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HISTORIC CONTEXT FOR DEPARTMENT OF DEFENSE FACILITIES WORLD WAR II PERMANENT CONSTRUCTION

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FINAL REPORT

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EXECUTIVE SUMMARY

The Historic Context for Department of Defense (DoD) World War II Permanent Construction combines two previous reports: Historic Context for Department of Defense Facilities World War II Permanent Construction (Hirrel et al., draft June 1994) and Methodology for World War II Permanent Construction (Whelan, draft August 1996). This project was designed to meet the following objectives:

- To analyze and synthesize historical data on the military's permanent construction program during World War II.
- To assist DoD cultural resource managers and other DoD personnel with fulfilling their responsibilities under the National Historic Preservation Act (NHPA) of 1966, as amended. Section 110 of the NHPA requires federal agencies to identify, evaluate, and nominate to the National Register of Historic Places historic properties under their jurisdiction. Section 110 Guidelines, developed by the National Park Service, U.S. Department of the Interior, direct federal agencies to establish historic contexts to identify and evaluate historic properties (53FR 4727-46).
- To develop a consistent historic context framework that provides comparative data and background information in a cost-effective manner, which will allow DoD personnel to assess the relative significance of World War II military construction.
- To develop a standardized methodology for the identification and evaluation of World War II permanent construction.

The report is divided into two parts. Part I examines the historical, architectural, and technological development of permanent facilities constructed on behalf of, and by, the military on the home front during World War II. Part II provides a framework for identifying and evaluating DoD permanent facilities constructed during World War II applying the National Register Criteria for Evaluation.

The military's World War II construction program was a massive effort that expended billions of dollars in the construction of thousands of facilities. While no one facility made the difference in the result of the war of resources, the cumulative effect of the effort was a decisive factor in the allied victory. Preliminary analysis of DoD real property data indicates that approximately 55,000 buildings currently classified as permanent and semi-permanent constructed during the World War II era are included in the DoD real property inventory. World War II-era properties now meet the 50-year age requirement of the National Register of Historic Places. This study describes the reasons for permanent vs. temporary construction and the role of permanent construction in the overall war effort.

This project was designed to assist DoD with the execution of their responsibilities under Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended, and to fulfill the legislative purposes of the Legacy Program. R. Christopher Goodwin & Associates, Inc., undertook this project on behalf of the Department of Defense, through the Baltimore District of the U.S. Army Corps of Engineers, as a demonstration project for the DoD Legacy Resource Management Program.

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CHAPTER I

INTRODUCTION

Cultural Resources in the Department of Defense

The Department of Defense (DoD) manages 25 million acres within the United States. These lands contain a range of properties associated with the historical development of the military, as well as with many other facets of North American history and prehistory. Cultural resources are non-renewable resources that document the historical development of the nation; they include real property, personal property, records, and community resources.

Military cultural resource programs, including the identification, evaluation, and management of historic properties, are on-going functions within the respective services. Although Federal Preservation Officers for each service provide guidance in cultural resource management, responsibility for the majority of DoD cultural resource management duties falls upon individual installations, activities, and commands.

As installation-based cultural resource programs evolved, DoD recognized the complex historical inter-relationship of properties associated with the military services. Military construction typically was planned and executed as part of a national defense program. As a result, assessment of the historical significance of DoD properties requires comprehensive comparative data on the historical development of DoD construction. Such comparative data provides a basis for developing consistent management strategies for historic properties. Through the development of comprehensive historic context studies, DoD seeks to provide background and comparative information in a practical and cost-effective manner that is in the public interest.

Project Description

The Historic Context for Department of Defense World War II Permanent Construction presents the historic background of World War II permanent and semi-permanent construction and a methodology for identifying and evaluating World War II permanent and semi-permanent construction on Department of Defense (DoD) facilities. This report combines the draft reports Historic Context for Department of Defense Facilities World War II Permanent Construction (Hirrel et al., draft June 1994), which examined the historical, architectural, and technological development of U.S. military permanent construction built from 1940 to 1945 on the home front, and Methodology for World War II Permanent Construction (Whelan, draft August 1996), which provided a methodological framework for identifying and evaluating World War II permanent construction. The integration of this work into a single report will facilitate the distribution and application of the project results.

The military's World War II construction program was a massive effort that expended billions of dollars in the construction of thousands of facilities. World War II often is characterized as a war of resources, a race to mobilize the men and materiel needed for victory. While no one facility made the difference in the result of the war of resources, the cumulative effect of the effort was a decisive factor in the allied victory. The fiftieth anniversary of World War II has sparked great interest in the physical remnants of wartime construction on the home front. Thus far, historic context studies of World War II construction have focused on the temporary construction program developed to erect temporary facilities to house and train millions of men quickly. The low cost and speedy construction rate of temporary buildings best served the war emergency. However, some specialized facilities necessary to the war effort were not suited to temporary buildings, and thus the military also built permanent construction.

Permanent and semi-permanent construction built by the military during World War II is the subject of this historic context study, which describes the reasons for permanent vs. temporary construction and the role of permanent construction in the overall war effort. Preliminary analysis of DoD real property data indicates that approximately 55,000 buildings currently are classified as permanent and semi-permanent constructed during World War II (Army, 32,909; Navy and Marine Corps, 16,781; Air Force, 5,310).

Buildings originally built from temporary construction mobilization plans that have been renovated and currently are classified as permanent or semi-permanent in DoD real property inventories are not the subject of this study. Historic contexts define properties by their historic rather than current real property classifications. Buildings originally built as temporary mobilization construction should be evaluated within the context of World War II temporary construction; modifications to their original design and materials should be assessed in relationship to the property's integrity, and its ability to convey its association with its historic context.

Legislative Background

The National Historic Preservation Act (NHPA) of 1966, as amended, established the legislative basis for federal historic preservation programs. The act established the National Register of Historic Places, the national inventory of properties significant in American history, architecture, engineering, archeology, and culture. The National Register is continually updated to include significant properties that represent many facets of American history. Section 110 of NHPA requires federal agencies to identify, evaluate, and nominate to the National Register historic properties under their control or jurisdiction. Section 110 also requires federal agencies to consider the preservation of the cultural and historical values of historic properties under their control or jurisdiction (16 U.S.C. 470h-2).

The Section 110 Guidelines, developed by the National Park Service, U.S. Department of the Interior, direct federal agencies to establish historic contexts to identify and evaluate historic properties (53FR 4727-46). The Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation provide technical guidance about historic preservation activities and methods, including identifying and evaluating historic properties. These standards also recommend developing historic contexts to assist with preservation planning.

Project Objectives

This project to develop a historic context for World War II permanent construction had several objectives:

- To synthesize and analyze historical data on the military's permanent construction program during World War II.
- To assist DoD cultural resource managers and other DoD personnel with fulfilling their responsibilities under Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended. Section 110 of the NHPA requires federal agencies to identify, evaluate, and nominate to the National Register of Historic Places historic properties under their jurisdiction. World War II-era properties now meet the 50-year age requirement of the National Register of Historic Places.
- To develop a consistent historic context framework that provides comparative data and background information in a cost-effective manner, allowing DoD personnel at individual installations to assess the relative significance of World War II military construction without conducting extensive historic context development.
- To develop a standardized methodology for the identification and evaluation of World War II permanent construction.

Application of the Historic Context for World War II Permanent Construction

Information Needed

DoD personnel undertaking the identification and evaluation of historic buildings on DoD installations can apply the methodology presented in this report as the basis for their evaluation of the significance of World War II military permanent construction. To apply the World War II permanent construction historic context to a particular property, whether an entire installation or an individual building, the following information about the property is needed:

(1) location;

(2) date of construction;

(3) type of construction, as classified during World War II;

(4) World War II function of the particular buildings or structures; and,

(5) World War II installation type.

Identification of Historic Properties

Section 110 of the National Historic Preservation Act of 1966, as amended, requires the identification of historic properties. Identification requires gathering information and establishing a research design to identify historic properties on the installation. The identification of historic properties is an on-going process; World War II properties, which only recently have reached the 50-year mark, often have not been identified in earlier surveys of installation historic properties. The World War II Permanent Construction Historic Context can be used to identify historical patterns and associated themes relevant to the development of a specific installation during World War II. Cultural resource managers can use the historic context to predict the range and type of historic properties on an installation. Useful material in determining installation- or property-specific significance include: real property lists that include dates of construction and construction material, building plans, historic maps, historic photographs, and studies documenting the installation's organization and mission during World War II.

While this study does not replace the need for site-specific archival and field investigations, it does provide a broad framework within which site-specific data can be integrated and information needs assessed. The discussion of the roles of different installations during World War II establishes the connection between the real property and historic events, and places the facility within the overall historical development of DoD construction activities.

Evaluation of Historic Properties

Section 110 of the National Historic Preservation Act of 1966, as amended, also requires the evaluation of historic properties. The National Register Criteria for Evaluation (36 CFR, Part 60.4) are the primary criteria for evaluating the qualities of significance and integrity in historic properties. To qualify for listing in the National Register of Historic Places, a property must possess the qualities of significance defined under one of the National Register criteria and possess several of the seven qualities of integrity. Properties may be significant on a local, state, or national level.

Evaluating an historic property is a four-step process: (1) categorize the property; (2) determine what historic context the property represents; (3) determine whether the property is significant under National Register criteria; and, (4) determine whether the property retains integrity. The application of the World War II Permanent Construction Historic Context to the evaluation of historic properties follows this same process. Chapter XIII of this report lists the National Register Criteria and provides a methodology for evaluating World War II permanent construction.

Treatment of Historic Properties

Federal agencies are required to take into account the effects of their actions on historic properties. This responsibility was established in the National Historic Preservation Act of 1966, as amended; in the National Environmental Policy Act of 1969; in Executive Order No. 11593 (Protection and Enhancement of the Cultural Environment); and, in numerous subsequent federal laws and regulations. This project is designed to assist DoD in executing these responsibilities, applying the Secretary of the Interior's Standards for Preservation Planning.

The Secretary of the Interior's Standards for Preservation Planning established a three-step approach to preservation planning:

1. Establishment of historic contexts;

2. Use of historic contexts to develop goals and priorities for identification, evaluation, and treatment of historic properties; and,

3. Integration of the results of preservation planning into the broader planning process.

Preservation planning is a dynamic process. The World War II Permanent Construction Historic Context includes comparative data and context statements that provide the basis for new or expanded historic contexts. This study also can assist DoD cultural resource managers in developing preservation goals and priorities.

DoD regulations require that installations develop management plans for historic properties. The World War II Permanent Construction Historic Context can be used as a predictive model to anticipate the property types associated with the World War II mission of an installation, and it can assist in the development of plans to identify historic properties.

The World War II Permanent Construction Historic Context also may be used in developing treatment strategies for historic properties. The study defines the installation types that possess important and specific associations with the World War II historic context. Through the determination of why a property is significant, a variety of treatment strategies that best preserve the cultural and historical values of the property may be developed. As this documentation indicates, many World War II permanent facilities represent standardized construction techniques. Programmatic Agreements have been developed that allow documentation of some types of installations (see Appendix III). Similar Programmatic Agreements could be formulated to document classes of property types, such as ammunition bunkers.

Relationship to other DoD Context Studies

Many installations were built over a period of years including, but extending beyond, World War II. DoD has sponsored other nationwide historic context studies, including National Historic Context for Department of Defense Installations, 1790 - 1940; World War II and the U.S. Army Mobilization Program: A History of 700 and 800 Series Cantonment Construction; World War II Temporary Military Buildings: A Brief History of the Architecture and Planning of Cantonments and Training Stations in the United States; Support and Utility Structures and Facilities (1917 - 1946) Overview, Inventory, and Treatment Plan; and Navy Cold War Guided Missile Context: Resources Associated with the Navy's Guided Missile Program, 1946 - 1989. Additional studies related to the Cold War era are underway. To evaluate fully the significance of DoD properties, a holistic approach incorporating guidance from these various context studies is necessary. Understanding an installation may require evaluating several layers of historic development, from establishment in the nineteenth century, through use during World War I and 1930s expansion, to World War II mission, and use during the Cold War. Facilities, including individual buildings and entire installations, may have undergone numerous transformations in response to changing military needs. The significance of various phases of development can be understood only within their relevant historic contexts.

Methodology

The Secretary of the Interior's Standards for Preservation Planning and technical literature from the National Register Program of the National Park Service were used to develop and implement the research design for this project. Three primary tasks were completed to develop a historic context for World War II-era permanent construction at DoD installations within the fifty states. These tasks were archival research, field investigation, and data synthesis. Data were collected and analyzed to identify the broad patterns of military construction immediately before and during World War II; to develop specific historic themes; and, to develop a method of categorizing property types related to World War II permanent military construction.

Archival Research

A literature search was completed of standard military secondary sources, both published and unpublished. The Technical Services portion of the "U.S. Army in World War II" series (the so-called "Green Books") proved an invaluable source of information. For the Navy Department, the best source of information on administration and logistics was the "Naval Administrative Histories of World War II," a manuscript available at the Navy Department Library, Washington Navy Yard. Building the Navy's Bases (1947) provided the best source for the Navy's World War II construction program. Semi-official and official monographs, such as Buford Rowland and William Boyd's history of the Navy Ordnance Bureau, also provided excellent overviews. Specialized monographs completed the secondary literature overview.

Published primary material that was consulted included memoirs, government documents, and periodicals. Memoirs of such men as Levin H. Campbell (Chief of Ordnance) and Donald M. Nelson (War Production Administration) provided valuable information. Periodicals reviewed included both military journals and trade publications. Some of the most useful magazines included: Architectural Forum, Architectural Record, Engineering News-Record, and Army Ordnance. Government publications varied from military technical manuals to studies by the Labor Department Women's Bureau.

Unpublished primary source research encompassed both archival works and special research collections. At the National Archives, some of the most valuable Records Groups included RG 71 (Records of the Bureau of Yards and Docks); RG 74 (Records of the Navy Bureau of Ordnance); RG 77 (Records of the Chief of Engineers); and RG 156 (Records of the Chief of Ordnance). Within RG 156, Entry 646 (Histories of Ordnance Installations and Activities) proved to be a lucrative source of information on ammunition production facilities. The files of the National Register of Historic Places, in Washington, D.C., were reviewed to identify World War II properties listed in the National Register.

Research in the Washington area was supplemented by work at some repositories elsewhere in the United States. The Library of the Naval Construction Battalion Engineering Center, Port Hueneme, California, contained the papers of Ben Moreell, head of the Bureau of Yards and Docks during World War II. The U.S. Air Force Historical Research Center, Maxwell Air Force Base, Alabama, contained collections on specific installations and War College papers. At the Armament, Munitions, and Chemical Command

(AMCCOM) Historical Office, Rock Island Arsenal, Illinois, historians examined the collection of documents on microfiche and special studies on AMCCOM installations, which include most of the Army's World War II-era industrial facilities that remain under DoD control.

Field Survey

Field visits to seven DoD installations with large inventories of World War II permanent construction provided additional information for the historic context. Four criteria were used to select the installations: (1) concentration of World War II facilities; (2) high level of integrity from the World War II period; (3) ability to illustrate a representative type of World War II facility; and, (4) geographic distribution. Installations visited included two former Navy ammunition depots (Crane and McAlester), one ammunition loading plant (Ravenna), one smokeless powder works (Indiana), one small arms ammunition plant (Twin Cities), one Navy research and development center, (China Lake), and one Air Force research and development center (Wright-Patterson AFB). These installations illustrated some of the most important categories of military permanent construction. At each installation, R. Christopher Goodwin & Associates, Inc., examined historic records and surveyed representative building types. In addition, the Baltimore District of the U.S. Army Corps of Engineers released information on Fort George G. Meade and Naval Station Anacostia for inclusion in this study. The results of these investigations were incorporated into the historic context, evaluation methodology, and case studies.

Data Synthesis and Analysis

This project required an analysis of the broad trends and patterns of the U.S. military permanent construction program from 1940 to 1945. The reasons for permanent construction and the role that these buildings and structures played in World War II were examined. Permanent construction was selected for buildings used in military operations, training, logistical support, research and development, and industrial production. The various World War II domestic installations all contributed to the Allied victory; construction undertaken to support the war effort was part of a vast system of interdependent installations. The surviving examples of permanent construction are best understood in comparison to similar facilities and their role in the war effort. Thus, the historic context is organized according to the various functions of the installations. While recognizing the differences between the services, this analysis emphasizes the common trends that reflected the role of the armed forces in marshalling the resources required by a global conflict.

Three primary functional categories of military construction were identified: command construction, industrial construction, and construction for special projects. Command construction includes facilities that operated in direct support of military forces. Industrial construction includes facilities that produced explosives, ammunition, weaponry, and associated implements of war; industrial construction was particularly noteworthy because the War and Navy Departments established a munitions industry during the war, using primarily permanent construction. The third category, construction on behalf of special projects, includes the Pentagon and the Manhattan Project; this study provides only a brief summary of these two important projects, which are the subject of several in-depth studies.

The archival research also was analyzed to identify specific themes especially relevant to World War II permanent construction: military, technology, social history, and architecture. The military theme is incorporated into the discussion of the overall military construction program and in the three primary categories of permanent construction. The technology theme is developed through separate analyses that describe the major technological processes housed in the World War II industrial facilities. The basic steps of the process, the design requirements of the technology, and the properties associated with the technology were identified. Industrial production facilities were designed as integrated systems; to evaluate the structures associated with industrial facilities, the processes contained within the buildings must be understood.

The theme of social history was developed in conjunction with the analysis of industrial facilities. The rapid development of enormous production facilities had a tremendous influence on the lives of those who remained on the home front. Two major topics within the theme of social history were identified during archival research: changes in the composition of the labor force, and the "boom town" effects on local economies. To illustrate this theme, examples of major shifts in employment patterns and of the effects of World War II factory construction on a few communities were selected. These examples, by no means exhaustive, provide a basis for further research and analysis of the social history relevant to specific facilities.

The theme of architecture was developed through an analysis of the development of the factory as a twentieth century building type and of the development of modern architecture as a twentieth-century building expression. Examples of World War II production works were examined within the framework of the development of modern factory design.

Project Background

The World War II Permanent Construction Historic Context is a demonstration project of DoD Legacy Cultural Resource Program. The Legacy Program was created by the Department of Defense Appropriations Act, 1991 (P.L. 101-511). The purpose of the Legacy Program is:

To better integrate the conservation of irreplaceable biological, cultural, and geophysical resources within the dynamic requirements of military missions. To achieve this goal, the Department of Defense will give high priority to inventorying, conserving, and restoring biological, cultural, and geophysical resources in a comprehensive, cost-effective manner in partnership with federal, state, and local agencies and private groups.

The lessons and data derived from demonstration projects are designed to be incorporated into the DoD cultural resource management program, and then applied to the on-going mission of cultural resource stewardship.

R. Christopher Goodwin & Associates, Inc., completed this project on behalf of the Department of Defense, through the U.S. Army Corps of Engineers, Baltimore District (DACAW31-89-D-0059). This project encompassed research at regional military archival repositories, field visits to selected installations with representative examples of World War II permanent construction, and analysis. The final report is a combined version of two draft reports, Historic Context for Department of Defense Facilities World War II Permanent Construction (D.O. 21) and Methodology for World War II Permanent Construction (D.O. 25).

The project research design was developed in consultation with the U.S. Army Corps of Engineers, Baltimore District, and the DoD Legacy Program. The World War II Permanent Construction Historic Context project was designed to fulfill the Legacy Program legislative objectives and to assist DoD in meeting its responsibilities under the National Historic Preservation Act of 1966, as amended.

Report Organization

Chapter I describes the purpose, organization, and background of the report. Chapter II summarizes the framework of the historic context developed for World War II permanent construction. Part I provides the historic background for the development of World War II permanent facilities. Part II presents a methodology for identifying and evaluating World War II permanent construction and case studies. Appendix I includes a time-line of events related to World War II. Appendix II contains lists of the number of buildings currently classified as permanent or semi-permanent construction, built between 1939 - 1946, at DoD installations. Programmatic Agreements relevant to World War II historic properties under DoD jurisdiction are included in Appendix III. Appendix IV contains a list of military properties documented as associated with World War II and listed in the National Register of Historic Places between 1993 and April 1997. Appendix V includes the resumes of key project personnel.

NOTES

1. Diane Shaw Wasch, Perry Bush, Keith Landreth, and James Glass, World War II and the U.S. Army Mobilization Program: A History of 700 and 800 Series Cantonment Construction (Washington, D.C.: United States Department of the Interior, National Park Service, Cultural Resources, HABS/HAER, 1993) and John Garner, World War II Temporary Military Buildings: A Brief History of the Architecture and Planning of Cantonments and Training Stations in the United States (Champaign, Illinois: U.S. Army Corps of Engineers Construction Engineering Research Laboratory, 1993).

2. These figures are based on an analysis of the real property inventories of the service branches performed by the U.S. Army Construction Engineering Research Laboratory (Keith Landreth, personnel communication, October 22, 1992). These inventories are included in Appendix II of this report.

3. U.S. Department of the Interior, National Park Service, "Archeology and Historic Preservation: Secretary of the Interior's Standards and Guidelines," Federal Register 48, no. 190 (29 September 1983).

4. "Archeology and Historic Preservation: Secretary of the Interior's Standards and Guidelines," Federal Register, 44717.

5. Deborah Cannan, et al., "National Historic Context for Department of Defense Installations, 1790-1940" (MS, R. Christopher Goodwin & Associates Inc., 1995; Wasch et al., World War II and the U.S. Army Mobilization Program; Garner, World War II Temporary Military Buildings; Katherine Grandine, et al., "Support and Utility Structures and Facilities (1917-1946) Overview, Inventory, and Treatment Plan" (MS, prepared by R. Christopher Goodwin & Associates, Inc., 1995); Brooke V. Best, et al., "Navy Cold War Guided Missile Context" (MS, prepared by R. Christopher Goodwin & Associates, Inc., 1995).

6. U.S. Department of Defense, Office of the Assistant Secretary of Defense for the Environment, Legacy Resource Management Program, Report to Congress, September 1991, 3.

CHAPTER II

WORLD WAR II PERMANENT HISTORIC CONTEXT AND ASSOCIATED PROPERTY TYPES

Definition of the Historic Context

Historic contexts are organizational frameworks that assist in interpreting the broad patterns of history by grouping information related to shared time period, geographic area, and theme. The World War II Permanent Construction Historic Context provides an historical framework for assessing the relative significance of Department of Defense (DoD) facilities constructed as part of the domestic war effort between 1940 and 1945.

The three elements of a historic context are time period, geographic area, and theme(s). This historic context was defined as follows:

Time Period: 1940 - 1945

Geographic Area: United States

Theme: World War II Military Permanent and Semi-permanent Construction on the Home Front

The time period defined for this project includes the years 1940 - 1945. For the purposes of this study, World War II-era construction begins with Protective Mobilization in the summer of 1940 and ends with the capitulation of Japan in August 1945.

The geographic area for this project is the United States, including the contiguous 48 states, Alaska, and Hawaii. Construction in overseas territories or other countries is not included in the project.

The theme or subject matter included in this project is the military's World War II permanent and semi-permanent construction program. For ease of reference, the term "permanent construction" is used to encompass both permanent and semi-permanent construction in this report. The properties related to this theme represent several facets of history. The research design for this project focused on developing four topics within the historic context: (1) military - the home front military construction program's contribution to the war effort; (2) industry -the development of industrial technology; (3) social history - the effects of the permanent construction program on social groups and local communities; and (4) architecture - the development of modern industrial architecture represented by permanent World War II construction.

The United States expended billions of dollars to construct thousands of World War II facilities to train and arm its military forces. World War II was a war of resources and a race to mobilize rapidly the men and materiel needed to defeat the Axis nations. The domestic construction program associated with military mobilization constituted an unprecedented wave of building activity across the nation. No one facility won the war of resources; however, the cumulative effect of the entire mobilization effort was a decisive factor in the victory of the Allied forces.

Types of Construction: Permanent vs. Temporary

The military employed two general types of construction in the war effort: temporary and permanent. These general types of World War II construction may be further subdivided into four categories: (1) permanent; (2) semi-permanent; (3) temporary; and (4) theater-of-operations. Permanent construction was intended for use after the war; it typically was built of masonry (brick, tile, or concrete) and metal frame. Semi-permanent construction typically consisted of cinderblock construction, wooden-frame construction clad with synthetic siding, or a mixture of wooden frame and masonry. Semi-permanent construction often resulted from ad hoc compromises between the desire for permanent construction and shortages of time and material. Temporary construction consisted of wooden-frame buildings, typically built according to standardized plans, and of modular metal buildings. Temporary construction was not intended for use after the war. Theater-of-operations (T.O.) construction was the least durable type of construction; it typically consisted of wood lath on wall sheathing covered in felt. Few, if any, examples of T.O. construction survive. These different methods of construction are associated with distinct functions and periods during the war effort. For the purposes of evaluating historical significance and integrity, the type of construction is determined by the construction category at the time of construction.

In order to maximize on the scarce resources of time and material, the military built temporary construction wherever possible. Temporary buildings particularly were associated with housing and training during the early mobilization phase of the war. The military built training camps and stations across the nation characterized by row upon row of standardized wooden-frame barracks and supporting facilities. By the end of 1944, the Army could house six million troops, in contrast to the 270,000 soldiers housed in 1939. Separate studies, World War II Temporary Military Buildings: A Brief History of the Architecture and Planning of Cantonments and Training Stations (Garner 1993) and World War II and the U.S. Army Mobilization Program: A History of 700 and 800 Series Cantonment Construction (Wasch 1993), provide historic contexts for temporary construction.

The military did not maintain separate accounts of the costs for temporary and permanent construction. Table 1 presents the overall cost of the domestic construction program. No cost breakdowns differentiating between permanent and temporary construction have been located. However, ratios of permanent and temporary construction may be estimated by comparing the costs of installations dominated by permanent construction with the costs of installations dominated by temporary construction. Rough estimates of these percentages indicate that permanent construction comprised approximately one-third of Army domestic construction and possibly as much as two-thirds of Navy domestic construction during World War II.

Despite the preference for temporary buildings, some wartime construction required permanent facilities. The military used permanent construction materials and designs for selected buildings intended for post-war use. Aside from these miscellaneous buildings, certain types of activities typically could not be accommodated in temporary buildings and required permanent construction. Permanent construction was used for industrial facilities; research and development facilities that required specialized or sterile laboratory conditions; storage facilities for volatile or perishable supplies; coastal fortifications; and, medical facilities.

By far, industrial facilities comprise the bulk of World War II permanent construction. While World War II temporary construction is associated particularly with troop housing, the wartime permanent construction is emblematic of the effort to arm and equip the newly expanded military in the war of resources.

TABLE 1: COST OF WORLD WAR II ARMY AND NAVY DOMESTIC CONSTRUCTION

VALUE OF ARMY CONSTRUCTION IN THE CONTINENTAL U.S.(JULY 1, 1940 - AUGUST 31, 1945)(in billions of dollars)

INDUSTRIAL	
Aircraft assembly, ordnance, and other plants	$ 3.2
Installed equipment and machinery	1.8
COMMAND	
Air	3.2
Ground	2.8
Storage and shipping	1.0
Miscellaneous	0.5
SPECIAL PROJECTS	
Manhattan District	2.0
CIVIL	0.8
TOTAL	$15.3 billion

VALUE OF NAVY CONSTRUCTION AS OF SEPTEMBER 30, 1945

SHIPBUILDING AND REPAIR FACILITIES	$1,097,778,755
FLEET FACILITIES	225,966,784
AERONAUTICAL FACILITIES	1,601,383,121
ORDNANCE FACILITIES	774,469,784
STORAGE FACILITIES	486,782,403
STRUCTURES FOR NAVAL PERSONNEL	556,507,038
MARINE CORPS FACILITIES	183,423,863
RADIO FACILITIES	34,924,081
HOSPITAL FACILITIES	182,801,868
STRUCTURES NOT OTHERWISE CLASSIFIED	227,536,648
TOTAL	$5,371,574,345

Property Types Associated with World War II Permanent Construction

Property types are groupings of properties that share common physical or associative characteristics. Specific property types are associated with specific historic contexts. Property types link the theoretical construct of a historic context to real property. This study adopts a three-level hierarchy in the analysis of World War II permanent construction. The first level of this hierarchy is construction category (i.e., Command, Industrial, or Special Projects). The second level is installation type (i.e., shipyard, depot, training, etc.). The final level of this hierarchy is building and structure specific.

Construction and Installation Types

The most useful way to group properties associated with World War II permanent construction is by the function they served in support of the war effort. The first broad classification is the definition of construction category. During World War II, there were three construction categories: Command, Industrial, and Special Projects. Command construction included installations that directly supported training, operational and logistical activities. Industrial construction included installations operated to produce war materiel. Special Projects were defined by the War Department.

The second classification of property is the type of installation based on its purpose or military mission. World War II installations generally comprise interrelated individual buildings and structures built to accomplish the mission of the installation. This is particularly true of the industrial facilities built to produce, repair, assemble, and store war materiel. Grouping the properties into broad categories that correspond to installation missions provides the best method of understanding the relationship between the historic context and its associated real property. An analysis of World War II permanent construction identified the following types of installations, which are organized to correspond to their appropriate construction category:

Command Construction

- Air Fields and Air Stations
- Coastal Defense and Combat Operations
- Depots (Non Ordnance) and Embarkation Ports
- Medical Facilities
- Navy Bases and Stations
- Navy Yards
- Research, Development, and Testing
- Strategic Communications
- Training

Industrial Construction

- Aircraft Production
- Ammunition Depots
- Artillery/Artillery Parts Production Plants/Arsenals
- Chemical Warfare Service Facilities
- Explosive Production Works
- Large Ammunition Assembly Plants
- Small Arms Ammunition Plants
- Tank Arsenals

Special Projects

- Manhattan Engineering District (Manhattan Project)
- Pentagon

Some installations can be categorized as both command or industrial construction. To simplify discussions for the purposes of this report, each installation was categorized as one type. Shipyards, for example, although designed to build and repair ships, were classified as command construction due to their role in supporting the fleet. Ammunition depots, whether they included production facilities or only storage facilities, were classified as industrial construction because of their close relationship to the other types of industrial installations.

Buildings and Structures

Each installation encompasses buildings and stuctures necessary to support its mission. The buildings and structures can be classified according to their use:

- Administration: Properties related to administration. Examples include the administration building, guard house, gate house or sentry box, fire station, and post office. Most installations had one or more buildings that housed the installation's administrative functions. Installations that served as regional or command headquarters also included buildings that housed the headquarters offices.

- Communication: Properties that house communication technology or perform communication functions. Examples include radio towers, radio houses, and telephone exchanges. All installations possessed communications facilities necessary to allow internal and external communication. Installations with the primary mission of communication operated facilities that were part of national or global strategic communications system.
- Defense: Properties related directly to combat operations or coastal defense. Examples include batteries, coastal fortifications, and airfields located in theatres of operation (i.e., Alaska and Hawaii) or coastal defenses.
- Education: Properties associated with the training and education of military personnel. Examples include classrooms and specialized training facilities. The vast majority of World War II training facilities, whether for the Navy, Army, or Army Air Forces, were constructed using temporary mobilization construction. A few specialized facilities and facilities intended for post-war use were built using permanent construction.
- Health Care: Properties associated with the medical care of military personnel and civilian workers. Examples include dispensaries, which were located on most installations, and complexes of hospitals, isolation wards, and nurses quarters located at regional medical facilities. The dispensaries at training camps and cantonments typically were built using temporary construction plans; general hospitals that served military personnel in wider regions were more likely to receive permanent construction.
- Industrial: Properties associated with the assembly, production, or repair of war materiel. Examples at shipyards include dry docks, shop buildings, and cranes. Examples at arsenals and ordnance works and plants include manufacturing facilities or assembly lines. Other types of industrial properties include aircraft production or assembly facilities and maintenance and repair shops for routine maintenance of installation equipment.
- Infrastructure: Properties associated with providing power, water, and waste disposal to installations. Examples include heating plants, electric substations, power houses, water towers, water treatment plants, sewage plants, and sewage pumping stations. Power sources were essential in the operation of industrial facilities.
- Personnel Support: Properties associated with the daily living requirements of personnel and workers. Examples include mess halls for military personnel, cafeterias for civilian workers, and recreation buildings. Industrial facilities include specialized personnel facilities such as change/shower houses and clock houses. Most personnel support facilities at command installations were housed in temporary buildings. During the mobilization phase of 1940, some personnel support facilities at command installations utilized permanent construction designs; these facilities typically were designed for post-war use. Naval operating bases, depots, Army airfields, and Navy air stations, which were installations that served the military's newly recognized aviation and logistics functions, tended to receive more funds for permanent construction for personnel support facilities than mobilization installations. The personnel support buildings at industrial installations typically were similar in design and construction materials to the other installation buildings.
- Research, Development, and Testing: Properties associated with research, testing, and development of military technology. Examples include laboratories, wind tunnels, test ranges, and specialized test facilities.
- Residential: Properties associated with housing military and civilian personnel at installations. Examples include barracks, bachelor officers quarters, single family detached houses, and multi-family housing. The majority of barracks were built using temporary construction; however, some barracks built during the mobilization period were constructed of permanent materials.
- Storage: Properties associated with the storage of military materiel. Examples include warehouses, ammunition magazines, igloos, and a wide array of various types of storage buildings. All installations included some storage facilities, which supported the installations' primary activities. Installations that served as regional centers of logistical support and storage, such as supply depots

and ammunition depots, include large numbers of storage facilities.

- Transportation: Properties associated with the transport of military personnel and materiel, including air, rail, and water. Examples include hangars, runways, piers, rail lines, loading platforms, and roads. Often properties related to transportation and storage are interrelated, as the government developed new and utilized existing transportation networks systems for moving stored materiel.

Tables 2, 2a, 3, 3a, 4, and 4a list specific buildings and structures likely to be found on various types of installations, and also indicate which properties were critical to the installation mission. Some categories of properties were essential to and inextricably linked with the mission of an installation, while others are incidental supporting structures. Identifying the purpose of the installation and understanding how the surviving properties contributed to that purpose are essential in determining which properties represent the historic context. Part II of this report presents a methodology for identifying and evaluating properties within the World War II Permanent Construction Historic Context.

