CHAPTER VI

RESEARCH AND DEVELOPMENT

The Naval Facilities Engineering Command's research and development programs during the ten years from 1965 through 1974 reflected the major political, economic and military driving forces of the time. These forces were: the Vietnam War, growing interest in deep ocean environments, changes in the United States Flag Merchant Marine and Department of Defense Sealift postures, national concern with the environment and energy, physical security of military installations within the continental United States and abroad, détente and force level reductions, the inflationary squeeze on defense budgets, leveling of defense budgets, the civilian challenge of the need for and relevance of military research and development, and changes in management practices emanating from changes in administrations.

The Command's research and development program conformed to the policies, planning and programming procedures promulgated by the Director of Defense Research and Engineering through the Assistant Secretary of the Navy for Research and Development, the Chief of Naval Operations and the Chief of the Naval Material Command. While these policies and procedures were formulated because of the need for effective management of technology in the acquisition of multi-billion dollar weapon systems programs, nonetheless they fixed the framework for programs of lesser magnitude such as those carried out by the Command. Meeting the Command's technology needs was a difficult management task throughout the ten year period under consideration. Two distinct management attitudes in defense research and development were prevalent during this period: the McNamara administration's emphasis on total and detailed advance planning, systems analysis and total design package/procurement as opposed to the emphasis of subsequent administrations on incremental decisions with test and evaluation at frequent intervals throughout.

During this ten year period, management's task became increasingly difficult because of inflation and defense budget reductions and realignments. At the beginning of the decade research and development expenditures throughout the federal government were on a steep rise. In 1965 the dollar value of the Command's research program was much less than in 1974, even after allowing for inflation.

Major trends in the Command's research and development programs during 1965-1974 can be summarized as follows:

The thrust for research and development to extend the technology required for facility support in extreme environments, such as nuclear, biological and chemical warfare research and development in facility/life support technologies came to an end about 1970 for two reasons. First, the attainment of an adequate technology base relative to the probabilistic assessment of the threat and second, the level of acquisition programs.

The pace for new technology for vertical and horizontal construction in polar environments experienced a significant reduction during the period 1965-1970. It leveled off at a low but relatively steady pace. This reflected the attainment of an adequate technology base to support the level of planned activity.

Deep ocean technology expenditures have also declined since 1969. The reasons for this were: (a) seafloor facility support requirements did not materialize at the level (originally anticipated) that would justify the initial pace of research and development expenditures, and (b) there was a decision to pursue developments within specific mission oriented weapons programs rather than in the Deep Ocean Program. Despite these setbacks, this program, unlike the nuclear, biological, chemical warfare and polar programs, continued at a relatively strong pace.

As one of the participants in the nation's campaign against environmental pollution, the Navy readily accepted its share in meeting the challenges that the pollution problem presented. The tempo of pollution oriented research and development programs picked up in the early 1970s. At that time, the Command was directed by the Chief of Naval Material to assume the lead in coordinating throughout the Navy the development of an environmental data base program aimed at establishing a Navy-wide baseline against which future programs might be measured. Research and development programs for the abatement of environmental pollution in those areas requiring military construction and the maintenance and operation of the naval shore establishment were expedited and redirected to produce a technology base needed to support the level of acquisition and operations and maintenance programs.

The Command's initiatives to improve effectiveness and efficiency in its shore facility service to the fleet brought about two noteworthy programs: (1) the Operations Analysis Program which carried out the development and application of operational analysis or operations research techniques for the management of facility programs, and (2) the High Quality Electric Power Program which worked to eliminate electric power distribution system problems. The former was initiated prior to the period under consideration and came to an end about 1970 after having produced a number of analytical techniques for use by management in matters of resource allocations, scheduling, costing, etc. The latter was initiated as continued modernization and upgrading of electronic equipment used in the Navy shore establishment, and the introduction of complex and sophisticated circuitry, gave rise to a number of technical problems attributed to transients in the electric power distribution systems.

Construction support for amphibious, advance base, Marine Corps and other services as assigned by the Joint Chiefs of Staff (JCS) was a major area of research and development during the period under consideration. Achievements and initiatives during this period included: (a) research and development "on-the-job" support to the

Naval Construction Force in Vietnam, (b) development of systems for unloading facility dependent ships (such as containerships, roll on-roll off ships and bargeships) in the absence of developed ports and (c) exploratory developments for Marine Corps logistics (i.e. engineering and cargo movement).

The demand for technology fixes in Vietnam was only partially met because time was not available for research and development procedures to function effectively. Much Vietnam generated demand for new technology turned out to be satisfiable with advanced techniques from the construction industry that had not yet been adopted by the Naval Construction Force.

Two factors led to the initiation in 1974 of the largest research and development program ever to be funded to the Command -- The Container Offloading and Transfer System (COTS). The first factor was the demand for and the inability to provide instand port facilities in Vietnam when they were needed in 1965. The second factor was the replacement of many, small, general purpose freighters (breakbulk ships) with a few large and fast highly specialized facility dependent ships like containerships, bargeships and roll on-roll off ships. In effect this effort, first proposed to the Chief of Naval Operations under the name "portable Port" in 1969 and subsequently designated "Expeditionary Logistic Facility" (until 1973), represented one of the few instances where the Command's exploratory development moved into a major Chief of Naval Operations sponsored advanced development program.

By special arrangement between the Assistant Secretary of the Navy (R&D) and the Commandant of the Marine Corps, the administration of the Marine Corps exploratory development program was transferred to the Naval Material Command. The Naval Facilities Engineering Command has, since that time, conducted an exploratory development program in support of the Marine Corps (engineer and cargo transfer and mission/support needs). This program dovetailed with the previous research and development efforts in unloading merchantships in the absence of ports and contributed significant technology advances and concepts.

The growth of federal research and development gave rise as far back as 1965 to congressional concern over how well all research and development generated knowledge was being disseminated to the many potential users throughout society. As a consequence, beginning in 1966 Command research and development efforts were stepped-up to insure that technology was transferred and utilized at as great a rate as possible. To achieve this a broad spectrum of actions was taken involving organizational fixes, research allocations, and changes in publications and other communication media-formats. But most importantly a modest but important program of "research on research" was initiated to develop an empirical understanding of the Command's peculiar technology transfer and utilization problems emanating from its research and development activities.

As part of the reorganization of the Naval Material Command in 1966, the Naval Civil Engineering Laboratory was transferred from the Naval Facilities Engineering Command to the Naval Material Command under the newly established Director of Navy Laboratories. In 1973 this laboratory was disestablished as a Navy laboratory. It was then designated the "Civil Engineering Laboratory" and was henceforth within the command structures of the Construction Battalion Center, Port Hueneme, California. The technical performance and responsiveness of this laboratory to the Command's research and development programs was not altered by these changes.

