National Aeronautics and Space Administration

Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center

N-238, RCC JSC Model Testing in Ames Interaction Heating Facility

N-258, Vertical Motion Simulator in Motion

Criteria of Eligibility for Listing in The National Register of Historic Places

Code of Federal Regulations, Title 36, Part 60

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Assessment

Final

Space Shuttle Program

NASA Ames Research Center
Moffett Field, California

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Prepared for
NASA Ames Research Center
Moffett Field, California

Prepared by
PAGE & TURNBULL, INC.
724 Pine Street, San Francisco, California 94108
415.362.5154 / www.page-turnbull.com

Table of Contents

I. Introduction

This Space Shuttle Program Assessment has been prepared at the request of National Aeronautics and Space Administration (NASA) for eleven properties that include ten buildings and one object located at NASA Ames Research Center in Moffett Field, California. The ten buildings and one object reviewed were: 36% Scale Orbiter Model; N-221 (40-By 80-Foot Wind Tunnel); N-227A to D (Unitary Plan Wind Tunnels); N-229 (Experimental Fluid Dynamics Facility); N-237 (Hypervelocity Free Flight Facility); N-238 (Arc Jet Laboratory); N-240 (Airborne Missions and Applied Life Sciences Experiments); N-240A (Life Sciences Flight Experiments); N-243 (Flight and Guidance Simulation Laboratory); N-244 (Space Projects Facility); and N-258 (NASA Advanced Supercomputing Facility) (See Map 1).

This evaluation was conducted as part of an Administration-wide effort at all NASA facilities in preparation for the Space Shuttle Program's closure. In January 2004, George W. Bush announced that the Space Shuttle Program would end in 2010. In response to this announcement, the National Aeronautics and Space Administration (NASA) undertook a historical survey and evaluation of all NASA facilities to determine their eligibility for the National Register of Historic Places (National Register) in the context of the Space Shuttle Program. This Space Shuttle Program Assessment was completed on behalf of NASA Ames Research Center at Moffett Field, California, in compliance with Sections 106 and 110 of the National Historic Preservation Act (NHPA) of 1966 (Public Law 89-665), as amended; the National Environmental Policy Act (NEPA) of 1969 (Public Law 91-190); Executive Order (EO) 11593; Protection and Enhancement of the Cultural Environment; Executive Order 13297, Preserve America, and other relevant authorities.

In July 2006, the Ames Research Center Historic Preservation Officer formed a qualified team to identify the properties at NASA Ames Research Center (ARC) that were utilized by or supported the Space Shuttle Program. This team consisted of the Facilities Planning Group (where the current and previous Facilities Historic Preservation Officer is located), the Ames History Office, and Code Q - Office of Director of Safety, Environmental and Mission Assurance, along with the support service contractor ISSi, Cultural Resources Management (CRM) Division. The team considered all properties at ARC, and determined a preliminary list of eleven properties that were studied by the Cultural Resources Management contractor, Page & Turnbull. Page & Turnbull concurred with this preliminary list and conducted an analysis that has been provided in this Space Shuttle Program Assessment.

This report examines the connection of these eleven properties to the history and development of NASA's Space Shuttle Program. The eligibility of these properties for listing in the National Register of Historic Places (National Register) in the context of the Space Shuttle Program was determined utilizing specialized evaluation criteria developed by NASA Headquarters in conjunction with the National Park Service.[1] These criteria allowed for a consistent approach for identifying and evaluating NASA's facilities and assets.

[1] NASA, "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)" (Washington, D.C.: NASA, Final Criteria: 5 June 2006).

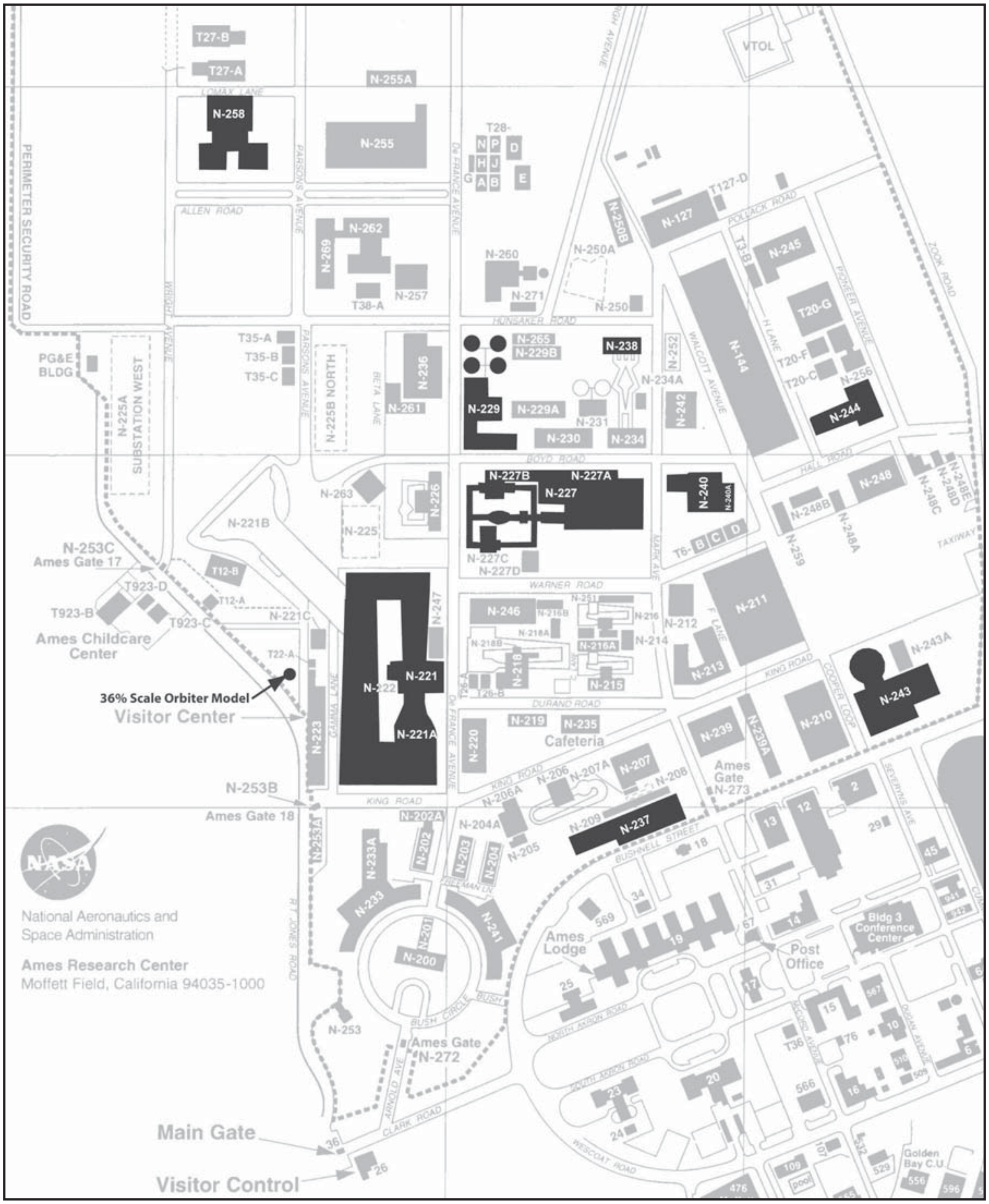
Executive Summary

This Space Shuttle Program Assessment provides an evaluation of eleven properties at NASA Ames Research Center (ARC) for their eligibility for listing in the National Register of Historic Places (National Register or NRHP) in the context of the Space Shuttle Program (SSP). This report was completed as part of an Administration-wide effort at all NASA centers to document and evaluate all properties that had a direct connection to the Space Shuttle Program. At NASA Ames Research Center, ten buildings and one object were reviewed.

Although all properties at ARC were considered within this context, only eleven properties were surveyed in detail by the CRM contractor. These eleven properties included: 36% Scale Orbiter Model (located adjacent to N-223); N-221 (40-By 80-Foot Wind Tunnel); N-227A to D (Unitary Plan Wind Tunnels); N-229 (Experimental Fluid Dynamics Facility); N-237 (Hypervelocity Free Flight Facility); N-238 (Arc Jet Laboratory); N-240 (Airborne Missions and Applied Life Sciences Experiments); N-240A (Life Sciences Flight Experiments); N-243 (Flight and Guidance Simulation Laboratory); N-244 (Space Projects Facility); and N-258 (NASA Advanced Supercomputing Facility). This Assessment Report will be part of a larger report compiled by NASA Headquarters in preparation to meet milestones in the Shuttle Transition and Retirement Program, and for the Space Shuttle Program's closure in 2010.

After researching and surveying the eleven properties, N-238 (Arc Jet Laboratory) and N-243 (Flight and Guidance Simulation Laboratory) were determined by Page & Turnbull to meet the general registration requirements for listing in the National Register within the context of the Space Shuttle Program. N-238 is significant under Criterion A (Events) for the research and development of the Space Shuttle's Thermal Protection Systems (TPS). N-243 is significant under Criterion A (Events) for the Vertical Motion Simulator (VMS), which contributed to the training of the astronauts for the Space Shuttle Program. Both properties retain historic integrity and qualify for NRHP Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years. The 36% Scale Orbiter Model, N-221, N-227A to D, N-229, N-237, N-240, N-240A, N-244, and N-258 do not meet the general registration requirements, and are therefore not eligible for listing in the National Register in the context of the Space Shuttle Program. The Ames Facilities Historic Preservation Officer, Keith Venter, concurred with these conclusions.

Aerial, NASA Ames Research Center, 1991
(Source: NASA Ames Research Center, AC91-0447-2)



Map 1. Site Map of NASA Ames Research Center identifying the eleven properties reviewed as part of the Ames Space Shuttle Program Assessment.

Table 1. Summary of the NRHP eligibility of the eleven resources reviewed under the Space Shuttle Program

	36% Orbiter Model	N-221	N-227A to D	N-229	N-237	N-238	N-240	N-240A	N-243	N-244	N-258
1. Resources Associated with Transportation (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
2. Vehicle Processing Facilities (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
3. Launch Operation Facilities (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
4. Mission Control Facilities (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
5. News Broadcast Facilities (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
6. Communication Facilities (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
7. Engineering and Administrative Facilities (Yes or No)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	No	**Yes**
8. Space Flight Vehicle (or Space Shuttle) (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
9. Manufacturing and Assemble Facilities (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
10. Resources Associates with the Training of Astronauts (Yes or No)	No	No	No	No	No	No	No	**Yes**	**Yes**	No	No
11. Resources Associated with Space Flight Recovery (Yes or No)	No	No	No	No	No	No	No	No	No	No	No
12. Resources Associated with Processing Payloads (Yes or No)	No	No	No	No	No	**No**	**Yes**	**Yes**	No	No	No
Eligible under one or more of NRHP Criteria (A, B or C)	No	No	**A**	**A**	No	**A**	No	**A**	**A**	No	No
Meets Appropriate Criteria Consideration B or G (B, G, No, or N/A)	No	No	No	**G**	No	**G**	No	No	**G**	No	No
Integrity (Yes or No)	No	**Yes**	**Yes**	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**	**Yes**
Meets requirements for listing in NRHP under Space Shuttle Program (Yes or No)	No	No	No	No	No	**Yes**	No	No	**Yes**	No	No

II. Methodology

The following section outlines the methodology utilized in the evaluation of the eleven properties at NASA Ames Research Center for listing in the National Register of Historic Places in the context of the Space Shuttle Program. The primary document utilized in the evaluation of these resources was "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)" prepared by NASA Headquarters and the National Park Service (dated 5 June 2006). This document has been included in this section. Also included in this section is an introduction to the National Register of Historic Places and other relevant evaluation criteria obtained from the National Park Service.

Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)[1]

Purpose

A "new era for the U.S. Space Program" began on February 13, 1969 when President Richard Nixon established the Space Task Group (STG). The purpose of this committee was to conduct a study to recommend a future course for the US Space Program. Three years later, on January 5, 1972, the Space Shuttle Program was initiated in a speech delivered by President Nixon. During this speech, Nixon outlined the end of the Apollo era and the future of a reusable space flight vehicle, which would allow the U.S. to construct Space Station by carrying cargo to and from outer space. Subsequently, the end of the Space Shuttle Program was announced in a speech delivered by President George W. Bush in January 2004. Although plans for space exploration would advance, the technology of the Space Shuttle and its associated facilities would change or end by 2010. The significance of the Space Shuttle was noted by the National Park Service (NPS) in the 1998 National Register Bulletin, Guidelines for Evaluating and Documenting Historic Aviation Properties. The following excerpt is from that bulletin.

> The Space Shuttle was the U.S. space program's next generation. Key aspects of the Shuttle's design and performance were based on a rocket-powered space plane, the X-15, the world's first transatmospheric vehicle. The Space Shuttle provided a new method of space flight, taking off like a rocket and landing like an airplane. The Space Shuttle Columbia, the first reusable manned spaceship, initiated the Space Shuttle flight program in April 1981, and a new era for the U.S. Space Program (Milbrooke 1998:12).

1 Excerpted from NASA, "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)" (Washington, D.C.: NASA, Final Criteria: June 5, 2006).

The historic values of this program, like the Apollo-era program which preceded it, are embodied in the facilities, that is; the buildings, structures and objects within NASA centers. The purpose of this study is to identify the NASA-controlled facilities of local, state, and/or national significance in the historic context of the U.S. Space Shuttle Program, circa 1969 to 2010. Such facilities may include, but are not necessarily limited to, those used for research, development, design, testing, fabrication, and operations. NASA will also look at certain types of resources that are not facilities and are considered "personal property" under federal regulations. These resources are typically large while they may be mobile, are also usually associated with a geographical location. An example of this type of resource are the Mobile Launch Platforms at the Kennedy Space Center.

The evaluation of historic properties within the context of the Space Shuttle Program will, in part proceed from an earlier studies of the Apollo-era resources at various NASA Centers. The first step in evaluating these facilities at many of these was to establish and describe the applicable historic contexts and subcontexts. The key reference relating to the Apollo program used in this assessment was the Man In Space Theme Study, completed in 1984 by the National Park Service. According to the study, the purpose was to evaluate:

> *All resources which relate to the theme of Man in Space and to recommend certain of those resources for designation as National Historic Landmarks.*
> *The Man in Space Theme Study considered resources relating to the following general subthemes:*
> *A. Technical Foundations before 1958*
> *B. The Effort to Land a Man on the Moon*
> *C. The Exploration of the Planets and Solar System*
> *D. The Role of Scientific and Communications Satellites*
>
> *The Theme Study considered the Space Program in an integrated fashion. In any given space mission thousands of scientists, technicians, and other support personnel were necessary to insure success. These support personnel performed vital work in a variety of ways using support facilities in many parts of the country. None of these personnel in all likelihood comprehended all aspects of each space mission, yet all were vital to the success of the program. Since individual missions lasted over many years and involved a wide variety of resources and people only a few managers at the National Aeronautics and Space Administration (NASA) were able to see all of the facets of the space program. It was this coordination, cooperation, and collaboration that enabled NASA to successfully manage the American Space Program. The theme study follows this same approach and attempts to identify, inasmuch as is possible, the surviving resources of those that were necessary to accomplish the goals of landing a man on the moon and exploring the earth, planets and solar system (Butowsky 1984).*

<u>The NRHP Criteria for Evaluation and Criteria Considerations</u>

The significance of a cultural resource is evaluated in terms of the eligibility criteria for listing in the NRHP. The National Register Criteria for Evaluation, as described in 36 CFR Part 60.4, are as follows:

> *The quality of significance in American history, architecture, archeology, engineering and culture is present in districts, sites, buildings, structures and objects that possess integrity of location, design, setting, materials, workmanship, feeling and association and:*
>
> *A. That are associated with events that have made a significant contribution to the broad patterns of history; or*
>
> *B. That are associated with the lives of persons significant in our past; or*
>
> *C. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or*
>
> *D. That have yielded, or may be likely to yield information important in prehistory or history.*

The significance of historic buildings, structures, objects and districts is usually evaluated under Criterion A (association with historic events); Criterion B (association with important persons); or Criterion C (distinctive design or distinguishing characteristics as a whole). Often, more than one criterion will apply to historic resources.

Some types of cultural resources are not typically considered eligible for the NRHP. These resources are religious properties (A), moved properties (B), birthplaces and graves (C), cemeteries (D), reconstructed properties (E), commemorative properties (F), and properties that have achieved significance within the past fifty years (G). As a result, a resource may meet one or more NRHP criteria and still not be eligible unless special requirements are met. These requirements are called Criteria Considerations and are labeled A-G. Of relevance to the Space Shuttle Program study are Criteria Considerations B and G, as follows:

Criteria Consideration B: Moved Properties - *A property removed from its original or historically significant location can be eligible if it is significant primarily for architectural value or it is the surviving property most importantly associated with a historic person or event.*

Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years – *A property achieving significance within the last fifty years is eligible if it is of exceptional importance.*

The Space Shuttle Program: Proposed NRHP Criteria for Evaluation and Criteria Considerations

In order to qualify for listing in the NRHP, resources must meet all of the following general registration requirements:

- Is real or personal property owned or controlled by NASA;
- Was constructed, modified or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);
- Is classified as a structure, building, site, object, or district;
- Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under;

  Criterion A - Events
  - must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,
  - must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or

  Criterion B - Significant Persons
  - must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or
  - must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or
  - best represents the important achievements or the cumulative importance of prominent persons; or
  - has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.

  Criterion C – Design/Construction
  - was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and

its associated payloads; or

- reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or
- reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era

Criterion D – Information Value

- As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.

- Meets appropriate Criteria Considerations - Certain kinds of property that are not usually considered eligible for listing in the NRHP, although they may meet the NRHP Criteria stated above, will require special considerations. Such properties which might fall into this category are those that have been moved (Criterion Consideration B) or properties that have achieved significance within the past fifty years (Criterion Consideration G)

  - *B: Moved Properties* – Some historic resources of significance in the context of the Space Shuttle Program may meet Criteria Consideration B since they were designed to be moved. Thus, it is not required that they, or their integral components, be at their original location in order to retain integrity. These resources are generally significant for their engineering or are significant for their association with events or persons integral to the Space Shuttle Program. However, objects removed from their original setting and that are now located within a museum are typically excluded from NRHP-listing as the change in setting and location diminishes the resources' historic integrity (NPS 1998:36).

  - *G: Properties that have Achieved Significance within the Past 50 Years* – The entire Space Shuttle Program is less than 50 years old. Therefore, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old. Properties that are determined to possess exceptional significance in the context of the Space Shuttle Program that are less than 50 years old must meet Criteria Consideration G.

- Retains enough integrity to convey its historical significance. The NRHP recognizes seven aspects or qualities that, in various combinations, define integrity: location, setting, materials, design, workmanship, feeling, and association. However, many original NASA Apollo-era facilities, for example, have undergone major modification and are in active use supporting the Space Shuttle Program. As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association" (ACHP 1991:33)

Criteria of Eligibility by Property Type

The following twelve property types and the associated National Register eligibility criteria, may be used in the evaluation of all NASA owned and controlled facilities at all NASA Centers. Use of these categories will help narrow the list of eligible properties to those that have true significance in the overall context of the Space Shuttle Program. Many of these facilities may have already been designated as eligible under the Apollo program. The use of these criteria on those properties in no way negates their previous designations. Rather it adds to the historical context of those properties.

1. Resources Associated with Transportation: A variety of transportation resources were constructed and/or modified to support mission and launch operations in support of the Space Shuttle Program. These resources include roadways, bridges, Crawlerways, runways and landing facilities, helipads, and waterways. Special-use vehicles also are part of the transportation network. These include Payload Transporters, Crawler Transporters, Multi-use Mission Support Equipment (MMSE) Transporters, 747 Carrier Aircraft, the astrovan, and recovery vessels. In order to qualify for NRHP listing, transportation resources must meet one or more of the following criteria:

- have been used for the transportation of unique objects, structures, or significant persons associated with Space Shuttle missions;
- have been an essential component to the Space Shuttle missions, such that the program could not function without it;
- clearly embody the distinctive characteristics of a type or method of construction specifically designed for the transportation of the Space Shuttle or its payloads;
- have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program;
- must be examples of one of the identified subtypes: road-related resources, water-related resources, rail-related resources, and air-related resources.

2. Vehicle Processing Facilities: Vehicle processing facilities include those resources which are vital to the preparation of the launch vehicle for its mission. NASA vehicle processing facilities administer such operations as assembly, testing, checkout, refurbishment, and protective storage for launch vehicles and spacecrafts.

Those processing facilities which are eligible for the NRHP were essential in support of the Space Shuttle Program and include but are not limited to the "Tile Shop", the Vehicle Assembly Building, the Orbiter Processing Facility, and Hangar AF. To be considered significant, the resources must have been essential to the successful completion of Space Shuttle missions. Vehicle processing facilities were specifically designed for processing the launch vehicle and, therefore, played a major role in nationally significant events related to space exploration. In order to qualify for listing, resources must:

- have been an essential component to the processing of the Space Shuttle;
- clearly embody the distinctive characteristics of a type or method of construction specifically designed or modified for the processing of the Space Shuttle for launch;
- have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program.

3. Launch Operation Facilities: Launch Operation Facilities support all activities which occur after the launch vehicle has been processed up to the point of launch. These facilities provide a base and support structure for the transport and launching of the vehicle, service the launch vehicle at the launch pad, control pre-launch and launch operations, and launch the vehicle. These facilities include but are not limited to launch pads, Launch Control Center (LCC) Mobile Launch Platforms (MLPs), the Rotating Service Structure (RSS), and the Fixed Service Structure (FSS). Such facilities function as the primary resources integral to the launch of the Space Shuttle. In order to qualify for listing, resources must:

- possess engineering importance and have facilitated nationally significant events associated with space travel;
- have been integral in pre-launch and launch preparation or the launching of the Space Shuttle;
- clearly embody the distinctive characteristics of a type or method of construction specifically designed for the Space Shuttle;
- have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program.