TABLE 2: COMMAND CONSTRUCTION INSTALLATION TYPES AND COMPONENT PROPERTY CATEGORIES

	PROPERTY CATEGORIES			
INSTALLATION TYPES	ADMINISTRATION	COMMUNICATION	DEFENSE	EDUCATI
Airfields/ Air Stations	administration building, fire station, gate, guard house operations building	control tower, radio house	n/a	academic building, celestial navigation training building, hangars, parachute training facility
Coastal Defenses/ Combat Operations	command post station, fire control station	radar station, switchboard building	anti-submarine net, bunkers, coastal searchlight shelters, gun emplacements, harbor entrance control post, personnel shelters, runways	n/a

Depots (non-ordnance) and Ports of Embarkation	administration building, fire station, gate, guard house	radio house	n/a	n/a
Medical Facilities	administration building, fire station, gate, guard house, post office	n/a	n/a	corpsmen training school
Navy Bases/Stations	administration building, fire station, gate, guard house	radio station, telephone exchange	n/a	n/a
Navy Yards	administration building, fire station, gate, guard house	radio control building	n/a	shop buildi

Research, Development, and Testing	administration building, fire station, gate, guard house	radio house	n/a	classroom buildings
Strategic Communications	administration building	antenna, helix house, operations building	n/a	n/a
Training	administration building, operations building	radio house	n/a	classroom buildings, hall, range operational training facilities an training devices, training towers

TABLE 2a: COMMAND CONSTRUCTION INSTALLATION TYPES AND COMPONENT PROPERTY CATEGORIES (CONTINUED)

	PROPERTY CATEGORIES				
INSTALLATION TYPES	Infrastructure	Personnel Support	Research, Development, and Testing	Residential	Storage
Airfields/ Air Stations	electric substations, sewage pumping station, sewage disposal facility, steam plant, water pumping station, water storage	chapel, enlisted mens lounge, mess hall, officers club, post exchange, post office, PX gas station, recreation building, Red Cross building, swimming pool and bath house, theatre	n/a	bachelor officer quarters, barracks, NCO quarters, officers family quarters, garages	aviation supply, flammable materials (paint, oil, dope) stora fuel storag general storage, ordnance storage

Coastal Defenses	power plant	mess hall	n/a	barracks, officers quarters	magazines, ration storehouse
Depots (non-ordnance) and Ports	electric substations, heating plant, sewage disposal facility, water distribution and storage	mess hall/cafeteria	n/a	barracks, civilian housing, officers quarters	cold storag fuel storag general sup warehouse storehouse heavy materials warehouse open stora yards, trans sheds
Medical Facilities	electric substations, incinerator, laundry, power house, steam plant, water storage	chapel, libraries, Med. Det. recreation, mess halls, officers and nurses recreation, patient recreation and welfare building, post exchange, Red Cross building, theatre	n/a	corpsmens barracks, guest house, nurses quarters, officers quarters	medical storehouse, storehouse
Navy Bases/Stations	electric substations, incinerator, sewage treatment plant, steam plant, water storage	chapel, enlisted personnel club, gymnasium, exchange, mess, officers club mess, post office, recreation building, theatre	n/a	bachelor officers quarters, barracks, receiving barracks, family housing	general storage, warehouse community storage, specialized storage, ordnance storage

Navy Yards	boiler house, electric substations, incinerator, power house, transformer stations, water storage	cafeteria, latrine, laundry, officers mess, post office, recreation building, time clock station, civilian support buildings	n/a	barracks, officers family quarters, bachelor officer quarters	coal storag yards, fuel storage tan general storehouse industrial storehouse ordnance storage, he materials storage, general storage warehouse
Research, Development, and Testing	electric substations, power house, steam plant, sewage treatment, water storage	cafeteria, civilian support buildings	laboratories, wind tunnels, firing ranges, test track, observation towers, airfield, test sites	bachelor officer quarters, barracks, single family housing	flammable material storage, general storage, ordnance storage, specialized storage as needed
Strategic Communications	electric substations, power house/stand-by generator	cafeteria, mess, recreation facilities	laboratories, radar test buildings	barracks, officers quarters	general storage, op storage

Training	electric substations, sewage pumping station, sewage disposal facility, steam plant, water pumping station, water storage	chapel, bakery, enlisted mens lounge, laundry, mess hall, exchange, officers club, post office, PX gas station, recreation facilities, Red Cross building, swimming pool and bath house, theatre	n/a	bachelor officer quarters, barracks, NCO quarters, officers family quarters	fuel storag commision storage, general storage, ordnance storage

TABLE 3. INDUSTRIAL CONSTRUCTION INSTALLATION TYPES AND COMPONENT PROPERTY CATEGORIES

	PROPERTY CATEGORIES			
INSTALLATION TYPES	Administration	Health Care	Industrial	Infrastructure
Aircraft Production	administration building, guard house and gate	flight hospital	assembly plant (large single structure), sub-assembly areas, production buildings	boiler house/power house, electric substations, water storage facilities, water wells
Ammunition Depots	administration building, fire station, guard house and gate	dispensary	maintenance and repair shops, cranes	boiler house/power house, electric substations, sewage treatment plant or pumping station, water treatment plant

Artillery/Artillery Parts Production Plants/Arsenals	administration building, fire station, guard house and gate, sentry boxes	dispensary	assembly buildings, factories, forge shop, machine shop	boiler house/power house, electric substations, water pumping station
Chemical Warfare Service Facilities	administration building, fire station, guard house and gate	dispensary	assembly and loading plants, manufacturing plants, pilot plants	electric substations, power house, sewage pumping station, water treatment plant
Explosive Production Works	administration building, fire station, guard house and gate, radio house	dispensary	acid concentration plants, ammonium oxidation plants, machine maintenance shops, propellant manufacturing lines (dehydrating press house, ether mix house, mixer house, horizontal screening and press house, solvent recovery house, controlled circulation dryer house, blending tower)	electric substations, power plant, sewage pumping station, water treatment plant, water wells, water pumping houses
Large Ammunition Assembly Plants	administration building, fire station, guard house and gate, radio house	dispensary	bag-loading plants, bag sewing buildings, bomb- and mine-filling plants, booster loading buildings, ignition filling houses, loading plants (large caliber, medium caliber), mine assembly plants, rocket motor loading buildings, ammonium nitrate manufacturing buildings	boiler house/power house, electric substations, sewage pumping station, water treatment plant

Small Arms Ammunition Plants	administration building, fire station, guard house and gate, radio house, sentry boxes	hospital	.30 and .50 caliber shops, ballistics building, lead shop, powder canning house, primer chemical distribution house, primer dry houses, primer manufacturing building, primer mixing building, proof houses, salvage building, tool and gauge shop, tracer chemical distribution house, tracer composition manufacturing building	boiler house/power house, electric substations, sewage pumping stations, water treatment plant, well houses
Tank Arsenal	administration building, personnel building, sentry building, telephone exchange	n/a	paint shop, tank assembly plant (single large structure with receiving, manufacturing, and assembly areas), tank repair shop	electric substations, power house, pump house, sewage treatment plant, water storage

TABLE 3a. INDUSTRIAL CONSTRUCTION INSTALLATION TYPES AND COMPONENT PROPERTY CATEGORIES (CONTINUED)

PROPERTY CATEGORIES					
INSTALLATION TYPES	Personnel Support	Research, Development, and Testing	Residential	Storage	Transpo
Aircraft Production	cafeteria, commissary	test facilities	barracks, single family detached houses	warehouses	loading platform lines, ro runways

Ammunition Depots	change house	n/a	barracks, single family detached houses	high explosives magazines (igloos), inert storehouses, magazines (high-explosive, projectile, smokeless powder), torpedo storehouses	loading platform piers, ra lines, ro
Artillery/Artillery Parts Production Plant	n/a	n/a	N/A	storehouses for parts, storehouses for finished production	loading platform lines, ro
Chemical Warfare Service Facilities	change/shower house, mess hall	laboratories, test facilities, observation bunkers	bachelor officer quarters, barracks, single family detached houses	high explosives magazines (igloos), storehouses, above ground magazines	loading platform lines, ro
Explosive Production Works	cafeteria, canteen, change house, clock house, search house	n/a	single family detached houses	magazines, storehouses	loading platform lines, ro
Large Ammunition Assembly Plants	cafeteria, change/shower house, clock house	n/a	barracks, single family detached houses	magazines, storehouses	loading platform lines, ro
Small Arms Ammunition Plants	cafeteria, commissary kitchen	target houses, tool and gauge laboratories	single family detached houses	magazines, storehouses	loading platform lines, ro
Tank Arsenal	commissary kitchen	test track	n/a	storehouses	loading platform lines, ro

Boldface denotes properties essential to the mission of the installation type.

Other properties supported the primary installation mission.

TABLE 4. SPECIAL PROJECTS AND COMPONENT PROPERTY CATEGORIES

PROPERTY CATEGORIES					
INSTALLATION TYPES	Administration	Communication	Health Care	Industrial	Infrastru
Manhattan Engineering District	administration building, fire house, gate house, guard house, offices, police station	post office, telephone exchange	dispensary, hospital	specialized assembly plant, sub-assembly areas, specialized production facilities, electromagnet separation plant, gaseous diffusion plant, plutonium production plant, specialized manufacturing plant, heavy water plant	boiler house/po house, electric substatio sewage treatment plant, wa treatment plant, se pumping stations
Pentagon	administration building	n/a	n/a	n/a	n/a

Boldface denotes properties essential to the mission of the installation type. Other properties supported the primary installation mission.

TABLE 4a. SPECIAL PROJECTS AND COMPONENT PROPERTY CATEGORIES

PROPERTY CATEGORIES					
INSTALLATION TYPES	Personnel Support	Research, Development, and Testing	Residential	Storage	Transportatio
Manhattan Engineering District	cafeteria commissary, theater, commercial areas	laboratories, test sites, workshops	civilian housing, barracks, single family detached houses, family housing, apartments, dormitories	warehouses, specialized storage buildings	vehicle fuelin station, loading platforms, rail lines, roads
Pentagon	n/a	n/a	n/a	n/a	n/a

Boldface denotes properties essential to the mission of the installation type. Other properties supported the primary installation mission.

PART I

HISTORICAL OVERVIEW AND THEME STUDIES

CHAPTER III

BACKGROUND OF THE MILITARY WORLD WAR II PERMANENT CONSTRUCTION PROGRAM

The U.S. Military after World War I

Following World War I, the United States hoped to avoid future world-wide conflicts and public opinion shifted in favor of isolationism. President Woodrow Wilson sought to prevent future conflicts by creating an international organization known as the League of Nations. But the Senate rejected the treaty, largely because of a fear of foreign entanglements. The United States did participate in the Washington and London Naval Disarmament Conferences of the 1920s and early 1930s, at which time limits were placed on ship construction. In 1928, the United States made another gesture towards world peace by signing the Kellogg-Briand Pact, which renounced war as an instrument of national policy.

With the expectation of an enduring peace, interest in the nation's military establishment declined. New weapons, such as tanks, were not developed to their full capabilities. The Army Air Corps profited from the growth and technological developments of civilian aviation; but the Air Corps remained tied to the ground forces. The Navy and Marine Corps grew irregularly during these years. The Navy did incorporate new types of ships, such as aircraft carriers and submarines, into its inventory. Yet the disarmament conferences of the 1920s and 1930s discouraged ship construction. Another factor limiting military expenditures was the severe economic constraints of the Great Depression, when the United States lacked the funds to invest in military build-up.

Hopes for a permanent peace proved illusory. Benito Mussolini established a fascist dictatorship over Italy in 1922. Germany's Nazi Party, under Adolf Hitler, seized control of Germany in 1933. Japan fell under the control of militarists who wished to expand into China. As the decade progressed, Germany, Italy, and Japan coalesced into an understanding known as the Axis Powers.

As Americans observed the growing instability in Europe and Asia, the nation was divided between a desire to remain out of foreign conflicts and the recognition of the importance of military preparedness. Advocates of neutrality found a congressional champion in Senator Russell Nye, who conducted a well publicized series of hearings on the munitions industry in World War I. He charged that these so-called "merchants of death" had encouraged American involvement in European affairs in anticipation of increased profits. Between 1935 and 1937, Congress passed three neutrality acts intended to avoid future foreign wars.

Nevertheless, the dangers for Nazi or Japanese expansion were sufficient to stimulate a modest increase in military and naval appropriations. Beginning in 1935, the strength of the armed forces increased steadily. The Army General Staff developed emergency mobilization plans. In 1938, Congress authorized "educational orders," which were small scale contracts designed to familiarize potential contractors with the requirements of manufacturing for the military.

Navy and Marine Corps officers generally recognized that Japan presented the most serious naval threat, and developed their plans accordingly. The Navy began shifting its forces to the Pacific bases of San Diego, Puget Sound, and Pearl Harbor. As the London and Washington Treaties expired in 1936, Congress authorized increased tonnages for the Navy, most notably in the Second Vinson Act of 1938. Marine Corps leaders recognized that any war in the Pacific would require seizure of island bases, and developed the amphibious assault techniques that they would use so effectively in the Pacific.

The Beginnings of War

Germany's Adolf Hitler proved to be a particularly dangerous menace to world peace. After the Nazi party gained control of Germany in 1933, Hitler initiated a German re-armament program. He then systematically began annexing neighboring countries, beginning with Austria in 1938. Germany continued its expansion unchecked until the invasion of Poland caused Britain and France to declare war on Germany in September 1939.

The German Army soon demonstrated that this time the war would be characterized by rapid movement. Using a combination of infantry, armor, and aircraft, the Germans overran Poland in one month, using "blitzkrieg" tactics. The British sent an expeditionary force to France, which first deployed on the French-Belgian border, then moved to Dyle River in central Belgium. In May 1940, the Nazi Army bypassed the fortifications, forcing the British and French to fall back in confusion. The British narrowly averted a complete disaster by evacuating their forces through the French port of Dunkirk. With the defeat of France almost assured, Italy declared war on France on June 10. France surrendered to Germany on June 22.

A complete German victory seemed imminent. Only Great Britain and her empire presented a credible barrier to Nazi conquests. German plans for a rapid invasion of Britain failed after the Royal Air Force denied the Germans air superiority in the Battle of Britain. Later that year, the Axis tried to defeat Britain by capturing the Suez Canal, which would have separated Britain from its Persian Gulf oil supplies and its Indian empire. The German action opened fighting in North Africa that continued through 1943. In the Atlantic, German submarines attempted to destroy British shipping, but never quite succeeded.

The prospects for an Axis victory led the United States to take its first tentative steps toward direct involvement in the war. In September 1940, President Franklin Roosevelt approved the transfer of 50 destroyers to Britain, in return for a lease on British bases in the Caribbean. That September, the United States initiated a peacetime Selective Service and a partial mobilization of the National Guard. In December 1940, Roosevelt announced the United States would provide military supplies to Britain under a policy termed "lend-lease." The President justified his actions by declaring that the United States must become the "arsenal of democracy." In the summer of 1941, Roosevelt ordered the Navy to escort merchant convoys as far as Iceland. This order resulted in an undeclared war between American destroyers and German submarines, and led to the sinking of the destroyer Reuben James by the Germans on 31 October 1941.

In the summer of 1941, Hitler made one of the greatest blunders of the war by invading the Soviet Union. Although initially successful, the German campaign could not overcome the vast distances of the Soviet Union, the harsh winter, or the fierce resistance they met. The exceptionally brutal fighting on the eastern front destroyed a large portion of the German Army. Following the German invasion, the United States included the Soviet Union in its lend-lease program.

The United States, in addition to the war in Europe, had to contend with the military expansion of Japan in the Pacific region. Japan rapidly emerged as a leading Asian power, following its opening to Western influences in the middle of the nineteenth century. It became a serious threat to Asian stability when a clique of aggressively militaristic officers and politicians gained control of the government during the 1930s. Japan invaded China, resulting in a full scale war by 1937. The Japanese war with China continued longer than the Japanese had expected, as Japan became mired in the vastness of China. The Japanese continued their expansion, and entered French Indochina in 1941.

Reasoning that their expansion made war with the United States inevitable, the Japanese decided to initiate hostilities with a decisive offensive action. On 7 December 1941, they launched an attack upon the United States fleet anchored in Pearl Harbor, sinking four battleships, badly damaging four others, and destroying over 200 aircraft.

The Japanese attack upon Pearl Harbor triggered direct American involvement in the war. Immediately after the attack, the United States declared war upon Japan. Three days later, Germany and Italy declared war upon the United States and Congress reciprocated. With American entry into the war, the coalition against the Axis nations coalesced into the Allied powers. Led by the United States, Great Britain, and the Soviet Union, the alliance also included members of the British Commonwealth, China, and exiled governments of occupied nations. During the first year of American involvement in the war, the military lacked the trained personnel and other resources to exert a decisive influence.

Military Operations

Europe

As American combat strength increased through the early stages of the war, American and British forces launched their first offensive actions. In November 1942, the Allies landed in North Africa. By May 1943, the British and Americans had cleared the Germans from North Africa. Next, they began a campaign against Italy, which soon resulted in the surrender of the Italian government. Although German soldiers continued fighting in Italy for the remainder of the war, the Allied victory secured the British lifeline to Asia through the Mediterranean. At approximately the same time, the British and American Navies gained supremacy over German submarines in the Atlantic.

By the spring of 1944, the Allies were strong enough to challenge the Germans in northern Europe. On 6 June 1944, the Allies invaded France through Normandy, and by September they almost reached the German border. Inadequate supplies stalled the Allied offensive, which was delayed further by a German counter offensive that winter in the Ardennes forest. By the spring of 1945, American and British forces reached the German western border while the Soviets reached the German eastern border. Germany surrendered on 7 May 1945.

The scope of the American contribution to the war against Germany and Italy started modestly and grew to enormous proportions. At the beginning of the North African invasion, the United States could provide only one corps. By the close of the war, six numbered American armies operated in western Europe, although the Fifteenth Army was not organized until the end of the war. Americans provided 61 of 91 Allied divisions in the western Europe theater of operations, plus 7 of 18 divisions in Italy. Four of the six Allied tactical air commands were American. Even these figures do not represent the full American contribution to the Allied victory. The United States provided ammunition, equipment, and other essential military supplies to British and Russian forces.

Asia and the Pacific

Japan followed its attack on Pearl Harbor with a successful invasion of the Philippines. By mid 1942, the Japanese had established a defensive perimeter that extended as far as the Solomon Islands and New Guinea. In May and June 1942, the Americans stopped the Japanese offensive with their victories at Coral Sea and Midway. Nevertheless, the Japanese control over the islands of the western Pacific created a formidable barrier to any Allied attempts to reach Japan. The Americans were forced to fight island by island to gain control of the Pacific.

The American counter-offensive advanced along two axes. American forces under General Douglas MacArthur or Admiral William Halsey advanced along a southern route towards the Philippines. Meanwhile, other forces under Admirals Chester Nimitz and Raymond Spruance moved through Micronesia in the central Pacific towards the Mariana Islands. By the middle of 1945, the two axes converged at Okinawa, on Japan's doorstep. Next the Allies began preparations for a bloody invasion of Japan.

The development of the atomic bomb made the assault upon Japan unnecessary. The United States secretly had developed a new weapon that unleashed tremendous energy through a process of nuclear fission. Production of the first nuclear weapons had required extensive efforts within the United States, and the strictest security measures. By the summer of 1945, the new bomb had been tested successfully, and it was used against the Japanese cities of Hiroshima and Nagasaki. On August 15 the Japanese announced their surrender to the Allies.

Organization of the Military Establishment

During World War II, the military was organized into separate War and Navy Departments. This organization differed significantly from today's Department of Defense. These differences affected the roles of each defense agency, and their construction activities.

Army

On 9 March 1942, the War Department adopted an organizational structure that remained essentially unchanged for the duration of the war. The War Department General Staff developed overall policies for the Army, including its air component. Theater commanders, such as General Dwight Eisenhower or General Douglas MacArthur, exercised control over all Army elements within their respective commands. Within the continental United States, three major commands executed the policies established by the War Department headquarters. These commands were the Army Ground Forces, the Army Air Forces, and the Army Services Forces.

The Army Ground Forces commander, General Leslie McNair, was responsible for organizing and training ground combat units. These duties included operating training centers, developing combat doctrine, and commanding Army ground forces within the United States. Units or personnel became the responsibility of the theater commander outside of the continental United States.

The commander of the Army Air Forces, General Henry H. (Hap) Arnold, exercised similar authority with respect to the air component. Within the continental United States, the Army Air Forces trained pilots, air crews, plus ground support personnel. These personnel then were organized into units for further training prior to transfer overseas. Once outside of the continental United States, Army Air Forces units became part of their respective theater commands. Unlike the Army Ground Forces, however, the Army Air Forces assumed greater logistical responsibilities, including the design and procurement of aircraft, and Air Corps specific equipment, in addition to responsibility for installation management.

The expansion of the Army Air Forces, as the equal of the Army Ground Forces, reflects the growing importance and independence of the air component, which eventually resulted in the creation of an autonomous Air Force. Throughout World War II, however, the air component was an integral part of the War Department. Senior aviation officers served in key command and staff positions, including command of the Army component of joint commands. Army aviation drew upon the same logistical system that served the Army Ground Forces, especially from the Corps of Engineers, the Ordnance Department, and the Quartermaster Corps.

The Army Service Forces represented a significant change from the peacetime methods of providing logistical support within the War Department. Prior to World War II, Quartermaster, Ordnance, Engineer, Signal, Medical, and Chemical Warfare branches, which were known collectively as the "technical services," operated independently with each branch chief reporting directly to the War Department. To achieve a unified logistical effort, the Army combined the technical services into a single command, under the energetic, if acerbic, leadership of General Brehon Somervell. Originally termed the "Services of Supply," the organization was renamed the "Army Service Forces" to reflect its diverse responsibilities. In addition to the technical services, the Army Service Forces eventually encompassed the offices of the Adjutant General, the Judge Advocate General, and the Provost Marshal General. During the war, the Transportation Corps became a separate branch within the Service Forces. The official history of the Army Service Forces summarized the mission of the organization by noting that "all responsibilities which did not fit into the Ground or Air Forces were dumped into the Service Forces. The ASF thus became a catch-all command . . . . Some of the duties logically belong in it; others were put there because they could not logically be placed anywhere else."

The Army Service Forces was responsible for both supporting the ground and air forces within the United States and for providing materiel to forces overseas. The latter mission required an extensive effort, especially by the Ordnance Department. With its responsibility for weapons and ammunition, the Ordnance Department either contracted for purchases directly from private industry, or supervised production of weapons or ammunition at government facilities. The Department also stored munitions prior to overseas shipment. Other technical services, such as the Quartermaster or Signal Corps, also procured and stored military supplies, but these items did not require the special care required by weapons and explosives.

Military construction was an important and controversial portion of the mission of the Army Service Forces. Until 1940, the Quartermaster General was responsible for cantonment construction, while the Chief of Engineers was responsible for the construction of fortifications and waterway projects. This system worked well during peacetime, when the pace of construction was relatively slow, but the massive pace of wartime construction overwhelmed the Quartermaster General's office. The Corps of Engineers seemed better suited to manage all construction because of its district offices, which could provide less centralized control. In the spring of 1941, the Corps of Engineers assumed responsibility for air field construction. In November 1941, Congress enacted legislation transferring all Army construction to the Corps of Engineers; President Roosevelt signed the bill on 1 December.

Navy

The Navy Department consisted of both the United States Navy and the Marine Corps, along with the administrative and logistical infrastructure to support both services. The Navy was divided into the numbered fleets directly engaged in combat and the Navy establishment within the United States. The latter consisted of the Navy headquarters, its bureaus, shore bases, and other supporting forces. The Marine Corps was composed of a Fleet Marine Force and its supporting structure. In wartime, the Coast Guard became a part of the Navy Department, while retaining its separate identity. After the war, the Coast Guard reverted to the Treasury Department.

The Navy's shore establishment evolved from the nineteenth-century bureau system. The Chief of Naval Operations, Admiral Ernest King, directed a staff that provided overall direction to the service. Most routine support functions were performed by the respective bureaus, which included Naval Personnel, Ordnance, Ships, Yards and Docks, Medicine and Surgery, Supplies and Accounts, and Aeronautics.

The Bureau of Yards and Docks had primary responsibility for Navy construction. It also was responsible for the maintenance and administration of Navy shore installations that were not under the control of a special bureau. As a result, the Bureau of Yards and Docks built and administered most Navy yards and bases. The most notable exceptions consisted of ordnance or aviation installations. The Bureau of Yards and Docks designed and built these installations, but the Bureaus of Ordnance or Aeronautics assumed responsibility for maintenance.

The Bureau of Ordnance also played an important role in the expanded permanent construction program. This bureau was responsible for all tasks related to Navy ordnance. These responsibilities included the production of weapons and ammunition, the development of experimental weapons systems, and the improvement of existing systems. Real property related to these tasks included production facilities, ammunition depots, and experimental stations. Although the Marine Corps obtained the majority of its weapons through the Army Ordnance Department, the Navy Ordnance Bureau provided weapons that could not be obtained from the Army.

The Marine Corps' fighting forces was designated the "Fleet Marine Force" and consisted of units assigned to support naval operations. The Marine Corps fighting units were composed primarily of infantry, with some support and aviation units. Marine Corps contingents based within the United States supported the Fleet Marine Force by providing trained personnel and equipment. Marine Corps shore installations primarily fulfilled training and logistical functions. The Bureau of Yards and Docks was responsible for construction of Marine Corps installations.

CHAPTER IV

THE HOME FRONT AND MILITARY CONSTRUCTION

World War II on the American Home Front

World War II affected Americans on the home front in ways that varied from the selection of movies to rationing of consumer goods. A crucial element of the home front effort was the mobilization of resources in support of the fighting forces. The tremendous mobilization of resources made the Allied victory possible. Mobilization included the training of personnel, and the production of weapons, ammunition, and equipment. These activities required an extensive domestic construction program to build the facilities necessary to train and equip the Allied forces.

Mobilization of resources within the United States began in earnest after the fall of France in June 1940. Americans were no longer secure behind the combined forces of France and Britain. Britain's tenuous position forced Americans to consider the possibility that the United States would confront Germany without any allies. In the late summer of 1940, President Roosevelt implemented a partial mobilization program known as the Protective Mobilization Plan.

The most publicized aspects of the Protective Mobilization Plan included the activation of National Guard units, establishment of a peacetime Selective Service for the Army, and strengthening the Navy. The increase in size of both services resulted in the initiation of wartime construction programs, comprising primarily temporary construction. The War Department immediately needed training facilities and hurriedly constructed mobilization cantonments. For the most part, these camps consisted of temporary buildings, constructed according to the so-called "700 series" plans.

The protective mobilization phase spurred other activities within the Army. For the first time since World War I, the Army conducted large-scale field maneuvers. The most notable of these exercises, the "Louisiana Maneuvers," engaged the Third Army against the Second Army during the spring of 1941. These exercises provided invaluable training to senior officers in the management of large formations of soldiers and operational logistics.

A critically important result of the Protective Mobilization Plan, which affected permanent construction, was the beginning of industrial mobilization. The military of the late 1930s lacked the materiel readiness to fight a sustained war, especially using the blitzkrieg tactics of World War II. The requirements for supplying materiel to Britain and the Soviet Union further amplified the challenges of industrial production.

The lack of all types of ammunition was among the most critical shortfalls. Speaking in 1943, the Secretary of War, Henry Stimson, recalled that in 1940 the United States lacked even a one day's supply of smokeless powder, and supplies of other types of weapons and ammunition also were critically low. Even worse, the capacity for the production of munitions disappeared following the close of World War I. The few existing Army arsenals and the Navy Powder Factory at Indian Head, Maryland, had preserved a knowledge of the processes of ammunition production, but these facilities did not have the capability for mass production of explosives. During the protective mobilization phase, the Army created the foundations of a munitions industry.

Immediately after the fall of France, the Navy also initiated an expansion program. On 19 July 1940, less than a month after the French surrender, Congress authorized the acquisition of 13 battleships, 6 aircraft carriers, 32 cruisers, 39 submarines, and 101 destroyers. The carriers were of the Essex variety, which constituted the backbone of the Pacific fleet in the forthcoming war. The increased number of ships was accompanied by a comparable expansion of shore facilities. In the eighteen months before Pearl Harbor, the Bureau of Ships transferred over $250 million to the Bureau of Yards and Docks to prepare dry docks, maintenance shops, and other facilities for supporting an expanded fleet. Congress also recognized the need for expanded shore facilities and appropriated additional funds for improvement of shore installations.

The threatened war also propelled the Navy toward greater activity in both the Atlantic and Pacific Oceans. In the Atlantic, the Navy escorted convoys of both British and American merchant ships as far as Iceland. In the Pacific, President Roosevelt ordered the fleet to Hawaii in May 1940 as a deterrent to Japanese expansion. The fleet based in Hawaii proved to be vulnerable to a surprise carrier strike, which the Japanese executed on 7 December 1941. The attack upon Pearl Harbor thus ended the Protective Mobilization phase of United States involvement in World War II.

An official Army history of economic mobilization during World War II summarized the importance of mobilization before Pearl Harbor:

Historians of America's total military and logistic effort in World War II may well agree that the eighteen months of preparations before Pearl Harbor played a crucial, if not decisive, part in the outcome of the war. During this period the Military establishment of the United States was rehabilitated and the foundation laid for America's tremendous war production achievement. The greatest barrier to military preparedness at the time of the crisis of 1940 was the lack of capital facilities, and these required from several months to two years or even longer to create. To have delayed the construction of such facilities until the United States was actually involved in battle might have lost the war before it began.

After the Japanese attack upon Pearl Harbor, American energies were concentrated on the defeat of the Axis powers. Though the conversion to wartime production in 1940 and 1941 provided a transition to declared war, even greater efforts were required after the United States entered the war. The industrial mobilization process begun during the protective mobilization phase intensified until the United States could overwhelm the Axis powers with its material resources.

More so than in previous wars, the outcome of World War II depended upon marshalling resources. These resources included trained personnel, weapons, ammunition, food, military clothing, transportation facilities, money, and all the other items needed to sustain the fighting forces. In order to provide the materiel required, the United States government needed to allocate raw materials, especially steel, rubber, petroleum, or cotton. The distribution of raw materials required the establishment of priorities within the military, and provisions for essential civilian needs. The war within the United States was characterized by managed scarcities.

Rather than rely upon the market forces to allocate resources, President Roosevelt formulated new government agencies or restructured existing agencies to control essential elements of the economy. As the war in Europe began, Roosevelt created the National Defense Advisory Council, which was soon followed by the Office of Production Management. The Office of Production Management tried to establish a system of priorities to allocate scarce materials until it was superseded by the Supply, Priorities, and Allocations Board (SPAB). In January 1942, Roosevelt created the last of the wartime administrative offices, the War Production Board, chaired by Donald M. Nelson. Like its predecessors, it attempted to divert scarce materials to defense industries by creating priority systems. With the priority systems, critical materials, such as structural steel, could only go to War or Navy Department projects that were certified as necessary to national defense, and using the minimum amount of resources.

Despite the shortages of raw materials, American industry soon began the transition to wartime production. Automobile factories converted their production lines to military vehicles, and other factories made similar conversions. Where existing facilities were unsuited for munitions production, new factories or shipyards were constructed to meet the production requirements. As the war progressed, the logistical advantages of the United States provided a crucial edge to the Allies. As the Axis powers gradually lost their war production capabilities to Allied bombing, the Allies increased their capabilities until the final defeat of Germany and Japan.

Military Construction and Wartime Logistics

Because the outcome of this war depended so much upon the proper management of resources, military construction received considerable attention. New military facilities universally were recognized as necessary for training, equipping, and maintaining the rapidly expanding forces. Other construction was necessary to create a munitions industry. Yet because all construction also consumed vital resources, even military construction required the strictest economy measures. The story of military construction, therefore, became a balance between the requirements for facilities and the conservation of scarce resources.

To balance these conflicting requirements, the services used temporary construction wherever feasible. Temporary construction conserved three of the most precious resources of the war: time, money, and building materials. These shortages became increasingly acute through the summer of 1942, with corresponding pressures to use temporary construction.

Temporary construction was most evident in the training camps that the military rapidly constructed throughout the nation. The training camps and stations consisted of wooden frame buildings with few amenities. Barracks often contained exposed 2 x 4 in framing, or ceiling trusses. Structures might be mounted on cinder blocks for support or placed upon a simple concrete floor. Within the War Department, these buildings were called the 700 or 800 series of buildings, because they followed standardized plans numbered from 700 to 799 or 800 to 899. The 700 series plans were drafted by the Quartermaster Corps before the war, while the 800 series reflected minor improvements to the basic design. Within the Navy Department, the Bureau of Yards and Docks constructed standardized wooden frame temporary barracks of 2 x 4 in stud walls clad with either wood siding or asbestos-cement shingles. Temporary construction was designed to last at least five years. For even more short-term construction needs, the military employed theater-of-war construction, which consisted of flimsy wood frame covered with tar paper.

Though temporary construction was preferred, the military could not avoid more substantial construction for some essential purposes. The most numerous examples of permanent construction were industrial facilities, such as ammunition factories or shipyards, where structural requirements precluded temporary construction. Several other types of specialized facilities required permanent construction. Research and development work might require a "clean" environment or special structures unsuitable for temporary construction. Some storage facilities, particularly those for ammunition or perishable subsistence, required permanent buildings. Coastal fortifications and medical facilities might also employ permanent construction. Anticipated use after the war might justify permanent construction during the earliest and the latest stages of the war, when materials shortages were least serious.

War Department construction, both temporary and permanent, was concentrated during the first years of the war. Following the fall of France in 1940, construction programs accelerated under the Protective Mobilization Plan, and reached a spending peak of over $200 million per month in the summer of 1941.

These figures seemed enormous by previous standards, but America's entry into the war soon caused construction to exceed all previous expectations. In July 1942, spending for construction within the United States reached a peak of about $750 million per month, and declined sharply thereafter. By December 1942, 85 per cent of all War Department World War II construction was complete. Within another year, that figure reached 98 per cent.

The problems of building material shortages plagued the military construction program throughout the years of the war, worsening as the pace of building increased. Shortages during the protective mobilization period were serious, but not insurmountable. Following America's entry into the war, shortages suddenly became the greatest obstacle to timely completion of the needed construction. Not only did the services multiply their construction efforts, but so did civilian defense industries. Civilian defense workers also required housing as they moved to new job locations. Although all materials were in critical supply, steel was of particular concern because it was essential for ships and for shell casings.

Materials shortages were most critical in the middle of 1942, at the same time that construction was reaching its peak. On 20 May 1942, the War Production Board adopted a directive intended to establish tighter priorities for construction. Even defense related construction would receive approval only if:

(1) it was essential for the war effort; (2) postponement of construction would be detrimental to the war effort; (3) it was not practical to rent or convert existing facilities; (4) the construction would not result in the duplication or unnecessary expansion of existing plants or facilities then under construction or about to be constructed; (5) all possible economies had been made in the project in order to delete all nonessential items or parts; and (6) the design for the structure was of the simplest type. All construction should be of the cheapest, temporary character and should use materials which were most plentiful.

In practice, this directive allowed military construction to continue, but limited such construction to the most austere designs feasible. After military construction had passed its peak in the fall of 1942, critical materials shortages became less of a problem. While the need to conserve materials, especially steel and copper, remained, shortages were less likely to delay construction.

With the materials shortages easing, field commanders attempted to initiate new military construction projects. Within the War Department, however, General Somervell opposed most new construction projects as unnecessary wastes of money. Rather than flatly refuse requests for new construction, he used bureaucratic delays to minimize the number of requests. At a service command conference, Somervell spoke quite bluntly to his subordinate commanders: "I have attempted to interpose all the red tape possible—and that is a lot." He went on to explain, "I cannot stand up before the country and before Congress and justify the expenditure of millions of dollars for construction work which is desirable but which does not have anything to do with winning the war; and so I have adopted . . . a policy of delay in the hope that eventually you will get tired of asking for new construction and quit."

Nevertheless, some new construction projects were inevitable during the last years of the war. With the success of medium artillery, especially the 155mm howitzer, the combat forces suddenly increased their demands for this caliber ammunition. Consequently, the War Department hurriedly constructed a new set of ammunition production facilities. With the prospect of a large number of seriously wounded service members returning home, more hospitals became necessary. The new B-29 "Superfortress" bomber required new landing fields and hangars. The still secret Manhattan Project required a substantial expenditure of resources, especially at Clinch River, Tennessee, and Hanford, Washington. Small construction projects and improvements to existing installations continued throughout the war.

The Navy Department experienced a similar change in its construction programs after the initial buildup.

Except for an amphibious training facility built in early 1944, new training installations were not required. Instead, Navy Department construction focused upon supporting committed Navy and Marine Corps units, especially in the Pacific. The Navy constructed additions to its depots on the Atlantic Coast and created a major annex to the Oakland Naval Supply Depot. Late in the war, the Bureau of Ordnance improved its ammunition handling facilities. Its later ordnance installations included a new ammunition and new depot at Seal Beach, and another ammunition magazine at Bangor, Washington. With the increasing numbers of Navy and Marine Corps casualties, hospital construction continued to the end of the war.

The Navy also added to its research and development facilities during the later war years. One of its most important new installations was the Naval Ordnance Test Station at Inyokern, California, better known as China Lake. Here scientists and Navy officers tested new rockets. Near Washington, D.C., the Navy constructed a new Naval Ordnance Laboratory at White Oak, Maryland.

From the first projects of the mobilization period to the final efforts at the close of the war, military construction within the United States played an essential role in the Allied victory. Construction work produced the training facilities to instruct service members, the logistical facilities to support the forces, the industrial facilities to manufacture materiel, the research and development facilities to improve existing weapons, the medical facilities to treat sick or wounded service members, plus an assortment of other types of facilities. Given the limitations on both time and building materials, the military's domestic construction programs of the war were a remarkable achievement. The construction programs aided the marshalling of men and materiel necessary to defeat the Axis nations.

CHAPTER V

COMMAND PERMANENT CONSTRUCTION

The War and Navy Departments divided their construction programs into command construction, industrial construction, and special construction projects. Command construction, the subject of this chapter, included all installations that operated in direct support of the military forces. Examples included cantonments, air bases, Navy yards and bases, storage and maintenance facilities, ports of embarkation, headquarters, medical facilities, communications installations, and all other types of construction necessary for the actual operation of the forces. Command facilities construction programs were characterized by a wide variety of building types and purposes. In keeping with wartime economy measures, the military used temporary construction wherever possible. Yet some command facilities unavoidably required permanent construction. In other cases, permanent construction presented long range advantages for use after the war, which outweighed its short term disadvantages.

Combat Operations and Coastal Defense

The Japanese threat in the Pacific presented the most pressing need for military construction directly related to combat operations. Even before the Japanese attack at Pearl Harbor, the defense of American possessions in the Pacific was a vital concern to both the War and Navy Departments. The Hawaiian territories long had been recognized as a key outpost in the Pacific, and both the Navy and Army had established their presence in the islands. After the war commenced, Japanese landings in the Aleutian Islands made Alaska a theater of operations. In fact, Alaska was the only one of the present states to be the scene of ground combat. In the United States, permanent construction related to operations included additions to the coastal defenses, and operating bases for anti-submarine activities.

Hawaii

Ever since the U.S. annexation of the Hawaiian islands, the U.S. military had established outposts on the islands. The Navy held an operating base and shipyard at Pearl Harbor since the beginning of the century, with smaller installations also located on the islands. The Army's most important posts included Schofield Barracks, an infantry garrison; Fort Kamehameha, a coastal artillery position in defense of Pearl Harbor; and an airfield on Ford Island in the middle of Pearl Harbor.

As the probability of war with Japan rose, both services sharply increased their levels of activity in Hawaii. In 1940, President Roosevelt ordered the Pacific Fleet to remain in Hawaii as a deterrent against Japanese expansion. The Japanese threat induced greater construction activities by the Navy, which built a new air station at Kaneohe and increased its depot activities at Pearl Harbor.

The War Department similarly expanded its Hawaii facilities, including accelerated construction of Hickam Field. During the late 1930s, the Army began construction at Hickam to replace the smaller field in the middle of Pearl Harbor; the first personnel occupied the site in 1937. By the winter of 1940/1941, the new installation was nearing completion. The Hawaiian Air Force headquarters moved to Hickam in July 1941. The new barracks at Hickam Field constituted an especially noteworthy feature. The huge building could house 3,000 enlisted personnel, and contained a mess hall large enough to serve this population. Married officers and senior non-commissioned officers lived in stucco houses with red tile roofs. During 1941, construction of temporary barracks began at Hickam.

Following the Japanese attack of December 7, the services rushed reinforcements to Hawaii. With the influx of new personnel came more construction, both temporary and permanent. Temporary housing sheltered over a million service personnel who arrived in Hawaii, often for further training enroute to the front lines. Storage depots, including steel petroleum tanks and ammunition igloos, often required permanent construction. Both the Army and Navy constructed communications facilities, typically on remote mountain tops.

During the emergency following the Japanese victory at Pearl Harbor, the Army pressed its construction of coastal defenses of the islands. Coastal artillery officers obtained surplus Navy guns, including guns recovered from the sunken battleship Arizona. The batteries for these guns were largely underground, with openings only for the turret. These fortifications were the product of round-the-clock work immediately after Pearl Harbor. New anti-aircraft weapons complemented the coastal artillery positions.

Among the more exotic forms of construction were the extensive underground projects built throughout the island of Oahu. The Army excavated an extensive ordnance storage tunnel near Fort Shafter beneath Alilamanu Crater, but converted it to a joint Army-Navy command post just prior to the attack upon Pearl Harbor. Elsewhere on Oahu, the Army and Navy employed an extensive system of tunnels for storage of both ammunition and petroleum. In early 1941, the Army built five additional bomb-proof and gas-proof shelters for communications equipment. Near Schofield Barracks, in the center of the island of Oahu, the Army created an underground three-story structure. It originally was intended to be an aircraft assembly plant, but the Army instead used it to reproduce maps and charts.

The Navy expanded its operating facilities on Oahu and the outer islands. Pearl Harbor became the base for submarine and surface ships, with the necessary piers, warehouses, shops, and other additions to the installations facilities. The Navy constructed an air station at Barber's Point on Oahu as an air center and technical school. On the island of Maui, the Navy built another air station as a maintenance installation for carrier aircraft.

Alaska

Alaskans also found themselves in a combat arena. Here the Japanese threat centered on the Aleutian Islands, which stretched from Alaska across the Pacific. Although the unpredictable climate proved a serious obstacle to military operations, the proximity of the Aleutians to both Japan and the United States made the islands a potentially valuable prize for either side.