However, since 1966 when the Naval Material Command assumed command of Navy laboratories,[1] and in line with the Naval Material Command's intent, the Naval Facilities Engineering Command sought the technical services of other laboratories as well. This enhanced the Command's capability to execute its programs -- especially those programs requiring expertise other than that found at the Civil Engineering Laboratory.

AMPHIBIOUS AND ADVANCE BASE TECHNOLOGY

In the latter half of the 1960s, major research and development efforts in support of amphibious warfare were directed toward the completion of development of the inflatable causeway. This causeway was intended to increase by twofold the number of causeways each

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[1]Laboratories under the Naval Material Command: Naval Air Development Center, Naval Coastal Systems Laboratory, Naval Civil Engineering Laboratory, Naval Electronics Laboratory Center, Naval Ordnance Laboratory, Naval Ship Research & Development Center, Naval Undersea Center, Naval Underwater Systems Center, Naval Weapons Center, and Naval Weapons Laboratory.

Tank Landing Ship (LST) could carry. However, the development was not fleet acceptable because of recently instituted shock loading criteria associated with the new twenty knot LST that was then being built.

The new 1179 Class LST, as it was finally designated, necessitated new developments with respect to causeway/LST marriages as well as new lifts and tie downs for causeways. Additionally, investigations were directed towards the feasibility of lighter causeways made of aluminum, plastics, and so forth. The development of the AMMI pontoon by Dr. Amirikian generated a host of requirements for test and evaluation as well as a significant comparative analysis of all known military and commercial pontoon systems. The conclusion was that the Navy lightered pontoon causeway was still the best considering its primary mission was that of amphibious assault. Improvements were developed for causeway end-connections, and mooring techniques for survival of causeways in storms.

Two major exploratory efforts initiated about 1967 to meet Vietnam War requirements were: (1) waterjet propulsion and (2) the elevated causeway. Waterjet propulsion was utilized for LST side-carry and for reduction of propeller draft to enable full (thrust) operations in very shallow waters. The elevated causeway increased the longevity and stability of rapidly installed piers in the surf zone. These developments were given renewed emphasis after 1972 when the Offshore Discharge of Containerships II (OSDOC II) tests and the Expeditionary Logistic Facility (ELF) concept study investigations highlighted new requirements for the ship-to-shore movement of twenty foot or larger containers and their transfer at the shoreline. Specifically OSDOC II demonstrated the need for a rapidly deployed elevating platform for cranes on causeways and large capacity beaching lighters.

The Pacific Fleet in 1971, evaluating the potential of a prototype waterjet propulsion unit and being plagued by the problems inherent in the deeper draft or 1179 Class LSTs (which required more causeways for the flat Pacific gradients, and had reduced well deck shipping), recommended to the Chief of Naval Operations that development efforts be directed towards a self-propelled sidecarried causeway. Shortly thereafter the Pacific Fleet requested assistance from the Naval Facilities Engineering Command for the development of an LST sidecarried pontoon warping tug. By mid-1973 it became apparent that both fleet assault-driven requirements and containerization-driven requirements could be met with a common development effort, i.e., the waterjet propulsion unit for use either as a sidecarried self-propelled causeway or as a sideloadable warping tug.

Fortunately for Vietnam overseas transportation needs, the National Reserve Defense Fleet had a sufficient number of Second World War vintage ships and enough time to activate them. Deep-draft ports in Vietnam, however, were not so easy to provide. As a result, during the period 1965-1966 up to 150 ships at any given moment were lying at anchor waiting to unload at the limited deep-draft facilities in Vietnam. At the same time the trend toward containerization revealed a new problem: a great many ships of the

United States Flag Merchant Fleet were not designed to efficiently handle containerized cargoes.

Directed by the Chief of Naval Material, the Command conducted a "Terminal Logistics Workshop" in 1966 to assess the nature of these Vietnam-related problems and to develop approaches to deal with them. The repeated failure of the Department of Defense to secure congressional backing for ships for military sealift was also causing people to look increasingly at the commercial ship as an alternative. The defense sealift capability had become highly facility dependent. There were not enough self-unloading breakbulk ships to meet contingency sealift needs. A series of exploratory development initiatives enabled the Command to demonstrate concepts for rapidly deployable components to provide "portable ports." Unfortunately, it was not possible to gain priority recognition for these needs until OSDOC II physically demonstrated the lack of capability to interface with the containership.

The Offshore Discharge of Containership tests, known as OSDOC I and OSDOC II, enabled the Command, through its lead laboratories, the Civil Engineering Laboratory and the Naval Ship Research and Development Center, to obtain technical and operational data necessary to validate and redirect the development of concepts and hardware for Project ELF. Through a joint Army-Navy-Marine Corps task force coordinated by the Department of Defense Project Manager Surface Container Supported Distribution System, the Command's ELF concepts, purged by OSDOC II experience, influenced the development of a defense position paper which set forth a coordinated Army-Navy-Marine Corps development plan. Largely because of the austerity and practicality of the Command advocated concepts for ship unloading, the development of the container-capable ship unloading components was assigned to the Navy. With respect to the ship-to-shore capability, mission differences between the Army (Transportation Corp) and the Navy (Amphibious Assault) precluded a common development approach. The Navy approach emphasized introducing as little new equipment as possible for the sustaining of logistics or expeditionary ports. Happily the elevated causeway, waterjet self-propelled causeway and sideloadable warping tugs seemed to satisfy both assault and sustaining logistics requirements quite adequately. Beginning 1 July 1974 the Command was funded to proceed with the advanced development program for the COTS. Initially proposed by the Command in 1969 (Portable Port), the program was approved by the Chief of Naval Operations in 1973 as the Navy's contribution to the Department of Defense Project Masterplan for the development of a container supported distribution system to serve all the military services.

The years 1972-1973 were a busy period in terms of exploratory tests which focused on amphibious logistics ship-to-shore cargo transfer. In the fall of 1972 and again in 1973 the Command and the Civil Engineering Laboratory participated in tests with the Advanced Research Projects Agency and the Army involving the tethered balloon functioning as an aerial tramway in the simulated ship-to-shore movement of containers. Subsequently the Command alone investigated the vulnerability and aerodynamic drag forces of the tethered balloon to further appraise the military, technical and operational feasibility of employing it in unloading containerships.

In 1973 the Command, supported by the Pacific Fleet Amphibious Forces, explored the feasibility of using Lighter Aboard Ship (LASH)[2] barges in logistic operations in open beach environments with the capabilities and assets then available in the Naval Beach Groups. These tests demonstrated a current capability and confirmed the concept that the system and components under development to move containers could also interface with LASH (or SEABEE)[3] barges. These tests, though less extensive than OSDOC, were sufficient to motivate the Atlantic Fleet to conduct its own operational tests. These tests culminated in the decision to issue a fleet SOP for the use of LASH barges in amphibious logistics.

These exploratory efforts were perhaps the most important contributions of the Command's Amphibious and Advance Base Technology Program because of the critical dependence of Department of Defense contingency sealift on rapidly deployable ship unloading facilities.