4. Mission Control Facilities: Support the design, development, planning, training and flight control operations for Space Shuttle flights. These facilities provide the infrastructure that allow the planning, training, and flight processes necessary to support the Space Shuttle from inception of requirements through the flight execution process. In order to qualify for listing resources must have:

- Developed integrated flight crew and flight control plans, procedures and training;
- Established simulators and flight control ground instrumentation;
- Configured Orbiter software;
- Contributed to the development and integration of spacecraft and payload support system;

- Provided onboard portable computer hardware and software for the Space Shuttle.

5. News Broadcast Facilities: Press facilities provide a primary site for news media activities at NASA-owned facilities. These broadcasting facilities were essential for relating to the American public news of the Space Shuttle Program to the nation and the world. In order to qualify for listing, resources must:
- Have been an integral facility in the dissemination of information about the Space Shuttle missions to the public;
- Clearly embody the distinctive characteristics of a type or method of construction specifically designed to broadcast information;
- Be associated with a significant person associated with the broadcast of Space Shuttle events.

6. Communication Facilities: Communication facilities in support of the Space Shuttle Program provide a vital site for instrumentation to receive, monitor, process, display and/ or record information from the space vehicle during test, launch, and/ or flight. Significant communication facilities were designed specifically to house computers and computer-related technology vital to the Space Shuttle mission. In order to qualify for listing, resources must:
- Have been integral to the mission of the Space Shuttle;
- Clearly embody the distinctive characteristics of a type or method of construction specifically designed for the Space Shuttle missions;
- Have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program.

7. Engineering and Administrative Facilities: Engineering and Administrative Facilities include those resources which are essential to the administrative, scientific, and engineering work of the Space Shuttle Program. Engineering and Administrative Facilities administer such operations as research and development, testing, fiscal matters, procurement, planning, central management, and facilities engineering and construction, as well as providing offices for associated contractors and laboratories for engineers and scientists. These facilities which qualify for listing under the Space Shuttle context must:
- Be places that are directly associated with critical activities of national significance which impacted the development, implementation and termination of the Space Shuttle Program or missions;
- Be places where persons who made lasting achievements to the Space Shuttle Program worked or convened;
- Should clearly embody the distinctive characteristics of a type or method of construction.

8. Space Flight Vehicle (or Space Shuttle): This property type includes resources that comprise and/or facilitate the space flight vehicle or Space Shuttle. These include, but are not limited to, the Orbiter, Solid Rocket Booster (SRB), and External Tank (ET), as well as mockups of these components that were used for flight test or other important development activities. In order to qualify for listing, resources must:

- Have been an integral component of the Space Shuttle Stack in its completed form, ready for space flight;
- Have been essential to the Space Shuttle missions and should clearly embody the distinctive aspect of reusability which reflects the goals of the Space Shuttle Program;
- Have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program.

9. Manufacturing and Assemble Facilities. This property includes facilities where major flight components were manufactured or assembled. These would include the manufacturing plants where the majority components of the Space Shuttle vehicle were fabricated and assembled. In order to qualify, these facilities must:

- Have been an essential component to the manufacturing or assembling of the Space Shuttle;
- Have been constructed or modified to house this manufacturing or assemble facility exclusively;
- Embody a design that is unique to the Space Shuttle requirements;
- Have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program.

10. Resources Associated with the Training of Astronauts: This property type includes resources constructed or modified for the purpose of astronaut training and preparation for Space Shuttle missions. These facilities may include but are not limited to: processing facilities, neutral buoyancy tank, flight simulators and training aircraft. In order to qualify for listing, resources must:

- Have been designed and constructed, or modified, for the unique purpose of astronaut training and be directly associated with preparing astronauts for the completion of a Space Shuttle mission;
- Clearly embody the distinctive characteristics of a type or method of construction specifically designed for aeronautical training;
- Have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program.

11. Resources Associated with Space Flight Recovery: This property type includes resources that facilitate the recovery of the Space Flight Vehicle or Space Shuttle and its significant components after its return to Earth. These include, but are not limited to, runways, the Mate/De-mate Facility (s) and equipment, the Solid Rocket Booster Retrieval Ships (Liberty and Freedom), the Transporter and Wash Building, and the flume that brings the SRB to the building from the ships. These resources are essential to the recovery and subsequent reuse of the Space Shuttle and are therefore a significant resource to the program as a whole. In order to qualify for listing, resources must:

- Have been integral to the recovery of the Space Shuttle and/or its significant components;
- Clearly embody the distinctive characteristics of a type or method of construction specifically designed for the recovery of the Space Shuttle;
- Have a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program.

12. Resources Associated with Processing Payloads: This property type includes facilities where fully assembled payloads are readied for insertion in the Space Shuttle Orbiter. These resources are essential to activities that resulted in scientific and technological advancements and are therefore a significant resource to the program as a whole. In order to qualify for listing, resources must have been used in the processing of payloads for the Space Shuttle. Eligibility is restricted to resources which:

- Represent outstanding achievements in technological, aeronautical or scientific research which would otherwise not have been attainable without the use of the Space Shuttle;
- Clearly embody the distinctive characteristics of a type or method of construction, and which reflect the distinctive aspect of reusability unique to the goals of the Space Shuttle Program;
- Have a direct historical association with the Space Shuttle, or a significant person associated with scientific and/or technological advancements of national significance made as part of the Space Shuttle Program.

National Register of Historic Places (NRHP)

The National Register is the nation's most comprehensive inventory of historic resources. The National Register is administered by the National Park Service and includes buildings, structures, sites, objects, and districts that possess historic, architectural, engineering, archaeological, or cultural significance at the national, state, or local level. Typically, resources over fifty years of age are eligible for listing in the National Register if they meet any one of the four criteria of significance and if the resources retain historic integrity. However, resources under fifty years of age can be determined eligible for listing in the National Register if it can be demonstrated that they are of "exceptional importance," or if they are contributors to a potential historic district. The National Register Criteria for Evaluation are described in full in Code of Federal Regulation, Title 36, Part 60 and in *National*

Register Bulletin Number 15: How to Apply the National Register Criteria for Evaluation. There are four criteria under which a structure, site, building, district, or object can be considered eligible for listing in the National Register. These criteria are:

> Criterion A (Event): Properties associated with events that have made a significant contribution to the broad patterns of our history;
>
> Criterion B (Person): Properties associated with the lives of persons significant in our past;
>
> Criterion C (Design/Construction): Properties that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant distinguishable entity whose components lack individual distinction; and
>
> Criterion D (Information Potential): Properties that have yielded, or may be likely to yield, information important in prehistory or history. [Note: Since Criterion D primarily applies to archaeological resources, it has not been included as part of the evaluation criteria for the Space Shuttle Program Assessment.]

A resource can be considered significant at the national, state, or local level in the areas of American history, architecture, archaeology, engineering, or culture.

Integrity

In addition to qualifying for listing under at least one of the National Register criteria, a resource must retain historic integrity. Integrity is defined as "the authenticity of an historical resource's physical identity evidenced by the survival of characteristics that existed during the resource's period of significance," or more simply defined as "the ability of a property to convey its significance."[2] According to the National Park Service's *National Register Bulletin Number 15: How to Apply the National Register Criteria for Evaluation,* the aspects of integrity are defined as follows:

- *Location* is the place where the historic property was constructed.
- *Design* is the combination of elements that create the form, plan, space, structure and style of the property.

[2] California Office of Historic Preservation, *Technical Assistance Series No. 7: How to Nominate a Resource to the California Register of Historic Resources* (Sacramento, CA: California Office of State Publishing, 4 September 2001), p. 11; National Park Service, *National Register Bulletin: How to Apply the National Register Criteria for Evaluation* (Washington D.C.: National Park Service, 1997), p. 44.

- *Setting* addresses the physical environment of the historic property inclusive of the landscape and spatial relationships of the building(s).

- *Materials* refer to the physical elements that were combined or deposited during a particular period of time and in a particular pattern of configuration to form the historic property.

- *Workmanship* is the physical evidence of the crafts of a particular culture or people during any given period in history.

- *Feeling* is the property's expression of the aesthetic or historic sense of a particular period of time.

- *Association* is the direct link between an important historic event or person and a historic property.

As noted in *Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)* (dated 5 June 2006), properties evaluated for eligibility in the National Register within the context of the Space Shuttle Program must retain enough integrity to convey its historical significance. As a general rule, in the case of highly technical and scientific facilities, the evaluation for integrity should identify a continuity in function, and integrity of design, materials, and association.

Special Considerations in the Evaluation of Highly Technical and Scientific Facilities

The highly technical and scientific nature of the facilities at NASA Ames Research Center presents unique issues for determining the resources' historical significance and level of integrity. Since the character of highly technical and scientific facilities includes the constant evolution of technology and use, an evaluation of historic significance and integrity must be based upon a firm understanding of a resource's functional history, historic context, character, and reason for the changes over time. One of the earliest public documents to address this issue was the Advisory Council on Historic Preservation's "Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities," published in 1991 (See Appendices). This document addressed the issue of stewardship of historic resources within scientific facilities, including facilities operated by NASA. Scientific facilities are faced with the challenge of balancing ongoing research activities—which often involve major alterations to historically significant buildings, equipment, and spaces—with consideration of the effects of these activities on historic properties. In terms of evaluating scientific or technical properties, questions arise regarding the resources' direct connection to a significant historic context and the ability of the resources to convey this connection through their physical features. These two issues, determining the historic context and assessing historic integrity, are the main challenges in evaluating the eligibility of the eleven resources under review at NASA Ames Research Center.

Determining the Appropriate Historic Context

The *National Register Bulletin: How to Apply the National Register Criteria for Evaluation* provides guidance towards determining the appropriate historic context. This document states:

> Historic contexts are those patterns or trends in history by which a specific occurrence, property or site is understood and its meaning (and ultimately its significance) within history or prehistory is made clear… Its core premise is that resources, properties or happenings in history do not occur in a vacuum but rather are part of larger trends or patterns.
>
> In order to decide whether a property is significant within its historic context, the following five things must be determined:
>
> - The facet of prehistory or history of the local area, State, or the nation that the property represents;
> - Whether that facet of prehistory or history is significant;
> - Whether it is a type of property that has relevance and is important in illustrating the historic context;
> - How the property illustrates that history; and finally
> - Whether the property possesses the physical features necessary to convey the aspect of prehistory or history with which it is associated.[3]

Scientific and highly technical resources are often significant because of their indirect connections to other events or resources. For example, testing at a certain facility may have been crucial in the understanding of a material, or a facility researcher's work may have allowed another researcher to design a new system. Therefore, the identification of a historic context for scientific and technical facilities should be crafted with consideration to the interrelationship between physical resources or locations and larger discoveries. However, this analysis can prove overly broad because it can

[3] National Park Service, *National Register Criteria for Evaluation,* p. 7.

be argued that nearly every scientific resource is related to a certain discovery. This issue has been resolved by the evaluation criteria provided by NASA Headquarters, which identifies significant historic contexts related to the Space Shuttle Program in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)" dated June 6, 2006. According to these guidelines, only those properties that had a direct association with the Space Shuttle Program can be considered significant in the context of the Space Shuttle Program. Properties without significance may still meet National Register criteria but in a different context, outside the scope of this assessment.

Assessing Historic Integrity

Scientific facilities or highly technical resources are often significant for the events that took place within them, rather than for their physical characteristics, which may have been significantly altered over time. This issue presents a challenge when evaluating the historic integrity of a property. As previously stated, a resource must be found significant within a historic context and retain the physical characteristics that best express this historical significance to be eligible for listing in the National Register. According to the National Park Service's *National Register Bulletin: How to Apply the National Register Criteria for Evaluation*:

> To retain historic integrity a property will always possess several, and usually most, of the aspects. The retention of specific aspects of integrity is paramount for a property to convey its significance.
>
> All properties change over time. It is not necessary for a property to retain all its historic physical features or characteristics. The property must retain, however, the essential physical features that enable it to convey its historic integrity. The essential physical features are those features that define both *why* a property is significant (Applicable Criteria and Areas of Significance) and *when* it was significant (Periods of Significance).[4]

For the eleven resources reviewed at NASA Ames Research Center, the aspects of integrity deemed to be of the highest value were workmanship and association. These two aspects allowed for latitude in the evaluation of the other aspects of aspects of integrity, which may have been significantly altered. As defined previously, workmanship is the physical evidence of the crafts of a particular culture or people during any given period in history or prehistory, and association is the direct link between an important historic event or person and a historic property.

[4] Ibid., 44; 46.

Although workmanship is often associated with traditional crafts and construction techniques, it can be adapted to suit the evaluation of scientific and technical resources. Examples of workmanship for these types of facilities include the presence of specialized equipment and other technological resources, such as computer stations, specialized infrastructure, large-scale cranes, vacuum spheres, and manufacturing equipment. These resources are often vital in scientific discovery and exploration and serve as the physical evidence of work conducted in a particular time and place. In many cases, equipment and technological resources function as the primary historic elements within scientific facilities, and the building housing them is often treated as a shell adapted to these resources. While the character of the equipment may change or evolve over time, the function of this equipment or technology remains constant despite the changes in appearance or design. Therefore, in evaluating the workmanship of a scientific property, significant equipment and technological resources that played a role in the history of scientific discoveries must be noted in the context statement and integrity evaluation. Although the structure or building occupying a place of scientific exploration may physically change and evolve over time, if the significant equipment and technological resources used in that discovery still exist, even if altered, then a resource may retain integrity of workmanship.

In a scientific or highly technical facility, integrity of workmanship is defined as the constant evolution of equipment and technology constructed for a specific goal. This technology often results in significant events or associations that are embodied within a place. The National Park Service defines this connection as the integrity of association – the direct link between an important historic event or person and a historic property. The National Park Service recognizes integrity of association as being subjective, and often, ephemeral in nature. The integrity of association of a scientific or highly technical facility is vital to convey its significance because some identifiable link to the significant event or person is essential. Integrity of association is not solely defined by its aesthetic attributes, which are identified as the integrity of feeling. Scientific facilities often lack this integrity of feeling, due to the evolution of the physical characteristics, which would have originally defined a building, structure or object. The integrity of association is more closely tied to the place. Therefore, integrity of association is required in order to convey a scientific or highly technical facility's connection to a past discovery or achievement.

Criteria Consideration G

According to National Register evaluation criteria, resources that are less than fifty years old must meet *Criteria Consideration G: Properties that Have Achieved Significance within the Last Fifty Years* in order to be eligible for listing in the National Register. Criteria Consideration G states that "[a] property achieving significance within the last fifty years is eligible if it is of exceptional importance."[5] In order for a property to be evaluated under Criteria Consideration G, there must be sufficient historical perspective to determine that the property is exceptionally important, as well as a comparison among other related properties within a geographic area to determine if the property qualifies as exceptionally important. Properties which have achieved significance within the past fifty years can also be eligible for the National Register if they are an integral part of a district which qualifies for the National Register listing.

As stated in the *National Register Bulletin: Guidelines for Evaluating Properties that Have Achieved Significance Within the Past Fifty Years:*

> The rationale or justification for exceptional importance should be an explicit part of the statement of significance. It should not be treated as self-explanatory… The second section should contain the justification as to why the property can be determined to be of exceptional importance. It must discuss the context used for evaluating the property. It must demonstrate that the context and the resources associated with it can be judged to be "historic." It must document the existence of sufficient research or evidence to permit a dispassionate evaluation of the resource. Finally, it must use the background just presented to summarize the way in which the resource is **important**.[6]

Examples of properties that have been listed according to Criteria Consideration G are the Cape Canaveral launch pad, from which the first humans traveled to the moon, the Chrysler Building in New York, for its significance as the epitome of "Style Moderne" architecture, and the home of nationally prominent playwright Eugene O'Neill.[7]

Approach to Data Collection

Between August and October 2006, a reconnaissance-level survey was conducted of the exterior and interior of the eleven resources identified on the preliminary list of properties utilized by or supporting the Space Shuttle Program at NASA Ames Research Center. This survey consisted of multiple site visits that included fieldwork and interviews with Ames staff. The interviews were conducted by a team of NASA Ames Research Center staff, which included Roger Ashbaugh (Cultural Resources Manager, Environmental Services Division, NASA Ames), Michael Makinen

[5] National Park Service, *National Register Criteria for Evaluation,* p. 41.
[6] Marcella Sherfy and W. Ray Luce, *National Register Bulletin Number 22: Guidelines for Evaluating and Nominating Properties that Have Achieved Significance Within the Past Fifty Years* (Washington D.C.: National Park Service, 1998), p. 11.
[7] Ibid.

(Ames Associate and retired Ames FHPO, NASA Ames), and Keith Venter (Ames Research Center Historic Preservation Officer, NASA Ames); Integrated Science Solutions, Inc. (ISSi) personnel, including Thomas Anderson (Senior Environmental Specialist, ISSi); Glenn E. Bugos from Lockheed Martin Engineering & Sciences, Co. - a contractor with the Ames History Office; and Cora Palmer and Richard Sucré, architectural historians with Page & Turnbull - CRM contractor for Ames SSP Assessment. Fieldwork focused primarily on identifying significant contributions made to the Space Shuttle program in each resource. All resources were documented in field notes and digital photography.

The site visits and surveys documented those interior portions of the building that were deemed relevant to the Space Shuttle Program by the project team and interviewees. These areas included significant equipment, technology, and spaces, and if found eligible would be considered the building's character-defining features. The other portions of the building not surveyed or identified are not considered to be character-defining features in the context of the Space Shuttle Program. In evaluating a property for the National Register, the resource must be considered as a whole, and should not be parceled or subdivided. According to the *National Register Bulletin: How to Apply the National Register Criteria for Evaluation*, "...parts of buildings, such as interiors, facades, or wings, are not eligible independent of the rest of the existing building."[8] For example, if only one portion of a building was considered to be significant to the Space Shuttle Program, the entire building would be eligible for listing in the National Register. Future alterations to a National Register-eligible property would have to consider the effect of a proposed project upon a resource's character-defining/ contributing elements.

The following NASA Ames personnel were interviewed as part of this assessment:

- Thomas Alderete, Assistant Chief for Simulation Facilities, 30 August 2006; interviewed in relation to N-243: Flight and Guidance Simulation Laboratory

- Ron Bailey, former Director of NASA Advanced Supercomputing Facility, 6 September 2006; interviewed in relation to N-258: NASA Advanced Supercomputing (NAS)

- Mark Betzina, Deputy Director National Full-Scale Aerodynamic Complex (NFAC), 23 August 2006; interviewed in relation to N-221: 40-By 80-Foot Wind Tunnel

- Jim Connolly, Code SLE Payloads and Facilities Engineering Branch, 21 September

[8] National Park Service, *National Register Criteria for Evaluation,* p. 4.

2006; interviewed in relation to N-240 and N-240A: Airborne Missions and Applied Life Sciences Experiments/Life Sciences Flight Experiments

- Charles Cornelison, Facility Manager, Ballistic Range Complex, 3 October 2006; interviewed in relation to N-237: Hypervelocity Free Flight Facility

- Scott Edelman, Deputy Chief, Thermophysics Facilities Branch, 23 August 2006; interviewed in relation to N-229: Experimental Fluid Dynamics Facility

- Howard Goldstein, Ames Associate, 21 September 2006; interviewed in relation to N-238: Arc Jet Laboratory

- Christine Gong, Multimedia Developer, 6 September 2006; interviewed in relation to N-258: NASA Advanced Supercomputing (NAS)

- Frank Hui, Aerospace Test Engineer, Thermophysics Facilities Branch, 23 August 2006; interviewed in relation to N-238: Arc Jet Laboratory

- Frank Kmak, chief of the Wind Tunnel Engineering Branch, 24 August 2006; interviewed in relation to N-227A to D: Unitary Plan Wind Tunnel

- Dochan Kwak, Ames Associate, 6 September 2006; interviewed in relation to N-258: NASA Advanced Supercomputing (NAS)

- Joe Marvin, former chief of the Experimental Fluid Dynamics Branch, 23 August 2006; interviewed in relation to N-229: Experimental Fluid Dynamics Facility

- John Parks, Assistant Chief for Operations and Engineering, 6 September 2006; interviewed in relation to N-258: NASA Advanced Supercomputing (NAS)

- George Sarver, SSBRP Project Manager, 13 September 2006; interviewed in relation to N-244: Space Projects Facility

- Ken Souza, former Deputy Director Code S, 21 September 2006; interviewed in relation to N-240 and N-240A: Airborne Missions and Applied Life Sciences Experiments/Life Sciences Flight Experiments

- Duc Tran, Laboratory Manager, 30 August 2006; interviewed in relation to N-243: Flight and Guidance Simulation Laboratory

Additional research was conducted at NASA Ames Research Center's Technical Library (N-202) and within relevant periodicals, including *Aviation Week and Space Technology*. The *Ames Research Facilities Summary* (1974) and the *Research Facilities Handbook* (1982) were used for basic information including construction dates and descriptions of function for many of the facilities. Roger Ashbaugh, Cultural Resources Manager of the Ames Environmental Services Division also provided additional information on the 36% Scale Orbiter Model, N-229, N-240, N-240A, and N-258 (See Appendices). As part of this additional research and supplemental information, interviews were conducted with: Donald James (Project Manager for Installation of the Model, Ames), Scott Edelman (Deputy Chief, Thermophysics Facilities Branch, Ames), and Bonnie Dalton (Deputy Director, Science Directorate, Ames). Where available, testing logs for wind tunnel facilities, including the Unitary Plan Wind Tunnels, were used to determine the type of testing that took place in individual facilities. *Life into Space: Space Life Sciences Experiments, 25 Years: 1965-1990* (1993) was used for information on the Life Sciences Program. Further research was conducted online using NASA Ames History Office website, which featured three main sources of information: Glenn Bugos' *Atmosphere of Freedom: Sixty Years at the NASA Ames Research Center*, Edwin Hartman's *Adventures in Research: A History of Ames Research Center*, and Elizabeth A. Muenger's *Searching the Horizon: A History of Ames Research Center 1940-1976*. Historic images were provided by the NASA Ames Imaging Database with assistance from Lynn Albaugh. Archival architectural drawings were provided by the NASA Ames Engineering Documentation Center (EDC) with assistance from Michael Nar.

