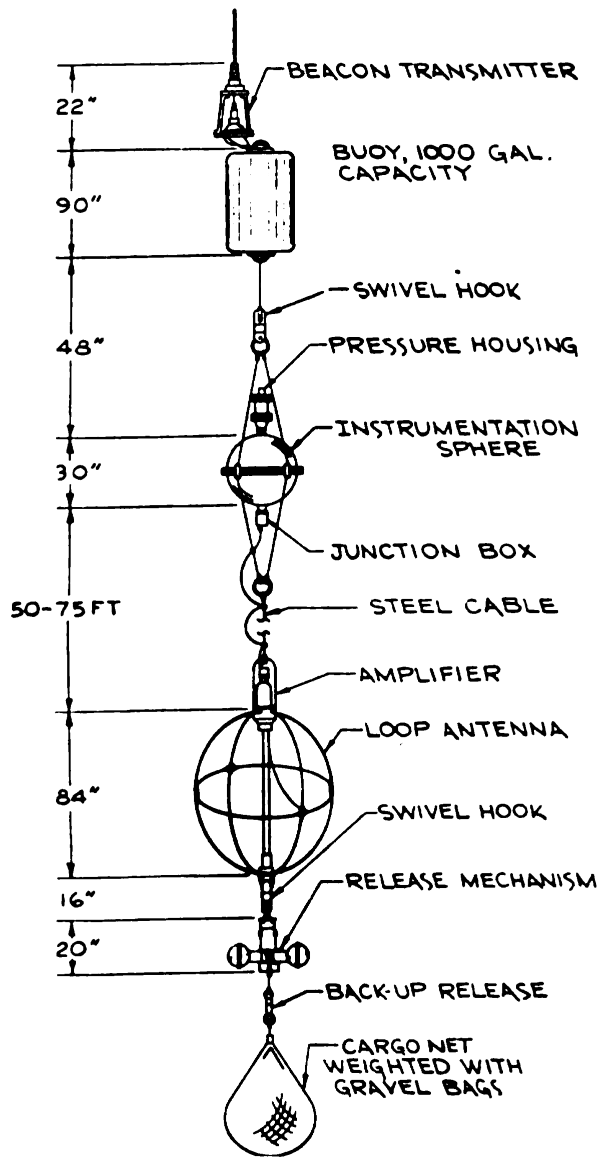
In the April 1964 booklet entitled, "Training Devices for Support of Anti-Submarine Warfare," 62 different devices are described. Thus the Sonar Operator's Target Classification Trainer systems described here represent only a small portion of the total NTDC effort in support of antisubmarine warfare.

Inventions

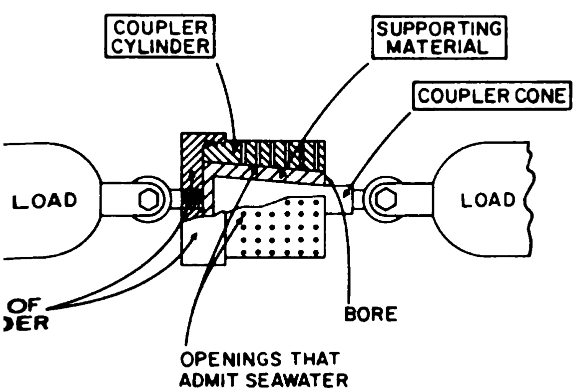
Deep-Sea and Space Coupler

Couplings which automatically separate after a predetermined time period have many uses in the Navy. One use is to separate automatically an instrumented deep-sea diving assembly from an anchor so that the assembly will float to the surface; an example of such an assembly is "Deep Dip," which is described in the accompanying illustration. Another use is to effect separation of the stages or payloads of rockets and missiles.

In the past, the general practice has been to cause the separation of loads by means of a coupler utilizing a supporting, or binding, material that changes its state or condition upon exposure to an external substance. This type of device has not proved entirely satisfactory under all conditions of service because of the difficulty in obtaining a supporting material which will not break while carrying a load.



A representation of the instrumented diving assembly, Deep Dip, right, and releasable coupler, below. Location of coupler in the assembly is indicated by caption, "Release Mechanism."