In addition to sealift interfacing, amphibious logistics involved the shoreside functions of the Marine Corps. Since the Command assumed responsibility for the program, a number of notable technological advances have been made, all directed towards solving the engineering and cargo moving problems of the Marines.

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[2]LASH is a new class of self-loading/unloading ships that transport barges loaded with all types of cargo.

[3]SEABEE designates a class of bargeships.

Because the Marine Corps was the primary beneficiary of the Navy's amphibious capability, much of the impetus and progress in the self-propelled causeway, elevated causeway and LASH barge tests were attributable to its support. Shoreside, Marine Corps sponsored developments were most impressive.

Techniques were developed to adopt air caster (or air film) technology into sub-systems capable of removing cargo (i.e. unstuffing) from containers in forward areas. A fivefold reduction in costs was possible in terms of hardware plus replacement of a skilled man (for a would-be forklift) with a less skilled man (operating a compressor).

Another development was the liquid bladder module in an ISO 4'x8'x6-2/3' collapsible container frame (1,000 gallon capacity) which was capable of complexing into any combination up to 8'x8'x20'. A pump and hose module was also developed. In the 8'x'x20' configuration, the capacity (five liquid and one pump unit) was 5,000 gallons and the unit weighed 50,000 pounds, or 5,000 pounds more than a fully loaded ISO twenty foot container. Smaller combinations were helicopter transportable.

A small fiberglass armor panel for use in improvising a variety of fortifications was developed. This item was conceived following an operations analysis study of Marine Corps functions and alternatives to reduce vulnerability and improve offensive and defensive capabilities.

Vibratory locomotion, a concept still in its infancy, was examined for application to logistics flow, bulldozer movement and increased effective thrust for moving landing craft stuck on sandbars or beaches. The vibratory locomotion principal called for reducing friction and introducing directional control thrusts for moving. As of 1974 no cost effective application had been found though new potential applications were continuously being examined.

Application of a laser beam reference system and automatic controls did produce systems that could be applied to various types of earth moving and material handling equipment. These control systems reduced the level of operator training necessary for precise operation in rough terrain or in situations where speed was of the essence. Such controls were developed and tested on graders and bulldozers for fine control of the blade, as well as on forklifts for steadying the load while traversing bumpy terrain.

Continuing the Marine Corps' 1966 initiated program for using plastics for surfacing, the Command developed both manual and mechanized (truck mounted) equipment for the rapid laying of fiberglass and for resin spraying to be used for surfacing soil to give it adequate bearing potential. These surfacing methods were known as ON FAST. The development of the ability to fabricate foam filled fiberglass sandwiches under field conditions was also begun. Depending on the thickness of the sandwich it was possible to create a surface of variable strength to suit specific load carrying requirements (i.e. aircraft, storage, etc). The development of this process, known as AMASS, continued during the 1970s. The single most important barrier to the use of resins in these processes was their limited shelf life.

Unlike complicated weapon systems, the performance of the Naval Construction Force depended in part on seemingly ordinary tools and materials. Research engineering's special expertise was often needed for the establishment of specification standards for these tools. Since 1965, Mobile Construction Battalion personnel have called upon the Command to improve the quality of their tools in order that they might increase their output without increasing the battalion's manpower levels. This was to be done by decreasing excessive breakage and by developing longer lasting tools.

The purpose of the hand tools program was not to design new tools or equipment, but to methodically investigate the existing industrial product for the best tools that could be had. One example of such an investigation was the stainless steel hand saw. Seabees found the regular hand saw would not hold an edge and rusted quickly. The stainless steel saw meant quicker cutting, less deterioration and less maintenance, thus adding up to longer tool availability. The introduction of the stainless steel hand saw resulted in savings of about $25,000 per battalion, per deployment.

Another example was a gasoline engine-powered hand drill. A job that took an hour to complete with a manually operated drill could be done in ten minutes with the power unit. The power unit, weighing only ten pounds, allowed Seabees to take it where the job was; up a pole, into a bunker, or unto a bridge construction site. These same advantages applied to a gasoline powered circular saw.

The development support for the Seabees, and the Advanced Base Functional Components consisted of numerous relatively small (but nonetheless significnat) developments motivated by specific field problems. One such case was the development of explosive cutting techniques for piles. Another example was desalination equipment. However, there were also cases where technology, not yet adopted by the construction industry was opted for because of its apparent potential; this is exemplified by the initial development of the hydro-acoustic pile driver. Development of the pile driver was discontinued when it was found that industry had decided to develop and commercialize it after all.

Since the Second World War, Seabees have found that, in general, commercial equipment has turned out to be the best when all factors were taken into consideration. Sometimes, however, this was not the case. One of the exceptions was the mobile sixteen cubic yard concrete mixer. It tended to tip over when towed by a vehicle at speeds of or greater than fifteen miles per hour. Therefore, substantially the same unit was redeveloped into a lower profile and a generally improved configuration. The new mixer rode stably at twenty-five miles per hour on paved roads. It should be noted that introduction of this mixer into the construction battalions was delayed for two reasons. First, no new procurements were made after development was completed and second, it was being manufactured for private industrial use and therefore the price remained high.

The containership, and its modular payload, also forced the military services to stop and assess the potential modularity of buildings and shelters. The most notable program in terms of size, scope, concepts and influence was the 1972 Marine Corps Shelter Program. In addition, the Navy developed the Quick Camp. The Quick Camp was developed to reduce the time spent by Mobile Construction Battalions in setting up camp and to improve their mobility. These camps were essentially composed of finished 8'x8'x20' containers which were expandable to 24'x20'. These Quick Camps were collectively designated the Tactical Container Shelter System (TACOSS). This system complemented the Marine Corps shelter program modules in that TACOSS was for large stable encampments while the Marine Corps shelters were for close support tactical mobile units.

OCEAN FACILITIES ENGINEERING

The objective of the Command's research program in ocean facilities engineering was to develop ocean engineering technology that would provide the Navy with the capability to reliably and effectively site, design, construct, install, inspect, operate, maintain and repair ocean-based facilities as required for military operations in the worlds oceans. The development of techniques and equipment for construction and implantation of these facilities was a part of the program. Existing and potential areas for these capabilities included fleet moorings, ranges for testing and training, rescue and salvage operations, surveillance, ocean-based support facilities logistics, disposal of materials, and energy from the sea. The facilities involved were generally limited to those that were attached in some manner to the seafloor. That is, they were either resting on the seafloor, embedded in the seafloor, suspended in the water column or moored at the sea surface.

During the period 1965-74, the Command's Ocean Facilities Engineering Research and Development Program concentrated its efforts on soil properties and foundations, construction systems, anchors and moorings and ocean structures. Most of the research, development, test and evaluation was assigned by the Command to the Civil Engineering Laboratory at Port Hueneme, California.