III. Historical Context

The following section provides a center-specific discussion of Ames' contribution to the development of the Space Shuttle Program. Included in this section is a brief outline of prior studies conducted by the National Park Service on the Space Shuttle Program and a historic context statement specific to Ames. For a historical overview of the U.S. Space Shuttle Program, refer to Dennis R. Jenkins, *Space Shuttle, The History of the National Space Transportation System. The First 100 Missions*, published in 2001.

Ames has supported elements of the Space Shuttle Program for more than thirty-five years. As early as the 1950s, Ames researchers completed fundamental studies on the lifting body concept, trajectory analyses, and thermal protection materials. Ames' direct contributions to the Space Shuttle Program were accelerated in 1971 with the formation of a Shuttle Project Office led by Victor Stevens and his deputy, Bob Nysmith. These individuals managed projects at the request of Ames as per the request from the Space Shuttle Program's lead center, Johnson Space Center. Ames played a critical role in making the Space Shuttle Program a reality, especially in the areas of wind tunnel testing, thermal protection systems, piloted landing simulation, computational fluid dynamics, and life sciences.

The following excerpt is from a 30 March 2006 article written for the twenty-fifth anniversary of the first Space Shuttle Flight by Jim Arnold and Ann Sullivan, with contributions from Howard Goldstein, Tom Alderete, and Jack Boyd.[1] The article also contains information from the 1 May 1981 issue of the NASA Ames' *Astrogram*. Portions of this article have been reformatted for inclusion in this report.

> *A Look Back at Ames' Contributions to the Shuttle*
> April 12 marks a historic milestone in the human exploration of space. It is the 45th anniversary of the flight of cosmonaut Yuri Gagarin, the first human to orbit the Earth. It also is the 25th anniversary of the fight of STS-1, the first orbital flight of the Space Transportation System, or space shuttle. This truly remarkable achievement was the result of work by thousands of individuals at NASA Headquarters, NASA field centers, major portions of the aerospace industry and academia.

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[1] Jim Arnold and Ann Sullivan, with contributions from Howard Goldstein, Tom Alderete and Jack Boyd, "A Look Back at Ames' Contribution to the Shuttle," *Astrogram* [http://www.nasa.gov/centers/ames/research/humaninspace/25th_shuttle.html] (30 March 2006).

Figure 1. STS-1 launched from Kennedy Space Center on April 12, 1981, with Commander John Young and Pilot Robert Crippen

Research at Ames has played a key role in the evolution of the shuttle program from the very beginning. The shape of the orbiter has its roots in the "lifting body" research pioneered by "Sy" Syvertson, Ames' fourth director, and Al Eggers. Once its 1- to 2-week orbital mission is complete, the shuttle executes a de-orbit burn, which slows it for its descent into the atmosphere. Initial entry occurs at about Mach 25, or 25 times the speed of sound in air. During the high-speed portion of the entry, the vehicle holds a high angle of attack. It executes a "blunt body entry" maneuver pioneered by Ames' second director, H. Julian "Harvey" Allen for the Mercury/Gemini/Apollo programs. After a long and fiery entry, the vehicle continues to dissipate energy through a series of S-turns. It then goes into subsonic flight and lands, unpowered, either at Dryden Flight Research Center or, as is most common today, at Kennedy Space Center. Astronaut pilots say the shuttle glides like a "falling brick," so being able to land unpowered is quite an achievement.

This article describes some of Ames' major contributions to the early development of the space shuttle and mentions a few of the many Ames employees whose contributions were crucial to the vehicle's development. These include contributions to the shuttle ascent aerodynamics/aerothermodynamics (a combination of aerodynamics and thermal effects), the thermal protection system (TPS) that prevents the orbiter from burning up during reentry, low-speed approach and landing technology and simulator research. The center's facilities that enabled these contributions also are briefly described.

Ames has supported space shuttle development for close to 30 years, beginning with the formation in the 1970s of a Shuttle Project Office, led by Victor Stevens and his deputy, Bob Nysmith. They managed projects at Ames at the request of the program's lead center, Johnson Space Center. Hans Mark, Ames' third director, played a key role in defining and directing Ames' involvement in the shuttle program. Various directorates at Ames provided staff and facilities to execute projects.

Aerodynamics of the Orbiter/Boeing 747 Ferry Configuration

One of Ames' first tasks was to understand the aerodynamics of the specially modified Boeing 747 used to ferry the orbiter from Dryden to Kennedy Space Center. The aerodynamics of the mated vehicles and the interference of flows between the vehicles had to be well understood prior to committing to design and flight. Understanding the separation process of the Boeing 747 and the orbiter was another requirement. (Figure 2). Testing in Ames' 14-Foot Wind Tunnel was a major contribution to the successful flight test of the Boeing 747/full-scale orbiter model Enterprise.

Ascent Aerodynamics/Aerothermodynamics

Ames made a huge effort to develop the aerodynamics and aerothermodynamics for the shuttle. Victor Peterson, former deputy director of Ames, has stated that over 50 percent of the wind tunnel testing conducted for the shuttle was done at Ames. Ames' contribution to these wind tunnel tests is a heritage of which we can all be very proud.

Figure 2. 14-Foot Wind Tunnel model of Space Shuttle Orbiter and 747 aerodynamic test of mated vehicles

Nearly all the aerodynamic studies at Ames used the center's extraordinary collection of wind tunnels, including the 40-By 80-Foot Wind Tunnel, 12-Foot Pressure Wind Tunnel, the 2-foot, 11-Foot and 14-Foot Transonic Wind Tunnels, the 6-By 6-Foot, 8-By 7-Foot and 9-By 7-Foot Supersonic Wind Tunnels, and the 3.5-Foot Hypersonic Wind Tunnel. [For additional information, refer to IV. List of Facilities Surveyed, N-221 (40-By 80 Foot Wind Tunnel), Historic Context; N-227A to D (Unitary Plan Wind Tunnels), Historic Context; and N-229 (Experimental Fluid Dynamics Facility), Historic Context]

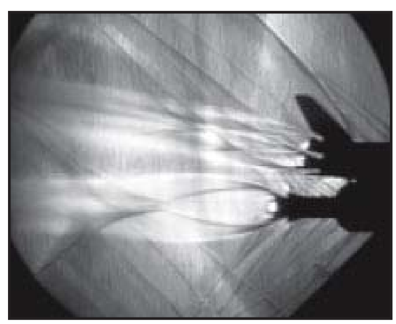


Figure 3. Schlieren photograph of Shuttle vehicle/exhaust plume interactions from 9-By 7-Foot Wind Tunnel test

More than 10,000 hours of wind tunnel testing took place even before the award of the shuttle design and construction contract in 1972. More than 25,000 hours of wind tunnel testing occurred after this. Key contributors to the Subsonic - Supersonic elements of the activity included Richard (Pete) Peterson, Jake Drake, Dan Petroff, Jim Monford, Jack Bronson, Len Roberts and Jack Boyd.

Testing for the ascent stack (the orbiter, external tank and solid rocket boosters) aerodynamics and exhaust plume interactions was carried out in the 9-By 7-Foot Supersonic Section of Ames' Unitary Plan Wind Tunnels. (Figure 3). These tests helped engineers ensure that the aft portions of the vehicle were properly designed, and that they would safely function during ascent. [For additional information, refer to IV. List of Facilities Surveyed, N-227A to D (Unitary Plan Wind Tunnels), Historic Context]

Other specialized aspects of Ames' wind tunnels were very helpful in the shuttle's development. Figure 4 shows multiple exposures of a special rig in the center's 14-Foot Tunnel that was used to study the aerodynamics of an abort maneuver implemented at transonic Mach numbers. This rig also was used in the study of the mated/separating configurations between the Enterprise and the Boeing 747 carrier aircraft.

Figure 4. Multiple-exposure photograph showing test positions of shuttle abort maneuver in the 14-Foot Tunnel

One of the most heavily used tunnels for shuttle testing was the 3.5-Foot Hypersonic Wind Tunnel, which was capable of simulating flight at Mach 5, 7 and 10. This facility provided about 47 percent of the total hours of wind tunnel testing at Ames. Many personnel were involved in this work, including Joe Marvin, Mike Horstman, Marvin Kussoy, Bill Lockman and Tom Polek. [For additional information, refer to IV. List of Facilities Surveyed, N-229 (Experimental Fluid Dynamics Facility), Historic Context]

Figure 5 shows a 1.5 percent ascent stack configuration in the 3.5-Foot Hypersonic Wind Tunnel test section. This model was tested at Mach 5. Another configuration tested in the 3.5-Foot Tunnel was secured to the sting by its tail, so the effects of protruding main engines and the orbital maneuvering system could be assessed. These studies led to the understanding of many different complex phenomena, including dynamics of shock-shock interactions

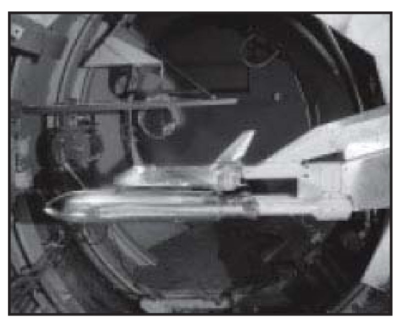


Figure 5. Shuttle ascent stack in the 3.5-Foot Hypersonic Wind Tunnel

caused from the proximity of the elements of the stack configurations, and the effects of split body flap deployments and turbulent flows.

Entry Aerodynamics and Aerothermodynamics

Before the Space Shuttle, most entry vehicles were relatively simple, blunt shapes with no aerodynamic control surfaces. The shuttle was to become the first airplane-like entry vehicle with movable control surfaces.

The 3.5-Foot Hypersonic Wind Tunnel contributed equally to both ascent and entry aerodynamics and entry aerothermodynamics. Figure 6 shows a shadowgraph of the side view of the orbiter at Mach 7. The fine lines enveloping the side view outline the front of a bow shock layer that forms over the vehicle. At higher Mach numbers, the bow wave is highly swept as shown in the figure, and the gases in this wave are shock-heated to very high temperatures. These shock-heated gases create an environment that would melt the surface of the vehicle were it made of materials such as aluminum or composites found in modern aircraft. Data and analyses from Ames' wind tunnel simulations later were used to refine methods for estimating the heating over the full-scale shuttle.

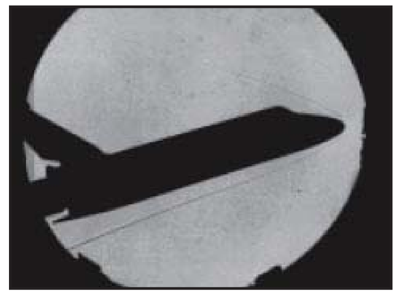


Figure 6. Shadowgraph of flow about the shuttle orbiter at Mach 7 showing the bow shock wave

The entry aero/aerothermodynamics of the shuttle were performed before the advent of modern 3-dimensional real-gas computational fluid dynamics, a later accomplishment led by Ames. In the 1970s, personnel including John Howe, Chul Park, Dave Stewart, John Rakich and Mike Green, working under the leadership of Dean Chapman, Vic Peterson and Howard Larson, used clever, approximate analytical tools, experimental results and engineering judgment to model the aerodynamic forces, heating rates and heating loads to understand the shuttle entry flow environment. This knowledge was required for the development of the shuttle TPS, another area of key contribution by Ames.

Thermal Protection System Contributions

The shuttle's thermal protection system prevents the vehicle from burning up from the searing heat of hot gases that exist within a bow shock layer that envelops the vehicle as it re-enters Earth's atmosphere. These gases reach temperatures as high as 25,000 degrees F (13871 degrees C), and heat the surface of the vehicle to as much as 3,000 degrees F (1,649 degrees C). The vehicle enters the atmosphere at an angle of attack of about 40 degrees. Figure 7 depicts the elements of the thermal protection system developed or invented by Ames. Key participants in this research include Howard Goldstein, Dan Leiser, Marnel Smith and Dave Stewart. [For additional information, refer to IV. List of Facilities Surveyed, N-238 (Arc Jet Laboratory), Historic Context]

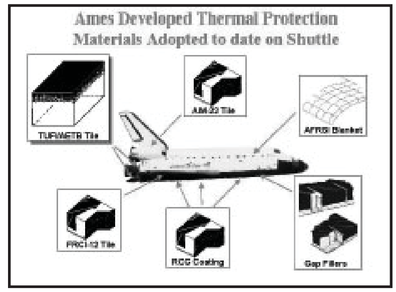


Figure 7. Ames' contributions to the space shuttle thermal protection system

In the early 1970s, Ames and Johnson Space Center evaluated a large number of candidate TPS materials for the space shuttle orbiter in their arc jet facilities. Among these new types of heat shield materials was the LI-900 silica tile system developed by Robert Beaseley and his team at Lockheed Missiles and Space Company, Sunnyvale, and several other conceptually similar systems developed by other companies. In order to understand why the various tile materials performed as they did in arc jet testing, Ames began a tile analysis research program, which rapidly turned into a tile development program. When the LI-900 tile system was chosen as the baseline in 1973, Ames had already begun to make significant contributions to the rapidly improving technology.

Ames showed in that same year how the purity of the silica fibers used in the tiles controlled their temperature capability and lifetime. In 1975, Ames invented the black borosilicate glass coating called Reaction Cured Glass (RCG) that was adopted by LMSC and the shuttle program in 1977 and that now covers two-thirds of the orbiters' surface. This coating provides a thermally stable high-emmitance surface for the tiles, which serves to radiate away heat and allows the tiles to be manufactured to the demanding tolerance required. The coating covers the tile, which is made by bonding pure silica high temperature-resistant fibers. The finished tile substrate is similar in appearance and density to Styrofoam, but its thermal properties are such that the surface can be glowing white hot at over 2,300 degrees F (1,260 degrees C) and the back face of the tile never exceeds 250 degrees F (121 degrees C), only a few inches below the surface. These remarkable heat-resistant tiles enable the space shuttle orbiter, which is essentially an aluminum airplane, to fly at hypersonic speeds.

In 1974, Ames invented the tile now known as LI-2200, which is stronger than LI-900 and contains silicon carbide to provide improved temperature capability. Adopted in 1978, this new tile replaced about 10 percent of the baseline LI-900 tile system on the first orbiter, Columbia, when a critical tile strength problem was encountered. Later, in 1977, Ames invented a new class of tiles called Fibrous Refractory Composite Insulation (FRCI 12). In 1980 it replaced about 10 percent of the earlier LI-2200 and LI- 900, providing a more durable TPS and saving about 500 pounds (227 kilograms) of the overall TPS weight.

Hot gas flow between the tiles during atmospheric entry was considered a serious problem during orbiter development. In response, Ames developed a gap filler, which consists of a ceramic cloth impregnated with a silicone polymer that was adopted as a solution to the gap heating for Columbia. The Ames gap filler was so successful that it was adopted as a permanent solution to the gap flow problems on all the orbiters. In excess of 10,000 are now used on each vehicle.

On the leeward side of the orbiter, gases are much cooler during entry. At first a low temperature reusable surface insulation (LRSI) tile developed by LMSC was used. Ames (with Johns Manville) developed a flexible silica blanket insulation called Advanced Flexible Reusable Surface Insulation (AFRSI) that replaced most of the LRSI on the last four orbiters (Challenger, Atlantis, Discovery and Endeavour) and was retrofitted to Columbia.

Arc Jet Facilities Simulate Entry Heating

Ames has a long heritage in the development of arc jets, tracing to the earliest days of NASA. These facilities are used to simulate the entry heating that occurs for locations on the body where the flow is brought to rest (the stagnation point, typically on the nose cap, wing leading edges and on the acreage of the vehicle). [For additional information, refer to IV. List of Facilities Surveyed, N-238 (Arc Jet Laboratory), Historic Context]

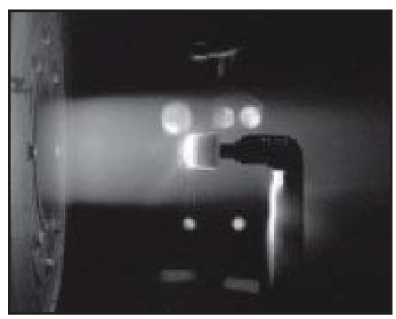


Figure 8. Stagnation point test

Simulations have to run from a few minutes to tens of minutes to understand the TPS materials' response to the hot gas flow environment. To support shuttle development, Dean Chapman and others led the effort to up upgrade Ames' capability. Ames' facilities group, including Howard Stein, Warren Winnovich and Frank Centolanzi, implemented the upgrades. Ames' 60-megawatt Interaction Heating Facility was brought on line in the mid-1970s. Highpressure air passes through the constricted arc heater (invented by Ames), where a "standing lightning bolt " is created and about 50 percent of this energy is deposited as

Figure 9. "Missing tile" heating test

heat into the flowing gas.

The heated gases are expanded through either conical nozzles for stagnation point and wing leading edge testing (Figure 8), or through semi-elliptical nozzles for acreage tests. Ames' capability of being able to test a 2-foot by 2-foot (.61-meter by .61-meter) section of the acreage tile field in conditions duplicating aeroconvective heating and reacting boundary layer chemistry during simulated entry conditions was a critical element in the development of the shuttle TPS. Figure 9 is a photograph of the "missing tile" test run to understand the effects that would occur should a tile be lost prior to entry.

Low-Speed Descent Aerodynamics

Early shuttle concepts had orbiters that would have exhibited less than ideal aerodynamic characteristics upon return to Earth. This could have lead to poor handling qualities, especially during approach and landing. Personnel at Ames with expertise in guidance and control tackled the challenge of developing concepts that might compensate for deficient aerodynamics and ensure adequate handling qualities.

Still glowing red hot from its highspeed entry, the orbiter slows and descends into the supersonic/transonic/subsonic regime of its return. Here again, Ames' wind tunnels played a key role in defining shuttle aerodynamics and design of the orbiter. The 2-Foot Transonic Wind Tunnel, with its capability up to Mach 1.4, was used to study potentially troublesome panel flutter problems. The 12-Foot Pressurized Wind Tunnel was used to investigate the orbiter's low-speed handling characteristics.

Ames' efforts demonstrated that unpowered landings could be made at speeds of at least 200 knots without significant problems. The 12-Foot Wind Tunnel was used to define the aerodynamics of a specially modified Gulfstream 2 (G2) business jet with direct-lift flaps and side force generators. This vehicle was used for flight tests and astronaut training. Ames' Convair CV 990 and the G2 aircraft were used to prove that the orbiter did not need a subsonic engine for fly-around landing capability, an important finding that avoided having to pay the weight penalty of hauling a landing engine, its fuel and supporting subsystem to orbit and back. The Gulfstream, now known as the STA (Shuttle Training Aircraft), is used to this day by pilot astronauts

Figure 10. 36% Scale Orbiter Model

for in-flight proficiency training.

Finally, an awesome 36 % scale model of the Orbiter, 44 feet (13.41 meters) long, was fabricated and tested in Ames' 40-By 80-Foot Wind Tunnel. Figure 10 shows the model, then painted yellow, in the test section with a person in view to give the scale. This model and the 40-By 80-Foot Wind Tunnel could create Reynolds numbers slightly higher than the 12-Foot Pressurized Wind Tunnel. An important purpose of the 40-By 80-Foot testing was to identify the influence of the TPS on the orbiters' lowspeed aerodynamics. This model still exists, painted with the striking black underbelly and white top. It is proudly displayed in front of the Ames Visitor Center, near the 40- by 80- where it was so intensely tested. [For additional information, refer to IV. List of Facilities Surveyed, 36% Scale Orbiter Model, Historic Context; and N-221 (40-By 80-Foot Wind Tunnel), Historic Context]

Approach/Landing Systems Development: FSAA

Landing simulation research for the shuttle orbiter began in the very early 1970s, using the Flight Simulator for Advanced Aircraft (FSAA). The large motion envelope of the FSAA provided many of the vital cockpit accelerations that enabled pilot astronauts to experience a truer "feel" of the g-forces of the orbiter during approach and landing. These simulations were conducted for that portion of the shuttle's flight from supersonic (following re-entry) to approach and landing. [For additional information, refer to IV. List of Facilities Surveyed, N-243 (Flight and Guidance Simulation Laboratory), Historic Context]

For many years, prior to first flight, all the pilot astronauts who would eventually fly the orbiter spent many hours in the FSAA, identifying handling qualities that needed improvement, and control system shortcomings. In this process, the pilots gained invaluable training in the skills needed to successfully land the orbiter. It was in the FSAA that investigations were conducted that determined the need for the Heads-Up-Display (HUD), and its alphanumeric symbology that became the primary guidance system for orbiter landing. Figure 11 shows a very early (1970) photograph taken in the simulator when the shuttle work was just starting. Depicted is pilot Kenneth White in the Space Shuttle Vehicle Simulation Cockpit.

Figure 11. Kenneth White in the Space Shuttle Vehicle Simulator (1970)

A pilot-induced oscillation (PIO) problem arose on the first approach and landing test program flight in July 1977, with pilots Fred Haise and Gordon Fullerton. A PIO is a longitudinal "porpoising" that worsens due to pilot over-control. It is generally not a piloting technique problem so much as a control system problem. On this first flight, as the oscillation began to diverge dangerously close to the ground, Haise had enough confidence and simulator training to simply let go of the controls and allow the oscillation to damp itself out.

Following that, a major investigation was conducted in the FSAA to re-evaluate the control systems gains, in order to minimize the possibility of future PIO problems. In addition, work was conducted for several years in the simulator to investigate the terminal area energy management concepts designed by engineers at Johnson Space Center. Development support for the space shuttle, prior to the first flight, also included approach/landing control system and handling qualities, heads-up display concept, speed brake scheduling, astronaut training, flight techniques for failure recovery, and landings of the shuttle from atop the Boeing 747 carrier aircraft.