Alaskan geography dictated that any defense of the territory would require the cooperation of the Navy, Army, and Air Corps. Much of the territory to be defended consisted of islands, and even mainland regions were separated so widely that the only practical transportation was by sea. Inattention to Alaska during the pre-war years further complicated the military situation. During the inter-war years, the Army maintained only a small garrison in Alaska. The Air Corps established Ladd Field, near Fairbanks, in 1939, primarily for the purpose of cold weather research. In 1939, a Navy study, known as the Hepburn Board, recommended reenforcement of Alaska at Sitka, Kodiak Island, and Unalaska Island (Dutch Harbor).

During the protective mobilization period, construction began at these three sites. Naval facilities consisted of airfields, seaplane ramps, base facilities for surface ships and submarines, communications equipment, and quarters for the sailors and marines. The Army built coastal artillery batteries and infantry barracks near each of the three Navy bases. Because the Army had the responsibility of defending these bases, Army installations were co-located with Navy bases. The Army built coastal batteries at Sitka, Fort Greeley near Kodiak (not the present Fort Greeley), and Fort Mears near Dutch Harbor. Army Air Force defenses of Dutch Harbor were located at Cold Harbor and Unak Island, neither of which was within close range of Dutch Harbor. Near Anchorage, the Army completed its important installations with the construction of Fort Richardson and Elmendorf Air Field. Fort Richardson served as the Army headquarters; Kodiak Island, as the Navy Headquarters.

Dutch Harbor was a typical example of wartime construction in Alaska. The installation was located on Unalaska Island, toward the eastern edge of the Aleutian Islands. In January 1941, work began on a naval base, with construction of a seaplane ramp, steel frame hangar, repair shop, ammunition storage facility, petroleum handing facilities, housing, and administrative buildings. During the summer of 1942, the Navy expanded the installation with an anti-submarine net depot, marine railroad with shops, fire station, and warehouses. By January of 1943, the base included an air station, submarine base, radio station, section base, fueling depot, and Marine Corps barracks. The Navy contracted the initial design to the architectural firm of Albert Kahn, which used large, multi-functional buildings to conserve scarce space in the mountainous terrain. The first plans called for reinforced concrete, but the design specifications were changed to steel and later to wood due to materials shortages. To protect the naval facilities, the Army built Fort Mears, using 700-series temporary construction plans, which were modified by the addition of blackout shutters and drying rooms.

The types of military construction in Alaska varied immensely. Much of the construction was temporary, yet some forms of permanent construction were inevitable. The most prominent type of permanent construction was the steel and concrete gun batteries for coastal artillery fortifications. At locations such as Sitka, Kodiak, Amaknak Islands, or Dutch Harbor, the Army built new batteries to protect both Army and Navy installations from air or sea attacks. Elsewhere, a few logistical activities such as a small torpedo assembly plant and ammunition magazines at Dutch Harbor were built from permanent materials.

In May 1942, the Japanese seized the outer islands of Kiska and Attu, marking the only time in the war that what would be one of the fifty states became the scene of ground combat during World War II. The ground attacks were accompanied by carrier-based air attacks upon the Navy and Army facilities at Dutch Harbor on 3 and 4 June, with a loss of 43 American lives. At that time, American forces in Alaska were not strong enough to eject the Japanese; they could merely hold their ground.

American forces continued to move to Alaska, until they were willing to take the offensive. On 11 May 1943, about one year after the Japanese invasion, Americans landed at Attu. For the remainder of the month, the island was the scene of bloody fighting. After defeating the Japanese on Attu, the Americans then landed at Kiska in July, but a Japanese evacuation of that island prevented any serious fighting. For the remainder of the war, the Alaskan theater diminished in importance. The miserable weather precluded use of the Aleutians as a staging area for further advances against Japan.

United States

Within the United States, the Army maintained and improved its coastal artillery fortifications on a less ambitious scale. Ever since the 1790s, the Army stationed heavy artillery units near strategic harbors to defend the nation against foreign invasions. During World War II, the threat of either Japanese or German amphibious attack against the United States itself was not likely. Still, the pressures of war produced an increase in seacoast fortifications.

In July 1940, the War Department decided to increase its fortifications, primarily with the addition of 27 new batteries along both the Atlantic and Pacific Coasts (Table 5). Each battery contained two 16-inch guns protected with overhead cover. The 16-inch guns were to be supplemented with 50 batteries of 6-inch guns, also protected from air attack.

In practice, the competition for scarce resources limited the scope of the coastal defense projects. In July 1941, when only four of the new 16-inch batteries were ready for operation, the War Department decided to limit its efforts to those projects that could be completed by 1944, reducing construction to 23 new batteries. As the war began to turn in favor of the Allies, the pressure for coastal defenses declined. By 1945, only 90mm anti-aircraft batteries were manned fully. The Army supplemented its artillery with underwater mines, anti-submarine nets and other devices. The World War II coastal defenses represented the end of a long tradition of harbor defenses within the U.S. Army. Following the war, the Coastal Artillery Corps was disbanded.

Navy Yards

Navy yards have performed essential work in support of the fleet since the Navy operated its first yards in the late eighteenth century. The Navy constructed its own ships, repaired ships, and provided logistical or administrative support to the fleet from its yards. During World War II, Navy yards performed both construction and repair functions (Table 6). Because the bulk of their work was repair, Navy yards are treated as command construction for the purposes of this study. This study uses the World War II-era term "navy yard," although the Navy currently designates these facilities as "naval shipyards." For example, the Norfolk Navy Yard is now the Norfolk Naval Shipyard.

Following the Washington Naval Disarmament Conferences, the U.S. Navy experienced a period of stagnation. Congress was reluctant to appropriate large sums of money to a Navy, when no war appeared likely. Increasing Japanese expansion in the Pacific, and a desire to create public works projects during the Depression years, however, resulted in a modest increase in the Navy funding during the mid 1930s. Depression-era relief measures such as the National Industrial Recovery Act (NIRA) of 1932 provided $238,000,000 for new naval vessel construction and $30,000,000 for shore facility improvements.

Under these programs, the Navy built a modest number of ships, especially destroyers. These vessels were important to the United States' military build-up since the country had far fewer destroyers than

Japan by the early 1930s. The Norfolk, Charleston, and Mare Island Navy Yards were some of the primary construction yards for these ships.

The construction work carried out at each yard under these New Deal relief measures was based on peacetime expansion plans developed by each facility. Most of the construction funded by these relief measures was permanent construction. Among the most essential construction undertaken at this time was the modernization and improvement of building ways and dry docks. Officials extended the New York Navy Yard building ways to handle battleship construction. Workers also carried out modernization work on dry docks such as replacing Norfolk Navy Yard Dry Dock No. 2's rotting wood timbers with concrete.

TABLE 5: WORLD WAR II ARMY COASTAL FORTIFICATIONS

WWII Name	Current DoD Name	Location	Date Established
Camp Hero	N/A	NY	1941
Fort Adams	N/A	RI	1799
Fort Andrews	N/A	MA	1901
Fort Armstong	N/A	HI	1907
Fort Babcock	N/A	AK	1942
Fort Baker	N/A	CA	1897
Fort Baldwin	N/A	ME	1905
Fort Banks	N/A	MA	1899
Fort Barrancas	N/A	FL	1839
Fort Barry	N/A	CA	1904
Fort Bulkley	N/A	AK	1942
Fort Brumbeck	N/A	AK	1942
Fort Canby	N/A	WA	1864
Fort Casey	N/A	WA	1890s
Fort Church	N/A	RI	1940

Fort Columbia	N/A	WA	1896
Fort Constitution	N/A	NH	1791
Fort Crockett	N/A	TX	1897
Fort Cronkhite	N/A	CA	1937
Fort (John) Custis	N/A	VA	1942
Fort Dawes	N/A	MA	1940
Fort Dearborn	N/A	NH	1941
Fort Delaware	N/A	DE	1814
Fort DeRussy	Fort DeRussy	HI	1908
Fort DuPont	N/A	DE	1898
Fort Duvall	N/A	MA	1921
Fort Ebey	N/A	WA	1942
Fort Emory	U.S. Naval Communications Station, Imperial Beach	CA	1942
Fort Flagler	N/A	WA	1897
Fort Funston	N/A	CA	1898
Fort Gaines	N/A	AL	1822
Fort Getty	N/A	RI	1900
Fort Glenn	N/A	AK	1942
Fort Greble	N/A	RI	1900
Fort Greely	N/A	AK	1943
Fort Greene	N/A	RI	1940

Fort Hamilton	Fort Hamilton	NY	1825
Fort Hamilton	N/A	RI	ca. 1810
Fort Hancock	N/A	NJ	1813
Fort Haydon	N/A	WA	1941
Fort Heath	N/A	MA	1899
Fort Hunt	N/A	VA	1898
Fort Jay	Governors Island (Coast Guard)	NY	1794
Fort Kamehameha	Fort Kamehameha	HI	1909
Fort (Philip) Kearney	N/A	RI	1909
Fort Lawton	N/A	WA	1899
Fort Levett	N/A	ME	1894
Fort Lyon	N/A	ME	1873
Fort Macon	N/A	NC	1826
Fort Mason	N/A	CA	1864
Fort McArthur	Fort McArthur (subpost of Fort Ord)	CA	1914
Fort McClary	N/A	ME	1776
Fort McGilvray	N/A	AK	1942
Fort McKinley	N/A	ME	1893
Fort McRee	N/A	FL	1834
Fort Mears	N/A	AK	1941
Fort Michie	N/A	NY	1900

Fort Miles	N/A	DE	1941-1942
Fort Miley	N/A	CA	1892
Fort Monroe	Fort Monroe	VA	1818
Fort Morgan	N/A	AL	1819
Fort Morrow	N/A	AK	1942
Fort Mott	N/A	NJ	1872
Fort Moultrie	N/A	SC	1809
Fort Peirce	N/A	AK	1943
Fort Pickens	N/A	FL	1829
Fort Preble	N/A	ME	1808
Fort Randall	N/A	AK	1942
Fort Ray	N/A	AK	1941
Fort Revere	N/A	MA	1901
Fort Rodman	N/A	MA	1898
Fort Rosecrans	Naval Complex, Point Loma	CA	1852
Fort Rousseau	N/A	AK	1942
Fort Ruckman	N/A	MA	1921
Fort Ruger	N/A	HI	1906
Fort San Jacinto	N/A	TX	1898
Fort Saulsbury	N/A	DE	ca. 1918
Fort Schwatka	N/A	AK	1943

Fort Schuyler	N/A	NY	1833
Fort Screven	N/A	GA	1898
Fort Slocum	N/A	NY	1861
Fort Smith	N/A	AK	ca. 1942
Fort (Myles) Standish	N/A	MA	1900
Fort Stark	N/A	NH	1873
Fort Stevens	N/A	OR	1903
Fort Story	Fort Story	VA	1917
Fort Strong	N/A	MA	1899
Fort Sumter	N/A	SC	1828
Fort Taylor	N/A	FL	1845
Fort Terry	N/A	NY	1898
Fort Tidball	N/A	AK	1942
Fort Tilden	N/A	NY	1917
Fort Totten	Fort Totten	NY	1862
Fort Townsend	N/A	WA	1856
Fort Travis	N/A	TX	1898-99
Fort Varnum	N/A (National Guard)	RI	1943
Fort Wadsworth	Fort Wadsworth (subpost of Fort Totten)	NY	1847
Fort Warren	N/A	MA	1837

Fort Washington	N/A	MD	1808
Fort Weaver	N/A	HI	ca. 1920
Fort Wetherill	N/A	RI	1776
Fort Whitman	N/A	WA	1909
Fort Williams	N/A	ME	1872
Fort Winfield Scott	N/A	CA	1905
Fort Wool	N/A	VA	1819
Fort Worden	N/A	WA	1898
Fort Wright (H.G.)	N/A	NY	1898
Presidio of San Francisco	N/A	CA	1776

Sources:

Stetson Conn, Rose C. Engelman, and Byron Fairchild, Guarding the United States and Its Outposts (Washington, D.C.: Office of the Center of Military History, Government Printing Office, 1964), *passim*.

Emanuel Raymond Lewis, Seacoast Fortifications of the United States (Washington, D.C.: Center for Military History, 1979), *passim*.

Robert B. Roberts, Encyclopedia of Historic Forts (New York: MacMillan Publishing Company, 1988).

TABLE 6: WORLD WAR II NAVY YARDS

WWII-era Name	Current Name	Location	Date Established
Bayonne Repair Base (Annex of New York Navy Yard)	N/A	NJ	1940
Boston Navy Yard	N/A	MA	1800
Charleston Navy Yard	Charleston Naval Shipyard	SC	1901
Hunters Point Navy Yard	N/A	CA	1940
Mare Island Navy Yard	Mare Island Navy Base	CA	1853
Pearl Harbor Navy Yard	Naval Complex Pearl Harbor	HI	1900
New York Ship Yard	N/A	NY	1800
Norfolk Navy Yard	Norfolk Naval Shipyard	VA	1800
Philadelphia Navy Yard	Philadelphia Naval Shipyard	PA	1872 (League Island)
Portsmouth Navy Yard	Portsmouth Naval Shipyard	NH	1800
Puget Sound Navy Yard	Puget Sound Naval Shipyard	WA	1891
South Boston Annex (Annex to Boston Navy Yard)	N/A	MA	1919
Terminal Island Dry Docks	Naval Shipyard Long Beach	CA	1940
Washington Navy Yard	Washington Navy Yard	DC	1800

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.: Government Printing Office, 1947).

The Axis nations' military expansions during the late 1930s led the United States to increase its fleet even further. The 1938 Vinson Bill approved a 20 per cent increase in the Navy's size. Until 1939, the Navy carried out most of the shore construction based on Bureau of Yards and Docks plans. The Bureau's increasing work load caused the office to ask for and receive Congressional permission to use private architecture and engineering firms for most Navy building design work. Under this arrangement, the Bureau still undertook work of a confidential, specialized, or very repetitive nature. Such buildings normally were permanent. The numerous examples included a four-story shop structure built at Mare Island Navy Yard, new sheet metal, pipe, and electric shops erected at Charleston Navy Yard, a steel turret welding house at New York Navy Yard, and a machine shop erected at Puget Sound Navy Yard. Construction of additional dry docks was a crucial part of this expansion, because the Navy needed additional docks to augment its twenty-five extant structures. Anticipating the possible struggle against Japan, the Navy improved its Pacific bases. During the late 1930s, the Navy began to construct a 435-foot dry dock at the Mare Island Navy Yard to service submarines, small craft, and destroyers. Additionally, work was begun on two large dry docks at Puget Sound in 1938 and 1939 to accommodate the largest battleships planned for the Navy.

With the beginning of the protective mobilization period in 1940, the U.S. Navy entered into a massive fleet and shore establishment buildup. Congress passed a bill calling for the establishment of a "two-ocean" navy and increasing the existing force by 70 per cent. The massive increase in fleet size demanded more shore facilities, while placing severe constraints on the availability of steel and other essential materials. Due to the constraints of time and material shortages, the Bureau ordered that all new naval building construction, except for structures whose function or intended post-war use required permanent construction, consist of temporary construction. As a rule, Ben Moreell, Chief of the Bureau of Yards and Docks, recommended that construction speed was the primary consideration in the construction of naval shore facilities, with cost or architectural planning ranking as secondary factors.

For the planned fleet buildup, the Navy established priorities for construction. In May 1940, the Bureau of Yards and Docks recommended that shipbuilding facilities receive the highest priority within this effort. On 11 June 1940, the passage of the Naval Appropriation Act initiated a massive naval building construction program. Later that year, the Navy convened the Greenslade Board to prepare a shore station master development plan to support the expanding fleet through 1946. The Secretary of the Navy eventually approved the Board's recommendations and advised all naval shore facilities planning agencies to use the recommendations as a guide in planning new facilities. The board recommended that shipyards on the East and West Coasts should have the capacity to maintain up to sixty per cent of the contemplated fleet. The Board determined that installations on the Eastern Seaboard already possessed the ability to perform this work. The Greenslade plan recommended that no yard use more than twenty per cent of its capacity for ship construction, with the rest being utilized for ship repair in case the United States entered the war. Congress appropriated up to $350,000,000 for these improvements.

Of the structures built during the protective mobilization period, some of the most important were new dry docks to accommodate construction and repair of the Navy's largest ships. The most valuable of these docks included Pearl Harbor Navy Yard's 1,000-foot dry dock Number 2, which was capable of handling battleships, and 497-foot Dry Dock Number 3, which was able to dock ships as big as submarines and destroyers. Workers used relatively new underwater concrete pouring methods in the construction of these dry docks. Both of these structures used the tremie concrete-deposition method, named for the tremies or pipes used in the construction process. This method involved pouring concrete through nine, 17-inch pipes at 10-foot intervals into forms supported by steel piles driven into a foundation bed. Once the forms were filled, the concrete cured underwater, then a cofferdam of steel-reinforced concrete was constructed. With the cofferdam in place, water was pumped from the dock and the non-tremie concrete floor and side walls were built in dry conditions. This building method enabled the workers to finish the dry docks in approximately two years as compared to the 10 years required for Dry Dock No. 1 at Pearl Harbor.

Additionally, the Navy began construction on other large dry docks at the Norfolk, Philadelphia, and Mare Island Navy Yards. A 1,092-foot dock constructed at Norfolk and a similar structure built at Philadelphia were the Navy's first "super docks" capable of handling the service's largest battleships. The tremie concrete construction methods cut construction time as much as 75 per cent. Other smaller shipbuilding and repair docks started during this time included a 435-foot dry dock built for submarine production and submarine, destroyer, and small ship repair at Portsmouth, New Hampshire. At the Norfolk and New York Navy Yards, massive 350-ton hammerhead cranes dominated the skyline, while smaller cranes were operated at other yards.

Navy dry docks also were constructed using another engineering innovation known as the steel box caisson. This large box sealed the basin for pumping after the ship entered its interior. The Bureau of Yards and Docks first employed caissons in 1940. Other sealing structures for dry dock entrances included miter gates favored for European dry docks and recessed caissons utilized at British dry docks.

Following American entry into the war, the Navy hurriedly finished the dry docks then under construction and began new structures. Most of these dry docks were intended for ship repair. Examples include a 1,092-foot "super" dock and two smaller 420-foot docks built at the Hunter's Point Repair Facility. Workers used tremie construction methods and also employed pre-cast concrete forms for the Hunter Point docks. Selected shipbuilding and repair dry docks were designed to accommodate specialized ships, including 365-foot docks built at Charleston for destroyer escort work.

By January 1945, the Navy had constructed 30 dry docks. These structures enabled the Navy to build and repair the multitude of ship types in the United States fleet that served during World War II. In addition to new dry docks, the Navy constructed shop and storage buildings at its yards. Examples include a turret shop building, foundry buildings, shipfitters assembly shops, and large machine shops. In May 1940, the Navy further augmented its repair capability with the acquisition of two new repair stations at Hunters Point, California, and Terminal Island, California.

With additional activity at the yards and the resulting increase in personnel, the Navy needed more housing at its facilities. The Navy built a six-story, reinforced-concrete receiving barracks at New York Navy Yard; at Philadelphia Navy Yard, the Navy constructed three-story, permanent, fireproof barracks to house up to 1,575 ships' crew members and an eight-story, permanent quarters to house 50 officers and 875 enlisted men.

After the United States' declaration of war, the Navy accelerated its existing fleet expansion program, augmented that work with specialized ship construction, and quickened its shore facility improvement effort. The Navy divided its existing warship construction and repair work between both coasts. Early heavy ship construction focused on launching battleships from East Coast facilities, including the New York and Philadelphia Navy Yards, but later turned to aircraft carriers as naval aviation dominated the fighting within the Pacific theater. By 1944, as Navy and private yards neared completion of new ships needed for the war against Japan,

Navy officials had redirected most of the facilities' work towards ship repair.

The size of the Navy increased beyond all previous experience. Not only did the number of ships increase, but the types of ships changed. Although battleships remained a vital part of the fleet, aircraft carriers assumed greater prominence. New categories of ships included destroyer escorts (used in anti-submarine warfare), and landing craft (used for amphibious operations). These new vessels were produced in prefabricated sections and assembled at Navy yards.

Navy officials also directed the building of many industrial structures to build and maintain the fleet during the war. These buildings ranged from a galvanizing plant at Portsmouth Navy Yard to a boiler shop and material storage building and a field shop building constructed at Norfolk Navy Yard to a seven-story fireproof general storehouse and a steel-frame shipfitters shop built at Puget Sound.

Living quarters were an important part of permanent building construction at Navy yards during the war years. The increase in naval personnel stationed at these facilities, as well as ship crews located there temporarily while their ship was under repair, led to a need for more housing. For example, a four-story, concrete-frame and brick barrack with a 2,000-man capacity was built at Philadelphia in 1942. The Navy also built family housing for uniformed personnel or defense workers near its installations. These projects were completed in cooperation with federal housing programs and included new housing complexes at Charleston and Mare Island.

The navy yard building construction program reached its peak on the East Coast in early 1943. Building construction continued at a significant pace at West Coast navy yards until the end of the war. The total value of structures built for ship construction and repair purposes between 1 July 1940 and 31 December 1945 was $1,116,258,384.00 or 13.7 per cent of total building construction performed for the Navy shore establishment.

For the Navy, the buildup of its yards during the 1930s, mobilization, and declared war periods played a vital role in the support of the American fleet. The modest construction and modernization work on industrial buildings, dry docks, and building ways during the 1930s allowed the Navy to start a fleet enhancement program that prepared its facilities for even greater ship production and repair work later. During the navy yard emergency building construction work in mid-1940 and the expanded construction program after the Pearl Harbor attack, the Navy produced many of its warships and specialty vessels, such as destroyer escorts and landing craft. This building construction effort also produced a shore establishment capable of carrying out repair and refit work on the two-ocean U.S. fleet and ships from other nations. This massive industrial construction in support of the U.S. fleet was essential to the war effort.

Navy Bases and Stations

The Navy supported the fleet's vessels and ships crews at naval bases and stations. Naval operational facilities fell into two categories: naval operating bases, and smaller operating bases (Table 7). Naval operating bases provided "safe anchorage for combatant and auxiliary vessels, replenishment of fuel, ammunition, and supplies, facilities for making minor repairs, [and] recreational and hospital facilities for personnel." Examples of this type of installation included Naval Operating Base Norfolk and the Naval Base Pearl Harbor, which were distinct from the yards at those locations. Naval operating bases had administrative control over activities such as Marine Corps barracks, training functions, naval air stations, and supply depots located within the installation's boundaries. The second type of operational facilities were small operating bases that had the capacity to handle "specific types of vessels [and were] known as destroyer bases, submarine bases,... They are equipped to furnish rapid servicing and repairs for these smaller vessels, and accommodations for their personnel, so that the larger yards will be left free for larger vessels." These facilities included the New London Submarine Base, Connecticut, and the San Diego Destroyer Base, California.

TABLE 7: WORLD WAR II NAVY OPERATING BASES

WWII Name	Current Name	Location	Date Established
Fleet Operating Base Terminal Island	Naval Shipyard Long Beach	CA	1940
Naval Base Dutch Harbor	N/A	AK	1942
Naval Operations Base Kodiak	CG Base Kodiak	AK	1941
Naval Operating Base Norfolk	Naval Base Norfolk	VA	1917
Naval Destroyer Base San Diego/Naval Repair Base San Diego (renamed in 1943)	Naval Station San Diego	CA	1922
New London Submarine Base	Naval Base New London	CT	1915
Pearl Harbor Navy Base	Naval Facility Pearl Harbor	HI	1900

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.: Government Printing Office, 1947).

Like Navy yards, naval operating bases were improved only modestly during the 1930s. Following the fall of France, however, Navy bases played an increasingly important role in American mobilization. The Pacific Fleet transferred to Pearl Harbor in 1940 to discourage further Japanese aggression. The newly created Atlantic Fleet established its headquarters at Naval Operating Base Norfolk. The Norfolk base also played an important role as the staging area for neutrality patrols on the East Coast.

As part of the mobilization efforts, the Navy increased its building construction programs at naval operational facilities. As a general rule, operating bases required fewer permanent buildings than Navy yards. However, in cases where construction was intended to outlast the war, the Navy chose permanent construction. For example, the Navy expanded a brick power plant at the Norfolk naval base to meet the base's additional requirements for electricity. At the San Diego destroyer base, the Navy built a graving dry dock to repair smaller ships.

Smaller operational installations also received permanent construction during the war. The New London Submarine base, which served as the home for a number of submarines operating in the Atlantic and a training facility for submariners, is a typical example. Among the structures built were "keyport" torpedo warhead storage magazines, a small arms magazine, a pyrotechnic magazine, two fixed-ammunition magazines, and a fuze magazine.

Like Navy yards, naval operational facilities were the site of projects to provide low-cost housing to Navy personnel and civilian workers. The first and most noted of these developments was Ben Moreell Park, in Norfolk, Virginia, which was intended for the families of enlisted Navy personnel. The project consisted of 57 twelve-family apartments, 11 two-family apartments, and 24 fourteen-family apartments.

Buildings were steel frame with either stucco or asbestos siding. The first phase of the project was completed in May 1940 with another 300 units ready for residents by October of the next year.

Training Installations

Mobilization of personnel was one critical aspect in preparing for war. Mobilization required expansion of existing training facilities and extensive new construction. Both the War and Navy Departments sought to use temporary construction for operations and training wherever possible, although some permanent construction was unavoidable or else considered desirable. During the early phases of the protective mobilization period, the Army and Navy anticipated a long term expansion of their forces, and constructed permanent buildings. Even temporary mobilization installations required some permanent buildings, while special purpose facilities required permanent structures. Air Corps training installations are included under the section entitled "Army Air Forces Installations."

In June 1940, the United States Army quickened its mobilization activities to train personnel in response to the situation in Europe. In the fall of 1939, Army personnel numbered a little more than 200,000 men. By November 1944, the Army had facilities to house and train six million troops in the continental United States. Most of the troops were billeted in temporary wood-frame construction. Only 270,000 out of the six million troops were housed in permanent buildings. Table 8 provides a list of Army mobilization camps.

Although temporary construction was the norm for mobilization training camps, some installations received permanent construction to support either the camps or long term expansion.

TABLE 8: WORLD WAR II ARMY MOBILIZATION TRAINING CAMPS

WWII Name	Current Name	Location	Date Established
Camp Adair	N/A	OR	1943
Camp Atterbury	N/A	IN	1942
Camp Barkeley	N/A	TX	1941
Camp Beale	N/A	CA	1941
Camp Beauregard	N/A	LA	1917
Camp Blanding	N/A	FL	1939
Fort Belvoir	Fort Belvoir	VA	1912
Fort Benning	Fort Benning	GA	1919

Fort Bliss	Fort Bliss	TX	1890
Camp Bowie	N/A	TX	1917
Fort Brady	N/A	MI	1892
Fort Bragg	Fort Bragg	NC	1918
Camp Branch	N/A	NC	1942
Camp Breckinridge	N/A	KY	1941
Camp Bullis	Fort Sam Houston	TX	1917
Camp Butner	N/A	NC	1942
Camp Callan	N/A	CA	1940
Camp Campbell	Fort Campbell	KY	1942
Camp Carson	Fort Carson	CO	1942
Camp Chaffee	Fort Chaffee	AR	1942
Camp Claiborne	N/A	LA	1940
Fort Clark	N/A	TX	1852
Camp Cooke	N/A	CA	1942
Camp Croft	N/A	SC	1941
Fort Custer	N/A	MI	1917
Camp Davis	N/A	NC	1941
Fort Devens	Fort Devens	MA	1917
Fort Dix	Fort Dix	NJ	1917
Camp Edwards	N/A	MA	1941

Camp Ellis	N/A	IL	1942
Fort Ethan Allen	Fort Ethan Allen	VT	1892
Fort Eustis	Fort Eustis	VA	1918
Camp Forrest	N/A	TN	1941
Camp Funston	Fort Riley	KS	1942
Camp Gillespie	N/A	CA	1942
Camp Gordon	Fort Gordon	GA	1941
Camp Grayling	N/A	MI	1911
Camp Grant	N/A	IL	1918
Camp Gruber	N/A	OK	1942
Camp Guernsey	N/A	WY	1932 ca
Camp Haan	N/A	CA	1941
Fort Benjamin Harrison	Fort Benjamin Harrison	IN	1903
Fort A.P. Hill	Fort A.P. Hill	VA	1941
Camp Hood	Fort Hood	TX	1941
Camp Howze	N/A	TX	1941
Fort Huachuca	Fort Huachuca	AZ	1882
Camp Hulen	N/A	TX	1940
Hunter Liggett Military Reservation	Fort Ord (sub-post)	CA	1941
Indiantown Gap Military Reservation	Fort Indiantown Gap	PA	1931

Camp Irwin	Fort Irwin	CA	1940
Fort Jackson	Fort Jackson	SC	1917
Fort Knox	Fort Knox	KY	1918
Camp Kohler	N/A	CA	1942
Camp Langdon	N/A	NH	1941
Fort Lawton	N/A	WA	1891
Fort Leavenworth	Fort Leavenworth	KS	1827
Camp Lee	Fort Lee	VA	1917
Fort Leonard Wood	Fort Leonard Wood	MO	1940
Fort Lewis	Fort Lewis	WA	1917
Camp Livingston	N/A	LA	1940
Camp Luna	N/A	NM	1942
Fort MacArthur	N/A	CA	1888
Camp MacQuaide	N/A	CA	1940
Madison Barracks	N/A	NY	1815
Camp Maxey	N/A	TX	1942
Camp McCain	N/A	MS	1942
Fort McClellan	Fort McClellan	AL	1917
Camp McCoy	N/A	WI	1909
Fort Meade	Fort Meade	MD	1917
Camp Millard	N/A	OH	1941

Fort Monmouth	Fort Monmouth	NJ	1917
Camp Murphy	N/A	FL	1942
Fort Myer	Fort Myer	VA	1863
Fort Oglethorpe	N/A	GA	1903
Fort Ord	Fort Ord	CA	1917
Camp Phillips	N/A	KS	1942
Camp Pickett	Fort Pickett (subinstallation of Fort Lee)	VA	1942
Camp Pike	Camp Joseph T. Robinson (National Guard)	AR	1917
Camp Pinedale	N/A	CA	1942
Pine Camp	Fort Drum	NY	1908
Camp Plauche	N/A	LA	1942
Camp Polk	Fort Polk	LA	1941
Camp Rapid	N/A	SD	1925
Camp (William C.) Reid	N/A	NM	1942
Camp Reynolds	N/A	PA	1942
Fort Riley	Fort Riley	KS	1852
Camp Ritchie	Fort Ritchie	MD	1926
Camp Roberts	N/A	CA	1941
Camp Rodman	Aberdeen Proving Ground	MD	1941
Camp Rucker	Fort Rucker	AL	1942

Fort Sam Houston	Fort Sam Houston	TX	
Camp San Luis Obispo	N/A	CA	1928
Camp Santa Anita	N/A	CA	1942
Camp Savage	N/A	MN	1942
Schofield Barracks	Schofield Barracks	HI	1908
Camp (Thomas A.) Scott	N/A	IN	1942
Camp Seeley	N/A	CA	1942
Camp Shanks	N/A	NJ	1943
Camp Shelby	N/A	MS	1917
Fort Sheridan	Fort Sheridan	IL	1887
Camp Sibert	N/A	AL	1943
Fort Sill	Fort Sill	OK	1869
Fort Snelling	N/A	MN	1819
Camp Stewart	Fort Stewart	GA	1940
Camp Swift	N/A	TX	1942
Camp Sutton	N/A	NC	1942
Camp Toccoa	N/A	GA	1943
Camp Travis	Fort Sam Houston	TX	1917
Camp (Jesse) Turner	N/A	AR	1942
Camp Tyson	N/A	TN	1942
Camp Upton	N/A	NY	1917

Camp Van Dorn	N/A	MS	1942
Camp Wallace	N/A	TX	1941
Camp White	N/A	OR	1942
Camp Whiteside	Fort Riley	KS	1924
Camp Wolters	Fort Wolters	TX	1941
Camp (Charles) Wood	Fort Monmouth	NJ	1942
Camp Young	N/A	CA	1942

Sources: Union Pacific Railroad, "Geographically Correct Map of the United States Issued by Union Pacific Railroad," Missouri Historical Society, St. Louis, 1942.

Robert B. Roberts, Encyclopedia of Historic Forts (New York: MacMillan Publishing Company, 1988).

Typical support facilities that required permanent construction included water or sewage treatment facilities and associated wells, pumps, and collection and distribution infrastructure; electrical distribution infrastructure; heating plants/boiler houses; cold storage; shops; ammunition magazines; and, general and specialized storage facilities. Some specialized projects also were constructed. Fort Knox, for example, was the site of an extensive enlisted family housing project sponsored by the Federal Works Agency; however, the housing at Fort Knox, reflecting the growing war emergency, was built of semi-permanent construction and did not resemble the inter-war housing.

In 1939, the number of Navy personnel was 110,000; by September 1945, personnel numbered 3,009,380. These vast numbers of personnel passed through the Navy's training stations (Table 9). The Navy entered the war years with four existing recruit training stations: Newport, Rhode Island; Great Lakes, Illinois; Norfolk, Virginia; and, San Diego, California. Norfolk was the largest of the four training stations. At that time, the Norfolk station had facilities for 10,000 men. The demand for new personnel rapidly outstripped the capacity of these stations. After the German invasion of France in May 1940, the authorized number of naval personnel was increased to 172,000. The existing training stations were expanded during the Protective Mobilization phase, with permanent barracks, mess halls, and recreation facilities that were streamlined versions of the inter-war construction built by the Navy. New construction could not keep up with the ever-expanding number of recruits. By the end of 1941, the training stations were severely overcrowded. After the attack on Pearl Harbor, recruits flocked to the Navy. Construction was immediately increased to accommodate the influx of recruits and the Navy planned new training stations built of temporary construction. The criteria for the locations of the new stations were: large areas of cleared, level land; proximity to a body of water; proximity to a city for liberty calls; adequate access to rail and road networks; availability of utilities; and, an adequate labor supply for construction. The three new stations opened in 1942 were: Bainbridge, in Maryland; Farrugut, in Idaho; and, Sampson, in New York. These stations were constructed primarily of temporary construction.

The Navy also constructed specialized training stations in addition to recruit training stations. Specialized training consisted of schools, where individuals received additional training in specific skills, and operational training, where groups of personnel participated in "team" training. During World War II, the Navy operated its schools in a variety of places, including factories, colleges, hotels, private houses, and trade schools, in addition to navy yards and other naval shore facilities. Operational training included a wide variety of activities at disparate installations: Acorn assembly and training at Port Hueneme, California; airship training at Lakehurst, New Jersey; amphibious training at San Diego (Coronado), California, Solomon's Island, Maryland, Little Creek, Virginia, and Ft. Pierce, Florida; anti-aircraft training at Lido Beach, New York, Pacific Beach, Washington, Point Montara, California, Newport, Rhode Island, Shell Beach, Louisiana, and Dam Neck, Virginia; minecraft training at Little Creek; pre-commissioning training at Treasure Island, California; small craft training at San Pedro, California; and, training in mine warfare at the newly established Mine Warfare School at Yorktown, Virginia. Some specialized training was accommodated at existing installations, while specialized facilities were developed for some kinds of training. Advance base personnel depots were established to provide training to units of men already assembled into functional units. The Navy built additional camps for anti-aircraft and amphibious training. These facilities typically featured temporary construction; however, in some cases specialized training facilities might receive permanent construction if temporary construction would not hold up under intensive use.

As the emergency turned into a declared war, materials shortages grew more acute and temporary construction became standard for both the War and Navy Departments. The War Department created new installations that were almost all temporary buildings, and added new sections of temporary construction to existing installations. Later, the War Department employed "theater-of-operations" construction, which consisted of tar paper tacked to thin wooden frames. Nevertheless, some functions at the mobilization camps required permanent structures. For example, perishable subsistence required buildings with masonry walls to ensure cold storage. Ammunition was stored in concrete "igloos" to minimize the dangers of explosion. Water, sewerage, or laundry plants were built using permanent construction. Flammable materials, including packaged petroleum products or paint, were sometimes stored in permanent buildings. These support buildings were minor elements of training and operational installments.

TABLE 9. WWII NAVY TRAINING STATIONS AND BASES

WWII-era Name	Current Name	Location	Date Established
Recruit Training			
Naval Training Station Bainbridge	N/A	MD	1942
Naval Training Station Farragut	N/A	ID	1942
Naval Training Station Great Lakes	Naval Training Center Great Lakes	IL	1911
Naval Training Station Newport	Naval Education and Training Center Newport	RI	1883
Naval Training Station Norfolk	Naval Base Norfolk	VA	1917

Naval Training Station Sampson	N/A	NY	1942
Naval Training Station San Diego	Naval Station San Diego	CA	1917
Specialized Training *			
Advanced Base Personnel Depot San Bruno	N/A	CA	1943
Naval Amphibious Training Base Fort Pierce	N/A	FL	1943
Naval Amphibious Training Base Galveston	N/A	TX	1943
Naval Amphibious Training Base Little Creek	Naval Amphibious Base Little Creek	VA	1942
Naval Amphibious Training Base Morro Bay	N/A	CA	1943
Naval Amphibious Training Base Ocracoke	N/A	NC	1943
Naval Amphibious Training Base Panama City	Panama City Coastal Systems Station	FL	1943
Naval Amphibious Training Base San Diego	Naval Amphibious Base Coronado	CA	1943
Naval Amphibious Training Base Solomon's Island	N/A	MD	1942
Naval Mine Warfare School Yorktown	N/A (Coast Guard)	VA	1918

- The U.S. Navy conducted specialized and operational training in many places and under various designations during World War II. Other training programs were carried out at other naval facilities, including air stations, operating bases, and shipyards.

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.: Government Printing Office, 1947):261 - 279.

Other permanent structures served training functions. Some of these buildings and structures employed unique designs. The 250-foot towers for training airborne units were dramatic examples of permanent training structures. Each tower included four arms that could accommodate an open parachute canopy. Soldiers were placed in the parachute harnesses on the ground and lifted 250 feet off the ground. The descent would simulate a parachute jump. Swimming pools, especially those constructed on Navy or Marine Corps training installations, were used for teaching water survival skills more than for recreation.

