Building N-221 Reuse Guidelines

NASA Ames Research Center, California

prepared for:

NASA/Ames Research Center

prepared by:

Architectural Resources Group

Architects, Planners & Conservators, Inc.

San Francisco, California

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Introduction

NASA Ames Research Center and Architectural Resources Group, Architects, Planners & Conservators, Inc. (ARG) have developed Reuse Guidelines for the 40 by 80 Foot Wind Tunnel, Building 221, at NASA Ames Research Center, California. The Reuse Guidelines have been designed to assist NASA Ames professional staff, tenants, and their consultants in rehabilitating historic structures by identifying character-defining features, outlining the opportunities for reuse, and evaluating code deficiencies.

I. Executive Summary

Constructed in 1944 along Moffett Field's western boundary, Building N-221, also known as the Ames Aeronautical Laboratory 40 by 80 Foot Wind Tunnel, is a five-story, steel frame building with various gable roofs and the wind tunnel projecting out from the northwest corner of the building. Roughly rectangular in plan and arranged around an interior courtyard, the building was historically designed as a closed loop wind tunnel with a geodesic steel bent exoskeleton around the tunnel structure and a streamlined interior with enhanced airflow capability. Since its construction, the wind tunnel has undergone various modifications including the addition and removal of test sections up until the 1990s. Despite the various modifications to the building since it opened in 1948, Building N-221 has a high degree of integrity; the building's character-defining features are intact on the exterior and interior. (Character-defining features, including significance and condition ratings are listed in section VII and Appendix 1.)

Rehabilitation of the building should comply with *The Secretary of the Interior's Standards for Rehabilitation (The Standards). The Standards* can be accessed on the National Park Service website (www.nps.gov) and are presently located at the following URL: http://www.nps.gov/history/hps/tps/tax/rhb. Plans for the reuse of Building N-221 should take into consideration the preservation of the building's character-defining and contributing features, including, but not limited to, the overall form of the building, fenestration pattern, materials, and open space. Changes to noncharacter-defining features may be undertaken, but the impact to the character-defining and contributing features should be carefully evaluated.

Future renovations will require Fire/Life Safety and Disabled Accessibility upgrades to comply with current codes. These include, but are not limited to, the addition of fire sprinklers, exit path of travel and exit door upgrades, and disabled access improvements to door and door hardware, restrooms, and locker rooms. The impact of these upgrades to the character-defining and contributing features should be carefully considered before changes are made.

Further analysis is required for the management of hazardous materials and upgrades to the mechanical, electrical and structural systems. Existing mechanical flues, ducts and conduits protruding from windows and exposed on the exterior should be removed unless original. The impact of these upgrades to the character-defining and contributing features should also be carefully evaluated.

II. Project Team

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III. Methodology

ARG staff conducted a site review of Building N-221 in March 2006. During the site visit, notes were taken on the character-defining features of the building and photographic documentation was completed on the exterior as well as major interior spaces. ARG staff utilized the available documents provided by the NASA Ames Research Center to assist in the development of this report. The documents provided by NASA Ames Research Center were used as a general reference in the production of this report. The verification of the accuracy of the documents was not included in the scope of work.

The site review was conducted with the understanding that the current use of the building would be continued. The review was limited to a general observation of the buildings and building components and detailed survey of all interior spaces was not included in the scope of work. Furthermore, limited access to some areas of the building were required due to issues of security, privacy, safety, or other limitation.

ARG staff reviewed both primary and secondary research materials at the following institutions:

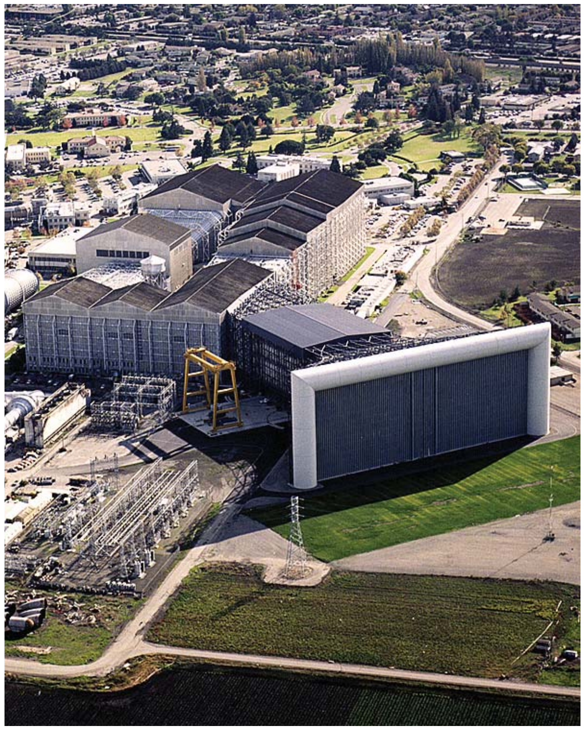
- 1950 Navy Docks & Yards Micro Film;
- Engineering Documentation Center (located in Building N-213); and
- Ames Imaging Library (located Building in building N-241).

The following documents were utilized as the main sources of information:

- The 1994 National Register of Historic Places Nomination Form for the US Naval Air Station Moffett Field Central Historic District;
- Aerial photographs dating from 1931 through 1944;
- Architectural Drawings including;
    - Ames Aeronautical Laboratory, Moffett Field, California. “Building N-221: 40 by 80 Foot Wind Tunnel General Plan.” Drawings dated 18 April 1941;
    - Ames Aeronautical Laboratory, Moffett Field, California. “Building N-221: 40 by 80 Foot Wind Tunnel West Elevation.” Drawings dated 18 April 1941;
    - Ames Aeronautical Laboratory, Moffett Field, California. “Building N-221: 40 by 80 Foot Wind Tunnel East Elevation.” Drawings dated 18 April 1941;
    - Ames Aeronautical Laboratory, Moffett Field, California. “Building N-221: 40 by 80 Foot Wind Tunnel Storage and Electrical Equipment Rooms Elevations.” Drawings dated 18 April 1941;
    - Ames Aeronautical Laboratory, Moffett Field, California. “Building N-221: 40 by 80 Foot Wind Tunnel Storage and Electrical Equipment Rooms Floor Plan.” Drawings dated 10 April 1941;
    - Ames Aeronautical Laboratory, Moffett Field, California. “Building N-221: 40 by 80 Foot

Wind Tunnel Offices Floor Plan." Drawings dated 8 March 1942;

- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Offices and Storage Rooms Elevations." Drawings dated 9 April 1942;
- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Warehouse Modification Floor Plan." Drawings dated 9 May 1960;
- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Control Room Modifications Plan Details and Index." Drawings dated 17 June 1969;
- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Modernization of the 40 x 80 Foot Wind Tunnel, Minor Model Modification Area General Plan." Drawings dated 12 May 1972;
- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Modernization of the 40 x 80 Foot Wind Tunnel, Exterior Elevation." Drawings dated 12 May 1972;
- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Minor Model Modification Plan." Drawings dated 16 June 1977;
- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Test Chamber Second Floor Computer Control Room, Second Floor Plan." Drawings dated 8 April 1982;
- Ames Aeronautical Laboratory, Moffett Field, California. "Building N-221: 40 by 80 Foot Wind Tunnel Test Chamber Second Floor Control Room 30 R Second Floor Plan." Drawings dated 8 April 1982.

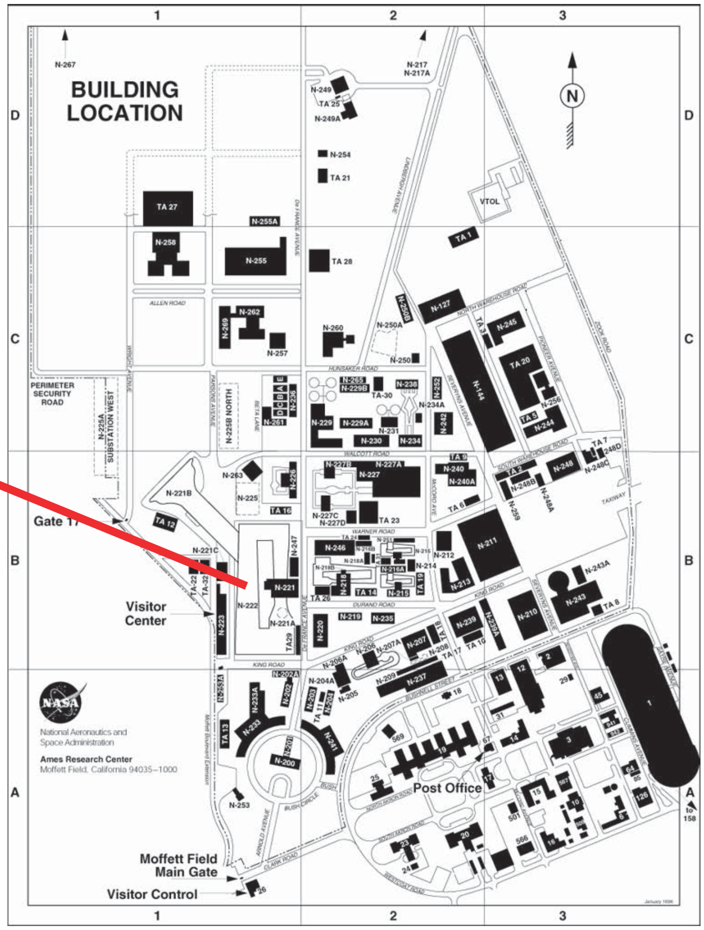


West and North Elevations of Building N-221.

IV. Building 221 Summary

Location:	Moffett Field, California
Area:	NASA Ames Research Center
Date of Construction:	1944
Historic Structure:	Draft National Register Nomination submitted to SHPO Nov. 2006 for Historic Eligibility Determination.
Historic Use:	Ames Aeronautical Laboratory 40 by 80 Foot Wind Tunnel
Current Use:	Ames Aeronautical Laboratory 40 by 80 Foot Wind Tunnel
Hazard Level:	Ordinary, building has a fire suppression system in some areas of the building (at office areas)
Number of Floors:	Five (Fifth level is access area only, not occupied)
First Floor:	124,950 gross ft^2
Second Floor:	7,512 gross ft^2
Third Floor:	5,380 gross ft^2
Fourth Floor:	1,275 gross ft^2
Fifth Floor:	None (Fifth level is access area only, not occupied)
Total:	139,117 gross ft^2
Exterior Materials:	Steel, corrugated metal siding, transite cement asbestos corrugated siding, concrete
Construction Frame:	Steel exoskeleton

Building N-221



"Ames Research Center, Moffett Field, California, Building Location Plan." February 2000.

V. Historical Background and Site Context

The NASA Ames Research Center was initially founded on December 20, 1939, as an aircraft research laboratory by the National Advisory Committee on Aeronautics (NACA), the forerunner of NASA. Ames has played a pioneering role in science and technology for over six decades. The center was named for Dr. Joseph S. Ames, NACA Chairperson from 1927 to 1939. Ames was NACA's second laboratory, established after the Langley facility in Hampton, Virginia. In 1958, Ames became part of the National Aeronautics and Space Administration (NASA). Since its inception, Ames researchers have broken new ground in all flight regimes—the subsonic, transonic, supersonic, and hypersonic—using a collection of wind tunnels and research aircraft, the sophistication of which has increased over time. Ames has evolved into a diverse and sophisticated research campus of buildings influenced by the clean lines and materials of the International style, fussed with elements of the Streamline Moderne; both styles are very well suited to industrial building types.

Ames specializes in research geared toward creating new knowledge and new technology, encompassing the fields of supercomputing, networking, numerical computing software, artificial intelligence, and human factors to enable advances in aeronautics and space. In aeronautics, Ames is the leading NASA agency in airspace operations systems, including air traffic control and human factors. Ames also has major responsibilities in the creation of design and development process tools and wind tunnel testing. Ames houses one of the world's largest collections of wind tunnels and simulation facilities.

The National Aeronautics and Space Administration (NASA) Ames Research Center borders the northern California towns of Sunnyvale and Mountain View near the heart of the Silicon Valley. The Ames facility occupies approximately 430 acres of the approximately 2,000-acre Moffett Field site, which once served as a United States Naval Air Station-Sunnyvale. (See Appendix 4 for historic aerial photographs.)

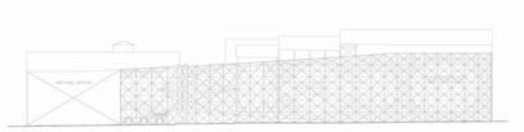
The 40 by 80 Foot Wind Tunnel was originally constructed in 1944 and the structure was named the Ames Aeronautical Laboratory 40 by 80 Foot Wind Tunnel. (See Appendix 6 for historical building plans.) Today, the voluminous structure sited at the western edge of the Ames campus is commonly referred to as the "40 by 80" or Building N-221. In 1982 the 80 by 120 Foot Wind Tunnel was appended to the west elevation of the 40 by 80 Foot Wind Tunnel. The 40 by 80 Foot Wind Tunnel is able to operate independent of the 80 by 120 Foot Wind Tunnel, but may also utilize the 80 by 120 Foot Wind Tunnel for additional airflow during craft testing. Together these two structures comprise the Ames National Full-Scale Aerodynamics Complex (NFAC). The NFAC is bounded by Gamma Lane and Wright Avenue to the west, King Road to the south, and DeFrance Avenue to the east.

VI. Building Description

Historic Appearance of the 40 by 80 Foot Wind Tunnel
Described as a "wind tunnel large enough to accommodate full-size bombing planes," the original 40 by 80 Foot Wind Tunnel structure was designed and built as a closed loop wind tunnel with a rectangular floor plan, an interior courtyard, a 150 ft. entrance cone, a 130 ft. balance house, which contained the 40 ft. by 80 ft. test chamber/section, and a test section diffuser. Multiple gable-roofed volumes connected by conical segments comprise the 40 by 80 Foot Wind Tunnel structure, and the entire structure is surrounded by a geodesic steel bent exoskeleton. The original engineering decision behind the exoskeleton was to enhance the wind tunnel's flow field – essentially to minimize the amount of interior objects in the structure in order to create a more streamlined space for airflow.

Modifications to the 40 by 80 Foot Wind Tunnel
The 40 by 80 Foot Wind Tunnel has undergone several phases of modification throughout the course of its existence. Little is known regarding the first modifications to the 40 by 80 Foot Wind Tunnel except that they occurred only four years after the structure was originally built. According to the NASA Ames history publication Atmosphere of Freedom, the facility was officially reopened in 1948. The publication does not elaborate on the extent of work causing the facility to be opened again in 1948.

The second modification to the 40 by 80 Foot Wind Tunnel facility occurred in mid-1961 when the Height Control Test Apparatus was constructed and attached to the south end exterior walls of the 40 by



80 Foot Wind Tunnel. Part of the Height Control Research Facility, the apparatus was a flight simulator that “yielded valuable data on pilot handling requirements in the fields of vertical takeoff and landing, supersonic transport landing approach, low altitude attack, and soft landings on other planets. The Height Control Facility and testing apparatus was removed from the 40 by 80 Foot Wind Tunnel exterior wall in approximately 1980.

In the 1960s extensive research studies determined a national need existed for additional low-speed aerodynamics research. Accordingly, engineering studies commenced in 1969 in order to determine how to best meet the research requirement. NASA concluded the most cost-effective approach consisted of re-powering and strengthening the existing 40 by 80 Foot Wind Tunnel structure. Various strengthening and re-powering projects were investigated including grafting a larger 40 by 80 ft. test leg onto the original structure. Ultimately, the proposal to replace the existing motor drives in the 40 by 80 Foot Wind Tunnel and add a new 80 by 120 ft. test section was determined the best approach.

In the spring of 1972 work began on a $6.5 million modernization project for the 40 by 80 Foot Wind Tunnel. The undertaking began as a result of the need to increase operational safety and efficiency. In addition, the modifications were required in order to accommodate the increasing demand for low-speed, large-scale testing of advanced Short Take-Off and Landing (STOL) aircraft and Vertical Take-Off and Landing (VTOL) aircraft. In June 1979 a $10.7 million wind tunnel contract was awarded to the Bostrom-Bergen Metal Products Company of Oakland, California that provided for construction work related to modifications to the 40 by 80 Foot Wind Tunnel facility. The contract called for the structural modifications to the 40 by 80 Foot Wind Tunnel in order to accommodate an “increase in the wind tunnel’s drive power from 36,000 to 135,000 horsepower and a new test leg with a much larger test section 24 m high by 36 m wide (80 by 120 ft.).” The construction was scheduled to last for approximately two years, and the two test sections were slated to be opened and operational by late 1981.

The December 27, 1979 edition of the NASA Ames employee newsletter *The Astrogram*, detailed the 40 by 80 Foot Wind Tunnel modification project:

> Initial design for the modification started in 1973 and is now approximately 95% complete. Contracts for long lead items were let starting in mid-1977. These items included the 6 drive motors and 90 fan blades, as well as most of the other mechanical parts of the drive system. At this point in time, the project has awarded 26 contracts totaling $47,967,000, or 56% of the estimated project cost of $85,000,000. Bids totaling approximately $10 million are expected to be opened prior to the end of 1979. This will mean that firm prices have been established for approximately 70% of the total project cost and that the project can probably be completed within the projected budget of $85 million.
>
> The current project schedule is as follows:

Start new leg foundation-	December 1979
Start assembly of first drive unit-	February 1979
Shut down 40 by 80 Foot Wind Tunnel operation-	June 1980
Start installing new leg steel-	August 1980

Install new drive unit-	September 1980
Complete construction of 40 by 80 Foot Wind Tunnel-	May 1981
Complete construction of 80 by 120 Foot Wind Tunnel-	January 1982[7]

In late January 1980, the modification project was well underway and by that time five of the six new drive motors had been delivered to the Ames facility. The Westinghouse Electric Corporation Round Rock, Texas motor plant, constructed the 18,000 horsepower motors. In addition, other projects that had been started included the driving of the pre-stressed concrete piles for the 80 by 120 Foot Wind Tunnel's foundation, structural strengthening work on the 40 by 80 Foot Wind Tunnel, and the construction of an electrical equipment room for the drive motors and tunnel control system.