Vertical Motion Simulator

In 1980, Ames' new Vertical Motion Simulator (VMS) began operation. It wasn't long before the VMS earned a reputation as the best simulator anywhere for the continuation of engineering design and shuttle pilot training. Landing systems and flight rules are done on the VMS with astronaut crews and Johnson Space Center engineers. Ames' SimLab and VMS have supported the shuttle program on a continuing and scheduled basis ever since. [For additional information, refer to IV. List of Facilities Surveyed, N-243 (Flight and Guidance Simulation Laboratory), Historic Context]

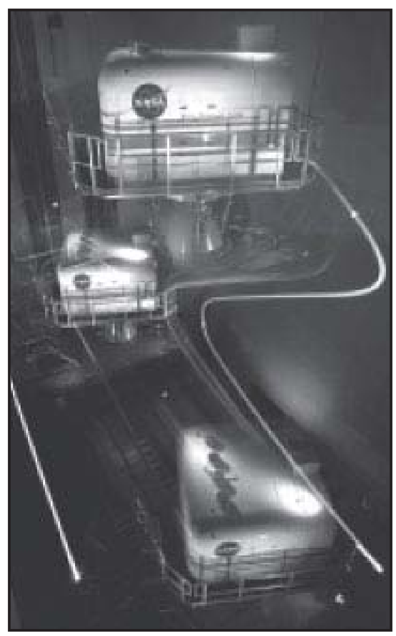


Figure 12. "Streak" photograph of the simulator showing how the piloted cabin moves to give the "feel" of flight and landing

Ames has continued to make major contributions to the shuttle program over the two decades following the flight of STS-1. This includes work in the area of aero/aerothermodynamics, where very significant, benchmarking CFD calculations were accomplished for the shuttle ascent stack configurations and for orbiter re-entry. CFD was a key contributor to the redesign of the space shuttle main engine. In the area of TPS, a second-generation material called Toughened

Unipiece Fibrous Insulation (TUFI) has been adopted and used to eliminate problems in regions of the orbiter where debris impact has proven to be an issue, especially on the aft heat shield and on the body flaps.

Figure 13. Successful landing of Columbia at Dryden Flight Research Center

In piloted flight simulation, a very close working relationship developed between the orbiter engineering design people from Johnson Space Center, the astronauts and Ames' SimLab. Virtually every pilot astronaut cycled through the VMS sim. Every day, from one to four of the astronauts' T-38s would park on the ramp beside the SimLab building, and the pilots would come in early and work late. More time was provided for commanders and pilots who had a near-term flight on the schedule. Besides looking at future design improvements in the flight control systems, the pilots would encounter every conceivable failure mode the Johnson Space Center engineers could imagine. This training proved invaluable in preparing shuttle commanders and pilots to deal with a wide array of possible landing failures. In addition to crew training, the VMS has supported redesign of the brakes, nose wheel steering and Multifunction Electronic Display System (MEDS); engineering development of the drag parachute; flight control automation for the Extended Duration Orbiter; and "return to flight" studies after the Challenger accident.

Today, work continues on the shuttle in the areas of aero/aerothermodynamics, TPS, VMS support and cockpit upgrades.

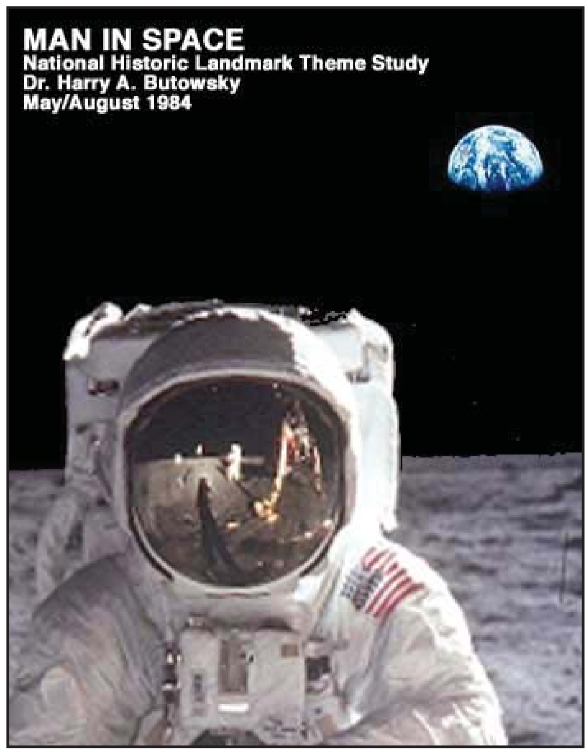
Conclusion

Space shuttle *Columbia* landed at Dryden Flight Research Center on April 14, 1981. The crew consisted of commander John Young and pilot Robert Crippen. The mission duration of 2 days, 6 hours, 20 minutes and 53 seconds included 36 orbits of the Earth. This first, brief mission proved the capability of the world's first and only reusable space vehicle, and the world's most reliable and versatile launch system.

Ames played a critical role in making the outstanding success of the space shuttle "happen," especially in the areas of aero/aerothermodynamics, thermal protection systems and piloted flight simulation areas. It is one element of the center's heritage that should be a source of pride to everyone at Ames.

Man in Space National Historic Landmark Theme Study

The *Man in Space Theme Study* identified twenty-four resources that represented the best and most important surviving examples of the technology necessary to support the Space Program. The only resource at Ames identified in this study was the Unitary Plan Wind Tunnels (N-227), which were one of only four wind tunnels determined significant for their contribution to the Space Program.[2] According to the *Man in Space Theme Study*, "These sites are recommended for designation as National Historic Landmarks because they represent the fine technological base of aeronautical research facilities created by the National Advisory Committee for Aeronautics. It was on this base that the National Aeronautics and Space Administration would build to create the success of the American Space Program."[3] Notably, the Unitary Plan Wind Tunnels were the only wind tunnels not located at Langley Research Center that were identified in this study as significant to the Space Program.



Man In Space National Historic Landmark Theme Study Cover (Source: National Park Service: Man in Space, http://www.cr.nps.gov/history/online_books/butowsky4; Original Photos Courtesy of NASA)

The Unitary Plan Wind Tunnels were identified as significant in the *Man in Space Theme Study* "because it represents the continuing effort of NACA to update its wind tunnel inventory to provide the American aircraft and aerospace industry with the most advanced testing facilities in existence in the world. The Unitary Plan Wind Tunnels were extensively used in designing new generations of aircraft that eventually led to the Space Shuttle of today. These wind tunnels represent only a small fraction of the more than 65 wind tunnels currently in NASA's inventory."[4]

[2] The other three wind tunnels designated include the Variable Density Wind Tunnel, Full Scale Tunnel, and the Eight-Foot High Speed Tunnel, all located at Langley Research Center in Virginia.
[3] Harry A. Butowsky, National Park Service, "Man in Space: Excerpts from a National Historic Landmark Theme Study" (Washington, D.C: National Park Service, 1984): 3.
[4] Ibid.

Space Shuttle Program Significance

The significance of the Space Shuttle Program is outlined in *Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP).* [Refer to II. Methodology, Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)]

The scheduled closure of the Space Shuttle Program in 2010 has led NASA to conduct a study of its facilities that would serve a similar purpose as the *Man in Space Theme Study*. In an effort to properly understand the historic context and significance of the Space Shuttle Program and the buildings, structures, and persons associated with it, NASA has requested each of its field centers to conduct a study of facilities that may have significance to the Space Shuttle Program within the period of 1969 to 2010.

According to existing documentation, the significance of the Space Shuttle was noted by the National Park Service (NPS) in the 1998 National Register Bulletin, *Guidelines for Evaluating and Documenting Historic Aviation Properties.* The following excerpt is from that bulletin.

> The Space Shuttle was the U.S. space program's next generation. Key aspects of the Shuttle's design and performance were based on a rocket-powered space plane, the X-15, the world's first transatmospheric vehicle. The Space Shuttle provided a new method of space flight, taking off like a rocket and landing like an airplane. The Space Shuttle *Columbia*, the first reusable manned spaceship, initiated the Space Shuttle flight program in April 1981, and a new era for the U.S. Space Program.[5]

The historic values of this program, like the Apollo-era program which preceded it, are embodied in the buildings, structures and objects within NASA centers. The purpose of this study is to identify NASA-controlled facilities of local, state, and/or national significance in the historic context of the U.S. Space Shuttle Program, from 1969 to 2010. Such facilities may include, but are not necessarily limited to, those used for research, development, design, testing, fabrication, and operations.

[5] Anne Milbrooke with Patrick Andrus, Jody Cook, and David B. Whipple, *National Register Bulletin: Guidelines for Evaluating and Documenting Historic Aviation Properties* (Washington, D.C: National Park Service, National Register of Historic Places, 1998), p. 12.

IV. List of Facilities Surveyed

The following section provides a list of the facilities surveyed at NASA Ames Research Center. This list was determined by the Ames Research Center Historic Preservation Officer in consultation with qualified personnel at NASA Ames Research Center (ARC), including the Facilities Planning Group (where the current and previous Federal Historic Preservation Officer is located), the Ames History Office, Code Q - Office of Director of Safety, Environmental and Mission Assurance, and the support service contractor, Integrated Sciences Solutions Inc. (ISSi). This list identified eleven resources to be researched and evaluated by the CRM Contractor, Page & Turnbull, for eligibility for the National Register in the context of the Space Shuttle Program. These eleven resources are:

- 36% Scale Orbiter Model [Located adjacent to N-223]
- N-221 (40-By 80-Foot Wind Tunnel)
- N-227A to D (Unitary Plan Wind Tunnels)
- N-229 (Experimental Fluid Dynamics Facility)
- N-237 (Hypervelocity Free Flight Facility)
- N-238 (Arc Jet Laboratory)
- N-240 (Airborne Missions and Applied Life Sciences Experiments)
- N-240A (Life Science Flight Experiments)
- N-243 (Flight and Guidance Simulation Laboratory)
- N-244 (Space Projects Facility)
- N-258 (NASA Advanced Supercomputing Facility)

Information provided within this section includes location, date of construction, brief description, type/function, historic context, and an evaluation utilizing the criteria set forth in NASA's "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)" (dated 5 June 2006). Photographs, images, diagrams, and illustrations related to each of the resources have been included in the Appendices.

36% Scale Orbiter Model
(Source: Tom Anderson, ISSi)

36% Scale Orbiter Model

Location: Outside of N-223, between Jones Road and Parsons Avenue, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1975

Brief Description: As noted in the dedication plaque, the 36% Scale Orbiter Model is the "largest model of the Orbiter ever tested in a wind tunnel. It was tested in the Ames 40-By 80-Foot Wind Tunnel for over 200 hours. The information gained from these tests was used in the final design phase." Designed by Rockwell International Corporation's Aircraft Division, this model is 43.9 feet (13.38 meters) long, weighs approximately 45,000 pounds (20,412 kilograms), and is constructed of a wood-and-steel frame covered with fiberglass epoxy.

Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

Type/Function: Test Model (original); Current: Commemorative and Display Object.

Historic Context: The 36% Scale Orbiter Model was designed by Rockwell International Corporation's Aircraft Division and built in 1975 at a cost of $1 million. The 43.9-foot-long (13.38-meter) model weighed approximately 45,000 pounds (20,412 kilograms) and was the largest Orbiter model used in the Space Shuttle Program. The 36% Scale Orbiter Model was fabricated and tested in Ames' 40-By 80-Foot Wind Tunnel. It is currently on display near the 40-By 80-Foot Wind Tunnel, north of N-223 (Former Visitor's Center).

In typical aeronautical research and development, wind tunnel testing of scale models provided aerodynamic predictions within specified tolerances that ensured acceptable flight characteristics for aircrafts and other vehicles.[1] At Ames, researchers conducted extensive SSP testing of varying scale Orbiter models, in order to better approximate flight characteristics. To this end, the 36% Scale Orbiter Model was created as the largest of these models, in order to be tested in the largest ARC wind tunnel, 40-By 80-Foot Wind Tunnel. The 36% Scale Orbiter Model and the 40-By 80-Foot Wind Tunnel created Reynolds numbers slightly higher than the 12-Foot Pressurized Wind Tunnel, thus providing for additional low-speed aerodynamic data. For example, disturbances from protuberances - antennas, cavities, landing gear well doors - were measured, and potential positions for sensors measuring airspeed and angle of attack were investigated.[2] During the Orbiter's development, engineers collected 250 hours of test data during a seven-day-per-week, two-shift-per-day period. Utilizing this data, the SSP conducted a total of thirty minutes of flight testing in which the Shuttle Enterprise (full-scale mock-up of the Orbiter) was released from an L1011 at 37,000 feet and observed during descent and landing. The scale model testing allowed for the necessary certification of the Orbiter for human flight.[3]

An important purpose of the 40-By 80-Foot Wind Tunnel testing of the 36% Scale Orbiter Model was to identify the influence of the Thermal Protection System (TPS) on the orbiter's low-speed aerodynamics. Most aircrafts were designed with a smooth skin to reduce drag; however, the shuttle's TPS tiles created a unique texture that required significant aerodynamic testing. The TPS tiles were brittle, and gaps must be left between them to allow them to flex without breaking. The grooves between the TPS tiles created a roughness, and ascertaining the aerodynamic effect at low speed was a major goal of the 40-By 80-Foot Wind Tunnel testing. At smaller scales, a precise simulation of

[1] Excerpted in part from Roger Ashbaugh, Cultural Resources Manager, Environmental Services Division, Ames Research Center, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.
[2] Richard G. O'Lone, "Shuttle Test Pace Intensifies at Ames," *Aviation Week & Space Technology* (24 June 1974): 71.
[3] Excerpted in part from Ashbaugh, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties."

the TPS became more difficult to replicate, thus testing of larger scale models became important to understanding the effect of TPS.[4] The larger scale test models were essential to understanding the aerodynamics of the final design of the orbiter. Unlike Apollo, the TPS on the Orbiter needed to withstand multiple launch and re-entry operations.[5] In order to test the Orbiter's TPS, engineers covered the 36% Scale Orbiter Model with tiles of plastic foam, cut to scale and interspersed grooves of proper depth and width. The early wind tunnel testing allowed for shorter field testing times. For example, the SSP tested the full-scale Orbiter, the Enterprise, with the same TPS. The Enterprise is now on display at the Udvar-Hazy Center of the Smithsonian National Air and Space Museum.[6]

NASA produced five technical reports on the Orbiter model tests:

- *Aerothermodynamic Data Base*; *Data File Contents Report* (NASA-CR-171807);
- *Results of Tests Using a 0.36-Scale Model (76-0) of the Space Shuttle Vehicle Orbiter in the NASA/ Ames Research Center 40 by 80-Foot Subsonic Wind Tunnel (0A100),* Volume 1 (NASA-CR-167364);
- *Results of Tests Using a 0.36-Scale Model (76-0) of the Space Shuttle Vehicle Orbiter in the NASA/ Ames Research Center 40 by 80-Foot Subsonic Wind Tunnel (0A100),* Volume 2 (NASA-CR-167365);
- *Results of Tests Using a 0.36-Scale Model (76-0) of the Space Shuttle Orbiter Vehicle 101 in the NAS/ Ames Research Center's 40x80-Foot Subsonic Wind Tunnel* (0A174), Volume 1 (NASA-CR-167340); and
- *Results of Tests Using a 0.36-Scale Model (76-0) of the Space Shuttle Orbiter Vehicle 101 in the NAS/ Ames Research Center's 40x80-Foot Subsonic Wind Tunnel* (0A174), Volume 2 (NASA-CR-167341).

The AIAA published: "The Space Shuttle Orbiter approach and landing tests- A correlation of flight and predicted performance data." (AIAA Paper 78-793).[7]

After fulfilling its functions as a test model, the 36% Scale Orbiter Model was utilized as a display object and educational resource. According to Donald James, Code D Project Manager for Model Installation, the Orbiter model toured the country and the world. It was sent to Paris, France for an Air Show, and was for many years displayed at Marshall Space Flight Center in Huntsville, Alabama. In more recent years, it was returned to Ames, where it was refurbished and installed in front of N-223 (formerly used as the Hypervelocity Ballistics Range, then as the visitor's center, and now as

[4] O'Lone, "Tunnel Tests Yield New Orbiter Data," *Aviation Week & Space Technology* (30 June 1975): 43.
[5] Roger Ashbaugh, Cultural Resources Manager, Environmental Services Division, Ames Research Center, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.
[6] Ibid.
[7] Ibid.

general office). The Orbiter Model currently resides in this location, although the Visitor's Center has moved to a new location.

Additional information on the property's historic context has been included in the Appendices.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[8]

- *Is real or personal property owned or controlled by NASA;*

The 36% Scale Orbiter Model is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

The 36% Scale Orbiter Model was constructed in 1975 for the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

The 36% Scale Orbiter Model is classified as an object, due to its current use and context. Objects are distinguished from buildings and structures to describe those constructions that are primarily artistic in nature or are relatively small in scale and simply constructed. An object is typically defined with a specific setting or environment, which is appropriate to their historic use, role or character.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

[8] NASA, "Evaluating Historic Resources," 3.

Criterion B - Significant Persons

- *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
- *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
- *best represents the important achievements or the cumulative importance of prominent persons; or*
- *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

Criterion C – Design/Construction

- *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
- *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
- *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

Criterion D – Information Value

- *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

Currently, the 36% Scale Orbiter Model can be categorized as a large movable display piece, located outside of N-223 (Former Visitor's Center). The Orbiter Model serves as a historic artifact and educational resource, and is one of many test models created for the Space Shuttle Program. As an educational resource, the 36% Scale Orbiter Model is now classified as a museum-quality object. The National Register criteria specify that museum-quality objects are not eligible for listing in the National Register because these objects do not have integrity of location or setting because there is no connection to their historic location.[9] Currently, no test models are listed in the National Register. These types of resource are considered to be museum-quality piece, and are therefore ineligible for listing in the National Register.

In relation to the Space Shuttle Program, the 36% Scale Orbiter Model qualifies under SSP Evaluation Criteria Eligibility Property Type *7. Engineering and Administrative Facilities*, as a resource that "should clearly embody the distinctive characteristics of a type of method of construction."[10]

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[9] National Park Service, *National Register Criteria for Evaluation,* 5; Milbrooke *et al.*, *Evaluating Historic Aviation Properties,* 36.
[10] NASA, "Evaluating Historic Resources," 7.

The 36% Scale Orbiter Model does not meet any of the NRHP criteria for listing in the National Register within the context of the Space Shuttle Program. The Orbiter Model is relevant as the largest model of the orbiter among the whole series of test models constructed for the Space Shuttle Program. Fabricated in the Ames Model Construction Facility and tested in the 40-By 80-Foot Wind Tunnel, the model allowed NASA scientists to gather low-speed aerodynamic data. This testing measured disturbance from proturbences such as antennas, and investigated potential positions for airspeed and angle of attack sensors. Testing of the Orbiter Model also identified the influence of the Thermal Protection System on the Orbiter's low-speed aerodynamics. The testing was considered important for the Space Shuttle Program, but is not considered exceptionally significant within the larger context of the Space Shuttle Program. Even though its scale and size was larger than other models within the Space Shuttle Program, it was one of many test models that supported this type of research.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

The 36% Scale Orbiter Model does not meet "Criteria Consideration B: Moved Properties" or "Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years." The significance of the Orbiter Model was in relation to the 40-By 80-Foot Wind Tunnel, and because it has been removed from the wind tunnel's testing chamber, it does not retain a relationship to its original location, setting, or function.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

The 36% Scale Orbiter Model possesses integrity of design, setting, materials, workmanship, feeling, and association. The Orbiter Model lacks integrity of location because it is no longer located in the 40-By 80-Foot Wind Tunnel. As part of the typical testing and experimentation, the Orbiter Model would have been repeatedly altered with varying nose, body, and wing configurations. Despite these alterations, which were part of the model's purpose and significance, the Orbiter Model still retains its essential physical features, which were composed of fiberglass and a steel-frame body. Therefore, it retains integrity of design, materials, and workmanship. The Orbiter Model possesses integrity of setting, since it is still located in the general vicinity of the 40-By 80-Foot Wind Tunnel at NASA Ames Research Center, although not within the interior of the test chamber of the 40-By 80-Foot Wind Tunnel. This relationship is important since the significance of the Orbiter Model is tied to that of the 40-By 80-Foot Wind Tunnel. The Orbiter Model and its associated interpretative material express the object's purpose and history; therefore, the model retains its integrity of feeling, but not association since it has been removed from the 40-By 80-Foot Test Chamber. Overall, the removal of the Orbiter Model from the 40-By 80-Foot test chamber has caused the resource to lose its historic integrity.

Conclusion

Although the 36% Scale Orbiter Model contributed valuable information to the Space Shuttle Program, it had a supporting and not a direct role to the SSP, therefore does not meet the general registration requirements for listing in the National Register of Historic Places within the context of the Space Shuttle Program. The 36% Scale Orbiter Model is not eligible for listing under any of the NRHP criteria, is not exceptionally significant within the Space Shuttle Program context, and is a museum-quality object. Currently, no test models have been listed in the National Register and, in general, models have not been considered to be eligible properties. Many models were constructed by NASA in support of the Space Shuttle Program. While these models have contributed valuable information to the Space Shuttle Program, they are not considered exceptionally significant within this context.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

N-221, east facade
(Source: Page & Turnbull)

N-221: 40-By 80-Foot Wind Tunnel

Location: 750 De France Avenue, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1944

Brief Description: Constructed in 1944, N-221 was originally built as the 40-By 80-Foot Wind Tunnel. This large eight-acre complex of buildings has had several additions over its lifetime. The current complex is composed of four sections: the 40-By 80-Foot Test Chamber (N-221), the 80-By 120-Foot Wind Tunnel (N-221B), the 20-G Centrifuge facility (N-221A), and the 2-By 2-Foot Transonic Wind Tunnel (N-222). N-221 and N-221B are interconnected; these two sections have been identified as the National Full Scale Aerodynamics Complex (NFAC). N-222 and N-221A are located in N-221, but are not related to the facility historically or scientifically. Only the 40-By 80-Foot Wind Tunnel will be discussed below. The building has concrete foundations, corrugated metal and Transite cement asbestos corrugated siding, geodesic steel bent structural

Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

frames, and a multi-gable roof.