Army Air Forces Installations

In the years between World War I and World War II, the Army's air arm underwent a period of mixed progress and stagnation. Experience during the First World War had established the utility of military aviation and fostered the conviction among a group of Army officers that future wars would be decided by air power. Moreover, Army aviation profited from steadily improving civilian aircraft technology. Yet the growth of military aviation was limited by the general lack of interest in military affairs during the 1920s and early 1930s. With limited appropriations for all its activities, the Army could not afford to take full advantage of the technological improvements in aviation.

Discord between air and ground officers further complicated the development of Army aviation. Led by Billy Mitchell, numerous air officers believed that future wars would be decided by strategic air warfare. In this view long range bombing would replace ground combat. Consequently, they favored the development of heavy bombers at the expense of smaller aircraft. They further argued that the nation's air component should be independent from the Army, creating a separate Air Force. Mitchell's argumentative style led to a well publicized court-martial that prompted endless inquiries and boards to study the future of Army aviation. Air power advocates received recognition when the Army Air Service was upgraded to the Air Corps in 1926. In 1935, the Air Corps received a further boost with the creation of a General Headquarters for the Army Air Forces. This headquarters was the command element for air units that could be employed as a strategic force. The Chief of the Air Corps continued to supervise the administration and logistical support of Army air units.

Air Corps installations reflected the uneven growth of Army aviation. Most of the airfields constructed during World War I were closed after the war. Airfield construction received a boost from the 1935 Wilcox Act, which emphasized construction of airfields along the nation's borders to protect the United States against hostile air attacks. By the close of the inter-war period, the Air Corps operated slightly more than 20 airfields.

With the increasing tensions in Europe and Asia, the Air Corps received its share of new appropriations during the late 1930s. The War and Navy Departments developed a series of contingency plans for fighting multiple enemies, known as the "RAINBOW" plans. The final revision, RAINBOW 5, emphasized the role of the Air Corps in frontier air defenses and air power projection.

McChord Field, near Tacoma, Washington is an excellent example of an air field constructed during the late 1930s after the adoption of RAINBOW 5. In 1938, this area was considered the Northwest Frontier and McChord was built to provide air defense for the Puget Sound Navy Yard and the Boeing aircraft plant in Seattle, and medium bomber support to the Navy. Construction at McChord was extensive and designed to be permanent. The airfield housed a mix of pursuit and medium bomber aircraft. Taking advantage of the freedom in site selection given by the Wilcox Act and funding from a generous Congress, the Air Corps built McChord to be a show place of air power. Contractors built four 350 by 500 ft. steel and concrete hangars, a hospital, power plant, housing, and one of the largest brick barracks in the United States at the time. Although the construction contracts were under Quartermaster Corps control, the Air Corps selected the designs for buildings directly related to aircraft operations.

Other facilities were built around the country to complement the nation's air defense system (Table 10). These air bases, including Elmendorf in Alaska, Hanscom and Westover in Massachusetts, MacDill in Florida, and McGuire in New Jersey, were all built to bolster the defense of the United States. Operations bases were only part of the overall network of facilities designed to meet national defense requirements. Like other arms of the military, the Air Corps underwent rapid expansion during the protective mobilization period. Pilots, aircrew, and technicians, both officer and enlisted, required suitable technical instruction; therefore, the Air Corps needed to expand its training facilities.

During 1940, the Air Corps surveyed the nation for suitable civilian airports that could be leased for the emergency. Eager to attract defense spending, municipal governments frequently offered to lease airports and adjoining land for one dollar per year. At the same time, the Quartermaster Corps construction division issued contracts to expand existing training facilities at Chanute Air Base, Illinois; Kelly Field, Texas; Lowry Field, Colorado; Maxwell Field, Alabama; and, Randolph Field, Texas. New construction at these fields was a mix of temporary and permanent construction. The expansion of Kelly Field, Texas, included a wide range of construction, from large, reinforced-concrete hangars to tent cities. At Lowry Field, the War Department authorized construction of new buildings, including an 850-man barracks. Construction was incomplete when the Protective Mobilization Plan was announced, and new soldiers were quartered in tents until September 1940. Thereafter, construction at Lowry was primarily temporary. The service members lucky enough to live in the brick barracks called their new home "Buckingham Palace." At other locations, the Army eventually resorted to leased hotels for troop housing.

The mobilization program strained the capacity of the Construction Division of the Quartermaster Corps' centralized management techniques. The Corps of Engineers seemed better suited for many construction projects because it used a decentralized management system, with district offices. To expedite construction, Congress gave the Secretary of War permission to shift the responsibility of Air Corps construction to the Corps of Engineers in late 1940. The engineers displayed ingenuity and flexibility in meeting the needs of the Air Corps. Utilizing the methods of large contract management gained from major river and harbor projects, the Corps of Engineers quickly took control of Air Corps construction projects.

The transfer of construction responsibility to the Corps of Engineers produced tension between the engineers and Colonel Frank Kennedy, chief of the Air Corps Buildings and Grounds Division. In 1940 and 1941, Colonel Kennedy, as the Air Corps point of contact to the engineers, set himself up as the air field design expert. Engineer officers complained that Kennedy prepared air field layouts from his office in Washington, D.C., without ever having visited the site, and dabbled in design.

TABLE 10: WORLD WAR II ARMY AIRFIELDS NOW ACTIVE DoD INSTALLATIONS

Original Name	Current Name	Location	Date Established
Hurlbert Field	Eglin AFB Auxiliary Field #9	FL	1943
Altus Army Air Field	Altus AFB	OK	1942
Camp Springs Air Base	Andrews AFB	MD	1943

Barksdale Field	Barksdale AFB	LA	1930
Del Valle Airfield	Bergstrom AFB	TX	1942
Blytheville Air Field	Blytheville AFB	AR	1942
Bolling Field	Bolling AFB	DC	1917
Brooks Field	Brooks AFB	TX	1918
Clovis Air Field	Cannon AFB	NM	1942
Tarrant Field	Carswell AFB	TX	1942
Merced Field	Castle AFB	CA	1941
Chanute Field	Chanute AFB	IL	1917
Charleston Field	Charleston AFB	SC	1941
Columbus Field	Columbus AFB	MS	1941
Davis-Monthan Field	Davis-Monthan AFB	AZ	1940
Cobb County Field	Dobbin AFB	GA	1943
Dover Army Air Base	Dover AFB	DE	1941
Abilene Air Base	Dyess AFB	TX	1942
Muroc Army Air Field	Edwards AFB	CA	1933
Eglin Field	Eglin AFB	FL	1935
Mile 26 Satellite Field	Eielson AFB	AK	1943
Rapid City Air Base	Ellsworth AFB	SD	1942
Elmendorf Air Field	Elmendorf AFB	AK	1940
Alexandria Air Base	England AFB	LA	1943

Victorville Air Field	George AFB	CA	1941
San Angelo Flying Field	Goodfellow AFB	TX	1940
Gunter Air Field	Gunter AFB	AL	1940
Bedford Air Field	Hanscom AFB	MA	1942
Hickam Field	Hickam AFB	HI	1935
Alamogordo Air Field	Holloman AFB	NM	1942
Homestead Air Field	Homestead AFB	FL	1942
Biloxi Air Corps School	Keesler AFB	MS	1941
Kelly Field	Kelly AFB	TX	1917
San Antonio Cadet Center	Lackland AFB	TX	1941
Langley Field	Langley AFB	VA	1916
Laughlin Air Field	Laughlin AFB	TX	1942
Lowry Field	Lowry AFB	CO	1937
Litchfield Park Air Base	Luke AFB	AZ	1941
MacDill Field	MacDill AFB	FL	1939
Great Falls Air Field	Malstrom AFB	MT	1942
March Field	March AFB	CA	1918
Mather Field	Mather AFB	CA	1918
Maxwell Field	Maxwell AFB	AL	1918
Yuma Army Air Field	MCAS Yuma	AZ	1941
McChord Field	McChord AFB	WA	1940

Wichita Air Base	McConnell Air Force Base	KS	1942
Fort Dix Air Field	McGuire AFB	NJ	1937
Moody Field	Moody AFB	GA	1941
Mountain Home Air Field	Mountain Home AFB	ID	1942
Myrtle Beach Air Field	Myrtle Beach AFB	SC	1941
Las Vegas Air Field	Nellis AFB	NV	1941
San Bernardino Air Field	Norton AFB	CA	1942
Air Support Command Base	Peterson AFB	CO	1942
Pope Field	Pope AFB	NC	1919
Randolph Field	Randolph AFB	TX	1930
Lubbock Army Air Field	Reese AFB	TX	1941
Napier Army Air Field	Fort Rucker	AL	1940
Scott Field	Scott AFB	IL	1917
Seymore Johnson Field	Seymore Johnson AFB	NC	1942
Shaw Field	Shaw AFB	SC	1941
Shemya Army Air Field	Shemya AFB	AK	1943
Sheppard Field	Sheppard AFB	TX	1941
Fairfield-Suisun Air Base	Travis AFB	CA	1943
Tyndall Field	Tyndall AFB	FL	1941
Enid Army Flying School	Vance AFB	OK	1941
Westover Field	Westover AFB	MA	1939

Wheeler Field	Wheeler AFB	HI	1922
Sedilia Glider Base	Whiteman AFB	MO	1942
Mesa Military Airport	Williams AFB	AZ	1941
Wright Field	Wright-Patterson AFB	OH	1927
Patterson Field	Wright Patterson AFB	OH	1931
Oscoda Army Air Field	Wurtsmith AFB	MI	1924

Source: Robert Mueller, Air Force Bases: Active Air Force Bases Within the United States of America on 17 September 1982 (Washington, D.C.: Government Printing Office, 1989).

By early 1942, however, cooperation between the Air Corps and the Corps of Engineers became the hallmark of construction operations and the Air Corps began to restructure their headquarters for wartime operations. Congress recognized the administrative and operational skills displayed by the Corps of Engineers and, on 16 December 1941, it transferred all construction functions to the Corps of Engineers.

With America's entry into World War II, the Air Corps suddenly assumed a new mission of anti-submarine warfare. German submarines threatened to sink British ships faster than they could be replaced, and the Allies sought a means to counter this threat. In pre-war planning, however, the Air Corps had not envisioned anti-submarine warfare as part of its operations, and therefore lacked a clearly defined doctrine for that type of operation. Nevertheless, since the Navy lacked the necessary land-based aircraft for coastal patrols, the Air Corps assumed this mission until the Navy could acquire the necessary aircraft.

The Air Corps worked to develop their aircraft to match the mission at hand and utilized coastal air facilities to their fullest extent. On 17 June 1942, the Air Corps established the 1st Sea-Search Attack Group (1st SSAG) at Langley Field, Virginia. The technical work of the 1st SSAG was vital to the success of the combined Army-Navy anti-submarine warfare campaign. Using devices tested by the Group, including the absolute altimeter, the magnetic anomaly detector, and radiosonic buoys, the Air Corps harassed and destroyed German U-boats both night and day. Anti-submarine squadrons operated from long established bases such as Langley, and from newly built air fields, such as Westover, Massachusetts, and Fort Dix Field (now McGuire AFB), New Jersey.

As the Air Corps shifted to a wartime footing operational requirements exceeded the capacity of existing bases. New additions to Air Corps facilities were constructed from less critical materials such as timber, masonry, or concrete, preferably timber. At smaller training fields, the standard four runway configuration was changed to two runways. The Air Corps directed that all construction on private land leased for the duration of the war be limited to temporary buildings, including hangars and control towers, except at tactical anti-submarine bases. The Air Corps Plans and Design Branch designed aircraft hangars based on the criteria that they be easily expandable to accommodate larger aircraft, use the least expensive type of door, have interior shops, and have access from both ends.

As early as 1941, the Air Corps planned to introduce a super heavy bomber into its inventory. The B-29 "Superfortress" could travel greater distances and carry heavier loads than any previous bomber. One of the problems associated with the new bomber was construction of runways that could accommodate the planes' heavy loads of up to 140,000 pounds. Existing highway construction theory had limited applicability for such demands, therefore the Corps of Engineers had to develop new construction techniques. Working with civilian engineers, especially experts in soil engineering, the Corps of Engineers pioneered new theories on the ability of soil to withstand pressure, and constructed runways with thicker bases of crushed stone. This research not only allowed the United States to employ the B-29 and later bombers, but it also contributed significantly to the growth of civilian aviation after the war.

The final blow to Japan came with the use of the atomic bomb in Hiroshima and Nagasaki in August 1945. The specially organized 509th Composite Group delivered the atomic bomb. To prepare for its mission, the Group initiated a program of secret training using B-29 bombers at Wendover Field, Utah, to practice the delivery of the exceptionally heavy load. The success and secrecy of the operation attested to the successful training program.

From 1938 to 1945, the war cost approximately 350 billion dollars, of which the Air Corps used an estimated 3.2 billion dollars for the construction and leasing of facilities. In cooperation with the Quartermaster Corps Construction Branch, and later the Corps of Engineers, the Air Corps expanded from a handful of facilities in 1939 to a peak of 783 operational facilities by the war's end. Of these 345 were main bases, 116 were sub-bases, and 322 were auxiliary fields.

Navy and Marine Corps Air Stations

During the inter-war years, naval aviation occupied an important position, but was decidedly secondary to the Navy's battleships. As late as 1940, a Navy War College study emphasized that 1,200 aircraft were required to carry as much ordnance as one battleship, while downplaying the greater range of carrier-based aviation. The successful Japanese attack upon Pearl Harbor, followed by the critical role of naval aviation in the battles of Coral Sea and Midway, suddenly placed naval aviation at the forefront of the war in the Pacific. The expansion of Navy aviation facilities was commensurate with the growth of the Navy's air arm. In 1939, the Navy operated 11 air stations and 8 reserve bases; by the war's end, the Navy included nearly 80 air stations and numerous satellite fields. The Navy divided its aviation program into three types: Navy heavier-than-air (HTA); Navy lighter-than-air (LTA); and, Marine Corps heavier-than-air. The Navy HTA program was further divided into seaplanes and landplanes.

During the 1920s and 1930s, the Navy Department operated relatively few aviation facilities. Pensacola Naval Air Station had been the primary naval aviation training station since 1914. The San Diego Naval Air Station complemented Pensacola in training Navy and Marine Corps aviators. Operating air stations for the Navy and Marine Corps included facilities at Norfolk, Anacostia, and Quantico. Lighter-than-air installations at Lakehurst and Moffett Field completed the Navy's air stations. In keeping with the slow but steady growth of Navy aviation, each of these installations received minor improvements during the pre-war period.

During the late 1930s, the Navy began to improve its aviation installations as part of a general improvement program for its shore facilities. Eight new reserve air stations were added at Squantum, Massachusetts; New York, New York; Miami, Florida; Grosse Isle, Michigan; Glenview, Illinois; Minneapolis, Minnesota; St. Louis, Missouri; and, Oakland, California. These bases required minimal construction; buildings were limited to those that housed planes and personnel. Other West Coast air stations at Seattle, Washington; Alameda, California; and San Pedro, California, served as operational bases. As the probability of war with Japan increased, the Navy added to its aviation facilities in the

Pacific, most notably at Kaneohe Bay in Hawaii, and Sitka, Alaska. Existing installations also received additional funding.

With American mobilization in 1940, construction of Navy aviation facilities acquired a new urgency (Table 11). German submarine activity in the Atlantic Ocean prompted the Navy to establish more bases for seaplane patrols of the Atlantic. Stations with landing fields to train carrier pilots were also necessary. New stations built during the mobilization period included installations at Jacksonville and Banana River, Florida; Quonset Point, Rhode Island; Floyd Bennett Field, New York; and, Cape May, New Jersey, plus some smaller fields. The Navy assumed control of British bases in the Caribbean under President Roosevelt's plan to provide the British with 50 destroyers in exchange for rent-free leases on British bases in North and South America. By the end of June 1941, the Chief of the Bureau of Aeronautics reported that the Navy owned 13 East Coast stations, 10 Caribbean stations, 6 West Coast stations, 3 Alaskan stations, and 9 Pacific stations.

Despite significant increases in the number of air stations, America's entry into the war again required more bases. The Navy established a war time goal of 27,000 thousand aircraft, which required shore facility support, including training stations and bases for anti-submarine patrols.

TABLE 11: WORLD WAR II NAVAL AIR STATIONS

WWII Name	Current Name	Location	Date Established
Beeville Auxiliary Field	Naval Air Station Beeville	TX	1943
Cecil Auxiliary Field	Naval Air Station Cecil Field	FL	1941
Corry Auxiliary Field	Corry Station	FL	1931
Ellyson Auxiliary Field	N/A	FL	1941
Fallon Auxiliary Field	Naval Air Station Fallon	NV	1943
Floyd Bennett Field	N/A	NY	1940
Lee Field	Naval Air Station Jacksonville	FL	1940
Moffett Field*	Naval Air Station Moffett Field	CA	1931
Naval Air Facility Cold Bay	N/A	AK	1942
Naval Air Field Amchitka	N/A	AK	1943
Naval Air Station Akron	N/A	OH	1930
Naval Air Station Alameda	Naval Air Station Alameda	CA	1940

Naval Air Station Anacostia	Naval Station Anacostia	DC	1918
Naval Air Station Astoria (Tongue Point)	N/A	OR	1942
Naval Air Station Atlanta	N/A	GA	1940
Naval Air Station Atlantic City	N/A	NJ	1942
Naval Air Station Banana River	Patrick AFB	FL	1940
Naval Air Station Barbers Point	Naval Air Station Barbers Point	HI	1942
Naval Air Station Brunswick	N/A	GA	1942
Naval Air Station Brunswick	Naval Air Station Brunswick	ME	1942
Naval Air Station Bunker Hill	Grissom AFB	IN	1942
Naval Air Station Cape May	USCG Recruit Training Center	NJ	1942
Naval Air Station Charleston	Naval Base Charleston	SC	
Naval Air Station Clinton	N/A	OK	1942
Naval Air Station Corpus Christi	Naval Air Station Corpus Christi	TX	1940
Naval Air Station Daytona Beach	N/A	FL	1942
Naval Air Station DeLand	N/A	FL	1942
Naval Air Station Fort Lauderdale	N/A	FL	1942
Naval Air Station Glenview	Naval Air Station Glenview	IL	1942

Naval Air Station Glynco*	N/A	GA	1943
Naval Air Station Grand Prairie	Naval Air Station Dallas	TX	1940
Naval Air Station Grosse Isle	N/A	MI	1942
Naval Air Station Hitchcock*	N/A	TX	1943
Naval Air Station Houma*	Naval Air Station New Orleans	LA	1943
Naval Air Station Hutchinson	N/A	KS	1942
Naval Air Station Jacksonville	Naval Air Station Jacksonville	FL	1940
Naval Air Station Klamath Falls	N/A	OR	1943
Naval Air Station Kaneohe Bay	MCAS Kaneohe Bay	HI	1939
Naval Air Station Key West	Naval Air Station Key West	FL	1941
Naval Air Station Kingsville	Naval Air Station Kingsville	TX	1943
Naval Air Station Lake City	N/A	FL	1942
Naval Air Station Lakehurst*	Naval Air Warfare Center Lakehurst	NJ	1925
Naval Air Station Los Alamitos	Los Alamitos Reserve Center	CA	1941
Naval Air Station Melbourne	N/A	FL	1942
Naval Air Station Memphis	Naval Air Station Memphis	TN	1942
Naval Air Station Miami	N/A	FL	1940

Naval Air Station Miami	CGAS Operations Locka	FL	1942
Naval Air Station Minneapolis	N/A	MN	1942
Naval Air Station New York	CGAS New York	NY	1941
Naval Air Station New Orleans	Naval Air Station New Orleans	LA	1940
Naval Air Station Norfolk	Naval Air Station Norfolk	VA	1918
Naval Air Station Norman	N/A	OK	1942
Naval Air Station Oakland	N/A	CA	late 1930s (reserve)
Naval Air Station Olathe	NAVAIRRESCEN Olathe	KS	1942
Naval Air Station Ottumwa	N/A	IA	1942
Naval Air Station Pasco	N/A	WA	1942
Naval Air Station Patuxent River	Naval Air Station Patuxent River	MD	1942
Naval Air Station Pensacola	Naval Air Station Pensacola	FL	1914
Naval Air Station Peru	N/A	IN	1942
Naval Air Station Quonset Point	N/A	RI	1940
Naval Air Station Richmond*	N/A	FL	1943
Naval Air Station St. Louis	N/A	MO	1930s
Naval Air Station San Diego	Naval Air Station North Island	CA	1919
Naval Air Station San Pedro (Reeves Field)	N/A	CA	1938

Naval Air Station Santa Ana*	Marine Corps Air Station Tustin	CA	1942
Naval Air Station Seattle (Sand Point)	N/A	WA	1938
Naval Air Station Sitka	N/A	AK	1939
Naval Air Station South Weymouth*	Naval Air Station South Weymouth	MA	1943
Naval Air Station Squantum	N/A	MA	ca. 1935 (reserve)
Naval Air Station Tillamook*	N/A	OR	1943
Naval Air Station Vero Beach	N/A	FL	1942
Naval Air Station Washington	Naval Station Anacostia	DC	1918
Naval Air Station Weeksville*	CGAS Elizabeth City	NC	1942
Naval Air Station Whidbey Island	Naval Air Station Whidbey Island	WA	1941
Naval Air Station Willow Grove	Naval Air Station Willow Grove	PA	1942
Naval Auxiliary Air Station Oceana	Naval Air Station Oceana	VA	1941
Saufley Auxiliary Field	Naval Training Center Saufley	FL	1942
Whiting Auxiliary Field	Naval Air Station Whiting Field	FL	1942

* Indicates lighter-than-air (LTA) facilities

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.: Government Printing Office, 1947).

Because existing reserve stations provided insufficient facilities, the Navy opened new training stations at such locations as Norman, Oklahoma; Memphis, Tennessee; Corpus Christi, Texas; Pasco, Washington; Peru, Indiana; Olathe, Kansas; Hutchinson, Kansas; Clinton, Oklahoma; and, Ottumuwa, Iowa.

Construction at these installations consisted of temporary buildings to the maximum extent possible, often even constructing temporary wooden hangars.

At the outset of the war, Navy aviation consisted of carrier aircraft and seaplanes. The service did not include land-based aircraft suitable for anti-submarine patrols. Consequently, Navy anti-submarine patrols used Catalina seaplanes, despite their operational limitations. For the first years of the war, anti-submarine patrols were a joint effort of the Navy and Army Air Forces, while the Navy rapidly acquired suitable land-based aircraft. In September 1943, the Army Air Forces withdrew from anti-submarine warfare and transferred their radar equipped B-24 bombers to the Navy. The Navy assumed full responsibility for anti-submarine patrols.

The Navy's lighter-than-air (LTA) program was applied in the anti-submarine mission. The Navy had abandoned its huge rigid airships, known as dirigibles, following a series of accidents during the 1930s. Dirigibles were replaced by smaller airships, called blimps, which were less vulnerable to weather and accidents. The ability of blimps to remain aloft for long periods of time at a slow speed seemed to make them ideal platforms for anti-submarine warfare.

At the beginning of the war, the Navy's two lighter-than-air stations, Lakehurst Naval Air Station, New Jersey, and Moffett Naval Air Station, California, were expanded with new hangars to accommodate more blimps. In addition, the Navy constructed new lighter-than-air stations at South Weymouth, Massachusetts; Weeksville, North Carolina; Glynco, Georgia; Richmond, Florida; Houma, Louisiana; Hitchcock, Texas; Santa Ana, California; and, Tillamook, Oregon. The stations at South Weymouth and Weeksville contained steel-frame hangars, which could hold six blimps. All other stations used timber hangars because of steel shortages. Like their steel counterparts, these hangars housed six blimps, making them among the largest timber structures built.

In practice, the effectiveness of blimps against submarines was difficult to assess. Critics pointed to the fact that blimps were not credited with sinking a single submarine and complained that their high visibility warned submarines. Naval historian Samuel Elliot Morrison noted that some Navy officers characterized blimps as "worse than useless." Yet supporters of the lighter-than-air program argued that blimps performed an invaluable service by deterring submarine attacks, pointing to the fact that not one ship escorted by blimps was lost to submarines. Assessing the contribution of blimps to anti-submarine operations is complicated by the fact they were not introduced in large numbers until the middle of 1943, after the worst submarine menace had passed. The slow speed of blimps also allowed them to perform search and rescue or mine sweeping operations.

The Marine Corps continued to employ its own aviation in close support of Marine Corps ground forces. The rapid expansion of Marine Corps aviation required a commensurate expansion of its air stations, which were used primarily to train aviators (Table 12). Prior to the war, the Marine Corps maintained air stations at Quantico, Virginia, and Parris Island, South Carolina; these facilities were improved in 1940. In 1941, the Marine Corps initiated construction at a major new facility near Cherry Point, North Carolina. Most of the buildings at Cherry Point were semi-permanent construction, with brick and steel used for the aircraft storehouse. In 1943, the Marine Corps began construction of temporary auxiliary airfields near Cherry Point. In California, the Marine Corps built El Toro, El Centro, and Mojave Air Stations, using wood frame construction.

TABLE 12: WORLD WAR II MARINE CORPS AIR STATIONS

WWII Name	Current Name	Location	Date Established
MCAS Cherry Point	MCAS Cherry Point	NC	1941
MCAS Eagle Mountain Lake	N/A	TX	1942
MCAS Edenton	N/A	NC	1942
MCAS El Centro	Naval Air Station El Centro	CA	1942
MCAS El Toro	MCAS El Toro	CA	1942
MCAS EWA	N/A	HI	1941
MCAS Mojave	N/A	CA	1942
MCAS Quantico	USMC Education and Development Command	VA	1919
MCAS Santa Barbara	N/A	CA	1942
Page Field (Parris Island)	MCRD Parris Island	SC	1919

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.: Government Printing Office, 1947).

Storage and Logistics Functions

Extensive depot systems served both the War and Navy Departments to hold materiel for long term storage, to serve the needs of units within the United States, and to support the movement of materiel overseas. Depots served a variety of purposes, including storage of ammunition, general supplies, communications equipment, and engineering equipment. Both Army and Navy depots can be divided into those depots that stored ammunition or explosives, and those depots that held other supplies. Safety requirements for ammunition storage resulted in distinctive depot plans and building design, which are discussed in Chapter XI.

Unlike ammunition, most military supplies were not hazardous materials and did not require specialized storage facilities or specialized handling. All categories of supplies required storage prior to distribution within the United States or overseas. Both the War and Navy Departments created extensive depot systems to receive, store, and issue supplies exclusive of ammunition. The War Department was also responsible for moving large numbers of troops to and from the front lines through a series of ports of embarkation.

War Department

War Department logistical policy provided for distribution systems that were maintained by each of the technical branches, in addition to general depots. The Ordnance Department, Quartermaster Corps, and Air Corps operated the largest number of depots, while the Signal Corps, Corps of Engineers, and Chemical Warfare Service operated much smaller logistical systems (Table 13).

The Ordnance Department required an extensive distribution system for non-explosive materiel, because of its responsibility for the procurement and distribution of tanks, artillery, small arms and other weapons, plus the repair parts needed to maintain the weapons. The logistical problems became acute after the Ordnance Department acquired responsibility for all types of motor vehicles. Pre-war contingency plans called for the maximum use of leased civilian warehouses but the design of civilian facilities presented additional problems for the Ordnance Department. Multi-story civilian warehouses were ill-suited for the storage of tanks or heavy equipment. Moreover, the Ordnance Department foresaw the need for long term equipment storage after the end of the emergency. While the War Department headquarters agreed to de-emphasize leasing of civilian facilities, authorizations for construction of general storage ordnance depots were not forthcoming. The Ordnance Department, therefore, built general purpose storage facilities at ammunition depots.

In 1941, as shipments of combat equipment increased, funding became available for permanent warehouse construction. The Ordnance Department constructed a depot at Ogden, Utah, which contained 40 general ordnance warehouses. In the Southeast, the Ordnance Department expanded the warehouse capacity at Anniston, Alabama, to support increased Army activities in that region. A large warehouse was constructed at Rock Island Arsenal, Illinois, for the storage of general ordnance supplies. Thereafter, as shortages of building materials and money increased, the War Department relaxed specifications for warehouse construction. New ordnance warehouses were constructed using temporary, or even theater-of-operations design and located at existing ammunition depots.

The Quartermaster Corps also faced the problem of storage and transportation of large quantities of supplies. Because nearly all of these supplies were non-explosive, the Quartermaster Corps had greater flexibility in the organization of its depots. Perhaps the most striking difference between Ordnance and Quartermaster depots was the size of the facilities. Quartermaster depots ranged from 100 to 800 acres, while Ordnance depots could be as large as 20,000 acres.

TABLE 13: WORLD WAR II ARMY DEPOTS (NON-ORDNANCE)

Original Name	Current Name	Location	Date Established	Type of Depot
Fairfield Air Depot	Wright-Patterson AFB	OH	1918	Army Air Forces
Galena Field	Fairchild AFB	WA	1942	Army Air Forces
Middletown Air Depot	N/A	PA	N/A	Army Air Forces
Midwest Air Depot	Tinker AFB	OK	1941	Army Air Forces

Sacramento Air Depot	McClellan AFB	CA	1936	Army Air Forces
Rome Air Depot	Griffiss AFB	NY	1942	Army Air Forces
San Antonio Air Depot	Kelly AFB	TX	1921	Army Air Forces
Robins Field	Robins AFB	GA	1941	Army Air Forces
Ogden Air Depot	Hill AFB	UT	1940	Army Air Forces
Atlanta Army Depot	N/A	GA	1941	Army Service Forces
Belle Mead Army Depot	N/A	NJ	1941	Army Service Forces
Columbus Army Depot	Defense Construction Supply Center	OH	1918	Army Service Forces
Memphis Army Depot	Memphis Defense Depot	TN	1941	Army Service Forces
New Cumberland Army Depot	New Cumberland Army Depot	PA	1918	Army Service Forces
Richmond Army Depot	Defense General Supply Center	VA	1941	Army Service Forces
Salt Lake City Army Depot	N/A	UT	1941	Army Service Forces
San Antonio Army Depot	Fort Sam Houston	TX	1876	Army Service Forces
Savannah Army Depot	N/A	GA	unknown	Army Service Forces
Schenectady Army Depot	N/A	NY	1918	Army Service Forces
Seattle Army Depot	N/A	WA	1941	Army Service Forces

Deseret Chemical Warfare Depot	Tooele Army Depot	UT	1942	Chemical Warfare Service
Eastern Chemical Warfare Depot	Edgewood Area, Aberdeen Proving Ground	MD	1940	Chemical Warfare Service
Gulf Chemical Warfare Depot	Redstone Arsenal	AL	1941	Chemical Warfare Service
Northeast Chemical Warfare Depot	N/A	NY	1942	Chemical Warfare Service
Midwest Chemical Warfare Depot	Pine Bluff Arsenal	AR	1941	Chemical Warfare Service
Albany Engineer, Depot	N/A	NY	unknown	Corps of Engineers
Granite City Engineer Depot	N/A	IL	1942	Corps of Engineers
Lathrop Engineer Depot	Sharpe Army Depot	CA	1942	Corps of Engineers
Marion Engineer Depot	N/A	OH	unknown	Corps of Engineers
Pasco Engineer Depot	N/A	WA	unknown	Corps of Engineers
San Bernardino Engineer Depot	N/A	CA	unknown	Corps of Engineers
Sharonsville Engineer Depot	N/A	OH	unknown	Corps of Engineers
Alexandria QM Depot (Cameron Station)	N/A	VA	1942	Quartermaster
Boston QM Depot	N/A	MA	1918	Quartermaster

Charlotte QM Depot	N/A	NC	unknown	Quartermaster
Chicago QM Depot	N/A	IL	unknown	Quartermaster
Fort Holabird QM Depot	U.S. Army Intelligence School	MD	1917	Quartermaster
Fort Reno QM Depot	N/A	OK	1874	Quartermaster
Fort Worth QM Depot	N/A	TX	1940	Quartermaster
Jeffersonville QM Depot	Jeffersonville Depot Activity	IN	1864	Quartermaster
Jersey City QM Depot	N/A	NJ	unknown	Quartermaster
Kansas City QM Depot	N/A	MO	unknown	Quartermaster
Oakland QM Depot	Oakland Army Base	CA	1941	Quartermaster
Philadelphia QM Depot	N/A	PA	unknown	Quartermaster
Washington QM Depot	N/A	DC	unknown	Quartermaster
Chicago Signal Depot	N/A	IL	unknown	Signal Corps
Dayton Signal Depot	N/A	OH	unknown	Signal Corps
Lexington Signal Depot	Lexington Army Depot	KY	unknown	Signal Corps
Ogden Signal Depot	Defense Depot Ogden	UT	1940	Signal Corps

Philadelphia Signal Depot	N/A	PA	unknown	Signal Corps
San Bernadino Signal Depot	N/A	CA	unknown	Signal Corps
Sacramento Signal Depot	Defense Depot Sacramento	CA	1942	Signal Corps

Source: Risch, Erna, The Quartermaster Corps: Organization, Supply, and Services (Washington, D.C.: Government Printing Office, 1953).

As early as September 1939, the Quartermaster General initiated plans for the expansion of the 12 existing depots. These plans did not achieve real momentum until the protective mobilization efforts of 1940, when the Army made additions to existing depots and constructed new facilities. By December 1941, the Quartermaster Corps increased its covered storage space by 50 per cent over the previous year. Existing storage space proved inadequate once war was declared, and the Quartermaster Corps increased its construction even further. This accelerated construction pace continued until May 1943 when the Army Service Forces terminated all depot construction, except for compelling circumstances.

The design of the Quartermaster depots also reflected the increasing shortage of building materials. During the protective mobilization phase, depots were comprised of single story warehouses with concrete floors and lofty ceilings. Railroad loading platforms spanned one side of the structure, and truck loading doors were located on the opposite building face. Depots constructed after the declaration of war reflected the War Department's temporary construction policies. The Army relied more upon open sheds to provide minimal protection to durable supplies. Commercial warehouses were leased to supplement depots and ease the burden of constructing new warehouse facilities. Yet the advantages of leasing commercial warehouses for general supplies were limited. Often the best warehouses were occupied, or were so geographically dispersed to preclude efficient operations.

Leased commercial facilities were used more widely to store subsistence supplies. During the mobilization phase, the Quartermaster Corps established regional food purchasing centers, which were responsible for supplying food to troops within their region. The Quartermaster General contracted with civilian warehouses to store food prior to distribution. Despite controversies over prices, the system worked reasonably well for non-perishable subsistence, or foodstuffs that did not require refrigeration. The system was less effective for perishable food, and the Army suffered from a failure to construct more than a handful of depot level cold storage facilities. Leased commercial cold storage warehouses were seldom available in the quantities required by the Army. The problem became especially acute in the New York area, which was responsible for supplying the European theater.

In addition to depots that were dedicated to the Ordnance Department or Quartermaster Corps, the Army Service Forces operated several depots intended for multi-branch use. Ten such depots were operating by December 1941. They were located in Seattle, Washington; Salt Lake City, Utah; San Antonio, Texas; Memphis, Tennessee; Columbus, Ohio; Atlanta and Savannah, Georgia; Richmond, Virginia; Belle Mead, New Jersey; New Cumberland, Pennsylvania; and, Schenectady, New York. Between April and July 1942, the Army Service Forces directly managed these depots, but that management system became unworkable. Overall responsibility for General Depots was assigned to the Office of the Quartermaster General, which served as the "landlord" for the other branches. The technical services, such as Ordnance

Department, Quartermaster Corps, Corps of Engineers, and Signal Corps maintained respective storage areas, as well as their own stock record accounts. The Quartermaster Corps established general policies and assigned warehouse space. At the Atlanta General Depot, the Army Service Forces experimented with standardized and consolidated stock record accounts, but eventually abandoned the effort.

As technical services, the Corps of Engineers, Signal Corps, and Chemical Warfare Service maintained smaller depot systems that combined use of the general depots, leased storage facilities, and specially constructed depots. In addition to assigned space in the general depots, the Signal Corps managed its own depots in Philadelphia, Pennsylvania; Lexington, Kentucky; Dayton, Ohio; Chicago, Illinois; San Bernardino, California; and, Ogden, Utah. The Corps of Engineers operated similar depots at Albany, New York; Marion and Sharonsville, Ohio; Granite City, Illinois; San Bernardino and Lathrop, California; and, Pasco, Washington.

The Chemical Warfare Service initially established depots near its principal arsenals at Edgewood, Maryland; Huntsville, Alabama; and, Pine Bluff, Arkansas. These depots were in the planning stages at the time of Pearl Harbor, and were not placed in service until the fall of 1942. Despite these new depots, the Chemical Warfare Service still required more storage facilities. In early 1942, the service constructed the Deseret [sic] Chemical Warfare Depot in Tooele County, Utah. Late in the war, the Chemical Warfare Service acquired the Lake Ontario Ordnance Works in New York as an additional depot. A leased warehouse in Indianapolis for repair parts completed its depot system.

The Materiel Division of the Army Air Forces maintained the system of separate depots for aviation specific supplies. The Air Corps operated four major supply and maintenance depots in 1939. These depots were located in Middletown, Pennsylvania; San Antonio, Texas; Fairfield, Ohio; and Sacramento, California. The facility in Sacramento, established in 1936, was the newest Air Corps Depot. All four depots stored aircraft and repair parts, plus performed extensive overhaul of engines and equipment. Robins and Tinker Air Force Bases opened in 1941 under the Protective Mobilization Plan. As in the case of the other Army Air Force depots, these facilities served both supply and maintenance functions, that were housed in buildings whose construction combined both permanent and temporary construction.

The history of the Fairfield and San Antonio Depots illustrates typical changes to existing Air Corps facilities during the World War II era. Fairfield Air Depot, at what is now Wright-Patterson Air Force Base, became a key depot for aircraft and repair parts. The depot was expanded through large scale temporary and permanent construction. Some of the most notable permanent structures included a new engine overhaul building and a new base headquarters building. The civilian work force grew so rapidly that a new housing project, Skyway Park, was built to accommodate the workers. San Antonio Depot, at what is now Kelly Air Force Base, became a huge industrial complex. Workers established production lines to overhaul engines, bombsights, guns, and electrical equipment. Like the Fairfield Depot, it enlarged its work force tremendously, largely through the addition of women war workers.