By September 1980, the 40 by 80 Foot Wind Tunnel was closed temporarily as part of the $85 million modification project. The tunnel was closed in order to complete several projects including the addition of the 600 ft. long structure (which houses the 80 by 120 Foot Wind Tunnel), and replacement of the six original drive's motors with six new 22,500 horsepower drive motors in order to increase the total horsepower from 36,000 to 135,000.[9]

The modification project was completed in late 1982, resulting in two separate but interconnected wind tunnels, the 40 by 80 Foot Wind Tunnel, and the 80 by 120 Foot Wind Tunnel, that share a common drive system and utilize low speed fans and acoustic treatments in order to abate some of the noise generated by the tunnels.

In addition to work performed by the Bostrom-Bergen Metal Company of Oakland, the modification project called for approximately forty-five separate contracts and employed many different contractors including the Turner-Lord Construction Company, who held the five-year modification contract for the 40 by 80 Foot Wind Tunnel. In the mid-1990s, the original 40 by 80 ft. test section was removed and replaced with the current test section.

Current Appearance of the 40 by 80 Foot Wind Tunnel

Although some modifications have occurred to the 40 by 80 Foot Wind Tunnel, the structure's current appearance, engineering design, dimensions, and use is consistent with its original appearance, design, dimensions, and use. Although the 80 by 120 Foot Wind tunnel was appended to the west elevation of the 40 by 80 Foot Wind Tunnel, the addition of the structure did not greatly modify the 40 by 80 Foot Wind Tunnel's original design or eliminate its original use. Following is a description of each elevation for the voluminous 40 by 80 Foot Wind Tunnel structure.

South Elevation

The south elevation measures approximately 400 ft. in length (from the west corner to the east corner) by 175 ft. in height (from foundation to peak in roofline). The wall-to-wall depth of the south elevation's center section is approximately 180 ft.

Exterior building materials in this section consist of a mix of corrugated metal siding and transite cement asbestos corrugated siding surrounded by the exoskeleton of the structure that is comprised of seventeen

(17) geodesic bents (numbered 83 through 99).

East Elevation
The east elevation of the structure spans 868 ft. in length and is comprised of several sections: the southeast corner of the structure measures approximately 235 ft. in length: the entrance cone of the 40 by 80 ft. test section measures approximately 150 ft; the test chamber or test section and balance house which contains the 40 by 80 Foot Wind Tunnel and measures approximately 130 ft.; the test section diffuser measures approximately 255 ft; and lastly, the northeast corner of the structure measures approximately 98 ft.

The height of the structure on the east elevation ranges from approximately 175 ft. at the southeast corner roof peak to approximately 135 ft. at the northeast corner roof peak.

East elevation exterior building materials consist of a mix of corrugated metal siding and transite cement asbestos corrugated siding, surrounded by the exoskeleton of the structure that is comprised of twenty-nine (29) geodesic bents. The entrance cone and test section diffuser are metal and also surrounded by the steel bents. Industrial style windows are located along the various levels throughout the east elevation and the northeast exterior wall contains the largest grouping of operable windows. Fenestration in this section of the façade consists of aligned three-sash awning windows on the structure's first and second levels. Also in this section is the official front entrance to the N-221 structure. The entrance features double doors, each with a multi-pane sash window panel above a plain lower panel, and are flanked one each side by a single narrow rectangular multi-pane sash window placed vertically on the façade. The original signage from the National Advisory Committee on Aeronautics (NACA) is still present above the entry doors.

North Elevation
The north elevation measures approximately 335 ft. in length by 135 ft. in height. The wall-to-wall depth of the north elevation's center section is approximately 98 ft.

Exterior building materials in this section consist of a mix of corrugated metal and transite cement asbestos corrugated siding surrounded by the exoskeleton of the structure that is comprised of eleven (11) geodesic bents. Fenestration continues in a similar pattern as that displayed on the north corner of the east elevation, and consists of aligned three-sash awning windows on the first and second levels. A double door entrance is located on the western end of the north elevation. Similar to those found in the main entrance, the doors contain two panels, one upper window panel with a multi-pane sash, and a plane lower panel. The doors are flanked one each side by a single narrow rectangular multi-pane sash window placed vertically on the façade.

West Elevation
The west elevation of the structure spans 868 ft. and is comprised of three sections: the drive section entrance cone measuring approximately 135 ft. in length, plus an additional 80 ft. before the section; the upstream shroud that measures approximately 45 ft. in length; the drive section and downstream shroud that measures approximately 230 ft. in length; and lastly, the south end diffuser that measures approximately 290 ft. in length, plus an additional 90 ft. (approximately).

The height of the structure on the west elevation ranges from approximately 135 ft. at the northwest corner roof peak to approximately 175 ft. at the southwest corner roof peak.

The west elevation exterior building materials consist of a mix of concrete on the lower wall portions and corrugated metal and transite cladding above. Thirty-three geodesic steel bents surround the west elevation exterior walls in order to provide structural support.

Wind Tunnel Interior

40 x 80 Foot Wind Tunnel
The NASA Ames Research Center's 40 by 80 Foot Wind Tunnel is a closed circuit, single return wind tunnel. Six 40 ft. diameter fans that are powered by six 22,500 horsepower electric motors drive the tunnel. The 40 by 80 ft. test section is 39 ft. high, 79 ft. wide, and 80 ft. long. It is lined with an acoustic lining to optimize acoustic research testing. The test section doors are 40 ft. wide and 49 ft. long. There is one door on each side of the tunnel centerline on top of the test section. When fully open, a clear opening of 78.5 ft. by 49 ft. is provided. Inside the test section are two hoists, a 5-ton and 35-ton, mounted on the common bridge at the top of the test chamber. These hoists were designed to lift models into the test section from the high bay floor.

80 by 120 Foot Wind Tunnel
The 80 by 120 Foot Wind Tunnel's test section is the larger part of the closed circuit, single return wind tunnel that makes up the National Full-Scale Aerodynamics Complex (NFAC). Its size makes it ideal for testing large-or full-scale models and prototypes, including full-scale rotors. It is equipped with a sound absorbent lining installed to create a semi anechoic space for aero-acoustic research studies of aircraft models. The test section's balance system measures the forces for six degrees of freedom. Constructed as a leg attached to the preexisting 40 by 80 Foot Wind Tunnel, the 80 by 120 Foot Wind Tunnel is driven by six 40 ft. diameter fans that are powered by six 22,500 electric horsepower motors.

The 40 by 80 Foot and 80 by 120 Foot Wind Tunnel test sections share an interconnected flow loop. By adjusting the position of the 80 by 120 Foot Wind Tunnel's vane sets, the airflow can be directed through one test section into the other. When the 40 by 80 Foot Wind Tunnel's test section is in operation, work may simultaneously continue in the 80 by 120 Foot Wind Tunnel's test section. However, due to the pressurized downstream airflow, work may not continue in the 40 by 80 Foot Wind Tunnel's test section when the 80 by 120 Foot Wind tunnel's test section is in operation.[11]

Illustration 1. 40 by 80 Foot Wind Tunnel is a significant feature. (Source: ARG, October 2006)

Illustration 2. Geodesic steel bent exoskeleton is a significant feature. (Source: ARG, October 2006)

Illustration 3. Corrugated metal siding is a significant feature. (Source: ARG, October 2006)

VII. Historic Character-Defining Features

Refer to Appendix 1. for a matrix of character defining features, including specific location of building components. For illustrated plans and elevations, see *Appendix 3. Significance Diagrams.*

Alteration of significant and contributing building components shall be in keeping with original design, configuration and material. For more information, see *The Secretary of the Interior's Standards for the Treatment of Historic Properties. The Standards* can be accessed on the National Park Service website (www.nps.gov) and are presently located at the following URL: http://www.nps.gov/history/hps/tps/tax/rhb.

See *Appendix 5. Current Conditions Photographs* for photos showing the character-defining building components listed below. For building floor plans, see *Appendix. 2. Existing Floor Plans and Rehabilitation*.

1. Significant Character-Defining Features: these are the features that convey the building's historic character and significance. Alteration or removal of these features could result in a loss of integrity and should be avoided.

The following are significant features:

- Overall form—large, rectangular floor plan and attached closed loop wind tunnel;
- Geodesic steel bent exoskeleton;
- Three sash awning windows on the 1st and 2nd levels of the east and north elevation;
- Double entrance doors;
- Corrugated metal siding and corrugated transite cement asbestos siding;
- Multi-lite metal sash windows with operable hopper segments (ground floor, and ground floor under exit cone and diffuser section);
- 3-lite wood windows with 2 operable awning segment over 1 hopper segment (second floor level under exit cone and diffuser section);
- Multi-lite metal sash windows (upper level);

- Metal roll-up door (north elevation-Wind Tunnel);
- Metal roll-up doors (north diffuser section);
- Metal canopy (north elevation-Wind Tunnel);
- 3-lite 1-panel metal doors (north elevation-Wind Tunnel);
- 2-lite transom (north elevation-Wind Tunnel);
- Multi-lite lexan glazed metal sash windows with operable awning segments (ground level, upper level, and upper level of Settling Chamber);
- 4-lite 1-panel metal door (under exit cone);
- 4-lite 1-panel metal door (north diffuser section);
- Metal roll-up doors (under exit cone);
- 3-lite 1-panel metal doors (under diffuser section);
- Metal canopy with NACA signage;
- Entrance cone (east elevation-Wind Tunnel);
- Exit cone (east elevation-Wind Tunnel);
- 40 by 80 Foot Wind Tunnel
- 80 by 120 Foot Wind Tunnel
- Multi-lite metal windows (flanking doors under diffuser section);
- Louvered air intake openings;
- Sloped screen wall;
- Rough concrete surface (lower wall under south diffuser section);
- Multi-lite lexan glazed metal panel stacking bottom rolling doors with 4-lite 1-panel walk-in service door and track (east elevation-Test Section); and
- Screened openings housing drive motors (second floor level of north diffuser section).
- Interior features including;
    - o Exposed steel framing;
    - o Metal elevator;
    - o Multi-lite metal windows; and
    - o Steel stairs and landings.

Illustration 4. 2-lite transom at north elevation of Wind Tunnel is a significant feature. (Source: ARG, October 2006)

Illustration 5. Multi-lite metal sash windows at ground floor are a significant feature. (Source: ARG, October 2006)

Illustration 6. Multi-lite metal windows and steel stairs on interior are significant features. (Source: ARG, October 2006)

2. Contributing Features: these features are important elements that contribute to the understanding of the original design. Alteration or removal of these features may be necessary for programmatic or building system requirements. However, removal should be minimized and where necessary mitigated.

The following are contributing features:

- 1-lite, 1-panel metal door (settling chamber);
- Steel ladder and platform (to entrance cone);
- Corrugated metal and corrugated transite cement asbestos shed roof (east elevation-Test Section);
- Corrugated metal siding and corrugated transite cement asbestos siding (west elevation-Test Section);
- Multi-lite lexan glazed metal sash windows with operable awning segments (west elevation-Test Section ground level);
- Multi-lite lexan glazed metal windows (west elevation-Test Section upper level); and
- Louvered openings (west elevation-Test Section upper level).
- Interior features including;
    - Large open volume;
    - Wood panel doors at first floor offices
    - Some light fixtures.

3. Tertiary Features: these features are original elements of the building that are of a lower importance relative to the understanding of the original design. Alteration or removal of these features, if necessary, would have a limited affect on the integrity of the building.

The following are tertiary features:

- Metal door (entrance cone);
- Metal roll-up door (south elevation-Wind Tunnel);
- Louvered openings (west elevation-Wind Tunnel ground level of North Diffuser section);
- Sliding Metal Door (west elevation-Wind Tunnel North Diffuser section); and
- 2-panel metal door (west elevation-Test Section).
- Interior features including;
    - Concrete flooring.

4. Non-Contributing Features: these features are elements of the building that have been remodeled or areas where additional alteration would not affect the original integrity of the building. In some cases, removal of the non-contributing features may be beneficial to the historic integrity of the building.

The following are non-contributing features:

- Half wire glass metal door (east elevation-Wind Tunnel under exit cone);
- Full glass metal door (east elevation-Wind Tunnel under exit cone);
- Fan drive section (west elevation-Wind Tunnel);
- Metal doors (west elevation-Wind Tunnel North Diffuser section);
- Louvered openings (west elevation-Test Section ground level);
- Metal door (west elevation-Test Section);
- Metal exit stair (west elevation-Test Section); and
- Interior features including;
    - Wall partitions;
    - Suspended acoustical ceilings;
    - Solid core veneer doors in hollow metal frames;
    - Vinyl composition tile;
    - Carpet; and
    - Fluorescent light fixtures.

5. Conservation of Intact Historic Fabric

The following materials require special care and treatment in their maintenance and rehabilitation:

- Transite asbestos cement corrugated siding;
- Steel sash windows;
- Steel structural frame; and
- Steel doors.

VIII. Opportunities for Reuse

As of the date of this report it is understood that the building is planned to continue to be used for the current use (wind tunnel testing) but by a different agency, the Air Force. A future use for the building could be light industrial use, with support Offices. The wind tunnel chamber could be used for interpretive purposes, and likely be limited to the areas of the wind tunnel and support spaces.

IX. Code Evaluations and Recommendations

A. Fire/Life Safety

Description

Constructed in 1944, Building N-221 has undergone several modifications in support of its principal function as a wind tunnel study center. At the northeast corner of the first floor, offices and support spaces have been added in several building campaigns. Improvements to the office areas include upgrade of finishes, addition of wall partitions, life safety improvements, and fire suppression systems. The office spaces appear to function well for the current use. The remaining areas of the building are primarily devoted to light factory/industrial use, and the 40 by 80 Foot Wind Tunnel test chamber. From reviewing the documents and visiting the building, there have been minor changes to the moderate factory/industrial use. Modifications to building 221 include construction of offices/computer rooms at the second floor of the test chamber, addition of a fitness center at the northwest corner of the first floor, and minor changes to the exterior envelope and door openings to improve building function. The building has a gross square ft. area of 139,117 ft^2 and consists of steel frame exterior walls, metal and transite corrugated siding, concrete floor slab, and steel truss with metal decking at upper floors and roof areas. The building was reviewed for general code compliance with the provisions of the 2001 California Building Code (CBC).

Building N-221 is a mixed occupancy building with the office areas and fitness center classified as B occupancy, and the light factory/industrial use classified as F1. The construction type is Type II-N. The following review is based on the occupancies remaining the same. If a change in occupancy is proposed, further detailed code analysis will be required. Section IX B. includes a glossary of building construction types and occupancy types that exist within the scope of this report.

California's State Historical Building Code (SHBC), located in chapter 34 of the CBC, shall be used in conjunction with the California Building Code as stated in section 8-102.1: "These regulations are applicable for all issues regarding building code compliance for qualified historical buildings or properties. These regulations are to be used in conjunction with the regular code to provide alternatives to the regular code to facilitate the preservation of qualified historical buildings or properties. These regulations shall be used whenever compliance with the regular code is required for qualified historical buildings or properties."

Analysis

1. Occupancy and Construction type: Building N-221 is currently classified as a mixed occupancy B and F1 occupancies, and Type II-N construction. Table 5A of the CBC allows occupancy B and F1 to be construction type II-N. There is a fire suppression system in the office areas, but no fire suppression system in the moderate factory/industrial use.

Recommendation: The current occupancy type is permitted in the existing construction type.

2. Location on Property: CBC Table 5-A limits the exterior bearing and nonbearing walls less than 20 ft.

to be one-hour noncombustible and walls elsewhere to be non-rated, noncombustible for all occupancies in building. Building 221 exterior walls are comprised of a steel frame at the exterior or interior of the building siding, with metal or transite asbestos cement siding. This wall assembly could not be found in the CBC 2001 or the Underwriters Laboratories Inc. “Fire Resistance Directory, 2000 edition”. As the building exceeds 20 ft. from the property line, the wall system may conform to the requirements of the code for non-rated construction. Exterior openings for both occupancies are required to be protected less than 10 ft. and not permitted less than 5 ft. from property lines. Building N-221 is separated more than 10 ft. in width on four sides and does not need exterior opening protection. The wind tunnel that exists at all sides of the building is considered part of the building for purposes of opening protection.

> *Recommendation:* No modifications to the building are required based on the location on the property.

3. Occupancy Separation: According to CBC Table 3B, there is no required occupancy separation between B and F1 occupancies.

> *Recommendation:* Occupancy separations are not required at Building N-221.

4. Allowable Area: Building N-221 is separated on three sides by yards in excess of 30 ft. (for a total of 50 ft. minimum on all sides.) CBC 505.1.2 allows for an area increase at the rate of 2.5% for each foot where the yard exceeds 20 ft., resulting in an area increase of 75% for the building. By using CBC Table 5-B and the allowable area increase, the net allowable areas for the mixed occupancies for Type II-N construction is as follows: B and F1 occupancy allowable area is 42,000 ft”.

CBC section 504.3 states, “When a building houses more than one occupancy, the area of the building shall be such that the sum of the ratios of the actual area for each separate occupancy divided by the total allowable area for each separate occupancy shall not exceed one.” When the calculation for a mixed occupancy building is performed in accordance with CBC section 504.3, building N-221 mixed occupancy exceeds the allowable area.

SHBC section 8-102.1.4 states “Qualified historical buildings or properties may have their existing use or occupancy continued if such use or occupancy does not constitute a distinct hazard to life safety as defined in this code”.

> *Recommendation:* As Building N-221 exceeds the allowable area allowed by the regular code, the use of the SHBC is recommended for the continued historical use. The addition of a fire suppression system in areas of the building not currently served would increase life safety for building occupants.

5. Allowable Height: Table 5-B of the CBC limits the number of stories of the building to two stories and an overall height of 55 ft. for Construction Type II-N. SHBC section 8-302.5 allows the height of the structure to not be limited, “provided such height or number of stories does not exceed that of its designated historical design.”

Recommendation: Building N-221 exceeds the allowable height permitted by the regular code, it is recommended to utilize the provisions of the SHBC to maintain the historical height of the building.