As a means of overcoming this shortcoming, Mr. Abraham Silverstein, of the Naval Ordnance Laboratory, White Oak, Maryland, invented a coupler which maintains a compressive force on the supporting material to increase its load-carrying ability. This coupler, described in U. S. Patent No. 3,139,032, issued June 30, 1964, consists essentially of two load-carrying members and the supporting material. The first load-carrying member is a cylinder that is closed at one end and open at the other and that has an internal bore that converges toward the open end. The second load-carrying member, which is in the form of a truncated cone, fits within the bore of the first member, its base end facing the closed end of the cylinder (see drawing). A layer of supporting material is placed between the inner and outer surfaces of the two members, so that it is subjected to compressive rather than shear forces. Therefore, the two members will not separate until the supporting material is removed.

When the coupler is used in the ocean, a number of holes are drilled through the cylinder to permit water to enter and contact the supporting material. This material—a gelatin or similar substance—is solid under normal atmospheric conditions but changes to a liquid after submergence for a predetermined period of time. When this change occurs, the cone-shaped load-carrying member slips easily out of the bore of the cylindrical load-carrying member.

When the coupler is used as part of a missile or rocket, the supporting material is a combustible or explosive substance, which, when ignited, burns or is blown away to effect separation.

Some of the important advantages of this coupler are (1) that the supporting material, which is loaded in compression, can withstand very large forces without breaking (in fact, tests have shown that the metal load-carrying members are more susceptible to failure than the gelatin material); (2) that the coupler is both easy and inexpensive to manufacture; and (3) that it has no moving parts.

Exploding Tape

Accurate simulation of conditions of the upper atmosphere is extremely important to studies of missile reliability and behavior. In one test that is made to determine the temperature and pressure reactions of a missile to the upper atmosphere, a model of the missile is mounted in a wind tunnel and exposed to a sudden blast of gas moving at supersonic velocity. To achieve accurate simulation, the gas must be completely free of any particles of solid mass. In the past, such particles have been produced by the material used to ignite the gas.

With this problem in mind, Stanley Ostrow, an employee of the Naval Ordnance Laboratory, White Oak, Maryland, developed an exploding metallic tape designed to provide instantaneous ignition of gases over an entire combustion chamber without leaving residual material having any appreciable mass. A patent on this invention, No. 3,143,069, was issued to Mr. Ostrow on August 4, 1964.

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On The Naval Research Reserve

Man in Extreme Environment

The second annual Research Reserve Space Science Seminar, based on the theme "Man in Extreme Environment," was held at the Moffett Field Naval Air Station during the period September 14-25, 1964. The program was sponsored jointly by the Office of Naval Research and Naval Research Reserve Company 12-3, located at Stanford University, Palo Alto, California.

RADM John McN. Taylor, USN, Commandant, Twelfth Naval District, gave the opening address at the seminar. He was followed by CAPT Malcom C. Friedman, USN, Commanding Officer, NAS, Moffett Field, who welcomed the reservists to the base, and by CAPT E. J. Hoffman, USN, Deputy and Assistant Chief of Naval Research, who discussed some of the current programs of the Office of Naval Research.

A "first" in seminar programming was an address by one of the 29 astronauts, LCDR Alan L. Bean, USN, who discussed "Man in Space." The reservists were fortunate that NASA approved the request for a presentation by an astronaut at this seminar, because of the some 7,000 requests received annually, only a few can be honored.

LCDR Alan L. Bean, USN

Engaging in a lively panel discussion on space and society are Mr. Robert Sackman, vice-president of AMPEX Corp.; Dr. W. N. Breswick (CDR, USNR), United Research Services; Dr. C. A. H. Thomson, Rand Corp.; and Dr. C. Alvarez Tostado, professor at Stanford University.

The seminar was broken down into sessions dealing with such topics as Man in Space, Aircraft as a Space Vehicle, Man in Orbit, Probing the Atmosphere, Man on the Moon, Man on the Planets, and Space Exploration. Some of the topics of sessions dealing with extreme undersea environments were Manned Aspects of Undersea Operations, Psychology of Limited Space, and Subsurface Physiology.