Hill Air Force Base, near Ogden, Utah, is an example of an Air Corps depot that began operations during the World War II era. Authorized in 1939, the depot was planned as part of a general expansion in the nation's air component. Construction of the Utah depot began in January 1940. Because the installation originated as part of a permanent expansion program, initial construction consisted of brick and other masonry buildings similar to the Army's building designs of the inter-war years. As the war progressed, temporary buildings were constructed where possible, especially for barracks and administration buildings. Still, some structures required permanent construction because of their function. Examples of permanent construction projects included warehouses, hangars, engine test facilities, and maintenance facilities. The installation contained a new housing complex known as Hillcrest Village.

Missions of the Ogden depot encompassed both supply and maintenance functions. With the first construction just completed by December 1941, the depot contained only a few empty warehouses and stock record paperwork. After the United States entered the war, activity at the Ogden Depot mushroomed. The depot stored aircraft repair parts and Air Corps-specific equipment for units in the United States and overseas. In January 1942, the depot opened an engine test facility to support the engine rebuilding program. The largest single maintenance project began in February 1943 with the complete overhaul of B-24 "Liberator" bombers. The depot established a production line for rebuilding used aircraft from Europe and the Pacific for active service. By the close of 1943, Ogden Depot was repairing one bomber per day.

Another logistical function of the War Department was the transporting of large numbers of troops to the front lines. Army ports of embarkation were located on both the Atlantic and Pacific coasts to facilitate the movement of personnel and materiel overseas. These activities combined leased civilian structures and temporary military construction, supplemented by permanent construction only when necessary. For example, at the Hampton Roads Port of Embarkation, the principal piers, wharfs, warehouses, and related facilities for moving non-explosive supplies were leased. Ammunition facilities, however, required permanent construction. To accommodate the mass of transient service personnel, the Army constructed Camp Patrick Henry north of the port, using temporary construction.

Navy Department

Similar to the War Department, the Navy Department developed an extensive system of supply depots for the receipt, storage, and issue of general supplies (Table 14). At the beginning of the war, the Navy Department had only two operating supply depots, which were located in Norfolk and San Diego. Their proximity to the major bases on the Atlantic and Pacific coasts enabled these depots to support to the fleet. The expanded operations of World War II, required rapid expansion of the Navy's supply storage facilities.

In 1940, construction began on two supply depots located near major bases. These facilities were located in Bayonne, New Jersey, and Oakland, California. At the same time, the existing Norfolk and San Diego depots received funding for additional buildings. As the war progressed, the Navy established new supply depots along the coasts, and near the major naval installations. In some cases, such as the New Orleans Depot, civilian warehouses were leased or converted. Other facilities, such as the depot at Newport, Rhode Island, were additions to existing installations.

In 1941, the Navy initiated a new approach to its distribution system, and began to select depot sites that were not adjacent to a specific port or base. The first such depot was located in Mechanicsburg, Pennsylvania, and was positioned to provide back-up support to all Navy installations on the East Coast. The Mechanicsburg Depot was sited near the Army's New Cumberland Depot to encourage cooperation between the two services. In 1942, the Navy Department established inland supply depots at Clearfield, Utah, and Spokane, Washington, to service bases along the Pacific Coast. Near Barstow, California, the Navy Department created a storage depot for Marine Corps supplies. The Navy built the Scotia Depot near Schenectady, New York, to complement the Mechanicsburg depot in supporting the East Coast ports.

Like other Navy construction projects, the creation of a supply depot system occurred at a time when rapidly changing requirements presented new challenges for orderly development. For example, two weeks after construction began at the Mechanicsburg Depot, the Bureau of Supplies and Accounts requested that the capacity of the depot be doubled. Warehouses were often multi-story buildings , or else masonry and steel single-story buildings. The transportation infrastructure including roads, railroads, and loading docks, was a prerequisite to construction.

TABLE 14: WORLD WAR II NAVY AND MARINE CORPS GENERAL SUPPLY DEPOTS (NON-ORDNANCE)

Original Name	Current Name	Location	Date Established
Marine Corps Supply Depot Barstow	MARCORSUPDEP Barstow	CA	1942
Marine Corps Supply Depot Philadelphia	N/A	PA	1904
Marine Corps Supply Depot San Francisco	N/A	CA	1923
Naval Supply Depot Bayonne	Naval Supply Center Bayonne	NJ	1939
Naval Supply Depot Clearfield	NSD Clearfield	UT	1942
Naval Supply Depot Mechanicsburg	Naval Supply Center Mechanicsburg	PA	1942
Naval Supply Depot New Orleans	NSD New Orleans	LA	1940
Naval Supply Depot Newport	N/A	RI	1942
Naval Supply Depot Norfolk	FISC Norfolk	VA	1917
Naval Supply Depot Oakland	NSD Oakland	CA	1942
Naval Supply Depot San Diego	NSC San Diego	CA	1922
Naval Supply San Pedro	N/A	CA	1942
Naval Supply Depot Scotia	NSD Scotia	NY	1941
Naval Supply Depot Seattle	N/A	WA	1942
Naval Supply Depot Spokane	N/A	WA	1942

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.:

Government Printing Office, 1947).

Research, Development, and Testing

More than in previous conflicts, World War II demonstrated the importance of technological superiority. New or improved weapons were a significant advantage. The extent of the research performed during World War II is indicated by the fact that seventy-five per cent of the ordnance equipment used by the Army either was replaced completely or radically improved. The government undertook complex research and development functions in specially designed buildings at installations across the country. The unique requirements of the various research and development projects resulted in a wide range of permanent construction that cannot be characterized easily. Some construction resulted in general laboratories or office buildings, while other properties associated with research, development and testing were the product of specific designs required for the specialized activities performed at the facilities.

Within the War Department, research and development functions were divided among the various departments, principally the Ordnance Department, the Air Corps, and the Signal Corps, as well as smaller programs operated by other branches. The Ordnance Department undertook research on many types of weapons, including aviation weapons, at its proving grounds. Wright Field served as a principal engineering center for the Air Corps. The Army's communication laboratory at Fort Monmouth was the Signal Corps' research and development center.

Aberdeen Proving Ground, Maryland, was the Army's only proving ground from 1917 to World War II. Here, Ordnance Department personnel performed acceptance testing for new weapons with approved designs and development testing for new types of weapons. During the inter-war years, a single proving ground was sufficient to meet the Army's needs, but one proving ground could not accommodate the wartime expansion of research and development activity. New proving grounds such as Erie Proving Ground, Ohio; Jefferson Proving Ground, Indiana; and, Southwestern Proving Ground, Arkansas performed acceptance testing of weapons and ammunition.

Aberdeen became the primary center for developmental testing of new weapons and equipment. The Army tested new artillery, tanks, rockets, aerial bombs, trucks, and all types of new weapons at Aberdeen. During the second half of 1944, the Arms and Ammunition Division at Aberdeen completed 1,466 test projects and submitted 183 formal reports. Workers there invented such new weapons as a shoulder launched anti-tank rocket, popularly known as the bazooka. Research required new buildings. A recent survey of Aberdeen Proving Ground identified 34 research facilities and 19 test facilities constructed as permanent buildings at Aberdeen between 1940 and 1945.

The Ballistics Research Laboratory at Aberdeen deserves special mention. The laboratory contained the most modern equipment for studying the movement of a projectile both within a gun barrel and while in flight. The three-story, brick R. H. Kent Building, another part of the laboratory, housed two supersonic wind tunnels to study the movement of aerial bombs and artillery shells. Scientists working here refined the design of critical weapons or developed new firing tables. Developing firing tables required extensive mathematical calculations; to simplify the process, scientists produced an elaborate electronic calculating machine. This machine, known as ENIAC, became the forerunner of the modern computer.

Since World War I, Fort Monmouth, New Jersey, had been the home of the Signal Corps, and served both training and research purposes. A radio research laboratory existed on the installation, but it was housed in wooden buildings until 1934. In that year, the first brick laboratory building was constructed, which was used for early experiments in radar development. In World War II, the research facilities were expanded with the addition of three more brick buildings in what is known as the "Evans Area," nine miles south of the main post. Here personnel developed a wide range of communications and electronic devices for the Army. In January 1946, Signal Corps personnel achieved a scientific milestone by bouncing radar signals off the moon.

Wilbur Wright Field, part of what is now Wright-Patterson Air Force Base, had served as an aeronautical engineering center for the Air Corps since 1927, under the Air Corps Materiel Division. With the reorganizations of the Air Corps during World War II, the Materiel Division was elevated to a separate command, with its responsibilities redefined to focus upon engineering. The Army constructed new facilities at Wright Field; including a massive new wind tunnel, laboratories, and testing facilities. The wind tunnel had a diameter of 20 feet, making it the largest wind tunnel built to that date. During the course of the war, these new testing facilities accelerated the procurement cycle for aircraft. During peacetime years, the Air Corps had followed extensive testing procedures on prototypes before purchasing quantities of an aircraft model. The demands of war necessitated the purchase of new aircraft models as soon as possible. Production orders frequently were written before a prototype was tested. To make this system work, the Air Corps relied heavily upon testing of models in the wind tunnel and testing of components in the laboratories.

Of the smaller research and development programs, the Army's Chemical Warfare Service used the facilities of the Massachusetts Institute of Technology and Columbia University for most of its basic research. In each case, leased laboratories became temporary government facilities. The Army still required a remote location for testing of chemical munitions, so it acquired an extensive proving ground in the Dugway Valley of Utah.

The Quartermaster Corps utilized its depots for the research and development that it conducted during the war. Testing was required for the clothing, footwear, tentage, and personal equipment that soldiers used in climates that varied from extremely cold to tropical. After the war, the Quartermaster General concluded that the Quartermaster Corps might have produced better equipment with a facility devoted exclusively to the research and development of Quartermaster equipment. The Army subsequently persuaded Congress to authorized Natick Laboratories in Massachusetts for this type of research.

The Navy Department also maintained an active research and development program during World War II. Its programs covered all aspects of naval development, including ship design, naval ordnance, aviation, and rocket development. Older installations, such as the Communications Laboratory in Anacostia, District of Columbia, or the Naval Proving Ground at Dahlgren, Virginia, were improved. Important new installations were established during the war including the Naval Ordnance Test Station Inyokern (better known as China Lake), White Oak Naval Ordnance Laboratory, and the David Taylor Model Basin.

Prior to World War II, the Naval Proving Ground at Dahlgren devoted most of its attention to proof-firing new guns. Heavy weapons were manufactured at the Naval Gun Factory in Washington, shipped to Dahlgren by barge, and then test fired to establish the gunnery tables. Workers at the installation also performed limited experiments with new weapons and equipment, and played a key role in developing the Norden Bombsight.

With America's entry into the war, activity at Dahlgren expanded to a frantic pace, with a commensurate increase in construction activities. The installation tested heavy ships guns, machine guns, ships armor, ammunition, aviation ordnance, and other equipment. The importance of Dahlgren as a testing ground for the variable time fuze, which consisted of a miniature radar, was particularly noteworthy. Equally important, Dahlgren began new laboratories during the war, beginning with an armor and projectile laboratory in 1941. Thereafter, Dahlgren expanded its laboratory work to include studies of gauges and measurements, aviation ordnance, rocketry, and trajectory calculations. The trajectory calculations resulted in the use of new electronic calculating machines that were the precursors of modern computers.

Since World War I, the Washington Navy Yard contained a Naval Ordnance Laboratory that concentrated upon research on underwater mines. With the expansions of World War II, however, the laboratory soon found its facilities inadequate. The Navy constructed an expanded Naval Ordnance Laboratory in White Oak, Maryland, near Washington D.C. Construction began on the 938 acre tract in early 1944; the fifty permanent structures were scheduled for completion in 1947. The installation contained laboratories, a wind tunnel, and associated facilities. Six of the buildings were designed to study magnetic influence mines, which were underwater mines triggered by a ship's magnetic field. Design specifications required buildings that were entirely free of magnetic properties. The laboratory buildings were constructed using hollow concrete block, instead of red clay tile, which contained iron oxide; copper or bronze was substituted for ferrous metals in the nails, plumbing, and electrical fixtures.

With its increasing reliance upon rockets and aviation weapons, the Navy sought a testing ground for rocket and aviation ordnance that would provide room for large scale testing. In March 1943, Navy officers found a suitable location at the small village of Inyokern in the middle of the California desert. The village contained a landing field and minimal utilities. A vast expanse of desert, including a dry lake bed known as China Lake, surrounded the village. Navy officers experimented with rockets and aircraft in seclusion, and the excellent flying weather guaranteed that the Navy could conduct tests during most of the year. In November 1943, the Navy began construction at the Naval Ordnance Test Station, Inyokern. The reservation covered a land area approximately the size of Rhode Island.

Due to the wartime shortages of materials and demands for speed, the station's original plans specified considerable temporary construction. The post-war Navy need for an ordnance test station influenced the modification of this program. The station commander and the officer-in-charge-of-construction decided to emphasize permanent construction. They developed a well-planned community in the desert, with space for future expansion. The installation included both laboratory facilities and a complete residential community. At Inyokern, scientists from the Navy and the California Institute of Technology created a first-class research and experimentation facility. In response to requests from combat units, they developed a High Velocity Aircraft Rocket (HVAR), which was commonly known as the "Holy Moses." This weapon proved to be particularly effective at penetrating concrete fortifications. Following the war, the station continued to be a leading center for rocket and missile experimentation.

The Navy had used a model ship basin in the Washington Navy Yard to test new ship designs since the beginning of the twentieth century. To allow more accurate testing of ships' hulls, Congress authorized an improved model ship basin in 1936. Construction was not completed until the beginning of the World War II era. Located in Carderock, Maryland, just outside Washington, D.C., this facility was named the David W. Taylor Model Basin. The precise experimentation on the resistance of a ship moving through the water required a research facility built to the most exacting specifications. For example, carriages mounted on rails, towed ship models through the basin; specifications required that the 5,000 feet of rail be constructed to a 0.005 inch tolerance in distance from the water in the basin. Achieving such unprecedented accuracy required that the builders adjust their measurements for the curvature of the earth. The engineers and builders met these requirements using a solid rock foundation and innovative construction techniques.

Other Navy ordnance installations combined research with production functions. For example, the Newport Torpedo Station and the Keyport Torpedo Station, both produced or overhauled torpedoes. The facility also tested new models and engineered improvements to existing models.

Medical Facilities

For both the War and Navy Departments, hospital construction required a balance between wartime material shortages and the desire to provide the best possible medical facilities. Not surprisingly, the Surgeons General of both services advocated permanent or semi-permanent construction, citing fire prevention and anticipated future use. The medical departments' desire for permanent construction met with little support from the Army and Navy leadership, who promoted temporary construction whenever possible.

War Department hospital construction fluctuated between temporary and semi-permanent construction (Table 15). Pre-war plans called for the expansion of existing hospitals, but existing facilities did not easily accommodate expansion. During the protective mobilization phase, the Army constructed hospitals resembling the temporary barracks built during these years. The hospital consisted of one-story wards, connected by extensive corridor systems. Later, the Surgeon General obtained permission to build semi-permanent brick hospitals, but the victory was short-lived. With the entry into the war, the Army Chief of Staff ordered that temporary construction be used for general and station hospitals. The Chief of Staff later imposed even more stringent economy measures on hospital construction, including "theater-of-operations" barracks for hospital personnel. As a further economy measure, the Army leased civilian hotels or other facilities to serve as hospitals.

As the war progressed, permanent and semi-permanent construction again became a possibility. By the summer of 1942, many locations suffered from lumber shortages, while brick and tile were available. Moreover, the Veterans Administration argued that Army hospitals should be designed for long-term care of veterans. Consequently, the Army constructed twenty-two semi-permanent general hospitals. Additionally, McGuire Hospital, Virginia, and Vaughan Hospital, Illinois, were designed in cooperation with the Veterans Administration for its use after the war. Twenty-four Army general hospitals, both temporary and permanent, were transferred to the Veterans Administration at the end of the war. Of the Army general hospitals that opened during World War II, 23 were of semi-permanent construction, 11 were converted civilian facilities, 22 were wooden cantonment hospitals, and 4 were masonry cantonment hospitals. Of the wartime semi-permanent general hospitals, only those near Fort Lewis, Fort Carson, and Camp Atterbury were retained in the Army inventory as of 1951.

Navy hospital construction consisted of a combination of new facilities and additions to existing hospitals (Table 16). Medical facilities at new training installations, such as Sampson, New York, or Farragut, Idaho, consisted entirely of temporary buildings. Other major wartime hospitals, such as St Albans, New York, or Corona, California, consisted entirely, or predominately, of temporary buildings. Existing hospitals were expanded through either permanent or temporary buildings. As in the case of the War Department, the Navy Department also faced pressure from the Veterans Administration to construct hospitals suitable for long term use. The Navy hospital at Dublin, Georgia, a brick, Colonial Revival style complex, was constructed to be transferred to the Veterans Administration after the war.

Some of the most noteworthy hospitals associated with World War II, were planned before the war, and opened during the World War II era. Fitzsimons Army Hospital, in Denver, Colorado, operated as a tuberculosis hospital since 1918. In 1938, the Army began construction on a new main building that opened just four days before the attack on Pearl Harbor. Victims of that battle were among some of its first patients. Brooke General Hospital, at Fort Sam Houston, opened as a permanent general hospital in September 1942. The Bethesda Navy hospital was authorized in the 1939 appropriations act; construction continued through the early war years. The main tower and hospital complex opened in April 1943. In 1942, even before the building was completed, construction began for two additional wards. These three general hospitals followed the precedent of recent civilian hospitals and adopted a centralized, multi-story tower design, rather than the one- to three-story, dispersed ward design of earlier and wartime hospitals.

TABLE 15: WORLD WAR II ARMY GENERAL HOSPITALS

WWII Name	Current DoD Name	Location	Date[1]
Army and Navy General Hospital	N/A	Hot Springs, AR	1887
Ashburn General Hospital	N/A	McKinney, TX	1943
Ashford General Hospital	N/A	White Sulphur Springs, WV	1942
Barnes General Hospital	N/A	Vancouver, WA	1941
Battey General Hospital	N/A	Rome, GA	1943
Baxter General Hospital	N/A	Spokane, WA	1943
Billings General Hospital	Ft. Benjamin Harrison	Ft. Benjamin Harrison, IN	1941
Birmingham General Hospital	N/A	Van Nuys, CA	1944
Borden General Hospital	N/A	Chickasha, OK	1943
Brooke General Hospital	Ft. Sam Houston	Ft. Sam Houston, TX	1942
Bruns General Hospital	N/A	Santa Fe, NM	1943
Bushnell General Hospital	N/A	Brigham City, UT	1942
Crile General Hospital	N/A	Cleveland, OH	1944
Cushing General Hospital	N/A	Framingham, MA	1944
Darnall General Hospital	N/A	Danville, KY	1942
Deshon General Hospital	N/A	Butler, PA	1942
DeWitt General Hospital	N.A	Auburn, CA	1944

Dibble General Hospital	N/A	Menlo Park, CA	1944
Finney General Hospital	N/A	Thomasville, GA	1943
Fitzsimons General Hospital	Fitzsimons Army Medical Center	Aurora, CO	1918
Fletcher General Hospital	N/A	Cambridge, OH	1943
Foster General Hospital	N/A	Jackson, MS	1943
Gardiner General Hospital	N/A	Chicago, IL	1943
Glennan General Hospital (POW)	N/A	Okmulgee, OK	1943
Halloran General Hospital	N/A	Willowbrook, S.I., NY	1942
Hammond General Hospital	N/A	Modesto, CA	1942
Harmon General Hospital	N/A	Longview, TX	1942
Hoff General Hospital	N/A	Santa Barbara, CA	1941
Kennedy General Hospital	N/A	Memphis, TN	1943
LaGarde General Hospital	N/A	New Orleans, LA	1941
Lawson General Hospital	N/A	Atlanta, GA	1941
Letterman General Hospital	Letterman Army Medical Center	San Francisco, CA	1941
Lovell General Hospital	Ft. Devens	Ft. Devens, MA	1941
Madigan General Hospital	Madigan Army Medical Center	Tacoma, WA	1941
Mason General Hospital	N/A	Brentwood, L.I., NY	1943
Mayo General Hospital	N/A	Galesburg, IL	1944
McCaw General Hospital	N/A	Walla Walla, WA	1943

McCloskey General Hospital	N/A	Temple, TX	1942
McGuire General Hospital	N/A	Richmond, VA	1944
Moore General Hospital	N/A	Swannanoa, NC	1942
Newton D. Baker General Hospital	N/A	Martinsburg, WV	1944
Nichols General Hospital	N/A	Louisville, KY	1942
Northington General Hospital	N/A	Tuscaloosa, AL	1943
Oliver General Hospital	N/A	Augusta, GA	1943
O'Reilly General Hospital	N/A	Springfield, MO	1941
Percy Jones General Hospital	N/A	Battle Creek, MI	1943
POW General Hospital No.2	N/A	Camp Forrest, TN	1944
Rhoads General Hospital	N/A	Utica, NY	1943
Schick General Hospital	N/A	Clinton, IA	1943
Stark General Hospital	N/A	Charleston, SC	1941
Thayer General Hospital	N/A	Nashville, TN	1943
Thomas M. England General Hospital	N/A	Atlantic City, NJ	1943
Tilton General Hospital	Ft. Dix	Ft. Dix, NJ	1941
Torney General Hospital	N/A	Palm Springs, CA	1942
U.S. Army General Hospital, Camp Butner	N/A	Wilkins, NC	1945
U.S. Army General Hospital, Camp Carson	N/A	Colorado Springs, CO	1945

U.S. Army General Hospital, Camp Edwards	N/A	Falmouth, MA	1945
U.S. Army General Hospital, Camp Pickett	Fort Pickett	Blackstone, VA	1945
Valley Forge General Hospital	N/A	Phoenixville, PA	1943
Vaughan General Hospital	N/A	Hines, IL	1944
Wakeman General Hospital	N/A	Camp Atterbury, IN	1944
Walter Reed General Hospital	Walter Reed Army Medical Center	Washington, DC	1909
William Beaumont General Hospital	William Beaumont Army Medical Center	El Paso, TX	1921
Winter General Hospital	N/A	Topeka, KS	1943
Woodrow Wilson General Hospital	N/A	Staunton, VA	1943

[1] Date ready for or received first patient.

Source: Clarence McKittrick Smith, The Medical Department: Hospitalization and Evacuation, Zone of the Interior (Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1956): 304-313.

TABLE 16: WORLD WAR II NAVAL HOSPITALS

WWII Name	Current DoD Name	Location	Date[1] Established
U.S. Naval Hospital	U.S. Naval Academy Clinic	Annapolis, MD	1907
U.S. Naval Convalescent Hospital[2]	N/A	Asbury Park, NJ	1945
U.S. Naval Convalescent Hospital	N/A	Asheville, NC	1943

U.S. Naval Hospital	N/A	Astoria, OR	1943
U.S. Naval Hospital	N/A	Bainbridge, MD	1942
U.S. Naval Convalescent Hospital	N/A	Banning, CA	1944
U.S. Naval Convalescent Hospital	N/A	Beaumont, CA	1944
Naval Medical Center	Bethesda Naval Medical Center	Bethesda, MD	1939
U.S. Naval Hospital	N/A	Brooklyn, NY	1942
U.S. Naval Convalescent Hospital (Sea Gate)	N/A	Brooklyn, NY	1944
U.S. Naval Hospital	Charleston Naval Base[3]	Charleston, SC	1917
U.S. Naval Hospital	N/A	Chelsea, MA	1823
U.S. Naval Hospital	N/A	Corona, CA	1942
U.S. Naval Hospital	Corpus Christi Naval Hospital	Corpus Christi, TX	1940
U.S. Naval Hospital	N/A	Dublin, GA	1943
U.S. Naval Hospital	N/A	Farragut, ID	1942
U.S. Naval Convalescent Hospital	N/A	Glenwood Springs, CO	1943
U.S. Naval Hospital	Great Lakes Naval Hospital	Great Lakes, IL	1904
U.S. Naval Convalescent Hospital	N/A	Harriman, NY	1942
U.S. Naval Hospital	N/A	Houston, TX	1945

U.S. Naval Hospital	Jacksonville Naval Hospital	Jacksonville, FL	1941
U.S. Naval Convalescent Hospital (Sun Valley)	N/A	Ketchum, ID	1943
U.S. Naval Hospital	Key West Naval Regional Medical Clinic	Key West, FL	1941
U.S. Naval Hospital	Long Beach Naval Hospital	Long Beach, CA	1940
U.S. Naval Hospital	Mare Island Naval Shipyard	Mare Island, CA	1854
U.S. Naval Hospital	Memphis Naval Hospital	Memphis, TN	1942
U.S. Naval Hospital (Camp Lejeune)	Camp Lejeune Naval Hospital	New River, NC	1942
U.S. Naval Hospital	N/A	New Orleans, LA	1942
U.S. Naval Hospital	Newport Naval Education and Training Center	Newport, RI	1913
U.S. Naval Hospital (N.O.B.)	Norfolk Naval Base	Norfolk, VA	1942
U.S. Naval Hospital	N/A	Norman, OK	1942
U.S. Naval Hospital	Oakland Naval Medical Center	Oakland, CA	1942
U.S. Naval Hospital (Santa Margarita Ranch)	Camp Pendleton	Oceanside, CA	1942
U.S. Naval Hospital	Parris Island MCRD	Parris Island, SC	1918
U.S. Naval Hospital	Pensacola Naval Hospital	Pensacola, FL	1828

U.S. Naval Hospital	Philadelphia Naval Medical Center	Philadelphia, PA	1935
U.S. Naval Hospital	Portsmouth Naval Shipyard	Portsmouth, NH	1900
U.S. Naval Hospital	Portsmouth Naval Medical Center	Portsmouth, VA	1830
U.S. Naval Hospital	Bremerton Naval Hospital	Puget Sound, WA	1925
U.S. Naval Hospital	Naval Regional Medical Clinic	Quantico, VA	1939
U.S. Naval Hospital	N/A	St. Albans, NY	1942
U.S. Naval Hospital	N/A	Sampson, NY	1942
U.S. Naval Convalescent Hospital (Arrowhead Springs)	N/A	San Bernardino, CA	1944
U.S. Naval Hospital	San Diego Naval Medical Center	San Diego, CA	1922
U.S. Naval Convalescent Hospital	N/A	Santa Cruz, CA	1942
U.S. Naval Hospital	N/A	San Leandro, CA	1942
U.S. Naval Hospital	N/A	Seattle, WA	1942
U.S. Naval Hospital	N/A	Shoemaker, CA	1943
U.S. Naval Convalescent Hospital	N/A	Springfield, MA	1944
U.S. Naval Convalescent Hospital	N/A	Yosemite National Park, CA	1943

[1] The dates listed reflect the dates the hospitals, not necessarily the adjacent naval activities, were established.

[2] In 1945, Convalescent Hospitals were renamed Special Hospitals due their expanded range of functions.

[3] The current DoD name listed in this column reflects, to the greatest extent possible based on available information, the name of the activity currently using the facilities that formerly housed the World War II Naval Hospitals. In some cases, the World War II hospital buildings have been converted to other non-medical uses. For example, at Charleston Naval Base the old hospital buildings house the Commander Naval Base. A new hospital was built nearby.

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.: Government Printing Office, 1947).

Strategic Communications

Both the War and Navy Departments operated strategic communications systems. Strategic communications systems were those that reached military units stationed throughout the world, not routine installation communications buildings. While both services had extensive overseas communications systems, a small number of specialized communications installations existed within the United States.

Both services relied upon existing civilian communications organizations to the maximum extent feasible. For example, the Army Command and Administrative Network leased the entire communication system of Globe Wireless Corporation, and additional communications facilities near Chicago, New Orleans, Seattle, and Los Angeles. The Navy leased approximately eighty per cent of its telephone lines.

Still, the military, especially the Navy, considered some installations with specially designed, high powered communications capabilities necessary. The Navy's oldest communications facility, at Point Loma near San Diego, was improved and expanded during the war to improve communications within the Pacific. Near Washington, D.C., the Navy improved its World War I era transmitting station at Annapolis through the installation of powerful new transmitters. For receiving messages near the nation's capital, the Navy built a communications station at Cheltenham in Prince George's County, Maryland. During its peak operations, the Cheltenham station could receive an average of four hundred million words per month.

One of the most ambitious construction projects of the war was undertaken on the windward side of the island of Oahu, Hawaii. Here the Navy sought to construct a radio transmitter powerful enough to reach submarines near Australia and Japan. Communications personnel found the desired location in the Haiku valley, where 2,000-foot cliffs rose from the jungle floor. To install transmitters along the cliffs, workers hacked their way through the jungle and scaled the cliffs. By August 1943, the station transmitted its first messages.

Despite its heavy reliance upon leased commercial facilities, the Army Command and Administrative Network (ACAN) also required specialized installations. The main Army transmitting station was located at Fort Myer, Virginia, and provided access to the White House. The Fort Myer terminal relied upon stations at nearby La Plata, Maryland, and Battery Cove, Virginia. The ACAN also operated stand-by circuits at Seattle, Fort Omaha, Wright Field, and Governors Island. Overseas, the Army maintained an extensive system at such remote locations as Ascension Island or Iceland.

CHAPTER VI

INDUSTRIAL PERMANENT CONSTRUCTION

Industrial construction included facilities and installations constructed for the purpose of producing war materiel. Two types of industrial complexes were constructed: heavy industry factories to produce aircraft, tanks, and artillery; and, ammunition production facilities. Industrial production was a critical element of the war effort. While the military preferred to rely upon private contractors for manufacturing its war material, the private sector was unable to perform some processes. Production of materiel such as ammunition, explosives, or weapons required specialized industrial facilities that were not readily available within America's industries.

Many American industries, such as clothing or textile manufacturers, could be converted to wartime production with few or no changes. In some cases, the conversion required more imagination than physical re-tooling. One Connecticut toy producer assembled electric motors for trains; the same motors could be used for military purposes, including in aircraft. A cosmetic case manufacturer adapted his product for use as cases for incendiary munitions. In 1938, Congress implemented an innovative program known as educational orders, which consisted of small contracts to familiarize industry with military requirements.

The production of some products required major spatial and engineering changes to the factories. Businesses were reluctant to invest money in facilities for the production of goods that would have a minimal post-war market. Business customarily recovered the cost of capital improvements through price adjustments. The unknown length of the war, with its markets for military products, made it impossible for business to factor the cost of capital improvements into the unit price.

To overcome this obstacle, the federal government explored ways to encourage the involvement of private industry in war production. The government offered an accelerated tax amortization to companies certified by the War or Navy Departments. In August 1940, the government created the Defense Plant Corporation, a federally-sponsored enterprise, similar to the Farm Security Administration. The Defense Plant Corporation loaned money to build new factories, while retaining title to the facility. The factory operator had the option of either repaying the mortgage or allowing the government to take possession of the plant.

Of all the methods used to stimulate industrial construction, the Government-Owned, Contractor-Operated (GOCO) facility has the most relevance to this study. The War and Navy Departments built complete industrial facilities and declared them military installations. The services retained established corporations to operate the facilities to compensate for the military's lack of expertise in industrial production or management. The contractors assumed responsibility for most personnel actions, production schedules, quality control, and other tasks associated with factory operations. In some cases, the contractor also assumed responsibility for the design and construction of the installation. The services assigned a small contingent to represent the interests of the government at each GOCO facility.

Ammunition Production

Facilities associated with ammunition production accounted for one of the largest categories of World War II permanent construction. These plants cost approximately three billion dollars in capital investment, and operated with annual budgets approaching one billion dollars. Government ammunition plants employed an estimated quarter million workers, and occupied a land area equalling that of New York City, Philadelphia, and Chicago combined.

The GOCO program was exceptionally well suited to the production of ammunition and explosives.

Ammunition production required buildings that could not be adapted to civilian use. The chemical processes were such that the production lines could produce only explosives. Building designs were developed to minimize the danger posed by explosions and included masonry walls with weak points to vent an explosion. Facilities occupied extensive tracts of land due to the requirements for dispersed buildings.

The experiences of U.S. corporations during World War I made private industry reluctant to produce ammunition during World War II. Throughout the 1920s and 1930s, critics of the munitions industries charged that private industry made excessive profits from wartime production. Senator Russell Nye was a particularly vocal critic of the role of private manufacturers through some well publicized hearings. Other critics labeled ammunition manufacturers as "merchants of death." As a result, private industries were reluctant to undertake extensive investments in plants and equipment that had no peacetime application, only to be caricatured as "merchants of death."

Government ownership of the production facilities offered an additional advantage from the government's point of view. After the crisis, ordnance facilities could be placed on stand-by status, and be available for future emergencies. If stand-by buildings were available, then the military could enter wartime production without the construction delays experienced in 1940 and 1941.

The critical shortage of ammunition in 1940 made the construction of ammunition plants essential for a credible defense program. Even as Hitler's army was marching through France, the United States lacked sufficient ammunition for a single day's fighting. The War or Navy Department Ordnance facilities produced the minuscule quantities of military ammunition required during peacetime, while commercial chemical companies, especially E. I. DuPont and Hercules Powder Company, manufactured powder for sportsmen. America lacked the necessary military ammunition for any conflict.

The few existing War and Navy Department installations that produced ammunition in small quantities during the inter-war years were invaluable assets in preparing the United States for the massive ammunition production necessary during World War II. Picatinny Arsenal and Indian Head Powder Plant produced military explosives. Frankford Arsenal assembled finished artillery and small arms ammunition. Though they were operated at a reduced rate of production, these installations preserved a knowledge of the special techniques and problems of producing military explosives and ammunition. Although munitions manufacturers still would require considerable training, the United States possessed a base of knowledge.

The War Department divided its ammunition production facilities into Ordnance Works and Ordnance Plants, which were usually GOCOs. Ordnance Works produced ordnance; Ordnance Plants loaded ordnance. The War Department used Ordnance Works to produce high explosives, smokeless powder, ammonia, or the chemical ingredients for explosives. Rounds or powder bags were loaded at Ordnance Plants. The War Department constructed 25 loading and component plants, 21 high-explosive/smokeless powder works, and 12 chemical works. Although Gadsden Ordnance Plant manufactured artillery shells, metal components usually were manufactured at contractor-owned facilities.

The Navy Department relied upon the War Department for propellants and high explosives beyond the capacity of its powder factory at Indian Head, Maryland. This arrangement was the result of a 1920s agreement that prevented the two departments from competing against each other. The Army agreed to provide the necessary explosive material for both services. The Navy loaded explosives into shells and assembled finished rounds at its ammunition depots, including Crane, McAlester, and Hastings Depots. Other Navy Ordnance activities performed specialized ammunition work. Hingham Depot, Massachusetts, loaded small caliber ammunition, while the Yorktown Mine Depot, Virginia, poured explosives into underwater mines.

Ammunition facilities were located in the interior of the country, away from the coastlines and borders, to minimize the dangers from enemy air raids. Other requirements for site selection included access to transportation, especially rail lines, and an abundant supply of water. The installations were located in rural areas, to obtain the large tracts of land required. These site selection criteria resulted in the construction of most of the ammunition facilities in the Midwest and Southeast.

Government-owned ammunition facilities were similar in design and construction. Speed of construction and economy in production partially offset the requirements for the substantial masonry and steel construction that normally characterized industrial facilities. The resulting buildings reflected this compromise between permanent and temporary construction; the trend toward expedient, less substantial, building construction became more pronounced as the war progressed.

In August 1940, as the Army contracted for its first ammunition facilities, construction specifications called for facilities comprised entirely of permanent buildings and structures. As the cost of permanent construction became apparent, Army officers sought to contain costs as much as possible. In January 1941, Major General Levin Campbell, then chief of the Ordnance Department Industrial Services, complained about the excessive construction costs to Brehon Somervell, then Chief of the Quartermaster Construction Division. Somervell responded with a directive to reduce costs where possible: "There is no excuse for masonry structures, monumental or otherwise, where a light frame structure will serve the purpose. There is no excuse for the use of expensive materials where less costly ones will serve the purpose for the period of time for which the construction is being provided." This directive did not affect Indiana Ordnance Works, which was close to completion; the design of all other ordnance facilities reflected this new drive towards economy.

In practice, the requirements for working with large quantities of explosives limited the ability to economize on construction. Although the contract for the Louisiana Ordnance Plant specifically forbade construction of permanent buildings without the prior authorization of the Secretary of War, buildings generally were constructed with concrete floors or asbestos siding. The Lone Star Ordnance Plant divided its buildings into four categories. Wood frame construction was used for administrative buildings and the hospital. Composite construction, with masonry walls and wood roofs, was used for minor caliber production lines and auxiliary lines. The ammonium nitrate plant, major caliber lines, and inert storage warehouse used steel truss construction, with masonry walls and concrete floors. Explosive storage magazines were constructed from reinforced concrete.

As the war progressed, steel shortages hindered facility construction. Builders used all available methods of construction to minimize the use of steel. Masonry or timber was substituted for steel wherever possible. The Army also saved steel by reducing the amount of steel reinforcement in concrete igloos. This savings was substantial due to the tens of thousands of these magazines built during the war. Early in 1942, the Dupont Corporation suggested that the government could achieve further cost reductions through the use of asbestos siding for process buildings and frame construction for shops and administrative buildings. These suggestions first were implemented in the West Virginia Ordnance Works, and were adopted for the remainder of the war. In April 1942, the War Department decided to subordinate safety considerations to economy measures even further through the construction of a small arms ammunition plant using predominately temporary construction.

The danger of explosion was addressed in the overall architectural program. The most apparent safety feature was the wide dispersal of buildings on the site, intended to prevent the spread of explosions. For example, the Kingsbury Ordnance Plant occupied 13,454 acres, with buildings connected by railroad lines. Buildings were designed with structurally stronger interior walls than exterior walls, in order to direct an explosion outward. The break room contained an electric cigarette lighter, so that workers could smoke on their breaks without violating rules prohibiting matches. Radford Ordnance Works contained similar features, including stationing the operator of the pressing machine behind a wall so that he or she could observe the operations through a window.

Regardless of the specific product, all ammunition facilities followed a similar architectural program for support buildings. Each facility contained administrative offices, fire stations, and buildings for security forces. An immense amount of water was required for these operations, therefore, most facilities contained their own water treatment and sewage plants. Where sufficient electricity was not available from local companies, ammunition facilities included their own electrical generating plants. Each installation also contained its own medical buildings, either a dispensary or a hospital. Change and shower houses, of either frame or brick construction, were especially important because they allowed workers to remove toxic chemicals before leaving work.