The 40-By 80-Foot Test Chamber has a rectangular-shaped plan with an interior courtyard and contains 150,900 square feet (14,019 square meters). The 40-By 80-Foot Test Chamber is surrounded by a structural exoskeleton comprised of steel bents that encloses the corrugated metal and cement asbestos siding. The interior test chamber is 40 feet (12.19 meters) in height and 80 feet (24.38 meters) in width with semicircular sides. A thick acoustical lining was added to the chamber's interior to absorb sound. The 40-By 80-Foot Wind Tunnel is a closed circuit wind tunnel with the following features: air speed variable up to 300 knots maximum (345 mph); power supplied by 100 megawatts (six fan motors, each rated at 22,500 hp); and drive fans that are 40 feet (12.19 meters) in diameter with 15 variable pitch blades per fan.

The building has a variety of interior uses including offices, laboratory and research space, machine shops, control rooms, and an exceptional building infrastructure, which supports the two wind tunnel facilities. A portion of the building has been converted into an exercise facility for Ames employees. Typical interior finishes include resilient or vinyl roll-out flooring, gypsum board partition walls, and acoustic tile ceilings with fluorescent lighting. Recently, the U. S. Air Force has leased the entire complex and is currently restoring the two wind tunnels to full operation. This restoration effort is in support of the National Full-Scale Aerodynamic Complex (NFAC).

Type/Function: 40-By 80-Foot Wind Tunnel; 80-By 120-Foot Wind Tunnel; research and laboratory facilities; office and administrative facilities; machine shops; gymnasium and exercise facility; Current: National Full-Scale Aerodynamic Complex (NFAC), managed by the U.S. Air Force.

Historic Context: Made operational in 1944, the 40-By 80-Foot Wind Tunnel was the fourth wind tunnel constructed at NASA Ames Research Center. Originally, N-221 was an experimental facility for researching and testing jet aircraft and first-generation jet engines, advanced rotor techniques, and peripheral space use testing. As defined in *The Wind Tunnels of NASA,* a wind tunnel is a device composed 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 airstreams, which produces a flow of air about the model, duplicating that of the full-scale aircraft."[1] N-221 is currently utilized in this same capacity and helps in testing takeoffs and landings of high performance aircrafts and spacecrafts, and testing Vertical and Short Take

[1] Donald D. Baals and William R. Corliss, *Wind Tunnels of NASA* (Washington, D.C.: NASA, 1981), p. 2.

Off and Landing (V/STOL) aircrafts and rotorcrafts. N-221 is part of "The National Full-Scale Aerodynamics Complex (NFAC)," which is comprised of the largest wind tunnel test sections in the world, consisting of the 40-By 80-Foot Wind Tunnel and the 80-By 120-Foot Wind Tunnel.

The 40-By 80-Foot Wind Tunnel was able to provide Reynolds numbers slightly higher than obtained in the 12-Foot Pressurized Wind Tunnel, resulting in more accurate low-speed aerodynamic data.[2] Early testing for the lifting body concept was carried out in the 40-By 80-Foot Wind Tunnel. According to the National Register nomination form, "test log records for the 40-By 80-Foot Wind Tunnel disclose significant work was done in 1966 and 1967 on lifting bodies (M2-F1 and M2-F2). This enabling work resulted in the design of the Space Shuttle craft."[3]

In addition to this early work on lifting bodies, the 40-By 80-Foot Wind Tunnel was used extensively for the Space Shuttle Program. The sheer size of the 40-By 80-Foot Wind Tunnel allowed the testing of large-scale models of the Space Shuttle orbiter; the larger the model, the more accurate the test results. A primary concern tested in the 40-By 80-Foot Wind Tunnel was the bluff back end of the orbiter. Since no analytical models accurately determined drag, the Tunnel was essential for testing large-scale models that assisted researchers in determining the drag caused by the back end of the orbiter.

The landing of the Space Shuttle orbiter was tested in the 40-By 80-Foot Wind Tunnel using the 36% Scale Orbiter Model; elements tested included the orbiter's unpowered aerodynamics, the aerodynamic character of the body, control surface (such as speed break), drag-chutes, and angle of attack. Another issue tested in the Tunnel was the aerodynamics of the orbiter when mated with the Shuttle Carrier aircraft, a modified Boeing 747.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[4]

[2] The Reynolds number is the ratio of inertial forces to viscous forces, and is used to test the dynamic similitude of a scale model and the actual object.
[3] Wendy L. Tinsley, National Register of Historic Places Nomination Form, "Ames Aeronautical Laboratory 40-By 80-Foot Wind Tunnel" (October 2004), Section 8, p. 6.
[4] NASA, "Evaluating Historic Resources," 3.

- *Is real or personal property owned or controlled by NASA;*

N-221 is owned and controlled by NASA Ames Research Center. It is currently leased by the United States Air Force.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-221 was not constructed or modified for the Space Shuttle Program, but was used for testing of large-scale Space Shuttle test models.

- *Is classified as a structure, building, site, object, or district;*

N-221 is classified as a combination of building and structure (wind tunnels).

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
  - *best represents the important achievements or the cumulative importance of prominent persons; or*
  - *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

  Criterion C – Design/Construction
  - *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
  - *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
  - *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

Criterion D – Information Value

- *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

Currently, the 40-By 80-Foot Wind Tunnel (N-221) is being considered for eligibility for listing in the National Register for its significance on a national level under Criterion A (Event) in the areas of Space Exploration and Settlement (1944-1969: Criteria Consideration G), and Science and Invention (1944-1969: Criteria Consideration G), and under Criterion C (Design/Construction) as an engineering structure which embodies the distinctive characteristics of wind tunnel construction, and as the world's largest wind tunnel (1944-1955).[5]

In relation to the Space Shuttle Program, N-221 qualifies under SSP Evaluation Criteria Eligibility Property Type *7. Engineering and Administrative Facilities*, as a resource that was "…directly associated with critical activities of national significance which impacted the development, implementation and termination of the Space Shuttle Program or missions."[6]

N-221 (40-By 80-Foot Wind Tunnel) does not meet any of the NRHP criteria for listing in the National Register within the context of the Space Shuttle Program. N-221 was the site of much of the early testing of lifting bodies that eventually led to the design of the Space Shuttle. The 40-By 80-Foot Wind Tunnel provided a test chamber capable of holding the 36% Scale Orbiter Model (Orbiter Model), the largest model constructed for the Space Shuttle Program. The testing of this large-scale model enabled the exploration of: the drag created by the bluff back end of the Orbiter, the aerodynamic character of the body, the aerodynamics of the orbiter when mated with the Shuttle Carrier aircraft, the Orbiter's unpowered aerodynamics, the landing of the orbiter, the angle of attack, and speed breaks and drag-chutes. The 40-By 80-Foot Wind Tunnel was one of several wind tunnels that conducted tests in support of the Space Shuttle Program. While the tests conducted within this wind tunnel provided valuable information, it does not have a direct connection to the Space Shuttle Program and is therefore not significant within this context.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

[5] Tinsley, "National Register Nomination Form," Section 8, pp. 1-7.
[6] NASA, "Evaluating Historic Resources," 7.

> [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

N-221 does not meet the appropriate Criteria Considerations as related to the Space Shuttle Program. Although the 40-By 80-Foot Wind Tunnel was important in the testing of the Orbiter test models, the connection between the tests and the actual design of the Space Shuttle Orbiter remains indirect. Even though the building is over fifty years old, the significance of the property is less than fifty years old, and therefore must qualify under Criteria Consideration G (Properties that have Achieved Significance within the Past 50 Years). In order to qualify for listing in the National Register under Criteria Consideration G, a property must demonstrate that it has exceptional importance. As related to the Space Shuttle Program, it can be argued that the 40-By 80-Foot Wind Tunnel has had importance to the overall program, however, due to the lack of a direct connection between Space Shuttle design elements and the tests performed at the tunnel. Therefore, the property does not meet Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years.

- *Retains enough integrity to convey its historical significance;*

> [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

As stated in the National Register nomination:

> The exterior of the 40 x 80 Wind Tunnel retains all seven elements of integrity. The structure remains at its original historic location. Although the 80 x 120 test section was added to the northwest corner in 1977, the structures original design and configuration remains largely intact.[7] The current setting of the 40 x 80 Wind Tunnel is consistent with its original setting. Many of the historic materials employed on the exterior portions of the structure are extant today. The original workmanship of the structure is still evident today, and lastly, the feeling of 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 structure's 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

[7] The 80-By 120-Foot Wind Tunnel was constructed between 1977 and 1982, and was made operational in 1986.

according to the changing needs of the facility.[8]

As related to the Space Shuttle Program, N-221 retains integrity to convey its historical significance.

Conclusion

Although N-221 contributed valuable information to the Space Shuttle Program, it had a supporting and not a direct role to the SSP, therefore does not meet the general registration requirements for listing in the National Register of Historic Places within the context of the Space Shuttle Program. N-221 did not have a direct association in the context of the Space Shuttle Program and does not meet the appropriate Criteria Considerations.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

[8] Tinsley, "National Register Nomination Form," Section 7, 5-6.

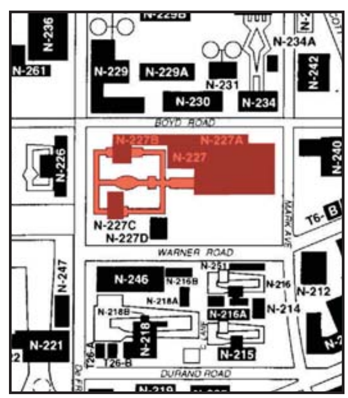
N-227, north facade
(Source: Page & Turnbull)

N-227A to D: Unitary Plan Wind Tunnels

Location: 355 Boyd Road, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1955

Brief Description: The Unitary Plan Wind Tunnels consist of three wind tunnels and several interconnected buildings and structures, including a transformer station, auxiliary equipment building, and cooling tower complex (located in Buildings N-227, N-227A, N-227B, N-227C, and N-227D).



Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

N-227 is an unpainted concrete research laboratory and office building with a flat roof. The front facade faces north and is connected to N-227A (11-By 11-Foot Transonic Tunnel) and N-227B (9-By 7-Foot Supersonic Tunnel) on the east and west sides. N-227C is located on the south side of the Unitary Plan Wind Tunnels and houses the 8-By 7-Foot Supersonic Tunnel, which is no longer functioning. N-227 provides the main entry into the tunnels and is three stories in height. It has recessed ribbon windows that run along each floor. The industrial steel-sash one-over-three windows operate as awning windows. A concrete canopy steps out over the first floor windows to mark the entry doors. The overhang is greatest in depth over the entry doors and recedes on either side until it is flush with the face of the building. Narrow concrete columns on both sides of the entry support the canopy. The center bay is flanked by two-story wings on either side that step back. These wings have the same ribbon windows as the main building on each floor. At both the east and west ends of the wings, the facade steps out again where N-227 connects to N-227A and N-227B. At these ends, the fenestration occurs only along the first floor except for three narrow vertical bands of glass block windows located at the inside corners. Secondary entrances into the building are located at these ends of the façade. The back (south side) of the building is clad in corrugated metal.

The typical interior finishes include concrete or vinyl roll-out flooring, gypsum board walls, and exposed or acoustic tile ceilings with fluorescent or incandescent lighting. The building contains offices and administrative facilities, machine shops, a high-bay testing facility, and industrial research areas.

Type/Function: The Unitary Plan Wind Tunnels include three test sections: 11-By 11-Foot Transonic Wind Tunnel, 9-By 7-Foot Supersonic Wind Tunnel, and 8-By 7-Foot Supersonic Wind Tunnel (inactive); offices and administrative facilities; machine and fabrication shops; a transformer station; Auxiliary Equipment Building; cooling tower complex; Current: same.

Historic Context: The Unitary Plan Wind Tunnels are currently listed as a National Historic Landmark and are identified in the National Park Service's *Man in Space Theme Study*. The Unitary Plan Wind Tunnels are the most heavily used NASA wind tunnels. Every major commercial transport and almost every fighter aircraft built in the United States over the last fifty years has been tested in these tunnels. In addition, models of the Space Shuttle and of the Mercury, Gemini, and Apollo capsules were tested at this facility. More than 1,000 test programs have been conducted in these tunnels, totaling over 60,000 hours of operation.

In the aftermath of World War II, the discovery of Germany's advanced wind tunnel facilities, in conjunction with its leadership in the research and development of rocket engines, jet engines, and supersonic guided missiles, posed a serious challenge to America's national security. Following the war, America found its basic aeronautical research was lacking. America's existing wind tunnels were not sufficient to meet the challenge of supersonic aircraft and missile research. The National

Advisory Committee on Aeronautics (NACA) and the Armed Services agreed that a "unitary plan" addressing the combined aeronautical needs of all the agencies involved was the best approach. A plan for wind tunnel facilities that would serve the combined needs of military and civil aviation was submitted to Congress in 1949. The Unitary Wind Tunnel Plan Act was passed by both the Senate and House of Representatives, although it had been reduced in scope from $136 million to $75 million. The Unitary Plan legislation paved the way for world-class research, development, and testing facilities for NACA, the Air Force, the Navy, and universities.

According to the 1949 Unitary Wind Tunnel Plan Act:

> The National Advisory Committee on Aeronautics and the Secretary of Defense are hereby authorized and directed jointly to develop a unitary plan for the construction of transonic and supersonic wind tunnel facilities for the solution of research, development and evaluation problems in aeronautics, including the construction of facilities at educational institutions within the constitutional limits of the United States for training and research in aeronautics, and to revise uncompleted portions of the unitary plan from time to time to accord with changes in national defense requirements and scientific and technical advances."[1]

The plan included five wind tunnel facilities, three of which were at NACA facilities (NASA's predecessor). The Unitary Wind Tunnel Plan Act commissioned and funded facilities at Langley, Glenn, and Ames. The Ames Unitary Plan Wind Tunnels were constructed on an eleven-acre site. Construction began in December 1951, and the three tunnels were operational in 1956. The total cost of the tunnels including buildings, auxiliary equipment, and basic instrumentation was $32 million.

The Unitary Plan Wind Tunnels are a unique system of wind tunnels comprised of three test sections: an 11-By 11-Foot Transonic Tunnel (Mach 0.40 to 1.40), a 9-By 7-Foot Supersonic Tunnel (Mach 1.55 to 2.50), and an 8-By 7-Foot Supersonic Tunnel (Mach 2.45 to 3.45), all capable of operating at variable stagnation pressures. The major common element of the tunnel complex is its drive system, consisting of four inter-coupled electric motors that can continuously provide 134.23 megawatts (180,000 hp).[2]

[1] Congressional Record, 81st Congress, Public Law 415, "Unitary Wind Tunnel Plan Act (27 October 1949).

[2] NASA Ames Research Center, *Research Facilities Handbook, 1982* (Moffett Field, California: National Aeronautics and Space Administration, Ames Research Center, 1982), p. 14.

11-By 11-Foot Transonic Wind Tunnel

The 11-By 11-Foot Transonic Wind Tunnel is a closed-return, variable density tunnel with a fixed geometry, ventilated throat, and a single-jack flexible nozzle. Airflow is produced by a three-stage, axial-flow compressor powered by four wound-rotor, variable-speed, induction motors. For conventional steady-state tests, models are generally supported on a sting. A mounted rear strut allows researchers to change the angle of attack. Internal strain-gage balances are used to measure forces and moments. A schlieren system is available for studying flow patterns, either by direct viewing or by photographs, as well as a system for obtaining 51 x 101 cm (20 x 40 in) shadowgraph negatives.[3] The wind tunnel is pressurized to increase the Reynolds numbers.

9-By 7-Foot Supersonic Wind Tunnel

The 9-By 7-Foot Supersonic Wind Tunnel is a closed-return, variable-density tunnel equipped with an asymmetric, sliding-block nozzle. The test section Mach number can be varied by translating the fixed contour block that forms the floor of the nozzle in the streamwise direction. Airflow is produced by an 11-stage, axial-flow compressor powered by four variable-speed, wound-rotor, induction motors. For conventional, steady-state tests, models are generally supported on a sting. Internal strain-gage balances are used to measure forces and moments. A schlieren system is available for studying flow patterns, either by direct viewing or by photographs, as well as a system for obtaining 51 x 51 cm (20 x 20 in) shadowgraph negatives.[4]

8-By 7-Foot Supersonic Wind Tunnel

The 8-By 7-Foot Supersonic Wind Tunnel is a closed-return, variable-density tunnel equipped with a symmetrical, flexible-wall throat (the side walls are positioned by a series of jacks operated by hydraulic motors). The upper and lower surfaces are fixed. Airflow is produced by an 11-stage, axial-flow compressor powered by four variable-speed, wound-rotor induction motors. For conventional, steady-state tests, models are generally supported on a sting. Internal strain-gage balances are used to measure forces and moments. A schlieren system is available for studying flow patterns, either by direct viewing or by photographs, as well as a system for obtaining 51 x 51 cm (20 x 20 in) shadowgraph negatives.[5] The 8-By 7-Foot Supersonic Wind Tunnel is no longer in operation.

The Unitary Plan Wind Tunnels have played a supportive role in the nation's space program.

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[3] Ibid., p.16.
[4] Ibid., p. 18.
[5] Ibid., p. 20.

Aerodynamic testing has been performed at the Unitary Plan Wind Tunnels for the Mercury, Gemini, and Apollo spacecraft and the Space Shuttle. Over 20,000 hours of testing at the Unitary Plan Wind Tunnels were conducted on the Space Shuttle, including the cold-jet simulation of the rocket plumes to study the effect of the plumes on the orbiter and launch configuration, the study of the complex flow field between the orbiter, tank, and solid rocket boosters, the shock wave impingement on TPS, and the aerodynamics of the TPS.[6] All three of the Unitary Plan Wind Tunnels were used for Space Shuttle testing.

The 11-By 11-Foot Transonic Wind Tunnel was used for nearly 9,200 hours of testing for the Space Shuttle between 1970 and 2006. The objectives of these tests included testing the shuttle wings for flutter, determining the plume effect on stability and control, testing the tile gap filler, and determining loads on the external tank.[7] This test section was used for final validation testing of the Space Shuttle.

The 9-By 7-Foot Supersonic Wind Tunnel was used for nearly 5,500 hours of testing for the Space Shuttle between 1970 and 2006. Testing for the ascent stack (the orbiter, external tank, and solid rocket boosters) aerodynamics and exhaust plume interactions was carried out in the 9-By 7-Foot Supersonic Section of Ames' Unitary Plan Wind Tunnels. Shocks from the integrated vehicle were simulated to determine their impingement on TPS tiles. Other tests included determining TPS tile pressures and loads, testing a three percent model to test the exterior aerodynamics of the body and how shape affects maneuverability and drag, aerodynamic characteristics of launch, aerodynamics loads, testing plume effects on the 1 percent model, TPS quilt and gap filler study, and Return to Flight (RTF) testing on the three percent model of the shuttle.[8]

The 8-By 7-Foot Supersonic Wind Tunnel was used for 1,868 hours of testing for the Space Shuttle between 1970 and 1982. The objectives of these tests included the plume effect on stability and control, aerodynamic loads, and the effects of missing tiles on the orbiter.[9]

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[6] American Society of Mechanical Engineers, "Unitary Plan Wind Tunnel, NASA Ames Research Center, Moffett Field, CA," *ASME International Historic Mechanical Engineering Landmark* (New York: American Society of Mechanical Engineers, 10 May 1996), 7.
[7] NASA Ames Research Center, Wind Tunnel Operating Division, Wind Tunnel Test Archives, v. 2.0, "11-By 11-Foot Tunnel." Courtesy Frank J. Kmak and server administrator Tim Steiger.
[8] NASA Ames Research Center, Wind Tunnel Operating Division, Wind Tunnel Test Archives, v. 2.0, "9-By 7-Foot Tunnel." Courtesy Frank J. Kmak and server administrator Tim Steiger.
[9] NASA Ames Research Center, Wind Tunnel Operating Division, Wind Tunnel Test Archives, v. 2.0, "8-By 7-Foot Tunnel." Courtesy Frank J. Kmak and server administrator Tim Steiger.

One of the most tangible links to the Space Shuttle program was the testing of a TPS failure on the Discovery shuttle while the orbiter was in flight. Exposed gap filler and a ripped TPS blanket had been discovered, and NASA headquarters directed Ames to run tests to determine if it was safe for the orbiter to reenter. Tests were run in the Unitary Plan Wind Tunnels on 3 August 2005 and within hours it was determined that the orbiter would be able to safely reenter.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[10]

- *Is real or personal property owned or controlled by NASA;*

N-227A to D is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-227A to D was not constructed or modified for the Space Shuttle Program, but was utilized for testing related to the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

N-227A to D is classified as combination building and structure (wind tunnels).

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program*

[10] NASA, "Evaluating Historic Resources," 3.

worked or trained; or

- *best represents the important achievements or the cumulative importance of prominent persons; or*
- *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

Criterion C – Design/Construction

- *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
- *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
- *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

Criterion D – Information Value

- *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

The Unitary Plan Wind Tunnels are currently listed as a National Historic Landmark for their association with the *Man in Space Theme Study*. The Ames Unitary Plan Wind Tunnels are a unique group of wind tunnels with three test sections: the 11-By 11-Foot Transonic Tunnel, the 9-By 7-Foot Supersonic Tunnel, and the 8-By 7-Foot Supersonic Tunnel. Built in response to the Unitary Plan Act of 1949, the Unitary Plan Wind Tunnels have contributed equally to both the development of advanced American aircraft and manned spacecraft. The Unitary Plan Wind Tunnels have been an essential part of the American space program, and have been used in aerodynamic testing for the Mercury, Gemini and Apollo spacecraft.