6. Means of Egress Identification: Section 1003.2.8.2 requires the path of travel to and within exits to be identified with code compliant exit signs. Illuminated exit signs with battery back-up power source are present in the Office occupancy. There are egress signs in the light factory/industrial occupancy areas, but the use of illuminated exit signs is not prevalent. CBC 1003.2.9 requires the means of egress serving the occupied portion to be illuminated at an intensity of not less than 1 footcandle at the floor level. The emergency lighting in the office occupancy corridors appears to comply with this requirement, however in the moderate factory/industrial occupancy there is limited egress lighting and we conclude that the egress lighting in these areas is not adequate.

Recommendation: In the moderate factory/industrial areas of the building, it is recommended to provide illuminated exit signs and path of egress lighting where lacking in the egress system.

7. Doors: CBC Section 1003.3.1.3 requires a clear opening of 32 in. A general survey of the doors found that doors are typically a compliant width, a detailed survey should be undertaken to confirm door width compliance. CBC section 1003.3.1.5 requires the door to swing in the direction of egress. Section 1003.3.1.6.2 requires a level landing on each side of all doors that are part of the means of egress system. This section also requires the landing to be 44 in. when the door swings away and 60 in. in the direction of the door swing. The exit door from the first floor of the test chamber section of the building (southeast corner) swings into the egress path of travel.

Recommendation: The exit door from the first floor of the Test Chamber section of the building (southeast corner) should be reversed to swing in the direction of egress.

8. Stairs and Guardrails: CBC section 1003.3.3.3 requires the rise and run of the stair to be a minimum of 7 in. and 11 in. respectively. CBC section 1003.3.3.6.1 requires all stairs (two or more risers) to have a handrail on each side. CBC section 1133B.4.2.6.1 requires handrails to have a maximum cross section dimension of 1-1/2 in., the interior and exterior exit stairs lack required handrails. Section 509 of the CBC requires 42 in. high guardrails at all unenclosed floor or roof openings, open or glazed stairways, aisles, landings, ramps, balconies, or porches, which are over 30 in. above grade or the floor below. CBC Section 509.3 requires a maximum opening in a guardrail to be 4 in. Several of the interior and exterior guardrails do not meet this requirement, with openings exceeding 12 in. SHBC section 8-502.1 exception 5 allows the enforcing agent to accept “any other condition which will allow or provide for the ability to quickly and safely evacuate any portion of a building with out undue exposure and which will meet the intended exiting and life safety stipulated by these regulations.”

Recommendation: Interior and exterior exit stairs should be fitted with compliant handrails, and guardrails should be modified to have a maximum opening of 4 in.

9. Ramps: There are no ramps in the building.

10. Travel distance: Section 1004.2.5.2.2 requires that the maximum travel distance in a non-sprinklered building not exceed 200 ft. (the building is partially sprinklered.) Travel distance is that distance an occupant must travel from any point within occupied portions of the exit access to the door of the nearest exit. Where path of travel includes unenclosed stairways or ramps the distance of travel on such components must be included in the travel distance measurement. The travel distances within the building appear to be compliant, owing to the narrow width of the building.

Recommendation: The travel distances appear to be compliant.

Summary of Recommendations

1. Construction type: The current occupancy type is permitted in the existing construction type.

2. Location on Property: No modifications to the building are required based on the location on the property.

3. Occupancy Separation: Occupancy separations are not required at Building N-221.

4. Allowable Area: As Building N-221 exceeds the allowable area allowed by the regular code, the use of the SHBC is recommended for the continued historical use. The addition of a fire suppression system in areas of the building not currently served would increase life safety for building occupants.

5. Allowable Height: Building N-221 exceeds the allowable height permitted by the regular code, it is recommended to utilize the provisions of the SHBC to maintain the historical height of the building.

6. Means of Egress Identification: In the moderate factory/industrial areas of the building, it is recommended to provide illuminated exit signs and path of egress lighting where lacking in the egress system.

7. Doors: The exit door from the first floor of the test chamber section of the building (southeast corner) should be reversed to swing in the direction of egress.

8. Stairs and Guardrail: Interior and exterior exit stairs should be fitted with compliant handrails, and guardrails should be modified to have a maximum opening of 4 in.

9. Ramps: None.

10. Travel Distance: The travel distances appear to be compliant.

B. Glossary of Terms: Construction and Occupancy Types
The following is a summary description of the Construction and Occupancy Types for Building N-221.

Glossary of Construction Types, referenced from the 2001 California Building Code:

Type II-N	The structural elements of Type II-N buildings shall be of noncombustible materials. Floor construction of Type IIII-N buildings shall be of noncombustible material, provided, however, that a wood surface or finish may be applied over such noncombustible material. Walls and permanent partitions of Type II-N buildings shall be of noncombustible materials.

Glossary of Occupancy Types: Referenced from the 2001 California Building Code

Group B	A building or structure, or a portion thereof, for office, professional or service-type transaction, including storage of records and accounts; eating and drinking establishments with an occupant load of less than 50.
Group F1	Moderate-hazard factory and industrial occupancies include factory and industrial uses not classified as Group F, Division 2 Occupancies.

C. Disabled Accessibility

Analysis

1. Accessible Parking: CBC section 1129B.1 requires that where parking is provided for the public as clients, guests, or employees' accessible parking will also be provided. Section 1129B.4 requires one van accessible space for every eight spaces. Currently, there is a disabled accessible parking space at the exterior of the fitness center. The space has a compliant sign for disabled parking, but the unloading area should be confirmed to be the minimum 96 in. width. For the number of parking spaces adjacent the building, approximately 39, two accessible parking spaces are required, including one van accessible parking space.

> *Recommendation:* The existing disabled accessible loading area should be verified to have a curb cut and sidewalk ramp to the accessible path to the entrance. An additional parking space is needed in the existing parking areas near the main/disabled accessible entrance, and should be a van accessible parking space.

2. Accessible Route: CBC section 1114B.1.2 requires an accessible route of travel to all portions of the building that are required to be accessible. The SHBC Section 8-604 allows for equivalent facilitation to be provided in lieu of a path of travel to all areas of the building where providing access "would

threaten or destroy the historical significance or character-defining features of the building or site or cause unreasonable hardship." Access from the parking lots at the north and east elevations are continuous to the building entrances.

Recommendation: The existing accessible route appears to be compliant.

3. Doors: Section 1133B.2.4 of the CBC requires a level landing on each side of a door. Section 1133B.2.4.2 requires maneuvering clearance to be 60 in. on the swing side of interior doors and 48 in. on the non-swing side of the door with a closer (44 in. without closer). The clearance on the swing side shall extend 18 in. beyond the strike side of the door for interior doors and 24 in. on exterior doors. The clearance for the non-swing side shall extend 12 in. when the door has a closer. Section 1133B.2.5.2 requires hardware that is hand operable with a single effort without requiring the ability to grasp. Currently most of the doors meet these requirements. However, some of them do not have code compliant lever-handled locksets.

Recommendation: Provide lever-handled hardware at doors where there are currently knob locksets.

4. Stairs and Guardrails: Section 1133B.4.4 of the CBC requires striping for the visually impaired on the lowest and upper most treads of a run of stairs. Currently some of the interior stairs do not meet this requirement. CBC Section 1133B.4.2 requires handrails to extend 12 in. beyond the top nosing and 12 in. plus the tread width, beyond the bottom nosing. Interior and exterior stairs do not meet this requirement, and lack a separate handrail from the stair guardrail.

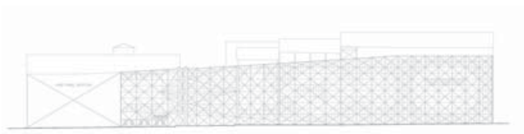
Recommendation: Code compliant handrails and tread striping for the visually impaired should be provided.

5. Restrooms: CBC section 1115B.1 requires buildings that are required to be accessible to have accessible restrooms. The restrooms have been partially upgraded and some of the fixtures, accessories, and required clear areas are disabled accessible.

Recommendation: Confirm/upgrade restroom fixtures, accessories and clearances.

6. Signage: Sections 1103.2.4, 1127B.3, 1129B.5, and 1115B.5 of the CBC require code-compliant signage identifying accessible entrances, parking, areas of refuge, passenger loading zone, toilet and bathing facilities, and exit signage at the exit stairs. In addition to the international symbol of accessibility, each unisex toilet or bathing room shall be identified by a tactile sign including raised letters and Braille. The accessible building entrances, and restrooms do not have disabled accessible signage.

Recommendation: Provide code-compliant signage identifying accessible entrances, parking, areas of refuge, passenger loading zone, toilet and bathing facilities, and exit signage at the exit stairs throughout the building. Identify each toilet room by a tactile sign including raised letters and Braille.



Summary of Recommendations

1. Accessible Parking: The existing disabled accessible loading area should be verified to have a curb cut and sidewalk ramp to the accessible path to the entrance. An additional parking space is needed in the existing parking areas near the main/disabled accessible entrance, and should be a van accessible parking space.

2. Accessible Route: The existing accessible route appears to be compliant.

3. Doors: Provide lever-handled hardware at doors where there are currently knob locksets.

4. Stairs and Guardrails: Code compliant handrails and tread striping for the visually impaired should be provided.

5. Restrooms: Confirm/upgrade restroom fixtures, accessories and clearances.

6. Signage: Provide code-compliant signage identifying accessible entrances, parking, areas of refuge, passenger loading zone, toilet and bathing facilities, and exit signage at the exit stairs throughout the building. Identify each toilet room by a tactile sign including raised letters and Braille.

D. Energy Conservation

Description

The historic structure was designed with very few energy efficient features, as it is primarily a warehouse construction with a small number of Offices. The walls in the test chamber and factory/industrial areas are not insulated, and are also not conditioned. Insulation in the exterior walls of the Office areas could not be confirmed without destructive testing. Window sash are single glazed. The Office areas have a forced-air mechanical system, but the type of system and its efficiency could not be confirmed. Energy efficient fluorescent lighting is the primary lighting source.

Analysis:

Building N-221 has been submitted to SHPO for a determination of eligibility for the National Register of Historic Places and could be exempt from energy code requirements. However, measures to reduce energy consumption and provide for user comfort are recommended.

> *Recommendation:* Recommended actions may include insulating the ceiling and exterior walls during future construction work. The existing steel sash windows are historic features and should be repaired and weather-stripped rather than replaced. High efficiency mechanical systems should be used to replace mechanical systems that have reached the end of their useful life.

X. Future Studies Needed

A. Hazardous Materials

Although a hazardous materials report has not yet been completed, there are several types of historical materials and finishes are known to contain asbestos and other hazardous materials in the building construction. Transite corrugated siding is presumed to be an asbestos-containing material, although the industry considers existing transite to be acceptably left in place, rather than abated. The steel structure and most painted surfaces in the building likely have some lead-based paint residues, and should be confirmed through testing.

It is recommended that a complete hazardous materials report be completed on the building.

B. Mechanical and Electrical Systems

The mechanical and electrical systems were not inspected as part of this report. It is assumed that should the rehabilitation and reuse of Building N-221 be undertaken, it will entail the installation of an upgrade to mechanical and electrical systems, and potentially the plumbing drainage/waste system. All new mechanical and electrical systems should be designed to preserve the character of the significant materials and spaces identified in this report.

C. Structural Systems

The exterior walls of Building N-221 are steel framed with transite or metal corrugated material. The roof structure is comprised of steel trusses and purlins and wood decking. The floor construction is a concrete slab on grade at the first floor, and steel structure with wood decking at the upper floors of the test chamber area. The wind tunnel is steel framed.

The building appears to be in excellent condition. In the course of rehabilitating the building the structural system should be analyzed for seismic and gravity load deficiencies and reinforced as necessary. Strengthening provisions should be designed to preserve significant materials and spaces.

(Footnotes)

[1] "Moffett Field To Get Greatest Wind Tunnel," no source or date provided. Ames Research Center Library, History Collection Series K, oversize Scrapbooks.

[2] *Atmosphere of Freedom*, 18.

[3] "Height Control Research Facility Under Construction," *The Astrogram*, May 11, 1961.

[4] "Ames Facilities Modernized, " *The Astrogram*, December 23, 1971.

[5] "Ames Facilities Modernized," *The Astrogram*, December 23, 1971.

[6] "Wind Tunnel Contract Awarded," *The Astrogram*, June 28, 1979.

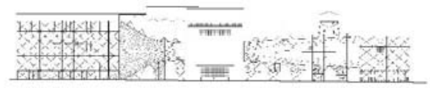
[7] "40 by 80 ft. Wind Tunnel Modification Project," *The Astrogram*, December 27, 1979.

[8] "40 by 80 ft. Wind Tunnel Modification Project," *The Astrogram*, January 24, 1980.

[9] "40 by 80 Foot Wind Tunnel closes for modification," *The Astrogram*, September 18, 1980.

[10] http://windtunnels.arc.nasa.gov/

[11] http://windtunnels.arc.nasa.gov/



NASA Ames Research Center
Building N-221 Reuse Guidelines

Appendix 1. Character-Defining Features

Character-Defining Features

Elements	Significance	Condition	Comments
Exterior			
North Elevation - wind tunnel			
Geodesic steel bent exoskeleton	S	G	
Corrugated metal siding and corrugated transite cement asbestos siding	S	G	
Windows:			
Multi-lite metal sash windows with operable hopper segments (ground floor)	S	F	some windows removed and replaced with metal or plywood panels, some glazing replaced with non-contributing wire glass or vertical striped patterned glass
3-lite wood windows with 2 operable awning segments over 1 hopper segment (second floor level)	S	F	some windows removed and replaced with metal panels and louvered openings
Multi-lite metal windows (upper level)	S	G	
Doors:			
Metal roll-up door	S	F	fixed open above non-contributing metal infill door
Metal Canopy	S	G	
3-lite 1-panel metal doors	S	G	added non-contributing metal canopy above
2-lite transom	S	G	
North Elevation - test section			
Corrugated metal siding and corrugated transite cement asbestos siding	S	G	
Windows:			

Significance Rating
S=Significant
C=Contributing
T=Tertiary
N=Non-contributing

Condition Rating
G=Good
F=Fair
P=Poor

Multi-lite lexan glazed metal sash windows with operable awning segments (ground level)	S	F	some glazing replaced with non-contributing wire glass or vertical striped patterned glass
Multi-lite lexan glazed metal windows (upper level)	S	G	
East Elevation - wind tunnel			
Geodesic steel bent exoskeleton	S	G	
Corrugated metal siding and corrugated transite cement asbestos siding	S	G	
Entrance cone	S	F	
Exit cone	S	F	
Windows:			
Multi-lite lexan glazed metal windows (upper level of settling chamber)	S	G	
Multi-lite metal sash windows with operable awning segments (ground floor under exit cone)	S	F/P	added corridor to building N247 in place of some windows, some glazing replaced with non-contributing wire glass
Multi-lite metal sash windows with operable hopper segments (ground floor under exit cone and diffuser section)	S	F	
3-lite wood windows with 2 operable awning segments over 1 hopper segment (second floor level under exit cone and diffuser section)	S	G/F	
Multi-lite metal windows (flanking doors under diffuser section)	S	G	
Doors:			
1-lite 1-panel metal door (settling chamber)	C	F	
Metal door (entrance cone)	T	G	
4-lite 1-panel metal door (under exit cone)	S	F	transom infilled with metal panel

Significance Rating
S=Significant
C=Contributing
T=Tertiary
N=Non-contributing

Condition Rating
G=Good
F=Fair
P=Poor

Metal roll-up doors (under exit cone)	S	G	added plastic curtain in front of 1 door
Half wire glass metal door (under exit cone)	N	G	
Full glass metal door (under exit cone)	N	F	
3-lite 1-panel metal doors (under diffuser section)	S	G	
Metal canopy with NACA signage	S	G	
Steel ladder and platform (to entrance cone)	C	G	
East Elevation - test section			
Corrugated metal siding and corrugated transite cement asbestos siding	S	F	
Windows:			
Multi-lite lexan glazed metal windows (upper level)	S	G	
Louvered openings	S	F	screens in poor condition
Doors:			
Multi-lite lexan glazed metal panel stacking bottom rolling doors with 4-lite 1-panel walk-in service door	S	G	
Door Track	S	F	
Corrugated metal and corrugated transite cement asbestos shed roof	C	G	bird protection screen above
South Elevation - wind tunnel			
Geodesic steel bent exoskeleton	S	G	
Corrugated metal siding and corrugated transite cement asbestos siding	S	G	
Windows:			
Multi-lite metal windows (upper level)	S	G	
Louvered air intake openings	S	G	
Sloped screen wall	S	G	
Doors:			

Significance Rating
S=Significant
C=Contributing
T=Tertiary
N=Non-contributing

Condition Rating
G=Good
F=Fair
P=Poor

Metal roll-up door	T	G	
South Elevation - test section			
Corrugated metal siding and corrugated transite cement asbestos siding	S	G	
Windows:			
Multi-lite lexan glazed metal sash windows with operable awning segments (ground level)	S	F/P	added non-contributing partial height corrugated metal and corrugated transite cement asbestos siding wall over bottom lites of several windows for MEP connections
Multi-lite lexan glazed metal windows (upper level)	S	G	
West Elevation - wind tunnel			
Rough concrete surface (lower wall under south diffuser section)	S	F	
Geodesic steel bent exoskeleton	S	G	
Corrugated metal siding and corrugated transite cement asbestos siding	S	G	
Fan drive section	N	G	
Windows			
Multi-lite lexan glazed metal sash windows with operable awning segments (ground level of north diffuser section)	S	F	one awning window segment removed and replaced with metal panel, some glazing replaced with non-contributing wire glass or vertical striped patterned glass
Screened openings housing drive motors (second floor level of north diffuser section)	S	F	One drive motor removed
Louvered openings (ground level of north diffuser section)	T	G	

Significance Rating
S=Significant
C=Contributing
T=Tertiary
N=Non-contributing

Condition Rating
G=Good
F=Fair
P=Poor

Multi-lite metal windows (upper level of south diffuser section)	S	G	
Doors:			
4-lite 1-panel metal door (north diffuser section)	S	F	glazing replaced with non-contributing wire glass
Metal roll-up doors (north diffuser section)	S	G	Added plastic curtain in front of 1 door
Metal doors (north diffuser section)	N	G	
Sliding metal door (north diffuser section)	T	G	
West Elevation - test section			
Corrugated metal siding and corrugated transite cement asbestos siding	S	F	
Windows:			
Multi-lite lexan glazed metal sash windows with operable awning segments (ground level)	C	F/P	added building N222 over several windows, some glazing replaced with non-contributing wire glass or vertical striped patterned glass
Multi-lite lexan glazed metal windows (upper level)	C	G	
Louvered openings (ground level)	N	G	
Louvered openings (upper level)	C	F	screens in poor condition
Doors:			
2-panel metal door	T	P	
Metal door	N	G	
Metal exit stair	N	G	
Interior			
40 by 80 Foot Wind Tunnel	S	G	
80 by 120 Foot Wind Tunnel	S	F	
Large open volume	S	G	
Exposed steel framing	S	G	

Significance Rating
S=Significant
C=Contributing
T=Tertiary
N=Non-contributing

Condition Rating
G=Good
F=Fair
P=Poor

Steel stairs and landings	S	G	
Multi-lite metal windows	S	G	
Metal elevator	S	G	
Wall partitions	NC	G	
Concrete flooring	T	G	
Vinyl composition tile	NC	F	
Carpet	NC	F	
Susp. acoustical ceilings	NC	G	
Solid core veneer doors in hollow metal frames	NC	G	
Wood panel doors at first floor offices	C	G	
Florescent light fixtures	NC	F	

Character Defining Features Matrix

Significance Rating
S=Significant
C=Contributing
T=Tertiary
N=Non-contributing

Condition Rating
G=Good
F=Fair
P=Poor

NASA Ames Research Center
Building N-221 Reuse Guidelines

Appendix 2. Existing Floor Plans & Rehabilitation

Building N221

40 x 80 Ft Wind Tunnel

Architectural Resources Group
Architects, Planners & Conservators, Inc.