Each facility also contained special structures to store explosive materials. High explosives ammunition storage buildings, known in the Army as "igloos," had a concrete floor with an arched, steel-reinforced concrete roof structure. The sides were bermed with earth, so that explosions were directed upwards. Despite efforts to reduce the amount of steel in each structure, igloo construction still consumed a substantial amount of steel. In 1942, the Corbetta Construction Company devised a "beehive" shaped magazine that required less construction material.

Ordnance works produced propellants, high explosives, or the chemical ingredients for explosives. Propellants consisted of the charge that projected a round out of the barrel. Smokeless powder, derived from nitrocellulose, was the most common propellant. High explosives consisted of the charge within the shell that exploded upon impact. Because of its relative stability until detonation, trinitrotoluene, or TNT, was the preferred high explosive. Other explosives consisted of primers, which were sensitive materials used to start an explosion, and boosters, which were charges used to ensure a complete explosion. Anhydrous ammonia was the most common basic ingredient for all explosives. Anhydrous ammonia is the gaseous form of ammonia, and consists of a combination of hydrogen and nitrogen. The chemical was used to produce nitric acid, and the nitrates necessary for explosives.

Once the basic ingredients had been produced, artillery rounds and aerial bombs were assembled at Ordnance Plants for the War Department or Ordnance Depots for the Navy Department. At these facilities the finished rounds or bombs were prepared for use overseas. Most shell filling plants operated several types of production lines, for large or small caliber artillery and for aerial bombs.

The process of shell filling began with melting TNT and pouring it into empty shells. Due to the need to prevent cavitation, or the formation of air pockets during the cooling process, this procedure proved more difficult than most contractors anticipated. After pouring the TNT, a fuze or plug was inserted in the nose of the projectile. The projectile then was painted and labeled before the final assembly of the completed round. In most cases, the round was completed by attaching the projectile to a cartridge case that contained a pre-measured quantity of smokeless powder and a primer. For larger caliber ammunition, however, the projectile, propellant, and primer were packaged separately. These processes are discussed in more detail in Chapter VIII.

Metal components for fuzes, with their delicate mechanisms presented special problems to the military. During the inter-war years, workers at Frankford Arsenal had preserved a knowledge of fuze production, but the arsenal lacked the capacity for mass production. The Ordnance Department therefore contracted with private manufactures experienced in precision metal work, such as watch or clock manufacturers.

Once the metal components of the fuzes were assembled, the explosive components were loaded at Army ordnance plants. A typical ordnance plant contained smaller loading lines for final assembly of the fuzes with the explosive material. A typical ordnance plant also contained lines for loading explosives into boosters, primers, and percussion elements.

The Navy followed procedures similar to the Army for final assembly of fuzes. It contracted with Reynolds Corporation to operate a GOCO at Macon, Georgia. Metal parts were produced at privately owned factories. At Macon, workers added explosive material and completed the final assembly of the fuzes, which were shipped to Navy depots.

Although high explosives constituted the bulk of artillery or bomb ammunition, other types of artillery ammunition included a wide range of special purpose shells. Other types of ammunition included pyrotechnics for illuminating the battlefield, or shells stuffed with propaganda leaflets. Redstone Arsenal acquired the mission of loading shells with chemical munitions. Such chemical munitions included toxic gases to deter Axis use of gases, plus flame and smoke.

In practice, the production of artillery ammunition was extremely complicated. Artillery ammunition required the most precise tolerances, especially in distribution or weight. Any cavities in the round created by the cooling of TNT could cause the round to become erratic in flight. Therefore all Ordnance facilities required extensive quality control programs. Changes in demand for specific types of ammunition also required constant adjustments to production lines.

Safety and toxicology presented constant challenges in ammunition production. During the first months of the war three explosions killed 83 workers. Later, however, government and industry safety efforts produced an enviable safety record for such a dangerous industry. The chemicals required for munitions production were toxic, even when absorbed through the skin. Workers therefore required protective clothing, with special laundry facilities. Following each shift, workers showered with a special soap that turned violet in the presence of TNT.

Small arms ammunition for rifles, pistols, and machine guns constituted an entirely different category of ammunition, which was manufactured at War Department Ordnance Plants. The operating process consisted of shaping cartridge cases, shaping the projectile, loading powder and primer into the cartridge case, and attaching the projectile to the cartridge case. A series of machining and heat treating operations shaped brass cups into cartridge cases. A similar series of operations shaped the copper jacket of the projectile, which was then filled with a lead slug or other suitable center. A small quantity of smokeless powder was added to the cartridge as the propellant. The primer consisted of a sensitive explosive, usually mercury fulminate that detonated when struck by a firing pin. The entire assembly was crimped together. Production of small arms ammunition also required strict adherence to Army specifications; yet the requirements for literally billions of rounds forced the producers to produce with extraordinary speed and still meet the quality control requirements.

Late in 1941, Brehon Somervell surveyed the progress of munitions construction and its effect upon defense preparations.

The whole interior of the United States of America has been transformed into a vast network of great munitions factories, the output of which will forever render this country free of dependence upon any other country for the tools of self-defense. ...

Today they are producing TNT and DNT, anhydrous ammonia, smokeless powder, toluol, shell forgings, small arms ammunition, armor-piercing cores for shells, armor plate, chemical warfare material, machine guns, rifles and tanks, while others are loading shells and powder-bags. Yet others have been recently authorized and still others are planned.

In the years that followed Somervell's remarks, the United States constructed even more ammunition facilities. By the end of the war, the American ammunition industry had produced 10,958,454 tons of artillery ammunition; 476,312 tons of mortar ammunition; 462,029 tons of grenades, pyrotechnics or mines; 5,989,603 tons of bombs and rockets; and, 38,866,000,000 rounds of small arms ammunition.

American soldiers employed the products of the these plants with devastating effectiveness. They placed tons of explosives upon the enemy through artillery and aerial bombardments. In the attack upon Cassino alone, American forces fired nearly 11,000 tons of artillery. Perhaps the effects of the ammunition production program was summarized best by a captured German officer who complained that "You people expend artillery ammunition, but mine expend only the bodies of men."

Artillery and Associated Components

Both the War and Navy Departments met the need for artillery and associated components utilizing existing facilities, new government-owned factories, and contractors. The combination integrated government technical expertise with mass production capabilities. Artillery, especially large caliber weapons, required special processes. The proper cooling of barrels was particularly important, to strengthen their performance while fired. Other components required extreme precision.

Since 1887, the Army produced heavy artillery, primarily coastal artillery, at Watervliet Arsenal, New York. During the inter-war years, Watervliet was the Army's repository of knowledge on the production of artillery. When the nation began its military expansion in 1940, Watervliet became the primary facility for instructing civilian contractors in artillery production, as factory representatives trained at Watervliet. The Arsenal continued to produce artillery tubes. Perhaps the most important production activity of Watervliet was the 155mm and larger caliber howitzers, which were produced exclusively at Watervliet due to the installation's technical capabilities.

The arsenal also expanded its facilities with the addition of at least twelve new buildings. In keeping with its expanded missions, Watervliet acquired twenty more acres for the new buildings. One of the these, Building 135, built in 1942-43, was reputed to be the finest cannon factory in the world at the time of its construction. The large 300 by 600 ft building was constructed with a heavy structural steel frame partially clad in brick with large expanses of industrial windows.

Rock Island Arsenal, Illinois, performed a similar function for artillery carriages, recoil mechanisms, and other components. The arsenal personnel both advised private industry and produced the items. Like almost every other military installation, Rock Island Arsenal reached a hectic pace of activity with America's entry into the war. Work continued on artillery carriages and parts, and expanded to include machine gun production. Buildings to accompany the new activities included an 18-acre ordnance warehouse, new assembly buildings, a forge shop, and a new post headquarters. To conserve steel, these buildings were constructed in concrete to the maximum extent possible.

The Washington Navy Yard, site of the Navy's gun factory, could not meet the ordnance requirements of the Navy, despite the addition of new buildings. Instead, Washington Navy Yard personnel provided technical assistance to other weapons producers, both Navy GOCOs and civilian contractors. A Navy historian compared the role of the Navy Gun Factory to that of a manager or executive, delegating routine tasks to other facilities and retaining the most difficult tasks for itself.

In 1940, Congress authorized the Navy Department to create new GOCO facilities to supplement its Gun Factory at the Washington Navy Yard. These facilities included the Center Line Naval Ordnance Plant, Michigan; the Canton Naval Ordnance Plant, Ohio; and, the Louisville Naval Ordnance Plant, Kentucky. Hudson Motor Company operated the Center Line facility, while Westinghouse operated the other two plants. All work was undertaken on a cost plus fixed-fee basis. Working under the direction of the Naval Gun Factory, the Center Line and Canton plants produced limited quantities of weapons and components. In effect, these plants operated as "job shops." One notable exception to this operation was the long term manufacture of 20mm anti-aircraft guns by the Center Line Plant. The Louisville Plant assembled the products of the other two plants.

Other Navy facilities completed the government-owned gun factories. The General Machinery Corporation operated part of the Charleston Naval Ordnance Plant to produce 3-, 5-, and 6-inch guns. Near the West Coast, the Navy established the Naval Ordnance Plant Pocatello to reline and service heavy guns coming from the Pacific fleet. War demands soon caused the facility to expand to the manufacture and repair all types of naval guns. The Pocatello plant was a government-owned, government-operated installation. Its workers were all civil service employees. A Marine Corps detachment provided security for the plant.

York Naval Ordnance Plant was an unusual case. It originated as a privately owned facility, producing 40mm "Bofors" anti-aircraft guns. Because the contractor, York Safe and Lock Company, proved unsatisfactory, the government took possession of the plant in January 1944, and the Navy completed condemnation proceedings in May 1944. Thereafter, York was operated as a GOCO under a contract with Blow Knox Corporation to produce 40mm anti-aircraft guns.

Tank Production

In their pre-war planning process, Army Ordnance officers assumed that the Army's limited need for tanks could be met through contracting to locomotive manufacturers. Railroad equipment required the same heavy steel forgings used in tanks, so locomotive companies appeared a natural choice for this type of work. Nevertheless, the Army had devoted little thought to the problems of tank production. Even when the Army began to place educational orders to defense industries in 1939 and 1940, only two minor contracts were devoted to tank production.

In large measure, this oversight in planning for tank production can be attributed to attitudes toward armored warfare during the inter-war years. Even though tanks were valuable during World War I, the Army did little to develop a coherent doctrine for employment of tanks after the war. Until 1932, the Infantry developed tank doctrine at its Tank School at Fort Meade. In that year, the Chief of Infantry discontinued the separate school and incorporated tank doctrine in the Infantry School at Fort Benning. An experimental Mechanized Cavalry Brigade at Fort Knox maintained an minimum of interest in armored warfare. In general, the Army did not develop the possibilities of armored warfare after World War I.

With little interest in tanks by the combat arms, the Ordnance Department expended few of its resources on development of new tanks. From 1920 to 1935, the Army produced 16 tanks. Each tank was a separate model built at Rock Island Arsenal. In 1935 and 1936, the Army produced 16 tanks of one design, marking the first time since World War I that more than a single model tank had been manufactured in the United States. The Ordnance Department placed a contract for 329 light tanks with a railroad car company in 1939, marking the first commercial production of tanks since the First World War.

German success in armored warfare, highlighted in the sudden defeat of France, changed this situation. The nation needed tanks in greater quantities than locomotive companies could produce. To meet the new demand, the War Department contracted with Chrysler Corporation to build an entirely new factory, which became the Detroit Tank Arsenal. It functioned as a government-owned, contractor-operated installation.

The Chrysler Corporation contract involved a degree of risks for all parties because Chrysler engineers had never even seen, let alone produced, a tank. The engineers visited Rock Island Arsenal and took away an estimated 186 pounds of blueprints for a tank. Based upon these blueprints, the company presented an estimate for the cost of a tank factory to the Army. Before construction of the arsenal began, however, the Army decided that the existing tank design was inadequate and began development of the M3, or General Grant, tank. Wishing to avoid construction delays of the tank arsenal, the government signed a contract with Chrysler before the final design for the M3 tank was complete. Chrysler contracted the factory design to the noted industrial architect Albert Kahn.

The contract for the Tank Arsenal was signed on 15 August 1940; construction started on 11 September. The cold Michigan winter set in during the middle of the construction process. By the end of January 1941, one-third of the steel frames for the outer factory walls were in place, but the concrete floors were not poured. To accelerate construction, the builders shut off that third of the building and moved a steam locomotive engine into the structure. Steam from the locomotive thawed the ground sufficiently to allow pouring and curing of the concrete floor. Machinery was moved into the completed portion of the building.

The entire arsenal occupied 113 acres in Warren, Michigan, about four miles north of Detroit. The arsenal had a four story administration building, a separate personnel building, a "figure-8" test track, and a main tank plant building. Tank components were produced elsewhere and the final product was assembled at the tank arsenal.

The main tank plant was a one-story, 500 x 1,380 ft structure, featuring numerous bays. At the north end of the plant a receiving bay occupied the entire length of the plant. At the south end, an assembly bay ran parallel to the receiving bay. Twenty-three manufacturing bays connected the receiving bay to the assembly bay. Materials entered the factory at the receiving bay, to be processed through one of the manufacturing bays. At the assembly bay, the parts came together to form a completed tank.

Each of the bays had a high, steel-truss roof, with butterfly monitors. For maximum lighting during the daytime, glass was used extensively. About 80,000 panes of glass covered ninety-five per cent of the exterior walls. Other aspects of the building reflected the requirements of heavy industry. Reinforced concrete floors and overhead cranes were designed to allow the movement of heavy materials. The open bays provided for maximum flexibility in the layout of production design. Outside railroad spurs ran directly into some of the structures.

While the factory was under construction, Chrysler engineers designed or obtained the necessary machine tools for tank production. One engineer was based outside of Aberdeen Proving Ground, where he could obtain information on the M3 tank then under development. He rushed drawings back to Detroit, or telephoned technical information to Chrysler engineers.

By April 1941, the first tank rolled off the assembly line, and production of tanks in large quantities soon followed. In July 1942, the factory converted its production to the new M4, or Sherman Tank. By 1945, the Detroit Tank Arsenal produced 22,234 tanks or about twenty-five per cent of the production within the United States, with locomotive manufacturers accounting for most of the remaining tanks.

In 1942, the Army built the Lima Ordnance Depot, outside of Lima, Ohio, to process tanks for overseas shipment. After the tanks were built, they required accessory equipment, such as radios. Because it was impractical to hold the tanks at the factory, the government established the Lima Ordnance Depot as a separate GOCO for the installation of accessory equipment in the tanks.

With the growing importance of the Detroit area to war production, Major General Campbell, then Chief of Ordnance, decided more supervision was needed on location. Consequently, he established the Tank-Automotive Center, which later became the Office of the Chief of Ordnance-Detroit.

Chemical Warfare Service Facilities

The Chemical Warfare Service originated during World War I, when the use of toxic gases caused the U.S. Army to create a specialized branch. The purpose of the branch was to develop methods of protection against enemy chemicals and to employ offensive chemicals. Following the war, the Chemical Warfare Service survived, despite the Army's antipathy towards further use of toxic chemicals. The Chemical Warfare Service was inactive during the inter-war period. The Army closed the production facilities at Edgewood Arsenal, the Army's principal chemical warfare installation.

With the approach of World War II, the Army's interest in chemical warfare revived. United States policy renounced the first use of toxic gases, but retained the right to retaliate if an enemy used gases. To maintain a credible deterrent, the Army required an ability to produce toxic gases. Moreover, preparation for war required large quantities of protective equipment, especially masks. The Chemical Warfare Service also had responsibility for flame and smoke devices; these responsibilities increased throughout the war.

Expansion of Chemical Warfare Service production facilities began with improvements to Edgewood Arsenal. At the beginning of the Protective Mobilization period, the Army renovated existing production facilities to produce toxic chemicals. New construction at Edgewood included manufacturing and filling plants, heating plants, sewage systems, and related facilities.

The Chemical Warfare Service also built three more arsenals as government-owned, government-operated (GOGO) installations for the production of chemical munitions. Construction started at the first of these new arsenals, at Huntsville, Alabama, on 21 July 1941. Due to a fear of enemy air attack, the Huntsville Arsenal was dispersed into three widely separated production areas. The first two production areas produced toxic chemicals, while the third area produced incendiaries. Later during the war, the Chemical Warfare Service constructed Pine Bluff Arsenal, Arkansas, and Rocky Mountain Arsenal, Colorado. Throughout the course of the war, all three arsenals produced a combination of toxic chemicals, incendiaries, and smoke. The Chemical Warfare Service produced the chemical ingredients, while the Ordnance Department produced the cases.

For production of protective equipment, the Chemical Warfare Service relied upon GOCOs. Masks required an impregnated charcoal, which was produced at specially designed plants. The first facility for the manufacturing of this particular charcoal was at Zanesville, Ohio; it was followed by more plants at Fostoria, Ohio; Niagara Falls, New York; East St. Louis, Illinois; and, Midland, Michigan.

Navy Ordnance Production Facilities

One of the most effective naval weapons of World War II was the torpedo, a cigar-shaped device that traveled underwater to destroy an enemy ship. Using either a steam or electric engine, a torpedo carried up to 500 pounds of explosives. Various models could be launched by either submarine, aircraft, or surface ship. Torpedoes launched from submarines alone sank over five million tons of enemy ships and damaged another two and one-half million tons.

Despite the torpedo's effectiveness, fleet personnel chronically complained about the quality and quantity of the weapons. Submariners, especially, complained that torpedoes ran too deep, failed to detonate upon contact, or behaved erratically. Moreover, torpedo production methods during the inter-war years had emphasized careful craftsmanship at the expense of quantity production, leaving the Navy poorly prepared to meet the demands of a war with Japan.

Since its establishment in 1869, the Navy's Torpedo Station near Newport, Rhode Island, had served a dual function of experimental and production work on torpedoes. To meet the increased demands for torpedo production during World War I, the Navy had established a Torpedo Factory in Alexandria, Virginia. The Alexandria facility reverted to an inactive status after the war. The station at Newport remained the Navy's most important installation for work with this weapon. Within the constraints of limited budgets, station personnel experimented with new models, including an electrical propulsion method. They also carefully fabricated new torpedoes to meet the limited needs of a peacetime Navy.

On the West Coast, the Naval Torpedo Station at Keyport, Washington, complemented the Newport Station. The extensive waters of the Puget Sound provided an ideal testing range for torpedoes. Other workers overhauled and repaired torpedoes at the Keyport Station.

Even before the United States officially entered the war, the Torpedo Stations at Newport and Keyport expanded their capacity. By the end of 1940, the work force at Newport had increased by nearly 1,000 to a total of 4,800. Before the end of the war, the Torpedo Station employed over 12,600 workers, at facilities scattered throughout the Narragansett Bay region. Additional production capacity resulted from the reactivation of the Torpedo Factory in Alexandria, Virginia. The Keyport Station expanded so rapidly that it required a new housing project. By the close of the war the Keyport Station increased its work force twelvefold. Soon all three installations were operating three shifts, seven days per week.

With the inexorably rising demand for torpedoes, the Navy entered into a contract with the American Can Corporation to construct and operate a torpedo plant. The company formed a subsidiary, the Amertorp Corporation, which operated the Forest Park, Illinois Naval Ordnance Plant as a GOCO. To augment its production capability further, the Navy contracted with Pontiac Motor Corporation, International Harvester, and Westinghouse to produce torpedoes. Extensive subcontracting for components completed the Navy's torpedo production efforts. The Torpedo Station at Newport served as the Central Torpedo Office and provided technical assistance to other production sites. These plants completed assembly of torpedoes with the exception of loading explosives. Explosives were loaded at McAlester Depot.

The Forest Park facility, located in a Chicago suburb and designed by the architectural firm of Albert Kahn, was intended as a permanent facility. The Navy expressed its desire for "a good looking layout without extravagance," and Kahn's firm responded with a complex that combined brick and glass. The glass walls provided a well lighted working environment. The main manufacturing building was T-shaped, with the components assembled at the head of the T. The parts were moved to the main column where they were assembled into the final product.

The Naval Mine Depot at Yorktown, Virginia, also experienced an increased level of industrial activities during the war, with a concurrent expansion through permanent construction. In December 1941, 21 officers and about 1,000 civilians were assigned to the depot. This figure represented a considerable increase from labor levels during the inter-war years. Depot workers tested and repaired depth charges, underwater mines, torpedoes, and similar pieces of naval ordnance. They also filled underwater munitions with TNT, using melt and pour methods similar to those used in the loading of artillery shells. Workers at the station mixed TNT with RDX, a more powerful explosive, to form Torpex. The new explosive was more powerful than TNT but less dangerous than RDX. They also poured explosives into rockets and aerial weapons. With the increased production activities came a wave of new construction, both permanent and temporary.

The Indianapolis Naval Ordnance Plant performed a specialized, critical function. The plant was a result of discussions between the Navy and Carl Norden Inc. regarding production of the famous Norden Bombsight. Norden agreed in principle to operate a GOCO and created a wholly owned subsidiary, Lukas Harold Corporation, to operate the plant. In July 1940, the Navy signed a contract with Lukas Harold Corporation for construction and operation of a GOCO to produce bombsights. The pace of construction proceeded slowly until the Japanese attack upon Pearl Harbor. The plant was commissioned in May 1942, and produced both Norden bombsights and gunnery fire control instruments. Both the War and Navy Departments used bombsights. In fact, the Norden bombsight was most useful in the high-altitude heavy bombers that the Army Air Forces favored. Of 12,792 bombsights produced at the Indianapolis Naval Ordnance Plant, 11,217 went to the War Department.

The South Charleston Naval Ordnance Plant, West Virginia, began during World War I as a facility for producing ships' armor, the heavy steel plating used to protect warships from enemy guns. The plant remained on stand-by status until 1939, when Carnegie Steel received a contract to rehabilitate a small portion of the plant to again produce ships' armor. As the Navy's ship building program increased, Carnegie received additional contracts to enlarge the plant until the original facility tripled in size. At the same time, the General Machinery Ordnance Corporation received a contract to rehabilitate the northern section of the plant for the production of various naval weapons. During the war, this portion of the plant produced rocket assemblies, gun barrels, torpedo air flasks, and related metal items. Thus the Charleston Plant conducted two different operations, using two contractors.

Aircraft Production and Assembly

Expansion of the American aircraft industry ranks among the more important industrial achievements of World War II. The contrast between the aircraft industry before and after the war is remarkable. In 1939, the private aviation industry, under contract to the Army Air Corps, began production of the first American made aircraft capable of exceeding 400 miles per hour, the P-38. Fewer than 100 of the first generation B-17 heavy bombers were flying. Within five years, the American aviation industry not only had produced sufficient numbers of aircraft to fight a two-ocean, multi-front war, but also was assisting Allied countries.

To create a military aviation industry, the U.S. government first identified existing aircraft manufacturers with room for expansion at their facilities. Demand for aircraft grew so rapidly that the government financed additions to existing privately-owned plants under the provisions of Defense Plant Cooperation contracts.

In 1939, Congress authorized over 34 million dollars for use in placing "educational orders" to private aircraft manufactures. These orders, in effect aircraft sample orders, were intended to provide a learning curve in developing the techniques for rapid aircraft production. By 1940, the need for aircraft was considered so critical that Congress allotted 12.5 billion dollars for military aviation to the pre-war emergency budget.

Major aviation manufacturers such as Boeing, Lockheed, and Consolidated utilized these funds to construct new facilities that could support around-the-clock manufacturing. These plants required new production buildings, runways, and test facilities, as well as security and defense modifications. The construction of these additional facilities absorbed all land available in the vicinity of the existing plants. Constraints on the ability of existing plants to expand further limited their aircraft production capacity. As a result, the Air Corps could not obtain the quantity of aircraft that it desired.

To alleviate the space and scheduling problems, President Roosevelt asked Congress to provide funds for the expansion of the aviation industry. In 1940, Congress passed "An Act to Expedite the Strengthening of the National Defense," which gave the Secretary of War broad powers to boost war equipment production.

To improve aircraft production, the War Department built GOCO aircraft plants. Their purpose was to assemble aircraft from components rather than to manufacture aircraft from raw materials. Thus, one of the more important site selection criteria was the proximity of rail lines to the plant site. A major consideration in the construction of GOCO aircraft plants was the need to operate the facility 24-hours a day. Around-the-clock operations required power and water availability that exceeded the capabilities of civilian infrastructure. Consequently, the Army spent over $75,000.00 in 1942 to build small power plants, install electrical lines, water storage and wells, plumbing, and the necessary support buildings for GOCO aircraft assembly plants.

The plant buildings were massive assembly line buildings that fed out to an aircraft ramp. The basic design included a concrete foundation with a steel or wood frame and steel exterior. The assembly buildings were large enough to allow the aircraft to be assembled inside; storage or office space was built along the side walls at the second or third floor levels on a mezzanine. Due to wartime scarcities of building materials, later plant designs increasingly utilized temporary construction techniques. The Cleveland Aircraft Assembly Plant is an excellent example of assembly plant architecture. Designed and build by the Hunkin, Conkey Construction Company in 1942, the plant was the largest all-timber building at that time.

By 1945, the American aviation industry had built 231,099 aircraft of all types. Aircraft assembled at GOCOs, including B-29s, C-47s, and B-24s, played a critical role in the war effort. The massive production effort enabled the Eighth Air Force to grow enormously despite its combat losses. GOCO-produced aircraft were used in the European, Mediterranean, and Pacific Theaters. American aircraft supplemented the flying stock of Allied air forces under lend lease programs and contributed to the Allied victory.

With the surrender of Japan in August 1945, the United States no longer required an aviation industry mobilized for total war. The major aircraft manufacturing companies made the transition to the civilian market. Although the Air Corps no longer required GOCOs, military planners understood the value of the large buildings and reinforced runways at the retired GOCO plants. The Air Corps identified fields with the greatest potential for conversion to active installations. The Air Corps selected sites in Fort Worth, Texas (Carswell AFB), Oklahoma City, Oklahoma (Tinker AFB), Marietta, Georgia (Dobbins AFB), and Fort Crook, Nebraska (Offutt AFB) as Air Force base sites. Over the next several years the industrial buildings on these stations were repaired and modified for continued use by the Air Force as storage areas, hangars, and modification centers.

The Navy Department had maintained an aircraft factory in Philadelphia since 1917. Its purpose was to produce small numbers of new models of aircraft, rather than produce large numbers of existing models. During World War II, the Naval Aircraft Factory performed important work on the Kingfisher, an amphibious patrol plane. The factory also produced new models of carrier catapults and arresting gears.

Personnel at the factory also produced drones and pilotless aircraft. Recognizing the potential for pilotless aircraft to carry a warhead, one officer, Commander (later Admiral) D. S. Fahrney began experiments that resulted in the beginnings of the Navy's guided missile program.

Social Conditions

The mobilization of American society during World War II restructured American culture in numerous ways. Large numbers of families and individuals relocated to temporary communities for war-related employment. Women and minorities became more visible in the workforce in an effort to meet wartime labor demands. Wartime shortages, including consumer goods, gasoline, and transportation, altered the lives of the civilian population.

The GOCO factories discussed above were involved closely with these changes, and their development documents an interesting chapter in United States social history. Because many of them were built in rural areas, defense plants spurred boom town economies, with new temporary housing developments. Despite on-site housing, other workers lived at considerable distances from the facilities and faced challenging transportation problems. The working and living conditions of war industry workers affected their productivity, which was a crucial element of the domestic war effort.

New Workers

One of the most publicized consequences of the wartime economy was the introduction of large numbers of women into previously male-dominated industrial jobs, as illustrated by the popular image of "Rosie the Riveter." Women previously had been employed in manufacturing including light industries such as textiles; nevertheless, large numbers of women as factory workers, especially in heavy industries, was a new wartime experience. At the beginning of the war, approximately 12 million women were in the workforce; the number increased to 18 million by 1945. Although these figures document an increase in the numbers of working women, they also indicate that the majority of working women were in the labor force before the war. For many of these women the war produced a shift from jobs in the service sector and light industry to heavy industrial employment. Other women entered the workforce for the first time, either as a wartime measure or with the expectation of permanent employment.

Reaction to women factory workers varied with the circumstances. In areas traditionally dominated by male workers, especially shipyards, women encountered hostility towards their presence. The demands for physical strength compounded problems for women in heavy industry. In other jobs, women achieved a greater degree of acceptance in their new roles.

The ammunition industry, which began almost entirely during the war, provided new opportunities to women. Most ordnance facilities employed men during the early phases of mobilization, but the Selective Service and labor shortages resulted in increased employment of women. These women were designated "Women Ordnance Workers," or WOWs. Because the United States had virtually no experienced workers in ammunition production, women were not at a disadvantage with respect to previous training. In a 1942 study, the Women's Bureau of the Labor Department noted that women workers were concentrated in jobs that required finger dexterity and attention to detail, including fuze and booster assembly, or inspection of components. Female workers also dominated powder bag sewing. As labor shortages intensified, however, the types of work available to women increased proportionately. In its official history, the Lone Star Ordnance Plant boasted that " 'FOR MEN ONLY' jobs at Lone Star are now often handled by women only," and illustrated the point with photographs of women performing soldering operations, or handling heavy aerial bombs. Kingsbury Ordnance Plant reported a similar expansion of the roles of its WOWs, even placing some women in stevedore jobs. By the end of the war, forty-five per cent of the workers at Kingsbury were women.

Nevertheless, disparities still existed between the treatment of men and women in the industrial workplace. The Women's Bureau Bulletin noted that women consistently received lower wages than men despite the absence of justification for the differential. Because women were considered more susceptible to skin problems, managers were more reluctant to expose them to TNT, which could create skin eruptions. Factory management complained that women would not wear protective covering for their hair.

Women in shipyards experienced far more difficulties than most other female workers. Shipyards long had been a male bastion, and the existence of powerful trade unions further exacerbated the problems of assimilating women into the workforce. Shipyard work demanded physical strength and ability to work at high places. Nevertheless, the scarcity of labor persuaded shipyard managers to hire women, and the prospect of high wages encouraged women to fill available jobs. Shipyards adjusted to the physical strength of women by such expedients as using hoists to move heavy tool boxes, or dividing heavy loads into two or more smaller loads. Kaiser Shipyards, a commercial builder, refined the specialization of tasks, so that new employees could perform one task with a minimum of training.

Even where they avoided hostility, women in shipyards might encounter conduct that would be considered condescending by the standards of the 1990s. One writer described women at Mare Island Shipyard by noting that, "Notwithstanding the rash of humor following in their wake, Mare Island's women workers turned out good work. . . . One slightly confused young thing did spend forty-five minutes trying to drill a hole through a steel bulkhead—the bit was in the chuck backwards—but at least she kept right on trying!" No doubt, the writer considered this passage a compliment to the women at Mare Island.

African-Americans also entered the labor force in larger numbers and in new fields. Even more than in the case of women, African-Americans faced open hostility in their new jobs. Much of their progress was attributable to insistent demands that African-Americans receive a proportionate share of defense employment. Led by A. Philip Randolph, African-American leaders called upon President Roosevelt to take action against racial discrimination. When Roosevelt evaded meeting with them, Randolph and others began to organize a protest march, proposing to bring 50,000 to 100,000 marchers to Washington, D.C. After a series of negotiations, Roosevelt signed an executive order opening defense employment to all races, and the African-American leaders canceled the march. The increasing scarcity of labor as the war progressed further eased racial barriers to employment.

In practice, the experience of African-American workers varied depending upon the circumstances. Roosevelt's order, by itself, did not end discrimination, nor did it prohibit segregation in the work place. These problems were managed at a local level. At the Twin Cities Ordnance Plant, a local newspaper boasted that "negroes ate in the same lunch room, sang in the plant chorus, played games, attended dances, and were in fact a part of the plant's organization." At Kingsbury Ordnance Plant, African-Americans first were hired in April 1942, after careful negotiations between management and workers to overcome the local tradition of segregation. Most African-Americans were concentrated in warehousing and detonator lines. The Naval Ordnance Plant at Macon, Georgia, did not hire African-Americans until April 1945, and only after instituting a training program with local vocational schools. Like the other official histories, the Macon history pronounced African-American workers "valuable employees."

The experience of both minority and women workers in World War II was a mixture of progress and frustration. Both groups managed to overcome barriers, yet neither group overcame discriminatory practices in employment. These problems persisted through the remainder of the twentieth century. Perhaps the change was most pronounced for African-American women. In 1940, working African-American women were concentrated in domestic or agricultural jobs. By the close of the war, African-American women were employed in factory, clerical supervisory, and a few professional jobs. Though the preponderance of working African-American women remained domestics, the old pattern of employment was beginning to change.

Living Conditions and Effects on Local Economies

The living conditions of all workers and their families constituted another important facet of the history of the war manufacturing efforts. War industries created thousands of new jobs, often in regions that were primarily agricultural. Over the course of the war, slightly over 15 million civilians migrated across the United States, usually in search of new jobs. Approximately 60 per cent of these migrants were women.

As workers moved into the new wartime industries, they required housing and the infrastructure that accompanies a community. With the instant appearance of large numbers of new workers, living conditions varied from tolerable to squalid. War workers rapidly filled boarding houses and available rental rooms. In Marion, Ohio, site of the Scioto Ordnance Plant, workers reported sleeping in shifts, using the same bed. At other places, workers lived in makeshift trailer camps, often assembled with inadequate water supplies and sewerage capacity. Within the vicinity of the Puget Sound Naval Shipyard, an estimated 2,500 families lived in trailer camps during August 1942.

The government and plant operators took steps to alleviate housing shortages. In October 1940, Congress passed the Lanham Act, which authorized public housing in areas with defense industries. Later, President Roosevelt established the Federal Public Housing Authority to coordinate defense housing. By the end of the war, the Federal Public Housing Authority managed the construction of over 700,000 housing units, principally near defense industries. These houses were designed to provide acceptable housing, but little more. Standards established in local building codes could be waived. At many facilities, employers sponsored housing for their employees. Radford Ordnance Works, Virginia, sponsored three housing projects, and built seven bunk houses for single employees.

Although housing conditions improved, workers at these installations were forced to adjust to conditions different from their previous experience. Workers found themselves living in new communities, frequently separated from their families, and living among strangers. Although the Lanham Act also authorized funding of day care for children of working mothers, adequate child care was seldom available. The war disrupted the lives of defense workers as well as soldiers.

Local residents in areas of the new facilities also felt the disruptive impact of the war. Ordnance facilities required large tracts of level land, with good access to water and transportation routes. These same characteristics defined prime agricultural land, thus the government often selected productive farm land owned by families for several generations as sites for new industrial facilities. Although most farmers sold their land for a negotiated price, the federal government's power to initiate condemnation proceedings placed pressure on the farmers to settle. Resentment against the Army was particularly strong at Weldon Springs Ordnance Plant, Missouri, and Letterkenny Ordnance Depot, Pennsylvania.

Ill will among displaced land owners was aggravated if the community perceived that the facility was unnecessary. In February 1942, the government announced construction of Gopher Ordnance Works in Rosemount, Minnesota, and acquired 84 farms. Believing that the price offered by the government was too low, most farmers refused to sell their land. The government initiated condemnation proceedings. Although the farmers eventually won substantial price increases in court, the government took possession of the land pending resolution of the court decision. Construction began once the government secured title to the land. Along with the ever-present trailer parks, the Gopher Ordnance Works brought money into the local economy. In April 1943, construction stopped, and the War Department placed the installation on stand-by status. In the second half of 1944, the Army attempted to re-activate the plant, and it produced some smokeless powder in 1945, but former land owners complained that this powder probably never made it to Europe or Asia. On aggrieved farmer complained: "The thing that really galls all of us people that were ordered out . . . is the fact that they never really needed the plant. . . . It was a waste. They did manufacture some powder, but if any of it was actually used in the war effort I don't know of it."

Conclusion

Having made their enormous contribution to the Allied victory, War and Navy Department industrial facilities faced an uncertain future at the war's end. The nation no longer needed the ammunition and other materiel produced at the industrial facilities. Yet the recent experience in preparing a production base for World War II demonstrated the need for preserving at least some facilities for future emergencies. The deteriorating relations with the Soviet Union further accentuated the need for preserving an ability to manufacture ordnance when necessary. Consequently, the services decided to preserve a portion of the World War II industrial base. Some facilities were closed with the end of the war, and transferred to the War Assets Administration for final disposition. Others, especially those in operation before the war, remained active installations, although now operating at a slower pace. As preparation for future conflicts, the services placed other facilities in a "stand-by" status. The government hired contractors to preserve the buildings and equipment, and to provide security for the vacant installations. The Department of Defense partially reopened a few installations for the Korean or Vietnam conflicts, but the industrial facilities never resumed their wartime pace of operations.

CHAPTER VII

SPECIAL CONSTRUCTION PROJECTS: THE PENTAGON AND THE MANHATTAN PROJECT

Within the scope of military permanent construction during World War II, two special projects merit discussion. The first such project was the construction of the mammoth five-sided office building called the Pentagon. The military also constructed the facilities to produce and test the atomic bombs, which ended the war and began the age of nuclear warfare.

The Pentagon

At the opening of World War II, the War Department shared its headquarters with the Navy Department at the Munitions Building, located on Constitution Avenue in the District of Columbia. Even if the War Department had use of the entire building, the Munitions Building was not large enough to hold all of the War Department agencies. To accommodate the overflow, Army personnel were scattered in leased office space throughout Washington, D.C. Staff officers lost valuable time trying to coordinate with other staff officers. Visitors to the War Department often traveled from building to building looking for the correct agency.

Brigadier General Brehon Somervell, then the Chief of the Quartermaster Construction Division, proposed to remedy this situation by building a single office building, large enough to house the entire War Department headquarters. On Thursday, 17 July 1941, he summoned two architects to his office and directed them to prepare plans by the following Monday for an office building that would house 40,000 workers. The architects hardly had begun working when the plans were changed. The War Department decided to locate its new office building at Arlington Farms, Virginia, near Arlington Cemetery and Fort Myer. To fit into the existing road network, the new office building was to have a five sided design, from which the building derived its name, the Pentagon.

At a time when military construction was consuming a substantial portion of skilled labor, materials, and money, Congress was reluctant to approve a large new office building. Somervell successfully argued, however, that the new office would enable the War Department to operate more efficiently. Moreover it would save the government money by reducing the amount of leased office space and allowing the Navy Department to have full use of the Munitions Building.