Soil Properties and Foundations

Soil properties and foundations investigations were directed toward learning how to use ocean sediments as we do terrestial soils. The effective installation and operation of facilities to support Navy missions required structures secured to the seafloor. The structures involved could be moored by anchoring systems or could be supported directly by the bottom soils. For these applications adequate knowledge of the engineering properties of these soils was required for the design of the anchor or support system. In order to develop this knowledge the research and development program was directed toward development of techniques for obtaining the required ocean soil engineering data in water depths to 20,000 feet (data acquisition) and predicting the behavior of these soils under carious long term and dynamic loadings (data analysis).

In the area of data acquisition, various techniques and equipment were developed. Included was the development of a bottom-resting tethered platform called the Deep Ocean Test-in-Place Observation System (DOTIPOS). This platform operated in water depths down to 6,000 feet and was used for remotely determining the in-site engineering properties of seafloor soils and for obtaining soil samples up to ten feet long. The DOTIPOS support platform provided the capability for making comparisons between in-site and laboratory soil tests.

An in-situ plate bearing device was designed and fabricated. This device was used to determine the short-term bearing pressure or settlement response of marine sediment. In addition, this device operated in water depths to 6,000 feet and provided the capability to compare the results of measured settlement data with that predicted based on core data taken from the same locations.

An expendable penetrometer for measuring sediment uniformity was developed. This device, when used with coring and sub-bottom profiling data, provided information on sediment type variation cheaper and more quickly than coring operations which required a ship on station for long periods of time. Another development was the remote-controlled bottom-resting tethered seafloor coring system. This system operated from a surface ship and obtained undisturbed cohesive sediment samples from ocean depths to 6,000 feet. This coring system, using the automated drill rig concept, incrementally obtained a series of three inch diameter, five foot cores successively one below the other to fifty foot sediment depths. Tests proved the system to be very hard to operate and maintain, thus it was not a cheap method for obtaining deep sea cores.

In the data analysis area, very sensitive laboratory soil testing equipment was built to study the strength of very soft ocean sediments. This equipment measured the shear strength of sediments where failure stress was about 0.3 psi.

Laboratory model tests were conducted to develop a procedure for predicting the long-term holding capacity of embedment anchors. Furthermore, a study was done to determine the effect of high hydrostatic pressure on engineering properties on seafloor sediments. This study showed that high pressure does not have any effect on the strength and consolidation properties of these sediments. In addition, dynamic tests were performed on laboratory samples to determine the liquefaction potential of ocean sediments.

Construction Systems

The Navy performed underwater construction and repair assignments for undersea surveillance activities, underwater test ranges and other types of activities. These assignments identified the need for improved construction tools, equipment and techniques for performing underwater tasks at both diver and sub-diver depths. The existing tools and techniques, although adequate to produce the end results in some cases, required a large expenditure of manpower and funds to accomplish a given mission.

In response to these types of requirements, the research and development program in the area of construction systems was directed toward the development of improved construction hardware and techniques. Items developed toward this goal included an experimental diver-operated, submersible work vehicle to transport divers, tools, power supplies and equipment to and from ocean bottom construction sites. The vehicle was designed to provide divers breathing air as well as power for diver tools while at the work site. Operational tests to the vehicles design depth of 120 feet indicated it was a stable work platform which provided engineers with a basis for writing specifications for a prototype vehicle.

Another vehicle developed was the Buoyancy Transport Vehicle (BTV). This vehicle was capable of lifting and moving up to 1,000 pounds of wet-weight cargo at depths to 850 feet in the ocean. This "underwater fork lift" was operated by free-swimming scuba divers.

In addition to the development of underwater vehicles there was a comprehensive program for the development and evaluation of diver tools and power sources. Tools and work methods using oil and salt water hydraulic pneumatic and electrical systems for underwater welding, gluing, drilling, tapping, sealing, torquing and impact were investigated and improvements developed.

A motion compensating winch capable of handling up to twenty ton payloads in water depths to 6,000 feet was designed and fabricated. However, the winch did not meet the design specifications during at sea tests, indicating that major efforts will be required in this area before the Navy will have a capability to handle heavy loads at sea. Additionally, techniques were developed for predicting dynamic stresses in lifting lines supporting loads suspended in the ocean from a heaving and pitching surface platform during at-sea load handling operations.

Anchors and Moorings

Analysis of existing and future missions indicates that most facility support requirements would be met by buoyant installations, including ship moorings, which will require anchoring systems. Although work has and is being done on anchoring systems, many deficiencies remain limiting the design and use of cable systems underwater.

To improve the Command's ability to handle these problems, the research and development program was directed toward developing new anchors, cables, and analytical techniques to predict the dynamic response of cable structures during implantment and in-situ. Work in this area included development of two types of anchors which were directly embedded rather than requiring horizontal pull for embedment.

The first was a vibratory anchor designed for operations down to 6,000 feet. It was a self-contained expendable unit with a holding capacity of 50,000 pounds in soft sediments. The second was an explosive embedment anchor with a designed operating depth of 20,000 feet and a designed holding capability of 20,000 pounds in all seafloor soils, including rock. Holding capacities generated by these test anchors generally exceeded design capacity; however, at the end of 1974, testing was still underway to expand the available data base and to prove the effecitveness of the concept.

In addition, lightweight cables were developed for ocean engineering applications requiring cables or ropes with high strength to weight ratios. The program was focused on developing and testing cables of a new material called Kevlar. This material had strength member tensile strength around 300,000 psi with a specific gravity of 1.33. By the end of 1974, Kevlar looked very promising for use in cables.

In the cable dynamics area, two basic problems were recognized. The first was the small displacement, relatively high frequency, vibration of cables caused by vortices shed from the cable as water flowed past it. This response is generally referred to as strumming. The second problem was the relatively large magnitude, low frequency gross motion of cables and cable structures generated during deployment or recovery of a cable structure, or in-situ by time-varying environmental or man-caused forces. The goals of this program, initiated in 1973, were analytical and predictive techniques for the dynamic behavior of cables suitable for use as design tools by ocean engineers.

Ocean Structures

Since support structures that will be required as weapon systems are employed in the deep oceans, the Navy must develop the engineering capability to build such structures. Although it is most difficult to predict the form and function of future structures, it is possible to acquire knowledge applicable to the building of all such ocean structures. For example, knowledge can be acquired in material behavior, design procedures and design criteria.

Because of these requirements, over 15,000 test specimens of more than 500 different materials were exposed at ocean depths down to 6,000 feet for periods of up to three years. Those specimens included steel, copper alloys, aluminum alloys, stainless steels, nickel base and titanium alloys. Ten protective coatings were exposed for periods up to two years and at various depths. These efforts substantially increased the total knowledge of material performance in the ocean. Much was learned of the effects on material of biological factors existing in the ocean and flood sediments at depth.

In addition, guidelines were developed and are continuing to be developed for the design and fabrication of plain and reinforced concrete pressure resistant structures for use down to a depth of 3,000 feet. Short and long-term hydrostatic tests were made of unreinforced and reinforced hollow spheres and cylinders to determine implosion strengths and the effects of parameters such as size, wall thickness, penetrations, joints and closure stiffness.

