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HISTORIC ASSESSMENT
DEPARTMENT OF COMMERCE BOULDER LABORATORIES FOR NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
BOULDER, COLORADO

PREPARED FOR:

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
ON BEHALF OF
METROPOLITAN ARCHITECTS & PLANNERS

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HISTORIC ASSESSMENT DEPARTMENT OF COMMERCE BOULDER LABORATORIES FOR NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY BOULDER, COLORADO

Final

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National Institute of Standards and Technology
on behalf of
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Executive Summary

This report presents the results of a comprehensive study of the history and development of the Department of Commerce (DoC) Boulder Laboratories campus in Boulder, Colorado, for the National Institute of Standards and Technology (NIST). NIST is a non-regulatory Federal agency within the DoC (National Institute of Standards and Technology [NIST] 2014). This historic context and architectural survey was designed to develop an historical overview of NIST, to identify associated historic themes and property types, and to identify those resources eligible for inclusion in the National Register of Historic Places (NRHP). This investigation included comprehensive architectural survey and evaluation applying the NRHP Criteria for Evaluation (36 CFR 60.4[a-d]) for all buildings, structures, objects, and landscapes included on the DoC Boulder Labs campus. Assessments of significance and integrity were made applying the historic context prepared as part of this current investigation. This project was undertaken by R. Christopher Goodwin & Associates, Inc. for Metropolitan Architects, Inc. on behalf of NIST to support the agency in its program to identify, evaluate, and protect cultural resources in accordance with Section 106 and Section 110 of the National Historic Preservation Act of 1966, as amended (NHPA).

The purpose of this project was threefold: to develop an historic context to support the evaluation of cultural resources that may be present on the DoC Boulder Labs campus, to comprehensively survey the built resources at the Boulder campus, and to evaluate those buildings, structures, objects, and sites applying the NRHP Criteria for Evaluation (36 CFR 60.4[a-d]). Archival research was undertaken to develop an historic context appropriate for the assessment of NIST built resources. Architectural investigations supplemented the archival research. Assessments of significance and integrity were made applying the historic context developed during this current investigation.

The objectives of this current investigation were as follows:

- To develop a historic overview of NIST;
- To develop the background and administrative history of NIST;
- To identify the historical themes, time periods, and people significant to the history of NIST;
- To document resources located at the DoC Boulder Labs campus;
- To identify the range of properties associated with significant themes and time periods; and,
- To evaluate the significance and integrity of properties applying the National Register Criteria for Evaluation (36 CFR 60.4[a-d]) within the appropriate historic context.

All work was completed in accordance with the guidelines set forth in the Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* (National Park Service 1983) and the Colorado Office of Archaeology and Historic Preservation's *Colorado Cultural Resource Survey Manual, Guidelines for Identification: History and Archaeology* (History Colorado 2007). NIST is responsible for complying with and implementing all cultural resources management regulations, policies, and directives. All work was undertaken by project staff who meet, or exceed, the Secretary of the Interior's professional qualifications in the disciplines of history, architectural history, and/or historic preservation.

The built resources contained within the DoC Boulder Labs campus were analyzed applying the NRHP Criteria for Evaluation (36 CFR 60.4[a-d]). The majority of buildings at DoC Boulder Labs are less than 50 years old, and were constructed between 1989 and 2013. None of the buildings at DoC Boulder Labs less than 50 years old appear to satisfy Criterion Consideration G for exceptional significance. Buildings at DoC Boulder Labs that are 50 years old or older include Building 1, Building 2, Building 3, Building 4/5, Building 8, Building 9, Building 11, Building 21, Building 22, and Anderson Ditch. Of these built resources, the Colorado State Historic Preservation Officer (SHPO) recommended Building 1 NRHP eligible under "Criterion A (History) and possibly for Criterion C (Architecture and Engineering)" in 23 February 2016 correspondence (Turner 2016). Buildings 2, 3, and 4 previously recommended potentially eligible for listing in the NRHP for their association with the Atomic Energy Commission as part of an undefined historic district at the DoC Boulder Labs campus. In correspondence dated 9 September 2015, the Colorado SHPO clarified that, due to a lack of integrity, Building 3 is not NRHP eligible (Nichols 2015). Because Building 3 is not eligible, the two other buildings (Buildings 2 and 4) associated with Building 3 also are not NRHP eligible. Anderson Ditch has been determined eligible for listing in the National Register, with a potential for significance under Criteria A, B, and C.

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Chapter 1.0

Introduction

1.1 Project Description

This report presents the results of a comprehensive study of the history and development of the Department of Commerce (DoC) Boulder Laboratories campus in Boulder, Colorado for the National Institute of Standards and Technology (NIST). NIST is a non-regulatory Federal agency within the U.S. Department of Commerce (National Institute of Standards [NIST] 2014a).

The project was undertaken to support NIST in its efforts to comply with Section 106 and Section 110 of the National Historic Preservation Act of 1966 (NHPA), as amended, through the identification and evaluation of built historic properties. The purpose of the current investigation is to identify and to evaluate built historic properties at NIST. Master planning efforts also currently are underway.

This historic context and architectural survey was designed to develop an historical overview of NIST, to identify important historic themes and associated property types, and to identify those resources that meet the criteria for significance and integrity for inclusion in the National Register of Historic Places (NRHP). This investigation included comprehensive architectural survey and evaluation applying the NRHP Criteria for Evaluation (36 CFR 60.4[a-d]) for all buildings, structures, objects, and landscapes included on the NIST campus. This project was undertaken by R. Christopher Goodwin & Associates, Inc. for Metropolitan Architects, Inc. on behalf of NIST to support the agency in its program to identify, evaluate, and manage historic properties in accordance Section 110 of the NHPA.

NIST is located in Boulder County, Colorado (Figure 1.1). The campus encompasses approximately 208 acres in the City of Boulder (NIST 2014a). NIST also maintains a research campus in Gaithersburg, Maryland, which is considered NIST headquarters. The DoC Boulder Labs campus is accessed from Rayleigh Road. Broadway/State Highway 93 forms the eastern boundary of the facility. The campus abuts a residential neighborhood to the north and south. The Flat Irons are located to the west.

1.2 Objective

The objective of the current investigation was to support NIST through the systematic identification of built historic properties pursuant to Section 110 of the NRHP. This objective was accomplished through an integrated program of archival research, site investigation, and data analysis. Archival research was undertaken to develop the historic context appropriate for the assessment of NIST built resources. An historic context defines the events, trends, and patterns of history through which a property is understood and its meaning made clear. Comprehensive architectural survey of built resources contained within the campus was completed to systematically document all buildings, structures, and landscapes. Archival and field data then were analyzed applying the NRHP Criteria for Evaluation (36 CFR 60.4[a-d]) to identify properties that possess the significance and integrity necessary for listing in the NRHP. To accomplish the objective of identifying historic properties, the following tasks were undertaken:

- Development of a historic overview of NIST;
- Development of the background and administrative history of NIST;
- Identification of the historical themes, time periods, and people significant to the history of NIST;
- Documentation of resources located at the DoC Boulder Labs campus;
- Identification of the range of properties associated with significant themes and time periods; and,

- Evaluation of the significance and integrity of properties applying the NRHP Criteria for Evaluation (36 CFR 60.4[a-d]) within the appropriate historic context.

All work was completed in accordance with the guidelines set forth in the Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* (National Park Service [NPS] 1983) and the Colorado Office of Archaeology and Historic Preservation's *Colorado Cultural Resource Survey Manual, Guidelines for Identification: History and Archaeology* (History Colorado 2007). All work was undertaken by project staff who meet, or exceed, the Secretary of the Interior's professional qualifications in the disciplines of history, architectural history, and/or historic preservation.

1.3 Regulatory Overview

Section 106 of the NHPA requires Federal agencies to take into consideration the effects an undertaking may have on historic properties. An historic property is any resource, i.e., building, structure, object, site, or district, eligible for or is included in the NRHP. The procedures for complying with the Section 106 are codified in 36 CFR 800. Section 110 requires Federal agencies to identify, evaluate, and nominate resources to the NRHP. In addition, Section 110 directs Federal agencies to develop a preservation program.

NIST's compliance with Federal cultural resources laws and regulations is directed through the Department of Commerce's broader environmental compliance program. Specific regulations and policies governing the treatment of historic properties are presented in two documents. The Department of Commerce Administrative Order 217-16 issued on 5 April 2012 directs the implementation of the NHPA and further directs all departmental offices and operating units to comply with all Federal, state, and local environmental and cultural and historic resources laws and regulations in addition to complying with Executive Orders and other Department of Commerce regulations, policies, and requirements (U.S. Department of Commerce 2012a:2). The Administrative Order further mandates compliance with the department's *Energy and Environmental Management Manual*. The manual, which is an extension of the administrative order, provides detailed guidance on the department's environmental program and policies (U.S. Department of Commerce 2012a:5). The *Energy and Environmental Management Manual* referenced in the Administrative Order, outlines the department's cultural resources management program and department responsibilities. NIST is responsible for complying with and implementing all cultural resources management regulations, policies, and directives (U.S. Department of Commerce 2012b:24-5).

NIST manages historic properties in accordance with Federal laws and Department of Commerce regulations. The primary steps undertaken in cultural resources management include:

- resource identification,
- resource evaluation,
- planning, and
- treatment of historic properties.

The NRHP establishes the criteria for significance and integrity used in the identification of historic properties.

The NRHP was authorized under the NHPA as the official list of properties significant in American history, architecture, archeology, engineering, and culture. Properties worthy of preservation are included in the NRHP, which continually is expanded to represent the many facets of American history. The NRHP serves as an important planning tool. The Secretary of the Interior maintains the NRHP and has developed regulations defining the procedures for listing properties in the NRHP (36 CFR 60) The NRHP program is administered by the National Park Service (NPS).

Two important provisions of the NHPA particularly are relevant to NIST's cultural resources management responsibilities. Under Section 110 of the NHPA, Federal agencies are charged with the identification of historic properties under their stewardship. Section 106 of the legislation requires Federal agencies to consider the effects of their undertakings on properties that are listed in, or are eligible for listing in, the NRHP and to afford the Advisory Council on Historic Preservation (ACHP) the opportunity to comment.

1.4 Organization of the Report

Chapter 1 summarizes the purpose of the investigations. The research design and methodology are presented in Chapter 2. Chapter 3 provides the historic context for NIST. Chapter 4 summarizes historic themes associated with the Boulder site. Chapter 5 presents a summary of previous architectural investigations at DoC Boulder Labs and the current architectural inventory. Survey and evaluation results are presented in Chapter 6. Appendix A includes acronyms commonly referred to within the report. Appendix B presents background information on architects involved in design/construction at DoC Boulder Labs. Appendix C presents relevant correspondence from the Colorado State Historic Preservation Officer (SHPO).

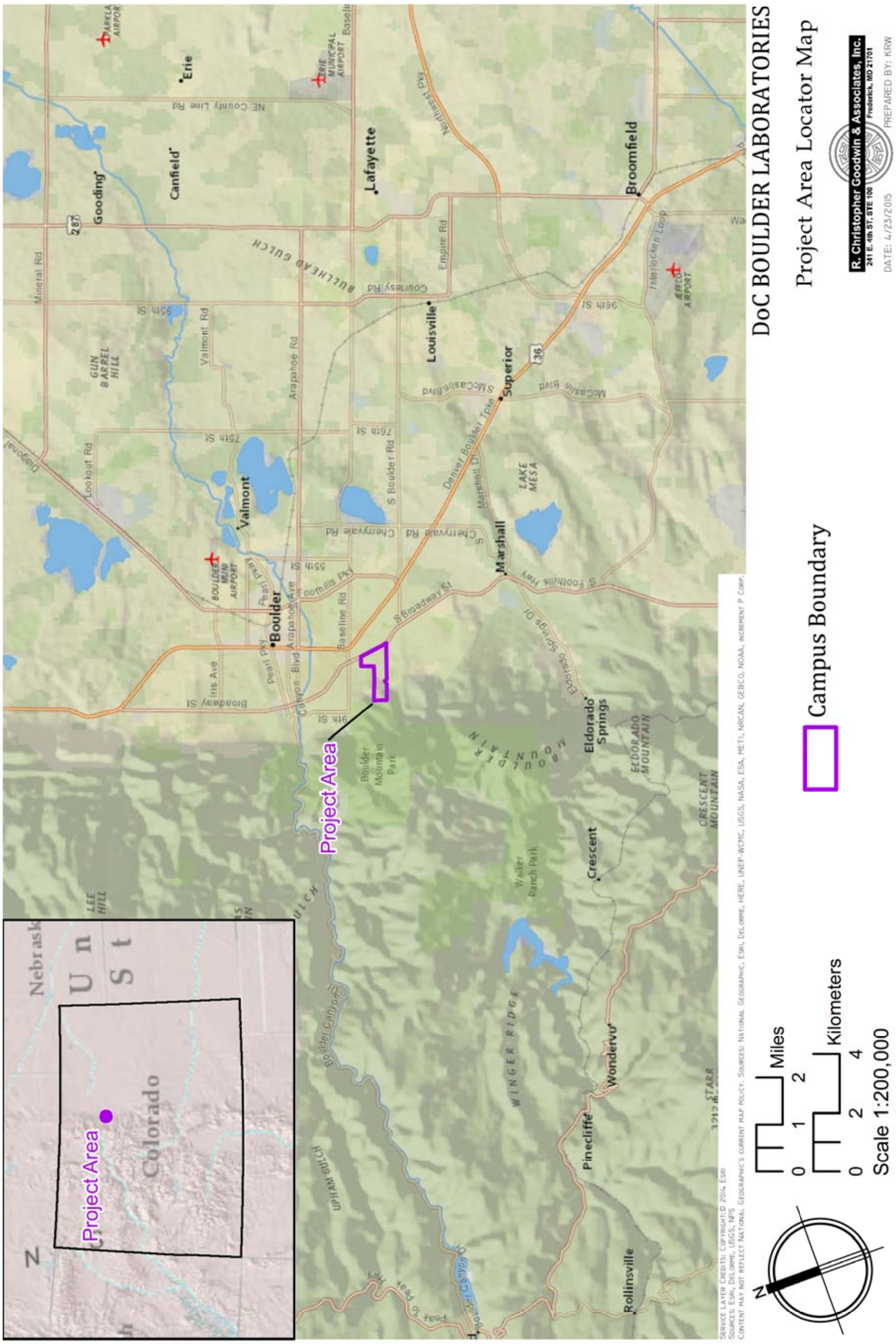


Figure 1.1 State Locator Map

Chapter 2.0

Research Design and Methodology

This project was completed through an integrated program of archival research, site investigation, data analysis applying the Criteria for Evaluation (36 CFR 60.4[a-d]) and integrity, and report preparation. All work was completed in accordance with the guidelines set forth in the Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* (National Park Service 1983), and the Colorado Office of Archaeology and Historic Preservation's *Colorado Cultural Resource Survey Manual, Guidelines for Identification: History and Archaeology* (History Colorado 2007). All project staff meet, or exceed, the Secretary of the Interior's professional qualifications in the disciplines of history and architectural history.

2.1 The Role of the Historic Context in Resource Evaluation

An appropriate historic context is fundamental to the evaluation of historic properties. The NRHP, a program under the NPS, Department of the Interior, refined the concept of an historic context for use in cultural resources management. An historic context is an organizational framework based on theme(s), geographic area, property type, and chronological period(s). An historic context provides the foundation for decisions regarding the significance and integrity of real property.

The historic context provides the foundation for assessing real property, including buildings, structures and landscapes, located at the Boulder campus of NIST. The historic context facilitates the evaluation of resources individually and collectively (as potential historic districts):

- for their association with events that have made a significant contribution to the broad patterns of our history (Criterion A);
- for their association with the lives of persons significant in our past (Criterion B);
- for their ability to embody the distinctive characteristics of a type, period, or method of construction, to represent the work of a master or possess high artistic values, or to represent a significant and distinguishable entity whose components may lack individual distinction (Criterion C); and,
- for their ability to yield, or be likely to yield, information important to prehistory or history (Criterion D).

2.2 Archival Research

Archival research into both primary and secondary sources was undertaken to develop a site-specific historic context for NIST. This historic context includes the following tasks:

- Development of a general historic overview for NIST to achieve an understanding of the role that NIST plays within the Department of Commerce as well as the role the Boulder campus plays within the larger NIST context;
- Synthesis of the NIST organizational history, doctrines, significant events, and policies that influenced the development and evolution of the DoC Boulder Labs campus between 1951, when construction of the campus was begun, and the present;
- Identification of events, historical themes, people, and time periods important in American history and represented in the NIST history; and,
- Identification of important themes and time periods relevant to the development of the campus in Boulder.

Research was conducted at the following repositories to achieve these objectives: the National Archives and Records Administration, Washington, D.C. and College Park, Maryland; and, the Carnegie Branch Library for Local History, Boulder, Colorado. In addition, a review of the materials in the collection of the NIST library and the drawing vault maintained by NIST's Office of Facilities and Property Management in Gaithersburg and a review of the materials maintained by the U.S. Department of Commerce Boulder Labs Library and the archives of DoC Boulder Labs were undertaken. A variety of data were collected during the archival investigations. General information regarding the establishment of NIST and information on key agency programs and areas of scientific investigation were collected. Data related to the creation of the Boulder campus, including the planning, construction, and modification of NIST real property were acquired. Information gathered included construction dates, original uses, architects/engineers, and subsequent alterations. Resources particularly useful for the preparation of this technical report include three official NIST histories: *Measures for Progress: A History of the National Bureau of Standards; A Unique Institution: The National Bureau of Standards 1950-1969;* and, *Responding to National Needs* (Cochrane 1966; Passaglia 1999; Schooley 2000).

A review of previous documentation prepared as part of cultural resources investigations conducted at the DoC Boulder Labs campus also was completed. These previous investigations are discussed in Chapter 5 of this report.

2.3 Comprehensive Architectural Survey

The purpose of the architectural field investigations was to collect data sufficient to document the current appearance of permanent built resources in the NIST inventory to enable assessment of their individual and collective significance and integrity. The current investigation comprised the survey of buildings, structures, sites, objects, and landscapes located at the Boulder campus; no archeological investigation was completed.

Comprehensive survey data were compiled for NIST resources (Table 2.1). In addition, resources identified during the course of field investigations, including accessible building interiors, were documented. Temporary buildings, such as trailers and prefabricated storage buildings not integral to NIST's core missions, were excluded from the architectural survey.

The following information was collected for each property:

- Date constructed;
- Type of construction;
- Overall descriptive data including building type, style, location, number of stories, plan shape and type, exterior wall materials, roof shape and materials, placement of building openings, and modifications over time;
- Function; and,
- Association with the NIST missions.

Written, graphic, and digital photographic data were collected for each resource using electronic data collection tools, including Terrasync V 5.20 software and Trimble GeoXH 6000 units containing Global Positioning System (GPS) with sub-meter accuracy. The electronic data collection provided the ability to process data to support data analysis, including resource mapping.

2.4 Data Analysis Guidelines

The NRHP program has established guidance for the evaluation of historic properties. In order for a property to merit consideration for inclusion in the NRHP, a property must have significance and retain integrity. The NRHP Criteria for Evaluation (36 CFR 60.4[a-d]) were applied to the NIST resources to determine whether the resources are significant. Integrity is a property's ability to convey its significance. Integrity is discussed in greater detail later in this chapter.

In addition to that issued by the NPS, guidance prepared by the ACHP was consulted in the evaluation of archival data. *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities* provides direction on the evaluation of resources associated with highly technical or scientific facilities. As the report notes, "Many of the facilities and much of the equipment associated with scientific engineering advancements remain in active use

Table 2.1 DoC Boulder Labs – Building Inventory

Building Number	Building Name	Construction Completed
1	Central Radio Propagation Laboratory (CRPL)	W 1-W 4 1954; W 6 1959; W 5 1962; on-going renovations 2012 - present
1, Annex C	Building 1, Annex C	1989
1, Annex D	Building 1, Annex D	1992
1, Annex E	Building 1, Annex E	2000
1, Annex F	Building 1, Annex F	2000
2	Cryogenics Lab	1951 (Cryogenics), 1964 Wing 'B' Addition, 1986 High Bay Addition, 1995 Addition
2A	Cryogenic Annex "A"	1989
3	Liquefier	1951
3A	Liquefier Annex "A"	1989
4	Camco Building	1951, 1986 Metal Siding, 1994 Addition, 2012 Window Replacements
5	Heavy Equipment	1951, 1986 Metal Siding, 1988 Renovations, 1992 Expansion, 2012 Window Replacements, 2015 Expansion
8	Mesa Test Site	1953
9	Gas Meter	1958
11	Vertical Incidence	1958
12	Hydrogen Research Facility	2008
21	Maintenance Garage	1963
22	Warehouse	1964
23	Hazardous Materials Building	1990
24	Plasma Physics	1967; High Bay Addition 1985, Annex A 1988, Air Handling Unit 1999, Elevator Tower 2002-2005
25	Offices	1975
26	Day Care Facility	1989; Addition 1995
27	High Frequency	1991
Antenna Field	Antenna Field	Circa 1990
33	David Skaggs Research Center/NOAA	1999
34	Solar Observatory	1999
42	Central Utility Plant (CUP)	2005
Access Tunnels (x3)	Access Tunnels, three accessing utility corridor along Compton Road	2009
51	Security Center	2006
Vehicle Check Building	Vehicle Check Building	2005
Guard House	Guard House	2014
81	Precision Measurement Laboratory (PML)	2012
91	Construction Research Facility	2008
111	Four Annex	2011
112	Warehouse	2011
131	Office Building	2013
Maintenance and Staging Yard	Maintenance and Staging Yard	Circa 1990
Gates (x2)	Gates to north and south residential areas	2014
Anderson Ditch	Anderson Ditch	1860

today, but need to be continuously upgraded and modified to stay at the cutting edge of technology" (Advisory Council on Historic Preservation [ACHP] 2002). The report acknowledges that a balance between cultural resources management needs and the needs of active research institutions is necessary. Further, the report makes a distinction between the quantity and changes in use or character as opposed to "natural, ongoing change and improvement to and in structures or equipment as they are continually subjected to minor change while they continue to function for their original purpose" (ACHP 2002). The ACHP acknowledges that resources used for scientific purposes can be altered and modified to enable the resources to continue to be used for their scientific purposes. Consequently, these changes may not necessarily affect resource integrity.

NIST actively has been responsible for the buildings in its real property since it was established. The agency maintained real property oversight even after the creation of the General Services Administration (GSA) in 1949, which established a division within the Federal government to design, construct, and manage buildings in the Federal inventory (General Services Administration [GSA] 2005:10). Real property oversight was reinforced through continuous modification to the agency's Organic Act (i.e., enabling legislation), which was revised in 1999 and updated with the America COMPETES Act in 2010. Under this act, the Secretary of Commerce was authorized to use NIST-appropriated funds to "undertake such construction of buildings and other facilities and to make such improvements to existing buildings, grounds, and other facilities occupied or used by" NIST (NIST 1999:16).

NIST has not developed internal guidance for assessing the significance and integrity of resources in its real property inventory. Therefore, a review of guidance prepared by the GSA, which has a robust and comprehensive cultural resources management program, was deemed apt. GSA developed an historic context for Federal buildings in the GSA real property inventory designed during the Modern period. *Growth, Efficiency, and Modernism. GSA Buildings of the 1950s, 60.s, and 70s* identifies key design philosophies of Modern architecture, provides a summary history of the GSA, and presents policies and guidelines that governed Federal construction during the 1950s through the 1970s (GSA 2005). The report provides a framework for the management of buildings constructed between 1950 and 1970 that are in the GSA real property inventory. In addition, the report provides an historic context for the GSA against which the GSA real property inventory can be evaluated.

While GSA guidance on modern buildings under its stewardship informed this current investigation it should be noted that the GSA's historic context is different than that of NIST. The GSA was established to provide a "centralized support service for the Federal government" (GSA 2005:10). Further, the 2005 report summarizes the GSA's role in the design, construction, and management of Federal buildings constructed throughout the country. The GSA guidance concludes with a methodology for evaluating the relative significance of resources in the GSA real property inventory constructed during the Modern era within the context of GSA's nationwide construction program.

In addition to the GSA guidance, a review of guidelines issued by other Federal agencies with a similar science and technology mission and resource type as NIST was deemed appropriate. The policies developed by the National Aeronautics and Space Administration (NASA) were reviewed for application to NIST. The applicability of the 50 year guidance for resources constructed between 1960 and 1969 in the assessment of resources from the recent past was raised during discussions between the NASA Federal Preservation Officer and NRHP staff during a NRHP symposium in May 2011. Subsequent coordination between NASA and NRHP program administrators in January 2012 affirmed that 50 years is a guideline for resource evaluation. The suggested age may not be necessary to achieve historical perspective in all cases. Therefore, resource evaluation under Criteria Consideration G was determined unnecessary in cases such as the Goddard Space Flight Center campus, where significance can be demonstrated clearly under the general criteria for evaluation (R. Christopher Goodwin & Associates, Inc. 2012:2-8).

2.5 Evaluation of Built Resources

Architectural field data were analyzed within the appropriate historic context applying the NRHP Criteria for Evaluation (36 CFR 60[a-d]). The historic context prepared as part of this current investigation provided the basis for assessing resources located at the DoC Boulder Labs campus for the qualities of significance in American history, architecture, engineering, and culture present in districts, sites, buildings, structures, and objects and for integrity of location, design, setting, materials, workmanship, feeling, and association. Further, the historic context made possible the individual and collective (as potential historic districts) evaluation of resources for their association with events that have made a significant contribution to the broad patterns of our history (Criterion A); for their association with the lives of persons significant in our past (Criterion B); for their ability to embody the distinctive characteristics of a type, period, or method of construction, to represent the work of a master or possess high artistic values, or to represent a significant and distinguishable entity whose components may lack individual distinction (Criterion C); and, for their ability to yield, or be likely to yield, information important to prehistory or history (Criterion D). The results of the evaluations are presented in subsequent chapters and are summarized in a facility-wide Colorado Cultural Resource Survey Architectural Inventory Form presented in the appendix to this report.

2.6 The Evaluation of Properties Using the NIST Historic Context

2.6.1 NRHP Categories, and Historic District vs. Individual Eligibility

The NRHP recognizes five resource categories. These include buildings, structures, objects, sites, and districts. Buildings are those resources that were constructed for creating human shelter whereas structures are those that were built for purposes other than human shelter. Each resource category may be present at NIST. Sites, which may include archeological resources, may also include resources associated with the environment including landscape design and site plan. Landscape design and site plan can incorporate elements such as circulation networks, building setbacks, and plant materials.

2.6.6.2 Integrity

In addition to possessing significance within an historic context, a property must possess integrity, a property's ability to convey its significance through the retention of essential physical characteristics from its period of significance, to be eligible for inclusion in the NRHP. The evaluation of NIST resources was completed through an assessment of the integrity of location, design, setting, materials, workmanship, feeling, and association for resources located at the Boulder campus.

Chapter 3.0

Historic Context – NIST Administrative History

3.1 Introduction

The National Institute of Standards and Technology (NIST) is charged with establishing national measurement standards and keeping them uniform, compatible, and reliable. Basic measurements include mass, length, time, temperature, electric current, resistance, and chemical composition. The original measuring devices comprised a metal cylinder weighing a kilogram and the platinum-iridium meter bar inherited from the predecessor organization the Office of Standard Weights and Measures founded in 1836 (NBS 1966a:5).

This chapter presents a general historic overview of the origins of NIST from its founding in 1901 as the National Bureau of Standards to its recent history. The overview focuses on the agency's evolution and summarizes some of the varied research projects conducted at NIST. NIST is tasked to disseminate the data regarding the national measures to government, industry, and the public. This task has expanded tremendously throughout the agency's history. From its founding, data from the experiments conducted at NIST were published as research publications, scientific and technical publications, articles in professional journals, circulars, data reference materials, standard reference materials, and conference materials. In 1988, Congress changed the agency's name to the National Institute of Standards and Technology and refocused the agency's mission to play a major role in revitalizing U.S. trade. This mission is reflected in the current NIST mission statement: "To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life" (NIST 2012a).

The following overview history is based on three official histories of NIST: *Measures for Progress* (1901-1950) by Rexmond C. Cochrane (1966); *A Unique Institution* (1950-1969) by Elio Passaglia (1999); and *Responding to National Needs* (1969-1993) by James F. Schooley (2000). *Achievement in Radio* also provided information on the history of NIST (Snyder and Bragaw 1986). The overview is augmented through materials collected from the NIST Library at Gaithersburg, the National Oceanic and Atomospheric Administration (NOAA) Library at Boulder, the Carnegie Library for Local History in Boulder, and the NIST website.

3.2 Establishment of the National Bureau of Standards to World War I

This section details the initial establishment of the National Bureau of Standards (NBS). It presents an overview of the early years of its development and its growth until World War I. The section highlights selected early research programs undertaken at the NBS that influenced its future growth.

The U.S. Congress chartered the NBS in March 1901 (Public Law 177-56th Congress, 2d Session quoted in Cochrane 1966:541). The NBS assumed the duties of the Office of Standard Weights and Measures founded in 1836 as part of the Coast and Geodetic Survey. The original mission of the Office of Standard Weights and Measures was to develop standardized weights and measures for use by the states in assessing cargo and taxes on goods shipped across state lines and exported internationally. The work of the office was focused on the measurements of length, volume, and weight (Cochrane 1966:20-21, 29).

By the late nineteenth century, the Federal and state governments operated without legislated standards for weights and measurements. Wide variations existed from state to state for the most basic of measurements. In addition, new standards of measurement were required for new products and technologies. These included electrical measurements; measurements for building materials, such as the tensile strength for concrete and the composition of steel; and, for consumer products (Cochrane 1966:37, 38).

The development of scientific standards was further advanced in Europe than in the United States. European countries already had established national standards laboratories and were working collaboratively to establish international standards. The *Bureau International des Poids et Mesures* was established in 1875 in Sevres, France. The *Physikalisch-Technische Reichsanstalt* was organized in Germany in 1887 and was credited with greatly improving production standards for German goods and precision instruments. In England, the *Standards Department* was established in 1879, the *Electrical Standardizing Laboratory* in 1890, and the *National Physical Laboratory* in 1899 (Cochrane 1966:29, 39, 44).

In 1900, Secretary of the Treasury Lyman J. Gage proposed the formation of a national standards laboratory in the United States. He selected Samuel W. Stratton to draft a bill establishing such an agency and to become its first director (Cochrane 1966:39-40). As legislated, the NBS duties comprised the following tasks:

- the custody of the standards [of measurement];
- the comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the government;
- the construction, when necessary, of standards, their multiples and subdivisions;
- the testing and calibration of standard measuring apparatus;
- the solution of problems which arise in connection with standards; and,
- the determination of physical constants and properties of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere (Passaglia 1999:19, 152, 608).
- The legislation identified the NBS as both the "source of the standards and their custodian," but provided no policing powers; policing powers were assigned to the states (Cochrane 1966:43).

The NBS was authorized to provide services to the U.S. government, state or municipal governments, and "any scientific society, educational institution, firm corporation, or individual with the United States engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments" (Passaglia 1999:608). As legislated, the staff was composed of the following: a director, a chemist, a physicist, two scientific assistants, two laboratory assistants, a secretary, a clerk, a messenger, an engineer, a machinist, a watchman, and a laborer. The director was appointed by the U.S. President with the consent of the U.S. Senate. The legislation also authorized the new agency to expend the sum of $250,000 to construct a fireproof laboratory on property purchased by the Secretary of the Treasury (Schooley 2000:790).

The NBS organizationally was placed in the Department of the Treasury. In 1903, the NBS was assigned to the Department of Commerce and Labor. When the Department of Commerce and Labor was divided in 1913, NBS was assigned to the Department of Commerce. The agency's placement in the Department of Commerce ensured that it would serve U.S. commerce and industry as directed by the Secretary of Commerce (Cochrane 1966:68-69).

Director Stratton spent the first years of the NBS hiring personnel, organizing research departments and programs, acquiring and designing new equipment, and designing new laboratories. He patterned the NBS organization on Germany's *Physikalisch-Technische Reichsanstalt* (Cochrane 1966:65). He immediately began to plan for new laboratory buildings. In 1901, he secured eight acres on Connecticut Avenue in northwest Washington, D.C., and negotiated a construction contract (Cochrane 1966:62). The D.C. campus was occupied by NBS personnel during late 1904 and served as the organization's primary facility until the move to Gaithersburg during the mid 1960s. By 1902, the original staff of 12 was increased to 22 persons, who were organized into 15 offices and laboratories. In 1903, the authorized number of staff rose to 58 (Cochrane 1966:67, 69).

The early NBS organization was divided into three divisions; the divisions reflected the focus of each division's research projects. Division 1 included weights and measures, heat and thermometry, light and optical instruments, engineering instruments, instrument shop, and administration. Division II was devoted to electricity, including resistance and electromotive force, magnetism and absolute measurement of current, induction and capacity, electrical measuring instruments, photometry, and the engineering plant. Division III was chemistry, which was not yet organized in 1904 (Cochrane 1966:74-75).

The NBS quickly expanded into new areas of research. In 1904, NBS scientists purchased the liquid hydrogen production equipment exhibited by the British Oxygen Company at the 1904 St. Louis World Fair. The purchase of the equipment marked the beginning of research into cryogenics, the study of low temperatures (Cochrane 1966:83). Research also was undertaken to standardize firefighting equipment hoses after a fire occurred on the new laboratory campus and in downtown Baltimore in 1904. When attempting to extinguish a fire on the D.C. campus, employees discovered that the fire hoses installed in two laboratories could not be coupled into a single hose due to differences in coupling threads. Similarly, the differences in couplings threads among fire companies in Baltimore hampered efforts to bring the downtown fire under control. NBS began a study on fire hose couplings that identified over 600 sizes and variations of couplings across the country. In 1905, NBS scientists provided a recommendation for a standard coupling to the National Fire Protection Association, but it was many years before the standard was accepted widely (Cochrane 1966:84-86).

In 1908, Director Stratton requested special funding from the Congress to "investigate what the states are doing with their standards." Between 1909 and 1911, NBS staff visited each state and tested 30,000 scales, weights, and dry and liquid measures. The results of the tests indicated that a large proportion of the weights and measures used in the market place were fraudulent. The NBS work attracted the notice of journalists. The public outcry resulted in the states adopting the model law for standards for weights and measure proposed by the NBS. In addition, an amendment to the Pure Food and Drug Act in 1913 required that net weight, measure or numerical count of contents be printed on sealed packages. This work by the NBS assured consumers that accurate weights and measures were used in the market place (Cochrane 1966:89-91).

In 1911, NBS personnel increased to 269 and included personnel transferred from the Geological Survey structural materials laboratories. The structural materials laboratories were engaged in researching and testing such items as paints, cements and concrete, clays, ceramics, steel, and protective coatings. The laboratories were located in Pittsburgh and Northampton, Pennsylvania; Atlantic City, New Jersey; and, Washington, D.C. These laboratories continued their work under the direction of the NBS (Cochrane 1966:94).

That same year, a purchasing agent of the Federal government requested that NBS test a shipment of light bulbs, three-quarters of which the NBS eliminated as substandard. Thus a long-standing program was initiated for testing products to develop procurement specifications for government purchasing to ensure that government funds were well spent. A sample of products tested by the NBS included rubber products, paper, inks, textiles, cordage, lubricating oils, leather and leather goods, metals and metal products, and refrigeration equipment (Sangster 1975:D-18; Cochrane 1966:90-91).

Electrical measurements and calibration of electrical equipment occupied a large percentage of time during the NBS' first decade. As U.S. industry transitioned to electric power, the NBS electricity laboratory was flooded with requests for basic electrical measurements, tests, and calibrations from electric light and power companies, appliance manufacturers, communication companies, and streetcar companies. NBS scientists made significant progress in precise electrical measurement, refining the accuracy of measurements to within a few parts in 100,000. Progress also was made in improving the constancy of measurements for the standard electrical cell used to measure the volt. One avenue of study was defining a uniform standard for electric lighting, or candle power, through comparisons of carbon-filament and tungsten-filament bulbs. NBS testing led to the 1907 specification for light bulbs purchased by the government (Cochrane 1966:103-105, 112).

In 1909, representatives of the coal industry requested that NBS develop safety standards for the use of electric lighting in mine shafts. The electric lights then in use frequently sparked, often resulting in hazardous and dangerous work conditions. After several years of study, the NBS published in 1915 the nation's first model electrical safety code for general use (NIST 2014b).

NBS extended its research work to other public utilities including gas, telephone and telegraph, street railways, and railroads after companies in these sectors became subject to government regulation under public service commissions after 1907. Over the next decade, NBS developed standards, distributed through circulars, for such areas as gas service. The standards were intended for use by public service commissions (Cochrane 1966:110, 114).

In 1913, at the request of the Interstate Commerce Commission (ICC), the NBS received Congressional funding to initiate an investigation of large railroad scales used to measure freight for interstate commerce. In 1913, the NBS outfitted a railroad car with calibrated weights and traveled the rails to test railroad scales used for interstate commerce. The investigation revealed that over 75 per cent of the railroad scales used to weigh loads transported by railroad cars were highly inaccurate. After this finding, state agencies revised inspection procedures and required the use of more accurate track scales. This NBS program continued until the 1930s (Cochrane 1966:116-117).

The ICC also requested that NBS analyze railroad components from train derailments, which had reached an alarming annual number of 41,578 in 1912. Faulty maintenance, inferior steel, and excessive wheel loads were suspected causes of the derailments. The ICC sent failed railroad components, such as broken rails and broken axles, to the NBS for analysis to determine the quality of the steel used in the tracks. The NBS researchers conducted chemical, microscopic, and mechanical tests on the metal and found transverse fissures in the interior of the rails. Between 1912 and 1923, NBS' Metallurgical Division investigated heat stress and treatments to develop recommendations for improving the manufacturing process to eliminate the fissures (Cochrane 1966:118-119).

Research into radio also began at the NBS during the first decades of the twentieth century. Guest researchers from the Navy and the Army conducted initial research on the practical applications of radiotelegraphy beginning in 1908. In 1911, NBS received a request to calibrate a wavemeter to measure high-frequency current in a radio transmitting apparatus. The project was assigned to J. Howard Dellinger, who would become a noted expert in the radio field for his research in high-frequency radio waves. Dellinger served as chief of the Radio Section from 1918 to 1946, then as chief of the Central Radio Propagation Laboratory (CRPL) from 1946 to 1948 before retiring (Cochrane 1966:139-140, 143-144; NIST 2000:n.p.; NIST 2014b; Snyder and Bragaw 1986:781-791).

As World War I raged in Europe, the NBS was requested to explore new areas of research. In 1915, the NBS staff began research into materials used in aircraft design. The manufacture of optical glass also became a critical priority. All high-quality optical glass prior to World War I was imported from Germany; no U.S. company possessed the capacity to produce such glass. NBS researchers spent a year working to perfect methods for the production of high-quality optical glass (NIST 2000:n.p.). A sample of other wartime activities involved investigations into airplane engines and instruments for the National Advisory Committee for Aeronautics; tests of airplane frames, wing fabrics, and engines for the U.S. Army Signal Corps; tests into the chemical, physical and structural properties of metals for use in ammunition shells for the Army; development of concrete cargo ships for the Shipping Board; ensuring the availability of precision gages for ordnance production; experiments into substitutes for leather and woolen products for the Council of National Defense and the War Department, and Army Quartermaster Corps; a study of dental amalgams at the request of the Surgeon General of the Army; and, development of an improved radio direction finder that was widely used to locate enemy positions during World War I (Sangster 1975:D-19; Cochrane 1966:159-186, 271).

The NBS campus in D.C. was expanded to include nine additional acres in 1913. The number of NBS staff rose to 517 in 1917 and to 1,117 in 1918 (Cochrane 1966:165, 167; NIST 2000:n.p.). The first women were employed at NBS during World War I to replace male employees who went into the military. While many of the nearly 100 women were clerks and secretaries, women also joined the agency as researchers. In 1918, Joanna Busse began her career at NBS as a researcher in thermometry. Dr. Louise McDowell, who held a Ph.D. degree in physics, joined the staff in 1918 to assist in the preparation of a handbook on radio. Dr. Mabel Frehafer, Ph.D., joined the colorimetry section in 1919 (Cochrane 1996:54, 170).

3.3 The NBS During the 1920s and 1930s

Between 1920 and 1940, the NBS continued to grow and mature as an organization. Projects undertaken during this time reflected political priorities. During the 1920s, NBS staff worked more closely with projects designed to benefit industry under the leadership of Secretary of Commerce Herbert Hoover. During the 1930s, the Great Depression directly impacted the agency. The agency's basic scientific programs returned to prominence.

Between 1921 and 1928, Herbert Hoover served as the Secretary of Commerce. Hoover redirected the focus of the NBS to support domestic economic recovery following World War I through his programs for standardization, specifications, and simplification. In particular, the NBS worked with industry to reduce "waste in manufacture and distribution through the establishment of standards of quality, simplification of grades, dimensions, and performance in non-style articles of commerce; through the reduction of unnecessary varieties; through more uniform business documents such as specifications, bills of lading, warehouse receipts" and to develop "pure and applied scientific research as the foundation of genuine labor-saving devices, better processes, and sounder methods" (Sangster 1975:C-21; Cochrane 1966:254).

While fundamental research continued, new areas of research emerged to support industry, including: investigations into standardized radio frequencies to support the popularization of the home radio; investigations into standardized building construction materials and codes to support Hoover's home building program; publication of a popular handbook for perspective home buyers; development of methods to test the fire endurance of buildings; development of standards for fuel economy and automobile safety; and, development of a radio guiding system for aircraft. Other areas of research included standardization of color, development of improved dental materials, research into textiles, and standardization of screw threads (NIST 2000:n.p.; Sangster 1975:D-21). Between 1913 and 1932, the NBS also supported crime detection. Wilmer Souder, employed at the NBS between 1913 and 1954, became a noted criminal investigator. By the early 1930s, Souder routinely participated in between 50 to 75 criminal investigations per year. In 1932, Souder's handwriting analysis of the ransom note in the Lindbergh kidnapping case contributed to the conviction of Bruno Hauptmann. Forensic investigation at the NBS dwindled after the Federal Bureau of Investigation established its scientific laboratory in 1932 (NIST 2000:n.p.).

The depression years of the 1930s resulted in curtailed research activities of the NBS. Staffing was reduced from 1,066 in 1930 to 668 by 1935 and total funding from all sources decreased to $1.9 million (Cochrane 1966:558, 563). The NBS was refocused on "maintenance and improvement of standards of measurement; calibration and certification of measuring instruments … [to ensure] that accurate and uniform standards of measurement would be used throughout the nation; development of improved methods of measurement for use in industry, engineering, and scientific research; determination of physical constants and essential data on the properties of materials or physical systems; [and] serving… as a centralized physical research laboratory for governmental agencies" (Sangster 1975:D-22; Cochrane 1966:323-324).

Some basic research programs at NBS did continue. The NBS continued studies into all aspects of radio transmission and receiving. In fact, NBS scientists established a WWV radio station at Beltsville, Maryland, in 1923 to transmit standard radio frequencies and time (NIST 2014b). Radio research also included the study of layers in the upper atmosphere that interfered with radio waves. Radio expert Dellinger conducted research that linked interruptions in long-distance radio transmissions to sun eruptions. As a result of Dellinger's research, NBS initiated monthly forecasts of ionospheric and radio conditions in 1937 (Cochrane 1966:350-353).

NBS researchers also conducted studies on X-rays and radium, and began projects in atomic studies. In 1931, Harold C. Urey, associate professor of chemistry at Columbia University, sought to prove the existence of a heavy isotope of hydrogen. Urey sought to isolate the hydrogen isotope. Fred L. Mohler of the NBS atomic physics section suggested that Urey work with Ferdinand Brickwedde of the NBS cryogenics laboratory. Their collaboration resulted in the identification of deuterium, i.e., heavy water, for which Urey won the Nobel Prize in chemistry in 1934. Though Urey received the award, he acknowledged the contribution of Brickwedde at NBS and shared the prize money with him (Cochrane 1966:358-359; Martin and Frederick-Frost 2014). NBS scientists from the cryogenics program continued to work with deuterium during World War II and the early Cold War (NIST 2000:n.p.).

NBS scientists were involved in early research in the U.S. to split the atom and to develop the atomic bomb. In 1939, President Roosevelt established an Advisory Committee on Uranium headed by then NBS Director Dr. Lyman Briggs. NBS scientists contributed critical initial research, including determining the purity of uranium, providing radioactivity measurements, and establishing safety procedures for bomb materials. When the Manhattan Project was transferred to Army Corps of Engineers, NBS remained a "central control laboratory for determining the purity of uranium" and other materials. Some NBS scientists undertook temporary assignments at Oak Ridge, Tennessee, and Los Alamos, New Mexico, the two major atomic research centers (Cochrane 1966:361-364, 377; NIST 2000:n.p.; Sangster 1975:D23).

3.4 World War II and the Postwar Period

This section describes the range of projects conducted by the NBS scientists during World War II. By 1943, all research conducted at the agency supported the war effort; most work was classified. Following the war, the NBS was reorganized to meet post-war scientific needs of the atomic age and the space age.

The beginning of World War II ushered in a period of explosive growth for NBS. From a staff numbering below 1,000 in 1939, personnel level rose to 1,204 and was supported by a budget of $3.37 million by December 1941. By 1945, the staff had increased to 2,206 and the budget had risen to $9.7 million (Passaglia 1999:16; Cochrane 1966:558, 563).

NBS scientists were involved in many significant projects, such as the radio proximity fuse, which contained a tiny radio that transmitted waves towards a target and controlled detonation to inflict maximum damage. This development increased the effectiveness of antiaircraft shells, rockets, and bombs (Briggs and Colton 1951:770). NBS scientists also developed a fully automated guided missile, known as the "Bat," that was used in the last months of the war against Japanese land and sea targets (Sangster 1975:D-23; NIST 2000:n.p.). NBS investigations also were conducted to develop methods to conserve petroleum, to manufacture optical glass, and to investigate a broad range of substitute materials, such as synthetic rubber, quartz crystals, and plastics (Sangster 1975:D-23).