The speakers, who came from various West Coast companies, universities, and Government laboratories, were some of the foremost experts in the space science fields. Thirteen were Lockheed scientists, eleven were from NASA's Ames Research Center, five came from the University of California, three were from Stanford Research Institute, and the remainder represented various other facilities in the bay area.

A banquet was held on the evening prior to the closing day of the session. CAPT E. M. Blue, USNR, a member of NRRC 12-5, Berkeley, California, most ably served as master of ceremonies and introduced the guest speaker, Bishop Lane, who conveyed some serious thoughts in a thoroughly enjoyable manner. CAPT D. J. Mooney, Jr., USNR, of Washington, D. C., Special Assistant to the Chief of Naval Research for Research Reserve, addressed the reservists the following day.

Fifty-one officers attended, the majority being members of the Naval Research Reserve from companies around the country. Seven Army officers who are engaged in scientific civilian occupations were present also.

The arrangements for the seminar were made by LCDR W. S. Lindberg, Jr., USNR, of the ONR Branch Office in San Francisco, and by LCDR T. J. Kowall, USNR, seminar chairman, from NRCC 12-3. CAPT J. R. King, CDR W. E. Weeks, LCDR J. T. Nawrocki, LCDR Janet Foster, and LT Wm. Prichard Jones, all of NRRC 12-3, were responsible for the smooth administrative functions of the highly successful seminar.

Electronic Computers Seminar

The second annual Research Reserve Seminar on Electronic Computers was held at Texas A&M University, College Station, Texas, from August 24 to September 4. The seminar was sponsored by the Office of Naval Research in conjunction with the University and Naval Research Reserve Company 8-3, College Station.

The seminar was attended by 30 officers of the Navy, Army, and Coast Guard Reserves. Twenty-six attendees were Naval reservists, three were Army reservists, and one was a Coast Guard reservist. Fifteen states were represented. The administrative staff for the seminar was composed of two officers and two enlisted men.

The seminar was opened by CAPT R. H. Ballinger, USNR, who served as Commandant's representative and seminar administrator. The keynote address was made by CAPT W. E. Berg, USN, Assistant Chief of Research, Office of Naval Research. CAPT Berg pointed out the great interest of the Navy in electronic computers because of the need to solve operational problems of ever-increasing complexity. He discussed the limitations of present computers and projects being conducted by the Office of Naval Research for the application of computers to various tasks.

CDR B. C. Moore, USNR, served as seminar chairman and chief instructor. The seminar was conducted as a working session. The participants were given instruction in FORTRAN programming and were assigned problems for which they wrote programs. These programs were then compiled and run on the IBM 709 of the University's Data Processing Center. In addition to the instruction and workshops on programming, a variety of special topics and computer applications, with emphasis on military problems, was presented. Special topics included random numbers, simulation, game theory, linear programming, PERT, and impact of computers on statistics. Applications of computers to management information, activation analysis, industrial operations, and scientific research were presented by authoritative speakers from the faculty of Texas A&M University and from industry. Participants were encouraged to write programs on their own subjects of interest, and some of them did so. These programs were also compiled and run. The University's Data Processing Center provided both facilities and personnel for the support of the seminar.

A field trip included visits to the computer facilities of the NASA Manned Spacecraft Center, near Clear Lake, Texas, and to commercial computer facilities in Houston, Texas.

On August 27, CAPT D. J. Mooney, Jr., USNR, Special Assistant to the Chief of Naval Research for Research Reserve, discussed the Research Reserve Program.

A critique of the seminar was held on the last day. Participants had previously written programs compiling statistics on the group and the group's evaluation of the seminar. The latter showed enthusiasm for the seminar and a strong recommendation that this training session be continued in the future.

Porpoise Research Symposium

Stimulated by the increasing interest in porpoise research (see *Naval Research Reviews, June 1964*), Reserve Research Company 11-3, Los Angeles, California, sponsored a one-day symposium on porpoise research programs on October 17, 1964. From its "home port" on the University of California at Los Angeles campus, the company moved to the Allen Center of the Long Beach Naval Station for the morning lecture session and to Marineland of the Pacific on the Palos Verdes Peninsula for the afternoon lecture and demonstration session of the symposium.