Design procedures, certification criteria and theory for predicting failure of flat, conical and spherical acrylic windows for use in deep ocean applications and deep ocean simulation facilities were developed. Experimental verification included long-term, short-term and cycling testing under various temperatures and to pressures of 20,000 psi.

A transparent submersible, NEMO was designed, fabricated and certified for operation to 600 feet. NEMO was a winch-down system with a sixty-six inch diameter pressure hull consisting of twelve two and one-half inch thick spherical pentagons of acrylic plastic, thus affording panaromic visibility for the two man crew. The research program on the acrylic material included model and prototype hull tests and development of fabrication methods.

Another development was the design and fabrication of underwater connectors. The connectors, for use on electrical power transmission cables, were tested at sea. They were capable of supplying 360 kilowatts three-phase power down to a depth of 6,000 feet. Both dry (make/break in air) and wet (make/break underwater) connectors were developed.

Seafloor Construction Experiments (SEACON)

In order to properly evaluate the latest technological developments and to determine the more critical deficiencies in ocean facilities engineering, a series of seafloor construction experiments were initiated during fiscal year 1970. The goal of these experiments was to achieve a demonstrated capability for the construction of ocean facilities.

SEACON I, conducted during fiscal years 1970 through 1972, highlighted the technologies involved in the construction of an unmanned habitat-like strucutre located in relatively shallow water (600 feet). The focal point of the SEACON I experiment was the construction and evaluation of an unmanned, one atmosphere, cylindrical concrete strucutre having a ten foot outside diameter, twenty foot overall length and nine and one-half inch wall thickness. Experimental evaluations of hardware and techniques for site selection and investigation, seafloor construction, structural and electrical elements were coordinated with the year-long seafloor testing of the concrete structure.

The construction site was investigated using tools operated from towed vehicles and manned submersibles as well as surface vessels. In-situ tests to determine short and long-term settlement behavior of model footings were performed. These data were used along with laboratory test data and theoretical considerations to design the SEACON I structure foundation. The foundation performed approximately as predicted.

A seafloor transporter navigation system was installed to accurately position the foundation. A wire guideline system was used to mate the structure with the foundation. NEMO dove to the SEACON I structure to evaluate its construction inspection capability. Structural elements evaluated included a forty-two inch diameter acrylic window, window cleaning hardware, waterproof point systems, and experimental utility penetrators. Wet and dry high power electrical connectors were successfully used to periodically power the structure for nearly one year; the wet connector was successfully mated underwater by divers.

After 314 days on the seafloor the concrete structure was refloated and towed back to Port Hueneme where anlaysis of its performance was made.

SEACON II was initiated during fiscal year 1973 and highlighted the installation of a tri-moor cable structure. The structure consisted of a horizontal delta-shaped cable structure buoyed at each apex, with 1,000 foot arms located 500 feet below the surface and tethered by three moorings legs in 2,900 feet of water. SEACON II was designed as a means of evaluating new developments in seafloor construction techniques, especially deep ocean embedment anchors and tongue-balanced electro-mechanical cables and as a field test to measure the response of a complex, three-dimensional cable structure to ocean currents.

UTILITIES TECHNOLOGY

Safe, economical, and efficient utility systems and equipment were required to assure the continued operation of the Navy's shore facilities during periods of energy shortages and rising material costs and labor. The utilities technology research and development program was directed toward achievement of these goals.

During the period covered by this history, utilities technology accomplishments included an evaluation of commercially available items such as multitap connectors for underground electrical distribution systems, plastic coated rigid electrical conduit, low voltage switchgear for shore-to-ship power, pipieline inspection systems, and static charge reducer for fuel-handling operations.

Another accomplishment of this program was the determination of the electromagnetic interference shielding requirements necessary in hospital construction. This was necessary to insure the electromagnetic compatibility of the electrical and electronic equipment used in and about hospitals. Furthermore, a study of electrical hazards associated with the use of electronic devices in hospitals provided recommendations for Navy use.

HIGH QUALITY ELECTRIC POWER

Modern Navy electronic equipment with its complex and sophisticated circuitry requires high quality, reliable electric power. Communications equipment and computers are particularly sensitive to disturbances in their power supply. To solve the problems of power quality it is necessary to identify those forms of line disturbances which cause either an interruption in service or damage to equipment.

To assist in solving this problem the Command developed power line transient monitoring and recording equipment capable of extremely rapid response and accurate reproduction of the waveform disturbances on a continuous basis over fairly long periods of operation. Furthermore, equipment was developed to simulate line transients, surges, voltage and frequency excursions. This equipment was used to ascertain which forms of synthesized disturbances actually caused equipment malfunctions and failures.

Among the devices developed in this research and development program was a power transient data acquisition monitor capable of automatically recording randomly occuring power disturbances and transients in an electrical power system. The monitor contained a magnetic drum/magnetic tape recording system. Up to twelve power waveforms at different points in the monitored power system could be recorded concurrently.

Other devices developed were a power system synthesizer which was used as a source of power with controlled output parameters for susceptibility testing and calibration of equipment. And, a pulse generator which supplied up to ten kilovolts of two, ten and one-hundred microsecond pulse duration with the time rise adjustable to less than one microsecond.

A power system simulator was developed which simulated a medium sized electrical power system having forty-eight transformers and sixty loads of various kinds. The purpose of the simulator was to investigate transient currents and voltages which appeared on the power elements of an electrical system under dynamic conditions.

Additional developments included a small portable power line disturbance monitor and a transient direction detector. The power line disturbance monitor identified and counted the number of typical power input anomalies. The monitor operated under an input line-toneutral voltage range of 90 to 140 rms. in three-phase, 50 to 60 hertz power circuits. This unit monitored undervoltage, overvoltage, under-frequency, over-frequency, low magnitude impulse voltage. The transient direction detector located sources of electrical impulse voltage transients in power systems. This unit was used independently or in conjunction with the power line disturbance monitor.

The equipment developed in this program was used to locate deficiencies in uninterruptible power system bypass installations to determine susceptibility limits of a digital data processing system to power anomalies, as laboratory test equipment for validating conformance to military specifications, to evaluate commercially available transient suppressors, and to determine whether computer malfunctions were caused by input power anomalies. The transient direction detector and power line disturbance monitors were expected to find wide application with both the Department of Defense and industry.

VLF ANTENNA INSULATOR TECHNOLOGY

Because of the importance of maintaining very low frequency (VLF) communications a program was initiated to improve VLF insulator technology. Objectives of this on-going effort included: development of antenna insulator test criteria, insulator failure analysis and incipient failure detection studies leading to improved inspection and maintenance procedures, development of improved inspection and maintenance procedures and development of improved design criteria. A joint Air Force-Navy 100 kilovolt VLF facility for testing dielectrics will be established at the Rome Air Development Center.