Radio research focused on improving radio direction finders, studying radio propagation phenomena, and supporting aerial navigation, radiotelephony, radio-telegraphy, and radar. An outgrowth of this radio research was the establishment at NBS of the Interservice Radio Propagation Laboratory (IRPL) in 1942. The objective of the IRPL was to centralize data on the behavior of transmitted radio waves for dissemination to all military services. (Sangster 1975:D-23). A critical service performed by the IRPL was to forecast ionospheric conditions, such as sun spots, that interrupted radio communications (Briggs and Colton 1951:771).

The experiences of World War II resulted in a dramatically changed scientific landscape. Technological advances made during the war posed the potential for immense changes in all areas of life. Development of the atomic bomb ushered in the atomic age, followed, in 1957, by the beginning of space age with the launch of Sputnik by the U.S.S.R.

The role of NBS in this new world of science and technology was a topic of discussion during the late 1940s. In 1950, the Secretary of Commerce proposed new enabling legislation to codify activities assigned to the NBS by "supplementary legislation, executive orders and customary procedure" (Passaglia 1999:149-150). The legislation, enacted in 1950, defined NBS functions as:

> (a) The custody, maintenance, and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards, including the comparison of standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the government.
> (b) The determination of physical constants and properties of materials when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.
> (c) The development of methods for testing materials, mechanisms, and structures, and the testing of materials, supplies, and equipment, including items purchased for use of government departments and independent establishments.
> (d) Cooperation with other government agencies on scientific and technical problems.
> (e) Advisory service to government agencies on scientific and technical problems.
> (f) Invention and development of devices to serve special needs of the government (Passaglia 1999:616).

The act also identified research to support government agencies, scientific institutions, and industry in the following select areas: investigation and testing of railroad track scales and other scales in weighing commodities for interstate shipment; the preparation of standard samples for use in checking chemical analysis, temperature, color, viscosity, heat of combustion, and other basic properties of materials; development of chemical analysis and synthesis of materials, including rare substances; the study of radiation and x-rays; the study of atomic and molecular structure of chemical elements; broadcasting of radio signals for standard frequency; investigation of conditions which affect the transmission of radio waves; and, the determination of properties of building materials, including fire resistance. In addition, the NBS was tasked with compiling, publishing, and disseminating scientific and technical data resulting from its research for public use (Passaglia 1999:616-617). The new law vested authority for the NBS in the Secretary of Commerce and gave the U.S. President the ability to appoint all future NBS directors (Passaglia 1999:151).

In 1950, the role of NBS organization was described as:

> … the principal agency of the Federal government for basic and applied research in physics, mathematics, chemistry, and engineering. In addition to its general responsibility for basic research, the Bureau undertakes specific research and development programs, develops improved methods for testing materials and equipment, determines physical constants and properties of materials, tests and calibrates standard measuring apparatus and references standards, develops specifications for Federal purchasing, and serves the government and the scientific institutions of the Nation in an advisory capacity on matters relating to the physical sciences. The Bureau also has custody of the national standards of physi-

> cal measurement, in terms of which all working standards in research laboratories and industry are calibrated, and carries on necessary research leading to improvement in such standards and measurement methods (Passaglia 1999:23).

In 1950, personnel employed at NBS numbered 3,100 (Passaglia 1999:15). The organization had grown to fifteen research divisions containing 107 sections. The NBS divisions reflected its research areas: Electricity, Optics and Metrology, Heat and Power, Atomic and Radiation Physics, Chemistry, Mechanics, Organic and Fibrous Materials, Metallurgy, Mineral Products, Building Technology, Applied Mathematics, Electronics, Ordnance Development, CRPL, and Missile Development. Support divisions included Budget and Management, Personnel, Plant, and Shops (Passaglia 1999:17-18; *Science and Engineering at NBS* 1953).

In 1950, the NBS budget totaled $20 million; 43 per cent of the budget was authorized directly by the U.S. Congress, while 57 per cent of the budget came from government agencies, primarily the military, to underwrite specific projects (Passaglia 1999:15). Research was conducted at the main campus Washington, D.C., and at Corona and Los Angeles, California. The master scale depot was located in Clearing, Illinois, and materials testing was performed in: Allentown, Pennsylvania; Seattle, Washington; Denver, Colorado; and, San Francisco, California. Radio propagation field stations numbered eleven and were distributed in the following places: Virginia (2), Maryland (1), Colorado (1), Panama Canal Zone (1), Puerto Rico (1), Hawaii (1), Guam (1), and Alaska (2) (*Science and Engineering at NBS* 1953).

Research projects conducted at the NBS included both basic research in physics, mathematics, electronics, chemistry and metallurgy and work in fields of electronic, electrical, mechanical, hydraulic, and structural engineering. A sample of projects included the installation of the NBS Standards Eastern Automatic Computer (SEAC) in 1950; studies in low temperature physics; the development of an omegatron to determine constants such as the faraday and magnetic moment of the proton; studies in electron optics to determine electric-field distribution and space-charge density within a magnetron; X-ray radiation protection studies; research to expand electronic memories in computers; carbohydrate studies; and, preparation of pure iron. In the field of engineering, studies were conducted in oil flow in plain journal bearings; aircraft materials; methods of measuring large currents and voltages; cement and concrete; and, in the engineering properties of specific building materials and entire structures, from residences to skyscrapers to dams. Projects that resulted in more precise measurements included the development of atomic clocks; development of a set of primary atomic standards; the development of improved reference standards for electrical units; and, the development of standards for the uniform measurement of light and illumination (*Science and Engineering at NBS* 1953).

In 1953, at the request of the Secretary of Commerce, the NBS underwent a thorough review of its organization and activities, which was conducted by the Ad Hoc Committee for the Evaluation of the Present Functions of the National Bureau of Standards. The committee's report contained ten recommendations, including: refocusing NBS on basic scientific research; modernizing facilities and increasing space; improving the NBS organizational structure; transferring military work to the Department of Defense; increasing support of standard samples program; and, decreasing repetitive test operations (Passaglia 1999:173-174).

One of the ad hoc committee's recommendations was implemented almost immediately. The NBS ordnance and guided missile work located in Corona, California, was transferred to the Department of Defense in September 1953 (Passaglia 1999:176). The remaining recommendations from the ad hoc committee were implemented gradually and shaped the evolution of the agency for the next two decades.

3.5 Need For New Facilities

This section explores the initial plans to construct new facilities to accommodate the expanding NBS research programs. Since 1903, the NBS headquarters was located on the west side of the intersection of Connecticut Avenue and Van Ness Street in northwest Washington, D.C. Originally eight acres, the campus had grown to sixty-eight acres by 1950. The D.C. campus was overcrowded with 93 buildings, a third of which were temporary buildings constructed during World War II. Buildings 1 through 9 were constructed around a quadrangle, while other buildings were sited on the property as need arose and with no overall master plan. Often personnel and equipment associated with a single research division were dispersed among several buildings. Typically one research division had personnel housed in eight separate buildings. Maintenance of the laboratories was expensive due to their condition. Upgrades to meet contemporary research programs and operating requirements, such as access to electricity and heating and air conditioning, were prohibitively expensive (U.S. Department of Commerce 1961; Passaglia 1999:475).

The developing residential areas of Washington, D.C., surrounding the campus restricted future expansion of NBS. One research area that was especially hampered was radio research conducted by the CRPL, formerly known as the IRPL. Scientists assigned to the CRPL performed research on line-of-sight microwave propagation, researched new ranges of radio frequencies, conducted research on troposphere and ionosphere as media for the propagation of radio waves, and developed and maintained the national primary standards for radio frequency measurements (Passaglia 1999:182; NBS 1954:1).

When the CRPL was formed in May 1946, personnel totaled 160. By July 1946, staffing had increased to 187. CRPL staff worked in the following locations on the D.C. campus: the Radio Building, the third floor of the Northwest Building, the reconditioned Stucco Building, the former Vapor Lock Building, and an assortment of rooms in other buildings, as well as two buildings in downtown D.C., and field stations at Fort Belvoir, Virginia, and Beltsville, Maryland. CRPL leadership immediately made plans for the construction of a new large building to house all CRPL staff in a single building (Snyder and Bragaw 1986:419, 704).

In 1949, the U.S. Congress authorized $4.4 million for land acquisition and the construction of a new radio laboratory for the CRPL to house programs in radio propagation and standards research (Passaglia 1999:612). Congress specified that the new laboratory be located outside of Washington, D.C., as a safeguard against the possibility of a nuclear attack. Site selection criteria included sufficient area to accommodate long-distance, line-of-site transmissions in diverse terrain; lack of radio interference from nearby communities; and, accessibility and proximity to a university that possessed strong programs in electrical engineering (Passaglia 1999:182-184; Meier 1996:4-7).

The NBS administration initiated a nationwide search for a suitable location for the CRPL. NBS Director Edward Condon solicited suggestions from colleagues on potential locations while attending a cosmic ray symposium in Idaho in June 1949. Colleagues suggested Boulder, Colorado, and Condon visited the town while attending the conference. He invited other members of the site selection committee to visit the town in early July 1949 (Meier 1996:7; Snyder and Bragaw 1986:706-709). In all, twenty-eight sites were investigated as potential locations for the CRPL; the three finalists were Boulder, Colorado; Charlottesville, Virginia; and Palo Alto, California (Passaglia 1999:182-183).

Boulder was founded by the Boulder City Town Company in 1859. Until the 1940s, the town's economy was based on agriculture and mining. The University of Colorado (CU-Boulder) opened in Boulder in 1876. During the mid-twentieth century, CU-Boulder developed strong curricula in engineering. Radio technicians for the Navy were trained at the school during World War II. In 1945, the Navy sponsored a project at CU-Boulder to study the upper atmosphere. By 1949, research activities at CU-Boulder dramatically increased and the university was ranked twelfth among U.S. research colleges in both dollars and "the effectiveness for its research" (Meier 1996:5-7).

When Boulder was selected among the top three locations for the new facility, its citizens launched a concerted campaign to secure the new NBS radio laboratory and its projected $2 million payroll (Passaglia 1999:182-184). The Boulder Chamber of Commerce located a tract of land adjoining the city's southern boundary, secured a purchase option, and offered the tract to NBS. The NBS administrators accepted the land offer and selected Boulder as the new location of the new CRPL in December 1949 (Meier 1996:7; Passaglia 1999:183). Town officials quickly raised the money to purchase the land during a one-week campaign in April 1950. A total of 296 individuals, businesses, and organizations contributed $90,000 to acquire the site (Meier 1996:8).

The Boulder property originally was acquired to house the CRPL in a single research laboratory building. Immediately after acquisition, an additional use for the property emerged in early 1950 following President Truman's announcement that continued development of atomic weapons was necessary for national security. Following the President's statement, the Atomic Energy Commission (AEC) initiated a "crash program" to identify requirements to advance studies of atomic weaponry. AEC quickly identified that a facility with "gas liquefaction plants and laboratories for engineering research and development at liquid hydrogen temperatures" would be vital (Passaglia 1999:185).

At that point, AEC looked to NBS and its newly proposed laboratory location at Boulder, which was close to the AEC's new Rocky Flats Plant (Passaglia 1999:185; Meier 1996:9). The director of Los Alamos Scientific Laboratory, at the direction of AEC, asked the NBS to: "build a large hydrogen-liquefaction plant; set up and run a hydrogen/deuterium electrolysis plant; test prototype dewars [containers for liquefied gases] for Los Alamos; assist MIT and Arthur D. Little Company in the design and construction of dewars and refrigerators; test hydrogen transport dewars; and train personnel in large-scale hydrogen production and hydrogen handling" (Kropschot 2001:107-108).

In April 1951 through the financial support of the AEC, ground was broken at Boulder to construct,

> the world's largest liquid hydrogen plant [Building 3] and cryogenic laboratory [Building 2]. The plant at Boulder was completed that summer and the staff to man the plant and laboratory buildings moved in. The hydrogen liquefiers, the units producing liquid nitrogen to precool the hydrogen, and the purifiers, all in duplicate to insure continuous operation, were designed and their construction supervised by the Bureau. Both the plants and laboratories incorporated elaborate safety and anti-explosion features to minimize the hazards of working with liquid hydrogen in large quantities (Cochrane 1966:472).

Russell B. Scott was named the first chief of the Cryogenic Engineering Laboratory at Boulder (Sloop 1978:68). Scott served as the Director of the Boulder Cryogenics Laboratory from 1952 to 1962; he was Director of the Boulder Laboratories from 1962 to 1965 (Kropschot 2001:110).

Meanwhile, planning and funding for building the radio laboratory began. Funds totaling $4,275,000 to construct Building 1 were appropriated in September 1950. A preliminary design for the radio building was prepared by Frank W. Cole of Washington, D.C. The initial design was functional with "maximum amount of laboratory and office space within the limits of the appropriation." The architects selected to prepare the final designs for the radio laboratory building was the firm of Pereira & Luckman from Los Angeles, California; Robert William Ditzen of Boulder and Jesse Earl Stanton of Beverly Hills, California served as associate architects. GSA handled the design and construction contracts (Snyder and Bragaw 1986:705, 713).

Originally envisioned as a classically-inspired building, Hugh Odishaw, Assistant to NBS Director Edward Condon, suggested that the design of Building 1 reflect its striking landscape at the foot of the Flat Iron mountains (Snyder and Bragaw 1986:713). As presented to NBS in January 1952, the radio laboratory featured a "central spine which tapers from four stories to one, into slowly rising ground. Two pairs of one-story wings extend outward at ground level" (NBS 1954:1). The building originally was designed with three pairs of wings, but the third pair of wings was dropped from the contract to save costs. The main entrance fronted onto a major public road and contained the main lobby, the library, and an auditorium. The spine and wings featured an off-center corridor with laboratories on one side and offices on the other. The laboratories incorporated a "use module" design to facilitate future space needs. As planned, administrative functions were placed in the building's spine. Wings 1, 2, and 4 housed the electronics laboratories. Wing 3 contained instrumentation shops to support research programs, the building maintenance personnel, service shops, and shipping and receiving facilities (NBS 1954:1; Boulder Chronology n.d; NIST Boulder Building Plans 1970; *The Boulder Daily Camera* 1954a; Hunter 1961:15).

Construction bids for the radio laboratory building were opened in May 1952; the winning bidder for the sum of $3.9 million was Olson Construction Company, a firm with offices in Denver, Colorado; Salt Lake City, Utah; and, Lincoln, Nebraska (*Boulder Daily News* 1954a). Excavation for the radio laboratory began in June 1952 and Building 1 at Boulder was completed in 1954. Some personnel who had been working in rented buildings in Boulder since summer 1951 moved into the building. They were joined by staff who transferred from Washington, D.C. Total personnel employed at the Boulder Laboratories numbered 466. President Eisenhower formally dedicated Building 1 on September 14, 1954 (Boulder Chronology n.d.; *Science and Engineering at NBS* 1953; Snyder and Bragaw 1986:419). Dr. Frederick W. Brown served as the first director of the CRPL at its new Boulder facility. He reported directly to the NBS director in Washington, D.C. (Passaglia 1999:189, 319).

In Washington, D.C., efforts were begun to find a new location for the NBS headquarters. In mid-1955, Assistant Secretary of Commerce for Administration James Worthy asked NBS Director Astin to consider relocating the NBS to a new location to support efforts to relocate Federal agencies outside of D.C. Astin accepted the offer and initiated the process to find a new headquarters for NBS in the Maryland suburbs. Reasons for the relocation from D.C. included the age of NBS buildings and facilities, the costs needed to maintain those structures, and the uneconomical and inefficient space arrangements to accommodate the present organization (Astin 1955).

The Fiscal Year (FY) 1957 Congressional appropriation included $930,000 for site acquisition and for the preparation of plans and detailed cost estimates for the new NBS headquarters (U.S. Department of Commerce 1961). However, the appropriation was contingent on immediate site selection (Passaglia 1999:477; NIST 1958:2.2). Astin and GSA selected 575 rural acres near Gaithersburg, Maryland, and the GSA began site acquisition in July 1956 (U.S. Department of Commerce 1956). The architectural firm of Voorhees Walker Smith Smith & Haines was awarded the architectural design contract for the new NBS headquarters (U.S. Department of Commerce 1961; NBS 1966b:6).

The NBS administrators, NBS scientists, and the architects began a carefully considered planning program for the new Gaithersburg campus by visiting many of the nation's noted research laboratories (Passaglia 1999:481; Laboratory Planning Committee 1957). The purpose of these visits was to gather data about the functionality and organization of the physical plant that could be incorporated into the design of the new NBS headquarters (NIST 1958:3.21-4).

Official groundbreaking ceremonies for the Gaithersburg campus were held at the site of Building 202 on June 14, 1961. Secretary of Commerce Luther H. Hodges commented that "it was typical of the NBS dedication to accuracy to hold the ground breaking on the exact site of the Engineering Mechanics Laboratory in spite of the remote location" ("Ground Broken for Gaithersburg Laboratories" n.d.). Dedication ceremonies occurred in November 1966 (Passaglia 1999:488-489).

3.6 Late Twentieth and early Twenty-First Century Period

This section details the administrative history of the NBS and its transformation into NIST. Throughout this period, the agency was tasked with an increasing number of projects and directed research into a wide variety of new areas. After the 1988 reorganization, NIST focused on applying the science of measurements and technology to benefit U.S. industry.

The program and physical facilities in Boulder were expanded. In 1959, Wing 6 of Building 1 was completed. This wing housed the Electronic Calibration Center to calibrate radio-related equipment for military standards laboratories and industry. The program began in 1958 with the calibration of 508 items. In 1959, 8,594 items were calibrated in Wing 6. The number of items calibrated between 1960 and 1963 averaged 3,600 per year. Harvey Lance, the head of the Electronic Calibration Center, established the National Conference of Standards Laboratories to support commercial, industry, and military standards laboratories. The first meeting of the conference occurred in Boulder in 1962 (Passaglia 1999:377-379). In 1962, Wing 5 of Building 1 was completed for a Computation Facility (Martin and Silcox 2010:90).

A 1961 review of existing facilities and anticipated needs found that additional facilities were required at Boulder. Personnel employed at the laboratories had risen from 225 persons in 1954 to 750 in 1961 with a "2 to 1 ratio of supporting personnel to technical and scientific personnel" (Hunter 1961:9). The authors of the 1961 long range planning study recommended against expanding Building 1 further through the construction of additional wings. Further expansion of the building would create "tortuous corridors, excessive travel distances in a horizontal plane, and general confusions of orientation because of complexity" (Hunter 1961:12). It was proposed that future expansion be accommodated in individual new buildings grouped by function in a campus setting (Hunter 1961:12-16). During the 1960s, individual buildings to house the service and maintenance functions were constructed near the former Camco Building (Building 4). These buildings included the warehouse (Building 22, 1964), and the maintenance garage (Building 21, 1963) (Martin and Silcox 2010:90).

In 1962, under the leadership of Lewis Branscomb, the NBS and the CU-Boulder collaborated to establish the Joint Institute for Laboratory Astrophysics (JILA). The new institute was founded to support space science and to research plasma physics and astrophysics by combining studies in astronomy and astrophysics with atomic and molecular physics (Passaglia 1999:322-329). In 1966, a ten-story building to house JILA was constructed at CU-Boulder (Schooley 2000:164-165).

During the 1960s, the NBS time and frequency broadcasting services were consolidated at Fort Collins, Colorado. Very low frequency broadcasts had begun under the CPRL in 1960, when a temporary antenna was set up in Four-Mile Canyon near Sunset, Colorado. This temporary set up was replaced by a permanent broadcast station at Fort Collins, Colorado, in 1963. In 1965, very high frequency broadcasts also were moved from Greenbelt, Maryland, to Fort Collins (Passaglia 1999:376-377, 529).

In January 1964, the NBS organization was restructured radically. The twenty-three NBS divisions that traditionally were organized by laboratory were structured under four institutes (Passaglia 1999:342, 344). The purpose of the institute structure was to facilitate a "systems approach to problems by grouping related programs under unified direction and by decentralizing management to permit closer evaluation and direction of program progress" (NBS 1966d:3). Prior to this change, division directors reported directly to the NBS director. After the establishment of the institutes, division directors reported to their institute director, who then reported to the NBS director. The institutes were:

- Znstitute for Basic Standards;
- Institute for Materials Research;
- Institute for Applied Technology (NBS 1966b:1); and,
- The CRPL in Boulder, Colorado (Passaglia 1999:343).

Each institute was assigned responsibility for specific research areas. The Institute for Basic Standards was focused on the standards program for physical measurements, coordination with international measurement systems, calibration of a wide variety of measuring devices, and data dissemination of the fundamental properties of matter. This institute comprised divisions located in the Engineering Mechanics, Metrology, Physics, Chemistry, Radiation Physics, and Administrations buildings at Gaithersburg and the Radio Standards Laboratory and Laboratory Astrophysics in Boulder (NBS 1966b:1; NBS

1966d:2). The Institute for Materials Research conducted research on methods to improve the understanding of the basic properties of materials for industry and on measurement techniques to determine those properties. This institute comprised divisions located in the Metrology, Physics, Chemistry, Materials, and Polymer buildings in Gaithersburg. The cryogenics division in Boulder was assigned to this institute. The Institute for Applied Technology's primary function was the development of criteria and the evaluation of the performance of technical products and services to support the Federal government and industry. This institute comprised divisions located in the Instrumentation, Building Research, and Administration buildings in Gaithersburg (NBS 1966b:1).

The CRPL in Boulder originally was planned to be the fourth institute (Passaglia 1999:493). In 1962, the CRPL contained four divisions: the Ionosphere Research and Propagation Division, Upper Atmosphere and Space Physics Division, Troposphere and Space Telecommunications, and Radio Systems (Wilkes 1964). In July 1965, a review of the environmental programs within the Department of Commerce led to the establishment of the Environmental Science Services Administration (ESSA). In October 1965, the four CRPL divisions were transferred administratively to ESSA, though the staff physically remained in Building 1 at Boulder (Passaglia 1999:322). In 1970, ESSA was renamed NOAA. NOAA's Earth Sciences Laboratory, Atmospheric Physics and Chemistry Laboratory, Space Environment Laboratory, Aeronomy Laboratory, and Wave Propagation Laboratory remained in Boulder.

Building 1 was occupied jointly by personnel from both NBS and NOAA. The name of the complex was changed to the U.S. Department of Commerce Boulder Laboratories (Passaglia 1999:493). Support functions were divided between the two agencies. NBS retained responsibility for the instrument shops; the Plant Division for buildings and grounds maintenance; the utility personnel in charge of electricity, heating, and plumbing; and, administrative services. The library, personnel division, and computer facility were administered under NOAA (Snyder and Bragaw 1986:736).

The Radio Standards Laboratory with its two divisions (Radio Standards Physics and Radio Standards Engineering) and the Cryogenic Engineering Laboratory remained assigned to NBS (Passaglia 1999:318). The Radio Standards Physics comprised three sections: solid state electronics, quantum electronicsc and plasma physics. By 1968, all NBS divisions at Boulder were united under the Institute for Basic Standards (The Boulder Laboratories 1968).

During the 1960s, JILA scientists collaborated with scientists from several institutions to plan an experiment to measure the distance between the earth and the moon. After nearly a decade of planning, in July 1969, the Apollo 11 crew left a brief-case sized array of reflectors to bounce back powerful laser pulses from two telescopes on earth. The distance between the earth and the moon was measurable using the round trip travel time of the pulse (approximately 2.5 seconds). The ongoing experiment has provided data about the length of the day on earth, the moon's orbit, lunar tides, and the combined mass of the earth and moon (Schooley 2000:230-233; NIST 2000:n.p; Passaglia 1999:525-526).

In August 1969, long-time Director A.V. Astin retired. The next two directors, Lewis Branscomb (1969-1972) and Richard Roberts (1973-1975), served relatively short terms, but both directors left enduring impacts on NBS research programs. Both directors stressed the connection of NBS research programs and national needs and the role of NBS to be a consumer-oriented, problem-solving institution. Director Lewis Branscomb, a founder of JILA in Boulder, created a Program Office that was assigned the tasks of developing policy, analyzing programs, and tracking funding sources and budgets to ensure that NBS research programs were related to justifiable national needs (Schooley 2000:171). Director Roberts strengthened this trend by instituting program reviews and continuing to streamline the organization (Schooley 2000:333, 337).

Director Branscomb also initiated problem-solving groups within the NBS. For example, when the problems of air and water pollution surfaced as national issues during the 1960s, Branscomb established a new office, Measures for Air Quality in Gaithersburg, Maryland. Scientists from several divisions collaborated to identify existing NBS programs capable of measuring various aspects of air pollution, particularly automobile emissions. NBS scientists conducted research to identify the key components of air pollution and prepared standard reference materials for gases to support compliance with auto emission laws (Schooley 2000:173-174).

Director Branscomb continuously emphasized the relevance of NBS research programs to solving national problems when testifying in budget hearings before Congress. By 1974, the NBS codified specific budget areas to describe its programs. The budget areas were scientific and technical measurements, use of science and technology, equity in trade, public safety, technical information, central technical support, and the experimental technology incentives program specifically requested by the Nixon White House (Schooley 2000:172, 185-186). During his tenure, Director Roberts continued the work initiated under Director Branscomb to increase the visibility and public image of the NBS and to tie NBS research programs to consumer-related areas (Schooley 2000:337, 339).

In 1971, the NBS divisions located at Boulder Laboratories were Quantum Electronics, Electromagnetics, Time and Frequency, Laboratory Astrophysics, and Cryogenics (NBS 1971:n.p). The term "radio" had disappeared from the administrative organizational structure. Only Building 1 remained known as the "radio building" (Snyder and Bragaw 1986:737).

Work continued on a wide variety of projects. One interesting project involved new measurements for the speed of light. In 1972, two groups of NIST scientists worked independently to advance precise measurement for the speed of light. At Boulder, Roger Barger, Bruce Danielson, Gordon Day, Kenneth Evenson, John Hall, F. Russell Petersen, and Joseph S. Wells used a methane-stabilized laser of known frequency and wavelength to measure the speed of light. The new measurement of the speed of light at 299,792,456.2 +/- 1.1 meters per second was 100 times more accurate than previous measurements (Schooley 2000:363-364, 369-370; NIST 2014b).

In 1970, some technical radio sections formerly assigned to the CRPL were reassigned to newly organized Office of Telecommunications within the Department of Commerce. The Office of Telecommunications staff also remained in Building 1 at Boulder. In 1978, the Office of Telecommunications became part of the National Telecommunications and Information Administration (NTIA) (NBS 1971:n.p.; NTIA n.d.).

Yet another agency restructuring occurred in 1977-1978 under Acting Director Ernest Ambler (1976-1978, then Director 1978-1989). Ambler's vision was to "undertake programs to foster the delivery of technology to the industrial, intergovernmental and international sectors" (Schooley 2000:452). Ambler appointed a steering committee and five task forces to guide the transition to the new organizational structure. The institutes established in 1964 were abolished. Research programs were realigned into the National Engineering Laboratory (NEL), the National Measurement Laboratory (NML), the Institute for Computer Sciences and Technology, the NBS/Boulder Laboratories, two National Centers for Cooperative Technology, and Administrative and Information Systems (Schooley 2000:452-453).

The NEL comprised: the Center for Fire Research, which included the Fire Science and Fire Safety Engineering divisions; the Center for Electronics and Electrical Engineering; the Center for Mechanical Engineering and Process Technology, which was divided in 1981 into the Center for Manufacturing Engineering and the Center for Chemical Engineering; the Center for Building Technology; the Center for Consumer Product Technology; the Center for Applied Mathematics; and a new Center for Chemical Engineering. The instrument shops were assigned to the NEL. At Boulder, the Electromagnetic Fields, Electromagnetic Technology, and Chemical Engineering Science Divisions were assigned to the NEL. The NML was assigned the traditional measurement standards, physics, and chemistry activities. These research activities fell under the Center for Absolute Physical Quantities, the Center for Radiation Research, the Center for Thermodynamics and Molecular Science (later the Center for Chemical Physics), the Center for Analytical Chemistry, and the Center for Materials Science. At Boulder, the NML divisions comprised the Time and Frequency and Quantum Physics (the NBS part of JILA) Divisions; the Fracture and Deformation Division was assigned to the Center for Materials Science in NML. The Institute for Computer Science and Technology established in 1966 remained a separate entity in Gaithersburg (Schooley 2000:453-457; NIST Boulder 1984:n.p.).

The implementation of the new NBS organizational structure coincided with President Carter's efforts to reform the civil service, and intense efforts under President Reagan's administration to reduce the size of government, particularly in areas that could be served by the private sector. In 1981, the NBS was required to reduce its work force by 10 percent (approximately 300) under President Reagan's reduction in force program (Schooley 2000:463-467, 472, 478). As NBS was under pressure to reduce personnel and costs, Congress passed legislation that assigned it new responsibilities. Despite pressures to downsize, Director Amber secured increased funding and later managed to grow the NBS budgets during his tenure as director (Schooley 2000:469, 479).

In 1988, the Omnibus Trade and Competitiveness Act (Public Law 100-418) redefined the roles and mission of the NBS. The NBS was renamed the National Institute of Standards and Technology (NIST) to reflect its new responsibility: to play a major role in revitalizing U.S. trade in the face of Japanese and German technological superiority. The drafters of Public Law 100-148 both acknowledged the traditional NIST research areas and defined its important future role:

> The National Bureau of Standards since its establishment has served as the Federal focal point in developing basic measurement standards and related technologies, has taken a lead in stimulating cooperative work among private industrial organizations in efforts to surmount technological hurdles and otherwise has been responsible for assisting in the improvement of industrial technology. It is the purpose of this Act to rename the National Bureau of Standards as the National Institute of Standards and Technology and to modernize and restructure that agency to augment its unique ability to enhance the competitiveness of American industry while maintaining its traditional function as lead national laboratory for providing the measurements, calibrations, and quality assurance techniques which underpin United States commerce, technological progress, improved product reliability and manufacturing processes, and public safety (Schooley 2000:615).

Director Ambler commented on the new focus of NIST: "We now have a direct, unambiguous charge to work closely with industry on the development of use of new technologies that U.S. companies need to stay competitive in the world marketplace" (Schooley 2000:635).

The new NIST essentially retained the same organizational structure implemented in 1978 with one addition. The Industrial Technology Services was formed to include the Advanced Technology Program, the Manufacturing Technology Program, and the offices of Standards Services, Technology Commercialization, Industrial Extension Services, and Measurement Services. The purpose of the Advanced Technology Program was to assist technology transfer to industry for quick commercialization of economically viable scientific discoveries and to enhance manufacturing technologies (Schooley 2000:632, 636, 638).

In 1990, John Lyons became the new NIST Director (1990-1993) and began to adapt the NIST organizational structure to his vision for the agency and to meet the goals of supporting industry. The new organizational structure formally was implemented in 1991 (Schooley 2000:645). The 1991 NIST organization comprised the following laboratories:

- Electronics and Electrical Engineering Laboratory (with the divisions of Electricity and Semiconductor Electronics in Gaithersburg and the divisions of Electromagnetic Fields, Electromagnetic Technology and Optoelectronics divisions in Boulder);
- Manufacturing Engineering Laboratory (with the Precision Engineering, Automated Production Technology, Robot Systems, Factory Automation Systems, and Fabrication Technology divisions in Gaithersburg);
- Chemical Science and Technology Laboratory (with the divisions of Biotechnology, Chemical Engineering, Chemical Kinetics

and Thermodynamics, Inorganic Analytical Research, Organic Analytical Research, Process Measurements, Surface and Microanalysis Science, and Thermophysics in Gaithersburg and the Physical and Chemical Properties division in Boulder);

- Physics Laboratory (with the divisions of Electron and Optical Physics, Atomic Physics, Molecular Physics, Radiometric Physics, Quantum Metrology, Ionizing Radiation, and Radiation Source and Instrumentation divisions in Gaithersburg and the Time and Frequency and Quantum Physics in Boulder);
- Materials Science and Engineering Laboratory (Office of Nondestructive Evaluation, Ceramics, Materials Reliability, Polymers, Metallurgy, and Radiation divisions in Gaithersburg and the Advanced Processing division in Boulder);
- Building and Fire Research Laboratory (Structures, Building Materials, Building Environment, Fire Science and Engineering, and Fire Measurement and Research divisions in Gaithersburg);
- Computer Systems Laboratory (Information Systems Engineering, Systems and Software Technology, Computer Security, Systems and Network Architecture, and Advanced Systems divisions in Gaithersburg); and,
- Computing and Applied Mathematics Laboratory (Applied and Computational Mathematics, Statistical Engineering, Scientific Computing, Computer Services, Computer Systems and Communications, and Information Systems in Gaithersburg) (Schooley 2000:635, 976-987; NIST 1996).

In 1993, President Clinton appointed the first female director of NIST, Arati Prabhakar, who came to the organization from the Microelectronics Office of the U.S. Army Defense Advanced Research Project Area (Schooley 2000:656). NIST employed approximately 3,300 scientists, engineers, technicians and support personnel with a budget of $810 million supported by Congressional appropriations, project funding from other agencies, user fees, and sales of Standard Reference Materials and publications. Publications numbered more than 480 per year and included reports on standards, research results, catalogs of products and services, and technical handbooks (NIST 1996:n.p.). One important element of public outreach was the dissemination of the 1996 *Guide to NIST*. The document was a consumer-oriented publication, providing an overview of research programs and available research facilities for the seven operating laboratories and their associated departments. By this time, the two computer laboratories were combined into the Information Technology Laboratory (NIST 1996:147).

A new building was added to Boulder Laboratories during the 1990s. In 1987, NOAA requested the GSA to consolidate their research laboratories and operational facilities located in Boulder and in Denver into one building at the U.S. Department of Commerce NIST property. The new NOAA building was designed by Fentress Bradburn and Architects (currently Fentress Architects) of Denver, Colorado. Ground breaking for the new building occurred in October 1996. In 1998, the new NOAA building was named the David Skaggs Research Center in honor of U.S. Representative David Skaggs. The building was occupied in 1999 (U.S. Department of Commerce Boulder Labs 2008a).

The NIST organization evolved as research areas continually were aligned to meet national research priorities. In April 2007, two new research centers were formed: the NCNR and the Center for Nanoscale Science and Technology. The Center for Nanoscale Science and Technology formerly had been a division within the Materials Science and Engineering Laboratory. By 2009, NIST comprised ten laboratory programs: Building and Fire Research, Center for Nanoscale Science and Technology, Chemical Science and Technology, Electronics and Electrical Engineering, Information Technology, Manufacturing Engineering, Materials Science and Engineering, NCNR, Physics, and Technology Services (Martin and Silcox 2010:139-140). Research areas located at the DoC Boulder Labs comprised: atomic clocks and the standards for time and frequency distributed by radio and the internet; nanotechnology; atomic, molecular, and optical physics; electromagnetics; optoelectronics; materials measurement methods; mathematical, statistical, and computational methods; laser science; measurements and standards for chemical properties of gases, liquids, solids, and ultracold refrigeration systems; and, quantum sensors (NIST Boulder 2007).

In 2010, the NIST's research programs again were realigned from a laboratory-based to a mission-based structure fostering interdisciplinary research groups collaborating on projects. The new organization replaced a single deputy director with three associate directors and reduced the number of laboratories to six. The laboratories comprised Material Measurement Laboratory, Physical Measurement Laboratory, Engineering Laboratory, Information Technology Laboratory, Center for Nanoscale Science and Technology, and NCNR (NIST 2010). By 2015, the Communications Technology Laboratory in Boulder became the seventh operating unit at NIST (NIST 2014c).

The research focus of the Physical Measurement Laboratory is the development and dissemination of "the national standards of length, mass, force and shock, acceleration, time and frequency, electricity, temperature, humidity, pressure and vacuum, liquid and gas flow, and electromagnetic, optical, microwave, acoustic, ultrasonic, and ionizing radiation." Divisions in the Physical Measurement Laboratory comprise Electromagnetics, Quantum Electronics and Photonics, Quantum Measurement, Quantum Physics, Radiation Physics, Semiconductor and Dimensional Metrology, Sensor Science, Time and Frequency, and the Office of Weights and Measures (NIST 2015). The Precision Measurement Laboratory (PML) in Building 81 at Boulder is part of the Physical Measurement Laboratory. The building was designed by HDR, Inc. and was completed in 2012 (NIST 2012b).

Scientists at Boulder have garnered numerous awards for their scientific achievements. Among the most prestigious awards in science is the Nobel Prize. NIST scientists historically have made scientific advances and have executed experiments that have won Nobel prizes. Between 1997 and 2012, two scientists were awarded Nobel prizes for their work conducted at NIST:

- In 1997, William Phillips of NIST shared the 1997 Nobel Prize in Physics for successfully developing the technique of laser cooling and trapping of atoms. This technique has the potential to build a new kind of atomic clock that will be more accurate than what currently is used. This work was undertaken from 1985-1988 on the Gaithersburg campus (Martin and Frederick-Frost 2014; NIST 2014b).
- In 2001, Eric Cornell of NIST/JILA and his colleagues shared the Nobel Prize in Physics for creating the first Bose-Einstein Condensate, "a new state of matter that emerges at just a few billionths of a degree above absolute zero." Scientists have incorporated this finding into their routine work to support research in quantum mechanics (NIST 2000:n.d.; Martin and Frederick-Frost 2014; NIST 2014b).
- In 2005, John Hall of NIST/JILA shared the Novel Prize in Physics for his "contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique." Frequency combs have the potential to increase the precision of a broad array of measurements in the future (Martin and Frederick-Frost 2014; NIST 2014b).
- In 2012, David J. Wineland of NIST shared the Nobel Prize in Physics for "groundbreaking experimental methods that enable measuring and manipulation of individual quantum systems." The research helped lay the groundwork towards building a computer using quantum physics and for a potential new time standard. This work took place between 1995-2005 on the Boulder campus (Martin and Frederick-Frost 2014; NIST 2014b).
- In 1980, NIST scientists at Boulder, along with ABC and PBS, won an Emmy award for closed captioning. In 1976, the Federal Communications Commission approved closed captioning for use with television transmission. Closed captioning evolved from NIST's TvTime program that was a method of broadcasting time and frequency over television airwaves. TvTime was developed by Dicky

Davis, James Jesperson, and George Kamas. The first use of closed captioning was an episode of the Mod Squad. By 1979, closed captioning was being used by all the major networks. The Emmy is located at DoC Boulder Labs (NIST 2000:n.p.; NIST 2014b).

The DoC is tasked with encouraging and prompting the economic growth of the United States. Through its collaboration with private-sector industry and businesses, universities, and local governments, the department helps to promote job creation and sustainable development. The 12 bureaus, including NIST, that fall under the DoC, collectively assist that Federal department with fulfilling its mission. NIST's location within the DoC helps ensure that new products and services are developed and improved for use in commercial applications. Further, NIST assists the department by facilitating the development of new technologies and innovations that can be adopted by the private sector (U.S. Department of Commerce 2014).

Chapter 4.0

NIST Boulder Themes

A review of the historic context developed for this project revealed that DoC Boulder Labs is identified with several important historical themes from the period of its establishment in the early 1950s through 1965. During this time period, the entire facility was administered by the NBS. After 1965, the complex was renamed U.S. Department of Commerce Boulder Laboratories. The complex retains this name today and is shared by three agencies under the Department of Commerce. The major themes identified for DoC Boulder Labs are science and technology and postwar research campus/architecture.

4.1 Theme: Science and Technology

DoC Boulder Labs originally was established in 1950 as the location for the CRPL. At the same time, the NBS cryogenics division was relocated to Boulder to conduct research on hydrogen and to produce the hydrogen required by the AEC for the hydrogen bomb program. Other important research conducted at Boulder included the atomic clock and frequency standards and lasers.

<u>4.1.1 Central Radio Propagation Laboratory (CRPL)</u>

The CRPL was established in 1946 as a separate division of NBS to combine the function of radio weather forecasting performed for the military with research into radio propagation, atmospheric studies, and radio standards (Passaglia 1999:271). Scientists assigned to the CRPL performed research on line-of-sight microwave propagation, new ranges of radio frequencies, the troposphere and ionosphere as media for the propagation of radio waves, and the national primary standards for radio frequency measurements (Passaglia 1999:182; NBS 1954:1). Boulder, Colorado, was selected for the new laboratory because the town offered sufficient land to accommodate long-distance, line-of-site radio transmissions in diverse terrain; lack of radio interference from nearby communities; and, accessibility and proximity to a university that possessed strong programs in electrical engineering (Passaglia 1999:182-184; Meier 1996:4-7).

Building 1 was designed to house the entire laboratory and its support and administrative functions in a single building. The CRPL comprised three divisions:

- Radio Propagation Physics Division that conducted research on the ionosphere and its effects on long-range radio waves;
- Radio Propagation Engineering Division that conducted tropospheric propagation research to evaluate the effects of terrain, climate, and meteorology on very high frequency, ultrahigh frequency, and microwave radio systems; and,
- Radio Standards Division that established and maintained basic standards and precision measuring systems (Boulder Chronology n.d; *The Boulder Daily Camera* 1954a).

Projects conducted by the CRPL between 1954 and 1965 included the study of the effect of terrain on radio waves and in determining the directivity of directional antennas; the study of the effects of storms occurring in the ionosphere on radio waves; the study of thermal and gravitational effects in the earth's atmosphere; investigation into the phenonomon of "forward scatter propagation" experienced at very high and ultrahigh radio frequencies; and, the effects of terrestrial and extra-terrestrial noise of radio waves. Research into noise led to the development of a noise receiver that became the international standard measuring device. Studies on cosmic noise conducted in 1956 found that the planet Jupiter was a source of radio noise. This finding, as well as studies of the effects of solar flares on radio waves, led scientists at the CRPL to undertake studies of radio astronomy (Passaglia 1999:272-275).

NBS and CRPL personnel also participated in the International Geophysical Year from July 1957 to December 1958, which corresponded to a period of major sunspot activity. Since occupying Building 1 in 1954, scientists had expanded a program to collect ionospheric soundings from 20 locations worldwide that were used to predict usable frequencies for radio communications and navigation. The data collection sites were expanded to 34 during 1957. The CRPL also established World Data Center-A to receive all data collected during the research effort for use by all researchers. The data center continued to collect and compile data until 1965, when the CRPL was dis-established (Passaglia 1999:439-443). The data collection center was then transferred to the ultimate successor agency, NOAA.

The Radio Standards Division, once part of the CRPL, remained with NBS. This division provided standards for all frequencies of radio waves and radio equipment, measuring methods, and calibration services for radio equipment. Typical standards included those for noise, voltage, power, impedance, radio interference measurements, attenuators, wave guides, field strength, and frequency (Passaglia 1999:277).

The Radio Standards Division became the keeper of the National Standard of Frequency and Time Interval, which is "the reciprocal of repeated time interval" (Passaglia 1999:367). The frequency standard was a master set of quartz crystal oscillators against which "every crystal in every radio transmitter was measured" and was used to calibrate frequency measuring instruments and to control the frequencies broadcast by the NBS radio stations in Greenbelt, Maryland, and Maui, Hawaii (*The Boulder Daily Camera* 1954a; Passaglia 1999:368). The crystals were housed in 50-ft wells to maintain rigid temperature controls. The crystals were transferred to Boulder in two stages. The first group of the master set of quartz crystal oscillators were hand carried to Boulder, installed, and compared with the set remaining in Washington, D.C. Once checks were completed, the second set of crystals were transferred to Boulder. This was the first set of primary standards housed outside of Washington, D.C. (NBS 1955; *The Bureau Drawer* 1955; Snyder and Bragaw 1986:276).

The need to improve the precision of the crystal oscillators led to the development of atomic oscillators as a potential standard. This transition in turn, led to the development of atomic clocks and increasing precision in the measurement of time. In 1954, the cesium-beam atomic clock (NBS I), developed in 1952, was disassembled in D.C. and moved to Building 1 in Boulder. Work on increasing the precision of atomic clocks continued in the Boulder laboratories with the construction of NBS II. In 1960, NBS adopted a new atomic definition of the second as 9,192,631,770 oscillations of the cesium atom and supplanted the quartz oscillators. This measurement was accurate to within one second per 30,000 years. Scientists at both the D.C. and Boulder campuses worked on this project. This new definition of the second became the international standard in 1964 (NBS 1966a:5; Passaglia 1999:373; Schooley 2000:104). NBS II in turn was supplanted by a series of new atomic clocks, including NIST-7 in 1993, as well as the first microchip-scale atomic clock in 2004 (NBS 1955; Passaglia 1999:369-371; NIST Boulder 2007).

Scientists in the Radio Standards Laboratory also conducted experiments with laser technology. In 1962, Boulder scientist Donald A. Jennings built a pulsed ruby red laser powered by xenon flash lamps. The new device opened up additional fields of research and was the fore-runner of lasers in experiments at both Boulder and Gaithersburg (Schooley 2000:100). The use of lasers opened new areas for more precise measurements, particularly in length (Passaglia 1999:522, 527).

4.1.2 Cryogenic Engineering Program

The cryogenics program was the second use assigned to the Boulder property. In fact, the first three buildings (Buildings 2, 3, and 4/5) completed at Boulder Laboratories housed the cryogenics program. The NBS cryogenics program expanded greatly following President Truman's announcement in early 1950 that the U.S. government would continue the development of atomic weapons for national security.