All reserve officers in the Los Angeles area were invited. In addition to presenting an informative technical program to those officers already within the Research Reserve Program, it was hoped the symposium would attract new membership for companies in the Los Angeles area.

Participants were welcomed to the symposium and the Research Reserve by CAPT R. J. Trauger, USN, and LCDR T. J. Kennedy, USNR, commanding officer and program officer, respectively, of the ONR Branch Office, Pasadena. A presentation entitled "U.S. Navy Experimental Marine Biology Programs"

LCDR Allen J. Curtis, USNR, commanding officer, NRRC 11-3, and CAPT Robert W. Rector, USNR, symposium chairman, enjoy the company of a member of Marineland's "staff."

was then given by Mr. Forest G. Wood, marine biologist in the Life Sciences Department at the Naval Missile Center, Pt. Mugu. Mr. Wood described the wide scope of Navy-sponsored cetacean research, both at Pt. Mugu and elsewhere.

Dr. J. J. Dreher, research biologist of the Lockheed-California Co., then described, in a talk entitled "Studies of Dolphin Communications," the studies he has conducted regarding the physiological and biological aspects of the dolphin's truly remarkable echo-ranging and communication capabilities. (See *Naval Research Reviews, June 1964*).

Almost equally remarkable is the dolphin's hydrodynamic performance, particularly in the ability to leap from 15 to 20 feet above the surface. For example, a 400-pound porpoise has jumped 7 feet above the water from a motionless underwater position, with the acceleration taking place in 0.6 to 0.7 seconds. Mr. T. G. Lang, Head of the Hydrodynamics Group of the Research Dept., Naval Ordnance Test Station, Pasadena, described research studies aimed at understanding this high performance for the obvious adaption of the results to Naval vessels and torpedoes.

After a pleasant lunch at Allen Center, participants adjourned to nearby Marineland. Here, Mr. William F. Monahan, Vice President, and Mr. David Brown, Curator of Mammals, described the scientific programs which Marineland has undertaken, both independently and cooperatively with such scientists as Dr. Dreher of Lockheed. The symposium concluded with demonstrations of animal training and communication experiments conducted at Marineland.

New Research Horizons

"New Research Horizons," the West Coast Reserve seminar sponsored by the Office of Naval Research Branch Office, Pasadena, was held in San Diego from October 19 through October 30, 1964.

Host company for the seminar was Naval Reserve Research Company 11-5, LT Edward H. Anderson, USNR, commanding. Development of the seminar program by NRRC 11-5 originated while the company was under the command of LCDR Harold F. Anderson, USNR, commanding officer for fiscal year 1964. Seminar chairman was CDR Raymond D. Tuttle, USNR, of NRRC 11-5.

The seminar opened with a warm welcoming address by RADM Walter H. Price, USN, Commandant, Eleventh Naval District. VADM Paul D. Stroop, USN, Commander, Naval Air Force, Pacific Fleet, a distinguished air offiicer, presented the keynote address, which concerned the values of research to the operating forces.

As indicated by its title, the principal objective of the seminar was to acquaint the officers attending with recent advances at the outer limits of research and their military applications. Some of the areas of interest were antisubmarine warfare, aero-space, behavioral science, bio-medicine, geodesy, hydrodynamics, nuclear science, oceanography, and radiation.

Outstanding presentations ranged from "A Review of Early Manned Planatary Mission," by Mr. Krafft A. Ehricke, Director of Advanced Studies at General Dynamics/Astronautics, San Diego, to "Geological Observations from the Diving Saucer," by Dr. Francis P. Shepard, Professor of Submarine Geology at Scripps Institution of Oceanography, La Jolla. The latter presentation was obtained through the auspices of Dr. Roger Revelle, Director of Scripps.