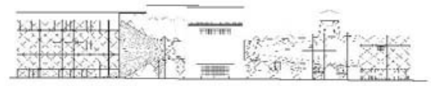
EXISTING PLANS & REHABILITATION

60 0 60
1" = 60'-0"

BUILDING N221
NASA Ames Research Center
Sunnyvale, CA

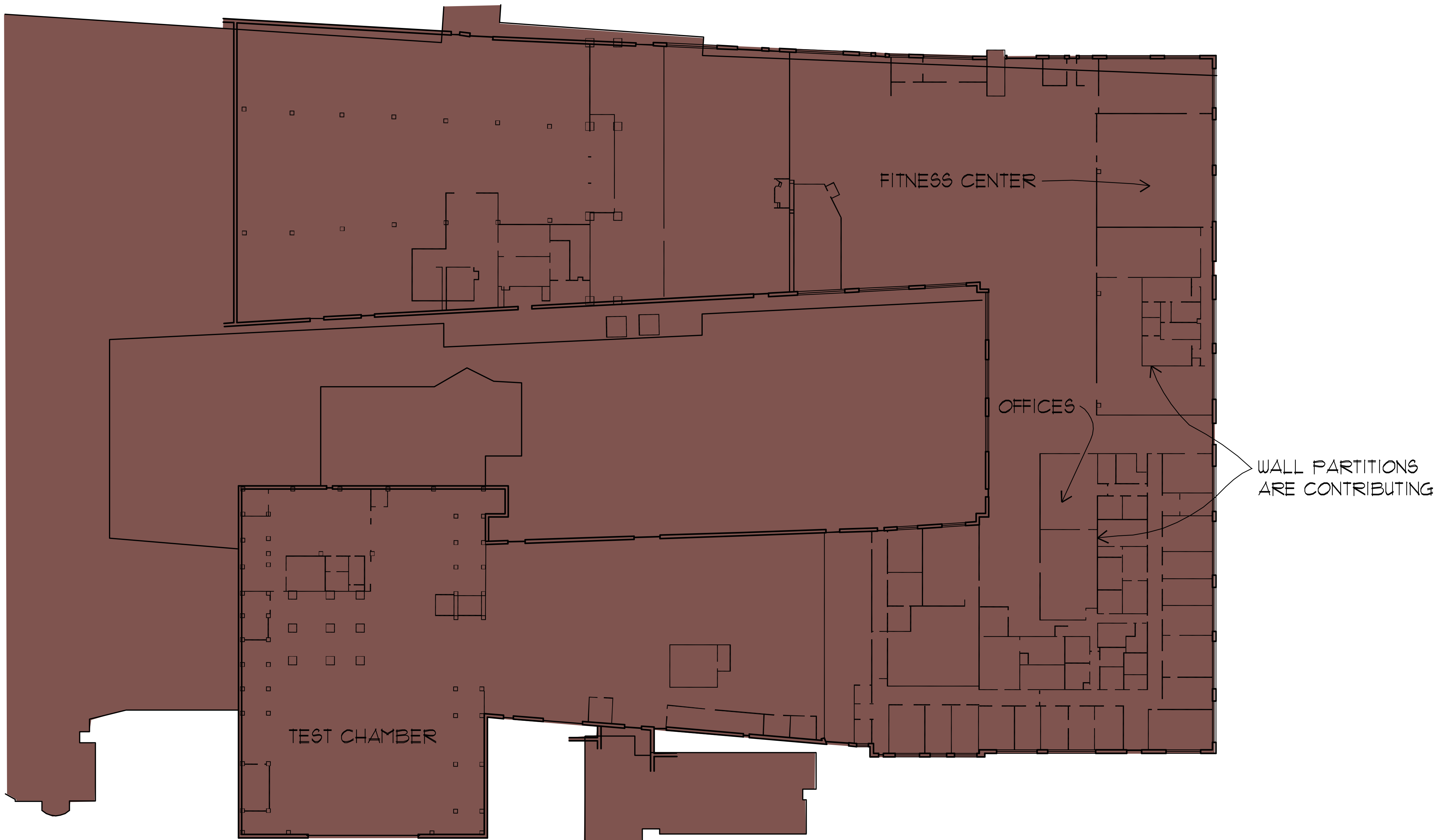
October, 2007

N



NASA Ames Research Center
Building N-221 Reuse Guidelines

Appendix 3. Historic Character-Defining
Significance Diagrams



N-221 PLAN

GENERAL NOTES

1. THESE DIAGRAMS ARE INTENDED TO SHOW THE PRINCIPAL CHARACTER-DEFINING FEATURES, NOT SPECIFIC COMPONENTS.

2. FOR A MATRIX OF SIGNIFICANCE RATINGS FOR INDIVIDUAL BUILDING COMPONENTS, REFER TO APPENDIX I. "HISTORIC CHARACTER-DEFINING FEATURES".

CHARACTER-DEFINING SIGNIFICANCE DIAGRAMS LEGEND

- SIGNIFICANT FEATURE
- CONTRIBUTING FEATURE
- TERTIARY FEATURE
- NON-CONTRIBUTING FEATURE
- NEW CONSTRUCTION - PROPOSED

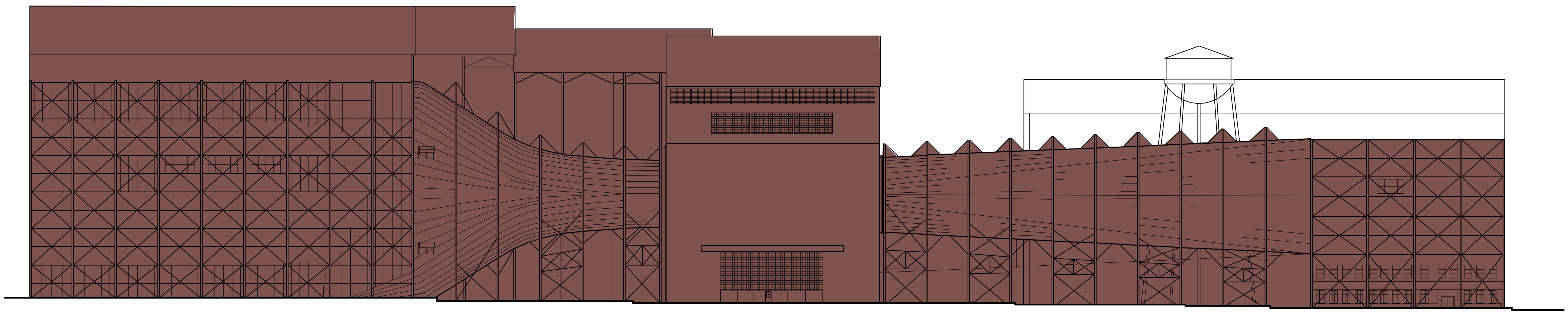
ARCHITECTURAL RESOURCES GROUP
Architects, Planners & Conservators, Inc.

HISTORIC CHARACTER-DEFINING SIGNIFICANCE DIAGRAMS - PLANS

60 0 60
1" = 60'-0"

BUILDING N221
NASA Ames Research Center
Sunnyvale, CA
October, 2007

N



EAST ELEVATION

GENERAL NOTES

1. THESE DIAGRAMS ARE INTENDED TO SHOW THE PRINCIPAL CHARACTER-DEFINING FEATURES, NOT SPECIFIC COMPONENTS.

2. FOR A MATRIX OF SIGNIFICANCE RATINGS FOR INDIVIDUAL BUILDING COMPONENTS, REFER TO APPENDIX I. "HISTORIC CHARACTER-DEFINING FEATURES".

CHARACTER-DEFINING SIGNIFICANCE DIAGRAMS LEGEND

- SIGNIFICANT FEATURE
- CONTRIBUTING FEATURE
- TERTIARY FEATURE
- NON-CONTRIBUTING FEATURE
- NEW CONSTRUCTION - PROPOSED

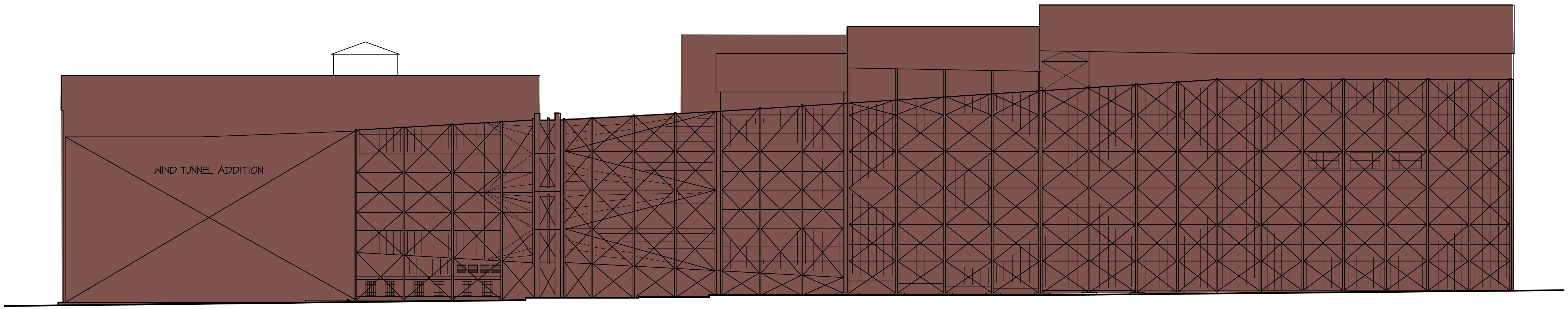
ARCHITECTURAL RESOURCES GROUP
Architects, Planners & Conservators, Inc.

HISTORIC CHARACTER-DEFINING SIGNIFICANCE DIAGRAMS - ELEVATIONS

60 0 60
1" = 60'-0"

BUILDING N221
NASA Ames Research Center
Sunnyvale, CA

October, 2007



WEST ELEVATION

GENERAL NOTES

1. THESE DIAGRAMS ARE INTENDED TO SHOW THE PRINCIPAL CHARACTER-DEFINING FEATURES, NOT SPECIFIC COMPONENTS.

2. FOR A MATRIX OF SIGNIFICANCE RATINGS FOR INDIVIDUAL BUILDING COMPONENTS, REFER TO APPENDIX I. "HISTORIC CHARACTER-DEFINING FEATURES".

CHARACTER-DEFINING SIGNIFICANCE DIAGRAMS LEGEND

- SIGNIFICANT FEATURE
- CONTRIBUTING FEATURE
- TERTIARY FEATURE
- NON-CONTRIBUTING FEATURE
- NEW CONSTRUCTION - PROPOSED

ARCHITECTURAL RESOURCES GROUP
Architects, Planners & Conservators, Inc.

HISTORIC CHARACTER-DEFINING SIGNIFICANCE DIAGRAMS - ELEVATIONS

60 0 60
1" = 60'-0"