The AEC approached NBS for assistance to advance their studies of atomic weaponry. Enhanced cryogenic research was critical to understand the liquefaction of gases essential for the creation of fuel for weapons, and NBS scientists had worked with deuterium since the late 1930s. In early 1950, AEC requested NBS to "build a large hydrogen-liquefaction plant; set up and run a hydrogen/deuterium electrolysis plant; test prototype dewars [containers for liquefied gases] for Los Alamos; assist MIT and Arthur D. Little Company in the design and construction of dewars and refrigerators; test hydrogen transport dewars; and train personnel in large-scale hydrogen production and hydrogen handling" (Kropschot 2001:107).

With the cooperation and financial support of the AEC, ground was broken at Boulder, Colorado, for the construction of the "world's largest liquid hydrogen plant" (Building 3) and a cryogenic laboratory (Building 2). As explained in *Achievements in Radio, Seventy Years of Radio Science, Technology, Standards, and Measurement at the National Bureau of Standards*:

> …in the spring of 1951, on March 28, the NBS announced that a cryogenics laboratory would be built on the new Bureau site in Boulder… later in the spring of 1951 construction began on the cryogenics laboratory building, funded by the AEC, to be known as the Liquefier Building or Building 'A,' [currently Building 3] and used for a highly classified project for the AEC. Shortly thereafter a second building, known as Building 'B,' [currently Building 2] was constructed as a laboratory facility associated with the same project. The two buildings housed the Cryogenics Engineering Section, later to become a division of NBS, and to be known as the Cryogenic Engineering Laboratory. A third building, a very large frame building to be known as the 'Camco' Building ['Camco' was an abbreviation for the Cambridge Corporation; currently Building 4] was constructed by the AEC for use by the Cambridge Corp., a private contractor. Later it became known publicly that these facilities served for certain operations of the AEC hydrogen-bomb project (Snyder and Bragaw 1986:715).

The hydrogen/deuterium liquefier equipment for the Boulder laboratory was fabricated at the NBS campus in Washington, D.C. and then was transported to Boulder. Four hydrogen/deuterium liquefiers were built to ensure continuous operations (Kropschot 2001:107). Each liquefier had a capacity of 320 liter/hour hydrogen/deuterium. The liquefiers at Boulder were in operation by March 1952. The liquid deuterium created at the Cryogenic Engineering Laboratory was used for the successful 1952 hydrogen bomb tests held at Eniwetok Atoll (Passaglia 1999:186).

Russell B. Scott was named the first chief of the Cryogenic Engineering Laboratory at Boulder (Sloop 1978:68). Scott served as the Director of the Boulder Cryogenics Laboratory from 1952 to 1962; he was Director of the NBS Boulder Laboratories from 1962 to 1965 (Kropschot 2001:110). In 1953, staff from the Cryogenic Engineering Division at Boulder, including Scott, received the Department of Commerce Gold Medal for "the design, construction and operation of large and unique hydrogen and nitrogen liquefiers" (Kropschot 2001: 108).

By 1954, AEC had modified the fuel used and ceased their support of the NBS cryogenic program. This did not put an end to the Cryogenic Engineering Division at Boulder. Experiments on low-temperature continued at Boulder for the Army, Navy, and Air Force. In 1955, the Division began a program specifically to research cryogenic engineering and to assess its general use (Passaglia 1999:186-187; Scott 1959:4). The cryogenic laboratory "was designed to provide the facilities for the development and evaluation of equipment for use at temperatures near absolute zero or the theoretical point on the temperature scale where absolutely no heat is present" (*The Boulder Daily Camera* 1954:22).

One area of research in 1956 was the support of a hydrogen-fueled supersonic airplane that was being explored by a private aircraft designer on behalf of the Air Force. While continuing his work for the NBS in Boulder, Russell Scott became a consultant for the project. The Boulder Cryogenic Laboratory provided liquid hydrogen for the experiments, "when larger quantities were needed for tank flow and spill tests" (Sloop 1978:142, 147). By 1958, the Cryogenic Engineering Laboratory included "projects in experimental and theoretical physics, such as the investigation of the thermal conductivities of pure metals and dilute alloys, to projects with immediate practical objectives, such as the study of the behavior of the liquid oxygen propellant used in a Jupiter missile" (*The Bureau Drawer* 1958:3).

During the late 1950s, scientists from the cryogenics laboratory assisted the University of California Radiation Laboratory in the design and construction a large hydrogen bubble chamber that used large quantities of liquid cryogens. The purpose of the chamber was to track sub-atomic particles emanating from experiments in accelerators at the laboratory. In 1967, Luis W. Alvarez was awarded the Nobel Prize in physics for his discoveries in the field of elementary particles based on the hydrogen bubble chamber. Alvarez credited NBS scientists Bascom W. Birmingham, Dudley B. Chelton, and Douglas B. Mann, with their assistance with the hydrogen bubble chamber (Schooley 2000:264).

During the early 1960s, staff with the Cryogenic Engineering Laboratory at Boulder served as consultants for the NASA, General Dynamics/Astronautics, and Pratt and Whitney Aircraft on the Atlas-Centaur project. Scientists at the Boulder laboratory were instrumental in harnessing hydrogen for use as fuel for the upper stages of the launch vehicle. The work of Scott and his staff at Boulder "advanced the state-of-the-art to the point that rocket engineers realized that it was feasible to use hydrogen as a fuel" (*The Bureau Drawer* 1963:7). In November 1963, NASA successfully launched an Atlas-Centaur; it was the "first in-flight burn of a liquid-hydrogen/liquid-oxygen engine" (NASA 2012:n.p.). Additional projects conducted by the Cryogenics Division to assist the space program included research on the thermodynamic properties of hydrogen and oxygen used for propulsion, fuel cells, and breathing oxygen systems and research on slush samples of hydrogen, methane, and natural gas for high-performance aircraft, rockets, and other vehicles (Schooley 2000:234-235).

Another area of cryogenics research was the accurate metering of the transfer of cryogenic liquids. The Compressed Gas Association and the State of California requested the assistance of the NBS Cryogenics Division to develop accurate measurements to meter the flow of cryogenic liquids. The cryogenic flowmeter was installed in Building 3 in 1969. The closed flow loop permitted the continuous testing of flow meters both for accuracy and for wear. NBS researchers also installed a leak proof valve that was fabricated on site (Schooley 2000:264-265).

<u>4.1.3 Summary</u>

Since its establishment in the early 1950s, DoC Boulder Labs was the location of the CRPL and the Cryogenics Division. Scientists associated with both divisions have conducted major research programs that led to advancements in their fields of study and in overall NIST objectives. In 1965, the CRPL was transferred to another agency within the Department of Commerce and the facility was renamed to the U.S. Department of Commerce, Boulder Laboratories. Scientific discoveries and important research have continued at the Boulder Laboratories and additional important themes related to science and technology will likely emerge with the passage of time.

4.2 Theme: Postwar Research Laboratories

Construction of the Boulder campus began in earnest during the early 1950s, when funds were appropriated for the construction of Building 1. Although construction of the building was preempted by AEC's construction of Buildings 2, 3, and 4/5 for the hydrogen program, Building 1 was the first attempt to create a research laboratory at the site to represent NBS in their new location. Construction of the Boulder campus of NIST took place during a period of architectural innovation in laboratory design. The following discussion explores the factors contributing to that innovation and provides a framework for understanding the philosophies influencing the creation and evolution of the DoC Boulder Labs campus.

<u>4.2.1 Early Precedents in Research and Corporate Campus Design</u>

Two closely related property types developed during the years following the end of World War II: the corporate campus and the research campus. These property types emerged during the second quarter of the twentieth century as corporations began moving their research divisions out of central cities. Corporate headquarters soon joined the migration from urban areas. Corporations left the cities with their noise, congestion, buildings with small footprints, and challenges to expansion. Suburban settings were seen as affording greater amenities than their urban counterparts.

The corporate and research campus was purpose-built and combined large, landscaped acreage with generally, low-rise buildings (Mozingo 2011:105). The design and quality of facilities of these pastoral campuses were used by business, industry, academia, and government to compete for a limited pool of scientists. Bucolic, tranquil landscapes were seen as conducive to productivity and key to attracting select qualified personnel. Aside from an idyllic environment, these new corporate campuses often were developed as self-contained facilities isolated from urban amenities. Site plans integrated formal landscape designs, vehicular and pedestrian circulation plans, expansive parking, hierarchies of building sites, and common amenities such as cafeterias (Mozingo 2011:110). Other amenities included health facilities, gift shops, and walking trails (Dunham-Jones and Williamson 2011). The campus developed for Bell Telephone Laboratories in 1939 introduced new approaches to spatial utilization and the separation of research functions from manufacturing. Bell Telephone Laboratories set the standard for the design of postwar research campuses.

4.2.2 Research Campuses

Bell Telephone Laboratories was located on Manhattan's lower west side prior to the move to Murray Hill, New Jersey in 1939. The company required additional space to conduct highly-sensitive research in strictly-controlled environments. Expansion within Manhattan was not feasible because urban noise, electrical intrusion, and traffic vibrations would interfere with the accuracy of experimental measurements (Mozingo 2011:54). The company's research needs led to the construction of the first corporate research campus. The design of the project was initiated in 1930 by the architectural firm, Voorhees, Gmelin and Walker; however, the Great Depression delayed realization of the plan until 1939. By that time, the architects of record were the reorganized firm of Voorhees, Walker, Foley, and Smith (now HLW International) (Mozingo 2011:57). Historians have noted that "Bell Labs invented the fundamentals of the corporate campus." The integrated plan featured:

- green space, centrally located at the site;
- flexible laboratory space incorporating specialized
- utilities;
- ample parking and truck access;
- underground utilities;
- fenced property;
- three-story height limits; and
- generous landscape setbacks (Mozingo 2011:63).

Two key innovations of the Bell campus were generous site plans and the use of moveable walls in the laboratory spaces (Rankin 2013:54). As the largest research facility constructed during the period, the Bell Laboratories became the prototype for future research laboratory construction. By the conclusion of World War II, the advantages of flexible space and site isolation had become accepted design practice. Architectural magazines, trade journals for the research-management field, and specialized laboratory-design handbooks extolled the benefits of the features first introduced at Bell Telephone Laboratories (Rankin 2013:54).

The innovations first applied in the Bell campus were developed in direct response to the client's need for an economic solution and maximum flexibility (Haines 1951:337). The resulting prototype for laboratory buildings integrated flexible laboratory space with common support space, such as cafeterias and libraries. Large-scale testing and research facilities, such as wind tunnels and nuclear reactors, were housed in separate, dedicated buildings (Rankin 2013:55). Laboratory buildings comprised flexible spaces, or modules, arranged in double-loaded corridor plans that could be modified, i.e., expanded or contracted, to suit research needs. Some featured wings that included only laboratories and offices. The use of such flexible plans became universally accepted practice during the postwar period. Notwithstanding the modular design standard for general research laboratories, research campuses were unique and sophisticated complexes requiring a broad-range of building types and specialized equipment. In addition, designs often included provisions for specialized service requirements and required sophisticated engineering to address such factors as fluctuating building loads. Safety features were major components of the design and might include safety showers, additional exits, and special grounding devices (McCulley 1968:10). Modern laboratories necessitated increasingly sophisticated technical facilities and complex mechanical equipment. The sensitivity of testing equipment demanded buildings systems that controlled humidity, temperature, and air quality (McCulley 1968:65). Finishes that could be easily cleaned, yet were resilient to damage from testing or chemicals, were installed (McCulley 1968:66).

4.2.3 Corporate Campuses

By the 1940s, an architectural image emerged for corporate headquarters: sweeping entry drives, gently rolling grassy topography, and ample parking lots (Mozingo 2011:105). Changes in corporate architecture and setting were adopted for economic as well as for aesthetic reasons. The exodus from the urban core continued through the 1950s. As Business Week noted in an article published during the early 1950s, firms were leaving New York for exurban locales because of increasing rent and a lack of office space in urban centers. The magazine article went on to state that it was increasingly difficult to attract "first class personnel to work in some of the more unsightly, congested New York areas" and "management thinks workers will be happier looking at trees instead of grimy buildings and listening to birds instead of honking taxis" (Mozingo 2011:105).

During the postwar period, many major corporations adopted the corporate campus as the architectural expression of new headquarters. Companies with household names including GE, GM, and IBM had adopted the model (Rankin 2013:52). Universities and government agencies quickly followed the precedent established by large corporations (Rankin 2013:52). The rise in popularity of the corporate campus facilitated the postwar move of businesses from the traditional urban core to the suburbs.

Businesses moved their research and development departments to suburban campuses; corporate headquarters soon followed suit (Mozingo 2011:98). One result of the move of corporations to the suburbs was the relocation of white collar jobs from the urban core to the outskirts of the city limits. Increased automobile ownership and the construction of the interstate highway system facilitated the rapid movement of employees from the central cities to jobs in the new suburbs (Dunham-Jones and Williamson 2011:n.p.). Sophisticated corporations chose well-known "celebrity" architects to design new corporate campuses. Principal buildings symbolized corporate status and prestige.

4.2.4 Innovations in Research and Corporate Campus Design

The DoC Boulder Labs were built during a period when many similar facilities were constructed. The New York City-based architectural firm Voorhees, Walker, Foley & Smith was at the vanguard of research campus design during the postwar years. Ralph Walker, principal at the firm, was an innovator in the design of modern research facilities. The early involvement of crucial personnel regarding the location of mechanical and electrical services and the size of the module were his key innovations in the development of research facilities. The "module," as defined by Walker, was the "a unit of work space determined by human needs. It is dimensional only through its use factors. … The character of the research carried on, the need for safety considerations in the width of aisles, for example, each determines the final result" (Walker 1951:149). The module was an effective use of research and office space because "the chief advantage of the module system is the known repetitive position of services and therefore the lack of interference between one laboratory at work and another in preparation for a new project requiring special and additional services" (Walker 1951:150). These concepts that were considered new and novel during the 1950s became accepted practice. By the mid-1960s, they had become industry standard, with the expectation that one fifth of the partitions in any laboratory would move once a year (McCulley 1968:15).

4.2.5 The Boulder Site

When funding for the construction of the new radio laboratory for the CRPL (Building 1) was authorized in 1949, Congress specified that the new laboratory be located outside of Washington, D.C. as a safeguard against the possibility of a nuclear attack. Site selection criteria included sufficient area to accommodate long-distance, line-of-site transmissions in diverse terrain; lack of radio interference from nearby communities; and, accessibility and proximity to a university that possessed strong programs in electrical engineering (Passaglia 1999:182-184; Meier 1996:4-7). While many research campuses during this period relocated to more remote areas for the idyllic setting, Boulder was chosen for more pragmatic reasons, to provide the perfect atmospheric environment for CRPL programs and to allow for a relationship between the site and the CU-Boulder. At the time of its selection, the property was adjacent to the city boundaries; the property subsequently was annexed into the municipal boundaries.

The Boulder site originally was planned to include a single building to house all the functions of the CRPL, including laboratories, offices, an auditorium, a library, and a snack bar. Building 1 was constructed as a solitary resource; in essence, it was intended to serve as a campus in itself. The desire to consolidate all activities in a single building was to eliminate the challenges associated with operating from dispersed facilities previously encountered by the CRPL on the D.C. campus. In its design, the radio laboratory building incorporated several elements common to contemporary post World War II research buildings. The building was low in scale; the main spine rose to four stories with a small penthouse on the roof. The low building scale was widely adopted for research buildings located outside of urban areas. The area around Building 1 also provided expansive parking (Mozingo 2011:105, 110). The building's wings featured long off-center corridors with laboratories on one side and offices on the other. The hallways facilitated informal interaction among scientists as they walked to common facilities, such as the library, auditorium, and cafeteria (Rankin 2013:55).

Building 1 was sited prominently near a main roadway leading into Boulder. Building 1 was the focus of the earliest landscaping efforts at the Boulder site. Early photographs of Building 1 reveal an intention to maintain grass lawns between each wing and a lawn between the building and Broadway. Some of the grass areas around the wings of Building 1 have been retained, but ongoing rehabilitation to wings and the placement of annexes has diminished significantly the designed landscape. The early landscaping efforts around Building 1 did not extend to the rest of the site once additional buildings were constructed.

Building 1 represents an approach to postwar laboratory design. The building contains a combination of laboratory, administrative, and public spaces. Researchers within the building maintained separate laboratory spaces, yet social encounters were encouraged through the use of long hallways and communal areas such as the library and cafeteria.

The prominent architecture firm of Pereira and Luckman was selected to design the building. The Los Angeles based firm was considered a "celebrity" among modern architects and their use of elements of the International Style of architecture allowed Building 1 to illustrate the status and prestige of NBS. Pereira and Luckman had won several AIA awards prior to the completion of Building 1. Previous designs by the firm included a department store in Beverly Hills, a studio complex for CBS in Los Angeles, and a large public marine park in California on the Pacific Ocean (See Appendix B, Architects) (Bowker 1956:428; Bowker 1962:544; AIA 2015:n.p.).

In contrast to the architectural design innovations for research laboratories and campuses seen in the design of Building 1, Buildings 2, 3, and 4/5 were designed as utilitarian, industrial buildings lacking architectural elaboration. The placement of Buildings 2, 3, and 4/5 was dictated by the requirements of the cryogenics program and public safety rather than a cohesive development plan. Later development on the site reflected expedient building siting decisions as seen in the development of the hydrogen research facility. In general terms, the laboratories typically were located near the public road, while services and support structures were placed in the interior of the property. Some buildings, such as the laboratories, were constructed to reflect design elements used in Building 1, but their overall design and placement does not tie in to an overall campus model.

In 1961, James M. Hunter and Associates, architects and planners of Boulder, created a *Long Range Planning Study* of the Boulder campus. By this time, buildings on the campus in addition to Building 1 and the buildings associated with the AEC hydrogen program (Buildings 2, 3, 4/5) included Building 8, Building 9, and Building 11. The original use of Building 8 (1953) is unknown; it was moved during the 1960s to Kusch Road to serve as part of a testing facility. Building 9 (1958) was constructed near the main entrance to the site to house gas meter equipment. Building 11 (1958) was constructed along Kusch Road as part of the testing program for the CRPL. The 1961 planning study explains that "a number of buildings of temporary type construction have been built for immediate short range and temporary functions. These buildings have a very short life expectancy and cannot be considered as a part of the permanent campus" (Hunter 1961:9). The planning study included the AEC buildings as a part of this "temporary" function and excluded all buildings, with the exception of Building 1, from their "permanent construction" square footage totals for the campus.

The 1961 study identified additional laboratory requirements for scientific and technological programs and expanded support and maintenance spaces. Building 1 originally was designed to contain all functions. Laboratories received the first priority in space assignments, while maintenance, shops, clerical, administrative and supply functions were "fitted into the complex as a secondary consideration" (Hunter 1961:9). As explained in the study, "this has caused, over the years, a considerable amount of 'split' functions, poorly and ineffectively located" (Hunter 1961:9-10). New facilities already funded in 1961 comprised a new warehouse (Building 22, 1964), a new maintenance garage (Building 21, 1963), additions to the cryogenics laboratory (Building 2 Wing 'B', 1964), and a new plasma physics laboratory (Building 24, 1967) (Hunter 1961:10; Martin and Silcox 2010:90).

The 1961 study explains the lack of a design plan for the Boulder site, beyond Building 1, with additional buildings constructed to fulfill a need and placed where space allowed. The study encouraged the creation of a "campus concept." It was proposed that future expansion be accommodated in individual new buildings grouped by function in a campus setting. Functional groupings were defined as a service and maintenance area, a general administration and service area, a reception and conference area, laboratory group areas, and consolidated utilities. The individual buildings could be tied together aesthetically through the repetition of various architectural elements used on Building 1, such as the use of native pink stone (Hunter 1961:12-16).

Following the study, during the 1960s individual buildings to house the service and maintenance functions were constructed near the former Camco Building (Building 4). These buildings included the maintenance garage (Building 21, 1963) and the warehouse (Building 22, 1964) (Martin and Silcox 2010:90). Both buildings are simply designed and constructed of concrete blocks. No efforts were made to use native pink stone as recommended in the 1961 study on these types of service buildings. In contrast, two new laboratory buildings, the plasma physics laboratory and an expansion of the cryogenics laboratory, both completed in 1964, were designed incorporating elements recommended in the 1961 study. The design for Building 24, the plasma physics laboratory, featured use of native pink stone and poured concrete sunshades; it currently is the only building that closely replicates the materials of Building 1. The design of the building expansion of the cryogenics laboratory, Wing 'B', utilized concrete panels with pink aggregate, duplicating the color of the native stone used in Building 1 and Building 24.

Although several buildings on the campus feature materials designed to replicate the use of native pink stone, the overall designs of these buildings do not reflect the compatibility in scale, mass, and proportion usually associated with a cohesive campus. Buildings constructed between 1999 and 2012 also have elements intended to complement Building 1, such as the use of pre-cast textured pink panels on Building 42 (2005), Building 81 (2012), and the access tunnel point structures (2009). In addition, Building 33 (1999), the observatory (1999), and the north and south site access gates are clad in natural stone.

4.2.6 Summary

The DoC Boulder Labs complex initially was planned to be a single laboratory building constructed to house the CRPL. Before construction started on the CRPL, Buildings 2, 3, and 4/5 were constructed quickly to support the cryogenics program. Building 1 was architect designed by the noted architects Pereira and Luckman in the International Style. Building 1 was the flagship building of the complex sited as the public face of NBS to the community of Boulder. The design of Building 1 incorporated many elements of contemporary design precepts for single-building research campuses; however, the plan to consolidate functions into a single integrated building was abandoned before it was realized due to the number and nature of assignments undertaken at the Boulder site. From the beginning, there appeared to be no overall cohesive campus plan.

Chapter 5.0

Architectural Data

This chapter presents a summary of previous architectural investigations at DoC Boulder Labs and the current architectural inventory. A total of 41 built resources were surveyed at DoC Boulder Labs including 37 buildings, two objects (gates to north and south residential areas), and two structures (antenna field and Anderson Ditch) (Table 5.1).

5.1 Previous Investigations

In 1994, an intensive cultural resource inventory of the DoC Boulder Labs campus was completed as part of consulting services provided by Larson-Tibesar Associates, Inc. and Gulf Engineers and Consultants through the U.S. Army Corps of Engineers, Omaha District (Larson 1994:1). A report was generated as a result of this investigation entitled, *Results of an Intensive Cultural Resource Inventory of the Boulder NIST Site, Boulder, Colorado*. At the time of the Larson investigation, none of the buildings constructed at NIST were 50 years of age or older, as generally required for consideration for listing in the NRHP. The report recommended that Building 3 and the Radio Building (Building 1) met the criteria for NRHP consideration under Criterion A for their association "with events that have made a significant contribution to, and are identified with, or that outstandingly represent, the broad patterns of United States history and from which an understanding and appreciation of those patterns may be gained [e.g.,… American at the forefront of the development of new sciences and technology…]." The report further recommended that the NIST facility be assessed for eligibility under Criterion B for its association with individuals important in our history. Furthermore, the report recommended: that the Colorado SHPO "be asked to comment on the general stance taken in this report regarding the significance of this facility"; that "a decision be made as to whether the buildings should be recorded one at a time or whether a National Historic Landmark or NRHP District designation might be the most appropriate method of recognition"; and that a decision be made "whether the final recording of the NIST facility should take place immediately or wait until the first buildings on the site reach an age of 50 years" (Larson 1994:27-28). The 1994 Larson report also discusses the Anderson Ditch (a man-made irrigation ditch created in 1860 that travels north-south through the campus), but clarifies that the "scope of work for this project specifically exempts the Anderson Ditch from additional study except for identifying it on project maps"; as a result, the report does not discuss its eligibility (Larson 1994:3).

In 13 September 1994 correspondence from James E. Hartmann, Colorado State Historic Preservation Officer, to Richard D. Gorton, Corps of Engineers, Omaha District, the Colorado SHPO responded to the submission of the Larson report. The SHPO stated that:

> the NIST campus has been determined to be eligible for the National Register of Historic Places under Criteria A and C for its exceptional significant (sic). The historic district is composed of the Radio Building, Liquefier Building and Laboratory plus the Camco Building as well as Anderson Ditch and all landscape features. It represents the important development of hydrogen bomb technology during the Cold War as well as illustrates modern industrial design and function. Building Inventory Record forms need to be completed on all structures on site to determine the exact boundaries of this historic district. This documentation needs to be completed as soon as possible (Hartmann 1994a).

In correspondence dated 28 October 1994, Robert S. Nebel, Chief of the Environmental Analysis Branch of the Planning Division of the Corps of Engineers, Omaha District informed Sharon Malloy of the GSA that a final draft of

Table 5.1 DoC Boulder Labs – Building Inventory and Eligibility Recommendations

Building Number	Building Name	Construction Completed	Eligibility Recommendations
1	Central Radio Propagation Laboratory (CRPL)	W 1-W 4 1954; W 6 1959; W 5 1962; on-going renovations 2012 - present	Eligible
1, Annex C	Building 1, Annex C	1989	Not Eligible
1, Annex D	Building 1, Annex D	1992	Not Eligible
1, Annex E	Building 1, Annex E	2000	Not Eligible
1, Annex F	Building 1, Annex F	2000	Not Eligible
2	Cryogenics Lab	1951 (Cryogenics), 1964 Wing 'B' Addition, 1986 High Bay Addition, 1995 Addition	Not Eligible
2A	Cryogenic Annex "A"	1989	Not Eligible
3	Liquefier	1951	Not Eligible
3A	Liquefier Annex "A"	1989	Not Eligible
4	Camco Building	1951, 1986 Metal Siding, 1994 Addition, 2012 Window Replacements	Not Eligible
5	Heavy Equipment	1951, 1986 Metal Siding, 1988 Renovations, 1992 Expansion, 2012 Window Replacements, 2015 Expansion	Not Eligible
8	Mesa Test Site	1953	Not Eligible
9	Gas Meter	1958	Not Eligible
11	Vertical Incidence	1958	Not Eligible
12	Hydrogen Research Facility	2008	Not Eligible
21	Maintenance Garage	1963	Not Eligible
22	Warehouse	1964	Not Eligible
23	Hazardous Materials Building	1990	Not Eligible
24	Plasma Physics	1967; High Bay Addition 1985, Annex A 1988, Air Handling Unit 1999, Elevator Tower 2002-2005	Not Eligible
25	Offices	1975	Not Eligible
26	Day Care Facility	1989; Addition 1995	Not Eligible
27	High Frequency	1991	Not Eligible
Antenna Field	Antenna Field	Circa 1990	Not Eligible
33	David Skaggs Research Center/NOAA	1999	Not Eligible
34	Solar Observatory	1999	Not Eligible
42	Central Utility Plant (CUP)	2005	Not Eligible
Access Tunnels (x3)	Access Tunnels, three accessing utility corridor along Compton Road	2009	Not Eligible
51	Security Center	2006	Not Eligible
Vehicle Check Building	Vehicle Check Building	2005	Not Eligible
Guard House	Guard House	2014	Not Eligible
81	Precision Measurement Laboratory (PML)	2012	Not Eligible
91	Construction Research Facility	2008	Not Eligible
111	Four Annex	2011	Not Eligible
112	Warehouse	2011	Not Eligible
131	Office Building	2013	Not Eligible
Maintenance and Staging Yard	Maintenance and Staging Yard	Circa 1990	Not Eligible
Gates (x2)	Gates to north and south residential areas	2014	Not Eligible
Anderson Ditch	Anderson Ditch	1860	Needs more information

the Larson report had been completed. The correspondence from Nebel explained that several inaccuracies were discovered by NIST within the earlier draft of the report, specifically language related to the assembly of the hydrogen bomb. The letter clarified,

> We do not feel that the NIST campus is eligible to the National Register at this time. The buildings on the NIST campus did not play an important contributory role in the development or assembly of the hydrogen bomb, nor did it supply fuel to the space program, as suggested in the draft report. This campus does not exhibit the "exceptional significance" that is required for a National Register property that is less than fifty years in age (Nebel 1994).

The final draft of the Larson report, along with the correspondence from Nebel, was submitted by the GSA, Rocky Mountain Region, to the Colorado SHPO 3 November 1994 (Brady 1994). James E. Hartmann, Colorado State Historic Preservation Officer, responded in 5 December 1994 correspondence, stating that

> we feel that the campus is still considered eligible under Criteria A and C. Activities on site included the development of engineering and research data for the American Space program, Cold War technology, and cryogenics, as well as the agency's responsibility for maintaining the nation's physical standards. Since it is unclear as to the role the campus played in hydrogen bomb development, the statement of significance will be as follows: The site represents important technological research and development during the Cold War and Space Age periods and also illustrates modern industrial design and function (Hartmann 1994b).

No further correspondence between the Colorado SHPO, the GSA, or NIST regarding the report was located within the files of the Colorado SHPO or NIST.

In 1996, an Environmental Impact Statement (EIS) was developed by the GSA in cooperation with the U.S. Department of Commerce NIST as a result of the proposed construction of buildings and the renovations of facilities at the DoC Boulder Labs campus. Proposed buildings for construction included the Central Utility Plant (CUP), an Advanced Technology Laboratory (ATL), and a building to house NOAA offices, laboratories, and research facilities. On January 11, 1995, prior to completion of the EIS, Paul Crowder, Boulder Site Manager for NIST, provided documentation on the designs for the proposed CUP and ATL to the Colorado SHPO. His correspondence, which was forwarded to GSA, notes, "as discussed on 3 January, we are in the process of acquiring photos of the buildings at 325 Broadway you've expressed interest in. We would like to show you contact sheets of these photos before we engage a professional to take archive quality photographs. We will contact you when we have something to show you in this regard" (Crowder 1995).

Additional correspondence regarding the proposed CUP and ATL were located within the files of the Colorado SHPO. On July 3, 1995, James E. Hartmann, Colorado SHPO, corresponded with Vince Brady, GSA. The letter clarifies that the SHPO considers Building 1, Building 2, Building 3, Building 4, and the Anderson Ditch and related landscaping as contributing to an historic district. The letter further explains that:

> The proposed undertakings will have no adverse effect on the historic district provided that the following conditions are met:
>
> 1. Our offices will be afforded an opportunity to review and comment on the evolving design at 50% and 90% completion points for the Advance Technology Laboratory.
> 2. The Anderson Ditch will be reestablished after construction and its banks landscaped with mature planting to recapture its character.
> 3. Historic Building Inventory Record forms will be completed on all structures on the campus.
> 4. Archival black and white photographs will be produced for all affected elevations on Building 1 and 2 to be impacted by the Advance Technology Laboratory project (Hartmann 1995).

No further correspondence regarding the photographs or the completed inventory forms was located in the files of NIST or Colorado SHPO. The 1995 Hartmann correspondence does not appear to have been forwarded to NIST (Hartmann 1995).

Chapter 2 of the EIS, "Affected Environment," addressed cultural resources and noted: "some of the campus buildings are considered to be historically important. Specifically, the Liquefier Building and Laboratory (Building 3), the cryogenics Laboratory (Building 2), the Camco Building (Building 4) and the Radio Building (Building 1), could be considered for historic recognition" (U.S. GSA 1996a:2-13). Chapter 2 of the EIS summarized that "the Colorado SHPO feels the DOC campus is eligible for inclusion to the NRHP as an historic district. NIST is currently completing historic inventory reports on a number of buildings possibly contributing to the NIST historic district. The buildings are being reviewed by the SHPO under Criterion A, as important technological research and development facilities during the Cold War and Space Age period, and Criterion C, modern industrial design and function. The SHPO has indicated to GSA and NIST that they concur with a determination of No Adverse Effect for the construction of the proposed ATL and CUP and GSA/NOAA Building as they relate to the historic nature of the buildings and the proposed district" (U.S. GSA 1996a:2-16). No additional documentation was located to specifically define the proposed historic district at DoC Boulder Labs or to further explain the referenced inventory reports.

Cultural resources also are addressed in Chapter 4 of the 1996 EIS, "Proposed Upgrade of NIST Facilities." Chapter 4 noted, "there will be no adverse effect on historic resources as the result of the proposed NIST facility upgrades" and identified Buildings 1, 2, 3, and 4 as eligible for inclusion in the NRHP and contributing to "the historic district" (U.S. GSA 1996a:4-13). Once again, the proposed historic district was not specifically defined. Neither a period of significance nor proposed boundaries for the district are detailed within the EIS.

As part of the review process for the 1996 EIS, a Record of Decision was established in 1996 for the "Proposed Federal Building for National Oceanic and Atmospheric Administration, Boulder, Colorado." Section 4.0, "Potential Environmental Issues," discusses cultural resources and notes that "the Colorado SHPO has concurred that implementation of the preferred alternative will have no adverse effect on the potential NIST historic district or on the Anderson Ditch. The Anderson Ditch and certain NIST buildings are eligible for the National Register of Historic Places" (U.S. GSA 1996b:9). An additional Record of Decision for the "Proposed Upgrade of NIST Facilities and Master Site Development Plan for NIST, Boulder, Colorado" also was completed in 1996. Section 4.0, "Potential Environmental Issues," discusses cultural resources and notes that

> The Colorado SHPO feels that the DOC campus is eligible for nomination to the National Register of Historic Places. Several buildings on the campus are considered to be important and eligible for this nomination: the Radio Building (Building 1), the Cryogenics Laboratory (Building 2), the Liquefier Building (Building 3), the laboratory associated with the Liquefier Building, and the Camco Building (Building 4). Likewise the Colorado SHPO has concurred in a determination of No Adverse Effect after reviewing NIST's plans to relocate the northern, channelized portion of the Anderson Ditch and to replicate its current configuration adjacent to the ATL (U.S. GSA 1996c:10).

In addition to cultural resource management investigations, two buildings on the Boulder campus have been documented with the Colorado SHPO. The earliest known documentation of Building 3 on file with the Colorado SHPO was completed by Ralph F. Desch, a Program Information Officer with current-day NIST in 1971. The one-page form (5BL588) provides a brief description of the building and a paragraph summarizing its importance. At that time, according to the form, the building held "components of the original liquefaction equipment now used for laboratory experiments, a cryogenic flowmeter calibration facility, and liquefied-gas storage facility" (Desch 1971:n.p.). Desch notes that Building 3 was in good condition and that it "was constructed to house the world's first large-scale hydrogen-liquefaction plant…and was easily the world's largest hydrogen liquefier." He continues to explain that Building 3 "served as a prototype for the giant industrial plants of today which furnish liquid hydrogen fuel for powering our excursions to the moon and outer space." No additional documentation or SHPO correspondence was associated with the one-page form.

In 2000, a Colorado SHPO architectural inventory form (5BL588) was completed for the National Bureau of Standards. This form was completed by Diane Wray as part of *Modern Architectural Structures in Boulder: 1947 – 1977, Context and Survey Report* (Paglia, Segal, and Wray 2000). This report was the result of a survey of modern architecture throughout Boulder and, according to the research design, "the objectives of the survey were to define the historic context of the development of Modern architecture in Boulder from 1890 to 1977" (Paglia, Segal, and Wray 2000:19). Specific resources were selected based on their representation of a particular architectural style. In this case, according to the documentation, Building 1 at DoC Boulder Labs represents the International Style of architecture (Paglia, Segal, and Wray 2000:20 and table). NRHP eligibility was not assessed as a part of the report. Although the resulting inventory form is for DoC Boulder Labs, the text within the form is specific only to Building 1. No other buildings are discussed within the inventory form.

5.2 Property Overview

NIST is located in Boulder, Colorado (Figures 5.1 – 5.4). The DoC Boulder Labs campus is accessed from Rayleigh Road. Broadway/State Highway 93 forms the eastern boundary of the facility. The campus abuts residential neighborhoods to the north and south. The Flat Irons are located to the west.

NIST comprises multiple buildings located in three research zones (Figure 5.5). Research Zone 1 is located west of the main area of campus along Kusch Road at the foot of the Flat Irons. The area includes 11.74 acres of land used for various testing activities; none of the built resources within this area are assigned numbers (Figures 5.6 – 5.9). The area connects to hiking trails managed by Open Space and Mountain Parks, which is owned by the City of Boulder. Research Zone 2 is located west of the main area of campus along Kusch Road at the foot of the Flat Irons; it is east of Research Zone 1. The area includes 7.11 acres of land. Research Zone 2 includes Building 8, Building 11, and Building 12. Research Zone 3 (also classified as the Development Zone) comprises the main campus area and includes 83.31 acres. All other buildings are located within this zone. The remaining 103.5 acres of the campus are protected land; 24.95 acres of this area are protected as part of a Tribal Memorandum of Agreement (MOA).

These three zones were created as part of a 1993 MOA between NIST, U.S. Department of Commerce, and the City of Boulder, Colorado. The MOA was developed to address proposed construction on the campus, specifically the creation of the NOAA building. Research Zones were defined in the MOA as areas "where research projects may be performed and certain research facilities may be located." The Development Zone (including Research Zone 3) is designated as the area "where all building will take place." The Protected Area is defined in the MOA as the land "where a buffer zone will be designated and the City will spend its money to construct underpasses and pedestrian and bicycle paths for public use" (NIST 1993:2).

The MOA restricts construction within the Research Zones as follows, "within the research zones, the parties agree that existing buildings may be redeveloped to similar size, height and use. No other habitable buildings are permitted in the primary research zones" (NIST 1993:4).

The Development Zone is further restricted in the MOA through building height limits, and the area is to "be used solely by the Federal government and solely for scientific research activities and necessary activities in support of those research activities, such as secretarial and clerical activities." The MOA also specifically states that "NIST shall not allow the United States Forest Service to occupy any portion of the development zone at any time for non-research purposes (NIST 1993:3).

Restrictions on the Protected Area include not using the area for research and not erecting a fence around the land, "unless prior written agreement is reached with the City concerning such construction" (NIST 1993:4). The MOA also addresses traffic management. In particular, "the parties agree that appropriate design techniques shall be employed in the landscaping of the NOAA building so that the parking areas will not appear to be a 'sea of asphalt'" (NIST 1993:5). In addition, berms and landscaping are encouraged to "enhance the appearance of the property and minimize or mitigate the environmental impact of the development of the property" (NIST 1993:5). In addition, NIST agrees to allow the City of Boulder a 30-day review and comment period for any construction over 10,000 square feet of gross floor area. The MOA also addresses pedestrian and bicycle paths, utilities, and environmental considerations.

Also in 1993, a Grant of Irrevocable Easement of Real Property was conferred to the City of Boulder. The easement protects a 103.5-acre portion of the NIST property from development. The easement was amended in 1998. A 24.95-acre portion of the easement is considered a Tribal protected area; this portion was designated as part of a MOA executed by 14 federally recognized tribes and The Medicine Wheel Coalition for Sacred Sites of North America (NIST 1998).

In 1995, a Programmatic Agreement (PA) Regarding Protected Areas at the Department of Commerce Site, 325 Broadway, Boulder, Colorado was executed among NIST, eleven Native American tribes, and the Medicine Wheel Coalition for Sacred Sites of North America. The PA clarifies that the 24.95 acre Tribal Easement "is an overlapping easement on an existing irrevocable easement held by the City on portions of the site" (NIST 1995:1). Stipulations of the PA include permitted maintenance and utility work as well as tribal use of the land.

The Tribal Easement is located on the eastern edge of the campus. Broadway travels along the east boundary of the area; Rayleigh Road is to the north. The western edge of the area follows Anderson Ditch and the southern edge follows the NIST boundary along the residential area to the south. The City's easement includes this area and extends west beneath Research Zone 3. It includes land between and south of the areas designated as Research Zone 1 and Research Zone 2.

Three roads travel through the main campus area, Research Zone 3. Rayleigh Road extends west off of Broadway and is the only vehicular entrance to the campus. The road travels west past the security center (Building 51) and then turns southwest between Building 24 and Building 33. Compton Road encircles an area of land that includes Building 1, Building 2, Building 81, and Building 91. Compton Road also extends south, crossing Rayleigh Road near Building 23. Lawrence Road (also referred to as Curie Circle) encircles an area of land that includes Building 3, Building 4, Building 5, Building 21, Building 22, Building 42, Building 111, Building 112, and Building 131.

5.3 Periods of Development

A review of resource construction at DoC Boulder Labs did not reveal defined periods of construction united by materials or design. As a result, periods of development were created based upon construction dates alone in order to illustrate the lack of cohesive development at DoC Boulder Labs. The periods created are illustrated on Figure 5.10. The periods include: one phase of construction for Anderson Ditch, 1860, which predates the existence of NIST; one period of construction for the U.S. Atomic Energy Commission (AEC) funded construction, 1951; 1953 – 1975; 1989 – 2000; and, 2005 – 2013. The following discussion illustrates that although the initial plans for the campus included the creation of one campus building, Building 1, subsequent phases of construction were based on a sporadic progression of construction as need, funding, and mission arose.

DoC Boulder Labs was not developed as a cohesive campus (Figure 5.10). The original use of the property was to house the Central Radio Propagation Laboratory (CRPL) in a single building (Building 1). However, new uses were quickly assigned to the property based on program needs assigned to the NBS by the AEC.

During the early 1950s, Buildings 2, 3, 4, and 5 were constructed for the NBS cryogenics program to support the AEC's need for a hydrogen-liquefaction plant and laboratory. The AEC supplied both the construction drawings and the funding. The buildings were sited with appropriate setbacks due to the nature of the work conducted in them. The two primary buildings, Buildings 2 and 3, are utilitarian, industrial buildings constructed with poured concrete and lacking exterior ornamentation. Buildings 4 and 5 were constructed as support buildings and are frame construction; they currently are clad in textured metal siding. While Buildings 2, 3, 4, and 5 are linked by their history and construction period, the buildings do not comprise a cohesive architectural or visual complex of buildings.

Building 1, the CRPL building, was completed in 1954. Building 1 was the flagship building designed for the property and incorporated architectural features that associated with the International Architectural Style. The building was constructed facing Broadway and is oriented intentionally to afford public views. The façade prominently displays NIST signage. Originally, the building incorporated signage directly on the poured concrete façade that read National Bureau of Standards. The current sign reads U.S. Department of Commerce Boulder Laboratories. In addition to its placement and visibility from Broadway, Building 1 prominence is reinforced by its overall size, massing, and architectural style. The overall design incorporated architectural features typically associated with post World War II research buildings, including consolidation of all activities into a single building, low scale, "use module" design for the laboratory wings, and expansive parking.

Expansion of DoC Boulder Labs continued between 1953 and 1975 to accommodate specialized research facilities (Buildings 8 and 11), utilities (Building 9), and building and grounds service shops and support buildings (Buildings 21, 22, and 25). By the 1960s, it was apparent that Building 1 could not be expanded efficiently following the construction of Wings 5 and 6. Long range planning efforts were initiated to create a campus-like setting through functional areas, such as that created for the warehouse (Building 22) and service shops (Buildings 22 and 25) along Lawrence Road (Hunter 1961:12). These utilitarian buildings are less visible from Broadway and feature minimalistic designs. Building 24 was completed in 1967 as the Plasma Physics Unit. As a laboratory building, it was sited close to Building 1. Although constructed later than the main core of Building 1 and designed by a different architect, Building 24 clearly mimics some architectural elements of Building 1, such as the use of local stone and concrete. Similar to the buildings constructed during the early 1950s, buildings constructed during the 1953 – 1975 period do not appear to visually represent a cohesive plan.

Additional buildings constructed on the campus between 1989 and 2000 included annexes to Building 1, an annex to Building 2, Building 3 Annex, Building 23, Building 26, Building 27 and its associated Antenna Field, Building 33, and Building 34. Building 33, the David Skaggs Research Center/NOAA Building, is a prominent building on the campus that was completed in 1999. Like Building 1, Building 33 is visible from Broadway and its overall modern design, scale, massing, and materials represent the ground breaking research that takes place on the campus. Building 34, a solar observatory, also completed in 1999, was designed to complement Building 33, and featured the same materials and modern design. The remaining buildings constructed during this period are utilitarian and are ornamented sparsely.

Construction on the campus between 2005 and 2013 included small buildings that appear to be prefabricated, including Building 91, Building 111, Building 112, and Building 131. Other small buildings added during this period include the guard house and vehicle check building at the Rayleigh Road entry, Building 51, and the utility access tunnels along Compton Road. Two larger buildings constructed during this period include Building 42, the Central Utility Plant, and Building 81, the Precision Measurement Laboratory. Both modern buildings are clad in prefabricated panels and feature large glazed wall surfaces.

The DoC Boulder Labs property does not reflect a planned progression of building periods that resulted in a unified design concept. Buildings were constructed as needs arose and funding became available. The buildings were sited based on the suitability of a particular location within general functional areas rather than conforming to a preconceived campus design. As a result, the property currently does not reflect a comprehensive plan implemented over time.

5.4 Landscaping at DoC Boulder Labs

Similar to site development and building placement, landscaping at the Boulder campus can be characterized as fragmented and lacking a comprehensive plan. Building 1 was the focus of the earliest landscaping efforts. Early photographs of Building 1 reveal an intention to maintain grass lawns between each wing and a lawn between the building and Broadway. Some of the grass areas around the wings of Building 1 have been retained, but ongoing rehabilitation to wings and the placement of annexes has diminished the designed landscape. Additional landscape changes to Building 1 include the construction of security fences constructed between the Building 1 wings; the placement of planters around the building; and the construction of arc-shaped parking lots to the east and west of the building in 2009. Collectively, these modifications have contributed to diminish the original design intent.

More significantly, however, are the changes in the roadways that have affected the original landscaping. The once-expansive lawn between Building 1 and Broadway has been modified to incorporate a new access road constructed in 2006 and a shared use path. The new road was completed as part of a larger effort to modify the original entrance to the site and to improve access to the facility. The realignment alters the public's perception of Building 1. In addition, due to security reasons, the lawn between Broadway and Building 1 has been downsized to accommodate permanent force protection measures including the placement of large boulders along Compton Road. Building 1 and Building 24 both feature integral landscaping beds adjoining the façade, but neither appear to have a formal planting scheme. Overall, the property lacks a comprehensive landscape design. Isolated landscape elements include ornamental grasses, rocks, and pathways used to highlight Anderson Ditch, a preexisting irrigation feature.