NUCLEAR WEAPONS DEFENSE

A research program was conducted to develop design criteria and new approaches for the design of hardened structures to protect personnel and equipment from the effects of nuclear weapons. The program effort was divided between structural design aspects and the equipment and utilities necessary to insure the continuance of operations within the shelter. One of the accomplishments of this program was the preparation of a handbook on nuclear electromagnetic pulse effects. This handbook provided information on the installation and operation of various devices and the use of various techniques for the protection of critical installations.

Other developments included a nuclear blast detector, a portable smoke and gas removal unit, and a blast valve. The nuclear blast detector was based on the use of the electromagnetic pulse signature of a nuclear weapon detonation as the phenomenon to be sensed. The purpose of this detector was to furnish a signal to automatically trigger blast closure valves.

The portable smoke and gas removal unit was developed to clear the atmosphere of a sealed room after a fire. The blast valve was tested in the field where it proved to have an air flow capacity of 10,000 cubic feet per minute which withstood pressures of 100 psi.

Also tested were hardened diesel engine driven electrical generators which were tested in a 500-ton high explosive event.

MATERIALS

Navy facilities were located in an environment of ocean/air interface which imposed severe corrosive effects on construction materials. This problem was compounded by possible abrasion, biota activity, application problems and operational factors. The materials program was directed toward providing a technology base which could lead to cost effective solutions to these problems.

Research for the Materials Program included a wide spectrum of technical projects. Among these was the development of improved coating and maintenance methods for mooring buoys. In addition, plastic mooring buoys were evaluated and as a result of these evaluations, the plastic buoys were recommended as replacements for steel buoys when additional procurements became necessary.

A cathodic protection system for fleet moorings was developed. This protection system consisted of sacrificial anodes on both the buoy and on the ground tackle. Special zinc anodes cast on steel links became an integral part of the ground leg chains. Anodes were also developed which could be attached to the chain while the mooring was in service.

Many proprietary paints and coatings were evaluated for a wide range of applications on various substrates. Additionally, new methods were developed to provide capabilities for applying protective coatings to a wide range of surfaces from underwater steel sheet piling to VLF antenna cables. A field kit for the identification of newly applied or weathered paints was also developed. The kit provided simple tests for classifying paints as to specific generic type. The kit was used to assure the compatibility of new paint which was to be applied over existing weathered paint.

Various methods for the in-place installation of barrier systems for the protection of wooden piles from marine borers were evaluated. As a result of the evaluation, a Command specification was prepared.

A surveillance system was developed that permitted monitoring tank-to-water potentials of cathodically protected steel water storage tanks from outside the tank.

New elastometric latex linings for concrete bulk fuel storage tanks were developed. The function of the linings was to prevent loss due to leaks and to prevent reactions between alkaline concrete and petroleum distillate products.

The results of the materials research was reflected in the preparation of new construction specifications and in the development of new capabilities for the protection of the already existing structures of the shore establishment.

POLAR RESEARCH

Command research in the polar environment from 1965 through 1974 was concentrated on perfection of snow-compacted roads, vehicles, structures, and airstrips. This research created new ways to use snow as a roadway and aircraft landing surface, new equipment, and techniques of coping with sanitation and utilities problems in polar regions.

Naval operations in Antarctica from the start used ice runways for its aircraft movement of personnel and cargo between New Zealand and McMurdo, Antarctica. Early runways were established on multiyear thick ice. Through ice breaker operation in McMurdo Sound and effects of environmental factors, the accessibility of this type of ice gradually diminished and forced the operation to the thinner annual sea ice.

Laboratory research of sea ice included an extensive series of tests on small samples where the parameters influencing strength could be isolated and controlled. In the field, work was primarily that of testing large ice beams. For this work, it was necessary to develop a large ice saw. Ice beams up to 100 feet long by 8 feet thick were cut and tested. The mechanical properties such as tensile strength, rupture modules in bending, and elastic modules were sufficiently defined to permit safe operational use of C-141 aircraft from the annual sea ice runways at McMurdo, Antarctica between October and mid-December. The load curves for all Antarctic operation of aircraft on sea ice were developed from this data.

The absence, however, of a full understanding of ice sheet failure modes precluded the establishment of failure criteria and the ability to accurately define the safety factor provided by the curves. Computer oriented solution methods were developed which indicated that the elastic plate theory solution was overly conservative for some of the ice sheet temperature conditions.

Heavy-haul wheeled transportation equipment used for the movement of cargo and personnel in the Antarctic required high strength snow roads. Methods of snow road construction developed in the 1960s were time consuming and required costly, special equipment. Based on the factors of construction time, equipment cost, and quality control, it was considered desirable to devise a more simplified procedure for constructing snow roads.

A layered compaction of snowblower-processed snow was investigated as a substitute for the former mixing process. The layered compaction method consisted of three steps. Snow was deposited on the roadbed by a ski-mounted snowblower. The snow was then leveled into four inch layers with a towed snowplane. For the final step, the snow was compacted by walking the area with tractors.

A one mile layered roadway was built using this compaction method, and its density, shear strength, and trafficability were compared to those of the earlier snowblown and pulvimixed roads. In both cases, the comparison was favorable. After four months of normal use, the road showed no evidence of deterioration from wheeled vehicles. The surface remained smooth and no failure points were found. Loads grossing over 70,000 pounds were carried over the road during the test period.[4]

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[4]CEL, Technical Activities (describes CEL accomplishments from 1 Jul 1972 through 31 Dec 1973).

Coupled with the advancement in technology for constructing snow roads, research and development efforts were started on a rubber-tired vehicle transportation system for rapid movement of cargo and personnel over the five-mile snow field between McMurdo and Williams Field Air Facility.

Prior to snow roads, sled trains moved cargo at speeds of two to five miles per hour. This presented a transition problem of going from a snow and ice covered surface to a dirt surface.

Twenty-ton commercial type trucks outfitted with high flotation tires were developed and introduced into the surface transportation system. In these trucks, cargo was moved at the rate of twenty to thirty miles per hour. Other rubber-tired vehicles in the transportation system included a twenty passenger bus, a station wagon, and pickup trucks.

An all-terrain sixteen wheel vehicle to travel unprepared surfaces was developed by the Naval Civil Engineering Laboratory and built under contract.[5] This vehicle provided aircraft crash and rescue capability around the ice and snow runways in Antarctica. Its weight was so distributed on high-flotation tires that it could cross snow that would not support a man on foot.

Command research and development in structures was focused on pioneer camps such as Williams Field, Antarctica. The deep snow field location of Williams Field created typical maintenance problems

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[5] Memo from CO, NCEL to Chief of Legislative Affairs, Navy Department of 25 May 1973.

such as snowdrift control and summer ablation. There was one unique problem, however: Williams Field was used as a single point air traffic control center for both the sea ice runway and the ski snow runway. In addition, the field had facilities for refueling aircraft and minor aircraft maintenance.