In relation to the Space Shuttle Program, N-227A to D qualify under SSP Evaluation Criteria Eligibility Property Type: *7. Engineering and Administrative Facilities* as a resource that was "…directly associated with critical activities of national significance which impacted the development, implementation and termination of the Space Shuttle Program or missions."[11]

N-227A to D is significant under Criterion A (Events) for the testing completed in the wind tunnels that influenced the design of the Space Shuttle. The Unitary Plan Wind Tunnels are important for their connection to the Space Shuttle Program and each of the three test sections were used for testing in the Space Shuttle program. Over 20,000 hours of testing at the Unitary Plan Wind Tunnels

[11] Ibid., 7.

were conducted on the Space Shuttle, including the cold-jet simulation of the rocket plumes to study the effect of the plumes on the orbiter and launch configuration, the study of the complex flow field between the orbiter, tank, and solid rocket boosters, the shock wave impingement on TPS, and the aerodynamics of the TPS.[12] The Unitary Plan Wind Tunnels are significant as the "workhorse" wind tunnels that conducted the majority of wind tunnel testing completed for the Space Shuttle Program. Testing for the Space Shuttle Program also occurred at other NASA facilities.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

N-227A to D does not meet the appropriate Criteria Considerations as related to the Space Shuttle Program. Although the Unitary Plan Wind Tunnels were important to SSP wind tunnel testing, the connection between the tests and the actual design of the Space Shuttle Orbiter remains indirect. Even though the building is over fifty years old, the significance of the property is less than fifty years old, and therefore must qualify under Criteria Consideration G (Properties that have Achieved Significance within the Past 50 Years). In order to qualify for listing in the National Register under Criteria Consideration G, a property must demonstrate that it has exceptional importance. As related to the Space Shuttle Program, the Unitary Plan Wind Tunnels have had importance to the overall program, but the specific connections between Space Shuttle design elements and the tests performed at the tunnel remains indirect. Therefore, the property does not meet Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-227A to D possesses integrity of location, design, setting, materials, workmanship, feeling, and association. The building remains in its original location and appears to have had few exterior or interior alterations; therefore, it retains integrity of location and design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center, as well as

[12] ASME, "Unitary Plan Wind Tunnel," 7.

other larger infrastructure, including transformers, cooling towers, and storage buildings. Therefore, the building maintains integrity of setting. The building retains its simple concrete exterior and Streamline ornamentation, and therefore, retains integrity of materials. Although the 8-By 7-Foot Wind Tunnel is inoperable, it has not been dismantled or removed from the facility. The other wind tunnels, 11-By 11-Foot and 9-By 7-Foot., and their associated equipment and technology appear to have been maintained in place and are currently in use, albeit altered from their original design. Despite these alterations, the building retains integrity of workmanship. Finally the building's general appearance, character, and association with the Unitary Plan Wind Tunnels appear to have been maintained, and therefore, the building retains integrity of feeling and workmanship.

Conclusion

Although N227A to D contributed valuable information to the Space Shuttle Program, it had a supporting and not a direct role to the SSP, therefore does not meet the general registration requirements for listing in the National Register of Historic Places within the context of the Space Shuttle Program. N227A to D does not have exceptional significance within the SSP context and therefore does not meet Criteria Consideration G. The tests performed at N-277A to D were indirectly related to the design of the Space Shuttle Program. Note: this determination does not affect the building's current historic status as a National Historic Landmark.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

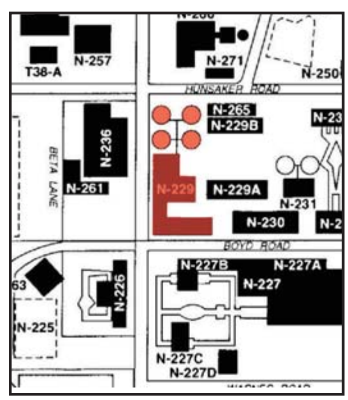
N-229, south facade
(Source: Page & Turnbull)

N-229: Experimental Fluid Dynamics Facility

Location: 300 Boyd Road, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1961

Brief Description: N-229 serves as the home to the Experimental Fluid Dynamics Facility. The facility is composed of two buildings: a two-story corrugated metal warehouse and a two-story concrete office/laboratory. These structures are connected to four large steel vacuum spheres by a large diffuser. The two buildings include 23,940 square feet (2,224 square meters) of space and have steel-frame structural systems with concrete foundations and flat roofs. The office portion features a scored concrete facade and fenestration composed of three-panel aluminum-sash windows with operable awning-sash lower panels. Concrete canopies are located above these windows on the first and second floors. The entry into the building is located along the south facade and is



Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

demarcated by roman brick exterior cladding and a set of glazed double doors with sidelights. The upper portion of the building is clad with vertical corrugated metal siding. At the northeast corner is a small shed addition. The diffuser and four large vacuum spheres occupy the southeast corner of the intersection of Hunsaker Road and DeFrance Avenue. The building is also connected to an adjacent auxiliary equipment building, cooling tower, and high pressure storage area.

The interior finishes are typical and consist of concrete or roll-out vinyl flooring, gypsum or concrete block walls, and exposed or acoustic tile ceilings with fluorescent or incandescent lighting. Significant equipment and facilities that once occupied the building included the pebble bed heater, control room, nozzles, wind tunnel test section, and diffuser.

Currently, all parts of the 3.5-Foot Wind Tunnel remain within N-229 in a dismantled state with the exception of the data control and systems control equipment, which have been removed.[1]

Type/Function: Experimental Fluid Dynamics Facility; 3.5-Foot Hypersonic Wind Tunnel; offices and administration facilities; control room; high pressure storage area; cooling tower; auxiliary equipment building; cryogenic separation tower; diffuser; and four vacuum spheres; Current: Experimental Fluid Dynamics Facility/Space Technology Division.

Historic Context: The Experimental Fluid Dynamics Facility was first made operational in 1961. The 3.5-Foot Hypersonic Wind Tunnel was designed by Alfred J. Eggers and Clarence "Sy" Syverston who came to Ames to work with H. Julian Allen in solving the problems of hypersonic flight. The 3.5-Foot Hypersonic Wind Tunnel was used between 1970 and 1976 and was refurbished in 1972. The wind tunnel was reactivated in 1985, but was shut down again in 1993 and has been dismantled. Currently, the 3.5-Foot Hypersonic Wind Tunnel remains dismantled.

The 3.5-Foot Hypersonic Wind Tunnel was one of the most heavily used tunnels for the Space Shuttle Program.[2] This wind tunnel was comprised of a pebble-bed heater, control room, nozzles, wind tunnel test section, and diffuser. The 3.5-Foot was capable of simulating flight at Mach 5, 7, and 10. This facility provided approximately 47 percent of the total hours of wind tunnel testing for the Space Shuttle at Ames. The facility operated two shifts a day, running ten tests during each

[1] Scott Edelmen, Deputy Chief, Thermophysics Facilities Branch, interview by Roger Ashbaugh, Cultural Resources Manager, Environmental Services Division, NASA Ames Research Center, 8 February 2007, Moffett Field, CA.
[2] The 3.5-Foot Hypersonic Wind Tunnel originally operated with interchangeable nozzles for simulations at Mach 5, 7, 10 or 14. The wind tunnel included a pebble-bed heater which preheated the air to 3,000 degrees Fahrenheit to prevent liquefaction in the test section at high Mach numbers. See Bugos, *Atmosphere of Freedom*, p. 62.

16-hour day. Each test was capable of continuously running from three to ten minutes. According to Joe Marvin, former chief of the Experimental Fluid Dynamics Branch, "approximately sixty-five tests, nearly ten thousand hours of testing, were completed in the 3.5-Foot Hypersonic Wind Tunnel in support of the Space Shuttle program."[3] Aerodynamic and heating aspects of the shuttle were explored in tests with small models, typically 1.5 percent scale. The 3.5-Foot Hypersonic Wind Tunnel included tests at higher Mach numbers with shock-heated gases that created an environment that would melt the surface of common vehicle materials. The data and analysis from these simulations were used to estimate the heating over the full-scale shuttle which was required for the development of the Shuttle's TPS.[4] Tests conducted in the 3.5-Foot Hypersonic Wind Tunnel were used to model interaction heating of the shuttle during ascent with and without external tanks. The 1.5 percent models were tested at high speeds (above Mach 3) with the aim of determining the angle of attack for initial reentry and interaction during ascent, and were also tested with solid rocket boosters (SRB), and with or without the external tank. Test results were captured using both digital data form and shadowgraphs using cameras.

Studies conducted in the 3.5-Foot Hypersonic Wind Tunnel led to the understanding of many different complex phenomena, including dynamics of shock-shock interactions caused from the proximity of the elements of the stack configurations, and the effects of split body flap deployments and turbulent flows. Many personnel were involved in this work, including Joe Marvin, Mike Horstman, Marvin Kussoy, Bill Lockman, and Tom Polek.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[5]

- *Is real or personal property owned or controlled by NASA;*

N-229 is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

[3] Joseph Marvin, Deputy Division Chief, Experimental Fluid Dynamics, interview, 23 August 2006, Moffett Field, CA.
[4] NASA, "Ames' contributions to STS-1: The Boldest Test Flight in History," [www.nasa.gov/mission_pages/shuttle/sts1/sts1_25.html].
[5] NASA, "Evaluating Historic Resources," 3.

N-229 was not constructed or modified for the Space Shuttle Program, but was utilized for testing related to the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

N-229 is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
  - *best represents the important achievements or the cumulative importance of prominent persons; or*
  - *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

  Criterion C – Design/Construction
  - *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
  - *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
  - *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

  Criterion D – Information Value
  - *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

In relation to the Space Shuttle Program, N-229 qualifies under SSP Evaluation Criteria Eligibility Property Type: *7. Engineering and Administrative Facilities* as a resource that was "…directly associated with critical activities of national significance which impacted the development, implementation and termination of the Space Shuttle Program or missions."[6]

N-229 is significant under Criterion A (Events) for the testing completed in the 3.5-Foot Hypersonic Wind Tunnel that influenced the design of the Space Shuttle.[7] The testing completed in the 3.5-Foot Hypersonic Wind Tunnel helped in the development of the Shuttle Thermal Protection Systems (TPS). The 3.5-Foot Hypersonic Wind Tunnel was one of the most heavily used tunnels in the Space Shuttle Program, and provided approximately 47 percent of the total hours of wind tunnel testing for the Space Shuttle that took place at Ames. The facility operated two shifts a day, running ten tests during each 16-hour day. Aerodynamic and heating aspects of the shuttle were explored in tests with small models, typically 1.5 percent scale. These tests led to a refinement of methods for determining the heating over the full-scale shuttle, which was required for the development of TPS. All of the testing of the entry/aerothermodynamics was done before computational fluid dynamics (CFD), and therefore, the facility is significant for the research methods prior to the integration of CFD.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

N-229 does meet "Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years." According to the 1974 *Ames Research Facilities Summary*, the 3.5-Foot Hypersonic Wind Tunnel was a "closed circuit, blow-down, wind tunnel, utilizing interchangeable contoured axisymmetric nozzles."[8] Tests conducted in the 3.5-Foot Hypersonic Wind Tunnel were used to model interaction heating of the shuttle during ascent with and without external tanks. 1.5 percent models were tested at high speeds (above Mach 3) with the aim of determining the angle of attack for initial reentry, interaction during ascent, and with solid rocket boosters (SRB), and with or without the external tank. The testing in the 3.5-Foot Hypersonic Wind Tunnel was vital to the understanding and development of the reentry heating that would need to be counteracted by the Space Shuttle's Thermal Protection System. The 3.5-Foot Hypersonic Wind Tunnel is also significant for the sheer

[6] Ibid., 7.
[7] Although a property is significant within one of the NRHP Criteria, it must also meet the requirements for historic integrity, as specified in the II. Methodology.
[8] NASA Ames Research Center, *Ames Research Facilities Summary, 1974* (Moffett Field, CA.: NASA Ames Research Center, 1974), p. 23.

number of hours of testing devoted to the Space Shuttle Program. Ames was responsible for half of all wind tunnel testing of the Space Shuttle Program, and the 3.5-Foot Hypersonic Wind Tunnel was responsible for 47 percent of Ames' wind tunnel testing.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-229 possesses integrity of location, design, setting, materials, and feeling. The building remains in its original location and appears to have had few exterior or interior alterations; therefore, it retains integrity of location and design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center and is interconnected to related resources, including four large vacuum spheres, cooling towers, and an auxiliary equipment building. Therefore, the building maintains integrity of setting. The building retains its simple concrete exterior, roman brick entryway, and incised ornamentation, and therefore, retains integrity of materials. The building's general appearance and character appear to have been maintained; therefore, the building retains integrity of feeling. In 1993, the 3.5-Foot Hypersonic Wind Tunnel was shut down and dismantled. Therefore, the building lacks integrity of workmanship and association. As stated earlier, a resource must retain the equipment and technology related to its historic function. Even though parts of the 3.5-Foot Hypersonic Wind Tunnel remain in the building, the retention of the wind tunnel's active function and other elements are essential in conveying the building's significance. Despite retaining the other aspects of integrity, the loss of the 3.5-Foot Hypersonic Wind Tunnel has caused N-229 to not retain integrity as related to the Space Shuttle Program.

Conclusion

Although N-229 was the site of a substantial amount of wind tunnel testing related to the Space Shuttle Program, it does not meet the general registration requirements for listing in the National Register of Historic Places in the context of the Space Shuttle Program, since it does not retain historic integrity due to the dismantling of the 3.5-Foot Hypersonic Wind Tunnel and the removal of certain of its parts. This assessment is based upon the existing condition of the building and its constituent parts during the time of the survey and evaluation.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

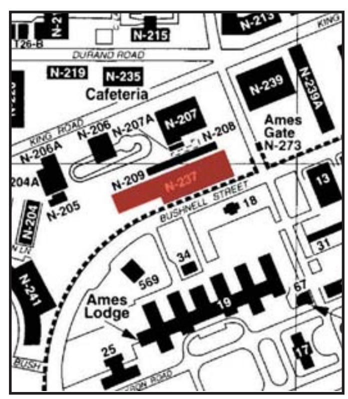
N-237, north and east facades, entrance to Hypervelocity Free Flight Facility (Source: Page & Turnbull)

N-237: Hypervelocity Free Flight Facility

Location: 350 Bushnell Street, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1964

Brief Description: N-237 is a 60,380 square feet (5,609 square meters) two-story office and test facility building with a concrete foundation, a flat roof, and exposed concrete exterior. Rendered in a Modern architectural style, this building has two distinct areas: a one-story scored concrete test facility to the north and a two-story brick-and-concrete office portion to the south. The warehouse portion features a scored concrete exterior and steel overhead doors along the east facade. The south facade of the office portion features brick accent walls and ribbon windows with a concrete shelf above. At the northeast corner of the building is a brick garden wall, which conceals exterior mechanical equipment. This facility has been used to conduct research on gas dynamic



Location Map, ARC (Source: NASA; Altered by Page & Turnbull)

problems of hypervelocity flight, particularly atmosphere reentry problems.

Type/Function: Research and testing facility; offices, shop; Hypervelocity Free Flight Aerodynamic Facility (current use), Hypervelocity Free Flight Radiation Facility (no longer in use), and Hypervelocity Free Flight Gun Development Facility.

Historic Context: The Hypervelocity Free Flight Facility was constructed at Ames between 1963 and 1965. The building was constructed for the Apollo program to simulate return from the Moon. The building included three test devices: the Hypervelocity Free Flight Facility Aerodynamic Facility (HFFAF), the Hypervelocity Free Flight Radiation Facility, and the Hypervelocity Free Flight Gun Development Facility (HFFGDF). Ames has a long tradition of leadership in the use of ballistic ranges for the study of the physics of hypervelocity flight. These devices added to Ames' aeroballistic testing facilities, and were NASA's most advanced Aeroballistic/Light-Gas Gun Facilities.[1] The HFFAF and HFFGDF are still in use, while the Hypervelocity Free Flight Radiation Facility has been dismantled.

The HFFAF is a combined ballistic range and shock-tube driven wind tunnel that combines the countercurrent motion of a model launched from a light gas gun with the short-duration, high-velocity gas stream from a shock tunnel. Flight conditions can be simulated at velocities up to Mach 25 under a variety of atmospheric conditions.[2] The test section of the HFFAF is equipped with 16 shadowgraph-imaging stations. Each station can be used to capture an orthogonal pair of images of a hypervelocity model in flight. These images, combined with the recorded flight time history, can be used to obtain critical aerodynamic parameters such as lift, drag, static and dynamic stability, flow characteristics, and pitching moment coefficients. For very high Mach number simulations, models can be launched into a counter-flowing gas stream generated by the shock tube. The facility can also be configured for hypervelocity impact testing and has an aerothermodynamic capability as well. The HFFAF is the Agency's only aeroballistic capability and is the only ballistic range in the United States capable of testing in atmospheres other than air.

The HFFGDF is used for gun performance enhancement studies and occasional impact testing. The Facility uses the same arsenal of light-gas and powder guns as the HFFAF to accelerate particles

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[1] NASA, "Ames Technology Capabilities and Facilities: Range Complex," [*http://www.nasa.gov/centers/ames/research/technology-onepagers/range-complex.html*].

[2] J. D. Boulgarides, W. S. Brown, and K. A. Richins, "Design of the Hypervelocity Free Flight Facility at Ames Research Center" in Gilbert S. Bahn, ed., *The Performance of High Temperature Systems: Proceedings of the Third Conference, Pasadena, California, December, 1964* (New York: Gordon and Breach, 1969), p. 531-546.

that range in size from 3.2 mm to 25.4 mm (1/8 to 1 inch) in diameter to velocities ranging from 0.5 to 8.5 km/s (1,500 to 28,000 feet/second). Most of the research efforts completed to date in the HFFGDF have centered on earth atmosphere entry configurations (Mercury, Gemini, Apollo, and Space Shuttle), planetary entry designs (Viking, Pioneer Venus, Galileo and MSL), and aerobraking (AFE) configurations. The facility has also been used for scramjet propulsion studies (NASP) and meteoroid/orbital debris impact studies (Space Station and RLV). Most recently, the facility was utilized for foam-debris dynamics testing in support of the Return to Flight effort.

The Hypervelocity Free Flight Facility was involved in the preliminary stages of the Space Shuttle design. The tests focused on flow field research of basic shapes such as cones and spheres. These preliminary studies were used to determine the aerodynamics of different shapes and informed the early design phases of the Space Shuttle Program. In addition to preliminary aerodynamic studies, the HFFAF was used for Return to Flight testing after the Columbia Accident, namely testing to verify computation fluid dynamics (CFD) codes for the dynamics of foam debris that led to the accident.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[3]

- *Is real or personal property owned or controlled by NASA;*

N-237 is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-237 was not constructed or modified for the Space Shuttle Program, but was utilized for testing related to the Space Shuttle Program.

[3] NASA, "Evaluating Historic Resources," 3.

- *Is classified as a structure, building, site, object, or district;*

N-237 is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
  - *best represents the important achievements or the cumulative importance of prominent persons; or*
  - *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

  Criterion C – Design/Construction
  - *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
  - *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
  - *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

  Criterion D – Information Value
  - *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

In relation to the Space Shuttle Program, N-237 qualifies under SSP Evaluation Criteria Eligibility Property Type: *7. Engineering and Administrative Facilities* as a resource that was "…directly associated with critical activities of national significance which impacted the development, implementation and termination of the Space Shuttle Program or missions."[4]

[4] Ibid., 7.

N-237 does not meet any of the NRHP criteria for listing in the National Register within the context of the Space Shuttle Program. Although N-237 contained NASA's only aeroballistic capability and was the only ballistic range in the United States capable of testing in atmospheres other than air, the building and its facilities do not embody a direct connection to the Space Shuttle Program. The Hypervelocity Free Flight Facility was not used to test models or complete research that directly affected the Space Shuttle Program or its related programs.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

Since N-237 does not have significance as related to the Space Shuttle Program, it does not meet the appropriate Criteria Considerations.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-237 possesses integrity of location, design, setting, materials, workmanship, feeling, and association. The building remains in its original location and appears to have had few exterior or interior alterations; therefore, it retains integrity of location and design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center, and therefore, maintains integrity of setting. The building retains its simple concrete exterior and incised ornamentation, and therefore, retains integrity of materials. The equipment and technology relating to the Hypervelocity Free Flight Facility appear to have been maintained in place; therefore, the building retains integrity of workmanship. Finally the building's general appearance, character, and association with the Hypervelocity Free Flight Facility appear to have been maintained; therefore, the building retains integrity of feeling and association.

Conclusion

N-237 does not meet the general registration requirements for listing in the National Register in the context of the Space Shuttle Program, since it does not convey significance directly related to the

Space Shuttle Program, and does not meet the appropriate criteria considerations.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

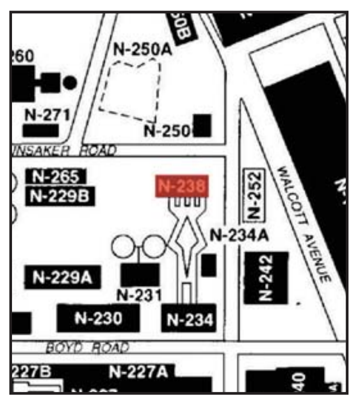
N-238, north facade
(Source: Page & Turnbull)

N-238: Arc Jet Laboratory

Location: 980 Mark Avenue, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1964

Brief Description: Located at the southwest corner of Hunsaker Road and Mark Avenue, N-238 is the home of the Interaction Heating Facility and Arc Jet Laboratory. The building has a long, 17,030 square feet (1,582 square meters) rectangular plan with two distinct masses: a one-story brick office portion and a one-and-one-half-story corrugated metal storage area. N-238 has a concrete foundation, a steel-frame structural system, a flat roof, and aluminum-sash awning windows. This building is accessed through three openings: a glazed double door on the north facade and steel overhead doors on the east and west facades. Along the south facade, N-238 is connected to adjacent cooling towers, vacuum spheres, and auxiliary buildings. The building's interior contains five discrete test bays. This laboratory has been used for space shuttle



Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

panel and leading edge thermal protection system tests.