5.5 Property Types

The NPS identifies a property type as "a grouping of properties defined by common physical and associative attributes" (NPS n.d.:53). Built resources at DoC Boulder Labs can be categorized into four main property types: laboratories/research facilities, administrative facilities, service facilities, and utility facilities. Many of the buildings serve multiple purposes, such as office/laboratory; they are categorized by their primary function.

The majority of buildings on the Boulder site are used for laboratories and/or research facilities. These include: Building 1 and associated annexes, Building 2 and associated annex, Building 3 and associated annex, Building 4/5, Building 8, Building 11, Building 12, Building 27, Building 24, Building 33, Building 34, and Building 81. In addition to being categorized under laboratory/research facilities, Buildings 2, 3, and 4/5 are associated by their historic use as support buildings for the AEC hydrogen program. Laboratory/research buildings on the Boulder site typically were designed for specific projects and are often changed over time to accommodate a new program and/or new research need. With the exception of Building 1 and Building 24, which feature pink natural stone cladding and Building 33 and Building 34, which feature natural tan stone cladding, laboratory/research buildings on the site do not share physical attributes. They are associated based upon their function as laboratory/research facilities.

Administrative facilities on the Boulder site include: Building 91, Building 111, and Building 131. All of these buildings are prefabricated and have flat roofs and rectangular footprints. Buildings on the site with specific administrative purposes typically are temporary construction and occupy a small footprint.

Service facilities on the Boulder site include: Building 21, Building 22, Building 23, Building 25, Building 26, Building 51 and associated vehicle check building and guard house, and Building 112. These include resources used for maintenance, storage, security, and one (Building 26) used as a daycare facility. These buildings feature minimal design elements and primarily have flat roofs and rectangular footprints.

Utility facilities on the Boulder site include: Building 9, Building 42, and the access tunnel point structures. Although Building 9, Building 42, and the access tunnel point structures all have flat roofs and rectangular footprints, they differ from one another in size and overall appearance.

5.6 Architectural Inventory

A review of architectural drawings and informal interviews with NIST staff suggest that the resources located at NIST have undergone a continuous program of modification and alteration. Changes to building interiors are particularly common as laboratory and testing spaces have been altered to make the spaces relevant in the face of ever-changing research needs. Other building modifications include the construction of additions. Such modifications are necessary in order for the buildings to meet contemporary research requirements.

Surveyed buildings are presented in Table 5.1 and mapped on Figure 5.11. A discussion of buildings is presented below. Evaluations of resource significance and integrity are presented in Chapter 6 of this report.

Building 1 (Other names: Radio Laboratory; CO SHPO Resource # 5BL588)
Construction completed 1954 (primary mass and Wings 1 – 4), 1959 Wing 6, 1962 Wing 5, 2012 - present on-going renovations
Figures 5.12 – 5.77

Building 1 is encircled by Compton Road. It is oriented northeast toward Broadway (State Highway 93). It was designed by the architectural firm Pereira & Luckman (See Appendix B, Architects). The building comprises a main block with six rear wings. The primary entrance is located on the northeast elevation of the main block, which also houses an auditorium, and a library. A central spine spans from the northeast to the southwest, and creates a circulation network accessing the six wings that extend to the southeast and northwest (Figure 5.12). The building is constructed of poured concrete and concrete blocks; portions of the concrete are faced in stone. The building has a flat-roof; this, along with the primary use of concrete and the low height of the building accentuate its overall horizontality. The building is constructed into a slight grade (Figure 5.13 - 14). As a result, the building is tiered and elevators or stairs must be used to access each individual wing from the spine of the building.

The façade (northeast elevation) of the building is divided into three sections vertically (Figures 5.15 - 5.16). The southeastern third houses a library; the northwestern third serves as an auditorium. The central section between the library and auditorium serves as a lobby area and hallway. The library section is one-story and is clad in stone; the roof of this section is flat (Figures 5.17 - 5.18). Ribbons of windows light the library on the southeast (Figure 5.19) and northwest elevations (Figure 5.20); the northeast elevation of the library is blind. The auditorium section is one-story and is clad in stone on each elevation (Figures 5.21 – 5.23); it has a flat-roof, with a slight flat-roof projection to allow for an acoustic ceiling within the interior space. The central section of the façade is recessed behind the northeast wall planes of the library and auditorium. A row of narrow square concrete columns extends between the northeast wall plane of the library and the auditorium. The columns are connected by a horizontal concrete beam. The space between the library and auditorium is only partially roofed, creating an open courtyard in front of the central section. This courtyard area consists of poured concrete walkways around a central planting bed. Currently, a single large tree is located within the planting bed. A narrow area of the space between the library and auditorium is roofed along the northwest and shelters a walkway leading to the main entry. The façade (northeast elevation) of the central section features square concrete columns; glazing extends from grade to ceiling between the columns (Figures 5.24 – 5.25). The glazing continues along a projecting vestibule that extends northeast and accommodates the main entry to the front of the building (Figure 5.26). The central section, or spine of the building, is three-stories. The façade of the second and third levels is constructed of concrete and has no openings. The northwest and southeast elevations of the second and third levels feature ribbons of three windows. Each ribbon of windows is separated by a concrete column. Concrete shed-roof awnings, or sunshades, span the window bays (Figures 5.27 – 5.29).

The lobby area is an open hallway that connects to the library, the auditorium and to steps leading up to the spine of the building and down to the cafeteria area (Figures 5.30 – 5.32). A reception area is located within the lobby, directly in front of the main entry (Figure 5.33). The interior of the library is open from wall to wall, with the exception of an office area (Figures 5.34 – 5.35). The auditorium, although it appears to retain its overall historic configuration, has been modified to accommodate modern seating and modern audio-visual equipment (Figures 5.36 – 5.37). Steps off of the lobby access a lower-level corridor that leads to the cafeteria area (Figures 5.38 – 5.39). The cafeteria features an outdoor seating area that is below grade (Figure 5.40). Steps off of the lobby area also lead upstairs to the spine of the building, which accesses individual wings (Figure 5.41). Offices and lab spaces line both sides of the spine hallway.

Each wing is similar on the interior, with a corridor flanked by offices and laboratories (Figures 5.42 – 5.43). The 1952 elevations by Pereira & Luckman depict the layout of each wing (Figures 5.44 – 5.45).

Wing 1 extends from the northwest side of the spine, directly behind (southwest of) the auditorium (Figures 5.46 – 5.49). Annex E and Annex F of Building 1 are located along the northeast elevation of Wing 1, partially masking the elevation. The one-story wing has a flat-roof projection on the roof, a clerestory, which features small single-sash windows. The Wing is constructed of poured concrete and features ribbons of windows along the northeast elevation (Figure 5.50). Each window bay features six sets of windows. Each window bay is divided vertically by a concrete column. A shed-roof sunshade spans the width of the windows. The southwest elevation of Wing 1 is similar to the northeast elevation, with ribbons of windows that feature concrete sunshades.

Wing 2 extends from the southeast side of the spine, directly behind (southwest of) the library (Figure 5.51). Similar to Wing 1, Wing 2 is one-story and is constructed of poured concrete. It also features ribbons of windows with concrete sunshades. Each window bay features six sets of windows. Each window bay is divided vertically by a concrete column. The Wing also has a clerestory with small, single-sash windows. The southeast elevation of Wing 2 has a dock area that is sheltered by a shed-roof awning that projects to the southeast (Figure 5.52).

Wing 3 extends from the northwest side of the spine, directly behind (southwest of) Wing 1 (Figure 5.53). Renovations currently are being made to Wing 3 and include sheathing the Wing in new materials. The Wing is one-story, with a clerestory; it originally featured the same materials and openings as Wing 1. The northeast elevation of the Wing is sheathed in narrow metal horizontal panels. The window openings have been modified to accommodate larger modern sashes and the concrete sunshades have been removed (Figure 5.54). The clerestory also has been altered, with new sheathing and replacement windows that are larger than the clerestory windows remaining on some of the other wings. The stepped building section has been significantly altered by extending the upper roof line to make space for mechanical equipment and ductwork, and the building wing has been widened to create a utility corridor for the labs. The wing now has a rectangular profile on the southwest elevation (Figure 5.55). The northwest elevation of the Wing features a dock area, which has also been extensively modified. A large opening that accesses the dock on this elevation is recessed within a poured concrete flat-roof projection that extends to the northwest. The southwest elevation of Wing 3 also has been modified (Figure 5.56). The elevation is clad in vertical panels and the original windows have been replaced with narrow slits (Figure 5.57). A ribbon of single-sash windows is located above the vertical panels along the eave of the elevation. Unlike Wings 1, 2, 4, and 5, Wing 3 now has an overhanging eave.

Wing 4 extends from the southeast side of the spine, directly behind (southwest of) Wing 2 (Figure 5.58). Similar to Wings 1 and 2, Wing 4 is one-story tall and is constructed of poured concrete. It also has a shallow clerestory. The northeast elevation of the Wing has ribbons of windows and also features a shed-roof sunshade that spans the elevation. Each window bay is divided vertically by a concrete column. The southeast elevation of Wing 4 has a dock area; a large opening with an overhead door pierces the elevation (Figure 5.59). A pedestrian door southwest of the large opening provides exterior access to the Wing. The southwest elevation is similar to the northeast elevation, with ribbons of windows and a shed-roof sunshade that spans the length of the elevation.

Wing 5 extends from the northwest elevation of the spine, directly behind (southwest of) Wing 3 (Figure 5.60). The Wing is one-story and is constructed of poured concrete. Unlike Wings 1, 2, and 4, Wing 5 does not have sunshades on the northeast and southwest elevations. Each window bay features six sets of windows. Each window bay is divided vertically by a concrete column. The clerestory on Wing 5 is taller than the clerestory on the other wings; unlike the other wings, the clerestory on Wing 5 also features a ribbon of six windows on the northwest elevation. The northwest elevation of the Wing has a dock area, and an extended wheelchair ramp with rails that spans to the northwest. The southwest elevation of the Wing is similar to the northeast elevation;

both elevations have the same bay configuration (Figure 5.61).

Wing 6 extends from the southwest elevation of the spine, directly behind (southwest of) Wing 4 (Figure 5.62). Similar to Wing 3, Wing 6 is undergoing extensive renovations. The northeast elevation has been sheathed in narrow vertical metal panels and the elevation has been altered to accommodate larger modern windows. The clerestory also has been enlarged and sheathed in new materials. Similar to Wing 3, the stepped building section has been significantly altered by extending the upper roof line to make space for mechanical equipment and ductwork, and the building wing has been widened to create a utility corridor for the labs. The wing now has a rectangular profile on the southwest elevation (Figure 5.63). The southwest elevation of the Wing is clad in vertical panels, similar to those on the southwest elevation of Wing 3. The original windows have been replaced with narrow slits (Figure 5.64). A ribbon of single-sash windows is located above the vertical panels along the eave of the elevation. The southeast elevation of the Wing features a dock area, which has also been extensively modified (Figure 5.65). Unlike Wings 1, 2, 4, and 5, Wing 6 now has an overhanging eave.

The *Spine* of the building extends from the central lobby (between the library and auditorium) to the southwest, connecting to each wing and to Building 81. The Spine originally terminated at the location of current-day Wings 5 and 6, even though these wings were not constructed until years after the completion of the first four wings. Recently, the spine was connected to Building 81 to the southwest (Figures 5.66 -5.67). The spine originally had features similar to the wings, including window bays separated by concrete columns and concrete sunshades extending above the windows (Figures 5.68 and 5.69). The majority of the spine retains the window arrangement and materials (Figure 5.70 – 5.71). One section of the spine, the southeast elevation between Wings 4 and 6, has been clad in metal panels; the sunshades in this section have been removed and the windows have been sheathed in vertical metal rails (Figure 5.72).

The penthouse located on the roof, was once an open observation deck. The deck was enclosed in 1960 to provide additional office space. Antenna platforms are mounted prominently on the roof of the spine and elsewhere affecting the feeling of stone mass. Other rooftop modifications include the fall protection around the wings, air handling units, antennae, and computer network conduit (Cantillli and Holtzman-Bell, personal communication, 2015).

Annex C (construction completed 1989) is connected to the northwest side of Wing 1 (Figures 5.73 – 5.74). It is not fifty years old or older. The one-story building has a rectangular foot print and a flat roof. It is clad in a pebble coat finish and appears to be a modular building. Windows pierce each elevation of the building and have two-light sashes. A poured concrete hyphen connects Annex C to the northwest side of Wing 1 (Figure 5.75). An entry with double-leaf half-light doors is located on the northeast elevation of the hyphen. An additional entry is located on the southwest end of the northwest elevation of Annex C.

Annex D (construction completed 1992) is located on the southeast end of the southwest elevation of Wing 1 (Figure 5.76). It is not fifty years old or older. The annex was not accessible due to ongoing rehabilitation work on Wing 3. The one-story building has a flat roof and a rectangular footprint; it appears to be modular. A pedestrian entry is located on the northwest elevation. Windows throughout have two-light sashes.

Annexes E and F of Building 1 are located along the northeast elevation of Wing 1, partially masking the elevation (Figure 5.77). Neither annex is fifty years old or older. Both annexes are constructed of metal panels and appear to encircle mechanical equipment. Both rest on poured concrete pads.

Building 2 (Other Names: Cryogenic Building, Building "B")
Construction completed 1951 (Cryogenics), 1964 Wing 'B' Addition, 1986 High Bay Addition, 1995 Addition
Figures 5.78 – 5.100

Building 2 is one of the first three buildings constructed on the current-day DoC Boulder Labs campus. The building was constructed in 1951. It was designed for the AEC Santa Fe Operations

Office in Los Alamos, New Mexico by Stearns-Roger Manufacturing Company, Denver, Colorado. Building 2 is located on Compton Road, southwest of Building 1 and Building 81 (Figure 5.78). The building has an irregular footprint and incorporates multiple building phases. It is oriented northeast. The façade (northeast elevation) of the building is partially masked from view by Building 81, which has been constructed directly adjacent to Building 2 (Figure 5.79). The first phase of construction for Building 2 included a one-story section with a rectangular footprint and a two-story section with a rectangular footprint. Both sections have flat roofs and are constructed of poured concrete. The one-story section runs north-south (Figures 5.80 – 5.81) and the two-story section runs east-west (Figure 5.82). The east elevation of one-story section of the building is pierced with window openings holding two-light sashes with metal frames. The west elevation of this section is masked by an addition. The south end of this section has a pedestrian entry and is pierced by two window openings. The two-story section is pierced by window openings on the north and west elevations. A small one-story shed-roof section projects from the north elevation of the two-story section and features an overhead door on the north elevation and a pedestrian entry on the west elevation. Windows on the west elevation include two-light sashes with metal frames, and glass block units.

The next phase of construction was in 1964, when the Wing 'B' Addition was added to the building. The architecture firm hired to design the addition was James Hunter & Associates (See Appendix B, Architects) (*The Bureau Drawer* 1963a:1). This addition included a two-story projection with a rectangular footprint on the east elevation and a one-story section with a rectangular footprint on the north elevation (Figures 5.83 – 5.86). The two-story projection became a new façade for the building and was known as the administration wing. According to a 1964 article in *The Bureau Drawer*,

> The administration wing will provide a new entrance as well as modern office space. It will house the division office, Cryogenic Data Center, and Division 81.00 drafting room. The wing is finished outside with precast concrete panels with exposed pink aggregate. A solar screen of the same material shields the entrance from direct rays of the sun. The exterior walls of the wing are windowless but a central court will be flooded with daylight from a skylight in the roof…the other new wing, designated B wing, will provide ten laboratories and 16 office spaces on the main floor (*The Bureau Drawer* 1964:3).

The administration wing retains its pink aggregate finish; however, windows have been added to the south and north elevations on the first and second levels. In addition, the solar screen above the main entry on the east elevation also has been replaced with glazing and metal framing placed in a geometric pattern. The interior of the administration wing retains some of its original features such as railings and open staircases (Figures 5.87 – 5.89). The one-story section of the addition is constructed of poured concrete (Figures 5.90 – 5.95). Two-light sashes with metal frames pierce the east and west elevations of this section. The north end of this section has an open area that is sheltered by a projecting flat roof (Figures 5.96 – 5.97). Based on aerial imagery, the southern-most portion of this section was added to Building 2 between 1999 and 2002; the northern end of this section was added to the building in 2012.

In 1986, a High Bay was added to the building (Figure 5.98). This section is located west of the one-story section of the original mass of the building. Due to its location between the 1951 section and a later addition, only the south elevation of this section of the building is visible. This section is two-stories tall and is constructed of poured concrete; it has a rectangular footprint and a flat roof. The south elevation features three window openings near the roofline; each holds glass block units. A pedestrian entry is located on the east end of the south elevation on the first level; it holds double-leaf doors. A dock area extends from the south elevation and provides access to the pedestrian entry; this dock extends east and also is attached to the south elevation of the 1951 one-story section. A one-story flat-roof projection extends from the south elevation of the 1986 addition; this projection has an overhead door on the east elevation.

In 1995, another addition was added to the building (Figures 5.99 – 5.100). The addition is attached to the 1986 addition on the east elevation and is attached to the two-story section of the 1951 construction to the north. As a result, only the west and south elevations of the addition are visible. The 1995 addition has a rectangular footprint, is constructed of poured concrete, and has a flat roof. The west elevation is pierced on the first and second levels with window openings that hold two-light sashes with metal frames. A pedestrian entry is located on the first level of the west elevation at the north end. The south elevation of the addition also is pierced by window openings on the first and second levels; each window holds two-light sashes with metal frames. A pedestrian entry is located on the first level of the south elevation, near the west end. A small one-story projection extends from the south elevation of the addition; the projection has a pedestrian entry on the west elevation.

Building 2, Annex A (Other name: Building 2A)
Construction completed 1989
Figures 5.101 – 5.104

Building 2 Annex A is located directly east of Building 2 on Compton Road. The one-story building has a flat roof and a square footprint. The building is clad in pre-fab pebble-coated panels (Figure 5.101). The façade of the building is oriented south and features a pedestrian entry that is sheltered by a small flat-roof awning. Windows with two-light sliding sashes pierce each elevation of the building. The west and east elevations are pierced only by windows (Figures 5.102 – 5.103). The rear (north elevation) has a raised dock area. Two pedestrian entries pierce the north elevation; one has double-leaf doors and the other has a single-leaf door (Figure 5.104).

Building 3 (Other names: Building "A", Liquefier Building)
Construction completed 1951
Figures 5.105 – 5.119

Building 3 is one of the first three buildings constructed on the current-day DoC Boulder Labs campus. The building was constructed in 1951. It was designed for the AEC Santa Fe Operations Office in Los Alamos, New Mexico by Stearns-Roger Manufacturing Company, Denver, Colorado. Building 3 is located west of Compton Road and north of Lawrence Road; it is oriented east toward Compton Road. It is a two-story building with a rectangular footprint measuring approximately 209' x 78' (Figures 5.105 – 5.107). The building comprises two masses, the primary mass which has a shed roof and a secondary mass, which has a flat roof. The secondary mass is attached to the south end of the primary mass (Figure 5.108). The façade and north elevation (Figures 5.109 – 5.110) of the primary mass are constructed with concrete masonry units (CMU) and have been parged, or covered in stucco. Based on the 1951 drawings of the building (Figures 5.111 – 5.112), the rear (west elevation) of the primary mass originally was clad in corrugated plastic (Drawings courtesy of DoC Boulder Labs). This created a frangible wall, which would breakaway in case of an explosion and reduce the amount of damage to surrounding resources.

The 1951 elevations also depict two monorail supports projecting from the rear of the building. These originally allowed the use of a crane to move heavy items in and out of the building. The elevations depict the openings at the monorails as having accordion type folding doors. Currently, the rear elevation is covered in stucco (Figures 5.113 – 5.114). The monorails have been removed. Similarly the roof of the primary mass originally was clad in corrugated transite, an asbestos-cement material. The current roof is corrugated, but paint masks the roofing material. The secondary mass also is parged; the southwest corner of the secondary mass has exposed CMU (Figure 5.115). The southeast corner of the secondary mass has been enclosed with CMU. The building rests on a foundation that is a combination of poured concrete slabs and poured concrete piers. The interior of the building is divided into workspaces (Figures 5.116 – 5.118).

The dominant feature of Building 3, the large roof ventilators, was one of the many safety features of the building. According to Russell B. Scott, the ventilators "completely changed the air in the building every two minutes, preventing hazardous concentrations of gaseous hydrogen" (Scott 1959:2).

Based on the 1951 drawings and a photograph from 1967 (Figures 5.119), Building 3 retains its original overall massing and scale, but many architectural features have changed (Drawings courtesy of NIST Boulder; National Bureau of Standards 1967:n.p.). Major alterations include a glazed entry vestibule addition to the primary entry on the east elevation, filled in louvers on the second level of the east elevation, filled in windows on the east elevation, replacement windows on the east, north, and west elevations, removal of monorail supports on the west elevation, and an enclosure on the south elevation. Windows on the façade (east elevation) originally held fixed sashes; these sashes have been replaced with reflective, single-light sashes. A window has been added to the north elevation of the building; it holds a two-light sash. The rear (west elevation) of the building also has replacement windows; they have three-light sashes and appear to be fixed. Windows on the south elevation of the building retain six-light casement sashes.

Building 3, Annex A (Other name: Building 3A)
Construction completed 1989
Figures 5.120 – 5.122

Building 3 Annex A is located west of Building 3 and directly southeast of Building 4 within the loop created by Lawrence Road. The building originally was located closer to Building 3; it was moved to its present location to accommodate the construction of Building 42. The one-story building has a rectangular footprint and is clad in horizontal metal panels (Figure 5.120). The façade (northwest elevation) has a pedestrian entry with a single-leaf door; the entry is sheltered by a flat-roof awning. Windows on each elevation have two-light sliding sashes. The southwest and northeast elevations are pierced only by windows (Figure 5.121). The rear (southeast elevation) has a pedestrian entry with a single-leaf door; the entry is sheltered by a flat-roof awning (Figure 5.122).

Building 4 (Other names: Camco Building, Building "C", Facilities Office)
Construction completed 1951, 1986 Metal Siding, 1994 Addition, 2012 Window Replacements
Figures 5.123 – 5.141

Building 4 is one of the first three buildings constructed on the current-day DoC Boulder Labs campus. The building was constructed in 1951. It was designed for the AEC Santa Fe Operations Office in Los Alamos, New Mexico by Stearns-Roger Manufacturing Company, Denver, Colorado. Alterations and additions were made to the building in 1953 by the Cambridge Corporation, Somerville, Massachusetts (Drawings courtesy of NIST Boulder). The building has a rectangular footprint and is frame construction; it is clad in textured metal siding (Figure 5.123).

Building 4 is located on the southeast side of Lawrence Road. It is northwest of Building 3. Building 4 is connected to Building 5 on the northwest elevation. The building is irregularly massed, with three sections. The northeast half of the building is a one-story section with a shed roof (Figures 5.124 – 5.125); the southwest half of the building consists of two masses including a two-story section along the southeast end (Figures 5.126 – 5.127) and a four-story section on the northwest end (Figure 5.128 – 5.129). The primary entry to the building, which holds a single-leaf pedestrian door, is located on the northeast elevation of the one-story section (Figure 5.130). The entry is sheltered by a gable-roof awning. Small windows pierce the northeast elevation; windows throughout the building hold two-light slider sashes. The southeast elevation of the one-story section is pierced by six small windows.

The southeast elevation of the two-story section of the building has one large entry with an overhead door; the elevation also is pierced by four windows and two pedestrian entries. The southwest elevation of the two-story section has windows on the first and second levels. The southwest elevation of the four-story section of the building also features windows on the first and second levels; the third and fourth levels of the elevation are blind. The first level of northwest elevation of the four-story section of the building is pierced by a large entry with an overhead door, one window, and a pedestrian entry with a single-leaf door. The second, third, and fourth levels of the northwest elevation are blind. A narrow one-story hyphen with a pedestrian door on the northeast elevation connects Building 4 to Building 5 on the northwest end (Figure 5.131).

Based on a 1967 photograph of Building 4, previously it was clad in wood; the second, third, and fourth levels of the four-story section of the building also had windows on the northeast elevation (Figure 5.132) (National Bureau of Standards 1967:n.p.).

The interior of Building 4 has been divided into office spaces and meeting rooms (Figures 5.133 – 5.134). The two-story section of the building currently is used for storage (Figures 5.135 – 5.136). Access to portions of the interior was restricted due to ongoing interior renovations.

Building 4 is known as the Camco Building because it was constructed originally to house the activities of the Cambridge Corporation, "Camco," while the corporation completed their work at the Boulder campus during the 1950s. According to a 1952 article in the *Boulder Daily Camera*, "The Cambridge Corporation, of Cambridge Massachusetts, which is associated with NBS, has the responsibility for design and production of containers for liquefied gases suitable for transportation and industrial storage. These huge containers, dubbed 'thermos bottles,' evidently are used to transport liquefied hydrogen away from Boulder but the destination has not been disclosed, for security reasons" (*Boulder Daily Camera* 1952:n.p.).

The 1952 AEC drawings of Building 4 depict a machine shop, restrooms, and offices in the one-story portion of the building, and an open room with overhead tracks in the two-story section of the building (Figure 5.137). Longitudinal sections of the building depict large trusses and trolley rails with hoists within the four-story section of the building, indicating that activities within the building included transporting heavy items, possibly the large "thermos bottles" or dewars associated with transporting liquefied gases (Figure 5.138). These drawings also depict a large exterior hoist, located north of Building 4.

The 1953 drawings by the Cambridge Corporation depict a floorplan similar to the 1952 drawings. A tool crib, restrooms, a shop, and an existing office are shown in the one-story portion of the building (Figure 5.139). As indicated on the plans, an enclosure appears to have been added to the southeast elevation of the building at this time. Interior modifications also appear to have been made to the overhead tracks. Notations on the 1953 drawings include reusing existing doors, adding cross bracing, and reusing columns (Figure 5.140). It is evident that the Cambridge Corporation modified the building based on their particular needs at the time.

The 1967 drawings of the building, located at the NIST Library, depict a similar floorplan, with offices and restrooms within the one-story portion of the building and a large open space with an overhead crane in the four-story section of the building (Figure 5.141) (National Bureau of Standards 1967:n.p.).

Currently the southeast elevation of the one-story section of the building is flush with the southeast elevation of the two-story section. This alteration took place after 1967. The textured metal siding that currently clads Building 4 was added in 1986; some of this cladding covered windows on the two-story section of the building. In 1994, a one-story flat-roof addition was added to the southeast corner of the building; this addition connects to the original one-story mass of the building. Windows throughout the building were last replaced in 2012. The overhead tracks depicted in the AEC drawings of the building are still in place, but have been covered in concrete.

Building 5 (Other names: Camco Annex, Heavy Equipment)
Construction completed 1951, 1986 Metal Siding, 1988 Renovations, 1992 Expansion, 2012 Window Replacements, 2015 Expansion
Figures 5.142 – 5.145

Building 5 is attached to the northwest end of Building 4. The building is depicted as a Butler Building on the original drawings from the AEC. It is unclear if the current Building 5 is an enclosure of this Butler Building. Building 5 currently is a one-story building clad in textured metal, with a gable roof and a rectangular footprint. An entry with a single-leaf pedestrian door is located on the northeast elevation (Figure 5.142). Four windows are located southeast of the entry. Windows throughout the building hold two-light slider sashes. The northwest elevation of the building has three entries, two with single-leaf pedestrian doors and one with double-leaf pedestrian doors

(Figure 5.143). Two windows also pierce the northwest elevation. The southwest elevation of the building is pierced by four windows (Figure 5.144).

Based on a 1967 photograph of the building, previously it was clad in corrugated metal panels (Figure 5.145) (National Bureau of Standards 1967:n.p.). A comparison of the building today with the 1967 photograph indicates that the window openings on the northeast elevation have been reconfigured. The windows southeast of the entry on the northeast elevation originally included three windows with four-light sashes and one with a six-light sash. The photograph also depicts one window northwest of the entry, which is no longer extant. A large metal-frame hoist is depicted in the photograph behind the building; this same structure is depicted in the 1952 drawings of Building 4. The hoist is no longer extant. The metal siding that currently clads Building 5 was added in 1986. In 1988, Building 5 was renovated to accommodate lab space. In 1992, the building was expanded with the enclosure of a partially open-air section on the west elevation. Windows throughout the building were last replaced in 2012. In 2015, additional exterior storage space was enclosed to create an Emergency Operations Center.

Building 8 (Other names: Mesa Test Site, Cryogenic Mesa Test Site Building)
Construction completed 1953
Figures 5.146 – 5.154

Building 8 was moved to its current location during the 1960s; previously it was located within the Maintenance and Staging Yard along Lawrence Road. Building 8 currently is located west of the main area of campus along Kusch Road at the foot of the Flat Irons. This area is known as Research Zone 2. The building has a rectangular footprint and a gable roof; it is clad in panelized metal siding (Figure 5.146). The east elevation of the building has two entries, one with a single-leaf pedestrian door and one with an overhead door (Figure 5.147). A poured concrete dock area is located along the north end of the east elevation (Figure 5.148). The south end of the east elevation is pierced by two windows; each holds a single-light sash (Figure 5.149). The south elevation of the building is pierced by one window opening that holds a six-light sash (Figure 5.150). The north elevation of the building is pierced by two windows; one holds a six-light sash and the other is covered to accommodate an air conditioning unit (Figure 5.151). An entry with a single-leaf pedestrian door is located between the windows. The west elevation of the building also is pierced by windows; they hold two-light sashes (Figure 5.152).

Currently, the building serves a Remote Control Room as part of the Hydrogen Testing Facility, along with Building 12. The Materials Reliability Division completes research at the location, "measuring the mechanical properties of metallic and composite structural materials proposed for use for the transport and storage of hydrogen gas" (NIST n.d.). Steps, located west of the building, lead up to Building 12 (Figure 5.153).

Based on a 1967 photograph of the building, the east elevation of the building has been substantially altered (Figure 5.154). The 1967 photograph depicts two pedestrian entries on the east elevation; the remainder of the elevation is blind. Also, based on the 1967 photograph, one window on the south elevation of the building is no longer extant (National Bureau of Standards 1967:n.p.).

Building 9 (Other names: Gas Meter)
Construction completed 1958
Figures 5.155 – 5.157

Building 9 is located near the main entrance to the Boulder campus. It is west of the security building (Building 51), on the north side of Rayleigh Road. The one-story building has a flat roof and a rectangular footprint (Figure 5.155). It is constructed of concrete blocks and has been parged. The façade (southeast elevation) of the building is oriented southeast. The façade is pierced by a pedestrian entry that has a single-leaf louvered metal door (Figure 5.156). A concrete wall projects from the façade of the building directly right of the entry; the wall connects to a flat-roof awning that shelters the entry. The façade of the building also is pierced by a large opening left of the entry; the opening holds a large metal louvered vent. The southwest and northeast elevations of the building also feature large metal louvered vents (Figure 5.157). The northwest elevation of the building is blind.

Building 11 (Other names: Vertical Incidence, Boulder Ionosphere Station, ULF Receiver Building)
Construction completed 1958
Figures 5.158 – 5.162

Building 11 is located west of the main area of campus along Kusch Road at the foot of the Flat Irons. This area is known as Research Zone 2. The building was created to support CRPL's vertical-incidence sounding program, which was a part of ionosphere research. According to Snyder and Bragaw's publication *Achievement in Radio*, the building initially was used "to train operators in the use of ionosondes" (Snyder and Bragaw 1986:435). By 1986, the building was being used by NOAA "as one of many stations for continuous observation of the ionosphere. The facility also serves for the final testing of ionosondes brought in from time to time from the widely-scattered NOAA stations" (Snyder and Bragaw 1986:435) (Figure 5.158).

Currently, the area around the building appears to be used for miscellaneous storage. It currently is classified as an ultra-low frequency (ULF) receiver. The one-story building has a rectangular footprint and is clad in vinyl siding. It has a gable roof that is clad in asphalt shingles. The façade (east elevation) has a central entry with double-leaf pedestrian doors (Figure 5.159). Windows on either side of the entry are boarded over; a gable-roof porch shelters the entry. One opening on the south elevation also is partially covered and accommodates an air conditioning unit. The west elevation of the building is blind (Figure 5.160). A small, one-story, corrugated metal building with a rectangular footprint is attached to the north side of the building (Figures 5.161 – 5.162). It also has an entry with a pedestrian door on the east elevation. The metal building has one window on the east elevation and one on the west elevation. The north elevation of the metal building is blind. This section of the building has a barrel roof.

Building 12 (Other names: Hydrogen Research Facility)
Construction completed 2008; associated blast walls constructed circa 1960
Figures 5.163 – 5.171

Building 12 is located west of the main area of campus along Kusch Road at the foot of the Flat Irons. This area is known as Research Zone 2. The one-story building is constructed of concrete blocks; it has an irregular footprint and a flat roof. The façade (south elevation) has an entry with a single-leaf pedestrian door on the east end (Figure 5.163). An additional entry with a single-leaf pedestrian door is located on the west end of the façade (Figure 5.164). The west elevation of the building is pierced by a large opening that has an overhead door. The rear (north elevation) has one opening that holds a single-leaf pedestrian door (Figure 5.165). The east elevation of the building is blind. Building 12 is constructed around a poured concrete blast wall. The blast wall projects from the south elevation at a northeast-southwest angle; it projects from the north elevation at a northwest-southeast angle (Figure 5.166). Based on aerial imagery, the blast wall pre-dates Building 12 (Google Earth 1999). A prefabricated storage shed with a gable-roof is located directly east of Building 12; the shed is clad in paneling and has an opening with double-leaf hinged doors on the south elevation (Figure 5.167).

An additional poured concrete blast wall is located south of Building 12 (Figures 5.168 – 5.169). Based on a photograph from 1967, located at the DoC Boulder Labs Library, this blast wall was used as part of a Cryogenic Test Facility (Figure 5.170) (National Bureau of Standards 1967:n.p.). Between 1969 and 1972, the blast wall was used for flow-metering research, which was funded by the American Gas Association (Radebaugh 2015:Slide 87). This research involved the Cryogenics Division and the "measurement of liquefied natural gas and methane" (Mann 1974:102). Douglas B. Mann, who was with the Cryogenics Division during this time, explained:

> Part of the LNG/methane effort concerns the metrology of flow-metering liquefied natu-

> ral gas and methane. Under this programme (sic) we have secured, from the US Air Force, a flow facility suitable for liquefied natural gas. Located at an outdoor test area…all control and instrumentation are remotely located in a control room on the far side of the protective-barrier wall (Mann 1974:102).

The flow stand and ancillary structures associated with activities during the 1960s and 1970s are no longer extant. A small metal shed with a gable-roof currently is located on the east side of the blast wall south of Building 12 (Figure 5.171). This building has a pedestrian entry on the east side. Based on aerial imagery the building appears to have been put in place in 2008, when Building 12 was constructed (Google Earth 1999).

Currently, the building serves as part of the Hydrogen Testing Facility, along with Building 8, which currently is used as a Remote Control Room. The Materials Reliability Division completes research at the location, "measuring the mechanical properties of metallic and composite structural materials proposed for use for the transport and storage of hydrogen gas" (NIST n.d.). Steps, located east of the building, lead down to Building 8.

Building 21 (Other name: Maintenance Garage)
Construction completed 1963
Figures 5.172 – 5.175

Building 21 is located directly southwest of Building 4, on Lawrence Road. The one-story building has a flat roof and a rectangular footprint. It is constructed of concrete blocks. The façade (northeast elevation) has three large openings with overhead doors on the southeast end (Figure 5.172). The southeast end of the building where the three large bays are located is slightly taller than the remainder of the building. Two additional bays are located directly northwest of the larger opening; these bays also hold overhead doors. Comparison of the current building to a 1967 photograph reveals that one bay on the façade with an overhead door has been infilled to accommodate a single-leaf pedestrian door (Figure 5.173) (National Bureau of Standards 1967:n.p.). The northwest end of the façade currently has three windows with slider sashes. A pedestrian entry in this area has been infilled. The northwest and southwest elevations of the building also are pierced by window openings holding slider sashes. The southwest elevation has one window opening that holds glass block units on the northwest end (Figure 5.174). Next to this window is an entry that holds double-leaf pedestrian doors. The southeast elevation of the building has one entry with a single-leaf pedestrian door (Figure 5.175). One window with slider sashes also pierces the southeast elevation. Based on the 1967 photograph, the elevation originally had two windows; one has been replaced by the pedestrian door. A small, one-story, shed-roof addition has been added to the southwest end of the southeast elevation. This small addition has double-leaf doors on the southeast elevation (National Bureau of Standards 1967:n.p.).

Building 22 (Other name: Warehouse)
Construction completed 1964
Figures 5.176 – 5.180

Building 22 is located on the north side of Lawrence Road, west of the intersection with Compton Road. The one-story building has a rectangular footprint and is oriented southeast. It is constructed of concrete blocks and has a flat roof (Figure 5.176). The façade (southeast elevation) is pierced by six window openings on the northeast end of the elevation; each opening holds a narrow four-light sash. A pedestrian entry is located directly southwest of the windows (Figure 5.177). Further southwest on the southeast elevation is a projecting concrete block loading dock area. A comparison of the current building to a 1967 photograph reveals that this projection is a later addition. Originally, the building had a recessed dock area on this elevation (Figure 5.178) (National Bureau of Standards 1967:n.p.). A portion of the recessed dock area is still extant, southwest of the projection. Two windows pierce the southeast elevation southwest of the dock areas. The southwest elevation of the building is blind. The northeast elevation of the building has four narrow windows with four-light sashes, similar to those on the northeast end of the façade (Figure

5.179). An entry also pierces the northeast elevation, at the northwest end; it holds double-leaf pedestrian doors. The rear (northwest elevation) is pierced by pedestrian doors; this elevation does not have road access. The interior of Building 22 primarily is open, to accommodate shipping and receiving as well as storage (Figure 5.180).

Building 23 (Other name: Hazardous Material)
Construction completed 1990
Figures 5.181 – 5.185

Building 23 is located on the north side of Lawrence Road, west of the intersection with Compton Road. It is directly southeast of Building 3. Building 23 was constructed on the foundation of a redwood cooling tower originally associated with Building 3. The one-story building has a rectangular footprint and a flat roof. It is constructed of concrete blocks that have been covered in stucco. The façade (northwest elevation) is pierced by two entry openings, one on the southwest end and one on the northeast end (Figure 5.181). Both hold single-leaf pedestrian doors and both entries are sheltered by flat-roof awnings that are supported by brackets. The façade also is pierced by two window openings; both hold two-light fixed sashes. The southwest elevation of the building has a window with two-light fixed sashes near the northwest end, and an entry with double-leaf pedestrian doors on the southeast end (Figure 5.182). The southeast elevation of the building is blind (Figure 5.183). A flat-roof awning projects from the northeast elevation of the building. The area beneath the awning is encircled with chain-link fencing; pedestrian entries provide access to this area. The roof of the building is pierced by several vent pipes and square ventilator units.

A small metal building with a rectangular footprint and flat roof is located directly northwest of Building 23 and is located between Building 23 and Building 3. The building is attached to Building 23 and Building 3, by metal piping. The southwest elevation of the building is pierced by one entry with a single-leaf pedestrian door (Figure 5.184). The southeast elevation is pierced by an entry that holds double-leaf pedestrian doors. Single louvered vents pierce the northwest and northeast elevations of the building (Figure 5.185).

Building 24 (Other name: Plasma Physics)
Construction completed 1967, High Bay Addition 1985, Annex A 1988, Air Handling Unit 1999, Elevator Tower 2002-2005
Figures 5.186 – 5.203

Building 24 is located between Compton Road and Rayleigh Road, southeast of Building 2. The two-story building has a flat roof and a U-shaped plan. Portions of the original mass of the building are clad in stone, similar to that found on Building 1. The east elevation has two, two-story projecting wings, one on the north end and one on the south end (Figure 5.186). The east elevations of these wings are blind and are clad in stone. The north and south elevations of the north wing and the north and south elevations of the south wing feature ribbons of windows with metal sashes on the first and second levels (Figure 5.187 – 5.188). Windows on both levels are sheltered by concrete shed-roof awnings, or sunshades similar to those found on Building 1. Pedestrian entries are located on the north elevation of the north wing and the south elevation of the south wing. The interior of the building contains offices and laboratory areas (Figures 5.189 – 5.191).

The east elevation of the building that is recessed west of the projecting wings is clad in pebble coated panels. Similar ribbons of windows are located in this section of the building; they also are sheltered by concrete shed-roof awnings, or sunshades (Figure 5.192). A comparison of the current building to a 1967 photograph appears to depict the same pebble-coated panels (Figure 5.193-5.194) (National Bureau of Standards 1967:n.p.). A two-story elevator tower has been added to the center of the recessed section of the east elevation (Figure 5.195). The tower is constructed of pink aggregate CMU and features a pedestrian entry on the north elevation. Based on aerial imagery, the elevator tower was added to the building between 2002 and 2005.

A stone lined planting bed extends along the east elevation of the building and wraps around the north side of the north wing and the south side of the south wing. The recessed area of the east elevation features planting beds and a stone patio area (Figures 5.196 – 5.197). Portions of the planting beds are lined with pink aggregate blocks, similar to the CMU used on the two-story elevator tower on the east elevation.

The south elevation of the original mass of the building, west of the south wing is clad in stone (Figure 5.198). The north elevation of the original mass of the building, west of the north wing also is clad in stone (Figure 5.199). The mass of the building that extends west is clad in pebble-coated panels (Figure 5.200 – 5.201).

In 1985, a High Bay was added to the southwest corner of the building (Figure 5.202). This section of the building has a rectangular footprint and a flat roof. A pedestrian entry is located on the south elevation of the High Bay; it holds double-leaf doors. An annex was added to the building in 1988 (Figure 5.203). This section is two-stories tall; it has a rectangular footprint and a flat roof. It has an entry on the south end of the west elevation that holds a single-leaf pedestrian door. In 1999, an Air Handling Unit was added to the southwest corner of Building 24. The unit was installed atop the High Bay and is clad in metal panels. When the Air Handling Unit was constructed on the second level, an exterior metal staircase was added to the west elevation of the building. This staircase travels along the west elevation of the annex and connects to the second level of the High Bay (the metal-clad 1999 addition) on the north end of the west elevation.

Ground was broken for Building 24 in December 1965. Boulder architect James M. Hunter designed the building and Ginley-Soper, a construction company from Denver, served as the contractor (See Appendix B, Architects). The building was considered major construction during the period, costing an estimated $600,000. According to an article in the *Boulder Daily Camera*, the new building "will replace space now being used in a temporary frame structure at the federal complex and release other space in the radio building for the expanded ESSA (Environmental Science Services Administration) research activity here" (*Boulder Daily Camera* 1965:30).

Building 25 (Other name: Maintenance Shop)
Construction completed North Shop 1966, Offices and South Shop 1975
Figures 5.204 – 5.208

Building 25 is located on the west side of Curie Road. The one-story building is constructed of concrete blocks. It has a rectangular footprint and a flat roof. The current building was constructed in two phases, the north shop and the south shop. A 1967 photograph depicts the north shop (Figure 5.204) (National Bureau of Standards 1967:n.p.). This section is now the northern half of the building. The elevation depicted in the 1967 photograph now is masked by the south shop addition. The northern half of the building has narrow window openings similar to those on Building 22 (Figure 5.205). The south shop addition incorporates the same style of windows (Figure 5.206). A vestibule projects from the northeast elevation of the building where the north shop and south shop join. Entries are located on the northwest and southeast elevations of the vestibule. A large opening with an overhead door is located on the southwest elevation where the north and south sections join (Figure 5.207). Another large opening with an overhead door is located on the southeast elevation of the south shop addition (Figure 5.208).

Building 26 (Other name: Day Care Facility)
Construction completed 1989, Addition 1995
Figures 5.209 – 5.212

Building 26 is located in the northwest corner of the intersection of Lawrence Road and Compton Road. The one-story building has a rectangular footprint and a flat roof; it is clad in prefabricated pebble-coated panels. The primary entry to the building is on the southwest elevation (Figure 5.209). Windows throughout the building have two-light fixed sashes (Figure 5.210). Outdoor play areas extend southeast and northwest of the building (Figures 5.211 – 5.212).

Building 27 (Other name: High Frequency Field Site)
Construction completed 1991
Figures 5.213 – 5.217

Building 27 is located west of Lawrence Road. The one-story building has a flat roof and a rectangular footprint; it is constructed of concrete block. An entry pierces the northeast elevation of the building; it holds double-leaf pedestrian doors (Figure 5.213). Windows on the northwest and southeast elevations have slider sashes and are covered by metal grilles (Figures 5.214 – 5.215). The building is connected to an antenna field, located directly to the southwest (Figures 5.216 – 5.217).

Antenna Field (Other name: Antenna-testing Site)
Construction completed circa 1990
Figures 5.218 – 5.219

The Antenna Field is located west of Curie Circle, directly southwest of Building 27. It is approximately 200' x 100' (Figures 5.218 – 5.219) and consists of large, flat panels. The area is used to assess the operation of antennae.

Building 33 (Other names: David Skaggs Research Center, NOAA Building)
Construction completed 1998
Figures 5.220 – 5.240

Although Building 33 is not managed by NIST, it is included within this report because of its location at the Department of Commerce Boulder Laboratories. Building 33 is managed by GSA. Building 33 is located west of Broadway (State Highway 93), south of Rayleigh Road. The three-story building has an irregular footprint and a flat roof; it is clad in stone and pre-cast concrete panels (Figures 5.220 – 5.226). The primary entry to the building is located on the west elevation, which faces a large parking lot (Figures 5.227 – 5.230). One entry on the west elevation serves as a service entry (Figure 5.231). Another entry on the west elevation is located near the south end (Figure 5.232). Additional entries are located on the east elevation (Figure 5.233). One mimics the main entry on the west elevation (Figure 5.234). Windows on each elevation feature multi-light sashes and are accented with the use of colored stone and concrete panels (Figures 5.235 – 5.236). A weather observatory, observation domes, and antennas are located on the roof of the building.