Other talks were given by nationally and internationally recognized speakers from such military, educational, and civilian sources as the U. S. Navy Electronics Laboratory, Cubic Corporation, University of California at San Diego, Delta Design, Incorporated, California Western University, Lockheed-California Company, Free Enterprise Institute, Ryan Aeronautical Company, Western Behavioral Sciences Institute, San Diego State College, General Dynamics/Convair/Electronics, ONR Washington, Grossmont Union High School District, U. S. Public Health Service, and General Atomic.

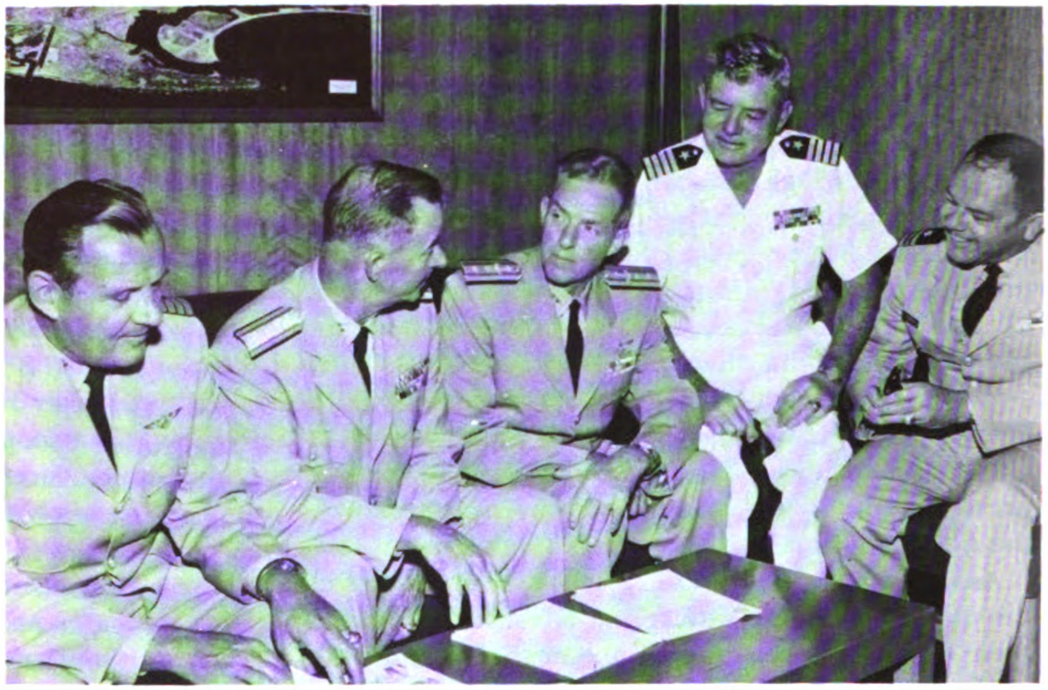
Field trips consisting of four full-day and four half-day sessions were offered to the seminar group. Two of the half-day trips were optional in consideration of the varied interests and specialties of attendees.

The General Dynamics/Astronautics factory area and its adjacent Sycamore Canyon Booster Test Site provided a one-day exposure to the aero-space research and development which will take us to the planets and beyond.

Another day's tour was made of the Scripps Institution of Oceanography, where insight was gained into studies of the ocean's many parameters and some of the research tools developed recently to explore them.

The U. S. Navy Electronics Laboratory, situated on Point Loma overlooking beautiful San Diego Bay and the Pacific Ocean, was host for one and one-half days of lectures on vital Navy research and for visits to its important laboratories.

One day at General Atomic was spent in touring the laboratories and reactors and learning of progress in fusion, direct conversion, and the Orion Program.



Formulating plans for the Research Reserve seminar held in San Diego in October are (left to right) CAPT R. J. Trauger, USN, Commanding Officer, ONR Branch Office, Pasadena; RADM Walter H. Price, USN, Commandant, Eleventh Naval District; RADM Marshall W. White, USN, former Commandant, Eleventh Naval District; CAPT E. H. Maher, USN, Deputy Chief of Staff, Eleventh Naval District; and LCDR Thomas J. Kennedy, USNR, Research Reserve program officer, ONR Pasadena.