Type/Function: Arc Jet Laboratory; research facility; machine shop; warehouse; Current: same.

Historic Context: Ames' Arc Jet Laboratory, which opened in 1964, includes five test bays: the 60-megawatt Interaction Heating Facility, the Direct Connect Facility (Linde); the Panel Test Facility (PTF), the Giant Planet Facility (150MGW); the High Enthalphy Facility (now closed). Only the 60-megawatt Interaction Heating Facility, operational since 1974, will be discussed.

An arc jet is a device in which gases are heated and expanded to very high temperatures and supersonic/hypersonic speeds by a continuous electrical arc between two sets of electrodes. The gases (typically air) pass through a nozzle aimed at a test sample in vacuum and flow over it, producing a reasonable approximation of the surface temperature, pressure, and gas enthalpy found in the high velocity, supersonic flow experienced by a vehicle on atmospheric entry.[1] The facilities of the Arc Jet Laboratory are used to simulate the aerothermodynamic heating that a spacecraft endures throughout atmospheric entry, and to test candidate Thermal Protection System (TPS) materials and systems. The Ames Arc Jet Laboratory has a rich heritage of over 40 years in TPS development for every NASA Space Transportation and Planetary program including Apollo, Space Shuttle, Viking, and X-37 and Mars Exploration Rovers.

In order to support the Space Shuttle Program, which required an innovative reusable heat shield, Ames upgraded its arc jet facilities so that they could simulate reentry heating for tens of minutes. The 60-megawatt Interaction Heating Facility, constructed for the Space Shuttle Program as part of this facility upgrade, produced heating environments expected by the Shuttle TPS on larger models than any other arc jet was capable of achieving. The Interaction Heating Facility, with an available power of over 60-megawatts, was one of the highest-power arc jets ever constructed. It was a very flexible facility, capable of both long run times of up to one hour, and testing of large samples in both a stagnation and flat plate configuration.[2]

According to a 31 March 1975 article in *Aviation Week & Space Technology*, Howard K. Larson, chief of the Ames Thermal Protection Branch, claimed that the Ames Research Center thermal protection laboratory contained NASA's largest collection of arc- or plasma-heated facilities, and three of its major units were dedicated to shuttle support. Larson stated the 60-megawatt heater at Ames was

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[1] NASA, "NASA Ames Arc Jet Complex" [*www.nasa.gov/centers/ames/research/technology-onepagers/arcjetcomplex.html*].
[2] NASA, "NASA Ames Arc Jet Complex." [*www.nasa.gov/centers/ames/research/technology-onepagers/arcjetcomplex.html*]

probably the highest-powered unit operating in the U. S. at the time.[3] The Arc Jet Laboratory at Ames conducted more arc jet testing for Shuttle TPS than all the arc jets in the country. Several other arc jets were used for testing Shuttle TPS, including those at Johnson Space Center and Langley Research Center.

Ames' capability to test a 2-foot by 2-foot (.61-meter by .61-meter) section of the tile in conditions duplicating aeroconvective heating and reacting boundary layer chemistry during simulated entry conditions was a crucial element in the development of the shuttle Thermal Protection System (TPS).[4] The 60-megawatt arc-heated facility was used to test different types of shuttle heat shield material, including the reinforced carbon-carbon (RCC) system designated for the nose cap and wing leading edge, and the silica tile reusable surface insulation (RSI) employed on the remainder of the vehicle. The 2-foot by 9-foot Turbulent Duct located in N-234 was also used to study gap heating between tiles, a critical design parameter.

Over the life of the Shuttle Program, after reviewing operational experience, NASA Ames scientists conceived of improved thermal protection materials. Their ideas were then fabricated into prototype materials in a Thermal Protection Materials Laboratory which in the early 1970s had been retrofit into some rooms in N-242 (Vestibular Research Facility). These prototype materials were then tested in the arc jets in N-238, and the data returned helped Ames scientists refine the materials. Once the materials proved flight-worthy, NASA transferred the manufacturing technology to the aerospace firms supporting the Shuttle. Through this iterative process of research, fabrication and testing, Ames scientists developed all the upgraded TPS materials for the Shuttle orbiter, including materials known by their acronyms LI-2200, FRCI, RCG, TUFI, and the Ames Gap Fillers. However, the laboratory in N-242 does not convey the historical connection and significance in the context of the Space Shuttle Program required to be included in this study.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[5]

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[3] Benjamin M. Elson, "New Unit to Test Shuttle Thermal Guard," *Aviation Week &Space Technology* (31 March 1975): 52.
[4] Arnold et al, "Ames' Contribution to the Shuttle," [*http://www.nasa.gov/centers/ames/research/humaninspace/25th_shuttle.html*].
[5] NASA, "Evaluating Historic Resources," 3.

- *Is real or personal property owned or controlled by NASA;*

N-238 is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-238 was modified for the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

N-238 is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
  - *best represents the important achievements or the cumulative importance of prominent persons; or*
  - *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

  Criterion C – Design/Construction
  - *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
  - *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
  - *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

Criterion D – Information Value

- *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

In relation to the Space Shuttle Program, N-238 qualifies under SSP Evaluation Criteria Eligibility Property Type: *7. Engineering and Administrative Facilities* as a resource that was "…directly associated with critical activities of national significance which impacted the development, implementation and termination of the Space Shuttle Program or missions" and as a facility that "should clearly embody the distinctive characteristics of a type or method of construction."[6]

N-238 is significant under Criterion A (Events) for the research and development of the Space Shuttle's Thermal Protection Systems (TPS). N-238 allowed for the advancement of the thermal protection systems and enabled the development of the reusable TPS systems in use on the Space Shuttle Orbiters through the Arc Jet testing. The Arc Jet is significant because it provides the only ground-based simulation of atmospheric entry heating conditions.[7] Therefore, the Arc Jet allowed for the understanding of aerodynamic heating in a thermal environment. Although other NASA Centers, such as Johnson Space Center, have arc jets, the Arc Jet Laboratory at Ames is unique because it is the only facility that tested TPS for the Space Shuttle Program. Additionally, the 60-megawatt Interaction Heating Facility is an important engineering achievement since it was capable of producing heating three times hotter and on larger models than any other arc jet.[8] This increased capacity gave Ames the ability to duplicate complicated heating and chemical reactions that assisted in the development of the shuttle's TPS. The Interaction Heating Facility contributed to the development of a reusable TPS which made it possible for the Space Shuttle to reenter the Earth's atmosphere multiple times, making the Space Shuttle Program a success.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

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[6] NASA, "Evaluating Historic Resources," 7.
[7] NASA, NASA Ames Arc Jet Complex. [*www.nasa.gov/centers/ames/research/technology-onepagers/arcjetcomplex.html*].
[8] Bugos, "Ames pioneers NASA science," 8.

N-238 does meet "Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years." According to the 1974 *Ames Research Facilities Summary*, the Interaction Heating Facility was "used for studies of aerodynamic heating in the thermal environment resulting from the interaction of a flow field with an irregular surface."[9] The testing in the Arc Jet facility was vital to the understanding and development of the Space Shuttle's Thermal Protection Systems. The Arc Jet facility is exceptionally significant as the only arc jet facility that tested the Space Shuttle's Thermal Protection Systems. The Interaction Heating Facility is also significant as a landmark of engineering, since it was the most powerful arc jet at the time of its construction, which allowed testing with hotter temperatures on larger surfaces. The testing and development of the shuttle's reusable TPS, which allowed the Orbiter to reenter the earth's atmosphere, was a major factor in the success of the Space Shuttle Program.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-238 possesses integrity of location, design, setting, materials, workmanship, feeling, and association. The building remains in its original location and appears to have had few exterior or interior alterations; therefore, it retains integrity of location and design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center and is interconnected to other facilities, including vacuum spheres, cooling towers, and N-234. Therefore, the building maintains integrity of setting. The building retains its simple concrete exterior, industrial aesthetic and material palette, and brick entry; therefore, it retains integrity of materials. The Arc Jet Laboratory is currently operational and will be used in the testing of the TPS for the upcoming CEV; therefore, the building retains integrity of workmanship. Finally the building's general appearance, character, and association with the Interaction Heating Facility appear to have been maintained, and therefore, the building retains integrity of feeling and workmanship.

Conclusion

N-238 does meet the general registration requirements for listing in the National Register of Historic Places in the context of the Space Shuttle Program. Although only a portion of the building, the

[9] NASA Ames Research Center, *Ames Research Facilities Summary, 1974* (Moffett Field, CA: NASA Ames Research Center, 1974)
p. 41.

60-megawatt Interaction Heating Facility, is directly associated with the Space Shuttle Program, the National Register criteria for evaluation state that the entire building is considered eligible for listing in the National Register of Historic Places.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

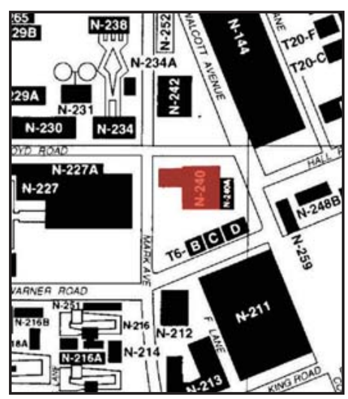
N-240, main entrance
(Source: Page & Turnbull)

N-240: Airborne Missions and Applied Life Sciences Experiments

Location: 465 Walcott Road, NASA Ames Research Center, Moffett Field, California

Dates of Construction: 1965

Brief Description: N-240 is a two-story office and laboratory building containing 51,140 square feet (4,751 square meters) of space with a concrete foundation, steel-frame-and-concrete structural system, and a flat roof. The south façade of Building N-240 is connected to the north facade of N-240A. N-240 features a scored concrete exterior and is minimally ornamented. It has aluminum-sash fixed windows and aluminum-frame glazed doors. The entry along the west facade is demarcated by a full-height glazed wall and a single glazed door. Along the north facade is an overhead steel door and loading dock area. The east facade also features a loading dock area and a mechanical screen and fire escape.



Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

N-240 has a rectangular plan. The typical interior finishes include concrete or highly-resistant tile flooring, gypsum board or concrete block walls, and exposed or acoustic tile ceilings with fluorescent or incandescent lighting. Significant interior spaces include Test Room 131, which functions as the high-bay and assembly area for the payload racks.

Type/Function: Airborne Missions and Applied Life Sciences Experiments (current); Airborne Mission & Application Building; Astrobiology Institute; Life Sciences Division; Airborne Sensor Facility; offices and administrative facility; research and experimentation.

Historic Context: The Life Sciences Flight Experiments building (N-240) was constructed in 1965. N-240A was constructed as an addition to N-240 in 1982. These buildings supported Ames' Life Sciences Program. The Life Sciences Program at Ames was established in 1962, with the aim of determining the effects of spaceflight and microgravity on living systems. N-240 and N-240A are research buildings with laboratories, offices and high bays. These buildings were the center of management, experiment development, crew training and payload creation for the Life Sciences Fundamental Space Biology Program.

The Life Sciences Program at Ames supported the Orbiter's payloads, which are defined as the scientific and technological experiments that were inserted into the space shuttle. The interface between the payload systems and the Orbiter systems had to be exact to avoid contamination of the Orbiter environment and to allow the astronauts to conduct the experiments under the necessary conditions. At Ames, engineers and researchers designed, fabricated, integrated and tested research payloads for at least fifty-six shuttle missions from 1984-2006. Most of this work was completed in N-240 and N-240A, though additional work was completed in N-236 (science), N-211 (fabrication shops), and N239A (centrifuge). In support of payload processing and the Life Sciences Program, N-240 was modified from its previous use as a Space Environment Research Facility.[1]

Individual experiment modules were designed and constructed at N-240 and N-240A. Modules were designed specifically for each experiment; an example is an animal enclosure module that contains food and watering systems, waste management, and air flow systems that would sustain the animal. The modules were designed to fit flight racks that could be launched aboard the Space Shuttle's Spacelab; there were mock-ups of the flight racks to ensure that the modules built at Ames matched the Space Labs flight rack dimensions. N-240 and N-240A was used to manage, develop, and package

[1] Ashbaugh, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.

payloads that are ready for launch on the Space Shuttle.

According to Supplemental Information on the history of N-240:

> The design, fabrication, and testing of the small payloads was a collaborative effort among the scientists, the mission crew members, and the engineers who designed the payload modules. Examples of engineering challenges addressed in the work carried out in N-240 and N-240A included re-design of the gloves in the glovebox to accommodate a variety of hand sizes while providing for dexterity sufficient to operate intricate instrumentation and live organisms and maintain controlled conditions. Another example was to develop a solution for mechanical feeding of the animals without creating backflow of fecal material and waste food into the Orbiter. A third example was to create and test state–of-the-art engineering systems to provide separation of the life support systems between the animal specimens and the crew members. On April 29, 1985, for the first time in U.S. history, two Squirrel Monkeys and 24 albino rats were launched into space aboard NASA's Spacelab Mission 3 in the Research Animal Holding Facility, designed by the Life Sciences Program at NASA Ames Research Center. The payloads were designed to the precise tolerances of the Shuttle to assure no cross contamination of the air shared by the astronaut crew under changing conditions of temperature and pressure.[2]

At Ames, Life Sciences experiments completed for the Space Shuttle were focused upon animal, plant, cell, and tissue experiments with the goal of understanding how spaceflight affects basic biological projects. Early experiments typically dealt with biomedical problems associated with spaceflight e.g., motion sickness, bone and muscle atrophy, and radiation damage. Life sciences experiments were an important part of the Space Shuttle Program. The Space Shuttle was unique in space life sciences because it presented scientists the capability to make experiments on a regular basis with a controlled environment and with the potential for crew participation in the sampling and preparation of specimens during flight.

One of the significant experiments made on the Space Shuttle was completed by Muriel Ross. Ross focused on the regeneration of nerves in a microgravity environment. Though Ross' laboratory was located in N-239, the laboratory package flown for her was built in N-240A. Ross found that as rats altered the structure of the vestibular system, the balance organs of the inner ear increased. Rats in microgravity were quick to increase the synapses connecting the acceleration sensors in the ear to the nerve transmitting the acceleration signal to the brain. In contrast to the thinking that the

[2] Ashbaugh, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.

nervous system regenerated slowly, if at all, Ross proved that nerves could quickly grow and adapt to changes in the nature and magnitude of simulation gravity. N-240 and N-244 were the focus of most biological research flown aboard the Space Shuttle and International Space Station.

According to educational information at ARC:

> The Life Sciences Division has developed experiments and flown on Shuttle flights since its inception. Significant experiments and flights have included: 30 Middeck flights; 8 Spacelabs (Spacelab 3 – April 1985, Spacelab Life Science I – June 1991, International Microgravity Lab – January 1992, Spacelab Japan – September 1991, Space Lab Life Sciences 2 – October 1992, International Microgravity Lab 2 – July 1994, Life and Microgravity Sciences Lab – June 1996, and Neurolab – April 1998); Spacelabs (STS 76 3rd Shuttle – Mir Docking – March 1996; STS 81 5th Shuttle Mir Docking – January 1997; STS 84 6th Shuttle – Mir Docking; and STS 95 John Glenn Mission – November 1998). These flights represent more than 100 experiments from investigators throughout the United States and in collaboration with our European and Japanese partners. They resulted in over 150 peer-reviewed publications and have provided understanding of the basics of space physiology and an increased knowledge of the mechanistic development of the biological system on earth.[3]

In particular, N-240 (Airborne Mission and Applications Building) was used for both the airborne sciences program (until it moved to Dryden in 1996) and the Pioneer flight operations group. It supported the Shuttle Life Sciences payload work, primarily completed in N-240A.

Additional information on the building's historic context has been included in the Appendices.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[4]

- *Is real or personal property owned or controlled by NASA;*

N-240 is owned and controlled by NASA Ames Research Center.

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[3] Excerpted from NASA Ames Research Center, Life Sciences Division, display panel located in N-240/N-240A.
[4] NASA, "Evaluating Historic Resources," 3.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-240 was not constructed or modified for the Space Shuttle Program, but was utilized for programs related to the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

N-240 is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
  - *best represents the important achievements or the cumulative importance of prominent persons; or*
  - *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

  Criterion C – Design/Construction
  - *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
  - *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
  - *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

  Criterion D – Information Value
  - *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

In relation to the Space Shuttle Program, N-240 qualifies under SSP Evaluation Criteria Eligibility Property Type: *12. Resources Associated with Processing Payloads* as a resource which "represent[s] outstanding achievements in technological, aeronautical or scientific research which would otherwise not have been attainable without the use of the Space Shuttle."[5] However, this study only examines those resources with a direct connection to the development of the Space Shuttle Program, and does not examine the sciences and payloads contained within the shuttle.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

N-240 does not meet "Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years," since the building is not exceptionally significant within aforementioned context.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-240 does not retain historic integrity to convey its significance. The building remains in its original location, and therefore, retains integrity of location. The building has had a number of alterations over its lifetime, including the addition of N-240A in 1982, and a one-story office addition for the high altitude (ER-2) mission involving airborne sciences. These alterations are in keeping with the general character and purpose of the original building. The building modifications were constructed to expand the number of departments that could be located within N-240. Therefore, the building retains integrity of design because the alterations are significant in their own right and have maintained the original character of N-240. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center, and therefore, maintains integrity of setting. The building retains its simple concrete exterior, and therefore, retains integrity of materials. Finally, the building is no longer associated with the Life Sciences Division. It has been reorganized for small satellite development, and therefore, does not retain integrity of workmanship, feeling, or association

[5] Ibid., 8.

that was present when the building was used for preparing life science payloads for the Space Shuttle.

Conclusion

Although N-240 contributed valuable information to the Space Shuttle Program, it had a supporting and not a direct role to the SSP, therefore does not meet the general registration requirements for listing in the National Register of Historic Places within the context of the Space Shuttle Program. N-240 does not meet any of the NRHP criteria, does not retain integrity to convey its historical significance, and is not exceptionally significant (Criteria Consideration G) within the context of the Space Shuttle Program.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

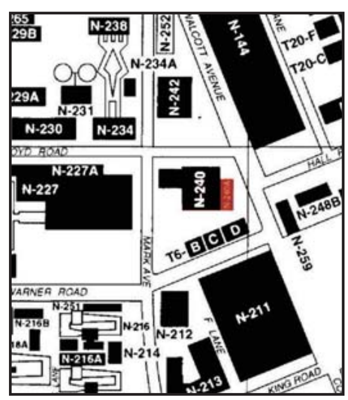
N-240A, main entrance
(Source: Page & Turnbull)

N-240A: Life Sciences Flight Experiments

Location: 465 Walcott Road, NASA Ames Research Center, Moffett Field, California

Dates of Construction: 1982

Brief Description: N-240A is a two-story office and laboratory building containing 9,370 square feet (870 square meters) of space with a concrete foundation, steel-frame-and-concrete structural system, and a flat roof. It is connected to the south facade of N-240. N-240A features a textured concrete panel exterior, which exposes the concrete aggregate. Regularly spaced aluminum-sash fixed windows are on the first and second floors. These windows are set back within concrete surrounds. The main entries into the building are demarcated by full-height glazed walls and a pair of glazed aluminum frame doorways.



Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

N-240A has a rectangular plan. The typical interior finishes include concrete or highly-resistant tile flooring, gypsum board or concrete block walls, and exposed or acoustic tile ceilings with fluorescent or incandescent lighting.

Type/Function: Life Sciences Flight Experiments (current); Airborne Mission & Application Building; Astrobiology Institute; Life Sciences Division; Airborne Sensor Facility; offices and administrative facility; research and experimentation.

Historic Context: N-240A was constructed as an addition to N-240 (Life Sciences Flight Experiments) in 1982. These buildings supported Ames' Life Sciences Program. The Life Sciences Program at Ames was established in 1962, with the aim of determining the effects of spaceflight and microgravity on living systems. N-240/N-240A are research buildings with laboratories, offices and high bays. These buildings were the center of management, experiment development, crew training and payload creation for the Life Sciences Fundamental Space Biology Program.

The Life Sciences Program at Ames supported the Orbiter's payloads, which are defined as the scientific and technological experiments that were inserted into the space shuttle. The interface between the payload systems and the Orbiter systems had to be exact to avoid contamination of the Orbiter environment and to allow the astronauts to conduct the experiments under the necessary conditions. At Ames, engineers and researchers designed, fabricated, integrated and tested research payloads for at least fifty-six shuttle missions from 1984-2006. Most of this work was completed in N-240 and N-240A, though additional work was completed in N-236 (science), N-211 (fabrication shops), and N239A (centrifuge). In support of payload processing and the Life Sciences Program, N-240 was modified from its previous use as a Space Environment Research Facility.[1]

Individual experiment modules were designed and constructed at N-240 and N-240A. Modules were designed specifically for each experiment; an example is an animal enclosure module that contains food and watering systems, waste management, and air flow systems that would sustain the animal. The modules were designed to fit flight racks that could be launched aboard the Space Shuttle's Spacelab; there were mock-ups of the flight racks to ensure that the modules built at Ames matched the Space Labs flight rack dimensions. N-240 and N-240A was used to manage, develop, and package payloads that are ready for launch on the Space Shuttle.

[1] Ashbaugh, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.