The building was designed by the Denver-based firm Fentress Architects (See Appendix B, Architects). According to the firm, the design "minimizes the building's mass by breaking it into four connected segments. The juxtaposition between the exterior stone façade, harvested locally, and the glass curtainwall stair enclosures recalls the relationship of the sophisticated research facility to the nearby Flatirons" (Fentress Architects 2015a).

The building design also complements the adjacent Anderson Ditch, which is located directly east of the building (Figure 5.237). The area between the building and Anderson Ditch has been landscaped with walkways and seating areas (Figures 5.238 – 5.240).

The design of the building was addressed in the 1996 EIS, "Proposed Upgrade of NIST Facilities":

> The blocks are loosely arranged along the north-south axis, each block slightly turned or laterally moved relative to the adjacent block. Conceptually, these seemingly random movements are in relation to the adjacent Anderson Ditch. Programmatically, they respond to the specific view and orientation needed by NOAA's research. Views in various directions are essential for tracking the sun, atmospheric conditions, weather events, and environmental information satellites, and for gathering other types of information…In the context of architectural aesthetics, the orientation and design of the proposed GSA/NOAA building have incorporated features of the natural setting to mitigate its impact upon the landscape. The choice of a site for the building west (as opposed to east) of Anderson Ditch was made to move the building farther away from Broadway thereby reducing its visual presence and taking advantage of the screening effect of the mature trees located along the ditch. The building's exterior facing material will use varying earth tone colors to visually break up the linear character of the roofline and avoid competing with the strong vertical lines of the Flatirons (U.S. GSA 1996a:3-24, 3-37).

Congress passed legislation in 1998 to name Building 33 the David Skaggs Research Center after Boulder Congressman David Skaggs (Department of Commerce Boulder Labs 2008a; Department of Commerce Boulder Labs 2008b).

Building 34 (Other name: Solar Observatory)
Construction completed 1998
Figures 5.241 – 5.248

Although Building 34 is not managed by NIST, it is included within this report because of its location at the Department of Commerce Boulder Laboratories. Building 34 is managed by GSA. Building 34 is located southwest of the intersection of Compton Road and Rayleigh Road. The building is located on a slight rise, and is accessed from Compton Road by steps (Figure 5.241). The one-story building has a flat roof and an irregular footprint. Similar to Building 33, this building is clad in stone (Figures 5.242 – 5.245). The primary entry to the building is located on the east end (Figure 5.246). An observatory dome is located on the west end of the building. An antenna field is located directly west of the building (Figure 5.247). A sundial, also clad in stone, is located directly southeast of the building, near the primary entry (Figure 5.248).

Building 42 (Other name: Central Utility Plant)
Construction completed 2005
Figures 5.249 – 5.254

Building 42 is located along Curie Circle, directly northwest of Building 3. The two-story building has a rectangular footprint and a flat roof; it is clad in pre-cast textured concrete panels. The east elevation of the building has a large glazed wall that projects at an angle to the east (Figure 5.249). A glazed stair tower projects from the north elevation of the building; an entry with an overhead door also pierces the north elevation (Figure 5.250). Similarly, the south elevation has an entry with an overhead door; it also is pierced by an entry with a single-leaf pedestrian door (Figure 5.251). Large glazed areas are also featured on the west elevation of the building (Figure 5.252). Large cooling towers are attached to the west elevation of the building (Figures 5.253 – 5.254).

The building was designed by HDR, Inc. (Henningson, Durham & Richardson, Inc.) (See Appendix B, Architects). The Central Utility Plant was created to allow the campus to stabilize and centralize its utilities. It provides "chilled water for cooling, high pressure steam for heating, and laboratory quality compressed air service to the NIST Boulder facility" (NIST 2008).

Access Tunnels
Construction completed 2009
Figures 5.255 – 5.261

Building 42 is connected to an underground utility corridor that spans east along Compton Road toward Broadway (Figure 5.255). The underground corridor is accessed through three tunnel access points along Compton Road (Figures 5.256 – 5.260). Each access point has a small building that shelters a metal staircase extending underground (Figure 5.261). The buildings are clad in prefabricated panels; each has a flat roof and a rectangular footprint.

Building 51 (Other names: Visitors Center, Security Center)
Construction completed 2006
Figures 5.262 – 5.264

Building 51 is located on the north side of Rayleigh Road, directly west of Broadway/State Highway 93. The one-story building has an irregular footprint. The east half of the building has a hipped roof, whereas the west half has a gable roof. The southeast corner of the building is chamfered and holds the primary entry, which has a single-leaf, full-light pedestrian door (Figures 5.262 – 5.263). The northwest corner of the building also is chamfered; it holds a secondary entry with a single-leaf, full-light pedestrian door. The south elevation of the building has a recessed angled wall; the roof projects over the recessed area to provide shelter for a seating area (Figure 5.264).

Vehicle Check Building
Construction completed 2005
Figures 5.265 – 5.266

A vehicle check building is located directly south of Building 51. The small building has a shallow-pitched hip roof and a rectangular footprint. A sliding door is located on the north and south elevations of the building; the east and west elevations have glazing (Figures 5.265 – 5.266). The building is clad in metal panels.

Guard House
Construction completed 2014
Figures 5.267 – 5.268

A Guard House is located southwest of Building 51. All vehicular traffic entering the campus is required to stop at the Guard House. The small building has a shallow-pitched hip roof and a rectangular footprint. A sliding door is located on the north and south elevations of the building; the east and west elevations have glazing (Figures 5.267 – 5.268). The building is clad in metal panels.

Building 81 (Other names: Precision Measurement Laboratory)
Construction completed 2012
Figures 5.269 – 5.276

Building 81 is located on Compton Road, directly southwest of Wings 5 and 6 of Building 1. The spine of Building 1 connects to Building 81 on the northeast elevation (Figure 5.269). The building is clad in prefabricated panels. It has an irregular footprint and a flat roof. The primary entry is located on the southeast elevation (Figure 5.270). The entry vestibule is glazed (Figure 5.271). A walled courtyard extends from the west end of the south elevation (Figure 5.272). Anderson Ditch runs along the northeast side of the building; the ditch has been lined with rock in this area (Figure 5.273). Windows throughout the building have fixed metal sashes (Figure 5.274). Another entry is located on the northwest elevation of the building; it is similar to the southeast entry (Figure 5.275). A loading dock area also is located on the northwest elevation of the building (Figure 5.276).

The building was designed by HDR, Inc. (Henningson, Durham & Richardson, Inc.) (See Appendix B, Architects). According to NIST, the building allows NIST to "fulfill its mission to meet the nation's measurement science needs for the 21st century and support U.S. innovation and competitiveness…the PML [Precision Measurement Laboratory] meets rigorous requirements for temperature and humidity control, air cleanliness, vibration stability, and electrical power quality" (NIST 2012).

The construction of Building 81 affected the landscaping of the campus and the relationship buildings had to one another and the environment. The original vistas between Building 1, Building 2, and Building 24 were altered through the construction of Building 81. In addition, construction of the building contributed to the elimination of some of the open space and expansive feel that originally was conveyed along the west side of Building 1. Construction of the building also minimized the impact of the Building 2 entrance through the construction of the paved courtyard and parking lot.

Building 91 (Other name: Construction Research Facility)
Construction completed 2008
Figures 5.277 – 5.278

Building 91 is located on the east side of Compton Road, directly northwest of Building 2. It is a prefabricated building with a flat roof and a square footprint (Figures 5.277 – 5.278). Windows throughout the building have slider sashes. The building is clad in textured wood panels.

Building 111 (Other name: Four Annex)
Construction completed 2011
Figures 5.279 – 5.280

Building 111 is located directly southeast of Building 4. It is a prefabricated building with a flat roof and a square footprint (Figures 5.279 – 5.280). Windows throughout the building have two-light sashes. The primary entry to the building is located on the northwest elevation. The entry is accessed by a metal ramp with railings. The building is clad in textured wood panels.

Building 112 (Other names: Warehouse, Butler Building)
Construction completed 2011
Figures 5.281 – 5.282

Building 112 is located north of Lawrence Road, directly southwest of Building 3. The one-story building has a gable roof and a rectangular footprint. The building is clad in panelized metal. A large entry with an overhead door and a pedestrian entry with double-leaf doors are located on the northeast elevation of the building (Figure 5.281). An additional entry with a single-leaf pedestrian door is located on the northwest elevation (Figure 5.282).

Building 131 (Other name: Office Building)
Construction completed 2013
Figures 5.283 – 5.284

Building 131 is located west of Compton Road, directly northeast of Building 3. The one-story prefabricated building has a flat roof and a rectangular footprint. An entry is located on the northwest elevation; it holds a single-leaf pedestrian door (Figure 5.283). An additional entry is located on the northeast elevation; it also holds a single-leaf pedestrian door and is accessed by a long metal ramp with railings (Figure 5.284). Windows pierce the northwest, northeast, and southwest elevations; all hold two-light sashes. Mechanical equipment projects from the southeast elevation. The building is clad in textured prefabricated panels.

Maintenance and Staging Yard
Buildings Constructed circa 1990
Figures 5.285 – 5.287

A maintenance and staging yard is located on the east side of Lawrence Road, northwest of Building 22. The area includes several large portable storage containers and miscellaneous materials. Four frame storage sheds are located within the area, none appear to be fifty years of age or older. Two gambrel-roof sheds are prefabricated and are clad in wood paneling (Figure 5.285). Two sheds are clad in metal siding and have shed roofs (Figure 5.286 – 5.287).

Gates North and South Residential Access
Constructed 2014
Figures 5.288 – 5.290

Gates are located at the south and north edges of the campus. Both gates feature two gate posts and a metal electronically operated gate. The south gate is located off of Compton Road along access to the residential neighborhood south of the campus (Figure 5.288). Two gate posts are clad in stone, similar to the stone used on Buildings 33 and 34. The north gate posts are located off of the parking lot northwest of Building 1 and access King Avenue and the residential neighborhood north of the campus. This gate also features two posts clad in stone similar to the stone used on Buildings 33 and 34 (Figure 5.289 – 5.290).

Anderson Ditch
Created in 1860
Figures 5.291 – 5.295

Anderson Ditch travels through the Boulder campus, entering from northwest of Building 81 at Green Mountain Cemetery (Figure 5.291), then traveling southeast between Building 81 and Wings 5 and 6 of Building 1 (Figures 5.292 – 5.293). The ditch travels under Rayleigh Road to the southeast and then extends east of Building 33 (Figure 5.294 – 5.295). It exits through the residential area south of the campus. The ditch continues northwest and southeast of the campus, originating at Boulder Creek on the west side of Boulder and terminating at Baseline Reservoir, southeast of Boulder.

Anderson Ditch was established in 1860. It was created by Swedish born Jonas Anderson and his neighbor Marinus Smith. The ditch was created to reroute water from Boulder Creek to provide irrigation to the area (Black n.d.). According to the 1994 Larson report,

> The Anderson Ditch was decreed as being the fourth in water rights priority for water from Boulder Creek as of October 1, 1860 as decided on June 2, 1882 in the State of Colorado District Court for Boulder County. This right affirmed that the ditch was allowed to withdraw water from Boulder Creek amounting to 25 cubic feet of water per second. The Anderson Ditch Company was formally incorporated on January 23, 1871 by three prominent Boulder pioneers: Jonas Anderson, Marinus G. Smith, and George A. Andrews (Larson 1994:14).

In 1891, the Anderson Ditch Company became the New Anderson Ditch Company. As explained in the 1993 *Cultural Resource Inspection of the Proposed Building Site for the National Oceanic and Atmospheric Administration, Boulder, Colorado* report by Butler,

The Anderson Ditch headgate is located along the south (right) bank of Boulder Creek near Arapahoe Avenue and Canyon Road…the ditch was extended in 1875 from the original three mile length to three and half miles. This original section of the Anderson Ditch from Boulder Creek to Broadway and Table Mesa Drive is presently owned and operated by the New Anderson Ditch Company. The "New" was added to the Anderson Ditch name in 1891 when the company was purchased and reorganized. By 1911, the ditch was extended to carry water to Base Line Reservoir by the Baseline Land and Reservoir Company; the continuance of the ditch is known as the "New Anderson Ditch Extension"; the extension is owned and operated by the Baseline Land and Reservoir Company (Butler 1993:8).

The portion of Anderson Ditch that spans through the NIST camp was originally part of the three-mile 1860 excavation. The 1875 extension of the ditch took place directly south of the NIST campus boundary, carrying the ditch south, then east to Baseline Reservoir (Holleran 2000:12). In 1953, the National Bureau of Standards contacted the New Anderson Ditch Company to gather information on the Ditch. A letter response from the Company explained:

The New Anderson Ditch Company is a mutual company organized for the purpose of supplying irrigation water to its shareholders. Shareholders may withdraw water from the ditch through accepted headgates during the irrigation season. This season normally extends from May into September although limits are somewhat flexible. Outside of irrigation season, the Baseline Reservoir Company leases the ditch for the purpose of filling their reservoir located some three miles east of Boulder.

New Anderson stock consists of 100 shares and the ditch is designed to carry 22 second-feet (cubic feet per second). Each share or fractional share would be entitled to a proportional amount of water. In the past, water has usually been sufficient to obviate the necessity of metering flow from individual headgates.

Headgates commonly used on the ditch are made of steel, are enclosed in cement in the wall of the ditch and are opened and closed by a convenient screw device and small handle. Headgates are installed by the ditch superintendent or by an acceptable contractor agreed upon. Expense of headgate and installation is for the account of the water user (NIST Papers: Philip Andrews, President of New Anderson Ditch Company to H.M. Howe, National Bureau of Standards, letter 8 July 1953, NIST Papers, Boulder Campus, Boulder, Colorado).

By 1956, the National Bureau of Standards owned 3-41/48 Shares of the New Anderson Ditch Company (NIST Boulder: Anderson Ditch File). By 1996, the main shareholders for Anderson Ditch included the New Anderson Ditch Company, University of Colorado, Baseline Water Storage, NIST, the City of Boulder, and some homeowners (U.S. GSA 1996a:2-7).

Anderson Ditch has been widened and lined with stones between Building 81 and Wings 5 and 6 of Building 1. Small bridges cross the ditch to accommodate foot traffic to the buildings. The area of the Ditch east of Building 33 is lined by trees along the east side. The banks along this stretch of the ditch appear to be natural.

5.7 Summary and Conclusion

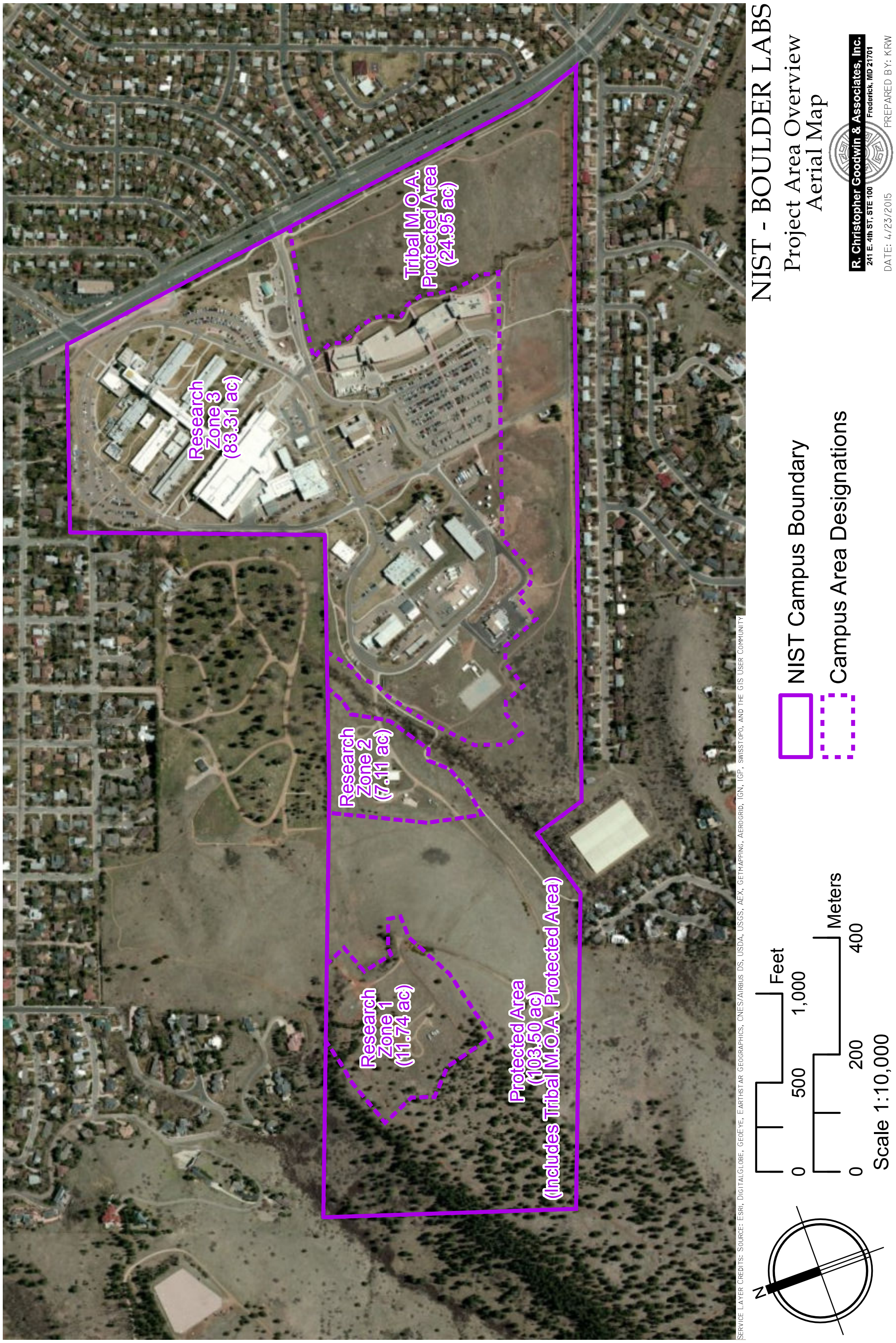
A total of 41 built resources were surveyed at DoC Boulder Labs, including 37 buildings, two objects (gates to north and south residential areas), and two structures (antenna field and Anderson Ditch). The built resources at DoC Boulder Labs range in date from 1951 to 2013, with Anderson Ditch as an exception dating from 1860. The majority of buildings surveyed have flat roofs and are utilitarian, with few architectural embellishments. Many of the older buildings have had additions or other significant modifications over the years. The heights of the buildings are relatively low, purposely accommodating a view of the mountains to the west. The largest buildings on the campus include Building 1, Building 33, and Building 81. Building 1 and Building 33 are prominently visible from Broadway and, as a result, represent the campus to the public. Utilitarian buildings used for storage, offices, maintenance, and utilities typically are located west of the center of the property and are encircled by Lawrence Road.

5.1 Overview, Rayleigh Road entrance

5.2 Overview from Kohler Mesa

5.3 Overview from Kohler Mesa

5.4 Overview from Kohler Mesa



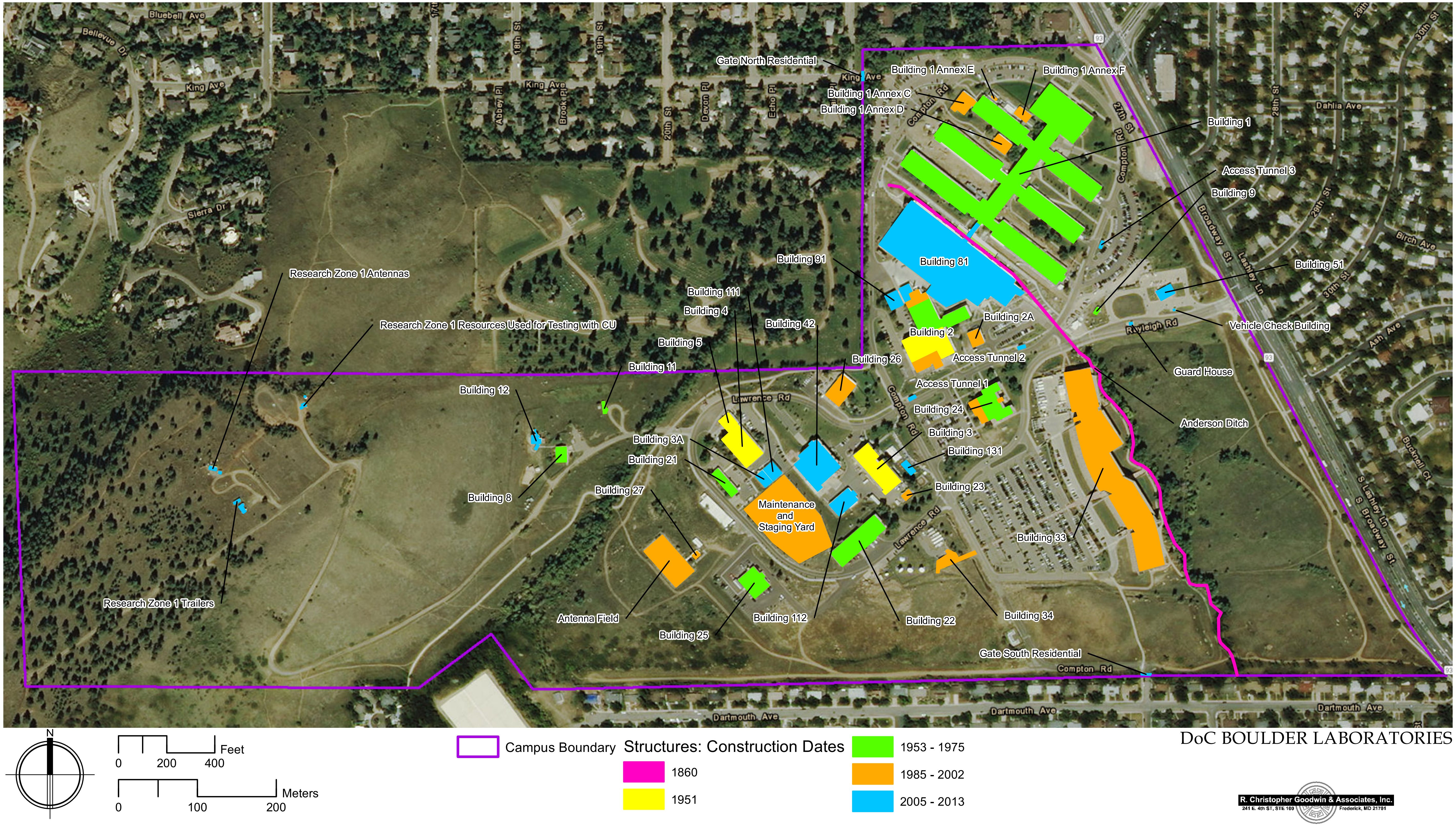
5.5 Research Zones and Protected Areas

5.6 Research Zone 1, looking northeast (Photograph RCG&A 2015)

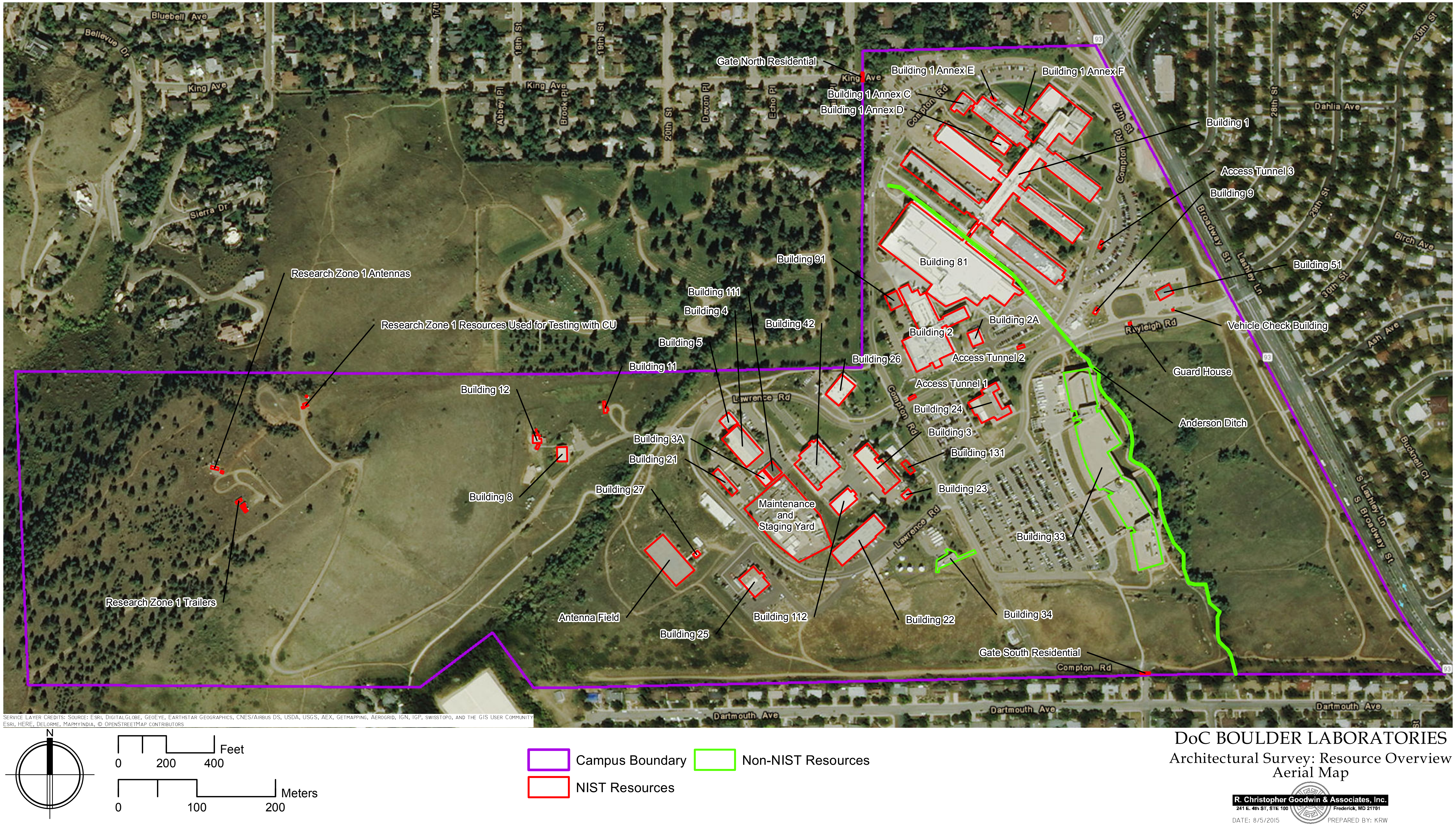
5.7 Research Zone 1, looking northeast (Photograph RCG&A 2015)

5.8 Research Zone 1, looking north (Photograph RCG&A 2015)

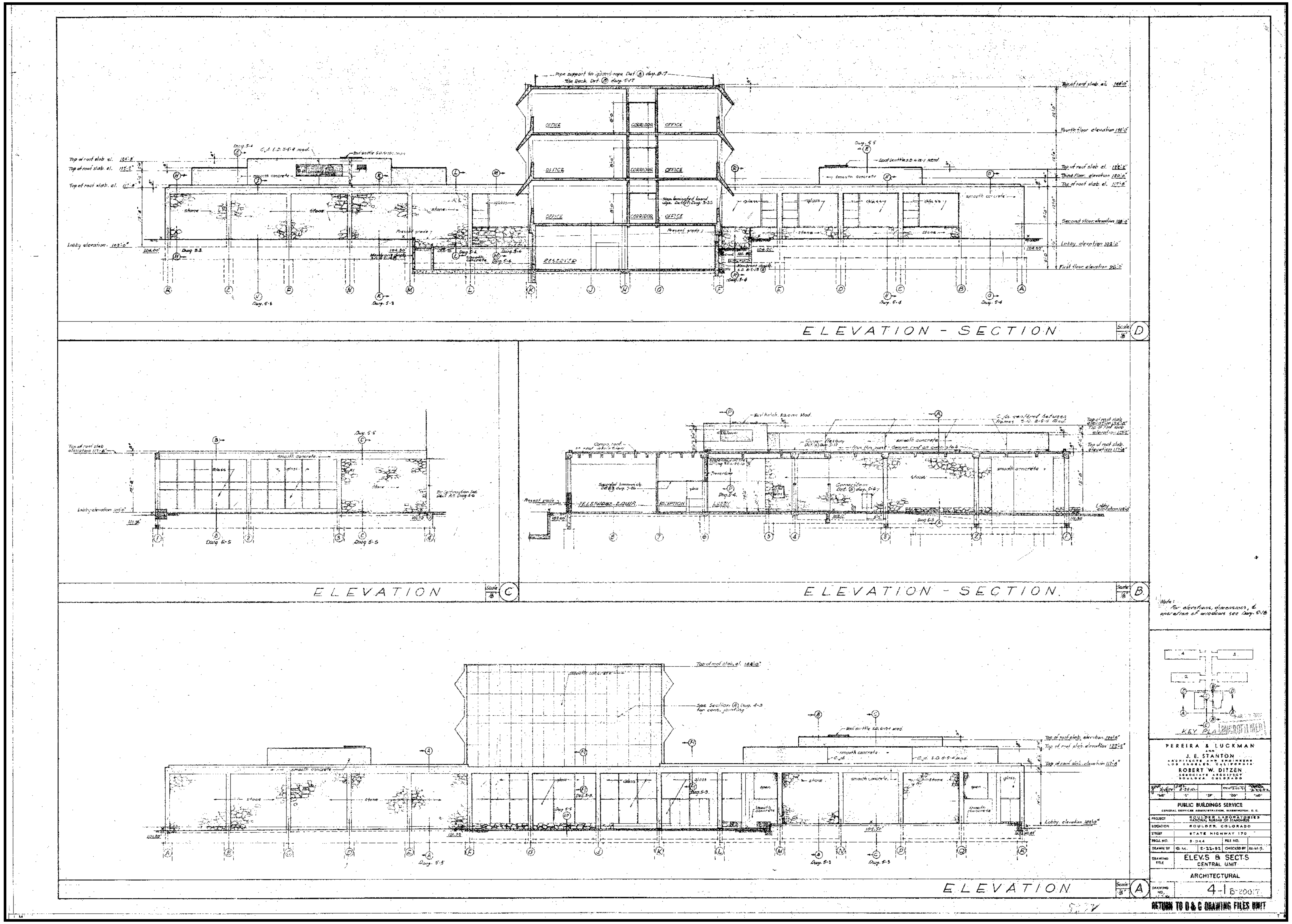
5.9 Research Zone 1, looking northwest (Photograph RCG&A 2015)



5.10 Campus Construction Periods Map



5.11 Architectural Resource Overview Map



5.12 1952 Elevations and Sections Central Unit (Image courtesy DoC Boulder Labs)

5.13 1954 Photograph of Building 1, looking southwest (Image courtesy of DoC Boulder Labs)

5.14 Wings 5 and 6 prior to the construction of Building 81 (Image courtesy of DoC Boulder Labs)

5.15 Building 1, looking southeast (Photograph RCG&A 2015)

5.16 1967 Photograph of Building 1, looking southwest (Image courtesy of DoC Boulder Labs)

5.17 1953 Photograph of Building 1, looking southwest (Image courtesy of DoC Boulder Labs)

5.18 Building 1, front elevation (Image courtesy of DoC Boulder Labs 2015)

5.19 Building 1, looking west (Photograph RCG&A 2015)

5.20 Building 1, looking southeast (Photograph RCG&A 2015)

5.21 Building 1, looking north (Photograph RCG&A 2015)

5.22 Building 1, looking southwest (Photograph RCG&A 2015)

5.23 Building 1, looking southwest (Photograph RCG&A 2015)

5.24 Building 1, looking southwest (Photograph RCG&A 2015)

5.25 1953 Photograph of Building 1, looking southeast (Image courtesy of DoC Boulder Labs)

5.26 Building 1, looking southwest (Photograph RCG&A 2015)

5.27 Building 1, looking west (Photograph RCG&A 2015)

5.28 Building 1, penthouse, enclosed (Image courtesy of DoC Boulder Labs 2015)

5.29 Building 1, looking southeast (Photograph RCG&A 2015)

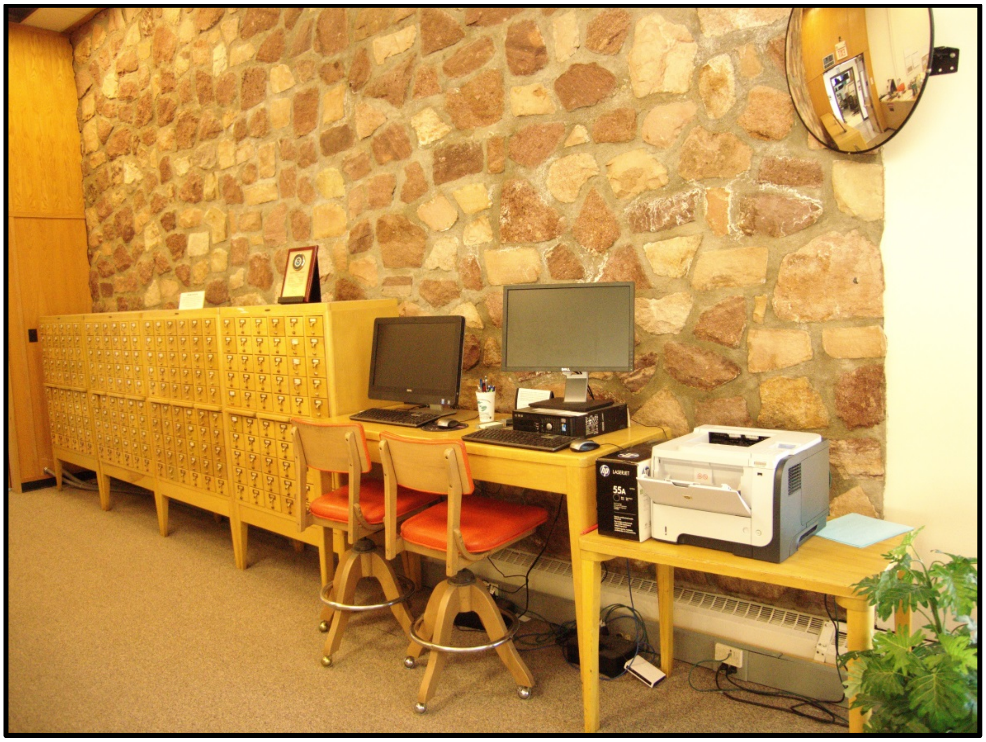
5.30 Building 1, Interior lobby (Photograph RCG&A 2015)

5.31 Building 1, Interior lobby (Photograph RCG&A 2015)

5.32 Building 1, Interior lobby (Photograph RCG&A 2015)

5.33 Building 1, Interior lobby (Photograph RCG&A 2015)

5.34 Building 1, Library interior (Photograph RCG&A 2015)



5.35 Building 1, Library interior (Photograph RCG&A 2015)

5.36 Building 1, Auditorium interior (Photograph RCG&A 2015)

5.37 Building 1, Auditorium interior (Photograph RCG&A 2015)

5.38 Building 1, Corridor interior (Photograph RCG&A 2015)

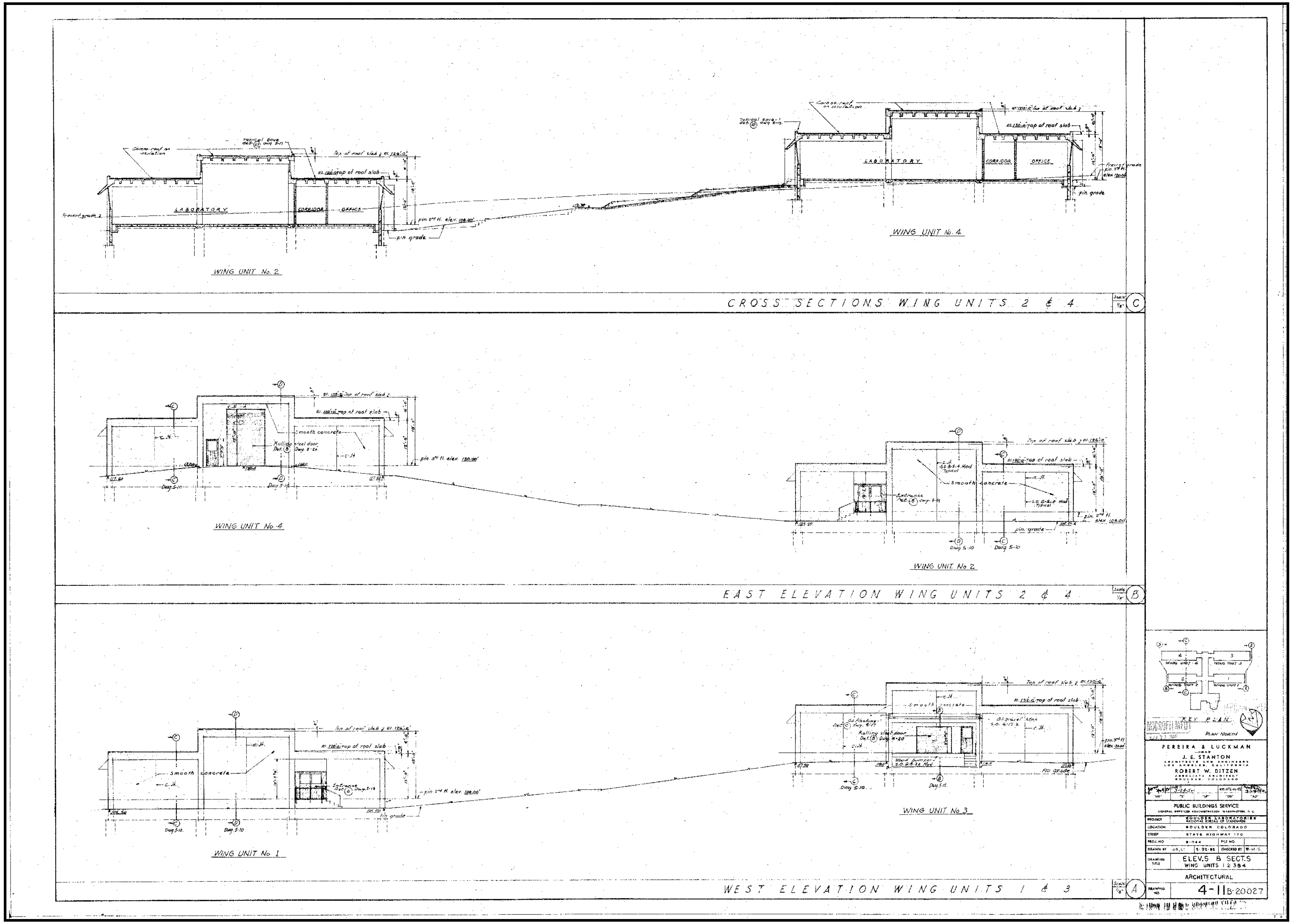
5.39 Building 1, Cafeteria area interior (Photograph RCG&A 2015)

5.40 Building 1, Cafeteria area interior (Photograph RCG&A 2015)

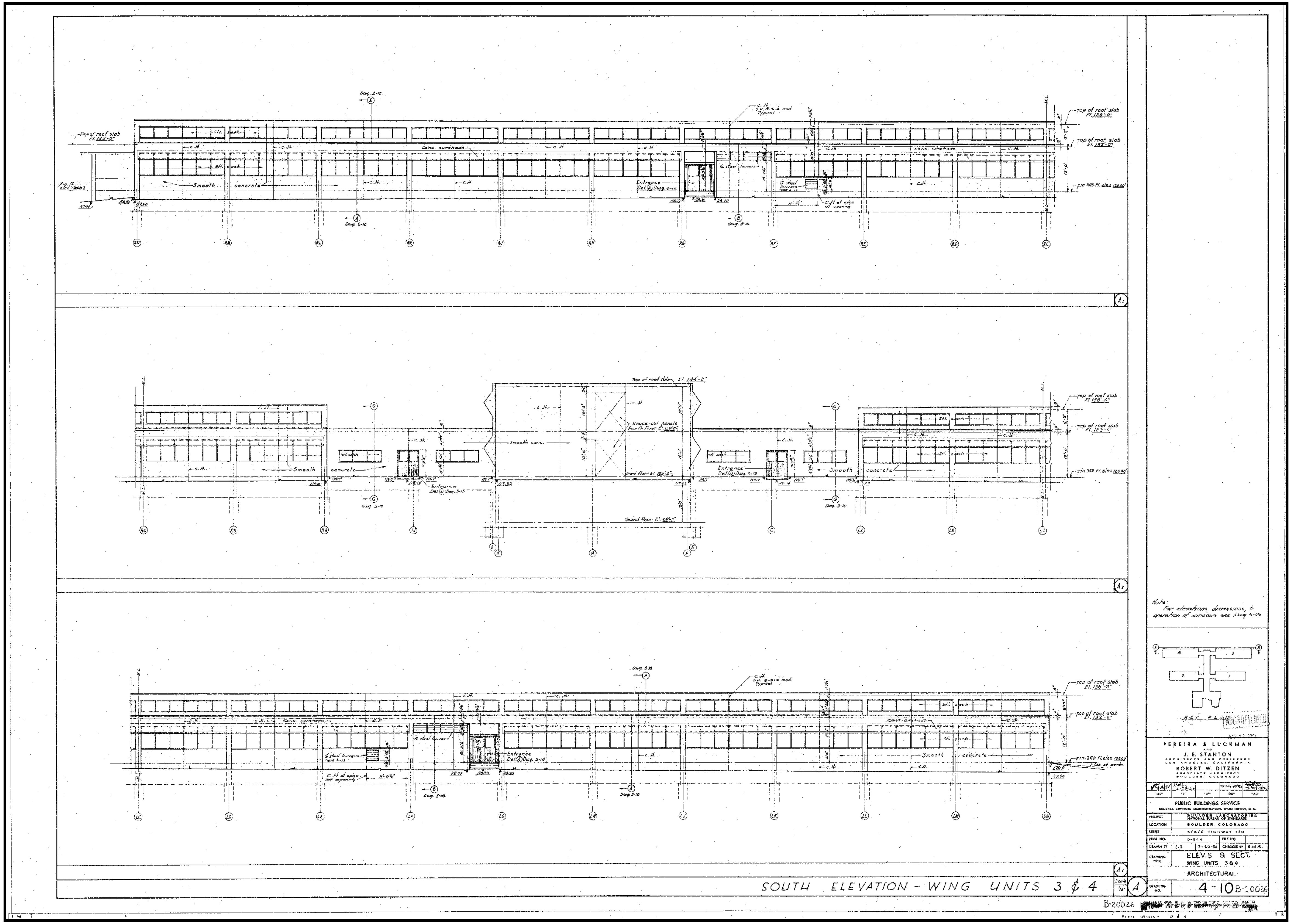
5.41 Building 1, Interior corridor of spine (Photograph RCG&A 2015)

5.42 Building 1, Wing 4 Interior corridor (RCG&A 2015)

5.43 Building 1, Wing 3 Interior corridor (Photograph RCG&A 2015)



5.44 1952 Elevations and Sections, Wing Units 1, 2, 3, and 4



5.45 1952 Elevations and Sections, Wing Units 3 and 4

5.46 Building 1, Wing 1, Annex E and F (Photograph RCG&A 2015)

5.47 Building 1, Wing 1, looking southeast (Image courtesy of DoC Boulder Labs 2015)

5.48 1953 Photograph of Building 1, looking southwest (Image courtesy of DoC Boulder Labs)

5.49 1953 Photograph of Building 1, looking northeast (Image courtesy of DoC Boulder Labs)

5.50 Building 1, Wing 1, looking southeast (Photograph RCG&A 2015)

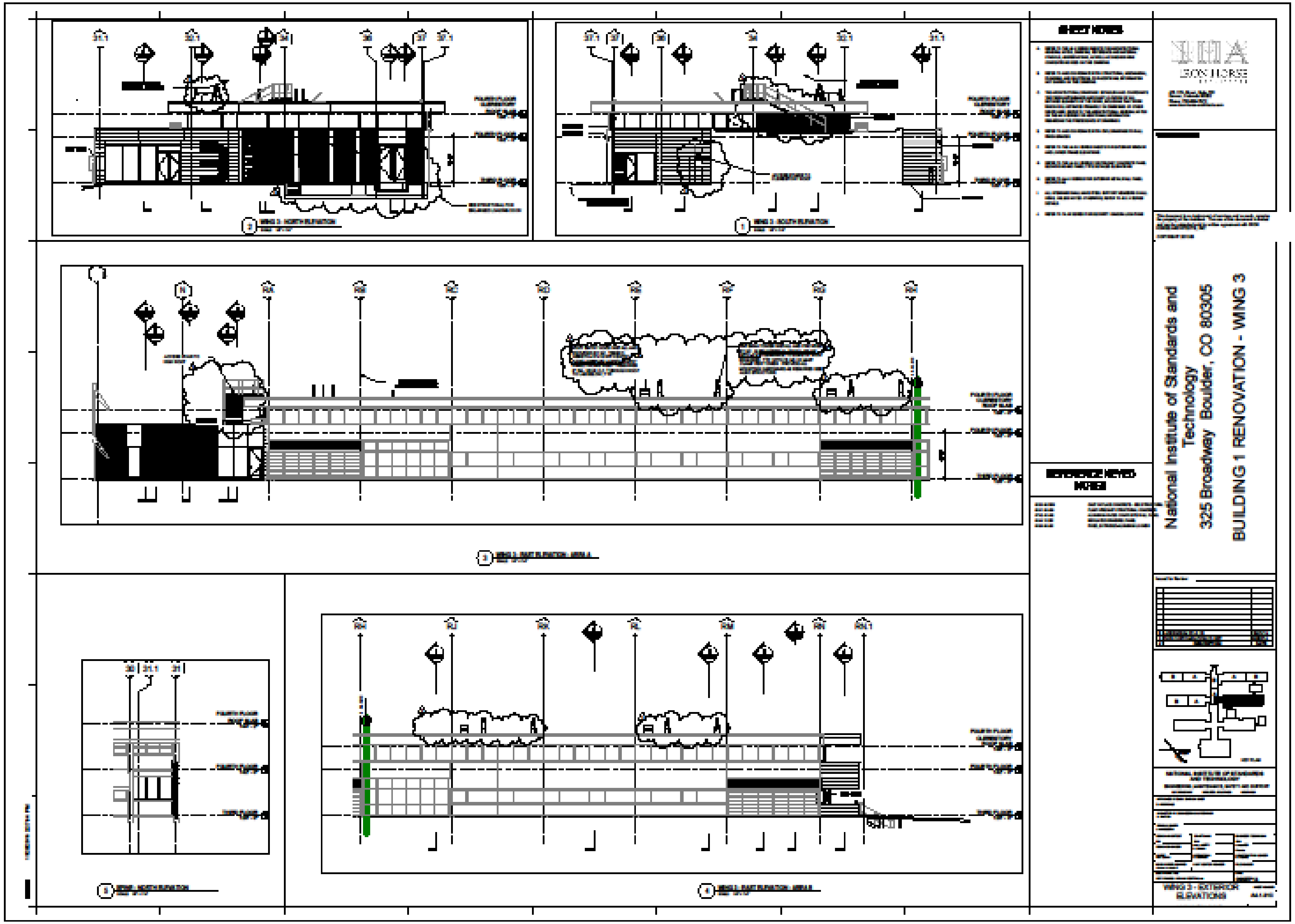
5.51 Building 1, Wing 2, looking north (Photograph RCG&A 2015)