BUILDING N221
NASA Ames Research Center
Sunnyvale, CA

October, 2007

NASA Ames Research Center
Building N-221 Reuse Guidelines

Appendix 4. Historic Aerial Photographs

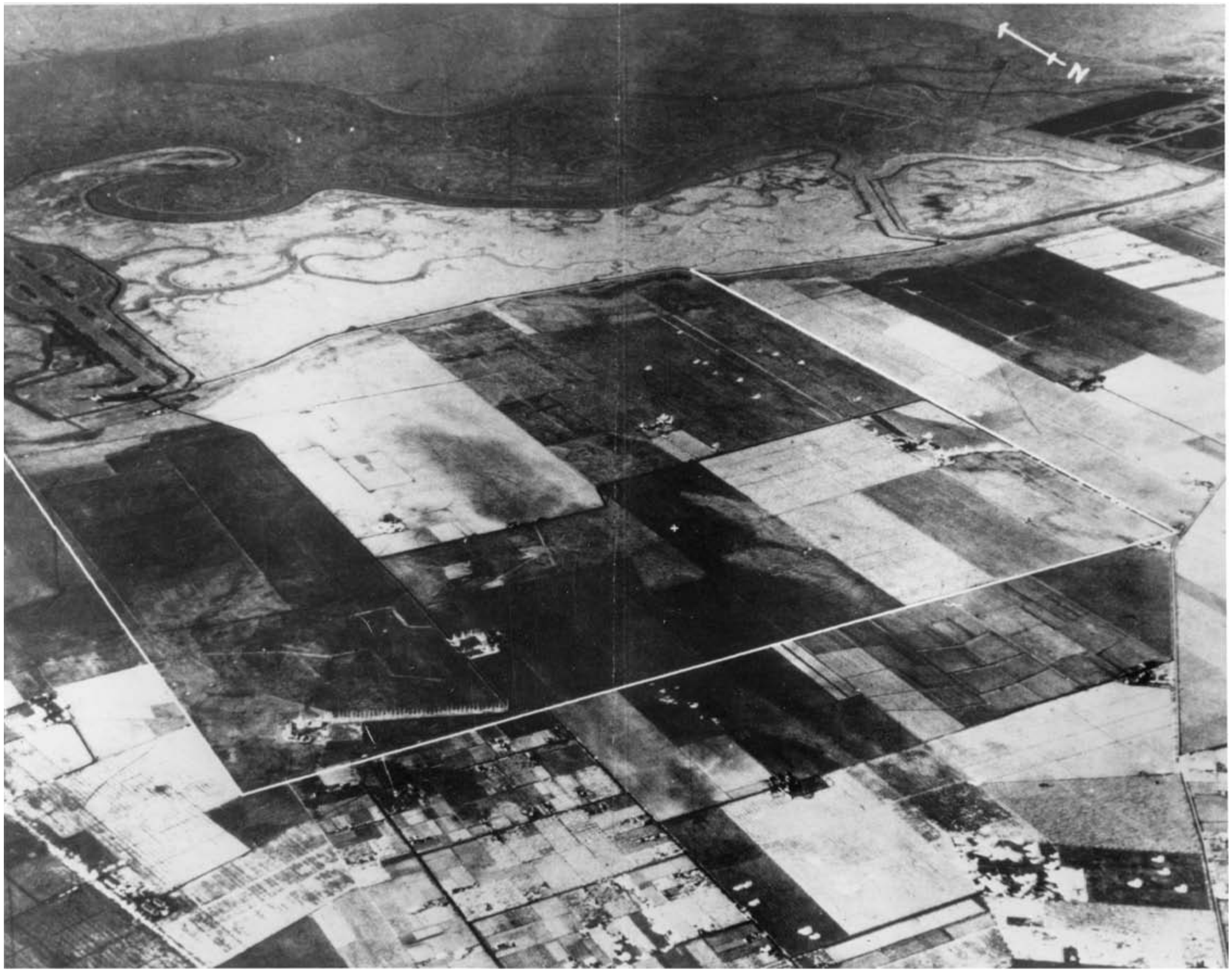


Figure 1: 1930 aerial of future Moffett Field site

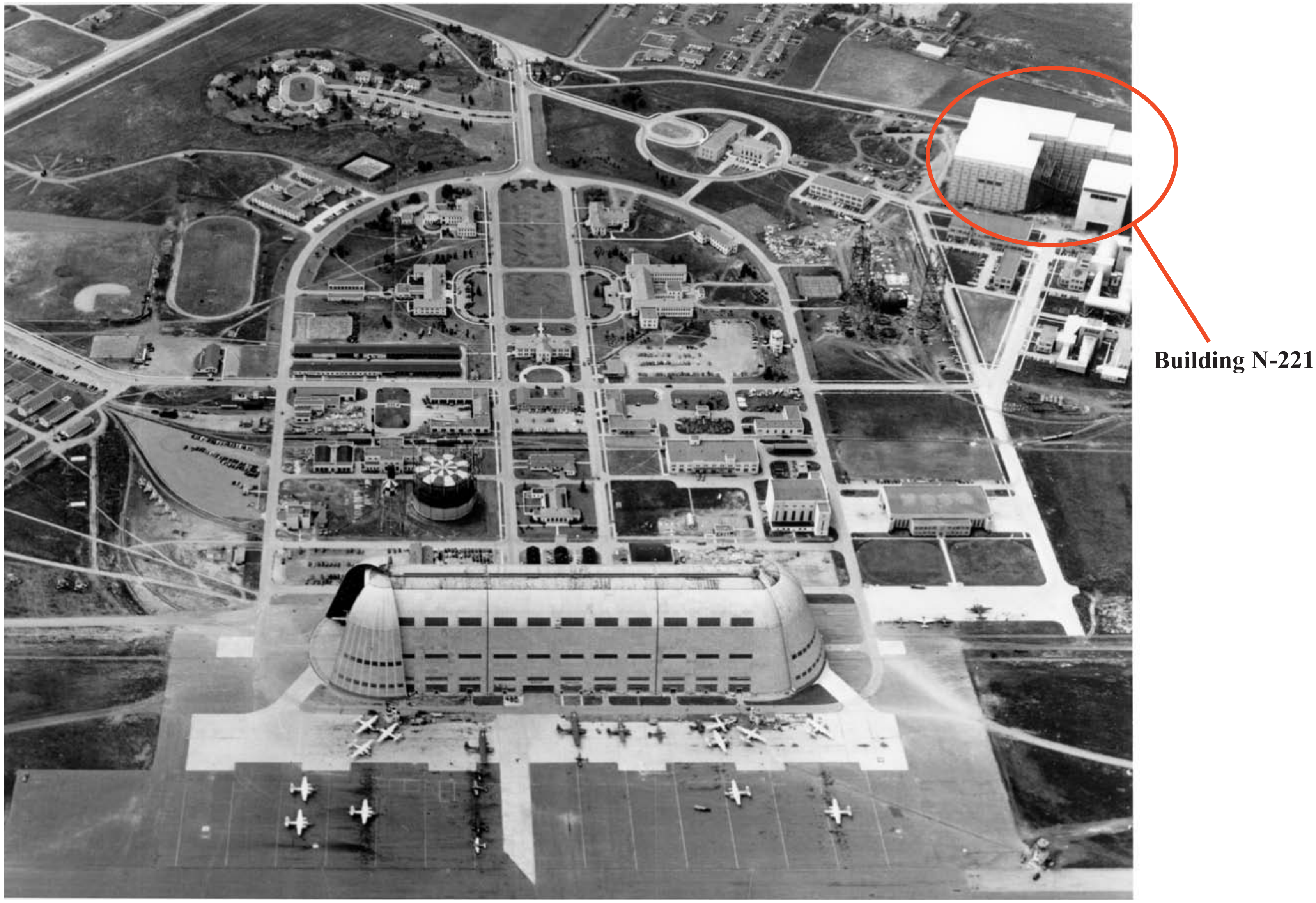


Figure 2: 1944 aerial showing Building N-221, top right

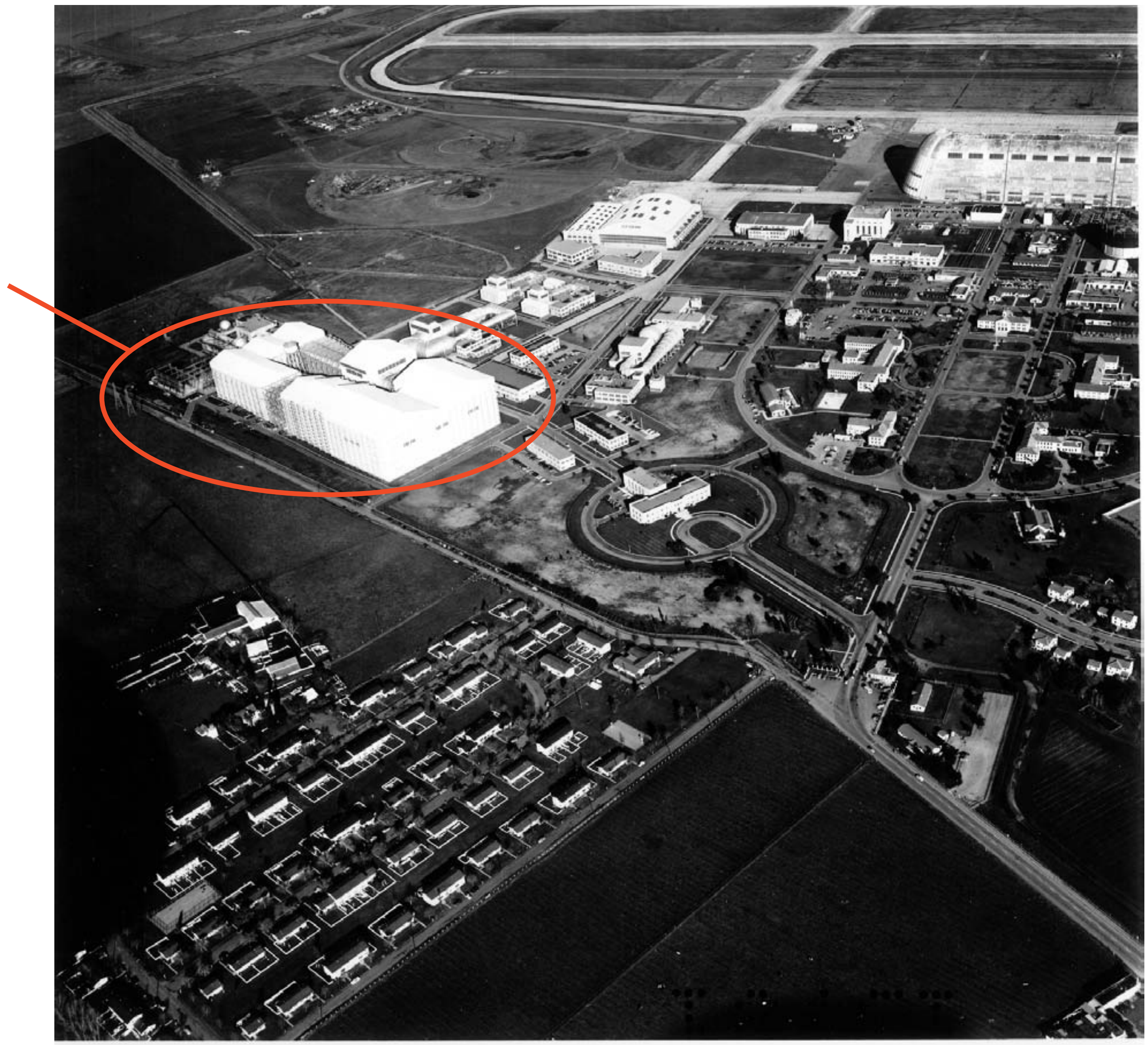


Figure 3: 1944 aerial of Building N-221, center left

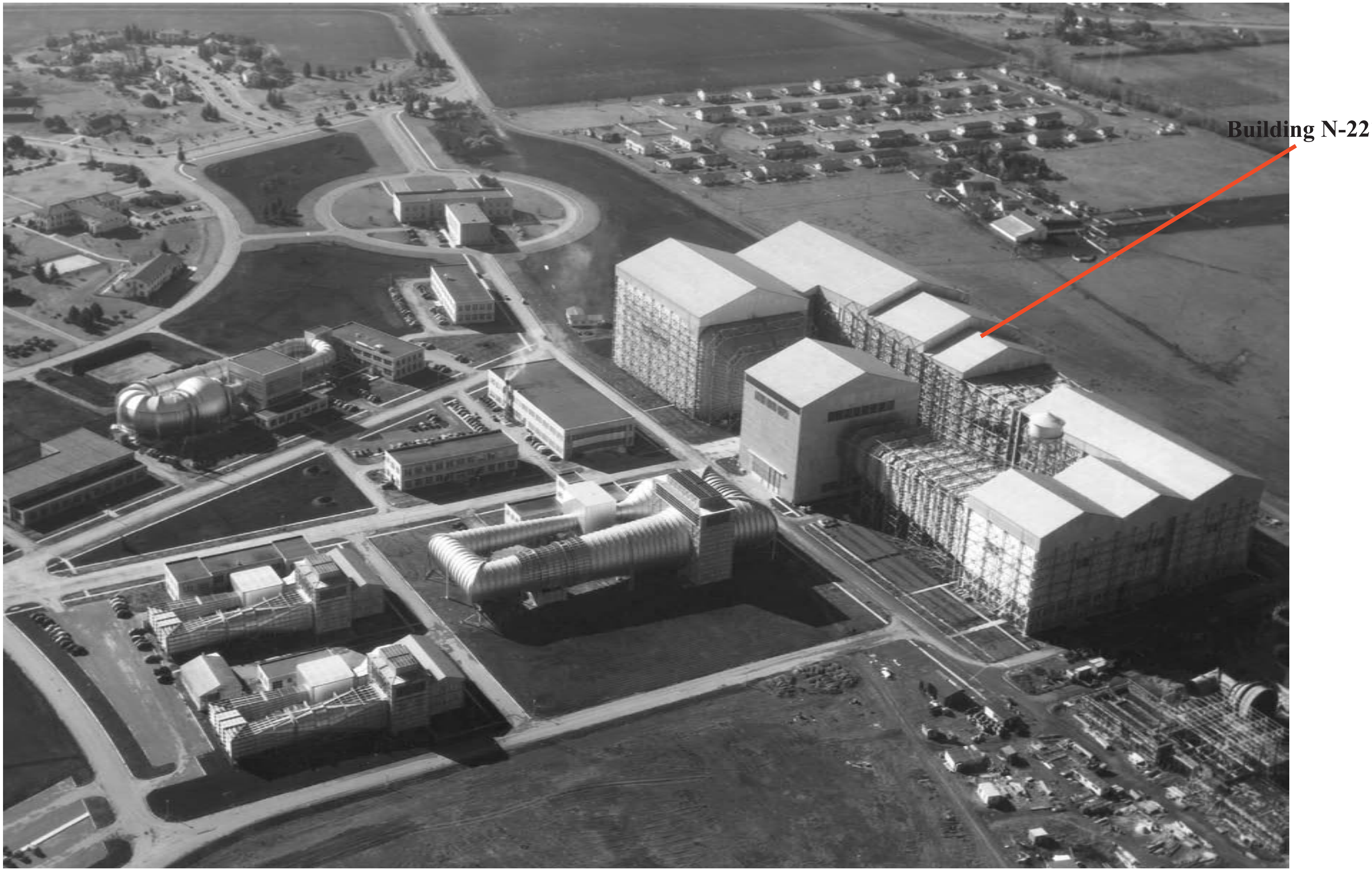


Figure 4: 1947 aerial of partial Building N-221

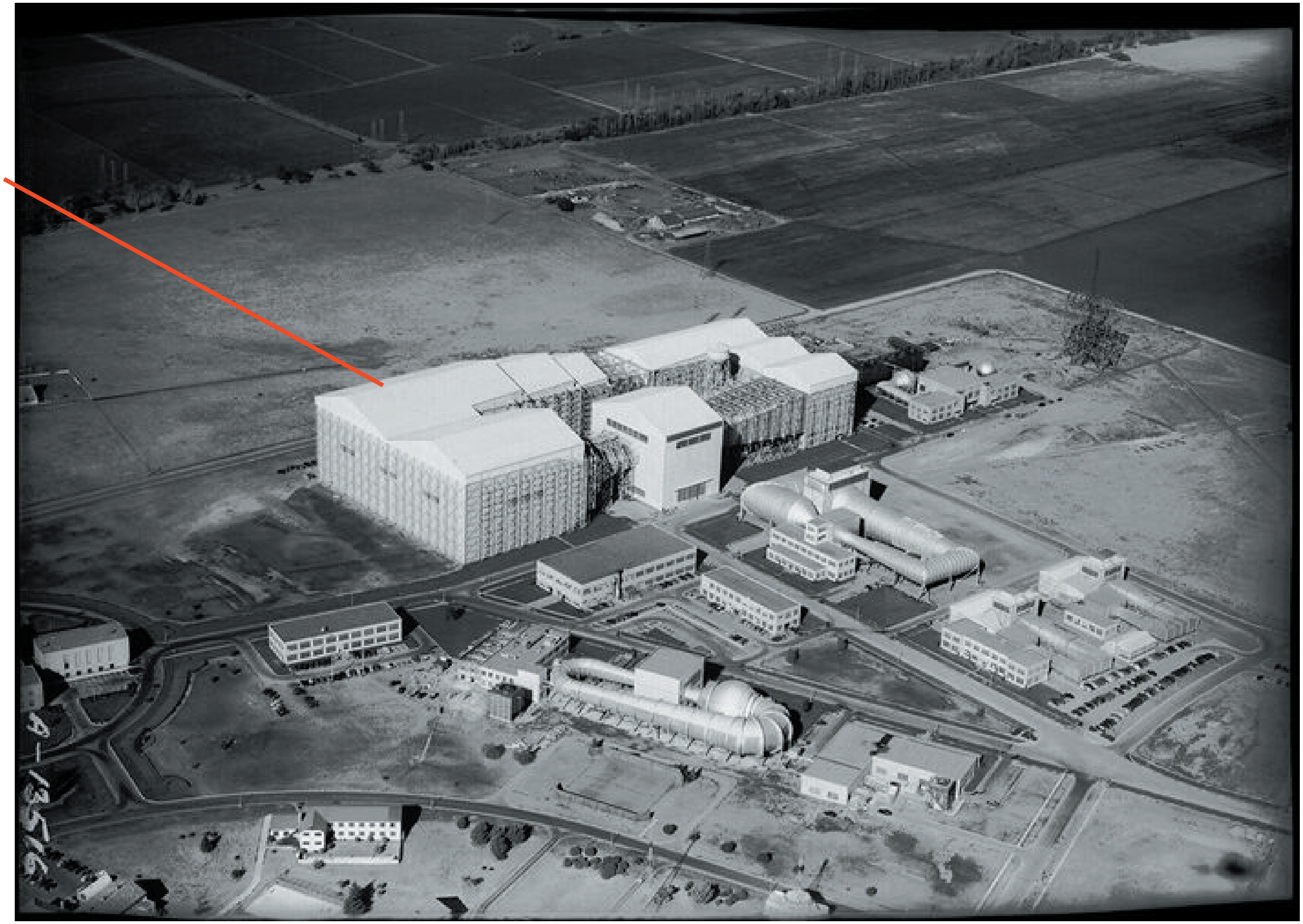


Figure 5: 1948 aerial showing Building N-221 without 80 by 120 Wind Tunnel

Figure 6: 1952 aerial of Moffett Field

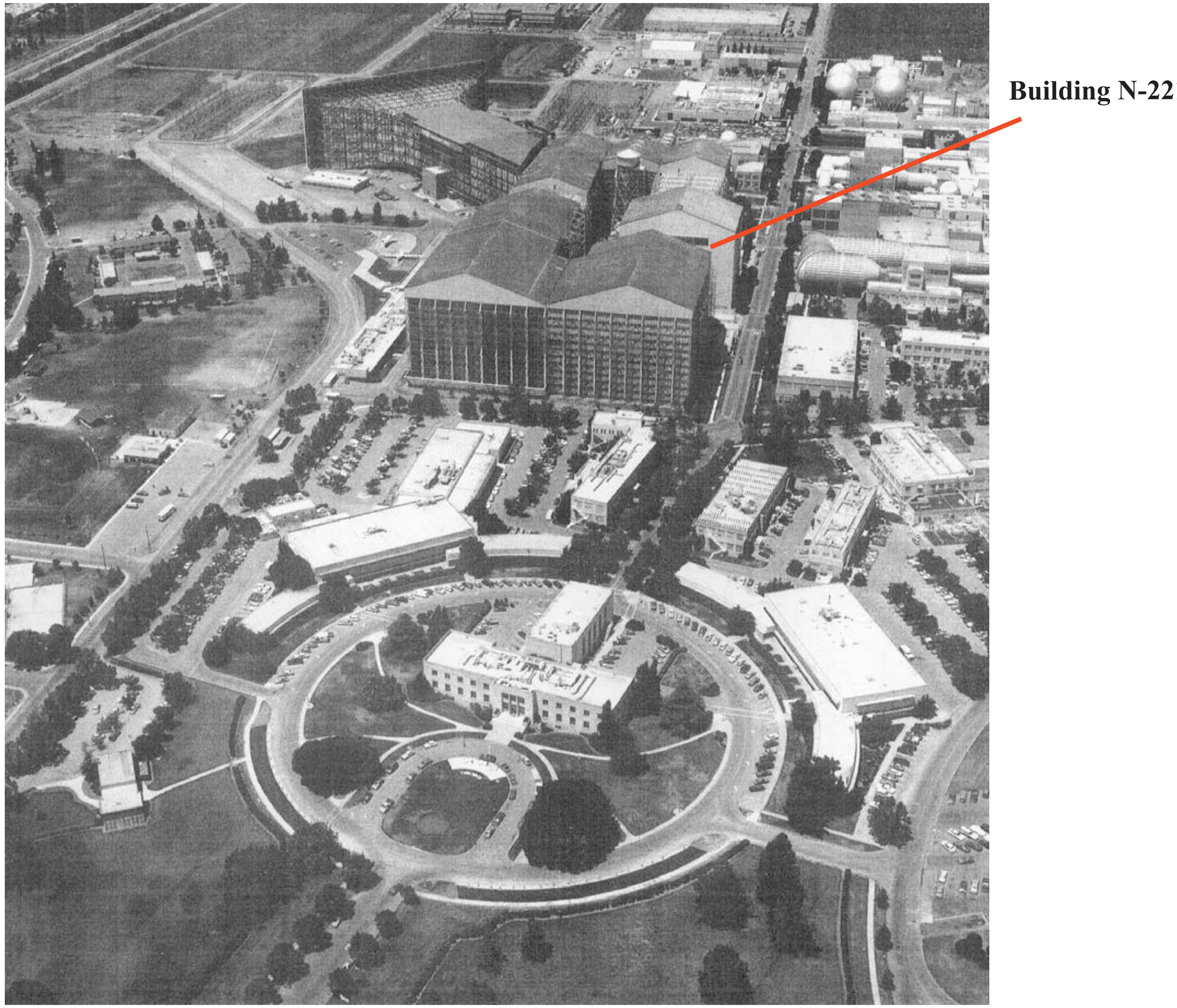


Figure 7: aerial showing Building N-221 with 80 by 120 Foot Wind Tunnel completed