A visit to Sea World in Mission Bay Park for a lecture-demonstration of dolphin communication research and two elective visits to various Naval vessels, including atomic submarines, and shore installations accounted for one-half day each.

A highlight of the seminar was a banquet in observation of Navy Day, which featured an address by CAPT B. F. Bennett, USN, Director of the Naval Research Laboratory, Washington, D. C. The banquet was held in the main dining room of the Admiral Kidd Commissioned Officers Mess, which provides a panoramic view of the harbor channel and Fleet anchorage.

The following morning, two officers from ONR Washington addressed the seminar—CAPT Lewis B. Melson, USN, Director, Naval Applications Group, who spoke on "Man and the Sea"; and CAPT D. J. Mooney, Jr., USNR, Special Assistant to the Chief of Naval Research for the Research Reserve, who brought the reservists up to date on the Research Reserve Program.

Conference of Reserve Assistants

On August 6-7, 1964, a conference of Reserve Assistants for the Research Reserve Program was held at the Office of Naval Research, Washington, D. C. CAPT D. J. Mooney, Jr., USNR, Special Assistant to the Chief of Naval Research for Research Reserve, chaired the conference.

RADM J. K. Leydon, USN, Chief of Naval Research, opened the conference. In his comments, the Admiral emphasized the importance and need of the Research Reserve, not only for ONR but also for the Naval Establishment.

Succeeding sessions were devoted to the following subjects: ACDUTRA, Mobilization, Awards Program, Recruiting, Publicity, Curriculum, Screening, Composition of Companies, and Inspections. During visits to companies this fall, Reserve Assistants planned to discuss these subjects with companies in their areas.

Attending the conference in addition to CAPT Mooney were CDR F. H. Langdon, USNR, Training Officer and Fifth and Sixth Naval Districts Research Reserve Liaison Officer; Miss Eleanor Kehoe, Education Specialist from the Washington office; and the following Reserve Assistants from ONR Branch Offices: CDR W. S. Adami, USN, Boston; CDR D. McKinlay, Jr., USNR, New York; CDR O. D. Hughes, USNR, Chicago; LCDR T. J. Kennedy, USNR, Pasadena; and LCDR W. S. Lindberg, Jr., USNR, San Francisco.

Inventions — Continued from page 40

The tape consists of a deeply notched strip of metal, preferably aluminum, mounted on cellophane tape for support. The metal strip is about half an inch wide and about as thick as metal foil. In a test, the exploding tape is strung through a pressure chamber, and the chamber is filled with combustible gas. A high-voltage current is then applied, causing the tape to burn at all of its narrowest points—those opposite the notches—where the electrical resistance is highest. This burning ignites the compressed gas simultaneously at many points throughout the chamber. Rapid combustion follows, consuming the tape in its entirety and preventing the accumulation of foreign particles.

The pressure generated by the expanding gas bursts the diaphragm valve of the pressure chamber and forces the gas into the wind tunnel and against the experimental missile model, thereby simulating pressures and temperatures which would exist if the missile were traveling through the upper atmosphere.

Radar Scope Interpretation Trainer — Continued from page 26

The positions of the interceptor and target aircraft with respect to a ground reference grid are displayed by means of special optical plotting projectors on a 70- by 70-inch projection screen. When target lock-on occurs, the ground track display automatically changes into a horizontal situation display. Special projectors are used to present silhouettes of the interceptor and the target on the screen. By rotation of these images, the headings of the two aircraft can be indicated. The interceptor silhouette is fixed at the center of the screen, and the target is moved relative to it. By means of a separate projector, circles indicating interceptor antenna-beam pattern and range are displayed.

Device 15C4A has proved to be a valuable classroom trainer for improving and maintaining the effectiveness of interceptor pilots and radar-intercept officers who operate radar and associated airborne missile-control systems.

History and Mission — Continued from page 6

On April 30, 1956, the Special Devices Center became the U.S. Naval Training Device Center, a laboratory of the Office of Naval Research. The change signified the growing acceptance of training devices by operating forces as well as shore establishments, and it provided a more descriptive title for the Center's mission.