5.52 Building 1, Wing 2, looking northwest (Photograph RCG&A 2015)

5.53 Building 1, Wing 3 (Image courtesy of DoC Boulder Labs)

5.54 Building 1, Wing 3 (Image courtesy of DoC Boulder Labs 2015)

5.55 Building 1, Wing 3, looking southeast (Photograph RCG&A 2015)



5.56 Building 1, Wing 3, Elevations (Image courtesy of DoC Boulder Labs)

5.57 Building 1, Wing 3, looking northeast (Photograph RCG&A 2015)

5.58 Building 1, Wing 4, looking southwest (Photograph RCG&A 2015)

5.59 Building 1, Wing 4, looking northwest (Photograph RCG&A 2015)

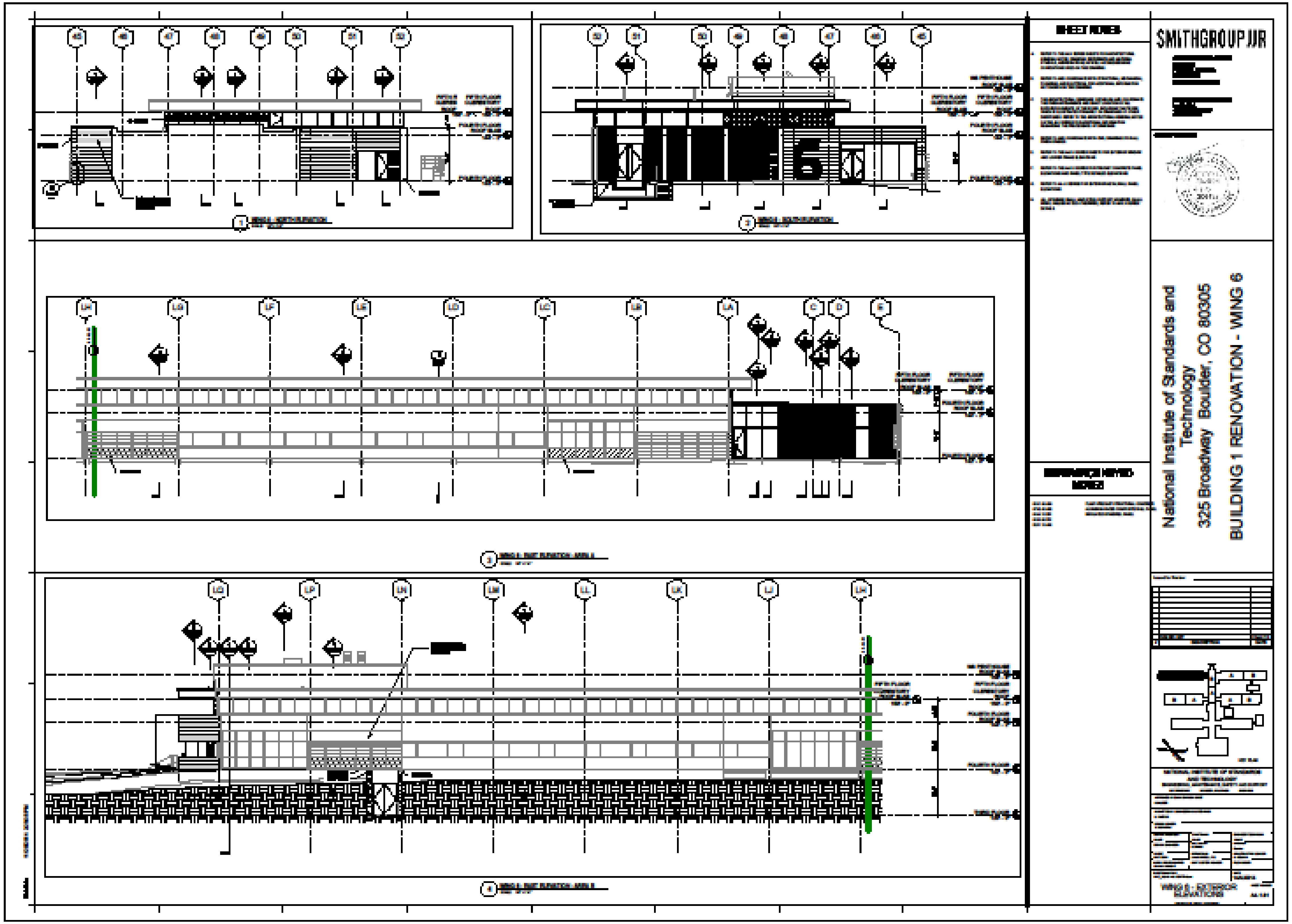
5.60 Building 1, Wing 5, looking south (Photograph RCG&A 2015)

5.61 Building 1, Wing 5, looking northeast (Photograph RCG&A 2015)

5.62 Building 1, Wing 6 (Image courtesy of DoC Boulder Labs 2015)

5.63 Building 1, Wing 6, looking west (Photograph 2015)

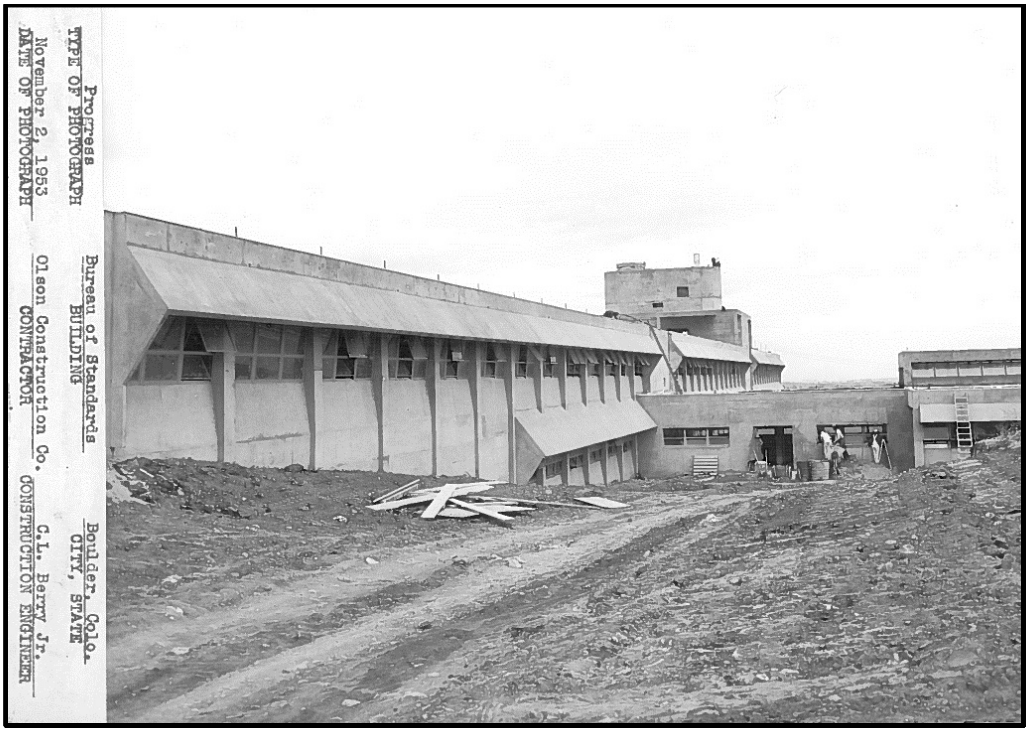

5.64 Building 1, Wing 6 (Image courtesy of DoC Boulder Labs 2015)



5.65 Building 1, Wing, 6 Elevations (Image courtesy of DoC Boulder Labs)

5.66 Building 1 and Building 81, spine connection, looking southeast (Photograph RCG&A 2015)

5.67 Building 1 and Building 81, spine connection, looking south (Photograph RCG&A 2015)



5.68 1953 Photograph of Building 1, Spine, looking northeast (Photograph RCG&A 2015)

5.69 Building 1, Spine, looking northeast (Image courtesy of DoC Boulder Labs)

5.70 Building 1, Spine, looking northwest (Photograph RCG&A 2015)

5.71 Building 1, Spine, looking northwest (Photograph RCG&A 2015)

5.72 Building 1, Spine southeast elevation between Wings 4 and 6 (Photograph RCG&A 2015)

5.73 Building 1, Annex C, looking south (Photograph RCG&A 2015)

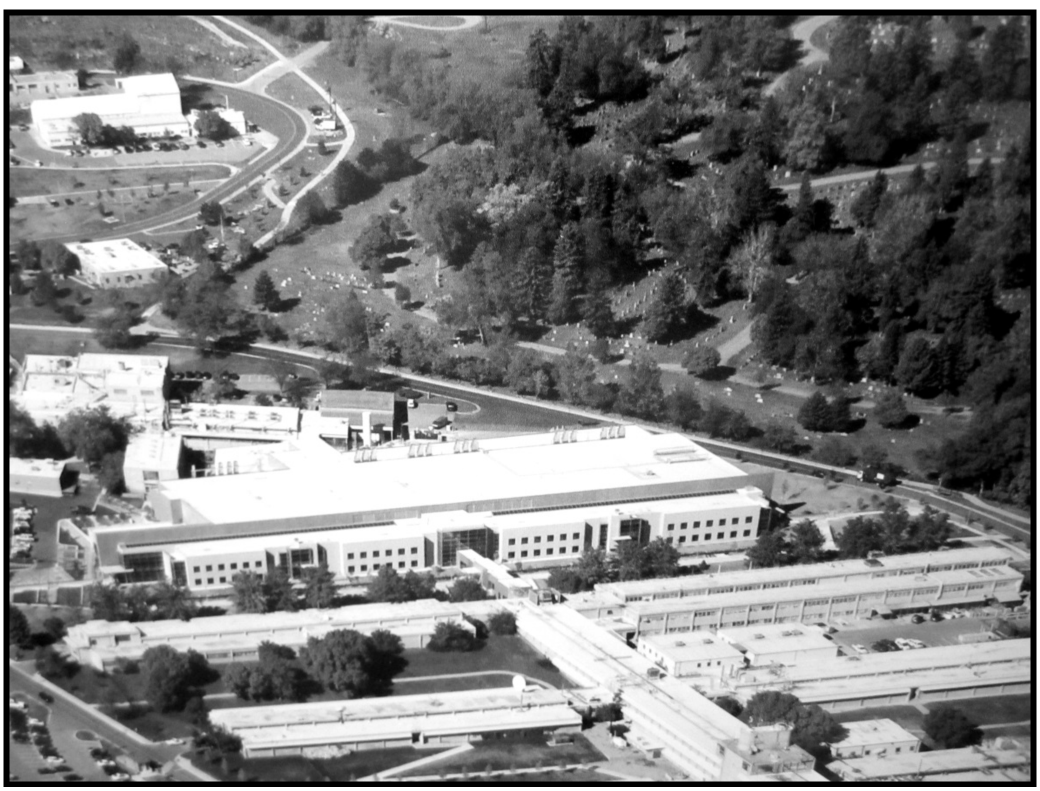
5.74 Building 1, Annex C, looking southeast (Photograph RCG&A 2015)

5.75 Building 1, Annex C connection to Wing 1 (Photograph RCGA& 2015)

5.76 Building 1, Annex D, looking southeast (Photograph RCG&A 2015)

5.77 Building 1, Annex E and Annex F, looking southeast (Photograph RCG&A 2015)

5.78 Building 2 with Buildings 81 and 1 (Image courtesy of DoC Boulder Labs 2015)



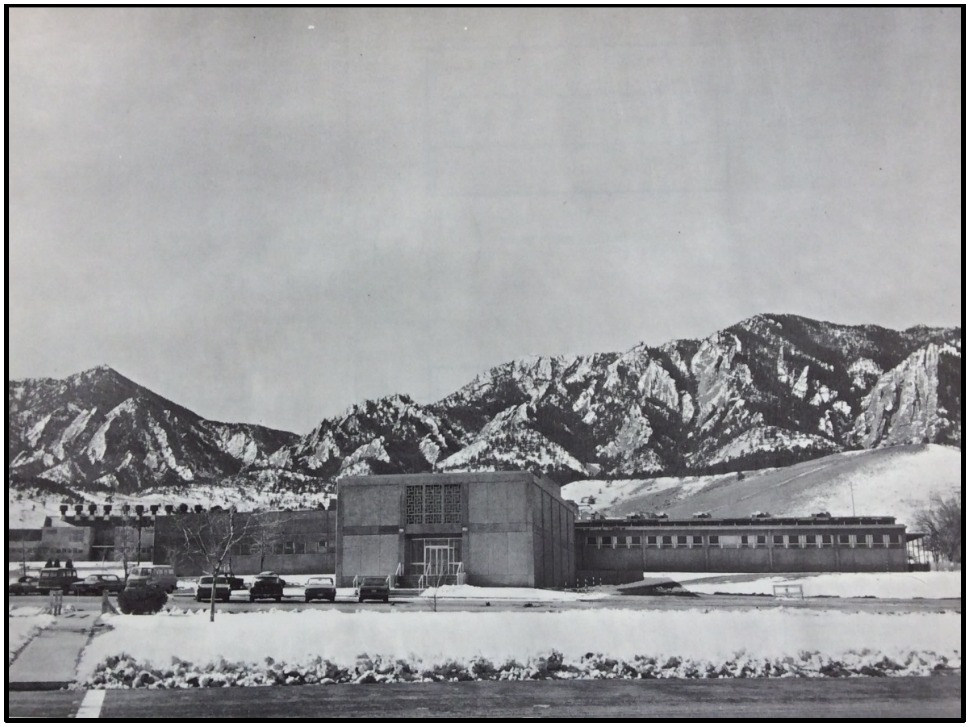
5.79 Building 81 with Buildings 1 and 2 (Image courtesy of DoC Boulder Labs 2015)

5.80 Building 2, One-story section, looking northwest (Photograph RCG&A 2015)

5.81 Building 2, One-story section, looking southwest (Photograph RCG&A 2015)

5.82 Building 2, Two-story section, looking east (Photograph RCG&A 2015)

5.83 Building 2, Wing "B" section (1964), looking west (Photograph RCG&A 2015)



5.84 1967 Photograph of Building 2, looking southwest (Image courtesy of DoC Boulder Labs)

5.85 Building 2, front elevation (Image courtesy of DoC Boulder Labs 2015)

5.86 Building 2 (Image courtesy of DoC Boulder Labs 2015)

5.87 1964 Photograph of Building 2, Interior Wing “B” (Image courtesy of DoC Boulder Labs)

5.88 1964 Photograph of Building 2 Wing "B" (Image courtesy of DoC Boulder Labs)

5.89 Building 2, Interior Wing "B" (Photograph RCG&A 2015)

5.90 Building 2, looking southeast (Photograph RCG&A 2015)

5.91 Building 2, looking northwest (Photograph RCG&A 2015)

5.92 Building 2, looking northeast (Photograph RCG&A 2015)

5.93 Building 2, looking northeast (Photograph RCG&A 2015)

5.94 1964 Photograph Building 2, looking northeast (Image courtesy of DoC Boulder Labs)

5.95 Building 2, looking southeast (Image courtesy of DoC Boulder Labs 2015)

5.96 Building 2, addition (2012), looking west (Photograph RCG&A 2015)

5.97 Building 2, addition (2012), looking west (Photograph RCG&A 2015)

5.98 Building 2, two-story additions (1995 L and 1986 R) looking west (Photograph RCG&A 2015)

5.99 Building 2, two-story addition (1995 R), looking northeast (Photograph RCG&A 2015)

5.100 Building 2, two-story additions (1995 L and 1986 R), looking north (Photograph RCG&A 2015)

5.101 Building 2 Annex, looking northwest (Photograph RCG&A 2015)

5.102 Building 2 Annex, looking south (Photograph RCG&A 2015)

5.103 Building 2 Annex, looking north (Photograph RCG&A 2015)

5.104 Building 2 Annex, looking south (Photograph RCG&A 2015)

5.105 Building 3, looking southwest (Photograph RCG&A 2015)

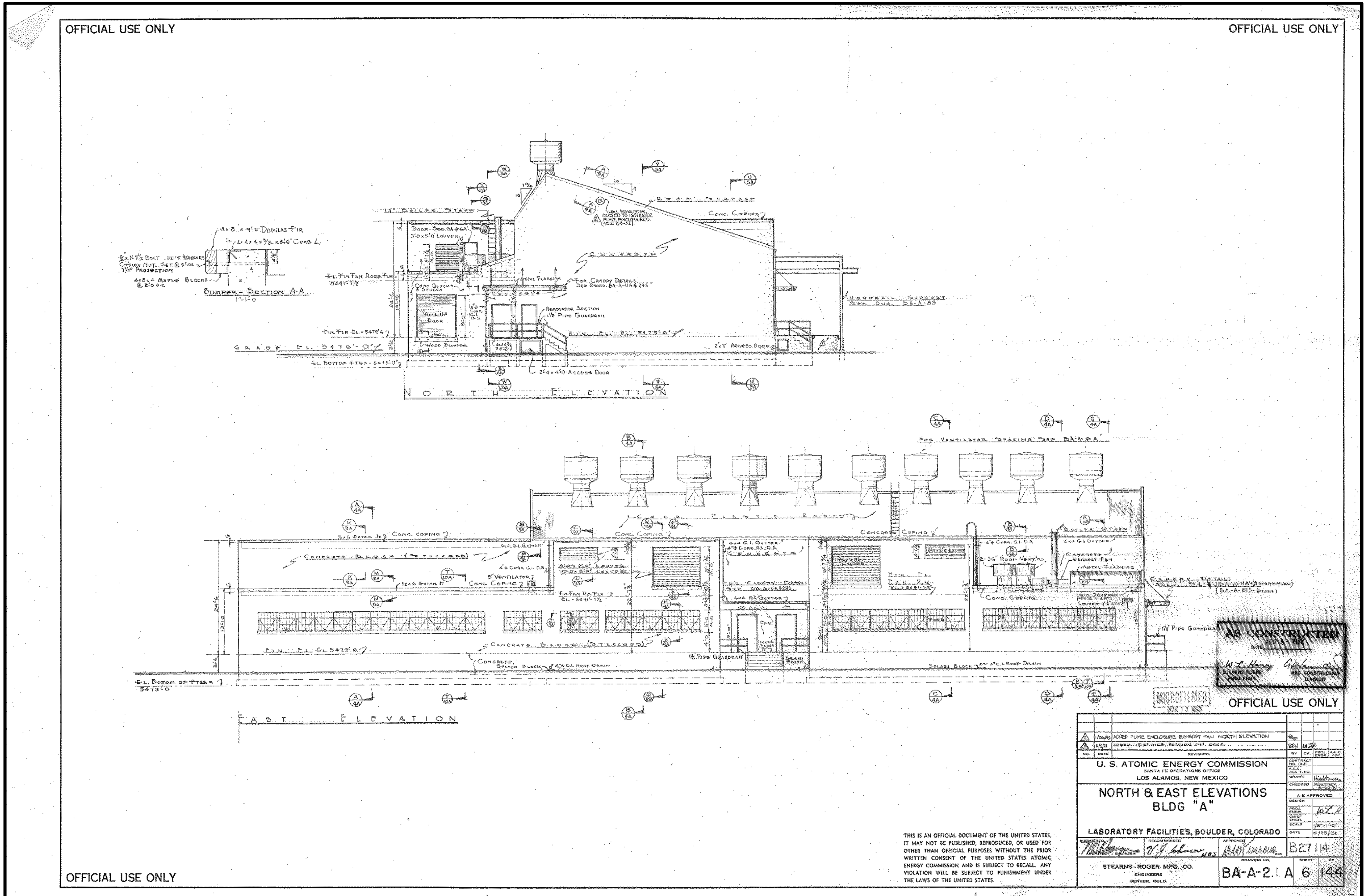
5.106 Building 3, looking southwest (Photograph RCG&A 2015)

5.107 Building 3, looking southwest (Photograph RCG&A 2015)

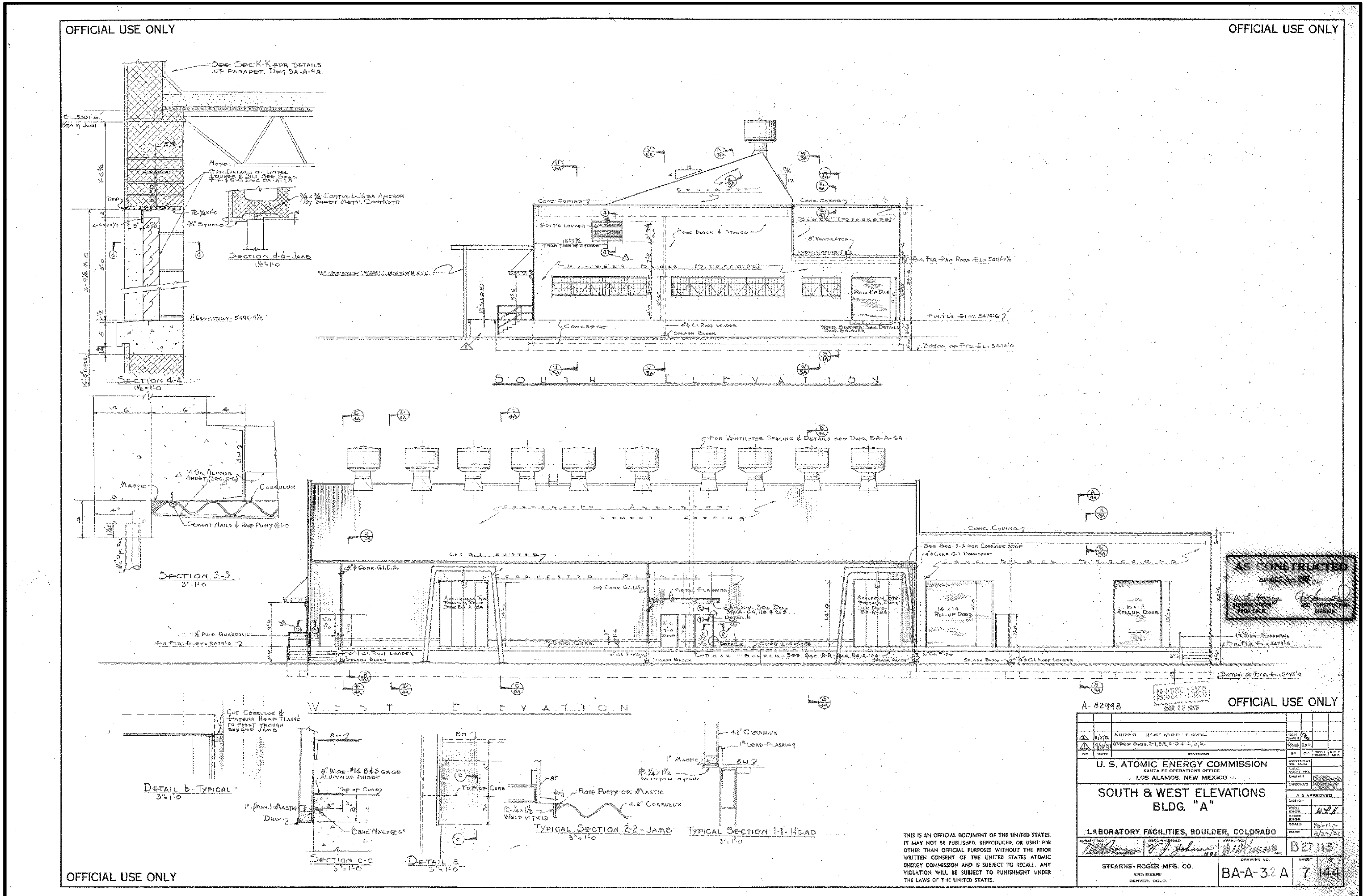
5.108 Building 3, looking north (Photograph RCG&A 2015)

5.109 Building 3, looking southeast (Photograph RCG&A 2015)

5.110 Building 3, looking south (Photograph RCG&A 2015)



5.111 1952 North and East Elevations (Image courtesy DoC Boulder Labs)



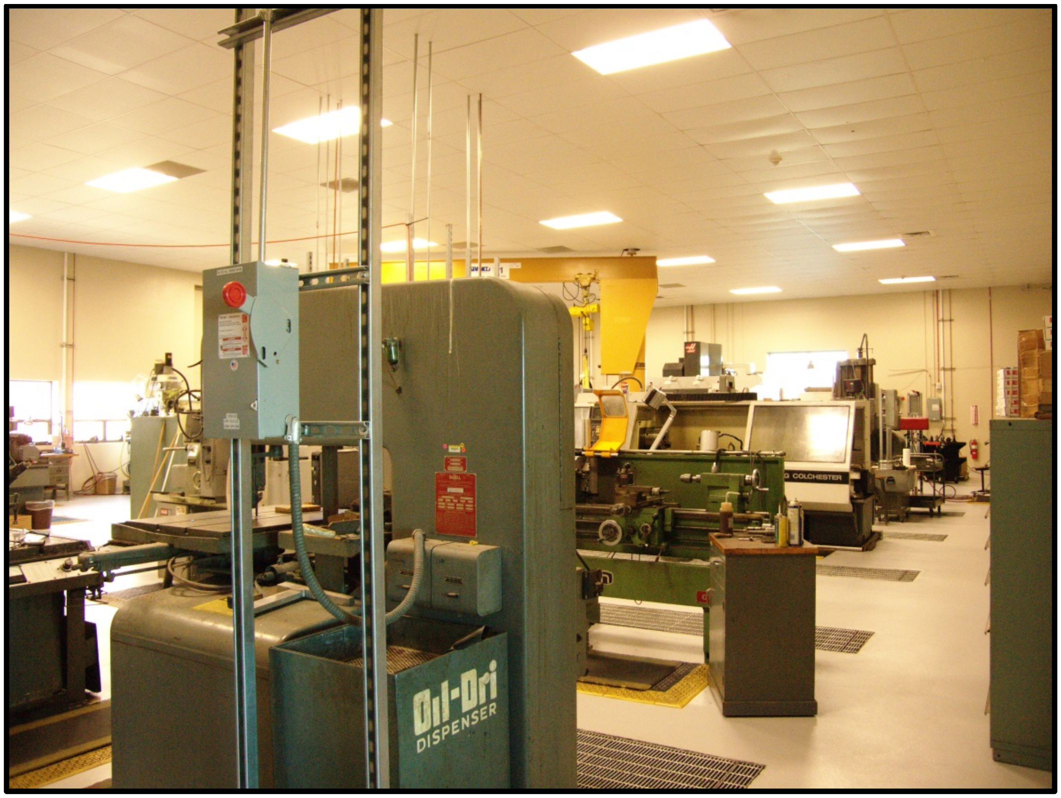
5.112 1952 South and West Elevations (Image courtesy of DoC Boulder Labs)

5.113 Building 3, looking northeast (Photograph RCG&A 2015)

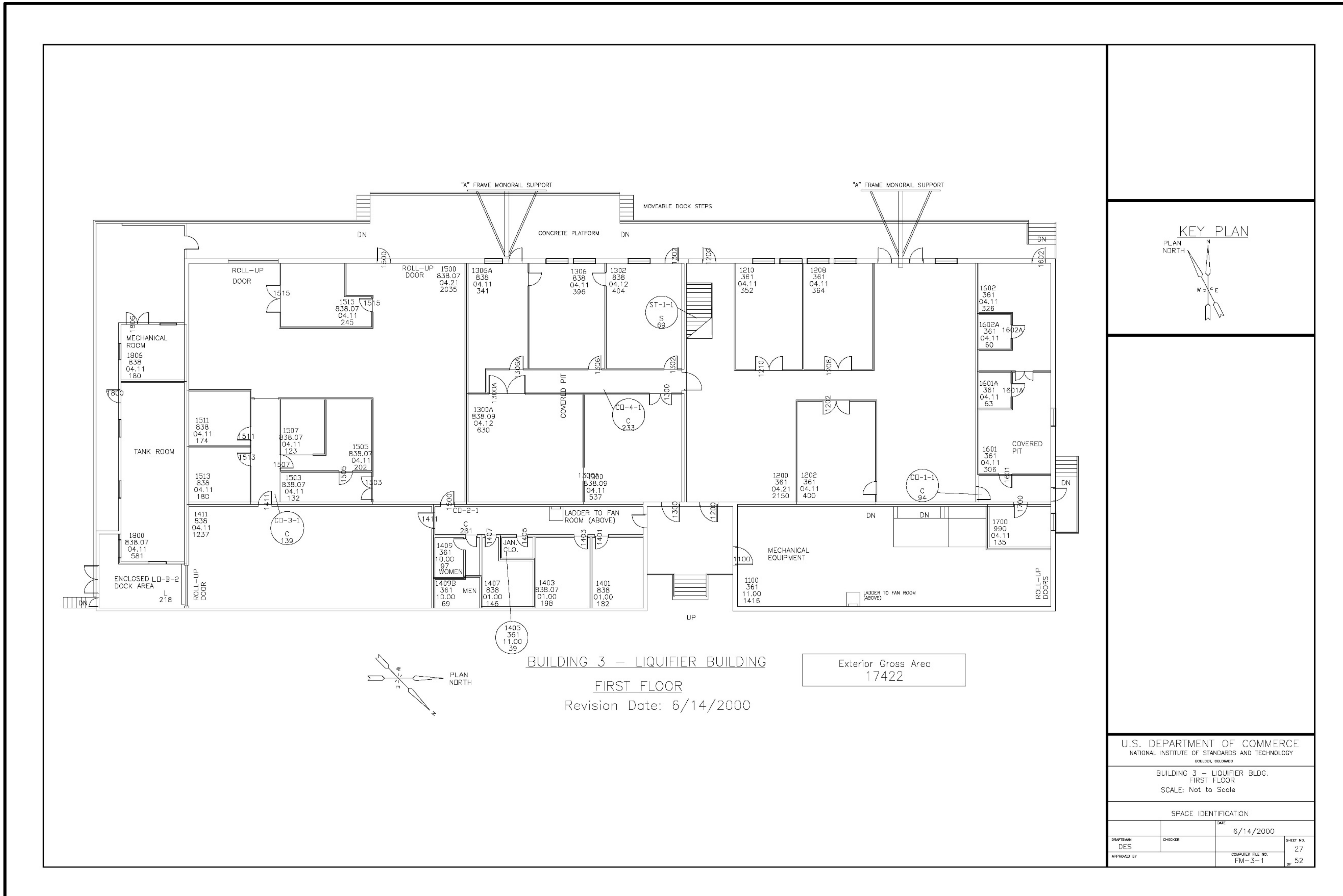
5.114 Building 3, looking northeast (Photograph RCG&A 2015)

5.115 Building 3, looking northwest (Photograph RCG&A 2015)

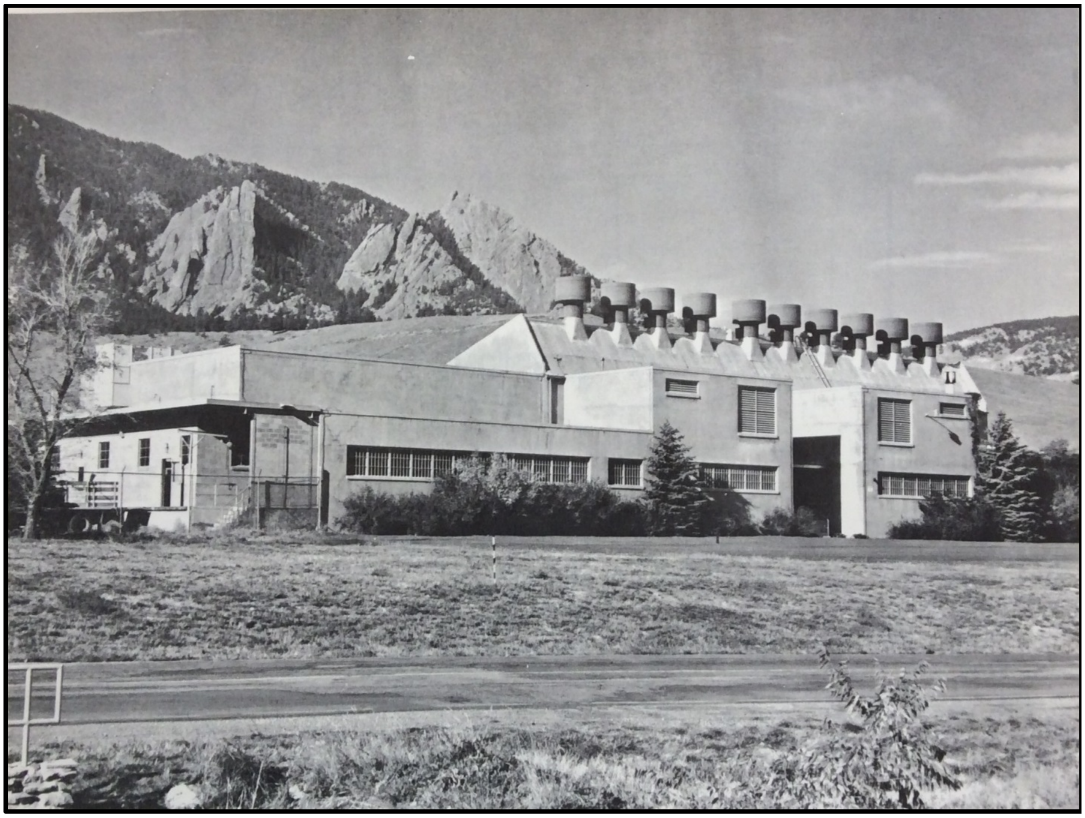
5.116 Building 3, Interior workspace (Photograph RCG&A 2015)



5.117 Building 3, Interior workspace (Photograph RCG&A 2015)



5.118 2000 First Floor Plan (Image courtesy of DoC Boulder Labs)



5.119 1967 Photograph of Building 3, looking west (Image courtesy DoC Boulder Labs)

5.120 Building 3 Annex, looking south (Photograph RCG&A 2015)

5.121 Building 3 Annex, looking southeast (Photograph RCG&A 2015)

5.122 Building 3 Annex, looking west (Photograph RCG&A 2015)

5.123 Buildings 4 and 5, looking southwest (Photograph RCG&A 2015)

5.124 Building 4, looking southwest (Photograph RCG&A 2015)

5.125 Buildings 4 and 5, looking west (Photograph RCG&A 2015)

5.126 Building 4, southeast corner addition to right (1994), looking north (Photograph RCG&A 2015)

5.127 Building 4, looking north (Photograph RCG&A 2015)

5.128 Buildings 4 and 5, looking southeast (Photograph RCG&A 2015)

5.129 Buildings 4 and 5, looking northeast (Photograph RCG&A 2015)

5.130 Building 4, looking south (Photograph RCG&A 2015)

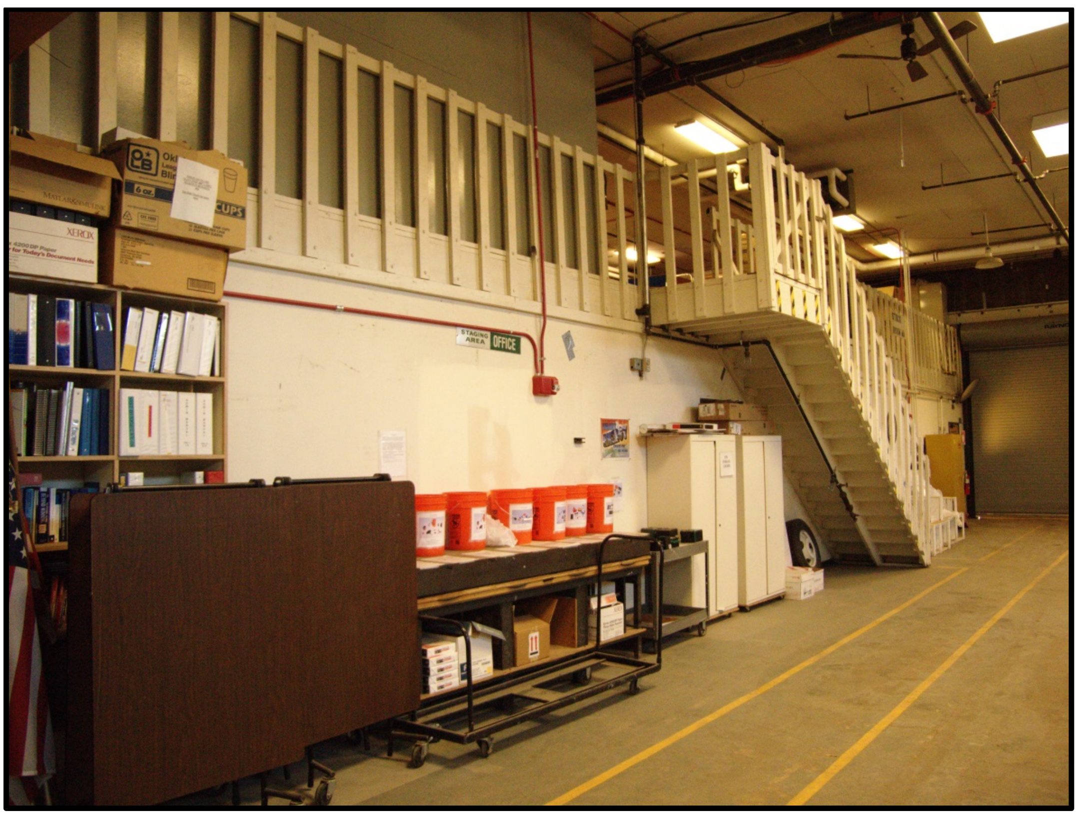
5.131 Buildings 4 and 5 connection, looking southwest (Photograph RCG&A 2015)

5.132 1967 Photograph of Building 4, looking southwest (Image courtesy of DoC Boulder Labs)

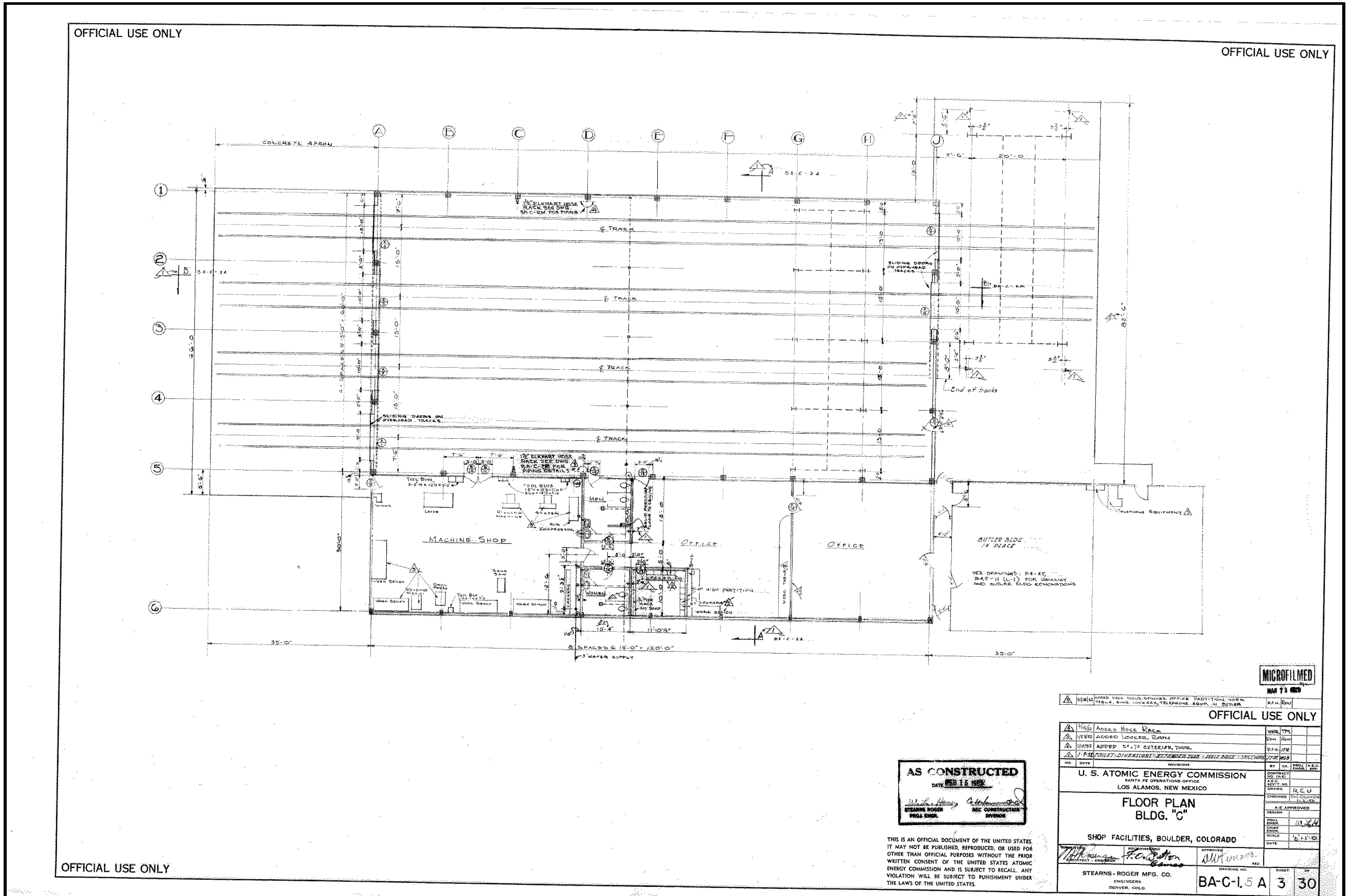
5.133 Building 4, Interior (Photograph RCG&A 2015)

5.134 Building 4, Interior looking toward interior of Building 5 (Photograph RCG&A 2015)

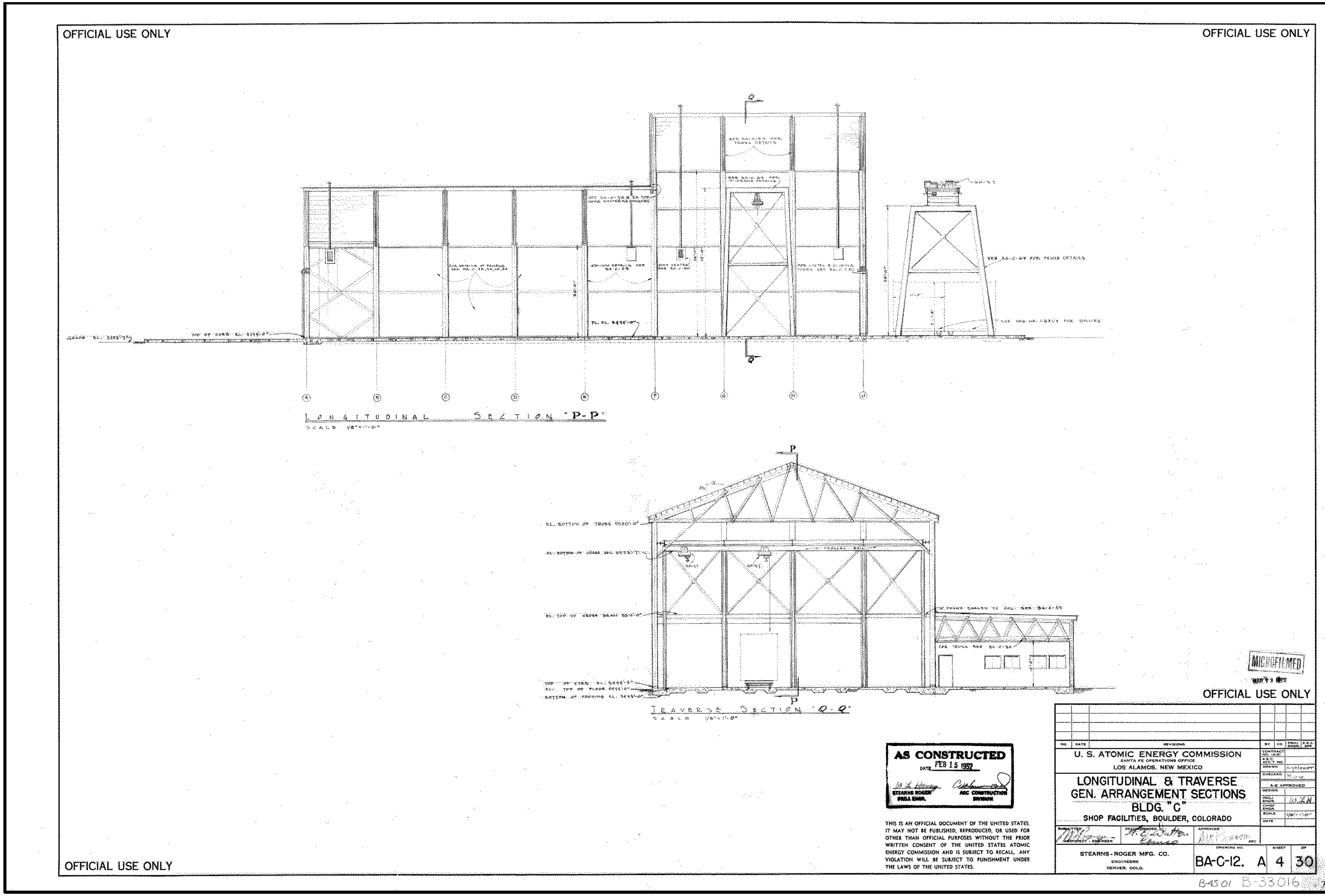
5.135 Building 4, Interior (Photograph RCG&A 2015)