Because it was used as both a sea ice runway and a ski snow runway, it was necessary for the field to be located near the edge of the Ross Ice Shelf. Since the Ross Ice Shelf flows into McMurdo Sound at the rate of about 300 feet a year and subsequently calves, it was necessary to periodically relocate the facility further up the ice shelf.

These relocations provided an opportunity to test and evaluate new camp concepts and designs, construction techniques, snowdrift control procedures, polar camp maintenance procedures, and water supply and sanitation systems.

During the summer of Deep Freeze 68, a survey was made of existing service shelters at Williams Field. To satisfy operational requirements for airfield and public works type functions at polar facilities on ice and snow, four designs were considered. These included a standard-use service shelter, a special-use service shelter, a mobile windscreen, and an unheated storage shelter. Because of the high cost as a result of limited procurement of these specially designed shelters, a survey of commercial building systems for potential use as service shelters was conducted. This survey indicated that the Fold-a-Way Building System was suitable for unheated storage shelters, and with minor modifications showed promise for other types of service shelters.

The Command was assigned the task of developing reinforcing methods, techniques and equipment for construction, maintaining and repairing oceanfounded and bottom-resting ice structures for wharves, docks, piers, causeways, and other waterfront facilities at critical polar coastal locations in the Arctic and the Antarctic where conventional construction was not feasible. Since maintaining ice-clear areas for docks, piers, causeways and other conventional waterfront structures was almost impossible in many otherwise desirable polar coastal sites, maximum use of sea ice and fast ice on sounds, bays, inlets and other coastal locations in the Arctic and Antarctic was essential for effective and efficient surface polar operations.

Floating sea ice at coastal locations often presented the only suitable surface for roads, runways, and other support facilities. It often required only a minimum of preparation. However, where available, natural fast ice usually required modification for use as docks and piers and other coastal works. An application of ice construction technology was the rehabilitation of the ice dock used by the ships to resupply the Antarctic operation. Erosion of the dock face during previous years was so severe that ships could no longer tie up against the dock because of decreased water depth.

The influence of polar environments on the design, construction, operation, and maintenance of facilities required investigation and documentation to determine the effects of a polar climate compared with a temperate climate. During this decade, the effects of a severe polar environment were observed at stations in the Arctic and Antarctic, but these effects were not sufficiently well defined to permit engineering application in planning, building, and operating polar facilities. Although there was considerable engineering knowledge available, a lack of precise definition of environmental effects was often responsible for faulty design.

Most of the efforts of the Polar Program during these ten years stemmed from a requirement to solve problems confronting the Naval Task Force operating in the Antarctic. The naval operation in the Antarctic not only benefited the scientific community but also provided a challenging environment for evaluating some phases of military operations in polar regions. In this way a backlog of experience and expertise was provided that could be put to use elsewhere when needed.

Funding for polar research reached its peak during fiscal year 1963. However after 1963 there was a gradual decline in funds available until a leveling trend was reached about 1970. As a result of this decline, it became necessary to compress the program into fewer projects or work units.

ENVIRONMENTAL PROTECTION

The shore facilities of the Navy are extensive and complex industrial communities. The replacement value of these facilities for fleet support is in excess of thirty billion dollars. Because of the nature of assigned defense responsibilities and logistic support, these facilities are located, for the most part, within populated coastal zones. This compounded and magnified the environmental impact of pollution discharges from these facilities.

In 1966 the Navy began its Air and Water Pollution Abatement and Control Program in response to a presidential executive order which required agencies to provide leadership in the drive to abate and control pollution from federal facilities.[6] The Bureau of Yards and Docks, now the Naval Facilities Engineering Command, was assigned as the single Executive Manager for the Navy-wide Air and Water Pollution Abatement Program.

The first step in pollution abatement was problem recognization. Once recognized the problems had to be solved. Therefore, a survey of the entire naval establishment was made to identify deficiencies based on evolving water and air quality standards being developed by the states in accordance with the Water Quality Act and the Clean Air Act.[7]

After they were identified, environmental problems were solved in order of priority. These priorities included situations which were a hazard to the health of man, economic implications, and those that affected recreational and natural resources.

As applied to shore facilities, Command Headquarters coordinated the Environmental Quality Program within the Command. It also

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[6]Executive Order 11258 of 17 Nov 1965.

[7]CDR Joseph A. D'Emidio, CEC, USN, "Navy Environmental Protection Program," Military Engineer, Vol 64, (Nov-Dec 1972), pp. 402-405.

coordinated the program with other components of the Navy and Marine Corps. Middle management of the program was carried out by the Engineering Field Divisions and local aspects were managed by the Public Works Centers and the facilities themselves. The Navy program concentrated on shore facilities and ships, and although significantly less in magnitude, programs to control engine emissions from vehicles and aircraft were also pursued.

Large shore facility pollution abatement programs of various types were conducted at Pearl Harbor, Hawaii; Norfolk, Virginia; San Diego, California; and Newport, Rhode Island. Elimination of shore discharge by the Navy and others made San Diego Bay a national model to show what could be achieved by a coordinated cleanup effort.

Every effort was made to cooperate with local communities in joint solutions to waste disposal projects, and at the same time achieve better pollution control. The Command performed pilot tests to identify and measure actual sources of pollution and to determine what instrumentation and techniques would be needed to monitor the pollution sources at the lowest cost. This required sampling, identifying and analyzing of waste products and of procedures for recording and handling the relevant data.

Work was done in developing systems for transferring liquid wastes from docked ships to shoreside treatment facilities. Couplings and hoses were a vital part of such systems and many different types of hardware were field tested and evaluated.

From time to time the Navy had problems with oil spills. To clean up harbor oil spills, a portable oil suction head was designed and fabricated by the Naval Civil Engineering Laboratory. The device proved so effective that a license was granted for it to be manufactured and sold commercially. For larger spills, hardware was designed for containment booms. These booms were assembled and the complete systems tested. In one test, seventy-five gallons of oil were deliberately spilled in Long Beach Harbor. The recovery system successfully cleaned up all but one quart of the oil.

Other environmental projects which affected the fleet included systems for the treatment of oily wastewater, such as that collected from ship's bilges, solid waste handling, and ship waster offloading systems.

In 1972 the Command was tasked by the Chief of Naval Material to create a Navy-wide Data Base Program within a two year time period.[8] The Command, as program manager, designated the Naval Civil Engineering Laboratory as Deputy Program Manager.

The major research effort on the Data Base Program during fiscal year 1972 was at three pilot test locations: Pearl Harbor, Hawaii; Naval Air Station, North Island, California; and the Naval Ammunition Depot, Crance, Indiana. The purpose of the pilot tests was to identify and measure actual sources of pollution to determine what instrumentation and techniques would be needed to monitor the

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[8] NAVMAT Instruction 6240.1B of 10 Oct 1972.

pollution sources at the lowest cost. The Navy needed reliable environmental data generated through recognized measurement and test procedures.