Figure 8: 1982 aerial showing Building N-221 with 80 by 120 Foot Wind Tunnel

Figure 9: 1982 aerial of Moffet Field

Building N-221

Figure 10: 1984 aerial of Building N-221

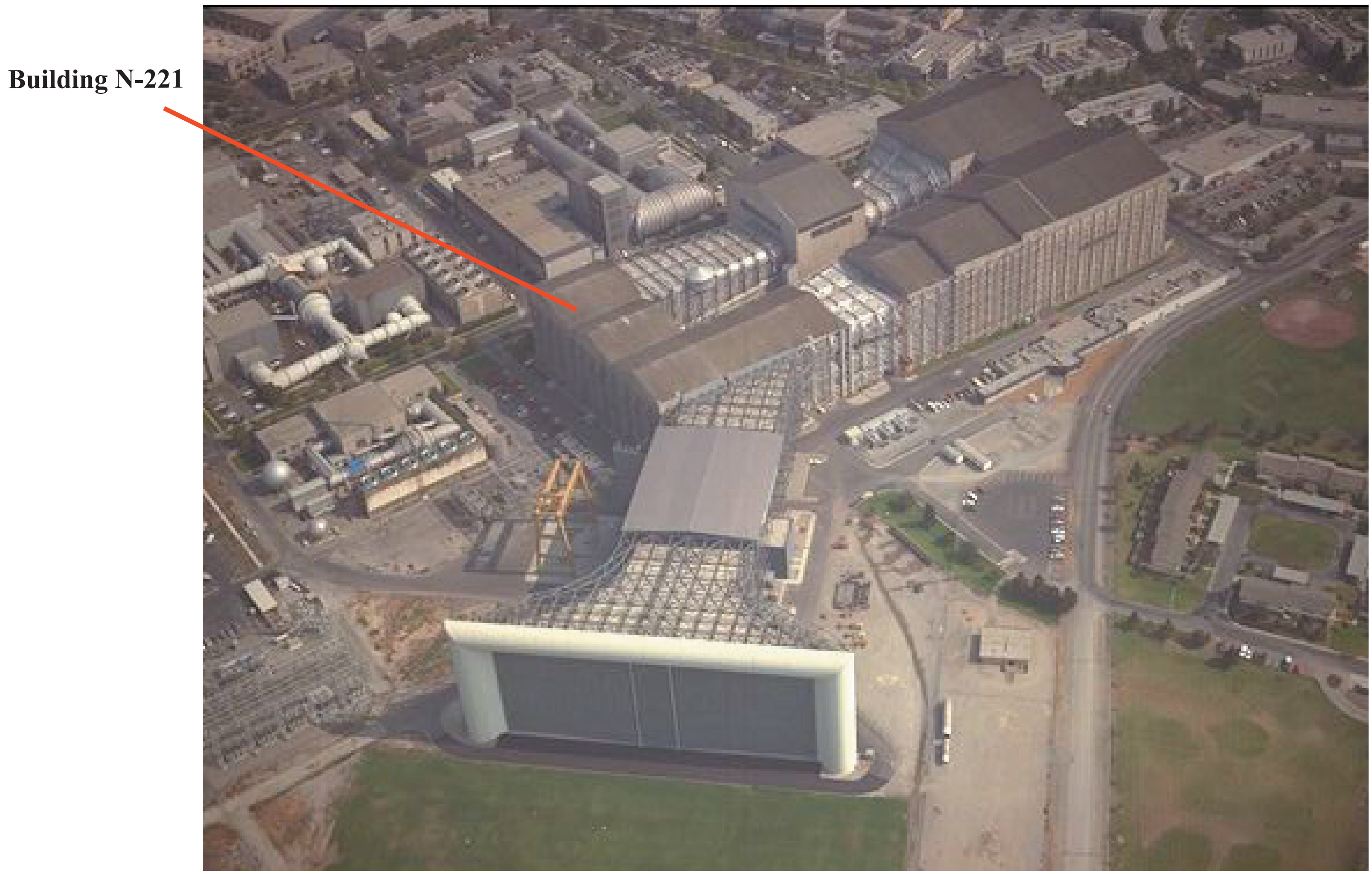


Figure11: 1986 aerial of N-221

NASA Ames Research Center
Building N-221 Reuse Guidelines

Appendix 5. Current Conditions Photographs (2006)

Figure 12. East entry of the 40 by 80 Foot Wind Tunnel with the original name "NACA"

Figure 13. East entry

Figure 14. Wall, window, and steel structure

Figure 15. East facade and N-247

Figure 16. East elevation and N-247

Figure 17. Fitness Center entry

Figure 18. East facade Tunnel entry

Figure 19. Hopper windows

Figure 20. Windows at the courtyard with hopper segments

Figure 21. Original 2 by 2 Foot Wind Tunnel doors

Figure 22. View of N-222 from the courtyard

Figure 23. Northwest view of the 80 by 120 Foot Wind Tunnel

Figure 24. Courtyard looking south

Figure 25. East entry of 40 by 80 Foot Wind Tunnel

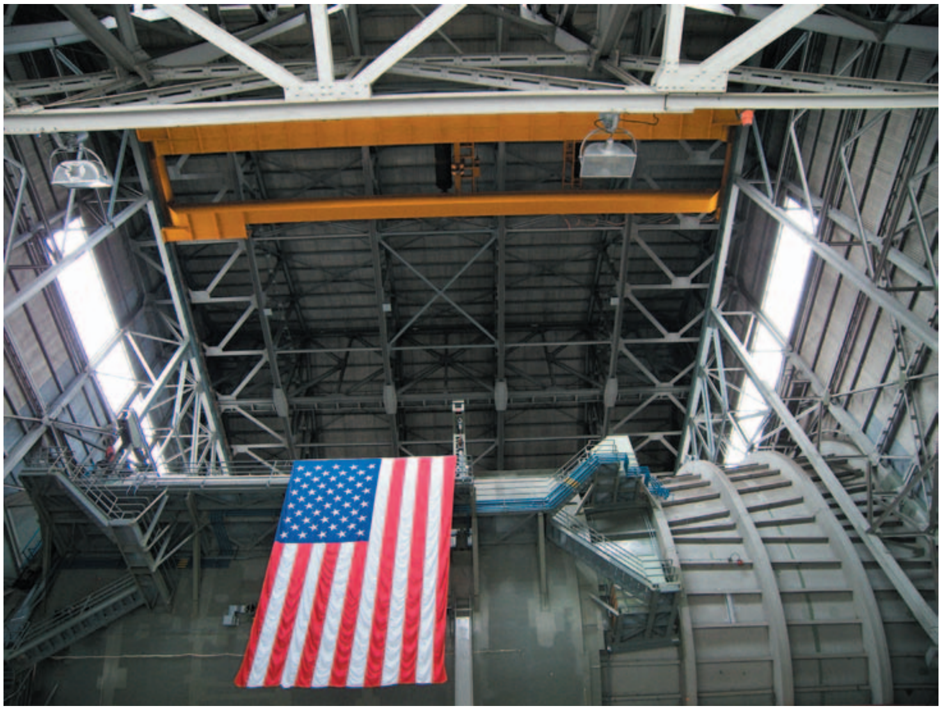


Figure 26. 40 by 80 Foot Wind Tunnel entry ceiling

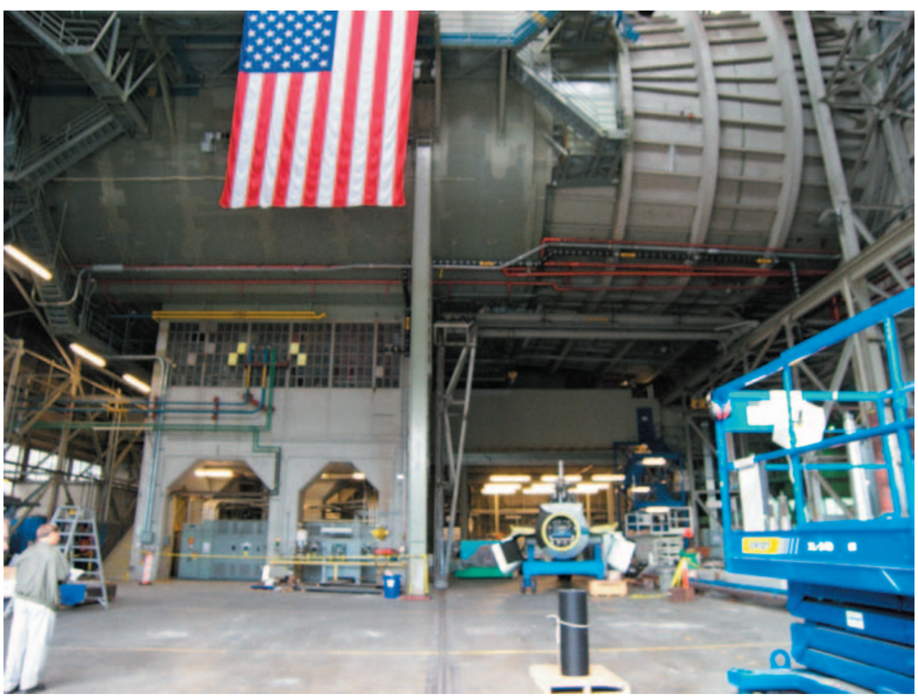


Figure 27. 40 by 80 Foot Wind Tunnel entry

Figure 28. 40 by 80 Foot Wind Tunnel entry

Figure 29. 40 by 80 Foot Wind Tunnel

Figure 30. 40 by 80 Foot Wind Tunnel

Figure 31. 40 by 80 Foot Wind Tunnel

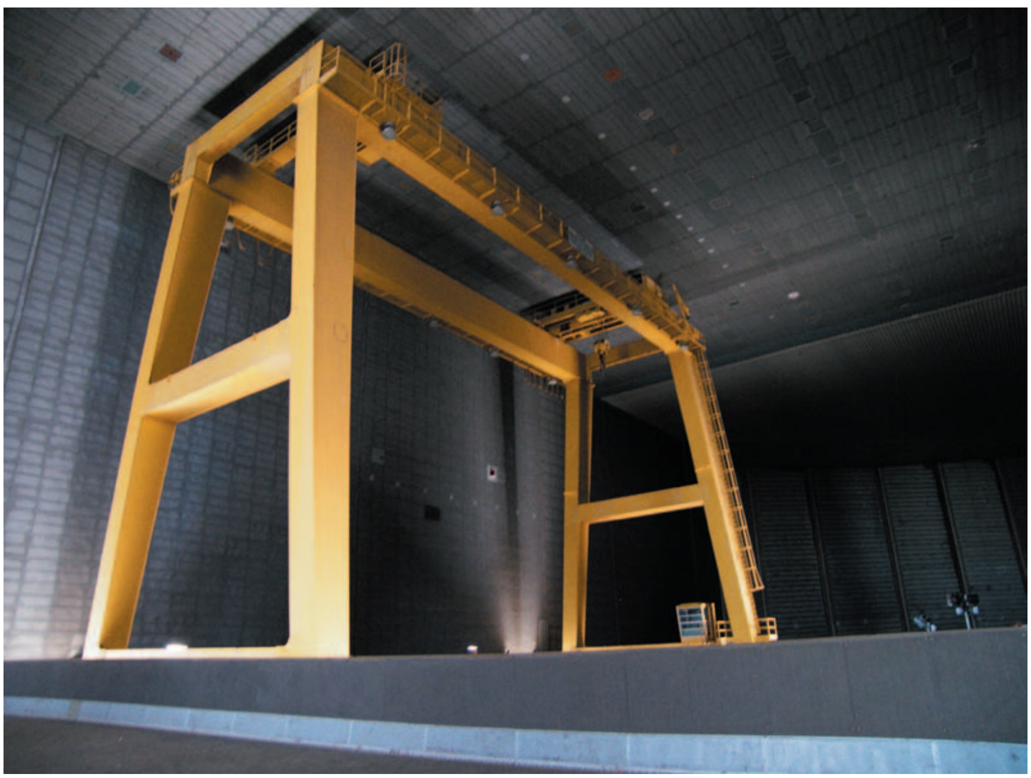


Figure 32. 80 by 120 Foot Wind Tunnel

Figure 33. 80 by 120 Foot Wind Tunnel

Figure 34. 80 by 120 Foot Wind Tunnel

Figure 35. Interior view of office

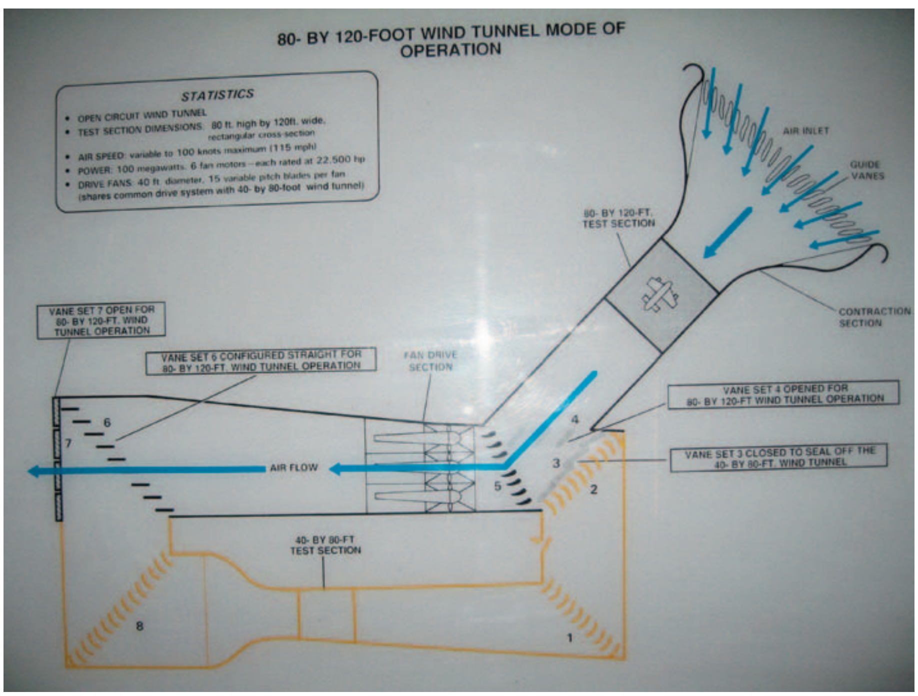
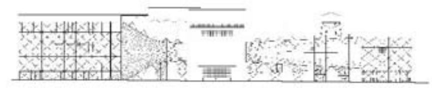
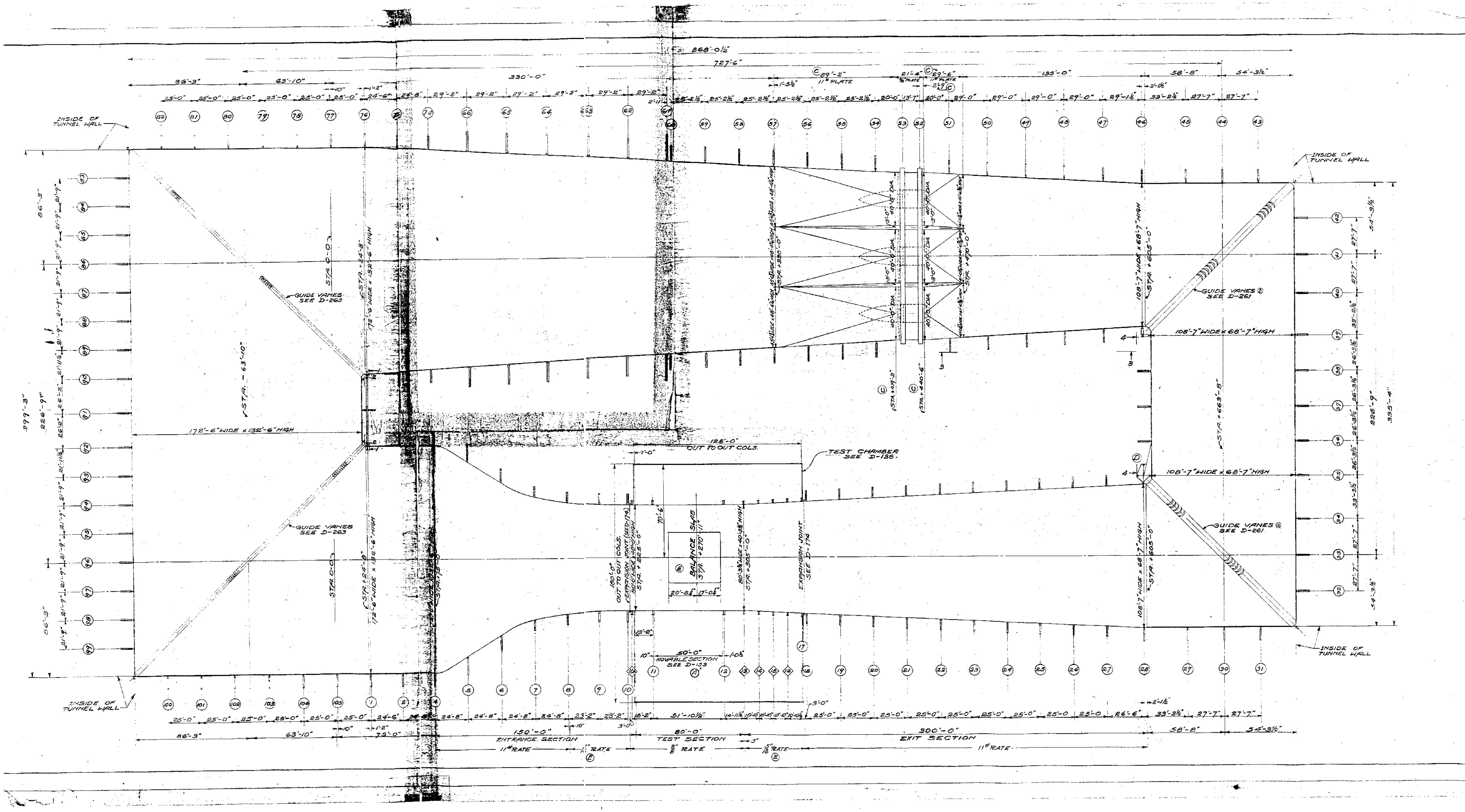


Figure 36. 80 by 120 Foot Wind Tunnel model of operation

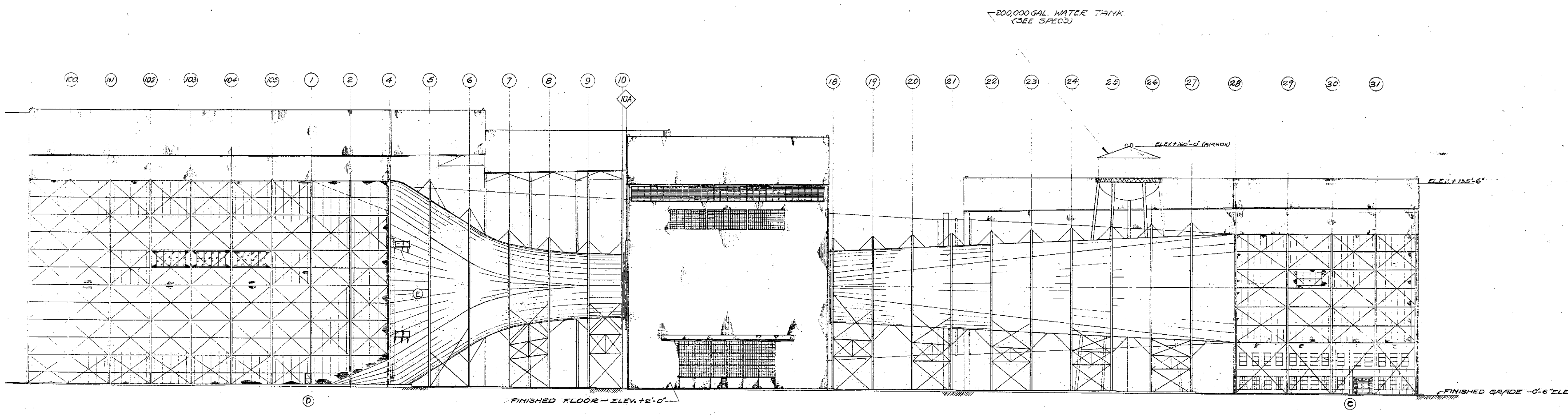


NASA Ames Research Center
Building N-221 Reuse Guidelines

Appendix 6. Construction Plans



868'-0½"
727'-6"
330'-0"
INSIDE OF TUNNEL WALL
GUIDE VANES SEE D-263
172'-6" WIDE x 132'-6" HIGH
GUIDE VANES SEE D-261
108'-7" WIDE x 68'-7" HIGH
TEST CHAMBER SEE D-156
125'-0" OUT TO OUT COLS.
BALANCE SLAB
EXPANSION JOINT SEE D-174
MOVABLE SECTION SEE D-153
150'-0" ENTRANCE SECTION
80'-0" TEST SECTION
300'-0" EXIT SECTION



EAST ELEVATION

[redacted]
MUST BE RETURNED TO
N.A.C.A., MOFFETT FIELD, CALIF.