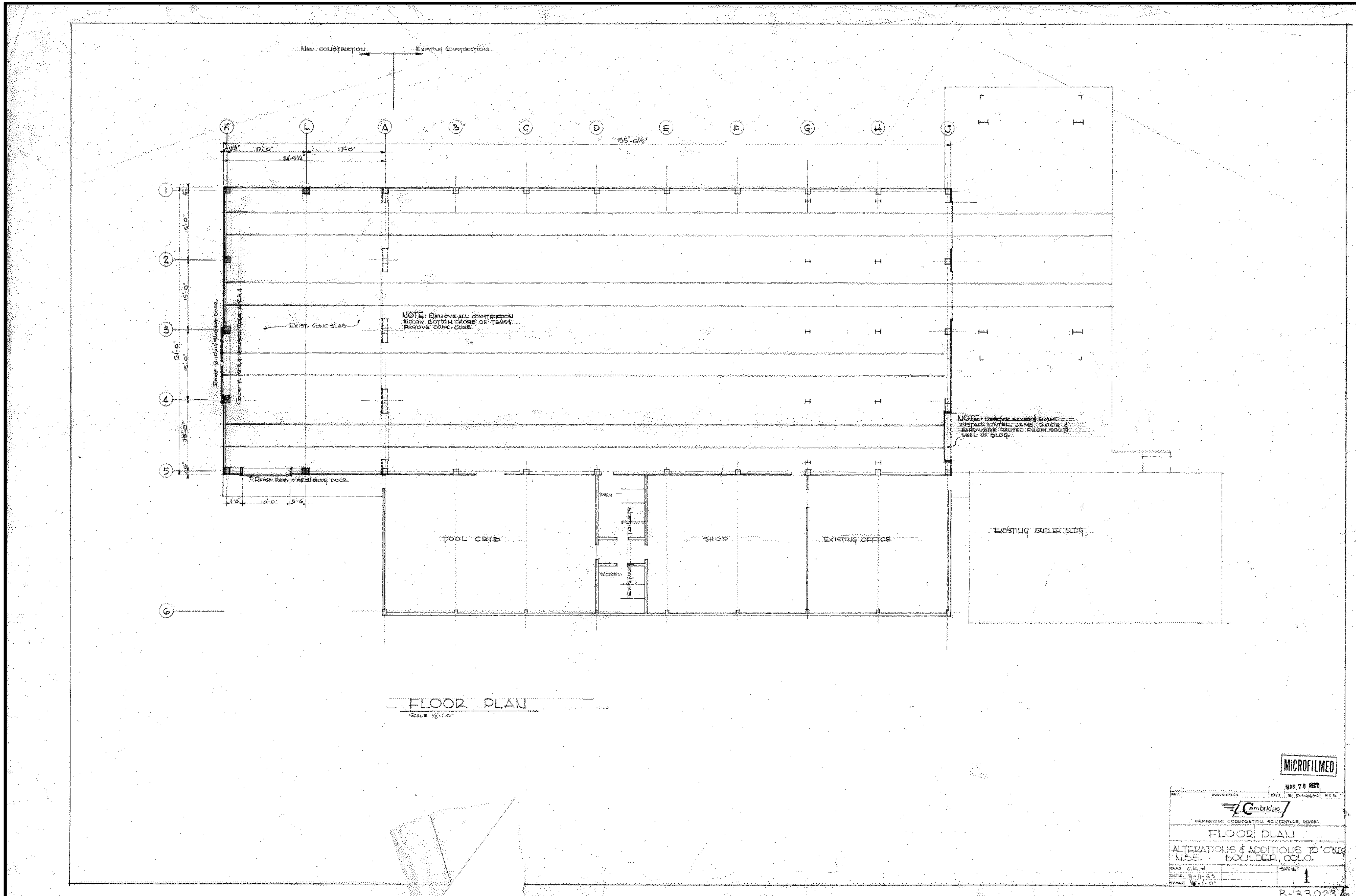
5.136 Building 4, Interior (Photograph RCG&A 2015)



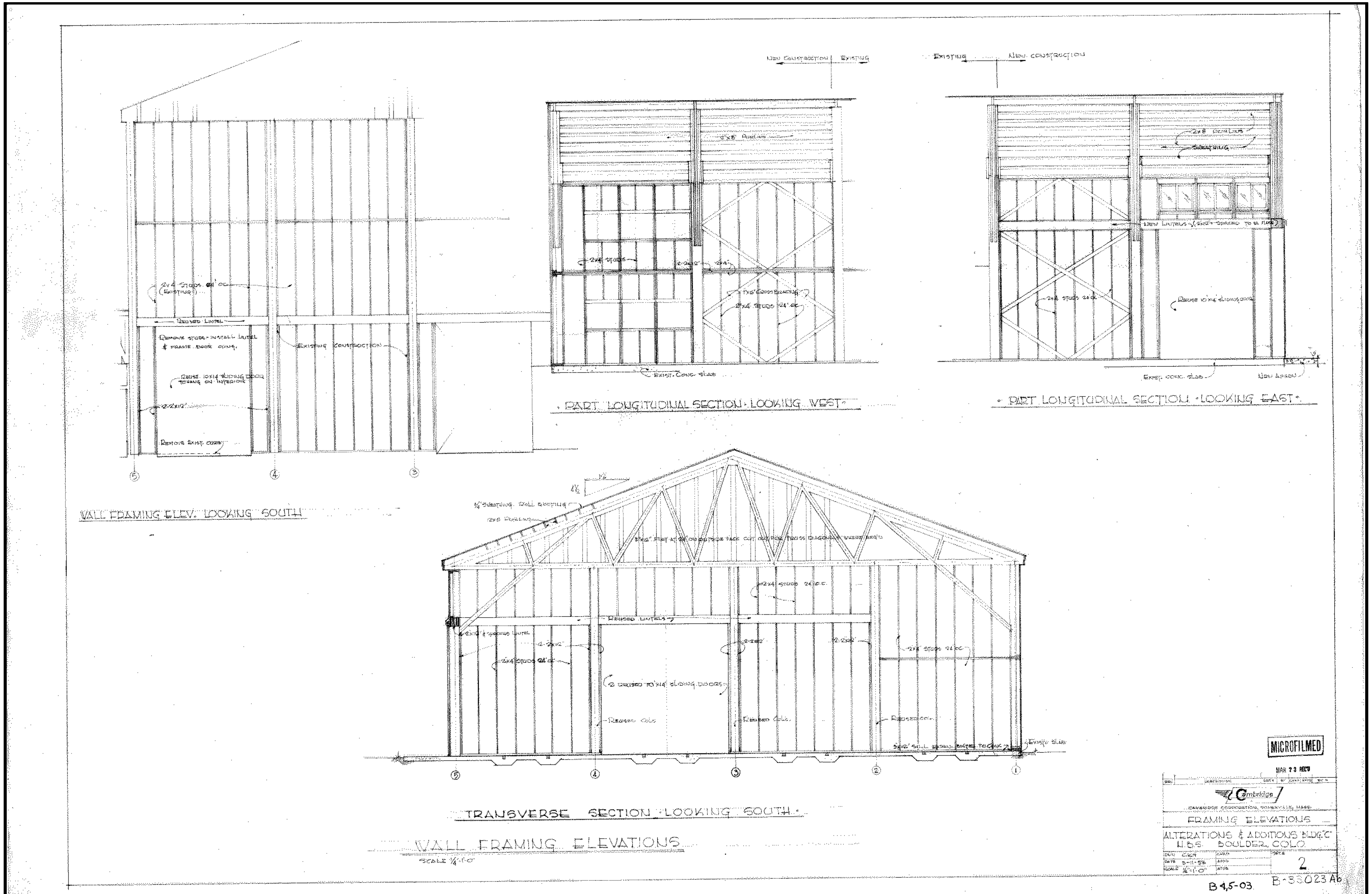
5.137 1952 Floor Plan (Image courtesy of DoC Boulder Labs)



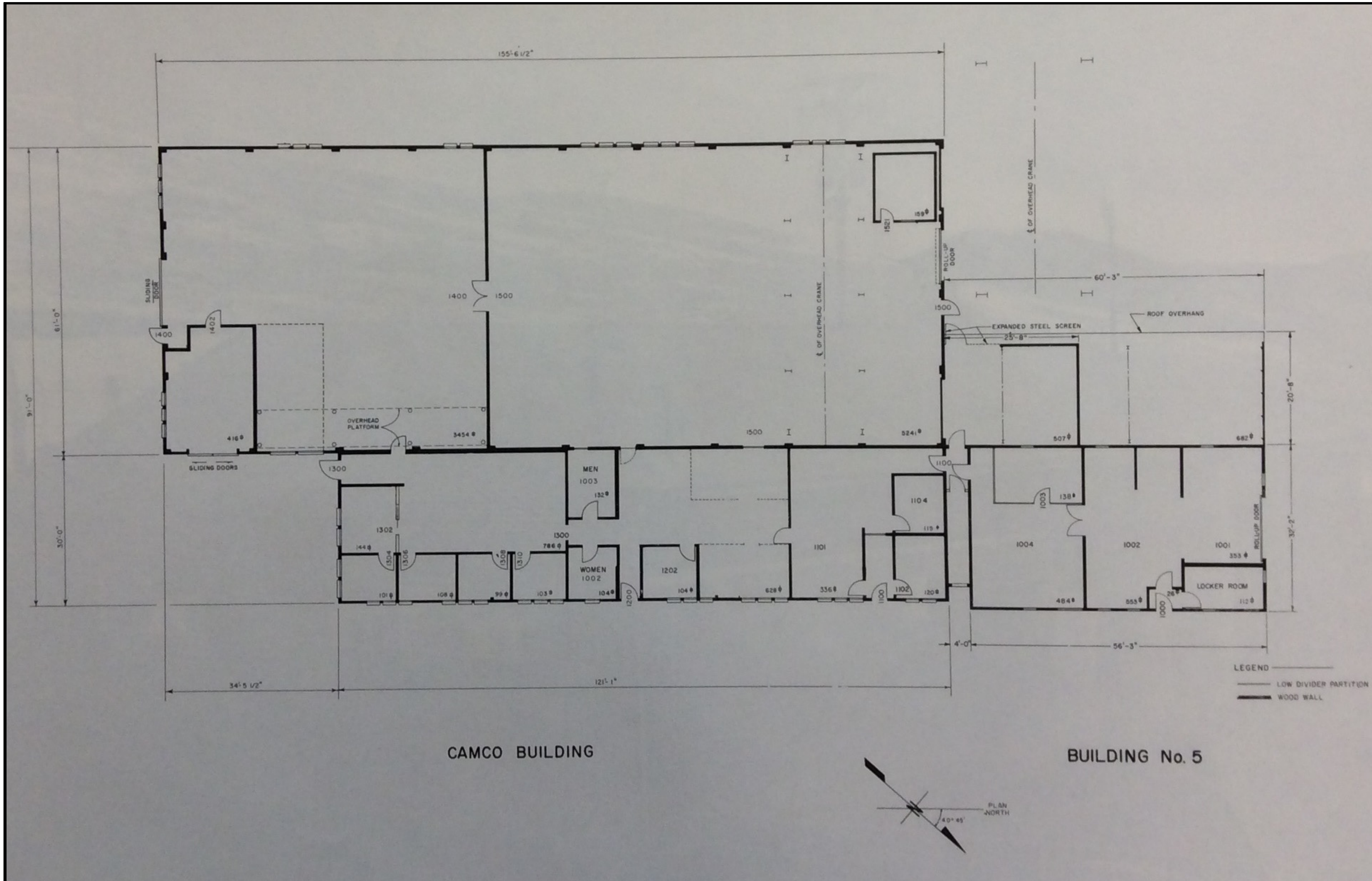
5.138 1952 Longitudinal and Traverse General Arrangement Sections (Image courtesy of DoC Boulder Labs)



5.139 1953 Floor Plan (Image courtesy of DoC Boulder Labs)



5.140 1953 Framing Elevations, Alterations and Additions (Image courtesy of DoC Boulder Labs)



5.141 1967 Floor Plan (Image courtesy of DoC Boulder Labs)

5.142 Building 5, looking south (Photograph RCG&A 2015)

5.143 Buildings 4 and 5, looking southeast (Photograph RCG&A 2015)

5.144 Buildings 4 and 5, flat-roof expansion Building 5 (1992 and 2015), looking east (Photograph RCG&A 2015)

5.145 1967 Building 5, hoist no longer extant, looking southwest (Image courtesy of DoC Boulder Labs)

5.146 Building 8, looking northwest (Photograph RCG&A 2015)

5.147 Building 8, looking west (Photograph RCG&A 2015)

5.148 Building 8, looking southwest (Photograph RCG&A 2015)

5.149 Building 8, looking west (Photograph RCG&A 2015)

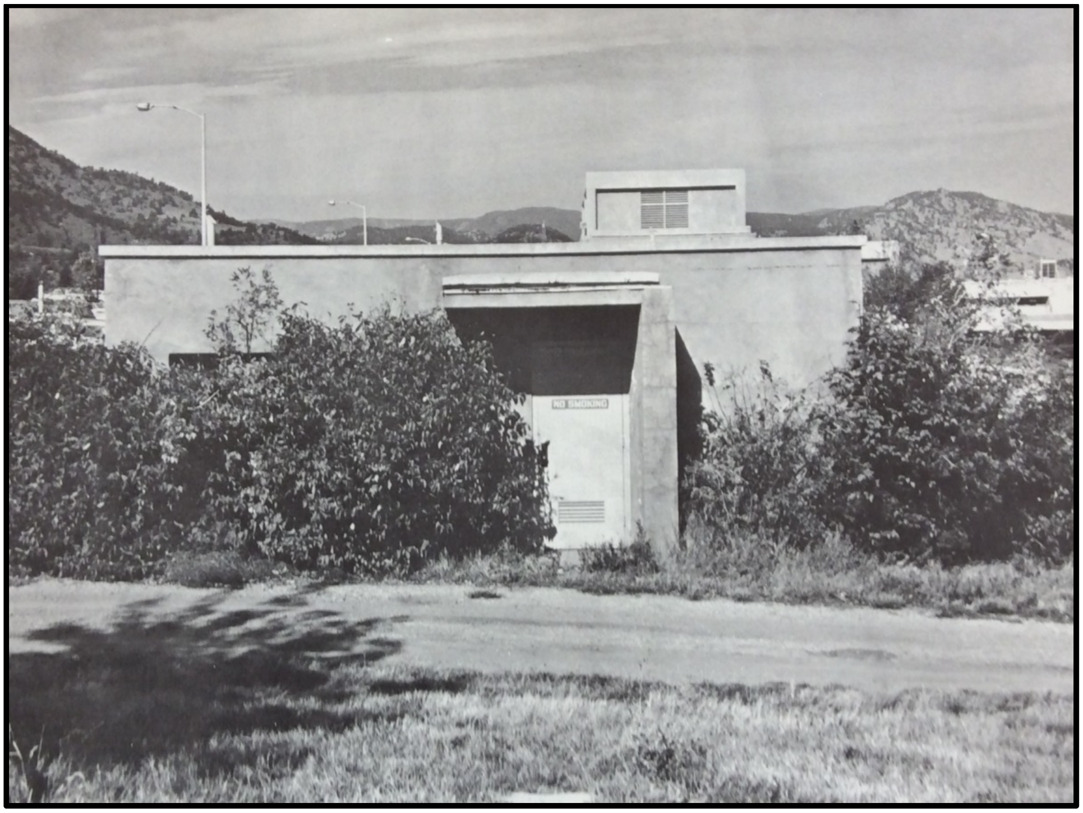
5.150 Building 8, looking northeast (Photograph RCG&A 2015)

5.151 Building 8, looking south (Photograph RCG&A 2015)

5.152 Building 8, looking southeast (Photograph RCG&A 2015)

5.153 Steps leading from Building 8 to Building 12, looking west (Photograph RCG&A 2015)

5.154 1967 Photograph of Building 8, looking northwest (Image courtesy of DoC Boulder Labs)



5.155 1967 Photograph of Building 9, looking northwest (Image courtesy of DoC Boulder Labs)

5.156 Building 9, looking west (Photograph RCG&A 2015)

5.157 Building 9, looking west (Photograph RCG&A 2015)

5.158 1967 Photograph of Building 11, looking northwest (Image courtesy of DoC Boulder Labs)

5.159 Building 11, looking northwest (Photograph RCG&A 2015)

5.160 Building 11, looking northeast (Photograph RCG&A 2015)

5.161 Building 11, looking west (Photograph RCG&A 2015)

5.162 Building 11, looking southeast (Photograph RCG&A 2015)

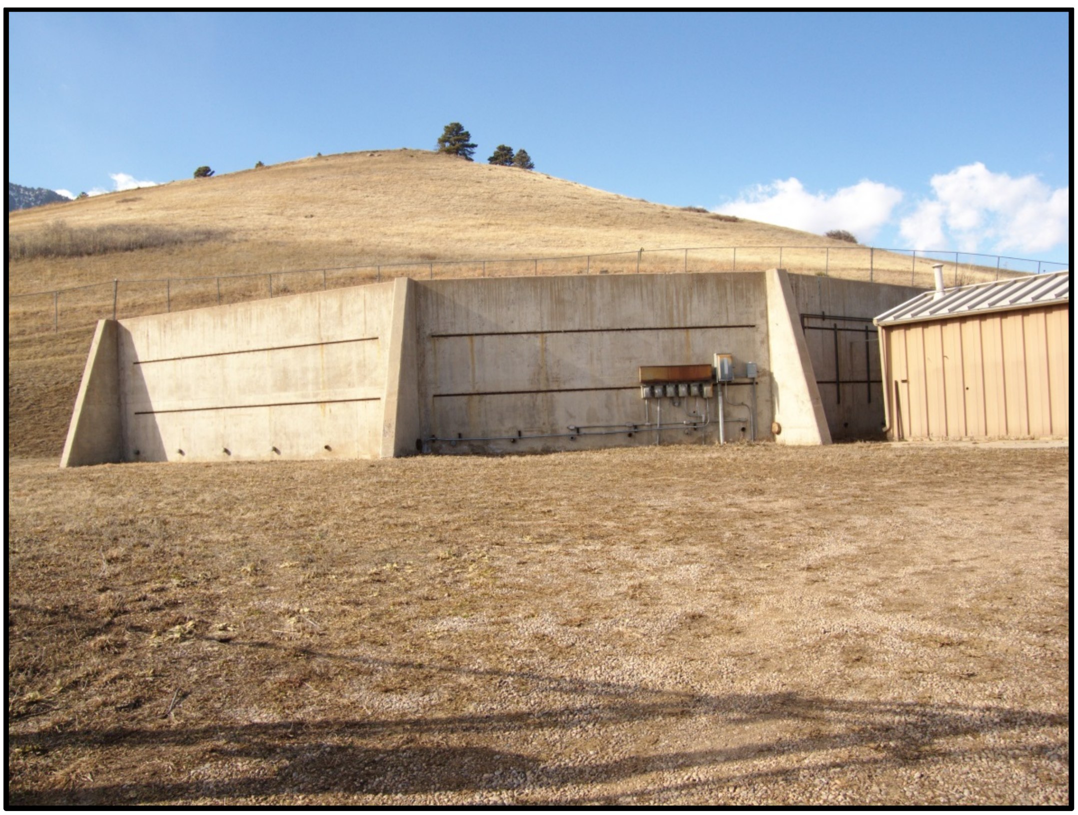
5.163 Building 12, looking north (Photograph RCG&A 2015)

5.164 Building 12, looking northeast (Photograph RCG&A 2015)

5.165 Building 12, looking south (Photograph RCG&A 2015)

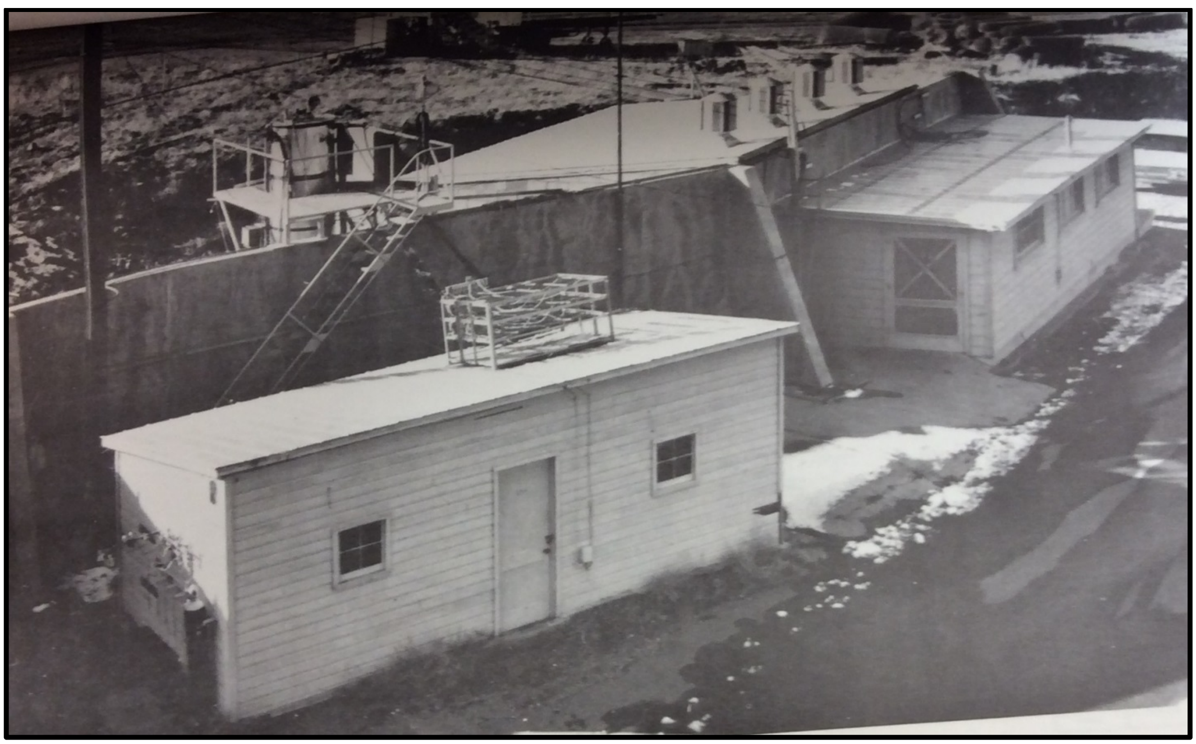
5.166 Building 12, looking south (Photograph RCG&A 2015)

5.167 Building 12 shed, looking north (Photograph RCG&A 2015)



5.168 Building 12 associated blast wall, looking west (Photograph RCG&A 2015)

5.169 Building 12 associated blast wall, looking north (Photograph RCG&A 2015)



5.170 Building 12 associated blast wall, looking northwest (Photograph RCG&A 2015)

5.171 Building 12 associated shed along blast wall, looking west (Photograph RCG&A 2015)

5.172 Building 21, looking south (Photograph RCG&A 2015)

5.173 Building 21, looking northwest (Photograph RCG&A 2015)

5.174 Building 21, looking east (Photograph RCG&A 2015)

5.175 Building 21, looking northwest (Photograph RCG&A 2015)

5.176 Building 22, looking north (Photograph RCG&A 2015)

5.177 Building 22, looking northwest (Photograph RCG&A 2015)

5.178 1967 photograph of Building 22, looking northwest (Photograph RCG&A 2015)

5.179 Building 22, looking west (Photograph RCG&A 2015)

5.180 Building 22, Interior (Photograph RCG&A 2015)

5.181 Building 23, looking southeast (Photograph RCG&A 2015)

5.182 Building 23, looking east (Photograph RCG&A 2015)

5.183 Building 23, looking west (Photograph RCG&A 2015)

5.184 Building northwest of Building 23, looking north (Photograph RCG&A 2015)

5.185 Building northwest of Building 23, looking south (Photograph RCG&A 2015)

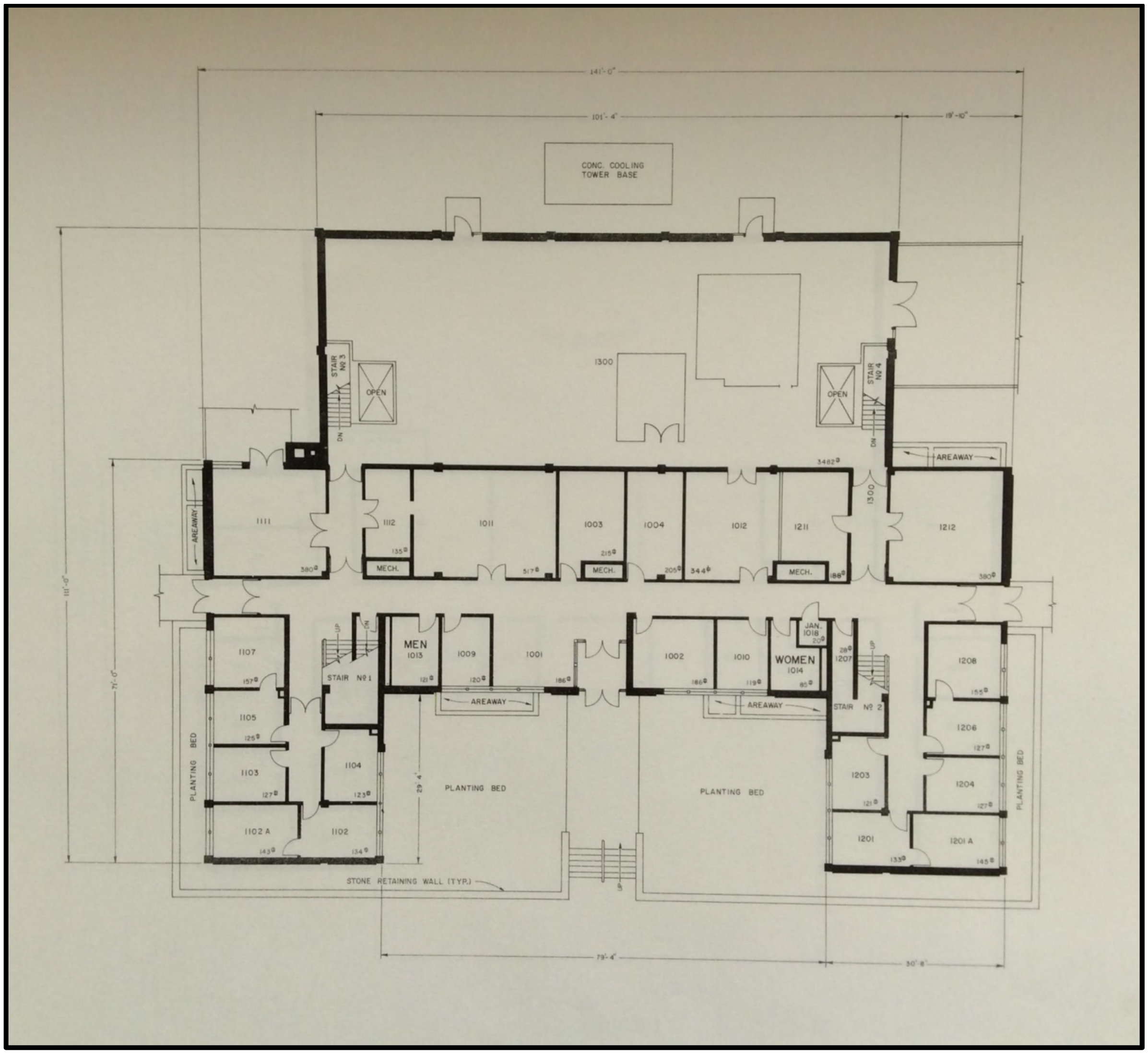
5.186 Building 24, looking southwest (Photograph RCG&A 2015)

5.187 Building 24, looking southwest (Photograph RCG&A 2015)

5.188 Building 24, looking southwest (Photograph RCG&A 2015)

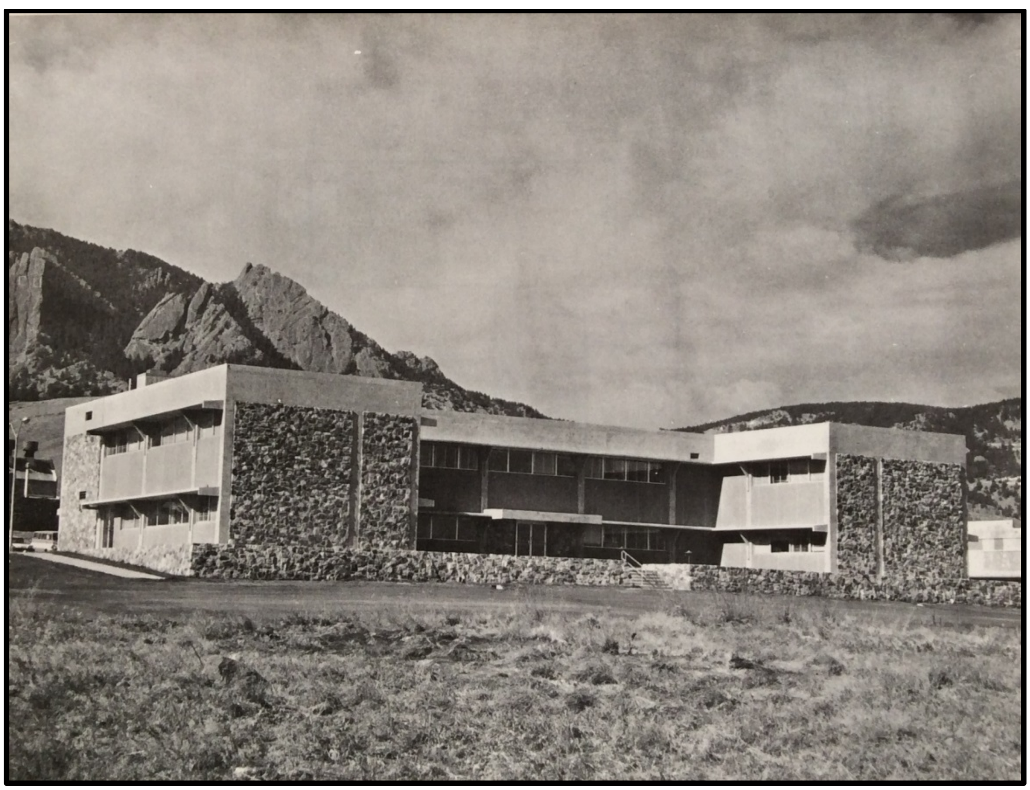
5.189 Building 24, Interior (Photograph RCG&A 2015)

5.190 Building 24, Interior (Photograph RCG&A 2015)



5.191 Floor Plan (Image courtesy of DoC Boulder Labs)

5.192 Building 24, looking southwest (Photograph RCG&A 2015)



5.193 1967 Photograph of Building 24, looking northwest (Image courtesy of DoC Boulder Labs)

5.194 Building 24, close up of addition (Image courtesy of DoC Boulder Labs 2015)

5.195 Building 24 elevator tower (2002-2005), looking south (Photograph RCG&A 2015)

5.196 Building 24, looking south (Photograph RCG&A 2015)

5.197 Building 24, looking south (Photograph RCG&A 2015)

5.198 Building 24, looking north (Photograph RCG&A 2015)

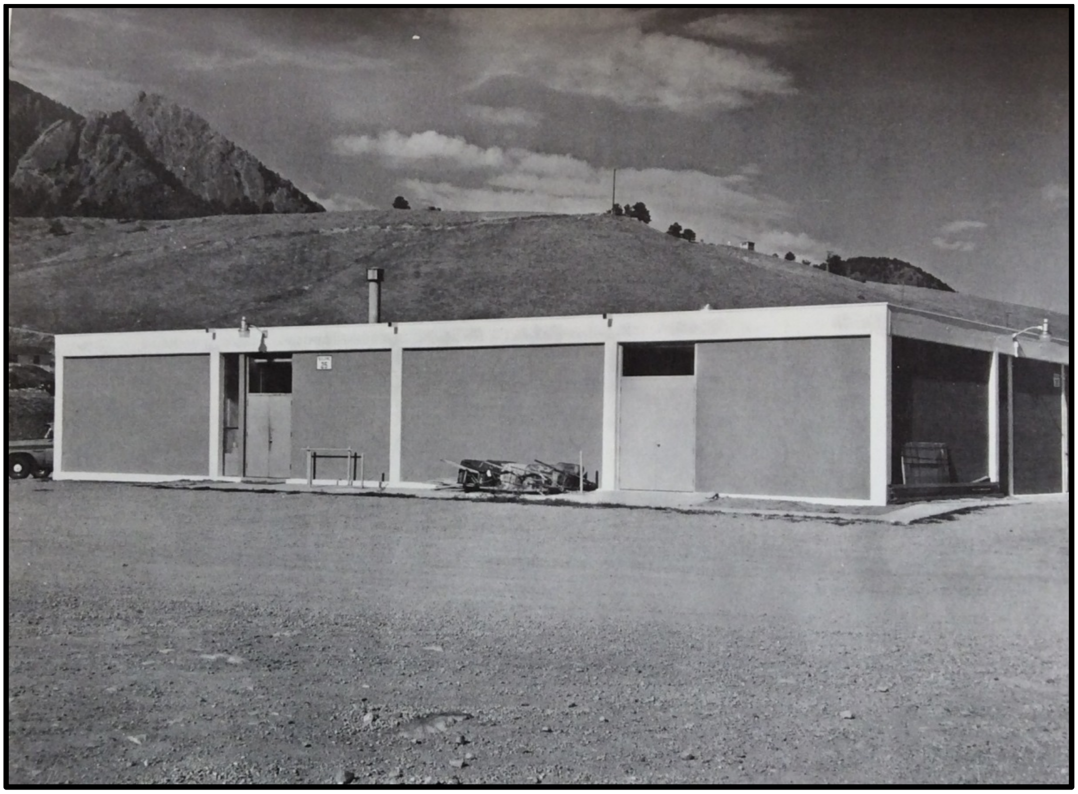
5.199 Building 24, looking southeast (Photograph RCG&A 2015)

5.200 Building 24, looking north (Photograph RCG&A 2015)

5.201 Building 24, looking southeast (Photograph RCG&A 2015)

5.202 Building 24, High Bay Addition (1985), Annex (1988), and Air Handling Unit (1999), looking northeast (Photograph RCG&A 2015)

5.203 Building 24, looking east (Photograph RCG&A 2015)



5.204 1967 Photograph of Building 25, looking northwest (Photograph RCG&A 2015)

5.205 Building 25, looking southeast (Photograph RCG&A 2015)

5.206 Building 25, looking northwest (Photograph RCG&A 2015)

5.207 Building 25, looking northeast (Photograph RCG&A 2015)

5.208 Building 25, looking south (Photograph RCG&A 2015)

5.209 Building 26, looking east (Photograph RCG&A 2015)

5.210 Building 26, looking west (Photograph RCG&A 2015)

5.211 Building 26, looking northeast (Photograph RCG&A 2015)

5.212 Building 26, looking northwest (Photograph RCG&A 2015)

5.213 Building 27, looking west (Photograph RCG&A 2015)

5.214 Building 27, looking northwest (Photograph RCG&A 2015)

5.215 Building 27, looking southeast (Photograph RCG&A 2015)

5.216 Building 27, looking north (Photograph RCG&A 2015)

5.217 Building 27, Antenna Field (Photograph RCG&A 2015)

5.218 Building 27, Antenna Field (Photograph RCG&A 2015)

5.219 Building 27, Antenna Field (Photograph RCG&A 2015)

5.220 Building 33, looking southeast (Photograph RCG&A 2015)

5.221 Building 33, looking northeast (Photograph RCG&A 2015)

5.222 Building 33, looking north (Photograph RCG&A 2015)

5.223 Building 33, looking west (Photograph RCG&A 2015)

5.224 Building 33, looking north (Photograph RCG&A 2015)

5.225 Building 33, looking northwest (Photograph RCG&A 2015)

5.226 Building 33, looking south (Photograph RCG&A 2015)

5.227 Building 33, looking southeast (Photograph RCG&A 2015)

5.228 Building 33, looking east (Photograph RCG&A 2015)

5.229 Building 33, steps to parking lot, looking west (Photograph RCG&A 2015)

5.230 Building 33, parking lot, looking west (Photograph RCG&A 2015)

5.231 Building 33, looking east (Photograph RCG&A 2015)

5.232 Building 33, looking east (Photograph RCG&A 2015)

5.233 Building 33, looking west (Photograph RCG&A 2015)

5.234 Building 33, looking northwest (Photograph RCG&A 2015)

5.235 Building 33, looking northwest (Photograph RCG&A 2015)

5.236 Building 33, looking east Building 33, looking northwest (Photograph RCG&A 2015)

5.237 Building 33, Anderson Ditch location east of building (Photograph RCG&A 2015)

5.238 Building 33, Walkway and areas between building and Anderson Ditch
(Photograph RCG&A 2015)

5.240 Building 33, looking north along pathway east of building (Photograph RCG&A 2015)

5.241 Building 34, steps from Compton Road, looking west (Photograph RCG&A 2015)

5.242 Building 34, looking northwest (Photograph RCG&A 2015)

5.243 Building 34, looking east (Photograph RCG&A 2015)

5.244 Building 34, looking south (Photograph RCG&A 2015)

5.245 Building 34, looking southeast (Photograph RCG&A 2015)

5.246 Building 34, looking west (Photograph RCG&A 2015)

5.247 Antenna Field west of Building 34, looking southeast (Photograph RCG&A 2015)

5.248 Building 34, sundial southeast of building (Photograph RCG&A 2015)

5.249 Building 42, looking northwest (Photograph RCG&A 2015)

5.250 Building 42, looking southeast (Photograph RCG&A 2015)

5.251 Building 42, looking north (Photograph RCG&A 2015)

5.252 Building 42, looking east (Photograph RCG&A 2015)

5.253 Building 42, looking east (Photograph RCG&A 2015)

5.254 Building 42, looking northwest (Photograph RCG&A 2015)

5.255 Undated photograph of Utility Tunnel (Image courtesy of DoC Boulder Labs)

5.256 Tunnel Access Point 1, looking southwest (Photograph RCG&A 2015)

5.257 Tunnel Access Point 1, looking southeast (Photograph RCG&A 2015)

5.258 Tunnel Access Point 2, looking southeast (Photograph RCG&A 2015)

5.259 Tunnel Access Point 3, looking west (Photograph RCG&A 2015)

5.260 Tunnel Access Point 3, looking east (Photograph RCG&A 2015)

5.261 Tunnel Access Point 1, interior (Photograph RCG&A 2015)

5.262 Building 51, looking northwest (Photograph RCG&A 2015)

5.263 Building 51, looking southwest (Photograph RCG&A 2015)

5.264 Building 51, looking northeast (Photograph RCG&A 2015)

5.265 Vehicle Check Building south of Building 51 (Photograph RCG&A 2015)

5.266 Vehicle Check Building south of Building 51 (Photograph RCG&A 2015)

5.267 Guard house southwest of Building 51 (Photograph RCG&A 2015)

5.268 Guard house southwest of Building 51 (Photograph RCG&A 2015)

5.269 Building 81, connection to spine of Building 1, looking south (Photograph RCG&A 2015)

5.270 Building 81, looking northwest (Photograph RCG&A 2015)

5.271 Building 81, looking west (Photograph RCG&A 2015)

5.272 Building 81, walled courtyard west of building (Photograph RCG&A 2015)

5.273 Building 81, looking northwest along Anderson Ditch (Photograph RCG&A 2015)

5.274 Building 81, looking west (Photograph RCG&A 2015)

5.275 Building 81, looking south (Photograph RCG&A 2015)

5.276 Building 81, looking southeast (Photograph RCG&A 2015)

5.277 Building 91, looking east (Photograph RCG&A 2015)

5.278 Building 91, looking north (Photograph RCG&A 2015)

5.279 Building 111, looking southeast (Photograph RCG&A 2015)

5.280 Building 111, looking northwest (Photograph RCG&A 2015)

5.281 Building 112, looking southwest (Photograph RCG&A 2015)

5.282 Building 112, looking south (Photograph RCG&A 2015)

5.283 Building 131, looking southeast (Photograph RCG&A 2015)

5.284 Building 131, looking northwest (Photograph RCG&A 2015)

5.285 Maintenance and Staging Yard, looking southwest (Photograph RCG&A 2015)

5.286 Maintenance and Staging Yard, looking north (Photograph RCG&A 2015)

5.287 Maintenance and Staging Yard, looking northwest (Photograph RCG&A 2015)

5.288 South gate off Compton Road (Photograph RCG&A 2015)

5.289 North gate to King Avenue (Photograph RCG&A 2015)

5.290 North gate to King Avenue (Photograph RCG&A 2015)

5.291 Anderson Ditch, northwest of Building 81, looking northwest (Photograph RCG&A 2015)

5.292 Anderson Ditch, between Building 81 and Building 1, looking southeast
(Photograph RCG&A 2015)

5.293 Anderson Ditch, between Building 81 and Building 1, looking southeast (Photograph RCG&A 2015)

5.294 Anderson Ditch, east of Building 33, looking south (Photograph RCG&A 2015)

5.295 Anderson Ditch, east of Building 33, looking north (Photograph RCG&A 2015)

Chapter 6.0

Evaluation Results

This chapter presents a summary of the analysis of archival and architectural data applying the NRHP Criteria for Evaluation (36 CFR 60 [a-d]. Buildings, objects, and landscape features contained on the NIST campus were assessed individually and collectively for significance and integrity within important themes and time periods. This chapter also includes a discussion of the integrity necessary for a resource to reflect its significance.

6.1 National Register of Historic Places Criteria for Evaluation

Built resources are evaluated for their potential as historic properties applying the NRHP criteria for significance and integrity found in 36 CFR 60 (a–d). To be listed, or considered eligible for listing, in the NRHP, a cultural resource must meet at least one of the four following criteria:

- **Criterion A**: The resource is associated with events that have made a significant contribution to the broad pattern of history.
- **Criterion B**: The resource is associated with the lives of people significant in the past.
- **Criterion C**: The resource embodies distinctive characteristics of a type, period, or method of construction; represents the work of a master; possesses high artistic value; or represents a significant and distinguishable entity whose components may lack individual distinction.
- **Criterion D**: The resource has yielded, or may be likely to yield, information important in prehistory or history.

In addition, the NRHP has established Criteria Considerations. Ordinarily, cemeteries, birthplaces, or graves of historical figures; properties owned by religious institutions or used for religious purposes; structures that have been moved from their original locations; reconstructed historic buildings; properties primarily commemorative in nature; and properties that have achieved significance within the past 50 years shall not be considered eligible for the NRHP. However, such properties will qualify if they are integral parts of districts that do meet the criteria or if they fall within the following categories:

(a) A religious property deriving primary significance from architectural or artistic distinction or historical importance; or
(b) A building or structure removed from its original location but which is significant primarily for architectural value, or which is the surviving structure most importantly associated with a historic person or event; or
(c) A birthplace or grave of a historical figure of outstanding importance if there is no appropriate site or building directly associated with his productive life; or
(d) A cemetery that derives its primary significance from graves of persons of transcendent importance, from age, from distinctive design features, or from association with historic events; or
(e) A reconstructed building, when accurately executed in a suitable environment and presented in a dignified manner as part of a restoration master plan, and when no other building or structure with the same association has survived; or
(f) A property primarily commemorative in intent if design, age, tradition, or symbolic value has invested it with its own exceptional significance; or
(g) A property achieving significance within the past 50 years if it is of exceptional importance.

The NRHP also defines seven aspects of integrity to determine if a resource retains the ability to convey significance: location, design, setting, materials, workmanship, feeling, and association (U.S. Department of Interior 1997:44). Not all seven aspects are required for eligibility, but the property must retain the integrity necessary to convey its significance. Resources must possess overall historical integrity as well as significance to qualify for NRHP eligibility. Each building at

DoC Boulder Labs was evaluated for integrity individually; the buildings also were evaluated for integrity as a group.

Additional relevant guidance, particularly that associated with NASA and GSA, regarding resources from the recent past and scientific facilities are discussed in Chapter 2.

6.2 Property Evaluations

The following is a summary of the evaluation of individual built resources on the DoC Boulder Labs property. The discussion begins with built resources that do not possess the significance or integrity necessary for listing in the NRHP. This is followed by a discussion of the built resources at DoC Boulder Labs that do possess the significance and integrity necessary for listing in the NRHP. This discussion provides information from the archival record that supports significance for these historic properties.