Congress approved the funding in August 1941, but President Roosevelt insisted upon changing the location to three-quarters of a mile east of the intended site, and expressed his preference for a building approximately half the size that Somervell contemplated. Somervell immediately initiated construction at the site that Roosevelt wanted, while architects prepared the final plans the building. The plans kept the five-sided configuration and large size. When Somervell presented the final plans to the President in October, construction of the foundation was already well under way. President Roosevelt relented and approved Somervell's plans.

Construction of the Pentagon continued through January 1943, though portions of the building were in use as office space by April 1942. At the peak of construction, the project employed over 13,000 workers. The architects made every effort to conserve scarce materials. Steel saving measures included concrete ramps instead of elevators and concrete drainage pipes. The use of concrete instead of steel required approximately 410,000 cubic yards of concrete. Sand and gravel for the building were dredged from the Potomac River. The dredging of the river created a lagoon that allowed barge traffic to deliver materials to the construction site, and later became a scenic attraction for the building.

Today, the Pentagon's distinctive architecture makes it a capital area landmark. It consists of five, concentric, pentagonal rings, with a spacious courtyard at the center. Ten corridors radiate from the center of the building, connecting the rings. The Pentagon served as the War Department headquarters until 1947, when it became headquarters for the newly-created Department of Defense. Today it remains the headquarters for the Defense Department and its subordinate offices.

The Manhattan Project and the Atomic Bomb

The use of the atomic bomb against the Japanese cities of Hiroshima and Nagasaki in August 1945 terminated World War II and initiated the age of nuclear warfare. In large measure, this new weapon resulted from the efforts of American scientists, who advanced nuclear physics under the stress of wartime conditions. The atomic bomb was also the product of the construction work of the Corps of Engineers. Working at an accelerated pace, the Army engineers constructed the physical plant for obtaining fissionable material.

The construction efforts in support of the atomic bomb were concentrated at three locations. At Oak Ridge (or Clinton), Tennessee, and at Hanford, Washington, the Army built enormous plants that provided the raw materials for the atomic bomb. At Los Alamos, New Mexico, the Army provided a home for a community of scientists who assembled the first nuclear weapons.

American physicists long had recognized the theoretical possibility of creating nuclear weapons through the fission of uranium isotopes. In 1939, Albert Einstein wrote to President Roosevelt on the potential of atomic energy, causing Roosevelt to establish an Advisory Committee on Uranium to study the subject.

In January 1940, the War and Navy Departments first funded university research on nuclear energy. A wartime Office of Scientific Research and Development (ORSD) further accelerated government interest in the possibility of nuclear weapons. By the beginning of 1942, the probability for success of the production and application of the weapons justified full scale military participation.

On 17 June 1942, work on the atomic bomb advanced significantly when the Corps of Engineers established the Manhattan Engineering District, under the command of then Colonel James C. Marshall. The district was unique in that it did not have geographical boundaries, rather it had responsibility for all construction efforts related to the atomic bomb. The name, derived from the District's headquarters in New York, sounded as if it were in keeping with other district names. To provide additional direction to the project, the Army assigned Colonel (later Major General) Leslie Groves as the overall director.

The essential problem confronting the Corps of Engineers was to construct facilities that would separate fissionable uranium isotopes from non-fissionable isotopes. Uranium naturally exists as a metal, in which its three most common isotopes are indistinguishable. About 99.28 per cent of the metal is an isotope known as U-238, while .71 per cent of the metal is an isotope known as U-235. The third isotope, U-234 exists only in trace quantities. The isotopes are integrated physically and chemically identical. The only differences is the atomic weight or mass. Of these isotopes, only U-235 is fissionable. The problem was to separate the small quantity of U-235 from the U-238. Another method of producing fissionable material was to create the element plutonium. Although normally not fissionable, U-238 could be converted to plutonium when bombarded with neutrons.

Although scientists believed that separating the isotopes was theoretically possible, it had never been accomplished in the quantities necessary to produce an atomic bomb. The Army therefore faced the challenge of constructing the facilities to separate isotopes, without the knowledge that their efforts would work. Standard practice was to build pilot plants before building large production plants, but the wartime haste precluded such steps. In some cases, construction on the facilities began before the physicists had resolved the technical questions. In hopes of improving the odds of success, the Army simultaneously tried two methods of uranium separation, plus the pile method of plutonium production.

One of the earliest processes to be used was the electromagnetic method. This technique relied upon the theory that particles of uranium gas could be accelerated in a magnetic field, and separated by atomic weight. To apply this theory, the Army retained the engineering firm of Stone & Webster to construct an electromagnet separation plant, known as the Y-12 plant, at Oak Ridge, Tennessee. The Army selected Tennessee Eastman, a subsidiary of Eastman Kodak, to operate the Y-12 plant.

Construction of the Y-12 plant was an enormous and difficult undertaking. For construction of the magnets, the Army borrowed 15,000 tons of silver from the Treasury Department. The entire plant required 38 million board feet of lumber. Lacking the experience of pilot plants, the builders encountered unexpected problems, such as 14-ton vacuum tanks popping out of place in response to the influence of the electromagnets. More serious problems developed from rust and corrosion in the pipes. Despite these obstacles, the Y-12 plant was operational by the fall of 1944. The final uranium separation operation became a two-step process. An Alpha plant made the first isotope separation, and a Beta plant refined the product of the Alpha plant into a weapons-grade uranium.

Another method of isotope separation was the gaseous diffusion method, which operated on the theory that the difference in atomic weight would cause the lighter isotopes to pass through a membrane more readily than the heavier isotopes. Although also located in Oak Ridge, different contractors constructed the gaseous diffusion plant. The M. W. Kellogg Company was the builder and Union Carbide was the operator. The gaseous diffusion facility was designated the K-25 plant.

The gaseous diffusion method existed only in theory at the time that construction began. As the builders were digging the foundations, scientists were trying to find a suitable membrane for the process. The main process building for gaseous diffusion was the single largest building within the entire Manhattan project; it was a four-story, U-shaped structure, measuring more than a mile from end to end. When the K-25 plant did become operational, it could not produce a grade of U-235 pure enough for an atomic bomb. The product went to the Beta tract of the electromagnetic plant for further processing.

In addition to uranium separation operations the Army attempted to produce plutonium. Conversion of U-238 into plutonium required bombardment of the uranium with neutrons. The Italian physicist Enrico Fermi had demonstrated that a sufficient concentration of radioactive material could create a self-sustaining reaction that would transform the uranium into plutonium. The uranium would be enriched while in a pile, and therefore the production of plutonium was known as the pile method.

Both the Oak Ridge and the Hanford sites were important to the development of the pile method. At Oak Ridge, the Army constructed the Clinton Semi-works, whose purpose was to provide experimental data for full-scale plutonium production facilities. At Hanford, the Army created the full-scale plutonium facilities, which were designed, built, and operated by DuPont Corporation.

Both the Oak Ridge and the Hanford facilities involved an enormous construction effort. In fact, construction costs accounted for 90 per cent of the money expended on the atomic bomb. In addition to the process buildings for isotope separation, each facility required buildings for chemical separation of the uranium, administration buildings, power and utility buildings, and assorted supporting structures. Equally important, the Army constructed family housing for the civilian work force at Hanford and Oak Ridge. During World War II, Oak Ridge became the fifth largest city in Tennessee, and Hanford rivaled Walla Walla, Washington, in population size.

Construction work at these two sites consumed an immense amount of resources, both men and materials. The Clinton and Hanford Works alone used 360 million board feed of lumber, 1.2 million cubic yards of concrete, and 75 thousand tons of structural steel. At a time when construction workers were scarce, Clinton employed 47,000 laborers; Hanford, 45,000 laborers.

A smaller part of the Manhattan project construction consisted of a secret community at Los Alamos, New Mexico. It began with the acquisition of the Los Alamos Ranch School for Boys and quickly expanded into a community of over 7,000 residents. The site was intended to provide an isolated home for scientists, government employees, and their families while they completed experimental work on the atomic bomb and assembled the final product. In his haste to build a plant, Groves directed strict economy methods for construction. The result was unrest among the families, especially because of the poor quality of drinking water. In time, improvements to the site, and the excitement of near completion of the project eased the discord among the residents.

In July 1945, scientists at Los Alamos witnessed the fruition of their work with the testing of the world's first nuclear explosion. On 6 August, a single atom bomb destroyed the Japanese city of Hiroshima, with the subsequent bombing of Nagasaki three days later. Stunned by the new weapon, the Japanese government surrendered on 14 August 1945.

An official Army history has estimated that under peacetime conditions the development of the electromagnetic plant at Oak Ridge would have required ten to fifteen years. The Army easily might have spent a generation trying to achieve what workers at the Manhattan project performed during the war. In large measure this success can be attributed to the crash construction programs at Oak Ridge and

Hanford, where military personnel, scientists, and civilian contractors hurriedly built facilities for the development of the atomic bomb. Their efforts led General Leslie Groves to describe the Manhattan project as the "most exacting construction job of the entire war."

CHAPTER VIII

EXPLOSIVES

Department of Ordnance Works

The swift construction of facilities for explosives production was one of the more impressive feats achieved by American industry during World War II. In the summer of 1940, the United States possessed a minimal number of facilities to manufacture explosives. By the end of the war, American superiority in ammunition produced a devastating effect upon the Axis nations. To manufacture explosives, the War Department constructed a series of ordnance works throughout the mid-western United States (Table 17). According to the terms of a pre-war agreement, the War Department was responsible for providing common explosives to the Navy. The purpose of this agreement was to avoid the counter-productive competition between the services that had occurred during World War I. The Navy still maintained its smokeless powder plant at Indian Head and purchased other explosives directly from contractors.

At the beginning of the war, the nation's only military facilities for the production of explosives were Picatinny Arsenal in Dover, New Jersey, and the Naval Powder Factory in Indian Head, Maryland. Both facilities retained a working knowledge of the art of explosive production through the inter-war period, and were indispensable to the production mobilization effort of World War II. Operating at their maximum capacity, however, these facilities could not produce more than a tiny fraction of the materiel required for the war. To meet the shortfall, the War Department constructed ordnance works and assigned management of the facilities to private contractors. These installations were termed Government-Owned, Contractor-Operated facilities, or GOCOs. In the area of ammunition production, these GOCOs were divided into ordnance works, which produced explosives or their basic ingredients, and ordnance plants, which loaded ammunition or otherwise produced the final product.

Explosives were divided into two categories: propellants and high explosives. Propellants were comparatively slow burning materials used to force the round out of the gun barrel, or to act as a rocket motor. Smokeless powder, or nitrocellulose, remains the most common propellant. High explosives, which exploded with greater force, were used to fill artillery shells or aerial bombs.

Both propellants and high explosives share common chemical characteristics. They combine a nitrate with a form of a hydrocarbon. The result is a mixture of nitrogen, oxygen, hydrogen, and carbon in a single, somewhat unstable molecule. Once the explosion process begins, the molecule breaks down, and the components immediately reassemble to form free nitrogen, water, and carbon dioxide or carbon monoxide. Because all of the elements are located within a single molecule, the process occurs with extraordinary speed. In fact, the effects of explosives are derived more from the speed of the process, rather than the total amount of energy released.

Production of World War II explosives began with anhydrous ammonia, a gaseous combination of hydrogen and nitrogen. Anhydrous refers to ammonia gas not dissolved in water. The production of anhydrous ammonia began with the extraction of nitrogen from the atmosphere and the production of hydrogen by mixing steam with coke or natural gas. Prior to World War II, ammonia was derived principally from coal and coke production, but to meet the wartime needs production shifted to the use of natural gas.

TABLE 17: WORLD WAR II EXPLOSIVES AND RAW INGREDIENTS ORDNANCE WORKS

WWII Name	Current Name	Location	Date Established
Product: Ammonia			
Buckeye Ordnance Works	N/A	OH	May 1943
Cactus Ordnance Works	N/A	TX	Aug 1943
Dixie Ordnance Works	N/A	LA	July 1941
Jayhawk Ordnance Works	N/A	KS	Sep 1941
Missouri Ordnance Works	N/A	MO	Nov 1942
Morgantown Ordnance Works	N/A	WV	Nov 1940
Ohio Ordnance Works	N/A	OH	Feb 1941
Ozark Ordnance Works	N/A	AR	Oct 1941
Product: Ammonium Picrate			
Maumelle Ordnance Works	N/A	AR	July 1941
New York Ordnance Works	N/A	NY	Mar 1942
Product: Formaldehyde Hexamine			
Cherokee Ordnance Works	N/A	PA	Oct 1942
Product: High Explosives			
Kankakee Ordnance Works	Joliet AAP	IL	Sep 1941
Kentucky Ordnance Works	N/A	KY	Dec 1942
Keystone Ordnance Works	N/A	PA	Dec 1941
Lake Ontario Ordnance Works	N/A	NY	Dec 1941

Longhorn Ordnance Works	Longhorn AAP	TX	Dec 1941
Naval Powder Factory, Indian Head	Indian Head Naval Surface Warfare Center	MD	1890; 1900
Pennsylvania Ordnance Works	N/A	PA	Jan 1942
Picatinny Arsenal	Picatinny Arsenal	NJ	1880; 1919
Plum Brook Ordnance Works	N/A	OH	Dec 1940
Volunteer Ordnance Works	Volunteer AAP	TN	Aug 1941
Weldon Spring Ordnance Works	N/A	MO	Dec 1941
West Virginia Ordnance Works	N/A	WV	Jan 1942
Product: Magnesium Powder			
Pilgrim Ordnance Works	N/A	MA	Mar 1942
Product: Oleum			
East Tennessee Ordnance Works	N/A	TN	Oct 1941
Product: Propellants			
Alabama Ordnance Works	N/A	AL	May 1941
Badger Ordnance Works	Badger AAP	WI	Jan 1943
Gopher Ordnance Works	N/A	MN	June 1942
Indiana Ordnance Works	Indiana AAP	IN	Aug 1940
Oklahoma Ordnance Works	N/A	OK	Sep 1941
Sunflower Ordnance Works	Sunflower AAP	KS	Mar 1942
Product: Propellants and High Explosives			

Chicksaw Ordnance Works	N/A	TN	Feb 1942
Radford Ordnance Works	Radford AAP	VA	Aug 1940
Product: RDX			
Holston Ordnance Works	Holston AAP	TN	Feb 1942
Wabash River Ordnance Works	Newport AAP	IN	Dec 1941
Product: Toluene			
Baytown Ordnance Works	N/A	TX	Sep 1941

Source: Lenore Fine and Jesse A. Remington, The Corps of Engineers: Construction in the United States (Washington, D.C.: Government Printing Office, 1972), 309-335.

Propellants

The process for producing smokeless powder remained essentially unchanged since the first smokeless powder was produced during the 1890s. The process combined a cellulose compound, usually cotton or wood pulp, with a nitrate and refined mixture. First, cotton linters or wood pulp were cleaned to remove dirt and impurities. The cellulose then was soaked in a bath of nitric acid to create nitrocellulose. Workers boiled the mixture in water to remove excess acid. The mixture was purified further by alternate baths in boiling water and cold water, with sodium carbonate added to the bath. Once the mixture was purified, the water was removed by pressing and adding alcohol to accelerate the drying process. The addition of ether changed the mixture into a paste-like substance, which could be shaped into blocks or ribbons to be cut into grains when dry.

Grains of smokeless powder were not necessarily a fine powder. These grains were large enough to contain holes called perforations, and were classified as multi-perforated, single perforated, or solid. The purpose of these perforations was to adjust the burning rate, which depended upon the amount of exposed surface in a grain. During the burning process, the exposed surface of a solid grain diminished so that the combustion rate also decreased. By contrast, the exposed surface of a multi-perforated grain increased when burned, resulting in an increased combustion rate. Single perforated grains maintained a steady rate of combustion.

Although the basic process remained essentially unchanged during the World War II era, minor modifications either expanded the production capability or improved the quality of the powder. For example, the War Department recognized that the nation possessed an insufficient number of flat presses to produce the necessary quantities of powder, and experimented with rolling presses. Rolling presses operating at such facilities as Radford Ordnance Works allowed the United States to produce the necessary quantities of smokeless powder. Hercules Powder Company also developed a continuous filter method of washing nitrocellulose, which proved to be more efficient that the previous method of decanting the settled mixture.

Flashless powder also was developed during this period. The explosion of smokeless powder produced a residue of hydrogen and carbon monoxide. Both gases burned once exposed to air, creating a bright flash that could blind gunners at night and identify their position. The flash could be reduced by adding inorganic salts to the powder, which lowered the temperature of the explosion, thus reducing the flash.

Another development was the increased use of double base propellants, which combined nitrocellulose and nitroglycerine. This combination produced more energy than a single base powder and was used primarily for rocket motors and mortar ammunition. Rockets were used in significant numbers for the first time since the Napoleonic Wars, and ranged in size from the shoulder-fired "bazooka" to large aircraft weapons. Each rocket contained a solid double-base propellant known as the motor. Mortar shells contained sheets of double base powder to provide energy for the round.

Initially the War Department made double base propellants using a solvent to shape the grain into the desired form. The use of solvents proved impractical for large grains because the grain became distorted during the drying process. The War Department followed the Navy's lead in casting the grains using a combination of heat and pressure to create what was termed a solventless double base propellant. Radford Ordnance Works became the War Department's leading producer of double base powders.

High Explosives

High explosives constituted the second major category of military explosives. They reacted with far greater speed than propellants, thus producing a more violent effect. While the reaction time for smokeless powder could be measured in hundredths of a second, the reaction time for TNT could be measured in thousandths or millionths of a second.

Trinitrotoluene, or TNT, was the preferred high explosive during World War II. Other substances produced greater explosive effect, but TNT offered significant advantages for military application. It was stable in storage and could withstand the shock of being fired from an artillery shell. The latter consideration minimized the danger of a premature explosion while a round was inside the barrel. TNT also had a comparative low melting temperature of 81 degrees centigrade. This characteristic allowed the explosive to be melted and poured into artillery shells or aerial bombs.

The basic ingredients of TNT are nitric acid and a hydrocarbon called toluene. During World War I, toluene was produced as a by-product of coke ovens, but following that conflict the War Department feared that the process produced too limited a quantity of toluene for military purposes. During the 1920s and 1930s, the War Department and Standard Oil Corporation experimented with the production of small quantities of toluene from petroleum. In 1940, the War Department contracted with Standard Oil and its affiliate, Humble Oil, to construct a toluene plant in Baytown, Texas. By October 1942, the Baytown Ordnance Works was producing 65 million gallons of toluene per year, compared with less than 9 million gallons total toluene production during all of World War I.

An important advancement in the TNT production process came almost by accident. While on a trip to Canada, an Ordnance Corps officer made an unscheduled visit to small TNT plant near Montreal. He discovered that the Canadians were adding toluene to acid, rather than the American practice of adding acid to toluene. The new process nearly tripled American TNT production.

Operations at the Volunteer Ordnance Works, in Chattanooga, Tennessee, provide a typical example of TNT production. The process began with the creation of acids. The nitric acid process began by burning ammonia against a platinum catalyst, and mixing the product with water in a descending tower. At the same time, sulphur was burned and the sulphur oxides were mixed with water to produce sulfuric acid. The two acids were mixed or strengthened, as required, in a series of mixing towers and gravity-fed pipes.

The next step was the nitrating of the toluene, which occurred in three stages, mono-nitrating, di-nitrating, and tri-nitrating. As the toluene became more highly nitrated with each step, the process required a stronger acid. The process began with the blending of nitric acid and toluene in the "mono-house," where workers agitated and heated the mixture in large vats. The mixture was moved to the bi-nitrating house, where a similar operation took place. Tri-nitrating was the most difficult and time consuming process. As a result, typical production lines contained two tri-nitrating houses, and only one mono- or di-nitrating house.

In the next step, the mix was purified by washing in sellite or a sodium sulphite solution, which absorbed impurities. A heating process removed any remaining water and the TNT cooled to a crystalline form. After testing to ensure that the TNT met government specifications, the crystals were boxed and shipped to an Ordnance Plant for loading into bombs or shells.

By mixing TNT with ammonium nitrate, the Army could increase the quantity of explosives. The mixture produced an explosive substance called amatol, which was almost as powerful as TNT, but required less toluene. At the Louisiana Ordnance Plant, ammonium nitrate was produced on site, and added to the TNT before the mixture was loaded into shells. Production specifications required that within eight hours of its manufacture, ammonium nitrate be mixed with the TNT and loaded into shells.

Although the ability of TNT to withstand shocks without premature explosion made it highly desirable for most military purposes, the Navy sought a more powerful explosive for its torpedoes. Torpex, a mixture of TNT and RDX, met the Navy's requirements. RDX is an extremely powerful explosive that was not usable because of its sensitivity to shock. Mixing RDX with TNT reduces the sensitivity sufficiently to allow its use in torpedoes. Torpex is 50 per cent more powerful than TNT. The Navy first used Torpex in its submarine torpedoes, but later it was used for torpedo airplanes. The increased sensitivity of Torpex presented a danger to the pilot, but "the Chief of Naval Operations declared that the casualty rate for torpedo planes was already extremely high, and that the added damage potential of Torpex justified the increased hazard of this bullet sensitive material." In accordance with the existing agreements between the Navy and War Departments, the War Department produced RDX for the Navy at its Wabash and Holston Ordnance Works.

Although TNT and RDX were the most common high explosives, others were used. Ammonium picrate, or explosive D, was used in antitank rounds because of its ability to withstand shock without accidental detonation. Its high melting temperature and short shelf life, however, limited its military usefulness. Tetryl was used as a booster to complete the explosion of TNT.

Production Facilities

The ordnance works that stretched across the interior of the country shared similar features, regardless of whether they manufactured propellants or high explosives. Each installation contained distinct administrative, storage, and production areas. Most, but not all, ordnance works also contained their own power and water systems. In addition to office space, the administrative areas contained fire stations, guard stations, medical facilities, and shower houses. The latter were important because the toxic chemicals required workers to shower after each shift. Storage areas normally contained widely dispersed igloo-type magazines for holding explosives, with rail facilities to move heavy material. Production areas typically consisted of multiple lines, each consisting of several buildings. For safety's sake, buildings were separated from each other. Despite the steadily increasing pressure for economy in construction, the demands of the industrial process and safety prevented the use of temporary constructed for the buildings in the production areas.

CHAPTER IX

ASSEMBLY OF LARGE AMMUNITION

Development of Ammunition Assembly Plants

War Department Ordnance Plants (Table 18) and Navy Ammunition Depots (see Table 21in Chapter XI) assembled artillery ammunition and aerial bombs in unprecedented quantities for World War II. The success of these facilities was apparent in the ability of the Allied forces to overcome the Axis powers through superior firepower. These achievements were noteworthy in light of the fact that the United States had only a nominal ammunition production capability at the beginning of the war.

The process of preparing artillery rounds or bombs appeared simple. Metal shells were shipped from commercial manufacturers to an Army Ordnance Plant or Navy Ammunition Depot. The hollow shells were filled with TNT or other explosive, painted, and labeled. Most artillery rounds then were attached to a brass casing that contained a propellant and primer. Fuzes were placed in the shells for small caliber ammunition, or metal plugs were installed in the nose of medium or large caliber shells.

In practice, however, large ammunition assembly required considerable skill and effort. The potential for disastrous TNT explosions necessitated stringent safety measures. Assembly of artillery rounds demanded adherence to precise specifications to ensure that the round would fly accurately. TNT contracted as it cooled inside the shell, so special attention was required to ensure an even distribution of weight. Moreover, the variety of ammunition produced required flexibility in shifting production lines.

The many types of ammunition could easily bewilder a casual observer. Ammunition can be divided into categories based upon its purpose. Anti-aircraft guns usually used smaller ammunition, such as 20mm, 37mm, or 40mm, but could also fire up to 90mm rounds. Anti-tank guns fired 37mm, 57mm, 75mm, 76mm, and 90mm rounds, while tanks used 75mm or 76mm guns. Field artillery howitzers ranged in size from 75mm to 240mm, although the 105mm and 155mm were the most common sizes. Guns might fire high explosive rounds, armor piercing rounds, tracer rounds, incendiary rounds, or illumination rounds. An ordnance plant also might assemble mortar rounds, bombs, or rockets. The likelihood of sudden changes in demands for a particular round, caused by changes in the tactical situation, precluded orderly production planning and scheduling.

Projectiles

Loading of a projectile began with the fabrication of a shell. The shell of an artillery round is the hollow steel component that carries an explosive to the enemy. With the exception of Gadsden Ordnance Plant, government facilities did not produce shells; instead, they procured shells from private facilities. The shells were transformed into finished ammunition at ordnance plants.

Filling shells with explosives, or the bursting charge, was one of the most difficult, and important, tasks. TNT could be melted and poured into a shell because of its comparatively low melting temperature. During the inter-war years, Picatinny Arsenal, in Dover, New Jersey, had performed this function for the Army. Working under peacetime conditions, the Arsenal felt no pressure to modernize the operations. Each shell was loaded by pouring molten TNT from a rubber bucket. After the TNT had cooled, additional layers of TNT were added to fill the cavities caused by the cooling.

TABLE 18: WORLD WAR II LARGE AMMUNITION ASSEMBLY PLANTS

WWII Name	Current Name	Location	Date Established
Bluebonnet Ordnance Plant	N/A	TX	Feb 1942
Cornhusker Ordnance Plant	Cornhusker AAP	NE	Nov 1942
Elwood Ordnance Plant	Joliet AAP	IL	Sep 1940
Gadsden Ordnance Plant	N/A	AL	Dec 1941
Green River Ordnance Plant	N/A	IL	Jan 1942
Gulf Ordnance Plant	N/A	MS	Apr 1942
Illinois Ordnance Plant	N/A	IL	Aug 1941
Iowa Ordnance Plant	Iowa AAP	IO	Apr 1941
Kansas Ordnance Plant	Kansas AAP	KS	Apr 1942
Kingsbury Ordnance Plant	N/A	IN	Nov 1940
Lone Star Ordnance Plant	Lone Star AAP	TX	July 1941
Louisiana Ordnance Plant	N/A	LA	July 1941
Nebraska Ordnance Plant	N/A	NE	Dec 1941
Pantex Ordnance Plant	N/A	TX	Mar 1942
Ravenna Ordnance Plant	Ravenna AAP	OH	Aug 1940
Picatinny Arsenal	Picatinny Arsenal	NJ	1880
Wolf Creek Ordnance Plant	Milan AAP	TN	Dec 1940

Source: Lenore Fine and Jesse A. Remington, The Corps of Engineers: Construction in the United States (Washington, D.C.: Government Printing Office, 1972), 309-335.

As the new GOCOs focused their attention upon meeting the wartime demands for ammunition, the plant operators were not satisfied with the slow methods used by Picatinny Arsenal. As experienced factory managers within the civilian economy, they were familiar with mechanized equipment to perform filling operations. Upon assuming responsibility for operation of the Kansas Ordnance Plant, officials from Johns-Manville confidently predicted that modern production methods quickly would improve the efficiency of operations.

The temperamental nature of TNT proved more challenging than contractors first imagined. Lumps or bubbles in the liquid TNT could create an uneven distribution of weight as the explosive solidified. The majority of plants used hot water jackets to keep the TNT just above the melting temperature, so that it could be poured into a load of shells. Kansas Ordnance used a wheeled cart that elevated the TNT above the shells and allowed for easier pouring. Illinois Ordnance Plant, operated by Sherwin Williams Inc., developed a volumetric pouring machine that allowed the operator to pour a pre-measured amount of TNT into the shell.

Cavitation of the TNT during the cooling process created another major problem in the production of shells. As the mixture cooled and contracted, cavities were created near the center of the nose. Early in the war, the cavities were filled with more TNT. Yet the deep cavity provided space for a booster, to accelerate the explosion. To be useful, however, the cavity must be absolutely conical, and the TNT cooled in an irregular pattern. The Kansas Ordnance Plant solved this problem by inserting a steam-heated probe into the mouth of the shell. The probe created a smooth cavity inside the round that met military requirements. Soon all other loading operations copied this invention.

To conserve TNT, especially during the early years of the war, the explosive was mixed with ammonium nitrate to form amatol. Amatol was almost as powerful as TNT, but could be produced in larger quantities. As the War Department's ability to produce TNT increased, the use of amatol diminished.

Ammonium picrate, otherwise known as explosive D, was used for armor piercing munitions, such as anti-tank weapons. Its ability to withstand shock and friction without accidental impact made it well suited for such uses. Unlike TNT, however, it could not be melted. Therefore, it was loaded into shell with an hydraulic press, in a process known as press loading.

The process of loading bombs was similar to that for loading artillery shells. Melted TNT was poured into the bomb shells and allowed to cool. The cavities then were filled. Most ordnance plants could load either bombs or artillery shells. Cornhusker Ordnance Plant, operated by Quaker Oats, specialized in loading aerial bombs.

A fuze, a device to initiate the explosion, was installed after the shell was filled with explosives. Fuzes were intricate devices, containing up to 100 parts, often with tolerances of one thousandths of an inch. Each fuze contained a sensitive explosive, such as mercury fulminate, and a mechanism to initiate the explosion. The mechanism could either detonate upon impact, or at a specific time. Some impact fuzes contained a device to delay the explosion for a second or less, which could be useful in anti-tank rounds or rounds intended to penetrate fortifications. Toward the close of the war, the Navy developed a variable time, or proximity, fuze, which contained a miniature radar to initiate the explosion within range of the target. This revolutionary new fuze was used in anti-aircraft weapons and to ensure airbursts for field artillery. The War Department contracted with private companies for the metal fuze components. Watch and clock producers were considered especially suited for this work. Workers at Army ordnance plants completed the final assembly of the fuze, including loading of the explosives. The Navy assembled its fuzes at the Macon Naval Ordnance Plant, another GOCO.

Detonation of the fuze set off a process called the explosive trains. By itself the fuze could not cause the TNT to explode due to TNT's high shock tolerance. Therefore a moderately sensitive explosive, called the booster, was installed between the fuze and the TNT. The fuze ignited the booster, which in turn ignited the TNT. Tetryl was the most common booster.

After explosives and fuzes were loaded into the shell, each projectile required painting and labeling. Labeling entailed painting for daytime identification of the round and punched markings, so that a gunner could identify a round using his fingers. Each shell also was weighed, and sorted by weight zone. The weight zone was marked on the round to assist the gunners.

Propellants

Filling and preparing shells was half the work of an ordnance plant. The plant also prepared the propellant, usually smokeless powder, used to launch rounds towards their targets. The process involved either joining the shell to a brass or steel cartridge case, or else preparing bags of powder. The task also required the preparation of the primer for initiating the explosion.

The particular job varied with the type of round, which could be fixed, semi-fixed, or separate loading. Each classification designated how the cartridge case was attached to the shell. Fixed rounds, used in small caliber ammunition, relied upon a cartridge case firmly crimped to the shell. In a semi-fixed round, common for medium caliber artillery, the case and shell were separable. Large caliber ammunition was too heavy to combine the shell and the propellant. The shell was loaded separately from the propellant. The propellants were loaded in silk bags. Semi-fixed and separate loading ammunition had the advantage of allowing the gunners to adjust the charge by changing the number of powder bags.

Fixed ammunition offered the advantages of rapid loading, and was most common in small caliber ammunition, such as anti-aircraft or anti-tank rounds. First, the smokeless powder was poured into the case. Then, a primer was placed at the base of the case, which ignited the propellant. The primer consisted of a sensitive material, usually mercury fulminate, which in turn ignited a charge of black powder, causing the smokeless powder to burn. For waterproofing, the primer would be covered with a wax coating. The shell then was placed in the case, and crimped to hold it in place until firing.

Semi-fixed ammunition, used for medium caliber field artillery, resembled fixed ammunition in most respects. However, the projectile was not crimped to the case. The powder was loaded in bags and placed into the shells. This arrangement allowed the gunner the adjust the number of bags within the charge just before firing.

Separate loading ammunition, used for 155mm and larger rounds, worked by placing the projectile, the propellant, and the primer into the artillery piece separately. These rounds were so heavy that lifting the projectile alone was a challenge to the gunners. Combining the projectile and propellant would have been excessively cumbersome. Bag loading plants prepared bags of smokeless powder for separate loading ammunition. The bags were cut and sewn, and filled with a measured amount of smokeless powder.

Production Facilities

The above summary provides only brief description of the many processes involved in ammunition production. Each task in the process involved multiple hand labor operations that were often tedious. Quality control required extraordinary efforts by all personnel. Workers checked measurements and looked for improper cooling of TNT to meet the strictest specifications for dimensions, weight, and balance.

Indeed, quality control was perhaps the most important concern of ammunition assembly operation. The

Ordnance Department selected a sample from each lot for acceptance testing. Failure of the lot to meet the government specifications required costly reworking. Managers tried to prevent such occurrences through inspections throughout the process.

Lone Star Ordnance Plant, near Texarkana, Texas, illustrated a typical arrangement for an Ordnance Plant. The facility contained five loading lines for shells and bombs, plus eight auxiliary lines for fuzes, boosters, primers, and detonators. To support these production lines, an administrative area, storage area, railroad system, and the requisite water, steam, and other utilities were included. The 105mm loading line provided a typical example of a World War II era organization for loading line layout. Its buildings were:

E-1 Inert Storage E-14 Fuze Service

E-2 Receiving and Painting E-15 Assembly & Shipping

E-3 Paint & Oil E-16 Inert Storage

E-4 Melt load E-17 Propellant Charge

E-5 TNT Screening E-18 Smokeless Powder

E-6 Ammonium Nitrate Service Magazine E-19 Primer Service

E-7 TNT Service Magazine E-20 Change House

E-8 Tools & Equipment E-21 Change House

E-9 Cooling Building E-22 Vacuum Pump House

E-10 Ammonium Nitrate Service Magazine E-23 Vacuum Pump House

E-11 Booster Service E-24 Vacuum Pump House

E-12 Drilling & Booster E-25 Heater HouseE-13 Booster Equipment

Other ordnance plants varied to some degree in the number and types of buildings. Yet, overall the similarities of each plant were greater than the differences.

Considering the practically non-existent state of ammunition production at the beginning of 1940, the quantity of ammunition produced during World War II is impressive. The War Department alone produced over 625 million minor caliber rounds, 239 million medium caliber rounds, 23 million major caliber rounds, over 4 million tons of bombs, plus mortar rounds, grenades and mines. This ammunition could be placed in a train that would stretch from Boston to the west coast. This vast quantity of firepower overwhelmed the Axis Powers.

CHAPTER X

SMALL ARMS AMMUNITION

Of all the materiel shortages at the beginning of World War II, the shortage of small arms ammunition posed a greater threat to the national security than other ordnance shortages. This category of ammunition included rounds up to .50 caliber, and was required for rifles, carbines, pistols, and machine guns, including aircraft and anti-aircraft weapons. The United States not only lacked a supply of small arms ammunition, but it also lacked the capability to manufacture ammunition.

Following World War I, the Army's stockpile of small arms ammunition was used for training. The consumption of training ammunition and the deterioration of ammunition in storage resulted in dwindling supplies of ammunition. The Army's only facility for small arms ammunition production was Frankford Arsenal near Philadelphia. The United States did possess a sports ammunition industry, but the differences between sports and military ammunition prevented the conversion of civilian industry to military use.

To remedy this situation, the Ordnance Department authorized construction of Government-Owned, Contractor-Operated (GOCO) small arms ammunition plants in the summer of 1940 (Table 19). The first wave of construction consisted of small-arms plants in Lake City, Missouri; St. Louis, Missouri; and, Denver, Colorado. These plants resembled other Army ordnance-related construction during the mobilization period, with one important difference. Facilities for the production of small arms ammunition received the highest priority for construction material, A-1-A. These facilities were the only Army ordnance activity to receive such a priority.

More construction soon followed. In the spring of 1941, the Ordnance Department authorized a second wave of plant construction, including the Utah, Twin Cities, and Des Moines Ordnance Plants. After Pearl Harbor, the War Department built new plants, expanded existing facilities, and converted selected civilian factories to ammunition production.

All of these new plants faced the same challenges in producing massive quantities of ammunition, while still meeting the Army's quality control requirements. A small arms round consisted of a brass cartridge case, a projectile, the powder, and a primer. The production process began with shaping the case and projectile, which were both metal components. Then the propellant and primer were added before crimping the assembly together. Although the process was reasonably simple in theory, the requirements for precise specifications and the demands for billions of rounds complicated the production process.

Manufacture of the cartridge case began with a small brass cup. The brass was shaped into a cartridge case through a series of "draws," and other shaping operations. During the shaping process, the brass was annealed, or heat treated, to remove the metal stresses caused by the reshaping. Between each annealing operation, the brass was pickled, or treated in acid, to remove oxides created by the heat, and washed to remove the acid.

The procedures for fabricating the projectile were similar to the process for shaping the cartridge case. Each projectile had a copper jacket that was shaped through a series of operations that resembled the production of the cartridge. Again, the process required meticulous attention to exacting measurements. A lead core then was inserted into the jacket.

TABLE 19: WORLD WAR II SMALL ARMS AMMUNITION PLANTS

WWII Name	Current Name	Location	Date Established
Alleghany Ordnance Plant	N/A	MD	May 1942
Denver Ordnance Plant	N/A	CO	December 1940
Des Moines Ordnance Plant	N/A	IA	July 1941
Eau Claire Ordnance Plant	N/A	WI	August 1942
Evansville Ordnance Plant	N/A	IN	March 1942
Frankford Arsenal	N/A	PA	1830
Kings Mills Plant	N/A	OH	Jan 1942
Lake City Ordnance Plant	Lake City AAP	MO	November 1940
Lowell Ordnance Plant	N/A	MA	November 1942
Milwaukee Ordnance Plant	N/A	WI	August 1942
St. Louis Ordnance Plant	St. Louis AAP	MO	December 1940
Springfield Arsenal	N/A	MA	1794
Twin Cities Ordnance Plant	Twin Cities AAP	MN	July 1941
Utah Ordnance Plant	N/A	UT	September 1941

Source: Lenore Fine and Jesse A. Remington, The Corps of Engineers: Construction in the United States (Washington, D.C.: Government Printing Office, 1972), 309-335.

Smokeless powder and primer were added to complete the round. The primer was a sensitive explosive, usually mercury fulminate, which was designed to initiate the explosion when struck by a firing pin. Primer was added to the base of the cartridge case and waterproofed with a varnish. A small quantity of smokeless powder was poured into the cartridge case. Finally, the projectile was crimped to the cartridge case.

Most ammunition used during World War II consisted of a lead core with a copper jacket known as ball ammunition. Other types of specialized ammunition were also produced in smaller quantities. Armor piercing, or "AP" rounds, contained a hardened steel core instead of the lead core. Tracer rounds contained an illuminating powder, which enabled the gunner to observe the path of the bullet. Incendiary rounds contained a chemical compound that ignited upon impact.