E		PLATFORMS & LADDER ADDED	RMH
D		DOOR AT BENT (1) ADDED	RMH
C		DOORS AND WINDOWS CORRECTED BETWEEN (28)-(32)	
B		VENTILATING TOWER REMOVED. CORRECTED TO 10/6/41	CFW
A		GENERAL CHANGES-ASBESTOS-CEMENT COVERING, ABOVE TUNNEL PASSAGEWAY CHANGED TO VERTICAL.	

REVISIONS

40-FT x 80-FT. WIND TUNNEL
EAST ELEVATION

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

DR.
CH. E.S.
APP.
APP.

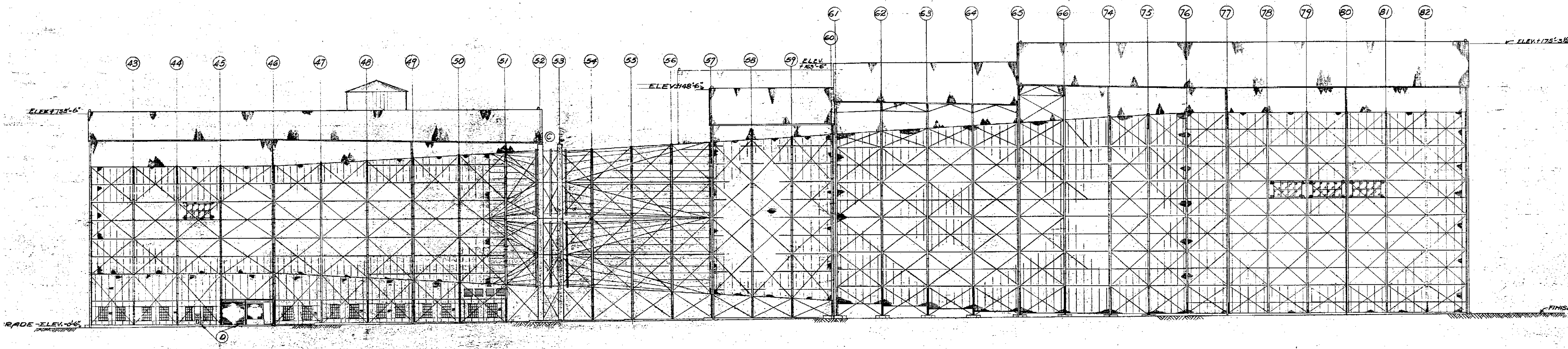
SCALE 1" = 25'-0"

X-102E

321 4091A 1 1 3

P4-1

SHT. 1 OF 2



WEST ELEVATION

NOTE:-
ELEVATIONS, +135'-6", +148'-6", & +175'-3½" AS GIVEN ON THIS AND DETAIL DRAWINGS ARE APPROXIMATE AND MAY BE CHANGED TO SUIT CONSTRUCTION DETAILS.

[redacted]

D	3/18/43	DOORS ADDED & WINDOW CHANGED BET.	CEB
C		CORRECTION AT (52) & (53)	BB
B		VENTILATING TOWER REMOVED. CORRECTED TO 10/6/41	
A		GENERAL CHANGES-ASBESTOS-CEMENT COVERING ABOVE TUNNEL PASSAGE CHANGED TO VERTICAL.	

REVISIONS

40-FT. X 80-FT. WIND TUNNEL
WEST ELEVATION

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

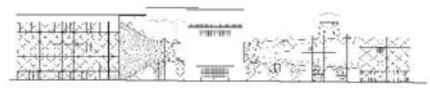
SCALE 1" = 25'-0"

DR. CFW 4-6-41
CH. E.S.
APP.
APP.

X-103D

3 2 1 4 0 0 AA 2 H-1

SHT. 1 OF 2



NASA Ames Research Center
Building N-221 Reuse Guidelines

Appendix 7. NRHP Nomination

SETTING

Situated at the southern end of San Francisco Bay, the National Aeronautics and Space Administration (NASA) Ames Research Center borders the towns of Sunnyvale and Mountain View, near the heart of Silicon Valley. The Ames facility occupies approximately 430 acres of land and hosts a number of other federal, civilian, and military resident agencies on the adjoining 1,500-acre former United States Naval Air Station, now known as Moffett Federal Airfield.

The Ames Aeronautical Laboratory 40 x 80 Foot Wind Tunnel is identified as Building N-221, the voluminous eight-acre facility sited on the western edge of Moffet Field that, today, is identified as the National Full-Scale Aerodynamics Complex (NFAC). The NFAC is comprised of the 40 x 80 Structure and the 80 x 120 leg. The facility is surrounded by Gamma Lane to the west, King Road to the south, DeFrance Avenue to the east, and Building N-226 to the north.

Three non-contributing structures are present within the boundaries of the nomination. These three structures are the 2 x 2 Foot Transonic Wind Tunnel; the 20-G Centrifuge facility; and lastly, the 80 x 120 test section. Identified as Building N-221, the 2 x 2 Transonic Wind Tunnel is an independent wind tunnel located inside the central courtyard of the 40 x 80 Structure. The 2 x 2 is not considered to be individually significant, and does not lend to the significance of the 40 x 80 Wind Tunnel. Identified as Building 221A, the 20-G Centrifuge facility was originally constructed in 1964 and is located outside the exterior walls, below the test chamber of the 40 x 80 Structure. The centrifuge facility performs unrelated activities separate from the 40 x 80. It is not considered to be individually significant, nor does it lend to the significance of the 40 x 80 Wind Tunnel. Identified as Building N-221B, the 80 x 120 leg was constructed in 1977 as an interconnected but separate wind tunnel test section that shares a common drive system with the 40 x 80 Wind Tunnel. Although similar testing activities occur in the 80 x 120 test section, the 80 x 120 leg does not contribute to the individual significance of the 40 x 80 Wind Tunnel.

FACILITY DESCRIPTION

Original 40 x 80 Structure

The original 40 x 80 structure was designed as a slow loop and has a general rectangular shaped plan with varying measurements for each exterior elevation. Each elevation features several segments of gabled roofline. The enclosed structure contains a courtyard space located between the innermost exterior walls. The structure is surrounded by a exoskeleton comprised of geodesic steel bents. The original engineers who designed the structure placed the skeleton on the exterior in order to enhance the wind tunnel's flow field. Essentially the goal was to minimize the amount of interior objects in order to create a more streamline space for air-flow.

South Elevation

The south elevation measures approximately 400 feet in length (from the west corner to the east corner) by 175 feet in height (from foundation to peak of roofline). The wall-to-wall depth of the south elevation's center section is approximately 180 feet.

Exterior building materials in this section consist of a mix of corrugated metal siding and transite cement asbestos corrugated siding surrounded by the exoskeleton of the structure that is comprised of seventeen (17) geodesic bents (numbered 83 through 99).

East Elevation

The east elevation of the structure spans 868 feet in length and is comprised of several sections: the southeast corner of the structure measures approximately 235 feet in length; the entrance cone of the 40 x 80 test section measures approximately 150 feet; the test chamber or test section and balance house which contains the 40 x 80 Wind Tunnel and measures approximately 130 feet; the test section diffuser measures approximately 255 feet; and lastly, the northeast corner of the structure measures approximately 98 feet.

The height of the structure on the east elevation ranges from approximately 175 feet at the southeast corner roof peak to approximately 135 feet at the northeast corner roof peak.

East elevation exterior building materials consist of a mix of corrugated metal siding and transite cement asbestos corrugated siding, surrounded by the exoskeleton of the structure that is comprised of twenty-nine (29) geodesic bents (numbered 100 through 105 and 1 through 31). The entrance cone and test section diffuser are metal and also surrounded by the steel bents (included in the numbers above). Industrial style windows are located along the various levels throughout the east elevation and the northeast exterior wall contains the largest grouping of operable windows. Fenestration in this section of the façade consists of aligned three-sash awning windows on the structure's first and second levels. Also in this section is the official front entrance to the N-221 structure. The entrance features double doors, each with a multi-pane sash window panel above a plain lower panel, and are flanked one each side by a single narrow rectangular multi-pane sash window placed vertically on the façade. The original signage from the National Advisory Committee on Aeronautics (NACA) is still present above the entry doors.

North Elevation

The north elevation measures 335 feet and 4 inches in length by 135 feet and 6 inches in height. The wall-to-wall depth of the north elevation's center section is approximately 98 feet.

Exterior building materials in this section consist of a mix of corrugated metal and transite cement asbestos corrugated siding surrounded by the exoskeleton of the structure that is comprised of eleven (11) geodesic bents (numbered 32 through 42). Fenestration continues in a similar pattern as that displayed on the north corner of the east elevation, and consists of aligned three-sash awning windows on the first and second levels. A double door entrance is located on the western end of the north elevation. Similar to those found in the main entrance, the doors contain two panels, one upper window panel with a multi-pane sash, and a plane lower panel. The doors are flanked one each side by a single narrow rectangular multi-pane sash window placed vertically on the façade.

West Elevation

The west elevation of the structure spans 868 feet in length and is comprised of three sections: the drive section entrance cone measuring approximately 135 feet in length, plus an additional eighty feet before the section; the upstream shroud that measures approximately forty-five feet in length; the drive section and downstream shroud that measures approximately 230 feet in length; and lastly, the south end diffuser that measures approximately 290 feet in length, plus an additional ninety feet (approximately).

The height of the structure on the west elevation ranges from approximately 135 feet at the northwest corner roof peak to approximately 175 feet at the southwest corner roof peak.

The west elevation exterior building materials consist of a mix of concrete on the lower wall portions and corrugated metal and transite cladding above. Thirty-three geodesic steel bents surround the west elevation exterior walls in order to provide structural support.

40 x 80 Wind Tunnel

The NASA Ames Research Center's 40 x 80 Wind Tunnel is a closed circuit, single return wind tunnel. Six 40-foot diameter fans that are powered by six 22,500 horsepower electric motors drive the tunnel. The 40-by 80-foot test section is 39-feet high, 79-feet wide, and 80-feet long. It is lined with an acoustic lining to optimize acoustic research testing. The test section doors are 40 feet wide and 49 feet long. There is one door on each side of the tunnel centerline on top of the test section. When fully open, a clear opening of 78.5 feet by 49 feet is provided. Inside the test section are two hoists, a 5-ton and 35-ton, mounted on the common bridge at the top of the test chamber. These hoists were designed to lift models into the test section from the high bay floor.[1]

80 x 120 Wind Tunnel

The 80-by-120 foot Test Section is the larger part of the closed circuit, single return wind tunnel that makes up the National Full-Scale Aerodynamics Complex (NFAC). Its size makes it ideal for testing large-or full-scale models and prototypes, including full-scale rotors. It is equipped with a sound absorbent lining installed to create a semi anechoic space for aero-acoustic research studies of aircraft models. The test section's balance system measures the forces for six degrees of freedom. Constructed as a leg of the preexisting 40-by 80-foot tunnel, the 80 x 120 is driven by six 40-foot diameter fans that are powered by six 22,500 electric horsepower motors.

The 40-by 80-foot and the 80-by 120-foot test sections share an interconnected flow loop. By adjusting the position of the 80 x 120's vane sets the airflow can be directed through one test section into the other. When the 40- by 80-foot test section is in operation, work may simultaneously continue in the 80-by 120-foot test section. However, due to the pressurized downstream airflow, work may not continue in the 40-by 80-foot test section when the 80-by 120-foot test section is in operation.[2]

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[1] http://windtunnels.arc.nasa.gov/

[2] http://windtunnels.arc.nasa.gov/

OMB No. 1024-0018

MODIFICATION HISTORY

Originally constructed in 1944, and described as a "wind tunnel large enough to accommodate full-size bombing planes,"[3] the 40 x 80 Wind tunnel has undergone several modifications throughout the course of its existence.

Little is known about the first modifications to the 40 x 80 except that they occurred only four years after the structure was originally built. According to the NASA Ames history publication *Atmosphere of Freedom*, the facility was officially reopened in 1948.[4] The publication does not elaborate on the extent of work causing the facility to be opened again in 1948.

The second modification to the wind tunnel facility occurred in mid-1961 when the Height Control Test Apparatus was constructed and attached to the south end exterior walls of the 40 x 80. Part of the Height Control Research Facility, the apparatus was a flight simulator that "yielded valuable data on pilot handling requirements in the fields of vertical takeoff and landing, supersonic transport landing approach, low altitude attack, and soft landings on other planets."[5] The Height Control Facility and testing apparatus was removed from the 40 x 80 exterior wall in approximately 1980.

In the 1960s extensive research studies determined a need existed nationally for additional low-speed aerodynamics research. Accordingly, engineering studies commenced in 1969 in order to determine how to best meet the research requirement. NASA concluded the most cost-effective approach consisted of re-powering and strengthening the existing 40 x 80 Wind Tunnel Structure. Various strengthening and re-powering projects were investigated including grafting a larger 40-by-80 test leg onto the original structure. Ultimately, the proposal to replace the existing motor drives in the 40 x 80 structure and add a new 80-by-120 test section was determined the best approach.[6]

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[3] "Moffett Field To Get Greatest Wind Tunnel," no source or date provided. Ames Research Center Library, History Collection Series
K, Oversize Scrapbooks.
[4] *Atmosphere of Freedom*, 18.
[5] "Height Control Research Facility Under Construction," *The Astrogram*, May 11, 1961.
[6] "Ames Facilities Modernized," *The Astrogram*, December 23, 1971.

In the spring of 1972 work began on a $6.5 million modernization project for the 40 x 80 wind tunnel structure. The undertaking began as a result of the need to increase operational safety and efficiency. In addition, the modifications were required in order to accommodate the increasing demand for "low-speed, large-scale testing of advanced Short Take-Off and Landing (STOL) aircraft and Vertical Take-Off and Landing (VTOL) aircraft."[7]

In June 1979 a $10.7 million wind tunnel contract was awarded to the Bostrom-Bergen Metal Products Company of Oakland, California that provided for construction work related to modifications to the 40 x 80 Foot Wind Tunnel facility. The contract called for the structural modifications to the 40 x 80 in order to accommodate an "increase in the wind tunnel's drive power from 36,000 to 135,000 horsepower and a new test leg with a much larger test section 24 m high by 36 m wide (80 by 120 ft.)."[8] The construction was scheduled to last for approximately two years, and the two test sections were slated to be opened and operational by late 1981.

The December 27, 1979 edition of the NASA Ames employee newsletter *The Astrogram*, detailed the 40 x 80 Foot Wind Tunnel modification project:

> "Initial design for the modification started in 1973 and is now approximately 95% complete. Contracts for long lead items were let starting in mid-1977. These items included the 6 drive motors and 90 fan blades, as well as most of the other mechanical parts of the drive system. At this point in time, the project has awarded 26 contracts totaling $47,967,000, or 56% of the estimated project cost of $85,000,000. Bids totaling approximately $10 million are expected to be opened prior to the end of 1979. This will mean that firm prices have been established for approximately 70% of the total project cost and that the project can probably be completed within the projected budget of $85 million.

The current project schedule is as follows:

Start new leg foundation –	December 1979
Start assembly of first drive unit -	February 1979
Shut down 40- by 80-foot wind tunnel operation-	June 1980
Start installing new leg steel -	August 1980
Install new drive unit -	September 1980
Complete construction of 40-by 80-foot wind tunnel –	May 1981

[7] "Ames Facilities Modernized," *The Astrogram*, December 23, 1971.
[8] "Wind Tunnel Contract Awarded," *The Astrogram*, June 28, 1979.