6.2.1 Built Resources of DoC Boulder Labs That Do Not Possess the Significance and Integrity Required for NRHP Consideration

6.2.1.1 Resources Less than 50 Years of Age

Several of the built resources at DoC Boulder Labs are less than 50 years of age, the general age requirement for consideration for listing in the NRHP. NRHP technical guidelines provide for exceptions to the 50 year general age requirement for resources of unusual importance. Built resources less than 50 years of age must satisfy Criteria Consideration G for exceptional significance. None of the built resources at DoC Boulder Labs that are less than 50 years of age meet the threshold of exceptional significance required under Criteria Consideration G. Although these resources do not currently meet the NRHP technical and substantive listing requirements, additional scholarly investigation on the historic significance of buildings constructed in the closing years of the twentieth century and the early years of the twenty-first century may result in recognition at a later time. Such scholarship requires the historical perspective generally associated with the 50-year age guidance for assessing resources.

Resources at DoC Boulder Labs that are less than 50 years of age include: Annex C of Building 1, Annex D of Building 1, Annex E of Building 1, Annex F of Building 1, Building 2A, Building 3A, Building 12, Building 23, Building 24, Building 25, Building 26, Building 27, the Antenna Field, Building 33, Building 34, Building 42, Access Tunnels for Utility Corridor, Building 51, the Vehicle Check Building, the Guard House, Building 81, Building 91, Building 111, Building 112, Building 131, the Maintenance and Staging Yard, and the Gates to the north and south residential areas.

Of the buildings at DoC Boulder Labs that are less than 50 years of age, Building 33 is the most architecturally distinguished due to its massing and scale. The building also was designed by a noteworthy contemporary architecture firm, Denver-based Fentress Architects. Although designed by a nationally respected architect, Building 33 does not represent the architectural paradigm expressed in Fentress' best known example to date—the main terminal of Denver International Airport (DIA). Lacking distinctive structural and ornamental elements, such as DIA's undulating roofline accented by spires, Building 33's horizontal emphasis, lack of structural and ornamental detail, and nearly-linear footprint is typical of industrial/commercial/institutional buildings of the late-twentieth century. As noted above, fifty years generally is considered the time frame necessary to enable the scholarly assessment of the relative significance of an architect's body of work. An examination of Fentress' other architectural work through time would be necessary to better illustrate his design philosophy and creativity. Based on NRHP evaluation criteria for resources less than 50 years of age, Criteria Consideration G, Building 33 does not meet the threshold of exceptional significance as either a distinctive representation of an architectural style, or as a paramount example of an individual's profession.

6.2.1.2 Resources 50 Years of Age or Older

Three utilitarian buildings at DoC Boulder Labs are over 50 years of age. These include Building 9 (constructed 1958), Building 21 (constructed 1963), and Building 22 (constructed

1964). These buildings feature functional designs with minimal architectural elaboration as appropriate to their use as warehouses, utility facilities, and maintenance and storage facilities. These buildings serve a support function on the facility. Their design, use, and operation are not associated with a significant event or person and while recognizable as utilitarian buildings, they do not possess significance for the quality of their architectural design. As a result, Building 9, Building 21, and Building 22 do not meet the criteria necessary to be eligible for listing in the NRHP (36 CFR 60 [a–d]).

Two additional buildings at DoC Boulder Labs are over 50 years of age, but do not necessarily fit into the category of utilitarian support for the facility, Building 8 and Building 11. Building 8, constructed in 1953, is located within Research Zone 2. It serves as a remote control room for the Materials Reliability Division. The building was relocated from Lawrence Road to its current location during the 1960s; it was remodeled following the relocation. As a relocated building, it must satisfy NRHP Criteria Consideration B for consideration as an historic property. In order for a moved property to retain significance it must be "significant primarily for architectural value" or be "the surviving property most importantly associated with a historic person or event" (NPS n.d.:29). Building 8 does not possess the architectural values necessary to satisfy the Criterion. In addition, its use is not associated with a significant event or person. As a result, Building 8 does not meet the criteria necessary to be eligible for listing in the NRHP (36 CFR 60 [a–d]).

Building 11, constructed in 1958, also is located within Research Zone 2. It currently is used for miscellaneous storage and as an ultra-low frequency receiver. Its use is not associated with a significant event or person. It addition, it lacks the character-defining features necessary to be considered eligible for its architecture. As a result, Building 11 does not meet the criteria to be considered eligible for listing in the NRHP (36 CFR 60 [a–d]).

6.2.2 Built Resources of DoC Boulder Labs That Possess the Significance and Integrity Necessary for National Register Listing

6.2.2.1 Building 1 (Historic name Radio Laboratory; CO SHPO Resource # 5BL588)

The Los Angeles, California, architecture and engineering firm Pereira & Luckman was selected to design Building 1; Robert William Ditzen of Boulder and Jesse Earl Stanton of Beverly Hills, California, served as associate architects (See Appendix B, Architects). The building was completed in 1954. Plans for the building were made available to the public in March 1952. As recounted in *Achievement in Radio, Seventy Years of Radio Science, Technology, Standards, and Measurement at the National Bureau of Standards*, Hugh Odishaw, assistant to the Bureau's director Dr. Edward Condon, was influential in the development of the final design for Building 1. Odishaw encouraged a design that would allow the building to blend into the surrounding landscape, with "terraced sets of low-profiled wings spreading out from a central spine and set upon the sloping terrain with a backdrop of spectacular foothills (the Flatirons)" (Snyder 1986:713).

The final publicized design "called for a reinforced concrete structure with stone facings in the main entrance area. The six wings were one-story structures (with clerestory roof design), three on each side of a central spine. The central unit or spine was four stories high in front and two at the rear, shaped to a sloping terrain" (Snyder 1986:713). In June 1952, the contract for construction of Building 1 was awarded to Olson Construction Company of Denver, Colorado. To reduce the cost of construction, two of the wings included in the original design were eliminated from the plans (Snyder 1986:715).

In 1954, *The Boulder Daily Camera* issued a special section "Dedicated to the National Bureau of Standards" to highlight the dedication of the Boulder campus by President Eisenhower. The section featured articles on the dedication and a lengthy description of the Radio Laboratory:

> The building contains more than 200 interior units used for radio laboratory work, administrative offices, service facilities, an auditorium, and a library. It features concrete sun shades over all windows to block off direct rays of sun yet still provides sufficient natural light. Portions of the building built underground are being air conditioned. A four story central spine with four single story wings outlines the design of the laboratory. The building faces northeast, and provision has been made for two additional wings on the southwest end if needed. Since the structure is built on sloping ground Wings 1 and 2, lead off the second floor level and Wings 3 and 4 off the third floor level of the central spine. Entrance to the building is made at the north end of the first floor level. Directly ahead the doors is the reception desk, while to the right of the wood-paneled entrance is a 534 seat auditorium to be used for scientific lectures. To the left of the entrance passage is the library. An east-west corridor separates the library and auditorium from the purchasing and personnel offices and lecture rooms. Steps beside the reception desk lead down to the lower level and up to the second floor. The lower level, a space of 10,000 square feet houses the boiler room, transformer room, locker room, and space which may eventually be made into a cafeteria but is used now as a snack bar (*The Boulder Daily Camera* 1954a:n.p.).

Pereira, Luckman, Ditzen, and Stanton were awarded the Award of Merit for the design of the building from the AIA in 1954 (Snyder 1986:713). Pereira cited the building as one of his notable works in his nomination form to become an American Institute of Architects (AIA) Fellow in 1957. He included Building 1 as one of ten distinguished designs and elaborated on the most interesting features of the project:

> The development of three kinds of space, each of which had a considerable variation in cost and use, that have been successfully resolved into a contiguous plan. The public facilities (non-security) are at the front in a simple rectangle; the small laboratories and offices for the scientists are located in the spine; and the shops are located in the wings. The grade was used to solve circulation problems of equipment and people (note the connection between the wings and the spine at various levels). In order to make the building work on the site, it was necessary to orient the spine East and West to eliminate glare and provide sun control. The sunshades as shown are formed concrete and are part of the structure (AIA 2015:n.p.).

Two years after the completion of the Radio Laboratory, construction of Wing 6 began. The wing was constructed for the Electronic Calibration Center and was completed in 1959. James M. Hunter of Boulder was the architect for the wing and construction was completed by the Denver Regional Office of the GSA. Wing 5 was completed in 1962 for the Computation Facility (Snyder 1986:716; Wilkes 1964:3; *Boulder Daily Camera* n.d.:n.p.).

In 1994, an intensive cultural resource inventory of the DoC Boulder Labs campus was completed as part of consulting services provided by Larson-Tibesar Associates, Inc. and Gulf Engineers and Consultants through the U.S. Army Corps of Engineers, Omaha District (Larson 1994:1). A report was generated as a result of this investigation, *Results of an Intensive Cultural Resource Inventory of the Boulder NIST Site, Boulder, Colorado*. At the time of the Larson investigation, none of the buildings constructed at NIST were 50 years of age or older, as generally required for consideration for listing in the NRHP. As explained in the report, NRHP technical guidelines provide for exceptions to the 50 year general age requirements for buildings of special importance.

The report recommended that the Radio Building (Building 1) met the criteria for NRHP consideration under Criterion A for its association "with events that have made a significant contribution to, and are identified with, or that outstandingly represent, the broad patterns of United States history and from which an understanding and appreciation of those patterns may be gained [e.g.,… American at the forefront of the development of new sciences and technology…]." The report further recommended that the NIST facility be assessed for eligibility under Criterion B for its association with individuals important in our history. Furthermore, the report recommended: that the Colorado SHPO "be asked to comment on the general stance taken in this report regarding the significance of this facility"; that "a decision be made as to whether the buildings should be recorded one at a time or whether a National Historic Landmark or NRHP District designation might be the most appropriate method of recognition"; and that a decision be made "whether the final recording of the NIST facility should take place immediately or wait until the first buildings on the site reach an age of 50 years" (Larson 1994:27-28). No additional documentation or SHPO correspondence was associated with the report.

In 1996, an Environmental Impact Statement (EIS) was developed by the GSA in cooperation with the U.S. Department of Commerce NIST as a result of the proposed construction of buildings and the renovations of facilities at the DoC Boulder Labs campus. Chapter 2 of the EIS, "Affected Environment," addressed cultural resources and noted: "some of the campus buildings are considered to be historically important. Specifically, the Liquefier Building and Laboratory (Building 3), the cryogenics Laboratory (Building 2), the Camco Building (Building 4) and the Radio Building (Building 1), could be considered for historic recognition" (U.S. GSA 1996a:2-13). Chapter 2 of the EIS summarized that "the Colorado SHPO feels the DOC campus is eligible for inclusion to the NRHP as an historic district. NIST is currently completing historic inventory reports on a number of buildings possibly contributing to the NIST historic district. The buildings are being reviewed by the SHPO under Criterion A, as important technological research and development facilities during the Cold War and Space Age period, and Criterion C, modern industrial design and function. The SHPO has indicated to GSA and NIST that they concur with a determination of No Adverse Effect for the construction of the proposed ATL and CUP and GSA/NOAA Building as they relate to the historic nature of the buildings and the proposed district" (U.S. GSA 1996a:2-16). No additional documentation was located to specifically define the proposed historic district at DoC Boulder Labs or to further explain the inventory reports discussed.

Cultural resources also are addressed in Chapter 4 of the 1996 EIS, "Proposed Upgrade of NIST Facilities." Chapter 4 noted, "there will be no adverse effect on historic resources as the result of the proposed NIST facility upgrades" and identified Buildings 1, 2, 3, and 4 as eligible for inclusion in the NRHP and contributing to "the historic district" (U.S. GSA 1996a:4-13). Once again, the proposed historic district is not specifically defined. Neither a period of significance nor proposed boundaries for the district are detailed within the EIS.

As part of the review process for the 1996 EIS, a Record of Decision was established in 1996 for the "Proposed Federal Building for National Oceanic and Atmospheric Administration, Boulder, Colorado." Section 4.0, "Potential Environmental Issues," discusses cultural resources and notes that "the Colorado SHPO has concurred that implementation of the preferred alternative will have no adverse effect on the potential NIST historic district…" (U.S. GSA 1996b:9). An additional Record of Decision for the "Proposed Upgrade of NIST Facilities and Master Site Development Plan for NIST, Boulder, Colorado" also was completed in 1996. Section 4.0, "Potential Environmental Issues," discusses cultural resources and notes that "the Colorado SHPO feels that the DOC campus is eligible for nomination to the NRHP. Several buildings on the campus are considered to be important and eligible for this nomination: the Radio Building (Building 1), the Cryogenics Laboratory (Building 2), the Liquefier Building (Building 3), the laboratory associated with the Liquefier Building, and the Camco Building (Building 4)" (U.S. GSA 1996c:10).

The earliest known documentation of Building 1 on file with the Colorado SHPO is an architectural inventory form (5BL588), which was completed by Diane Wray in 2000 as part of *Modern Architectural Structures in Boulder: 1947 – 1977, Context and Survey Report* (Paglia, Segal, and Wray 2000). This report was the result of a survey of modern architecture throughout Boulder and according to the research design, "the objectives of the survey were to define the historic context of the development of Modern architecture in Boulder from 1890 to 1977" (Paglia, Segal, and Wray 2000:19). Specific resources were selected based on their representation of a particular architectural style. In this case, according to the documentation, Building 1 at DoC Boulder Labs represents the International Style of architecture (Paglia, Segal, and Wray 2000:20 and table). Although the report did not address eligibility, the resulting inventory form includes a description and statement of significance for DoC Boulder Labs. The text within the form is specific to Building 1. It is assumed that the "National Bureau of Standards" discussed in the text of the inventory form specifically refers to Building 1 only. According to the text:

> The National Bureau of Standards is significant because it is the work of the California architectural firm of Pereira and Luckman Associates...The National Bureau of Standards is significant for the high standard of the construction craft. The building is almost entirely formed from well executed cast-in-place concrete walls. Accent walls at the front entrance are clad in field stone. The random layering of the stone is inspired, and the mortar joints have been finely done. The National Bureau of Standards is significant for its association nationally with American intellectual history, technology, engineering, science and research. The National Bureau of Standards is significant for the relationship of the complex to the topography of its site. The complex is located on a gently sloping meadow that slowly rises toward the west. The complex is set above Broadway with the Flatirons in the background. The National Bureau of Standards is significant for its relationship to associated landscape design. The building is sited at an angle to Broadway, set behind a landscaped lawn partially defined by concrete driveways. Specimen trees and bushes on the grounds are typically native Colorado species including Colorado Blue Spruce and various types of pine and juniper. The National Bureau of Standards is significant for the extensive and thus distinguishing use of cast-in-place concrete. The National Bureau of Standards is significant for the appearance of natural stone walls, a prominent feature in Boulder's architecture that relates to the University of Colorado campus and to many historic buildings off-campus. The National Bureau of Standards is significant for its location on a prominent city street and because it constitutes an outstanding landmark in the surrounding landscape (Wray 2000:3).

Although Building 1 was not 50 years old or older during the time of the survey, the inventory form notes that it:

> also satisfies Criteria Consideration G, achieving significance within the past fifty years due to its exceptional significance. This exceptional significance is defined by its integral relationship to the post-war development of Modern architecture in Boulder, a movement which has received extensive press coverage; by comparison with other Modern architecture of the post-war period in Boulder; and as documented by an ever-increasing body of scholarly evaluation on the historical importance of Modern architecture which developed during the post-war period (Wray 2000:3).

No correspondence from the Colorado SHPO or notes on the inventory form from Colorado SHPO exist to indicate a concurrence with the specific language within the form.

The NRHP defines seven aspects of integrity to determine if a resource retains the ability to convey significance: location, design, setting, materials, workmanship, feeling, and association (U.S. Department of Interior 1997:44). Building 1 has undergone renovations since 2000, primarily including changes to Wings 3 and 6. The changes have included replacement windows and replacement wall materials. Although these changes have been made, Building 1 retains the integrity necessary to convey significance as an example of modern architecture. The 1996 EIS indicates that the building was being reviewed by SHPO for significance under Criterion C for "modern industrial design and function" (U.S. GSA 1996a:2-16). The 2000 Wray inventory form for Building 1 supports eligibility under Criterion C (Wray 2000:3). According to the *Modern Architectural Structures in Boulder: 1947 – 1977, Context and Survey Report*, the building reflects the characteristics of the International Style of architecture. Distinctive characteristics of the style include "horizontally oriented, large areas of glazing, use of industrial materials like concrete and aluminum, no ornament, walls eaveless or with overhanging eaves, and flat roofs" (Paglia, Segal, and Wray 2000:70, 65).

Previous discussions of the building included in various documents indicate that it derives its significance from the events that took place within the building and for representing important technological research and development facilities during the Cold War and Space Age period. Building 1 was constructed to house the CRPL and currently is used for ongoing research projects. The use of the building and individual laboratories within it changed over time as funding and research needs dictated. In order to be eligible under Criterion A, the building must be associated with a specific event or patterns of events and it must retain integrity to reflect the period during which these events took place. The NRHP clarifies that “mere association with historic events or trends is not enough, in and of itself, to qualify under Criterion A” and that “a property is not eligible if its associations are speculative” (NPS n.d.:12). Although successive atomic clocks have been housed within Building 1, the building was not specifically designed for that use. The first atomic clock was moved to Building 1 in 1954. Although work to increase the precision of the atomic clock was completed within Building 1, the building was not specifically constructed for that purpose and the areas used for research no longer retain integrity from that period. In addition, the CRPL was dis-established in 1965. Continued use of Building 1 for other research has resulted in substantial changes to the interior of the building. As a result, Building 1 no longer appears eligible under Criterion A for representing important technological research and development facilities during the Cold War and Space Age period; however, Building 1 does reflect the broad patterns of an agency’s history.

Building 1 was constructed during a period of NBS growth and expansion. NBS desired new facilities to accommodate expanded research programs and this was not possible at its Washington, D.C. location. A nationwide search was completed in order to locate the new campus in an ideal environment that allowed room for expansion. The citizens of Boulder and the Boulder Chamber of Commerce launched a concerted campaign to secure the new NBS radio laboratory. When it was completed, it was the flagship building of the Boulder site and it was highly visible from the public highway. Through the construction of Building 1, NBS was able to move forward with expanded research, but it also was able to identify themselves as a progressive and modern agency. As a result, Building 1 appears to be eligible for listing under Criterion A for representing the broad patterns of an agency’s history.

Building 1 has been grouped with Buildings 2, 3, and 4/5 in previous discussions of a potential historic district; however, its eligibility is not tied to the same context as the buildings constructed in 1951 to support the AEC hydrogen program. Archival research indicated no association with Building 1 and Buildings 2, 3, 4/5 in function or mission. The buildings are only associated based upon their location on the DoC Boulder Labs campus. As a result, Building 1 does not appear to be a contributing building to an historic district on the campus. Building 1 was the only building on the Boulder campus designed by Pereira & Luckman. At the time of its construction, Building 1 was the flagship building of DoC Boulder Labs. The use of elements of the International Style of architecture were considered cutting edge for the period. In addition, the design of the building incorporates elements typically associated with post World War II research buildings, including consolidation of all activities into a single building, low scale, “use module” design for the laboratory wings, and expansive parking. As a result, Building 1 possesses the significance to be individually eligible for listing in the NRHP under Criterion C with a period of significance of 1954 to 1965. This period covers the completion of the main section of the building along with Wings 1 through 6 and also corresponds to the period during which Building 1 was used for its intended purpose as CRPL. The Colorado SHPO found Building 1 “eligible for listing on the National Register of Historic Places under Criterion A (History) and possibly for Criterion C (Architecture and Engineering)” (Turner 2016). The SHPO correspondence is presented in Appendix C.

The character-defining architectural features of Building 1 include the use of stone and poured concrete for the primary mass of the building that includes the lobby area, auditorium, and library. The concrete sunshades used above windows within the spine and wings of the building also are considered character-defining architectural features of the Building. In addition, the overall configuration, massing, and scale of Building 1 as a large singular built resource with expansive wings designed to house laboratories, offices, a library and an auditorium is considered a character-defining feature.

6.2.2.2 Building 2 (Other Names: Cryogenic Building, Building “B”)

Building 3 (Other names: Building “A”, Liquefier Building)

Building 4 (Other names: Camco Building, Building "C", Facilities Office)

Building 5 (Other names: Camco Annex, Heavy Equipment)

Buildings 2, 3, 4/5 (Building 2, Cryogenics Laboratory; Building 3, Liquefier Building; Building 4/5, Camco/Heavy Equipment Building) were the first three buildings constructed on the current-day DoC Boulder Labs campus. The buildings were constructed in 1951 and were designed for the AEC Santa Fe Operations Office in Los Alamos, New Mexico by Stearns-Roger Manufacturing Company, Denver, Colorado (Drawings courtesy of NIST Boulder). As explained in the U.S. Department of Commerce publication *Achievements in Radio, Seventy Years of Radio Science, Technology, Standards, and Measurement at the National Bureau of Standards*:

> …in the spring of 1951, on March 28, the NBS announced that a cryogenics laboratory would be built on the new Bureau site in Boulder…later in the spring of 1951 construction began on the cryogenics laboratory building, funded by the AEC, to be known as the Liquefier Building or Building 'A,' [currently Building 3] and used for a highly classified project for the AEC. Shortly thereafter a second building, known as Building 'B,' [currently Building 2] was constructed as a laboratory facility associated with the same project. The two buildings housed the Cryogenics Engineering Section, later to become a division of NBS, and to be known as the Cryogenic Engineering Laboratory. A third building, a very large frame building to be known as the 'Camco' Building ['Camco' was an abbreviation for the Cambridge Corporation; currently Building 4; Building 5 is shown as a 'Butler Building' on the original drawings from the U.S. Atomic Energy Commission] was constructed by the AEC for use by the Cambridge Corp., a private contractor. Later it became known publicly that these facilities served for certain operations of the AEC hydrogen-bomb project (Snyder and Bragaw 1986:715).

The three buildings as a group were considered the NBS Cryogenic Engineering Laboratory/Division at Boulder. Russell B. Scott was named the first chief of the Cryogenic Engineering Laboratory at Boulder (Sloop 1978:68). Scott served as the Director of the Boulder Cryogenics Laboratory from 1952 to 1962; he was Director of NBS Boulder Laboratories from 1962 to 1965 (Kropschot 2001:110). The hydrogen/deuterium liquefier equipment for the Boulder laboratory was created at the NBS Van Ness campus in Washington, D.C. and then was transported to the Boulder facility. Four hydrogen/deuterium liquefiers were built. Two were created by Stearns Roger Engineering for the Boulder site; one was created for the Eniwetok Atoll testing site; and, one was created to be used for parts (Kropschot 2001:107). Each had a capacity of 320 liter/hour hydrogen/deuterium. The liquefiers at Boulder were in operation by March 1952. The liquid deuterium created at the Cryogenic Engineering Laboratory was used for the 1952 hydrogen bomb tests held at Eniwetok Atoll (Passaglia 1999:186). Two water electrolyzers were assembled at the Boulder facility and heavy water was brought to the site from Canada; both were necessary for the production of deuterium. The deuterium produced at Boulder was "compressed into high-pressure tanks and shipped to the atomic proving station on Eniwetok in the Marshall Islands where it was condensed using the NBS liquefier" (Kropschot 2001:107). In addition to providing liquid hydrogen for the testing at Eniwetok, the Boulder facility also provided liquid hydrogen for component testing at Los Alamos. The hydrogen was transported using dewars that were fabricated by the Cambridge Corporation; Cambridge Corporation and Los Alamos were responsible for fabricating and testing dewars prior to transport. In spring 1952, Herrick Johnston, who became the director of installations for the cryogenic equipment at Eniwetok, visited the labs at Boulder to hone his skills in liquefier fabrication and procedures (Kropschot 2001:107-108).

The following November, Eniwetok Atoll "was evacuated of all personnel, and the 'ivy MIKE' shot was detonated. It was the first hydrogen thermonuclear device and was regarded as extremely successful, yielding 10.4 megatons of TNT equivalent and providing scientific data for future tests and development of weapons" (Kropschot 2001: 108). In 1953, staff from the Cryogenic Engineering Division at Boulder, including Scott, received the Department of Commerce Gold Medal for "the design, construction and operation of large and unique hydrogen and nitrogen liquefiers" (Kropschot 2001:108).

The type of fuel used in the hydrogen bomb was debated. By 1954, it was determined that liquid deuterium was not ideal and AEC ceased their support of the cryoengineering program. This did not put an end to the Cryogenic Engineering Division at Boulder. Experiments on low-temperature continued at Boulder for the Army, Navy, and Air Force. In 1955, the Division began a program specifically to research cryogenic engineering and to assess its general use (Passaglia 1999:186-187; Scott 1959:4). According to a September 1954 article in *The Boulder Daily Camera*, the cryogenic laboratory "was designed to provide the facilities for the development and evaluation of equipment for use at temperatures near absolute zero or the theoretical point on the temperature scale where absolutely no heat is present" (*The Boulder Daily Camera* 1954b:22). The article specifically references Building "A" as a "liquefaction plant" and explains that the building featured specific safety measures for the protection of employees, including "hydrogen gas indicators [that] sound an alarm and close off all sources of explosive hydrogen gas when the hydrogen gas concentration reaches 10 per cent of the lower explosive limit" (*The Boulder Daily Camera* 1954b:22).

In 1956, the creation of a hydrogen-fueled supersonic airplane was being explored by a private aircraft designer on behalf of the Air Force. While continuing his work for NBS in Boulder, Russell Scott became a consultant for the project. The Boulder Cryogenic Laboratory provided liquid hydrogen for the experiments, "when larger quantities were needed for tank flow and spill tests" (Sloop 1978:142, 147). By 1958, the Cryogenic Engineering Laboratory included "projects in experimental and theoretical physics, such as the investigation of the thermal conductivities of pure metals and dilute alloys, to projects with immediate practical objectives, such as the study of the behavior of the liquid oxygen propellant used in a Jupiter missile" (*The Bureau Drawer* 1958:3).

During the early 1960s, staff with the Cryogenic Engineering Laboratory at Boulder served as consultants for the NASA, General Dynamics/Astronautics, and Pratt and Whitney Aircraft on the Atlas-Centaur project. Scientists at the Boulder laboratory were instrumental in harnessing hydrogen for use as fuel for the upper stages of the launch vehicle. According to the NASA publication *Liquid Hydrogen as a Propulsion Fuel, 1945-1959*, "the decision to use liquid hydrogen in developing the nation's largest launch vehicle was particularly bold, for many experienced engineers doubted the advisability of using a highly hazardous fuel associated with the *Hindenburg* disaster of 1937" (Sloop 1978:xiii). Liquid hydrogen was considered difficult to store and handle and although it had been studied as a fuel in the past, the idea was routinely abandoned. Until 1952, liquid hydrogen was used only in laboratory experiments. The plant created at Boulder under the auspices of AEC enabled further research necessary to enhance the uses of liquid hydrogen (*The Bureau Drawer* 1963b:7). The work of Scott and his staff at Boulder "advanced the state-of-the-art to the point that rocket engineers realized that it was feasible to use hydrogen as a fuel" (*The Bureau Drawer* 1963b:7). As a result, hydrogen became "just another flammable liquid that could be handled and used safely with reasonable caution" (Sloop 1978:xiii). In November 1963, after several failed launches, NASA successfully launched an Atlas-Centaur; it was the "first in-flight burn of a liquid-hydrogen/liquid-oxygen engine" (NASA 2012:n.p.).

Buildings 2, 3, and 4 were previously recommended potentially eligible for listing in the NRHP as contributing buildings to an undefined historic district at the DoC Boulder Labs campus. Although Building 5 previously has not been included within discussions of the undefined historic district, it is assumed that, due to its physical connection to Building 4 and indications that it also was created as part of the AEC efforts at Boulder, that Building 5 is considered along with Building 4 for the potential district.

Building 2 has undergone several modifications and additions since its construction. In 1964, Wing 'B' was added to the building. As described in the architectural description and illustrated through photographs, this addition altered the historic plan of Building 2 and introduced new materials to the exterior of the building. Later, the addition of the High Bay in 1986 altered the overall scale and massing of the building. As a result, the building no longer retains integrity of design, materials, workmanship, feeling, and association from its period of construction; as a result, Building 2 does not retain the integrity necessary to be eligible for listing in the NRHP under Criterion C as an individual resource.

The modifications to Building 3 include window replacements, infilled bays, removed monorail frames, an addition, and alterations to the primary entry. These alterations have diminished the architectural integrity of the building; as a result, Building 3 does not does not retain the integrity necessary to be eligible for listing in the NRHP under Criterion C as an individual resource.

Similarly, Buildings 4/5 have undergone modifications, including window alterations and cladding. Building 4, originally clad in wood, is now covered in textured metal panels. Building 5, originally clad in vertical corrugated metal is now covered in horizontal textured metal panels. Windows have also been reconfigured throughout both buildings. As a result, Buildings 4/5 no longer retain integrity of design, materials, workmanship, feeling, and association from their period of construction. Buildings 4/5 do not retain the integrity necessary to be eligible for listing in the NRHP under Criterion C, as an individual resource.

Changes over time to Buildings 2, 3, 4/5 have impacted their original architectural design; these changes include infilled bays, replacement windows, replacement wall materials, and the removal of certain architectural elements and equipment. The Colorado SHPO recently confirmed that, despite “the role it played in the development of liquid hydrogen as a rocket fuel,” Building 3’s “lack of architectural integrity diminishes the ability of the building to be considered eligible for the National Register” (Nichols 2015). Because the Colorado SHPO found that Building 3 is not NRHP eligible, the other resources associated with the AEC efforts at Boulder, including Buildings 2 and 4/5, also are not individually NRHP eligible or contributing resources to a historic district. The SHPO correspondence is presented in Appendix C.

6.2.2.3 Anderson Ditch

Anderson Ditch is a manmade irrigation ditch completed in 1860. It travels through the DoC Boulder Labs campus traveling southeast-northwest. The 1993 Butler report recommended that the Anderson Ditch be considered eligible for listing in the NRHP under Criterion D “as being capable of yielding information important to history” and potentially for Criterion A for its association “with agricultural events that have made a significant contribution to the Anglo-American settlement and growth of Colorado.” Also, the report recommended that the Ditch may be eligible under Criterion B “in that the ditch was associated with individuals important to the development of Boulder, Colorado. In addition, the report recommended that the Ditch be considered eligible under Criterion C for embodying “distinctive characteristics of a method of construction associated with early historic irrigation systems” (Butler 1993:18).

The 1994 Larson report also discusses the Anderson Ditch, but clarifies that the “scope of work for this project specifically exempts the Anderson Ditch from additional study except for identifying it on project maps”; as a result, the report does not discuss its eligibility (Larson 1994:3). In 13 September 1994 correspondence referencing the Larson report, the Colorado SHPO stated that “the NIST campus has been determined to be eligible for the NRHP under Criteria A and C for its exceptional significance” and included Anderson Ditch as part of a potential historic district (Hartmann 1994a).

According to the 1996 *Environmental Impact Statement GSA/NIST Proposed Actions Boulder, Colorado, Volume 1,* the Anderson Ditch was considered a “potential historic resource.” As stated in the EIS, “The Colorado SHPO has agreed to a determination of ‘No Adverse Effect’ on Anderson Ditch from the proposed construction of the NOAA building. The SHPO has also reviewed NIST’s plans to relocate the northern channelized portion of the Ditch, and has tentatively agreed to a ‘No Adverse Effect’ determination” (for construction of the ATL, currently Building 81). The EIS clarified that there would be no adverse effect to the Ditch caused by the construction of the new NOAA building (currently Building 33) "provided that GSA protects the ditch during construction activities, and restores any alignment and/or wall disturbances resulting from placement of utility lines beneath" (U.S. GSA 1996a:2-16 and 3-33).

The 1996 Record of Decision for the proposed construction of the NOAA building confirmed that the Anderson Ditch was eligible for the NRHP and that the proposed project would not have an adverse effect (U.S. GSA 1996b:9).

Appendix A of the EIS provides a record of comments and responses to the draft EIS. One comment/response specifically discusses the eligibility of the Anderson Ditch. A question from Anne Fenerty, Chair of the Enchanted Mesa, asks "why is the Anderson Ditch not included in the National Register of Historic Places?" (U.S. GSA 1996a:Appendix A:0078). The response from the agency to Fenerty's question states "The State Historic Preservation Officer has identified that part of Anderson Ditch south of Lawrence Road for eligibility to the Register, but it has not yet been nominated by the property owner, the New Anderson Ditch Company, for inclusion in the NRHP. The portion of the ditch north of Lawrence, having been significantly altered at the time NIST's Building 1 was built, is not believed to be eligible for the Register" (U.S. GSA 1996a:Appendix A:00103). No SHPO correspondence was identified to clarify or further explain this statement. Portions of Lawrence Road were rerouted and renamed during the late 1990s; sections once known as Lawrence are now Compton Road or Rayleigh Road (Passaglia 1999:781).

A review of previous documentation related to Anderson Ditch indicates that the Ditch is considered eligible for listing in the NRHP. Colorado SHPO has concurred with eligibility, but no documentation discussing the specific applicable Criteria or a boundary for the resource has been located. Future consultation with the Colorado SHPO may be required to more definitively define the NRHP-eligible sections of the Anderson Ditch.

6.3 Summary and Conclusion

The built resources contained within the DoC Boulder Labs campus were analyzed applying the NRHP Criteria for Evaluation (36 CFR 60.4[a-d]). The majority of buildings at DoC Boulder Labs are less than 50 years old, and were constructed between 1989 and 2013. None of the buildings at DoC Boulder Labs less than 50 years old appear to satisfy Criteria Consideration G for exceptional significance. Buildings at DoC Boulder Labs that are 50 years old or older include Building 1, Building 2, Building 3, Building 4/5, Building 8, Building 9, Building 11, Building 21, Building 22, and Anderson Ditch. Of these built resources, the Colorado SHPO confirmed the recommendation that Building 1 is individually eligible for listing in the NRHP under Criteria A and C (Turner 2016). Anderson Ditch has been determined eligible for listing in the NRHP, with a potential for significance under Criteria A, B, and C.

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APPENDIX A

LIST OF ACRONYMS

ACRONYMS

ACHP Advisory Council on Historic Preservation

AEC Atomic Energy Commission

AIA American Institute of Architects

ATL Advanced Technology Laboratory

CMU Concrete Masonry Unit

CRPL Central Radio Propagation Laboratory

CU-Boulder University of Colorado Boulder

CUP Central Utility Plant

DIA Denver International Airport

DoC Department of Commerce

EIS Environmental Impact Statement

ESSA Environmental Science Services Administration

FY Fiscal Year

GPS Global Positioning System

GSA General Services Administration

ICC Interstate Commerce Commission

IRPL Interservice Radio Propagation Laboratory

JILA Joint Institute for Laboratory Astrophysics

MOA Memorandum of Agreement

NASA National Aeronautics and Space Administration

NBS National Bureau of Standards

NEL National Engineering Laboratory

NHPA National Historic Preservation Act

NIST National Institute of Standards and Technology

NML	National Measurement Laboratory
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRHP	National Register of Historic Places
NTIA	National Telecommunications and Information Administration
PA	Programmatic Agreement
PML	Precision Measurement Laboratory
SEAC	Standards Eastern Automatic Computer
SHPO	State Historic Preservation Office
ULF	Ultra-Low Frequency

APPENDIX B

BACKGROUND INFORMATION ON ARCHITECTS

BACKGROUND INFORMATION ON ARCHITECTS

Robert William Ditzen was born in 1917 in North Dakota. In 1946, Ditzen received a B.S. in architecture from the University of Illinois. He served as a chief draftsman for James M. Hunter from 1946 to 1950. Ditzen organized his own firm, Robert W. Ditzen, in Boulder in 1950. Ditzen's designs included educational facilities, religious institutions, residential buildings and public buildings. In the early 1950s, he worked with the firm Pereira & Luckman as an associate architect on Building 1. His work as an associate architect on the Radio Laboratory appears to be his only professional connection to the Pereira and Luckman firm. In 1954 Pereira & Luckman, along with Ditzen, received a design honor award from the AIA for their work on the building. In 1961, Ditzen organized the firm Ditzen, Rowland, Mueller & Associates in Boulder. Ditzen passed away in 2006 (Bowker 1956:138; Bowker 1962:172; Ancestry 2015:n.p.).

Jesse Earl Stanton was born in San Francisco in 1887. He received a M.S. from the Beaux Arts School in 1915. Stanton primarily worked in California. His designs included housing projects, a women's prison, public buildings, military structures, and residential buildings. In the early 1950s, he worked with the firm Pereira & Luckman as an associate architect on Building 1. His work as an associate architect on the Radio Laboratory appears to be his only professional connection to the Pereira and Luckman firm. In 1954 Pereira & Luckman, along with Stanton, received a design honor award from the AIA for their work on the building. Stanton died in 1985 (Bowker 1956:530-531; Bowker 1962:668; AIA 2015a:n.p.).

William Leonard Pereira was born in Chicago in 1909. He received a B.S. in architecture from the University of Illinois in 1930. He was an associate with the law firm Holabird & Root in Chicago from 1930-1931. Pereira created an architecture firm in Chicago with his brother in 1931; the firm continued until 1943. Pereira eventually moved to Los Angeles while maintaining his affiliation with the Chicago firm. During the early 1940s, Pereira became interested in Hollywood. He was hired as an architect and art designer by Paramount Pictures. In 1943, William Pereira was one of four winners for special effects awarded by the Academy Awards for the Cecil B. DeMille directed movie "Reap the Wild Wind." Pereira created his own architecture firm in Los Angeles in 1944, William L. Pereira; the firm ended in 1950, when Pereira joined his University of Illinois classmate Charles Luckman to form the architecture and engineering firm Pereira & Luckman in Los Angeles. The new firm also specialized in master planning (Bowker 1956:428; Bowker 1962:544; Academy Awards 2015:n.p.; AIA 2015b:n.p.). In the early 1950s, the firm Pereira & Luckman began work on Building 1 for the National Bureau of Standards in Boulder. In 1954 Pereira & Luckman, along with associate architects Stanton and Ditzen, received a design honor award from the AIA for their work on the building (Bowker 1956:530-531). In 1958, the firm was dissolved. Pereira once again opened his own architecture firm, William L. Pereira and Associates. He continued to practice master planning. In 1963, Pereira was on the cover of Time Magazine due to his work on the Irvine Ranch Master Plan, a 93,000-acre property in Orange County, California; the Irvine Ranch property is regarded as "one of the largest and most successful master-planned urban environments in the United States" (AIA 2015b:n.p.; Irvine Company 2015:n.p.). He went on to work on prestigious architecture projects such as the Transamerica Tower in San Francisco, which was finished in 1972 and the University of California San Diego's Geisel Library completed in 1970. Pereira passed away in 1985 (AIA 2015b:n.p.).

Charles Luckman was born in Kansas City in 1902. He received a B.S. in architecture in 1931 from the University of Illinois. Following graduation, Luckman became a draftsman for advertising for a soap company. He eventually became president of the Pepsodent Company. In 1946, Pepsodent was purchased by Lever Brothers and Luckman became president of their American office. In 1950, following a disagreement with the company, Luckman left Lever Brothers. He moved to Los Angeles where he joined his University of Illinois classmate William Pereira to form the architecture and engineering firm Pereira & Luckman. In the early 1950s, the firm Pereira & Luckman began work on Building 1 for the National Bureau of Standards in Boulder. In 1954 Pereira & Luckman, along with associate architects Stanton and Ditzen, received a design honor award from the AIA for their work on the building (Bowker 1956:343). In 1958, the firm was dissolved. Luckman purchased his interest in the firm and began his own, Charles Luckman Associates. By 1961, Luckman Associates was one of the five largest architectural firms in the world. Luckman Associates went on to design the United States Pavilion at the 1964 World's Fair in New York, Madison Square Garden (1967), as well as several high profile buildings for banks, convention centers, hotels, and office buildings (Bowker 1970:560; AIA 2015c:n.p.). Luckman died in 1999 (Muschamp 1999:n.p.)

Pereira & Luckman, an architecture and engineering firm, was formed in 1950 in Los Angeles. Together, Pereira and Luckman worked on high profile projects, including: C.B.S. "Television City" (1952), awarded an AIA Honor Award and an Academy of Color and Design Award; J. W. Robinson's stores, Beverly Hills, Pasadena, and Palm Springs (1952), awarded an AIA Honor Award; Marineland of the Pacific in Palos Verdes, California (1954), awarded an AIA Honor Award; and, the IBM Building, Los Angeles (1958), given an Award of Merit by the Southern California Chapter of the AIA. The firm also was involved in several significant master planning projects, including the new Los Angeles International Airport, Cape Canaveral, and military bases in the U.S. as well as Spain. The firm received a Progressive Architecture Award for Design for the Los Angeles International Airport Master Plan in 1954. Pereira & Luckman began designing Building 1 for the NIST campus during the early 1950s. In 1954, Pereira & Luckman, along with their associate architects Stanton and Ditzen, received a design honor award from the AIA for their work on the building. In 1958, the firm was dissolved and Pereira and Luckman went their separate ways to form individual firms that continued to thrive (Bowker 1956:428; Bowker 1962:544; AIA 2015b:n.p.).

James M. Hunter was born in Omaha, Nebraska in 1908. He graduated with a Bachelor of Architecture from the University of Illinois in 1936. After graduation, Hunter moved to Boulder and began work as a draftsman. Between 1940 and 1945, he was a partner with the firm Huntington, Jones, and Hunter. Hunter formed his own architecture firm in Boulder in 1945. He completed projects for several college campuses and was instrumental in creating an architecture degree program at the University of Colorado in Boulder. Hunter completed several projects within the city of Boulder, including the public library, a high school, a masonic lodge, a medical center, and several residential buildings. In 1956 Hunter was named architect for the Wing 6 addition to Building 1. The wing was completed in 1958. In the early 1960s, he designed the addition for Building 2. The addition was completed in 1964. The following year, Hunter designed the Plasma Physics building (Building 24) on the DoC Boulder Labs campus. The building cost an estimated $600,000 to construct and was around 30,000 gross square feet in space. Hunter continued practicing architecture through the early 1970s. He died in 1983 (Colorado Historical Society 2006:1; Snyder 1986:716; Wilkes 1964:3; *Boulder Daily Camera* n.d.:n.p.; Bowker 1956:265; *Boulder Daily Camera* 1983:2B; *Boulder Daily Camera* 1965:24).

Fentress Architects is a Denver-based firm that was created in 1980 by Curtis Fentress. Fentress was born in Greensboro, North Carolina. After graduating from the North Carolina State University College of Design, Fentress worked for I.M. Pei and Partners in New York. He then went on to work for the architectural firm Kohn Pedersen Fox in New York, before founding his own firm in 1980. Today, Fentress Architects is well known for airport designs, including their design of the Denver International Airport, which was completed in 1995. During this same period, Fentress Architects designed the David Skaggs Research Center (NOAA Building, Building 33) at the DoC Boulder Labs campus; the building was completed in 1998 (Fentress Architects 2015b).

HDR, Inc. (Henningson, Durham & Richardson, Inc.) began as an engineering firm established by Henning H. Henningson in in 1917. The firm, Henningson Engineering Company, began in Omaha, Nebraska. During the 1930s, the firm primarily completed projects for the Rural Electrification Administration, which allowed them to survive the Great Depression. Electrical engineer Willard Richardson and civil engineer Charles Durham became partners in the firm in 1946. Henningson served as president; Durham was vice president and Richardson served as secretary and treasurer. Henningson transferred the business to Durham and Richardson in 1950 and retired in 1963. During the 1950s, the company expanded to include an Architectural Department. The firm was responsible for the design of Building 81 (Precision Measurement Laboratory) and Building 42 (Central Utility Plant) at the DoC Boulder Labs campus. Building 42 was completed in 2006; Building 81 was completed in 2012. Today, HDR, Inc. continues as an engineering and architectural firm. They have offices nationwide as well as in Canada, Asia, Australia, Europe, and the Middle East (HDR 2007:5, 9, 11, 13, 15).

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APPENDIX C

SHPO CORRESPONDENCE

HISTORY Colorado

23 February 2016 HC #67537

Virginia Holtzman-Bell
Boulder Laboratories Site Manager
National Institute of Standards and Technology
325 Broadway
Boulder, CO 80305-3328

RE: National Register Eligibility of Building 1, Boulder Laboratories Campus, Boulder, Boulder County

Dear Ms. Holtzman-Bell:

Thank you for your recent correspondence dated 1 February 2016, concerning the National Register eligibility of Building 1 at the Boulder Laboratories campus. Our office has reviewed the submitted materials, and applied the National Register criteria for listing per 36.CFR.60.4. We believe that Building 1 is eligible for listing on the National Register of Historic Places under Criterion A (History) and possibly for Criterion C (Architecture and Engineering).

If you have any questions, please contact Joseph Saldibar, Architectural Services Manager, at (303) 866-3741.

Sincerely,

Steve Turner, AIA
State Historic Preservation Officer

HISTORY Colorado

9 September 2015

HC #67537

Virginia Holtzman-Bell
Boulder Laboratories Site Manager
National Institute of Standards and Technology
325 Broadway
Boulder, CO 80305-3328

Redevelopment of Building Number 3, Boulder Laboratories Campus, Boulder, Boulder County

Dear Ms. Holtzman-Bell:

Thank you for your recent correspondence dated 30 July 2015, concerning the proposed renovation of Building #3 on the Department of Commerce's Boulder Laboratory Campus to accommodate new office and lab space. Our office has reviewed the submitted materials. Regretfully, Building #3 has been heavily altered over the years. Although the building is somewhat notable for the role it played in the development of liquid hydrogen as a rocket fuel- a development that played an important role in America's early space program- it is not a strong link (the rocket engines themselves were developed and produced elsewhere), and the lack of architectural integrity diminishes the ability of the building to be considered eligible for the National Register. Therefore, we find that the building is not eligible for the National Register of Historic Places. The proposed project will have no adverse effect on historic resources.

If you have any questions, please contact Joseph Saldibar, Architectural Services Manager, at (303) 866-3741.

Sincerely,

Edward C. Nichols
State Historic Preservation Officer, and
President, Colorado Historical Society