As in the case with all ammunition production, quality control was a major consideration. To avoid malfunctioning weapons, the Ordnance Department imposed exact specifications for external dimensions, weight, etc., which were verified by more than fifty inspections during the production process. After delivery of a lot to the government, an ordnance inspector selected a few rounds from the lot for inspection. The final examination included test firing or disassembly of a few rounds from each lot. Failure of a round to meet the specifications could result in the rejection of the entire lot. To prevent such an event, companies stationed inspectors at critical locations to examine parts as they moved through the production process.

The machines used to produce small arms ammunition were designed at Frankford Arsenal during the inter-war years. Each machine typically performed a single, repetitive operation. One operator manned each machine.

An article in the December 1942 issue of Architectural Forum provides insight into the design and construction of small arms ammunition plants. In the design process, architects analyzed the spatial requirements for each stage of the manufacturing process to develop flow charts. The building plan was developed from these flow diagrams. Wherever possible, existing plans were used to decrease the design time, and to expedite construction. Work began almost immediately after the drawings were complete, and proceeded as rapidly as possible.

Building design reflected the functional requirements for ammunition production. Shortages of steel forced builders to employ alternative materials, including masonry, glass, and wood frame. The danger of explosion and fear of sabotage prompted the design of buildings containing reinforced masonry at the base wherever possible. Areas that contained smokeless powder required extra air filters to remove explosive dust from the atmosphere and air humidifiers to minimize static electricity. The most noticeable feature of these small arms plants was their size. The St. Louis plant, for example, covered 300 acres and employed 40,000 men and women.

As was the case with artillery ammunition, the American capability to exceed the production of its enemies in small arms ammunition provided a crucial advantage on the battlefield. The ammunition produced at small arms plants was used by infantry units, in aircraft machine guns, in anti-aircraft machine guns, in tanks, and in virtually all other combat operations.

CHAPTER XI

AMMUNITION DEPOTS

Finished ammunition required safe storage prior to shipment overseas. For this purpose, the Army and Navy acquired vast tracts of land throughout the United States. Safety considerations for storage of large quantities of explosives required special design features, including permanent construction facilities.

Ammunition Depot Design

The design of ammunition depots was influenced strongly by the disastrous 1926 explosion at the Navy's Lake Denmark Ammunition Depot in New Jersey. A severe thunderstorm sparked a fire that caused an explosion in a temporary ammunition storehouse. The building was not designed for explosives, and was overloaded. The explosion spread to nearby magazines. The resulting series of explosions not only demolished Lake Denmark, but it also severely damaged the Army's Picatinny Arsenal and several nearby towns. Investigations following this disaster resulted in recommendations for strict limitations on the quantity of explosives stored in one structure and for increased distances between storage buildings.

In 1928, in response to the Lake Denmark disaster, both services adopted a new type of high explosive magazine. The new design called for a low-scale, earth-bermed, concrete structure. The sides were semi-circular so that the weakest structural point was the roof. The design directed the force of an explosion upwards, rather than toward adjacent magazines. The top was covered with earth and grass. An elaborate set of lightning rods and steel reinforcing rods were added as lightning protection. These magazines generally were 26 feet wide, 13 feet high, and from 40 to 80 feet long. The Army called the new magazine structures "igloos," while the Navy continued to call them "high explosives magazines."

As an additional design feature to prevent the spread of explosions, ammunition magazines were dispersed widely. Igloos were grouped in blocks of 100, with a minimum distance of 1,400 feet between blocks. Within each block, magazines were separated by at least 400 feet. The distance between each structure in the design of ordnance depots required considerable acreage. Six Army Ordnance Department depots contained more than 20,000 acres. To connect the various magazines, each depot normally had extensive road and railroad networks.

Despite its acknowledged superiority for holding explosive munitions, igloo construction consumed an excessive quantity of steel, a critical war material. Between 1942 and 1943, engineers proposed an alternate design to reduce the amount of steel used for magazines. The design consisted of a circular, dome-shaped magazine, which they termed a "beehive." The new design proved to be equal to the igloo in structural strength, but required less steel, copper, and other vital materials. Development of the beehive design, however, came after most ordnance depots had already been completed, and therefore had little effect upon ammunition storage during the war.

Ammunition Depot Facilities

The War Department used its ammunition depots for long term storage, to support military activities in a geographic area within the continental United States, and to hold ammunition prior to overseas shipment. As a result, depots were dispersed across the United States (Table 20). Some depots were located near ordnance plants, where they could provide long term storage, with minimum transportation cost from the point of manufacture. In the early phases of the war, when most ammunition requirements were associated with training activities, the wide geographic distribution of depots worked well. As the burden of supporting committed forces increased throughout the war, the workload of depots near ports increased. Depots within the coastal regions acquired the additional mission of providing back-up support the port depots.

Army depots along the Atlantic, Gulf, or Pacific Coasts, such as Letterkenny, Pennsylvania; Seneca, New York; San Jacinto, Texas; Umatilla, Oregon; or, Sierra, California were used to hold ammunition prior to its final shipment overseas. Other depots, such as Milan, Tennessee; Red River, Texas; or, Portage (Ravenna), Ohio, were located near ordnance plants to hold the ammunition immediately after its production. The dry climate of western depots, such as Fort Wingate, New Mexico, or Tooele, Utah, enhanced their suitability for long term storage.

Like most other World War II construction projects, Ordnance Department depot construction followed a time sequence. During the mobilization period, the War Department either expanded or initiated construction at Anniston, Alabama; Umatilla, Oregon; Portage, Ohio; Fort Wingate, New Mexico; Milan, Tennessee; Seneca, New York; San Jacinto, Texas; and Red River, Texas depots. These depots, collectively called the "A" program, featured permanent construction ammunition "igloos," inert warehouses, and administrative buildings. As the war progressed, the demand for depots increased, but shortages of building materials also increased. To meet the wartime requirements, the Ordnance Department undertook a program for "B" depots. Igloos at these depots were permanent structures, but the other buildings were temporary. At some depots, the Army used a "theater-of-operations" type construction, which was designed as less permanent than the temporary buildings. Although the Ordnance Department provided the requirements, the Quartermaster Corps or the Corps of Engineers completed the actual construction.

Naval ammunition depots performed both industrial production and storage functions. The Navy Department used depots to load explosives into the ammunition and to assemble complete rounds. These depots also supported command functions (Table 21).

At the close of World War I, the Navy had eight coastal depots located near Navy yards or bases. The Hingham Depot was located near the Boston Navy Yard, while the Iona and Lake Denmark Depots serviced the New York Navy Yard. Fort Mifflin Depot and St. Juliens Creek Depot supported the Philadelphia and Norfolk regions, respectively. A mine depot at Yorktown, Virginia, provided a specialized operation in the loading and storage of underwater mines. On the Pacific coast, ammunition depots at Mare Island and Ostrich Bay on Puget Sound completed the coastal depots. In 1930, the Navy constructed a large inland depot at Hawthorne, Nevada, to reduce congestion at other depots and to meet modern specifications for explosive storage.

As the United States entered the protective mobilization phase, the Navy Department achieved its goal of constructing an inland ammunition depot east of the Mississippi. In June 1940, the government announced its intention to build a new depot in southwestern Indiana, which was named the Crane Ammunition Depot. Construction began in November of that year. By the official dedication on 1 December 1941, only a small percentage of the buildings were complete. When completed in 1942, the depot contained 1770 magazines, 1084 of which were designed for high explosives. It also contained 332 miles of road and 195 miles of railroad.

TABLE 20: WORLD WAR II ARMY ORDNANCE DEPOTS

Original Name	Current Name	Location	Date Established
Anniston Ordnance Depot	Anniston Army Depot	AL	1941
Benecia Ordnance Depot	N/A	CA	1851
Black Hills Ordnance Depot	N/A	SD	1942
Blue Grass Ordnance Depot	Lexington-Blue Grass Army Depot	KY	1941
Charleston Ordnance Depot	N/A	SC	1916
Curtis Bay Ordnance Depot	N/A	MD	1918
Delaware Ordnance Depot	N/A	NJ	1918

Letterkenny Ordnance Depot	Letterkenny Army Depot	PA	1942
Milan Ordnance Depot	Milan AAP	TN	1941
Nansemond Ordnance Depot	N/A	VA	1918
Navajo Ordnance Depot	Navajo Army Depot	AZ	1942
Ogden Ordnance Depot	Ogden Defense Depot	UT	1920
Portage Ordnance Depot	Ravenna AAP	OH	1940
Pueblo Ordnance Depot	Pueblo Army Depot	CO	1942
Raritan Arsenal	N/A	NJ	1918
Red River Ordnance Depot	Red River Army Depot	TX	1941
San Jacinto Ordnance Depot	N/A	TX	N/A
Savanna Ordnance Depot	Savanna Army Depot Activity	IL	1917
Seneca Ordnance Depot	Seneca Army Depot	NY	1941
Sierra Ordnance Depot	Sierra Army Depot	CA	1942
Sioux Ordnance Depot	Sioux Army Depot	NE	1942
Tooele Ordnance Depot	Tooele Army Depot	UT	1942
Umatilla Ordnance Depot	Umatilla Army Depot	OR	1942
Ft. Wingate Ordnance Depot	Fort Wingate Army Depot	NM	1940*

* Date ordnance depot established; Fort Wingate predates ordnance depot.

Source: Lenore Fine and Jesse A. Remington, The Corps of Engineers: Construction in the United States (Washington, D.C.: Government Printing Office, 1972), 309-335.

TABLE 21: WORLD WAR II NAVY AMMUNITION DEPOTS

WWII Name	Current Name	Location	Date Established
Charleston Naval Ammunition Depot	Naval Base Charleston	SC	1941
Crane Ammunition Depot	Naval Weapons Support Center Crane	IN	1941
Earle Ammunition Depot	N/A	NJ	1943
Fallbrook Ammunition Depot	Fallbrook Annex of NWS Seal Beach	CA	1942
Fort Mifflin Ammunition Depot	N/A	PA	1897
Hastings Ammunition Depot	Hastings NG	NE	1942
Hawthorne Ammunition Depot	Hawthorne AAP	NV	1930
Hingham Ammunition Depot	Naval Ammunition Depot Hingham	MA	1903
Iona Island Ammunition Depot	N/A	NY	1900
Lake Denmark Ammunition Depot	part of Picatinny Arsenel	NJ	1892
Mare Island Ammunition Depot	Naval Ammunition Depot Mare Island	CA	1853
McAlester Ammunition Depot	McAlester AAP	OK	1942
New Orleans Ammunition Depot	N/A	LA	1941
Ostrich Bay Ammunition Depot	Naval Ammunition Depot Puget Sound	WA	1891
Port Chicago Magazine	N/A	CA	1942

St. Juliens Creek Ammunition Depot	Naval Ammunition Depot St. Juliens Creek	VA	1897
Seal Beach Navy Depot	Naval Weapons Station Seal Beach	CA	1944
Yorktown Mine Depot	Naval Weapons Station Yorktown	VA	1918

Source: United States Navy, Bureau of Yards and Docks, Building the Navy's Bases in World War II (Washington, D.C.: Government Printing Office, 1947).

As the war progressed, the Navy established two additional inland ammunition depots. Hastings, Nebraska, and McAlester, Oklahoma, were selected as depot sites in the summer of 1942 due to their location near major railroad lines. The design and functions of these depots was nearly identical. Both installations contained storage magazines, and facilities for loading shells and bombs.

Along the Atlantic and Pacific coasts, the Navy followed established practices for expanding existing installations while creating new depots as warranted. An example of expansion is provided by Hingham Depot, in Massachusetts. The Hingham Depot relied on lighters, or smaller boats, for transportation of materiel to the Boston Navy Yard. As the workload increased, the Navy used more lighters, with a corresponding increase in wharfs and elevators. At the same time, Hingham's railroad and motor transport facilities were increased. At St. Juliens Creek, near Norfolk, the Navy built new magazines, barracks, and related facilities, to support its distribution and its loading missions.

Even upgraded and expanded depots could not meet wartime demands. Consequently the Navy established new ammunition depots at New Orleans, Louisiana; Sandy Hook, New Jersey; and, Charleston, South Carolina on the Atlantic and Gulf Coasts. The depot at Sandy Hook, named the Earle Naval Ammunition Depot, became a major shipping point for both Army and Navy ammunition to the European theater. On the Pacific Coast, the Navy built new depots at Fallbrook and Seal Beach, California, and acquired Indian Island in the Puget Sound for additional ammunition storage.

The Navy redeveloped an ammunition depot at Port Chicago in 1942 from an abandoned shipyard on the San Francisco Bay. Designated a permanent installation, Port Chicago was selected for its isolated location which minimized potential damage to civilian communities in the event of an explosion. Despite these precautions, Port Chicago was the site of one of the worst ammunition disasters of the war. In July 1944, an ammunition ship exploded, killing over 300 sailors and damaging the port and nearby civilian communities. The stevedores at Port Chicago, who were African-American sailors, believed that they had been assigned exceptionally hazardous duty because of their race and refused to load ammunition ships. In a controversial series of courts-martial, the government dishonorably discharged fifty sailors and sentenced them to extended prison sentences; 208 sailors received shorter prison sentences and bad conduct discharges. After the war, the Navy reduced the sentences.

As a part of the Army and Navy ordnance systems, ordnance depots played an essential role in the distribution of ammunition. Their functional design, with rows of similar structures separated by large distances, provided an important safety feature to the ordnance systems. With the Lake Denmark disaster in mind, the War and Navy Departments carefully ensured that future depots would avoid similar accidents.

CHAPTER XII

MODERN INDUSTRIAL ARCHITECTURE AND THE RISE OF THE WORLD WAR II INDUSTRIAL COMPLEX

As the United States moved closer to involvement in World War II during the late 1930s, the necessity to increase the military's supply of weaponry and ammunition became apparent. Between the two world wars, the United States Army maintained few ordnance production facilities. The Frankford Arsenal in Philadelphia was the only existing small arms production plant during the 1920s and 1930s. By 1936, Army planners realized that U.S involvement in a global war would require both large-scale arms manufacturing in existing plants, and the construction of new facilities to supplement commercial manufacturers. Between 1939 and 1942, the U.S. military devoted a large percentage of its construction program to industrial production facilities, including heavy industry factories used to produce aircraft, tanks, and heavy artillery; and ammunition production facilities. Modern architectural theory, technology of building materials, and the production process influenced the design of the modern factory building. In addition to theoretical and technological developments, economic and time constraints imposed by the global emergency of the late 1930s and early 1940s played an equally significant role in the development of the World War II industrial building.

European Roots of the 1930s Industrial Building

Industrial factory designs emerged in the late nineteenth and early twentieth centuries that greatly influenced modern architecture. The industrial building symbolized man's new partnership with the machine. During the first decade of the twentieth century, architects and builders in both Europe and the United States created the first truly modern factories, dedicated to mechanized industry and the utilization of modern building materials. European architects consciously developed architectural theories that reflected their interpretation of the spirit of the modern age. Communities of architects, artists, and craftsmen established as forums for progressive designers, flourished throughout Europe at this time.

In 1908, Peter Behrens, emerging from one such progressive community, the Deutsche Werkbund, designed the AEG Turbine Factory in Berlin. Behrens's factory was constructed of reinforced concrete and steel, both of which were expressed on the exterior of the building. Though the factory lacks traditional ornamentation, the regularity of its composition establishes a design rhythm on the facade of the building. The turbine factory achieves a sense of monumentality while simultaneously abandoning historicism. It has been described frequently as a temple to industrial power and one of the earliest expressions of the spirit of the modern age.

In 1910 Behrens' pupil, Walter Gropius, designed the Fagus Factory in Alfeld, Germany, which effectively established the International Modern style with its rhythmic proportions and glass curtain wall. Gropius's use of a structural steel frame and glass curtain wall is one of the earliest examples of a building with an exposed supporting skeleton. The industrial work of both Behrens and Gropius illustrates the conscious development in Europe of the factory building type as a symbol of modern industry and of technology. The early work of these architects established the basis from which both the twentieth century industrial complex and the Modern stylistic movement emerged.

American Roots of the 1930s Industrial Building

Industrial architecture in the United States during the first decades of the twentieth century developed primarily from the practical and economic directives of the businesses they served, rather than from the theories of architects consciously pursuing an architectural identity for the modern age. Industrial buildings in the United States were built to serve industry, and consequently often lay outside of the academic and cultural centers of the country. Most were designed by engineers rather than architects. The designers of these buildings became interpreters of the practical, operational, and economic needs of the building and the industry. Architects and engineers replaced the conscious pursuit of the creation of "style" with the attempt to use the machine and its processes to create architectural form.

Like European architects, American designers exploited the modern building materials of steel and reinforced concrete. In the United States, however, the materials were chosen solely because of their suitability to house modern industry. Concrete buildings are solid, resistant to sway, and capable of supporting heavy floor loads. One of the principal examples of early twentieth century industrial construction is the daylight factory. In this example, the building incorporates large areas of glass set between concrete slab floors. The reinforced concrete frame replaced load-bearing walls. Walls no longer needed to support the building were opened with large banks of windows that provided natural light. Reinforced concrete frames could span enormous spaces, providing uninterrupted interiors for industrial processes under one roof.

European architects noted the prominence of the daylight factory in the industrial buildings of the United States. Innovative European architects in the 1930s and 1940s studied the practical use of reinforced concrete, glass, and steel in the daylight factory, as well as the aesthetic qualities of regularity and order inherent in its form. During the first quarter of the twentieth century, many European architects sought to develop designs that expressed the modern, machine-oriented era and rejected historicist architectural allusions. In the early twentieth-century American factory, these designers recognized the roots of such a style, and adapted its principles to their practices.

In 1932, Henry Russell Hitchcock and Philip Johnson served as curators for an exhibit of current architecture at the Museum of Modern Art in New York City. They called the exhibit the International Style. Hitchcock and Johnson displayed the work of five architects, from whose work they distilled three dominating characteristics: 1) Volume was expressed rather than mass; 2) Regularity of form was emphasized over symmetry; and, 3) Applied decoration was abandoned completely. The architectural characteristics of the International Style eventually dominated much of European and American building for a large part of the twentieth century. Though adapted to all building types, the features of the International Style are especially suited to industrial construction. The industrial complex of the late 1930s displays many characteristics of the International Style, linking it to both early twentieth century European theory as well as to the functionalism inherent in American industrial architecture from two decades earlier.

By the late 1930s, the most common form of the factory adopted by American architects and engineers was an architectural descendent of both European and American theory and practice. The form of this factory can be traced to the Fagus Factory at Alfeld designed by Gropius in 1910. From the exposed frame and glass wall of the Gropius factory evolved buildings including the van Nelle tobacco factory in Rotterdam, designed by Brinkmann and van der Vlucht in 1927. The van Nelle factory displayed continuous horizontal bands of windows across the facade of the building, divided by continuous horizontal concrete floor slabs. The form of the 1930s American industrial building, with its cubic proportions and emphasis on horizontality, evolved, in part, through this lineage.

The more important influence on the form of the 1930s industrial building was the American predisposition toward efficiency rather than tradition. The primary purpose of the industrial building was to house the manufacturing process efficiently. The architect studied the manufacturing process in order to generate the form of the building. The designer drew a flow diagram of the industry that included the movement of both materials and workers within the factory. The industry's production line was the most important element considered by the architect. The production line included the route travelled by materials from the point that they entered the plant as raw materials, to their exit as finished products. The requirements of the production line determined the form of the building.

Both multi-story and single-story factories appeared throughout the first half of the century, depending on the manufacturing process housed in the building. Manufacturers often chose to build multi-storied factories in areas with high land costs or limited construction sites. In addition, multi-story factories best accommodated light industry with lighter floor loads. In cases where gravity assisted the production process, or where materials progressed from one level down to another level, multi-story factories offered the most efficient solution. Architects and manufacturers chose single-story factory buildings for heavy industry that required extremely high floor loads. Single-story factories with vast interior spaces divided by only one or two rows of support piers were better suited to the expansive, increasingly mechanized assembly lines of modern production. Single-story facilities also were preferable for industries anticipating expansion, because these buildings more easily accommodated layout changes and the reconfiguration of heavy machinery.

By the end of the first decade of the twentieth century, architects designing industrial complexes almost exclusively worked with reinforced concrete or steel. Both materials had advantages. Though reinforced concrete was used frequently for both single- and multi-story buildings, the material was used most successfully in the design of the multi-story factory. The use of reinforced concrete structural systems provided a degree of safety impossible before the twentieth century. Concrete is fireproof and extremely solid. Factories built with a reinforced concrete frame appeared almost monolithic, and were resistant to the vibration and sway created by mechanized industry. The reinforced concrete structural frame enabled architects to abandon traditional load-bearing walls and create vast spans of glass wall that provided plentiful natural light.

By the 1930s, designers usually chose a steel frame to support a single-story factory. If a standardized arrangement of bays could accommodate the manufacturing process, steel structural bays were fabricated off-site. These pre-fabricated frames reduced construction time and eased the construction process. Steel offered several advantages. Steel frames could withstand greater stresses than wood frames. Steel support piers occupied less interior space than reinforced concrete piers. These factors enabled architects to use steel structural systems to enclose immense and complex manufacturing operations within expansive, simple, and direct plans. Finally, a factory composed of the orderly arrangement of steel frame bays could be expanded, modified, or disassembled easily.

Characteristics of the 1930s Industrial Building

By the 1930s, with the development of the modern assembly line and heavy mechanized production, the single-story, steel-framed factory became the most industry-efficient type of factory constructed in the United States. This type of factory dominated the industrial landscape during the late 1930s and possessed several distinctive characteristics. Though the design of the buildings rarely displayed conscious symmetry, steel-frame structural systems resulted in a regularity in the spacing of bays that often imbued a sense of dignity in the facade of the building. This regularity is one characteristic of the International Style. The steel frame also freed the walls from supporting the building. Non load-bearing walls therefore could be composed of glass, or clad with brick, stucco, or metal veneer. The 1930s factory could enclose enormous amounts of space, often creating an almost monumental interior work environment.

The functional arrangements of architectural features frequently emphasized horizontality on the exterior of the building. Bands of windows set above horizontal bases clad in brick or stucco provided a regularity and quiet procession to the factory facade. Flat roofs with plain cornices added to this horizontal order. The emphasis on horizontality is another characteristic of the International Style. The light needs of the industry housed within the building often dictated the roof shape. When natural light was desirable on the interior of the factory, one of three basic types of roofs, the sawtooth, butterfly, or monitor roof, provided large amounts of overhead natural light. Consequently, the factory often displayed an unusual, animated roof line. Designers chose a flat roof, often with a plain eave treatment, if artificial illumination and strip windows could provide sufficient light to the interior.

For the most part, the 1930s industrial building lacked decoration, illustrating the third characteristic of the International Style. The horizontal rhythm of the continuous run of bays, the strip windows, and extended eaves supplanted the traditional decorative vocabulary. In the industrial building of the 1930s, efficiency of design replaced the desire or need to follow historicism.

Influence of Albert Kahn

The most powerful influence in the development of the late 1930s industrial building was the architect Albert Kahn. The organization of his office and the buildings he designed became the standard by which the majority of World War II industrial complexes were built. Kahn was born in 1869 in Rhauen, Germany. In 1880, Kahn's father moved the family to Detroit, where he hoped they might find a more prosperous future. At the age of sixteen, Kahn took a job as an office boy in the architectural office of Mason and Rice in Detroit. As a child, Kahn had dreamed of becoming an artist; he became a draftsman at Mason and Rice and studied architecture in the firm's library.

Kahn received no formal architectural education, but in 1891 won a scholarship for a year's study in Europe. In Italy, he met and travelled with the architect Henry Bacon, who later designed the Lincoln Memorial in Washington. Kahn, with two other architects, left Mason and Rice in 1896. The three young architects formed an independent firm. Kahn's early work for both Mason and Rice and his own partnership reflected the historical tradition observed during his European travels. By 1902, Kahn had left the partnership and was working alone. In 1903, his brother Julius joined him as chief engineer. At this time, Kahn slowly began to receive industrial commissions. His career coincided with the emergence of the auto industry, which created a demand for factories. While many of his contemporaries refused industrial commissions, Kahn enthusiastically accepted the challenge, and over the next four decades was a major influence on modern American industrial architecture.

In many ways, the organization and structure of Kahn's firm was as important in the creation of the industrial building as Kahn was individually. Kahn became a master of organizing work to achieve maximum efficiency. His office structure was atypical of contemporary architectural firms. Kahn viewed his position as one of coordinating information among his staff and clients. He regarded his practice as a collaboration of equals, referring to himself as the "conductor of the symphony." He arrived at concept for a particular building by bringing together experts from different fields, including the client. Therefore skilled technicians became involved as generators of the design concept, rather than solely as its executors.

Kahn learned about handling and organizing information from the industries that he served, specifically the auto industry. He divided his firm into two divisions, the Technical and the Executive. Each division contained several subdivisions. Individual projects began with round-table meetings attended by Kahn, the client, and leaders of the relevant divisions and subdivisions of the firm. Extensive discussion generated elaborate flow charts that outlined the design of the industrial complex, as well as detailed design and construction processes. Meticulous organizational procedures enabled the leaders of various departments to monitor closely the design process throughout its development, thus reducing the number of time-consuming mistakes. Kahn created a process in which mammoth industrial complexes could be designed and built with great speed. This speed and organization enabled Albert Kahn's practice to flourish during World War II, when the need for modern industrial complexes grew dramatically.

Two of Kahn's early industrial plants were significant precursors of the industrial factory of the late 1930s and World War II periods. In 1906, Kahn designed the George N. Pierce Plant in Buffalo, New York. The plant was a complex of eight buildings, one administrative and seven production buildings, used for the manufacture of the Pierce Great Arrow Automobile. Most of the seven production buildings were single-story structures of various heights, supported by reinforced concrete frames, and lit by different forms of roof lighting. Concrete structural bays defined the exteriors and interiors of each of the buildings. The plan of this industrial complex became the model for factory design during the next several decades. The industrial flow-chart developed for production of the automobile generated the design of the complex. The position of each of the buildings within the complex was determined by the factory's flow of work. Rail lines connected the separate buildings. Most of the production operations were located within single-story buildings, with monitor and sawtooth roofs evenly distributing natural light throughout the building. Kahn was able, therefore, to increase the length and width of the interiors of the plant as needed without worry over the light source, in order to accommodate the industrial process. This type of manufacturing complex proved remarkably well suited to modern production techniques.

The second of Kahn's most influential early works is the Ford River Rouge Plant, built outside Detroit in 1918. With the auto industry's adoption of the assembly line came the predominance of the single story factory. Though the Pierce plant included some single-story industrial buildings, the River Rouge plant was composed of a series of single-story buildings of uniform height, and marked a major industrial client's commitment to single story construction. The plant housed a large and complex manufacturing process within a simple and economical plan of modular mechanical systems and conveyors. River Rouge also marks Kahn's commitment to steel frame construction. Before 1914, Kahn worked almost exclusively in concrete. With the adoption of the mechanized assembly line by the auto industry and the resulting predominance of the single-story factory, steel frame construction became the most practical design alternative. By utilizing prefabricated steel frames, Kahn was able to construct the plant with remarkable speed. The River Rouge Plant received critical acclaim and wide publicity.

World War II Military Industrial Facilities

As war engulfed Europe, the U. S. government realized that if the United States became involved in the conflict, it would need to increase rapidly its supply of weaponry, especially ammunition. In 1940, the United States lacked sufficient ammunition for a single day's fighting. Many American peacetime industries converted to military production without trouble, but the nature of ordnance production required the construction of entirely new facilities, with little potential for civilian use after the war. To meet the need for ordnance production, the U.S. government built industrial facilities, declared them to be military installations, and hired private corporations to run them. These Government-Owned, Contractor-Operated (GOCO) facilities comprised the majority of World War II period permanent industrial construction.

Both the planning of most GOCOs and the administration of the design process followed work patterns established by Albert Kahn. The impending war with Europe and Japan in the late 1930s created a state of emergency in the United States, and speed consequently became the most important requirement in the design process. Kahn's approach to design had proved fast and efficient before the war, and was adopted without hesitation by many designers during the emergency. During this period, many architects and engineers collaborated in order to achieve almost miraculous construction goals.

The two most prolific architect and engineering firms during the World War II period were Albert Kahn and Associates, and Smith, Hinchman, and Grylls of Detroit. From December 1939 to December 1942, Albert Kahn received over $200 million in government commissions. During the same period, Smith, Hinchman, and Grylls received almost $500 million in government contracts, accumulated a staff of 1,200, and built numerous industrial complexes containing over 1,000 buildings. When dealing with numbers so great and with short time spans, standardization became the means by which these firms achieved such dramatic results. In 1941, Albert Kahn wrote that these years were "no time for philosophizing, waiting for inspiration...A prompt and direct solution of practical problems dealing with housing machines and manufacturing processes is demanded. Simplicity of design and construction is imperative." Architects reproduced and repeated designs where possible making alterations only to accommodate individual site or manufacturing constraints.

The military emphasized efficiency and economy of construction in the industrial design process. In January 1941, Brehon Somervell, then Chief of Quartermaster Construction, issued a memorandum to the field, stating, "There is no excuse for the use of expensive materials where less costly ones will serve the purpose for the period of time for which the construction is being provided." A growing shortage of materials eventually dictated a shift from steel and concrete construction to wood-frame construction.

With the exception of munitions storage and loading complexes, the design of small arms production facilities generally followed the model of the 1930s single-story factory discussed earlier. Designers adapted the characteristics of this type of factory to suit the needs of a wartime facility. For the most part, heavy industrial complexes produced planes, tanks, armaments, and machine tools. Albert Kahn established five guidelines for the adaptation of the industrial factory to a wartime industry:

1) Must permit ultra-rapid construction if the plant is to serve its purpose;

2) Must, as a factory building,meet the requirements of the industry it serves;

3) Must provide for safety of plant and process if attacked;

4) Must provide for the safety of workers under air attack particularly; and

5) Must be practicable in view of today's labor and materials market.

Guideline (1) resulted from the need to provide support to the fighting forces as rapidly as possible. Guideline (2) addressed the nature of the industry, which directed the form of the building. Because the manufacturing process for heavy industries implemented the use of the assembly line and could be contained under one roof, the single-story, steel frame factory provided the most space-efficient alternative. Facilities were planned and constructed so that plant expansion could occur without interruption to the manufacturing process.

Modifications to the 1930s factory design were implemented that addressed guidelines (3) and (4). For example, architects designed windowless manufacturing facilities to protect buildings from night air raids. To protect both manufacturing equipment and factory workers from high-explosive bombing, non-load-bearing walls were built independently of the steel framework of the factory. A bombing attack would destroy the walls of the building without extensively damaging its structural system. For the most part, however, industrial facilities that housed heavy wartime industry followed design patterns established for factories during the 1930s.

Style was not a consideration in the design of the World War II industrial building. During this period, economy of time, materials, and funds required the elimination of everything but the utilitarian. In observing this requirement however, Kahn wrote that "there lies an element which itself makes for attractive external effect...the structural element of the industrial building automatically makes for impressive results. External beauty as such is never achieved by application of useless decoration, but rather by good planning, grouping, massing, and proportion." The World War II industrial complex exemplifies one of the most extreme examples of American functionalist architecture, and displays a beauty in the relationship and order of its different structural elements.

The munitions GOCO complex encompassed a wide array of munitions production, from relatively stable small arms ammunition production, to the more volatile processes of loading and storing munitions. Like heavy industry facilities, munitions complexes relied on the design principles of the 1930s prototype factory when possible. This design was altered, however, to accommodate specific production needs. A small arms ammunition production facility, for example, had a relatively low degree of danger involved in the production process. This type of facility, therefore, could follow the basic steel frame, single-story factory design. Munitions facilities that dealt with more volatile explosives adopted planning principles to suit the needs of the specific production process. Two facilities provide examples of these broad planning and design patterns.

The Twin Cities Army Ammunition Plant, located in New Brighton, Minnesota, was constructed in 1941 as a production facility for small arms ammunition. Smith, Hinchman, and Grylls received the design contract for the facility. Its design was based on the recently completed small arms ammunition plant in Lake City, Missouri, which Smith, Hinchman, and Grylls designed as a model for future manufacturing installations.

The Twin Cities Army Ammunition Plant initially contained five manufacturing buildings, which were the largest facilities on the installation. The initial manufacturing buildings were low-lying, expansive buildings constructed of brick, steel, and concrete. Building 103, a .50 Caliber Shop, illustrates the features of a typical small arms manufacturing building. It exhibits a clean-cut profile, with an emphasis on horizontal lines. The nature of the specific production process required a two-story building. The design of Building 103 is based on the mechanized production process, however, and exhibits many of the prototypical features of the modern single-story factory. Smith, Hinchman, and Grylls developed the design of the building by examining closely the manufacturing process and the machines employed:

A carefully prepared template for each machine is cut out of cardboard and these are then assembled into plans of departments...colored strips...indicate the movement of materials from one bank of machines to another. Ultimately these department units are assembled to form the entire production unit housed in the manufacturing building....As the machine layout becomes more definitely established the template plans begin to take the outline of actual buildings.

Building 103 has a steel-frame structural system, with non-load-bearing exterior walls clad with brick. The steel framing system, comprised of exterior and interior supports, enabled the building to enclose a vast amount of space. Window arrangement is predominantly horizontal, varying from narrow bands to wide ranges of strip windows with steel framed industrial sashes. The building's flat, steel, extended roof and low-lying monitors also emphasize the horizontal lines of the composition. The only instance of consciously applied decoration occurs on the entry facade of the building. The architects have incorporated an abstracted reference to a classical portico and colonnade in the square brick piers separating the individual entries. The remainder of the building relies upon the regularity of the window and cornice lines to provide a pleasing aesthetic quality to the building.

Safety requirements also influenced the design of the manufacturing building. The high masonry walls shielded workers from splinters and shrapnel in the event of attack. In most areas of the building, windows sat at a point immediately below the roof line. In the case of an explosion on the production line, these windows were designed to blow out and relieve pressure inside the building. Because some production tasks were more hazardous than others, the building was divided into a complex system of wings. This plan neatly separated the most volatile areas of the building from the more stable areas, while containing the entire manufacturing process under one roof.

In January 1942, the government authorized the expansion of the ordnance plant, which doubled the size of the original installation. Smith, Hinchman, and Grylls again carried out the contract. Because of material shortages, building designs incorporated wood-frame structural systems rather than steel and concrete systems. The new buildings housed similar manufacturing processes with the same production capacity as the original plant buildings, but were built to serve as temporary structures.

Ammunition facilities built to house more volatile production processes adopted a different approach to industrial design. These facilities consisted primarily of installations used for the loading and storage of heavy artillery, and the manufacture of explosives. McAlester Army Ammunition Plant provides a useful example, because its seven original production plants remain relatively unmodified.

In 1942, the Navy established a depot used for both loading and storage near McAlester, Oklahoma. The Army has operated the plant since 1977. The materials handled at McAlester were highly sensitive and the risks involved in production were significantly higher than at small arms ammunition plants such as Twin Cities AAP. For this reason, the production process required separate, detached buildings. This separation reduced the chances of the entire plant igniting if an explosion occurred in one of the buildings. The design of individual buildings varied according to the processes housed within the buildings. Because each stage of the production line was contained within a separate building, individual buildings were often quite small. The Major Caliber loading plant at McAlester AAP sits on roughly 150 acres of land, and consists of about 30 individual buildings. The buildings of primary importance included two explosive loading facilities, ignition and fill buildings, a bag filling building, and a sifting building. The explosive loading facilities enclosed the largest amounts of space, roughly 16,000 square feet, and were over twice the size of the other plant facilities. Because highly sensitive explosives passed through each of the buildings during the loading process, each building was designed to withstand powerful explosions. A steel-frame structural system with brick splinter walls supported the large loading facilities. The other significant buildings in the complex had steel or concrete structural systems with walls clad in concrete or brick. Doors were located at frequent intervals, providing easy escape. Second story escape chutes descended from some of the more sensitive buildings. For the most part, manufacturing facilities built to load and store highly volatile explosives displayed utilitarian architectural characteristics. Architects designed these facilities to contain dangerous manufacturing processes in as safe and efficient a manner as possible.

The architectural significance of this type of munitions complex lies not in the design of the individual building, but in the planning of each component within the manufacturing process. The plan of the manufacturing plant at such an installation is in many ways a macrocosm of the production line. Because the production process cannot be contained safely under one roof, each step in the manufacturing process must be isolated from the next, and contained within an individual building. Railroad lines linked the buildings, transporting materials from one stage in the production process to the next. Replacing conveyor belts, covered sidewalks also linked buildings, allowing munitions to be carted from building to building. In addition to rail lines and covered sidewalks, a network of tunnels often provided additional links among buildings.

Though highly explosive munitions facilities could not follow the most current production theory by developing the form of the factory around the circuit of the assembly line, architects adapted the theory to suit the requirements of these facilities. The prototypical planning concept remains at installations such as McAlester, where the assembly line expanded in order to isolate each step of the manufacturing process. Here, the assembly line appears outside of the building, in the form of rail lines and covered sidewalks, and the buildings themselves become analogous to stations within the manufacturing process.

Conclusion

During World War II, the United States military created two broad types of permanent industrial construction. These included heavy industry factories that produced planes, tanks, and heavy artillery; and ammunition production and loading facilities. Architects and engineers relied on the form of the 1930s factory for the design of the World War II industrial complex. This architectural building type evolved from both American and European early twentieth-century industrial construction. The evolution of factory design was influenced by new construction technologies as well as changing architectural theories. Perhaps the greatest influence on the design of the 1930s factory and industrial complex was the development of the manufacturing process. The industry production line, which included the route of the product from its entry as raw material to its exit as finished product, dictated the form of the building. Wherever possible, architects relied on precedents established in the 1930s, specifically modular steel-frame, single-story construction, for the design of the World War II industrial complex. Heavy industry military production facilities were housed in factories similar in design to the factories that housed automobile production a decade earlier. The form of the more volatile ammunitions loading facilities, which for reasons of safety could not be housed within a single building, still relied on the production line to generate the plan of the entire complex. Under the military's supervision, architect/engineering collaborative firms designed and built enormous war-related industrial complexes in remarkably short periods of time during the late 1930s and early 1940s. The success of these ventures was due to standards established in the efficient design of the modern American factory.