Complete construction of 80-by 120-foot wind tunnel- January 1982."[9]

By late January 1980, the modification project was well underway and by that time five of the six new drive motors had been delivered to the Ames facility. The Westinghouse Electric Corporation Round Rock, Texas motor plant, constructed the 18,000 horsepower motors. In addition, other projects that had been started included the driving of the pre-stressed concrete piles for the 80 x 120's foundation, structural strengthening work on the 40 x 80, and the construction of an electrical equipment room for the drive motors and tunnel control system.[10]

By September 1980, the 40 x 80 was closed temporarily as part of the $85 million modification project. The tunnel was closed in order to complete several projects including the addition of the 600-foot long structure which houses the 80 x 120 wind tunnel, replacement of the six original drive motors with six new 22,500 horsepower drive motors in order to increase the total horsepower from 36,000 to 135,00.[11]

The modification project was completed in late 1982 with the result being two separate but interconnected wind tunnels, the 40 x 80, and the 80 x 120, that share a common drive system and utilize low speed fans and acoustic treatments in order to abate some of the noise generated by the tunnels.

In addition to the work performed by the Bostrom-Bergen Metal Company of Oakland, the modification project called for approximately forty-five separate contracts and employed many different contractors including the Turner-Lord Construction Company, who held the five-year modification contract for the 40 x 80 wind tunnel.

In the mid-1990s, the original 40 x 80 test section was removed and replaced with the current test section.

INTEGRITY

The exterior of the 40 x 80 Wind Tunnel structure retains all seven elements of integrity. The structure remains at its original historic location. Although the 80 x 120 test section was added on to the northwest corner in 1977, the structures original design and configuration remains largely intact. The current setting of the 40 x 80 Wind Tunnel is consistent with its original setting. Many of the historic materials originally employed on the

[9] "40 x 80 ft Wind Tunnel Modification Project," *The Astrogram*, December 27, 1979.
[10] "40 x 80 ft Wind Tunnel Modification Project," *The Astrogram*, January 24, 1980.
[11] "40 x 80-foot wind tunnel closes for modification," *The Astrogram*, September 18, 1980.

exterior portions of the structure are extant today. The original workmanship of the structure is still evident today, and lastly, the feeling or historic sense of the 40 x 80 Wind Tunnel is still conveyed today through its appearance, use, and setting.

Due to the types of uses that occur in the 40 x 80 Wind Tunnel structure, the interior sections have been modified several times in the past six decades. These changes are inherent in the structures use as a research and testing facility. In order to maintain technological proficiency, changes to the test section and its supporting components must be made according to the changing needs of the facility.

SUMMARY OF SIGNIFICANCE

The Ames Aeronautical Laboratory 40 x 80 Foot Wind Tunnel is eligible for inclusion on the National Register of Historic Places at a national level of significance under Criterion A (event) in the areas of space exploration and settlement (1944-present), and science and invention (1943-present). In addition, as the largest wind tunnel in the world, it is also eligible for inclusion under Criterion C as an engineering structure which embodies the distinctive characteristics of aeronautical wind tunnel construction.

The structure was originally built to be an experimental facility to house the research and testing of jet aircraft and first generation jet engines, advanced rotor techniques, and peripheral space use testing.

The current use of the wind tunnel is consistent with the original use and today the 22,500 horsepower facility conducts testing and research on the landing and takeoff of high performance aircraft and spacecraft, and testing Vertical and Short Take-Off and Landing (V/STOL) aircraft and rotorcraft.

The 40 x 80 Foot Wind Tunnel is the largest low-speed wind tunnel in the world. The second largest wind tunnel is the 30 x 60 Foot Full-Scale Wind Tunnel located at NASA's Langley Laboratory in Hampton, Virginia.

This determination of significance is exclusive to the original 40 x 80 wind tunnel structure and does not include the 80 x 120 leg.

HISTORICAL BACKGROUND

The NASA Ames Research Center was initially founded on December 20, 1939, as an aircraft research laboratory by the National Advisory Committee on Aeronautics (NACA), the forerunner of NASA. Ames has played a pioneering role in science and technology over six decades. The center was named for Dr. Joseph S. Ames, NACA Chairperson from 1927 to 1939. Ames was NACA's second laboratory, established after the Langley facility in Hampton, Virginia. In 1958, Ames became part of the National Aeronautics and Space Administration (NASA). Since its inception, Ames researchers have broken new ground in all flight regimes--the subsonic, transonic, supersonic, and hypersonic--using a collection of wind tunnels and research aircraft, the sophistication of which has increased over time. Ames has evolved into a diverse and sophisticated research campus of buildings influenced by the clean lines and materials of the International style, fused with elements of the Streamline Moderne, both styles are very well suited to industrial type buildings.

Ames specializes in research geared toward creating new knowledge and new technology, encompassing the fields of supercomputing, networking, numerical computing software, artificial intelligence, and human factors to enable advances in aeronautics and space. In aeronautics, Ames is the leading NASA agency in airspace operations systems, including air traffic control and human factors, and the lead center for rotorcraft technology. Ames also has major responsibilities in the creation of design and development process tools and wind tunnel testing. Ames houses one of the world's largest collections of wind tunnels and simulation facilities.

The 40 x 80 Foot Wind Tunnel was the fourth wind tunnel to be constructed at Ames. Built after the 16 Foot High Speed and the twin 7 x 10 Foot Wind Tunnels, the 40 x 80 opened in June 1944 as part of the new Full-Scale and Flight Research Division. This included research aircraft, and the 40 x 80 was determined to be best suited for aircraft development work rather than basic research.[1]

PERIOD OF SIGNIFICANCE

The Ames 40 x 80 Wind Tunnel is significant from 1944 through the present. This determination means that a majority of the events that lend to the building's significance have taken place within the past fifty years. These events are exceptional in national aviation and space history. Due to the type of research testing conducted inside the 40 x 80, exceptional events continually occur that supplement the significance of the structure. As a result, the period of significance has been established as 1944 to the present (2003). During this fifty-nine year period, the structure has consistently served as a wind tunnel testing facility.

DISCUSSION OF SIGNIFICANCE

Criterion A:

The 40 x 80 Foot Wind Tunnel is eligible for inclusion on the National Register of Historic Places under criterion A (event) in the following areas:

1) The areas of science and invention for its use as a testing and research facility where many significant discoveries have occurred which have affected the design and construction of aircraft, rotorcraft and spacecraft.
2) The area of space exploration and settlement due to its direct association with aerospace development from 1944 to the present.

[1] Atmosphere of Freedom, 18-19.

SCIENCE AND INVENTION

The 40 x 80 Foot Wind Tunnel has been an invaluable component of the Ames Research Center from 1944 through the present. Inside this voluminous structure, full size models of aircraft, spacecraft, and rotorcraft have been tested and retested by NACA, and later NASA engineers in order to arrive at the best possible design specifications for such government, military and civilian craft. The designs and subsequent modifications to craft originally tested in the 40 x 80 have resulted in significant advances in the fields of aeronautics and aerospace.

SPACE EXPLORATION AND SETTLEMENT

Similar to the areas of science and invention, the 40 x 80 Foot Wind Tunnel is significant in the area of space exploration and settlement as a testing facility for the original Space Shuttle Oribiter model that the Space Shuttles Orbiter Enterprise and subsequent shuttle orbiters were modeled after.

Criterion C

Definition Of A Wind Tunnel

According to *The Wind Tunnels Of NASA*, a wind tunnel is a device that consists of "an enclosed passage through which air is driven by a fan or any appropriate drive system. The heart of the wind tunnel is the test section, in which a scale model is supported in a carefully controlled airstream, which produces a flow of air about the model, duplicating that of the full-scale aircraft. The aerodynamic characteristics of the model and its flow field are directly measured by appropriate balances and test instrumentation."[2] The five elements necessary to create a wind tunnel are a drive system, a test section, a model, a controlled airstream, and test instrumentation.

Although not the first facility to design and build wind tunnels, the Ames facility houses the greatest collection of wind tunnels (both active and decommissioned). In these wind tunnels, craft designed for air and space flights by civilian, military and government space agencies are tested and retested until the best possible design strategy is obtained. "The wind tunnel is indispensable to the development of modern aircraft. Today no aeronautical engineer would contemplate committing an advanced aircraft design to flight without first

[2] *Wind Tunnels Of NASA*, http://www.hq.nasa.gov/office/pao/History/SP-440/ch1-3.htm

measuring its lift and drag properties and its stability and controllability in a wind tunnel. Tunnel tests first, free-flight tests later, is the proper order of things."[3]

Historical Overview Of Wind Tunnels

The first wind tunnel was designed and built in 1871 by Frank H. Wenham, a Council Member of the Aeronautical Society of Great Britain. According to the *Wind Tunnels of NASA*, "with the advent of the wind tunnel, aerodynamicists finally began to understand the factors that controlled lift and drag, but they were still nagged by the question of model scale. Can the experimental results obtained with a one-tenth scale model be applied to the real, full-sized aircraft? Almost all wind tunnel tests were and still are performed with scale models because wind tunnels capable of handling full-sized aircraft are simply too expensive."[4]

The first wind tunnel in the United States was designed and built by Dayton, Ohio residents, brothers Wilbur and Orville Wright in 1901. This tunnel "consisted of a square tube for channeling the air, a driving fan, and a two-element balance mounted in the airstream. One balance element was a calibrated plane surface; the other was a cambered test surface inclined at the same angle but in the opposite direction. When the wind tunnel was brought up to speed, the vane-type balance turned one way or the other, thereby indicating the relative lifting forces. The preliminary results from the makeshift tunnel were so encouraging that the Wrights immediately built a larger and more sophisticated facility with a 16-square-inch test section. Here they obtained the critical data they needed for their first manned, powered aircraft."[5]

After two previous glider designs the Wright brothers designed and built their third glider according to specification derived from wind tunnel tests. The third glider was modified through the addition of two propellers and flying controls to be manned by Orville Wright. The famous Wright Flyer made three successful manned flights at Kitty Hawk, North Carolina in 1903. "Then, in 1908, Wilbur Wright startled the European aviation community... at Le Mans, France, in August 1908, he demonstrated absolute mastery of the air with precise control of his Flyer. One flight lasted 1-1 /2 hours…the Wrights' barnstorming revolutionized Europe's thoughts on aviation."[6]

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[3] http://www.hq.nasa.gov/office/pao/History/SP-440/ch1-1.htm
[4] http://www.hq.nasa.gov/office/pao/History/SP-440/ch1-3.htm
[5] http://www.hq.nasa.gov/office/pao/History/SP-440/ch1-5.htm
[6] http://www.hq.nasa.gov/office/pao/History/SP-440/ch2-1.htm

The 1903 and 1908 flights prompted European governments to advance aircraft research and production in order to enlarge their aerial fleets for wartime use. This drive for increased aircraft resulted in the design and construction of approximately eleven wind tunnels of varying sizes between 1903 and 1918. As a result, the number of military aircraft used by European countries in World War I was significantly higher than that employed by the United States. According to the *Wind Tunnels of NASA*, by World War I, the United States possessed 23 military aircraft, while in sharp contrast France had 1,400; Germany, 1,000; Russia, 800; and Great Britain, 400.[7]

In 1915, enabling legislation was passed by the United States Congress that resulted in the creation of the National Advisory Committee for Aeronautics (NACA). Passed under the Naval Appropriation Act, the legislation called for the establishment of an aeronautical research facility, and in 1917 the Langley Memorial Aeronautical Laboratory was opened at Hampton, Virginia. By 1929, Langley had developed a wind tunnel complex comprised of three wind tunnels; the Variable Density Tunnel, the 5 Foot "S" Tunnel, the 7 x 10 Foot Atmospheric Wind Tunnel, and that same year the decision was made to build a 30 x 60 Foot Full-Scale Wind Tunnel (FST).[8] The FST became operational in 1931, and upon completion of construction, was considered to be the largest wind tunnel in the world. Today the Langley FST is a National Historic Landmark.

In October 1936 the NACA *Special Committee on Relation of NACA to National Defense in Time of War* was formed due to the increasing information being uncovered about Nazi Germany's aeronautical advances. In October 1938 NACA formed a new *Committee on Future Research Facilities* and by 1939 the Naval Air Station at Moffett Field, California was selected as the site for the NACA's west coast research laboratory. By December 20, 1939 construction began on the original 43-acre site at Moffet Field for the Ames Aeronautical Laboratory.[9]

Wind tunnel construction began immediately at Ames, starting with the construction of the 16 Foot High Speed Wind Tunnel (1941), the two 7 x 10 Foot tunnels (1941), and the 40 x 80 Foot Subsonic Wind Tunnel.

[7] http://www.hq.nasa.gov/office/pao/History/SP-440/ch2-1.htm
[8] http://www.hq.nasa.gov/office/pao/History/SP-440/ch3-1.htm
[9] Atmosphere of Freedom, 13.

The Ames 40 x 80 Foot Subsonic Wind Tunnel

In July 1940 the first test piles were dug for the 40 x 80 Foot Wind Tunnel at Ames. Recognizing the need for a wind tunnel equal to that of the Full-Scale Tunnel (FST) at Langley, Ames Director and Langley FST designer Smith De France called for the construction of a wind tunnel capable of testing full size craft. According to the publication *Wind Tunnels Of NASA*:

> "The fourth war-time wind tunnel built at Ames departed from the high-speed theme that was supposedly Ames' reason for being. In fact, this new tunnel could not generate test section velocities beyond a paltry 230 mph. Yet this low-speed tunnel was an invaluable addition to NACA's repertoire of tunnels because it was big: 40 x 80-feet at the test section. It was big enough to handle all but the largest bombers and transports-with their engines operating. The low airspeeds did not matter because the purpose of the tunnel was to examine the takeoff and landing characteristics of aircraft. These two periods of flight are extremely sensitive in terms of lift, drag, and stability. Full-scale tests in the 40 x 80-foot tunnel led to seemingly small improvements that actually meant a great deal in aircraft operations. For example, after tunnel tests, the Douglas XSBD-2 dive bomber was provided with a modified wing-flap system that lowered landing speeds from 90 to 84 mph. When landing on carriers, these few miles per hour gave the pilot much better control and, in addition, significantly reduced the energy that had to be absorbed by the carrier's aircraft arresting gear.
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> The technical challenge of the 40 x 80-foot tunnel was its sheer physical size. The facility covered 8 acres, and the air circuit was just over 1/2 mile long (2700 feet). Six 40-foot-diameter fans, each powered by a 6000-horsepower electric motor maintained airflow at 230 mph or less (these are still tornado velocities). Construction began in late 1941, the mammoth construction task sorely taxing the resources of the new center. Two and a half years later, in dune 1944, the 40 x 80-foot full-scale tunnel went into operation.
>
> In later years this tunnel became the primary facility for investigating the flying characteristics of fullscale helicopters and vertical takeoff and landing (VTOL) aircraft. In the case of the VTOL craft, the tunnel tests explored the critical flight regime where the craft makes the transition from powered lift at low forward speeds to wing-borne lift at high speeds.
>
> Inadvertently, the 40 x 80-foot tunnel also helped study the structural failures of advanced helicopter rotors and new VTOL aircraft. In each instance of unplanned failure, tunnel damage was slight, and the facility was back in operation quickly. Since the tests were well instrumented, the causes of failure were soon found, leading to successful modifications.

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> So successful was the 40 x 80-foot tunnel in testing full-scale aircraft that 35 years after its initial startup, tunnel power was increased to 135,000 horsepower, raising the maximum speed to about 330 mph (Mach 0.45). Modifications were begun to incorporate a new leg with an 80 x 120-foot test section. The largest fighter-bombers, helicopters, and VTOL/STOL aircraft will be accommodated here."[10]

The $5,202,302.00 wind tunnel construction contract was awarded to the Pittsburgh-Des Moines Steel Company of Des Moines, Iowa and by June 1944, the completed 40 x 80 Foot Wind Tunnel was officially dedicated. The dedication coincided with the NACA dedication of the entire Ames Aeronautical Laboratory.[11] Upon completion of construction, the cost of the new wind tunnel sans motors and other operational equipment was approximately 6.5 million dollars. Pittsburgh-Des Moines project managers Gordon R. Lunt and Cedric A. Fegtly supervised all construction work.[12]

The 40 x 80 Foot Subsonic Wind Tunnel is significant under Criterion C, because as the largest low-speed wind tunnel in the world, it is an exceptionally important work of engineering. With a test chamber almost twice as large as the full-scale predecessor at Langley, at the time of its construction, the 40 x 80 Foot Wind Tunnel was the only low-speed tunnel large enough to hold full-scale craft. The voluminous 40 x 80 test chamber and the more recent 80 x 120 leg are monumental engineering accomplishments. The facilities enormous bulk dominates the western edge of the Ames campus, and the entire structure creates a building envelope of eight acres. As the first low-speed wind tunnel constructed with such massive dimensions, resourceful engineering methods were executed in order to erect the structure.

[10] http://www.hq.nasa.gov/office/pao/History/SP-440/ch4-2.htm
[11] *Los Altos News*, June 4, 1944. *San Jose Evening News*, June 7, 1944.
[12] *Des Moines Sunday Register*, July 16, 1944.

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VERBAL BOUNDARY DESCRIPTION

The property boundary includes the two structures that make up the National Full Scale Aerodynamics Complex. This includes the building envelope of the 40 x 80 Structure and the building envelope for the 80 x 120 leg appended to the northwest corner of the 40 x 80 structure.

BOUNDARY JUSTIFICATION

The boundary was selected in order to include the building envelope of the original 40 x 80 Wind Tunnel Structure. The 80 x 120 leg is a separate, but interconnected facility, that shares a common drive system with the 40 x 80 Wind Tunnel. The massive structure is appended to the northwest corner of the 40 x 80, and as a result is included as a non-contributing resource located within the resource boundary. Although similar testing activities occur in the 80 x 120 test section, the 80 x 120 leg does not contribute to the individual significance of the 40 x 80 Wind Tunnel.

Two additional non-contributing structures are present within the boundaries of the nomination. These two structures are the 2 x 2 Foot Transonic Wind Tunnel and the 20-G Centrifuge facility. Identified as Building N-221, the 2 x 2 Transonic Wind Tunnel is an independent wind tunnel located inside the central courtyard of the 40 x 80 Structure. The 2 x 2 is not considered to be individually significant, and does not lend to the significance of the 40 x 80 Wind Tunnel. Identified as Building 221A, the 20-G Centrifuge facility was originally constructed in 1964 and is located outside the exterior walls, below the test chamber of the 40 x 80 Structure. The centrifuge facility performs unrelated activities separate from the 40 x 80. It is not considered to be individually significant at this time, nor does it lend to the significance of the 40 x 80 Wind Tunnel.