On 1 July 1973, the Navy Environmental Protection Data Base became operational. In the short span of just two years, a service-wide system was developed which provided the Navy's decision makers with the environmental information needed to combat Navy-generated pollution. However, continued research and development support of the program was required through fiscal year 1975. This support was needed to develop more suitable instruments for data collection and to advance and update the system design, including the automatic data processing support for data handling. Furthermore, research and development support was needed to further develop mass emission factors, computational methods, and data banks for ship and aircraft environmental data.

OPERATIONS RESEARCH

Operations research studies were initiated in 1966 to analyze and predict the resource requirements of the Naval Construction Force, and to devise methods of improving their military readiness capability. These studies resulted in a computer simulation of all Seabee operations called the STINGER system. The acronym, STINGER, stands for Seabee Tactically Installed, Navy Generated, Engineering Resources.

Questions which the STINGER system probed included estimates of support requirements of a Marine Expeditionary Force, the identity of trade-offs which would improve the responsiveness of construction force units to changing construction needs, the maximum effectiveness in the balance of men, materials, spare parts and equipment, and the prediction of future Civil Engineer Corps officer strength requirements.

When the simulation model of the system reached an operational stage, a staff office was established at the Naval Construction Battalion Center, Port Hueneme, California. This office was established on 15 January 1968 to further develop and exercise the computer models produced in the laboratory.[9]

Another computer system was devised by the Command to assist public works departments. This system produced weekly work center schedules by preparing schedules and arranging priorities four weeks in advance for eighteen work centers and four equipment groups. The system made possible close manpower management and the orderly completion of work units.

Also developed was a computerized systems analysis model to quickly identify the facility requirements of a Construction Battalion Center under varying Mobile Construction Battalion home-ported and student-base loads. This model was expanded to identify all the costs associated with homeporting a battalion at a Construction Battalion Center. It was also used to determine the assignment of a homeport for a battalion or the assignment of an increased training mission based on the minimum total cost.

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[9] See Chapters 14, and 15 for a complete discussion of STINGER.

VIETNAM LABORATORY ASSISTANCE PROGRAM

In 1966 events in Southeast Asia led to the establishment of the Command's Vietnam Laboratory Assistance Program at the Naval Civil Engineering Laboratory. This program provided quick-response support to the United States forces in Vietnam. Trouble-shooting staff experts were sent to Vietnam to spot problems before they arose when possible, or, in any event, to alert the Laboratory for possible solutions while at the same time providing guidance to field forces. The main field contacts were construction battalion commanders, officers in charge of construction, and public works officers.

In addition, the program included modification and evaluation of equipment and the assignment of specialists in materials engineering, chemical engineering, and soils and pavement engineering to aid local commands.

Evaluations were made on such things as airfield pavement capacity, development of a pontoon structure to armor tank landing ships, and off-shore moorings. Performance evaluations were made on equipment such as earthmoving scrapers, a reverse osmosis facility, and water supply plants.

There were many instances of assistance provided in Vietnam. For example, an on-site inspection was made of causeway problems in Vietnam. As the result of the inspection several recommendations on modifications to the "P" series pontoons were made.

Guidelines for stabilizing soils in Vietnam were developed and a manual for asphalt-soil stabilization was published and distributed to field forces.

A lightweight, gasoline-engine-powered, air-transportable fuel line-reel system capable of expeditiously handling six inch fuel lines was developed. The system was based on a Seabee field-designed, hand-operated turntable.

A system was designed to fill and drain two by fifteen pontoon sections with water. The water-filled pontoons were locked to the sides of tank landing ships to protect the ships as they moved cargo up rivers in Vietnam.

Soil erosion and blowing sand caused many problems in certain areas of Vietnam. To overcome this problem the feasibility of soil stabilization by planting was investigated. Hydroseeding with both imported and locally harvested seeds was tried, as was the transplanting of cuttings of endemic ground covers. During the post-planting months, plant growth or deterioration was measured and recorded.

Results indicated that the soils in the dune areas of Vietnam could be stabilized by planting, and that the increased use of local vegetation was effective.

Many of the problems supported by this program bore directly on the Seabees and the Mobile Construction Battalions. For example, battalion hand tools were studied in order to provide the battalions with the least expensive, most durable and most useful tools. Some of the research, development, testing, and evaluation of hand tools was the first of its type.

TECHNOLOGY TRANSFER AND UTILIZATION

In the mid-1960s, because of mounting expenditures for national research and development, concern over utilization of research and development increased. This increased concern came about because conservation or management of resources demanded that utility be derived from the output of research and development investments.

The matter of Command research and development utilization was established in the office of the Assistant Commander for Research and Development. However, its initial mode of operation proved unworkable.

Subsequently, research, development, test and evaluation liaison engineers were established in the various Engineering Field Divisions for the purpose of facilitating the matching of an engineer's need for new technical knowledge or information and the source of such information -- whether it was at the Civil Engineering Laboratory or elsewhere in the research and development community. The liaison engineers also worked to improve technology exchange among the Engineering Field Divisions. In addition, an Applications Division, intended for intensive management, replaced the Utilization Division. Although this division was subsequently disestablished because of personnel shortages, its intended functions were maintained within the Command's research and development organization.

A number of research studies were conducted under contract by the Naval Postgraduate School. These studies were aimed at the establishment of an empirical understanding of the Command's technology transfer and utilization patterns as a data base for management action.

Research studies were also conducted aimed at the documentation aspects of the Civil Engineering Laboratory's research and development efforts. As a result of these studies, the following improvments in information transfer were implemented:

1. A new biannual publication, "RAP[10] Briefs," was established in order to enable Command field operating personnel to keep track of work underway at the Civil Engineering Laboratory.

2. The distribution basis of technical reports was reviewed and revised for improved technology transfer.

3. Abbreviated bulletins of specific end products, called "TechData" sheets were issued with the purpose of reaching outside of the research and development area. They attempted to get the pertinent message across without all the "research jibberish" of the technical reports that were essentially written for the research and development community.

Another development was the initiation of a twenty-four hour telephone information service so that anyone could call the Civil Engineering Laboratory for technical advice on any subject and at

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[10]"RAP" - Research Applied to Public Works.

any time. This servie has been well received and the concept seems to be spreading elsewhere.

A contact point was established at the Civil Engineering Laboratory to provide speedy and effective response to field requests for short term research and development and consultation assistance. The results were most impressive with a 3:1 payoff between cost of service and user benefits.

The Research, Development, Test and Evaluation Assistance Program was another way in which the climate for research and development utilization was improved. The purpose of the program was to provide a funded basis whereby laboratory scientists and research engineers could take time from their primary research tasks and conduct short term research and development (brushfire research and development) or consulting investigations in order to provide quick answers to field problems whose urgency or scope did not warrant inclusion in the annual program. Much technology was thus readily transferred to field engineers who ultimately determined the degree of applications and utilization. In addition, the time interval between development and application has been shortened because information can be transferred long before the formal technical reports have been distributed. This program doubled in dollar value during the ten year period under consideration.