That mission is more important now than ever before. The magnitude of the effort of the military services to stay abreast of foreign powers in the development of new, complex weapons, such as guided missiles and nuclear devices, and in advances made in supersonic flight and nuclear-powered ships, make it necessary to find new and more effective ways of teaching the operation and maintenance of these systems to young and unskilled personnel.

This brief history reveals the tremendous part that synthetic training has played in the past, and it should indicate the part it is destined to play in the future. By providing a means for men to learn under conditions that otherwise could be experienced only in actual combat, this type of training saves time, money, and lives.

Simulation Engineering and Research — Continued from page 34

however, no conclusive results of human-factors studies could be applied to the AWST. Consequently, the project officer or the project engineer had to visit Fleet activities using an antecedent training device and infer the good and bad features of the instructor-station design in terms of mission simulation.

It can be seen from these examples that, if possible, the simulation engineering and research should precede the trainer development, whether undertaken in search of general solutions to problems common to a number of training devices or in search of specific solutions to problems raised by the TSA. Regardless of the approach, the research task progresses through some or all of the following stages, which are listed chronologically:

I. A preliminary study is made to define the specific problem.
II. An investigation is undertaken to describe a possible solution.
III. A research tool is developed and tested to demonstrate a specific solution.
IV. An engineering prototype incorporating the solution is developed for service testing.
V. The research results are added to the specifications for the proposed new trainer.

The goals of the Naval Training Device Center are achieved through a vigorous simulation engineering and research program. When possible, future training-device engineering requirements will be met through the supporting-research program rather than through the trainer development program. Therefore, when the prototype-trainer project is undertaken, only the development or application of known solutions to specific problems will be required prior to the fabrication and testing of the new training device.

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Guided-Missile Team Trainer

The Navy has successfully operated its first guided-missile-systems operational team trainer, a $1.7-million device that electronically simulates air-sea battles. By means of the trainer, teams of Navy missilemen from Fleet missile ships and guided-missile schools are gaining realistic experience by entering into "electronic combat" with Terrier, Tartar, and Talos missiles against simulated enemy aircraft.

The trainer, designated 20C6, was built by Honeywell Inc., at the company's California Ordnance Center, West Covina, California. It was developed under contract to the Naval Training Device Center, Port Washington, N. Y., and is located at the Fleet Anti-Air Warfare Training Center, Dam Neck, Virginia.

The new device simulates, in a typical shipboard environment, operational Navy weapon equipment. An almost infinite variety of attack and defense situations can be programmed into the trainer for solution or tactical evaluation. Simulated signals from a three-dimensional air-search radar, missile fire-control systems, missile launch systems, and surface-to-air missiles are fed as required to the trainees. The signals are displayed on five target-selection-and-tracking consoles, two weapon-assignment consoles, and two director-assignment consoles.

The basic controlling element of the trainer is an AN/UYK-1 digital computer. A large analog "problem generator" provides target-position information on as many as 36 aircraft as well as simulating range and bearing of 12 ships in the trainees' task force.

Electronic combat is realistically simulated during a training exercise conducted at the Fleet Anti-Air Warfare Training Center, Dam Neck, Virginia. The trainees work at consoles that are identical to operational weapon equipment carried aboard Fleet missile ships. By means of these exercises, the men gain experience in the conduct of full-scale air-sea battles.

IN THIS ISSUE

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Military Training Devices

A key factor in the maintenance of operational readiness by the military services is training. To prepare men to handle the complex weapons systems of this age – in time for them to assume their stations when the finished systems are delivered to the Fleet or other military units – special training devices must be designed and developed far in advance of the delivery dates. That vital effort, the focal point of which is the U.S. Naval Training Device Center, is the subject of this special issue of NAVAL RESEARCH REVIEWS.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important Naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 740, Office of Naval Research, Washington, D.C., 20390. The magazine is listed for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.50 per year in the U.S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

EDITOR: Richard D. Olson

NAVEXOS P-510

A parachutist is dunked in the ocean during exercise simulating an emergency landing. The simulation device, which is currently being developed by the Naval Training Device Center, will give pilots practice in freeing themselves from their chutes, especially under conditions of high wind.