According to Supplemental Information on the history of N-240A:

> The design, fabrication, and testing of the small payloads was a collaborative effort among the scientists, the mission crew members, and the engineers who designed the payload modules. Examples of engineering challenges addressed in the work carried out in N-240 and N-240A included re-design of the gloves in the glovebox to accommodate a variety of hand sizes while providing for dexterity sufficient to operate intricate instrumentation and live organisms and maintain controlled conditions. Another example was to develop a solution for mechanical feeding of the animals without creating backflow of fecal material and waste food into the Orbiter. A third example was to create and test state–of-the-art engineering systems to provide separation of the life support systems between the animal specimens and the crew members. On April 29, 1985, for the first time in U.S. history, two Squirrel Monkeys and 24 albino rats were launched into space aboard NASA's Spacelab Mission 3 in the Research Animal Holding Facility, designed by the Life Sciences Program at NASA Ames Research Center. The payloads were designed to the precise tolerances of the Shuttle to assure no cross contamination of the air shared by the astronaut crew under changing conditions of temperature and pressure.[2]

At Ames, Life Sciences experiments completed for the Space Shuttle focused upon animal, plant, cell, and tissue experiments with the goal of understanding how spaceflight affects basic biological projects. Early experiments typically dealt with biomedical problems associated with spaceflight e.g., motion sickness, bone and muscle atrophy, and radiation damage. Life sciences experiments were an important part of the Space Shuttle Program. The Space Shuttle was unique in space life sciences because it presented scientists the capability to make experiments on a regular basis with a controlled environment and with the potential for crew participation in the sampling and preparation of specimens during flight.

One of the most important experiments made on the Space Shuttle was completed by Muriel Ross. Ross focused on the regeneration of nerves in a microgravity environment. Though Ross' laboratory was located in N-239, the laboratory package flown for her was built in N-240A. Ross found that as rats altered the structure of the vestibular system, the balance organs of the inner ear increased. Rats in microgravity were quick to increase the synapses connecting the acceleration sensors in the ear to the nerve transmitting the acceleration signal to the brain. In contrast to the thinking that the nervous system regenerated slowly, if at all, Ross proved that nerves could quickly grow and adapt to changes in the nature and magnitude of simulation gravity. N-240 and N-244 were the focus of most

[2] Ashbaugh, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.

biological research flown aboard the Space Shuttle and International Space Station.

According to educational information at ARC:

> The Life Sciences Division has developed experiments and flown on Shuttle flights since its inception. Significant experiments and flights have included: 30 Middeck flights; 8 Spacelabs (Spacelab 3 – April 1985, Spacelab Life Science I – June 1991, International Microgravity Lab – January 1992, Spacelab Japan – September 1991, Space Lab Life Sciences 2 – October 1992, International Microgravity Lab 2 – July 1994, Life and Microgravity Sciences Lab – June 1996, and Neurolab – April 1998); Spacelabs (STS 76 3rd Shuttle – Mir Docking – March 1996; STS 81 5th Shuttle Mir Docking – January 1997; STS 84 6th Shuttle – Mir Docking; and STS 95 John Glenn Mission – November 1998). These flights represent more than 100 experiments from investigators throughout the United States and in collaboration with our European and Japanese partners. They resulted in over 150 peer-reviewed publications and have provided understanding of the basics of space physiology and an increased knowledge of the mechanistic development of the biological system on earth.[3]

In particular, N-240A housed two decades of work on the Spacelab Life Sciences program, in program management, experiment validation, data collection, and payload construction. Life Sciences experiment packages flown on more than 45 STS missions were managed from this building, notably SL3 (Spacelab 3 in April 1985), SLS1 (June 1991), SLJ (Spacelab J in September 1992), SLS2 (October 1993), and Neurolab (STS90 in April 1998).

N-240A was further distinguished by the initial experiment orientation and proficiency training programs that the astronauts undertook prior to their launch. According to Ken Souza, astronauts assigned to conduct scientific experiments that were developed and managed at Ames, received orientation and training within the Hi-bay and associated laboratories in N-240A. At least seventy-five astronauts trained for two to three year prior to their launch at Ames, in order to understand the workings of certain payloads within a weightless environment.[4] Afterwards, additional astronaut training occurred at either Johnson Space Center (JSC) or Marshall Space Flight Center (MSFC), depending on the Spacelab management responsibility for a particular flight. Ames was responsible for all animals, cells, tissues, and plants payloads, MSFC for material research payloads, and JSC for

[3] Excerpted from NASA Ames Research Center, Life Sciences Division, display panel located in N-240/N-240A.
[4] Ashbaugh, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.

human-centered research payloads.[5]

Additional information on the building's historic context has been included in the Appendices.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[6]

- *Is real or personal property owned or controlled by NASA;*

N-240A is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-240A was not constructed or modified for the Space Shuttle Program, but was utilized for programs related to the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

N-240A is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*

[5] Ashbaugh, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties" 8 February 2007.
[6] NASA, "Evaluating Historic Resources," 3.

- *best represents the important achievements or the cumulative importance of prominent persons; or*
- *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

Criterion C – Design/Construction

- *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
- *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
- *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

Criterion D – Information Value

- *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

In relation to the Space Shuttle Program, N-240A qualifies under SSP Evaluation Criteria Eligibility Property Type: *12. Resources Associated with Processing Payloads* as a resource which "represent[s] outstanding achievements in technological, aeronautical or scientific research which would otherwise not have been attainable without the use of the Space Shuttle," and under SSP Evaluation Criteria Eligibility Property Type: *10. Resources Associated with the Training of Astronauts* as a resource which has "...a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program."[7] However, this study only examines those resources with a direct connection to the development of the Space Shuttle Program, and does not examine the sciences and payloads contained within the shuttle.

N-240A qualifies for listing in the National Register under Criterion A (Events) as a site for initial astronaut training. N-240A contained the orientation program, which introduced and trained astronauts on certain experiments related to the Space Shuttle's payloads. This training was later continued at Johnson Space Center or Marshall Space Flight Center.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot

[7] Ibid., 8-9.

be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

N-240A does not meet "Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years," since the building is not exceptionally significant within the aforementioned context. In terms of the astronaut training, N-240A only supported a selection of SSP missions, and therefore did not contribute to the training of all SSP astronauts. For example, qualifying significance based on the SSP evaluation criteria includes the WHSH, where the three runways are eligible for listing in the National Register based on the fact that every Shuttle pilot and commander has trained there, and that it played a role essential to every SST deployment.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-240A does not retain historic integrity to convey its significance. The building remains in its original location, and therefore, retains integrity of location. The building has had minimal alterations over its lifetime. These alterations are in keeping with the general character and purpose of the original building. The building retains integrity of design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center, and therefore, maintains integrity of setting. The building retains its simple concrete exterior, and therefore, retains integrity of materials. Finally, the building is no longer associated with the Life Sciences Division. It has been reorganized for small satellite development, and therefore, does not retain integrity of workmanship, feeling, or association that was present when the building was used for preparing life science payloads for the Space Shuttle.

Conclusion

Although N-240A contributed valuable information to the Space Shuttle Program, it had a supporting and not a direct role to the SSP, therefore does not meet the general registration requirements for listing in the National Register of Historic Places within the context of the Space Shuttle Program. N-240A does not retain enough integrity to convey its historical significance and is not exceptionally significant (Criteria Consideration G) within the context of the Space Shuttle Program. Only a select number of astronauts were trained at N-240A, thus this building does not possess exceptional significance within this context.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

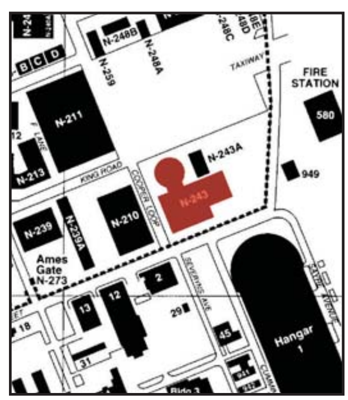
N-243, east facade
(Source: Page & Turnbull)

N-243: Flight and Guidance Simulation Laboratory

Location: 655 Cooper Loop, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1967

Brief Description: N-243 is a large, three-story, Brutalist complex used as a research facility, office, and laboratory. The building's footprint is 108,670 square feet (10,095 square meters) and is rectangular in plan with a circular mass at the northwest corner that formerly housed a centrifuge. The building is occupied by three separate flight simulation machines that are connected by a building that houses offices and the common control computer. The rectangular massing features circular drums at the southwest and southeast corners, as well as several overhead steel warehouse doors and aluminum-frame doorways. Along the east facade is a seven-story tower, which faces the adjacent air fields. The exterior of this complex is primarily composed of scored concrete punctured with regularly spaced openings. The west facade features



Location Map, ARC
(Source: NASA; Altered by Page & Turnbull)

an integral concrete frame, aluminum-sash windows, and an exterior staircase, all of which mark the main entry into the complex; this is the only facade with fenestration. The circular form at the northwest corner is two-and-one-half stories in height with an overhead steel door and a corrugated metal penthouse. The seven-story concrete tower also features an overhead steel door, three-stories in height. On the south facade of the rectangular massing is a series of concrete piers, which are also scored like the rest of the exterior. An additional entry is located within a rounded niche at the southeast corner. This building has served as a flight simulator for advanced aircraft.

Typical interior finishes include concrete or resistant vinyl flooring, gypsum board or concrete walls, and exposed or acoustic tile ceilings with incandescent or fluorescent lighting. Significant interior areas and equipment include the Vertical Motion Simulator (VMS) and the Visual Display Laboratory.

Currently, the VMS is scheduled to undergo modernization to address reliability and simulation fidelity concerns. Goals include both the replacement of all system components whose failure could result in an unplanned extended facility shutdown, and the installation of a control system that is reliable, easily modified, has improved diagnostics, and can provide system trending and data logging functions.

Type/Function: Flight and Guidance Simulation Laboratory; Vertical Motion Simulator (current use); Crew Station Research & Development Facility; ICABS Development Station; ACAVS Development Station; office and administrative facilities; research and experimentation support.

Historic Context: N-243 was constructed between 1965 and 1967 for the Apollo Program. The first simulator located in the Flight and Guidance Simulation Laboratory was the Flight Simulator for Advanced Aircraft (FSAA). The Flight Simulator for Advanced Aircraft was used to investigate the landing, takeoff, and general handling qualities of large aircraft during the 1970s. The FSAA allowed the feeling of G-forces as pilots landed the Shuttle. The time spent in the FSAA helped NASA engineers determine what handling qualities needed to be improved for successful landing of the shuttle. Now dismantled, the FSAA contributed to the early simulation of the orbiter landing for the Space Shuttle Program. All of the pilot astronauts spent time in the FSAA identifying handling issues and control system shortcomings. According to NASA,

> A pilot-induced oscillation (PIO) problem arose on the first approach and landing test program flight in July 1977. A PIO is a longitudinal 'porpoising' that worsens due to pilot over-control. It is generally not a piloting technique problem so much as a control system problem. On this first flight, as the oscillation began to diverge

> dangerously close to the ground, the pilot had enough confidence and simulator training to simply let go of the controls and allow the oscillation to damp itself out. Following that, a major investigation was conducted in the FSAA to re-evaluate the control systems gains, in order to minimize the possibility of future PIO problems.[1]

The FSAA contributed to the simulator research and flight control systems for the Space Shuttle Program. The FSAA was dismantled in the early 1990s, though the four-story enclosure for the facility remains.

The man-carrying rotation device, a centrifuge used to expose humans to high degrees of gravitational force, was constructed in the early 1970s. The device made it possible to study the effects of hypergravity responsible for some of the physiological effects of spaceflight. The man-carrying rotation device was dismantled in the late 1970s. The shell of the centrifuge remains in the building and has been modified for use by the U.S. Army.

The Vertical Motion Simulator (VMS), the focus of this evaluation, was constructed by 1979 and began operation in 1980. The six-degree-of-freedom VMS, with a 60-foot (18.3-meter) vertical and 40-foot (12.2-meter) lateral motion capability, is the world's largest motion-base simulator. The VMS includes seven interchangeable cabs that simulate helicopters, tilt-roters, fighter jets, transport aircraft, supersonic transports, and the Space Shuttle.[2] VMS earned a reputation as the best simulator anywhere for the continuation of engineering design and shuttle pilot training.

The process of developing piloted flight simulation resulted in a very close working relationship among the orbiter engineering designers from Johnson Space Center, the astronauts, and Ames' SimLab.[3] Virtually every pilot astronaut in the shuttle program trained using the VMS. Besides looking at future design improvements in the flight control systems, the pilots could encounter every conceivable failure the Johnson Space Center engineers could imagine. This training proved invaluable in preparing shuttle commanders and pilots to deal with a wide array of possible landing failures.[4]

Experience gained in the VMS has resulted in the redesign of the brakes, nose wheel steering, and

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[1] NASA, "Ames' contributions to STS-1: The Boldest Test Flight in History," [*http://www.nasa.gov/mission_pages/shuttle/sts1/sts1_25.html*].
[2] Ibid.
[3] Arnold et al, "Ames' Contribution to the Shuttle," [*http://www.nasa.gov/centers/ames/research/humaninspace/25th_shuttle.html*].
[4] Ibid.

Multifunction Electronic Display System (MEDS); engineering development of the drag parachute; flight control automation for the Extended Duration Orbiter; and "return to flight" studies after the Challenger accident.[5]

The VMS was used twice a year to study landing and rollout of the Space Shuttle orbiter. VMS was the only facility that can simulate final descent and landing of the orbiter, and was an essential training facility for the Space Shuttle program. According to Thomas Alderete, Assistant Chief of Simulation Facilities at Ames, former astronaut John Young at Johnson Space Center stated that all changes to the takeoff and landing system and procedures need to be validated by VMS testing.[6] VMS gave the shuttle pilot astronauts the opportunity to effectively practice landing scenarios or critical maneuver involving the orbiter. The simulator provided worst-case scenarios for pilots, such as blown tires, crosswinds, or failed auxiliary power units. The VMS was essential for the study of drag-chute design and testing, tire wear, brakes, and crew evaluation and testing.[7] The VMS made other important contributions including Head-up display (HUD) symbology, and determination of wind, visibility, and ceiling limits.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[8]

- *Is real or personal property owned or controlled by NASA;*

N-243 is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-243 was modified for the Space Shuttle Program with the new addition of the Vertical Motion Simulator (VMS).

[5] Ibid.
[6] Thomas Alderete, Assistant Chief of Simulation Facilities, NASA Ames, interview, 30 August 2006, Moffett Field, CA.
[7] NASA Ames Research Center, Aviation Systems Division, "VMS Overview" (Moffett Field, CA: NASA Ames Research Center, n.d.).
[8] NASA, "Evaluating Historic Resources," 3.

- *Is classified as a structure, building, site, object, or district;*

N-243 is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
  - *best represents the important achievements or the cumulative importance of prominent persons; or*
  - *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

  Criterion C – Design/Construction
  - *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
  - *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
  - *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

  Criterion D – Information Value
  - *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

In relation to the Space Shuttle Program, N-243 qualifies under SSP Evaluation Criteria Eligibility Property Type: *10. Resources Associated with the Training of Astronauts* as a resource that has "been designed and constructed, or modified, for the unique purpose of astronaut training and be directly associated with preparing astronauts for the completion of a Space Shuttle mission;" "Clearly embody the distinctive characteristics of a type or method of construction specifically designed for aeronautical training;" and has "a direct historical association with the Space Shuttle, or a significant person associated with the Space Shuttle Program."[9]

N-243 is significant under Criterion A (Events) for the Vertical Motion Simulator (VMS), which contributed to the training of the astronauts for the Space Shuttle Program. The Vertical Motion Simulator is significant as the world's largest motion base simulator and as the sole training simulator for landing and rollout of the shuttle orbiter. VMS earned a reputation as the best simulator anywhere for the continuation of engineering design and shuttle pilot training. Almost every pilot astronaut involved with the shuttle program trained using the VMS. The VMS continues to be used twice a year to study landing and rollout of the Space Shuttle orbiter. VMS is the only facility that can simulate final descent and landing of the orbiter, and is therefore, an essential training facility for the Space Shuttle program. In addition to crew training, the VMS has supported redesign of the brakes, nose wheel steering, and Multifunction Electronic Display System (MEDS); engineering development of the drag parachute; flight control automation for the Extended Duration Orbiter; and "return to flight" studies after the Challenger accident.[10] The VMS has made other important contributions including Head-up display (HUD) symbology, and determination of wind, visibility, and ceiling limits.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

N-243 does meet "Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years," and is exceptionally significant within the context of the Space Shuttle Program. N-243 is significant for its association with the VMS, which is the sole flight simulator for the Space Shuttle Program that simulates landing and roll out, and is the world's largest motion-base simulator.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-243 possesses integrity of location, design, setting, materials, workmanship, feeling, and

[9] Ibid., 7-8.
[10] NASA Ames Research Center, "VMS Overview," n.d.

association. The building remains in its original location and appears to have had few major exterior alterations; therefore, it retains integrity of location and design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center, and therefore, maintains integrity of setting. The building retains its simple concrete exterior and Brutalist aesthetic, and therefore, retains integrity of materials. The building includes the Vertical Motion Simulator and the five interchangeable cabs (I-CABS) that allow the ability to simulate the flight deck of almost any aerospace vehicle. The building does not retain the Flight Simulator for Advanced Aircraft or the man-carrying rotation device. Although the equipment has sustained changes and alterations over time, it remains consistent with the building's original use as a research center for aircraft and spacecraft simulators. Therefore, the building retains integrity of workmanship. Finally the building's general appearance, character, and association with the Vertical Motion Simulator appear to have been maintained, and therefore, the building retains integrity of feeling and workmanship.

Conclusion

N-243 does meet the registration requirements for listing in the National Register of Historic Places in the context of the Space Shuttle Program. Although only a portion of the building, the Vertical Motion Simulator, is directly associated with the Space Shuttle Program, the National Register criteria for evaluation state that the entire building is considered eligible to the National Register of Historic Places.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

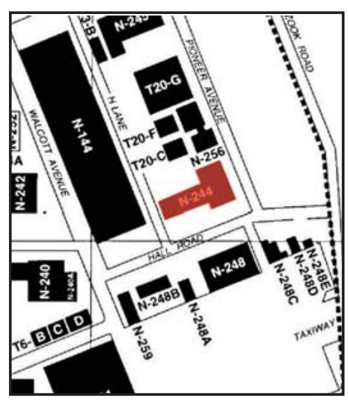
N-244, south facade, main entrance (Source: Page & Turnbull)

N-244: Space Projects Facility

Location: 590 Hall Road, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1967

Brief Description: N-244 is a two-story concrete office and research laboratory that contains 61,630 square feet (5,725 square meters) of space and is rendered in a Modern architectural style. The building is L-shaped in plan and features office and warehouse portions. It has a concrete foundation, a concrete exterior, a flat roof, and aluminum-sash fixed windows. The office portion features exposed concrete walls, regularly-spaced fenestration with concrete sunshades, and an entrance on Hall Road. The warehouse portion features concrete walls with vertical grooves and a steel overhead door on the west facade.



Location Map, ARC (Source: NASA; Altered by Page & Turnbull)

Type/Function: Offices, research laboratories, and administration facilities; warehouse; Current: Space Projects Facility.

Historic Context: Constructed in 1967, the Space Projects Facility was not involved in the development of the physical or mechanical equipment of the Space Shuttle. Instead, N-244 participated in researching and developing the experiments and payloads the shuttle was designed to carry. Several laboratories and a portion of the building's mezzanine area were modified to support a centrifuge technology development activity and a full-scale Centrifuge Accommodation Module mock-up.

The Space Projects Facility was important to the Pioneer Missions as well as several space shuttle and space station life sciences projects. According to George Sarver, Space Station Biological Research Project (SSBRP) Manager, and current manager of Ames' Orion/ Crew Launch Vehicle (CLV) Support Project, the original purpose of the Space Projects Facility was to manage and operate the Pioneer missions, placing four spacecraft in orbit around the sun and sending spacecraft to Jupiter, Saturn, and Venus.[1]

The Space Projects Facility has housed several Space Shuttle and Space Station projects including the Space Station Biological Research Project (SSBRP) and the Space Infrared Telescope facility (when it was a shuttle payload). It has also been the flight operations facility for the Passive Dosimeter (ISS payload), the Avian Development Facility (Shuttle payload), and the Biomass Production System (ISS & Shuttle payload). The environmental test facility in the Space Projects Facility has supported all shuttle flights managed by the NASA Ames Research Center starting with early animal habitat experiments and all Spacelab flights. N-240 and N-244 were the focus of most biological research flown aboard the Space Shuttle and the International Space Station.

Hundreds of shuttle payloads were tested at the Space Projects Facility. The high bay at the Space Projects Facility was used as a testing facility for many of the payloads flown with the Space Shuttle. The Space Projects Facility continued its support of the shuttle and space station flights managed out of Ames through the environmental test facility located in the Space Projects Facility.

One of the projects based in the Space Projects Facility was the Space Station Biological Research Project (SSBRP). SSBRP was responsible for facilities that were used to conduct life sciences research onboard the International Space Station (ISS). Proposed to be the world's first complete gravitational biology laboratory in space, the SSBRP aimed to provide basic tools to conduct musculoskeletal, neurophysiology, developmental biology, and genetic research on the whole organism and at the cellular level. Computers on the ISS transferred data to Ames where it was relayed to scientists

[1] George Sarver, Space Station Biological Research Project (SSBRP) Manager, interview, 13 September 2006, Moffett Field, CA.

at their institutions and laboratories. The SSBRP managed the project and developed science requirements. It also managed the development of the hardware from established developers, thus ensuring that it would support all the research protocols. The team was also responsible for integrating, testing, and verifying (on-orbit) the hardware. Following hardware verification, the Life Sciences Division developed experiments and managed ongoing operations. A full scale mock-up of the laboratory was located on the second floor of the High Bay in the Space Projects Facility.[2]

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[3]

- *Is real or personal property owned or controlled by NASA;*

N-244 is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-244 was not constructed or modified for the Space Shuttle Program, but it was utilized for programs related to the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

N-244 is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

[2] NASA Ames Research Center, Space Projects Division, "Contributing Across the Enterprises, The Present, SSBRP" [http://spaceprojects.arc.nasa.gov/Space_Projects/ThePresent/ssbrp.html].
[3] NASA, "Evaluating Historic Resources," 3.

Criterion B - Significant Persons

- *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
- *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
- *best represents the important achievements or the cumulative importance of prominent persons; or*
- *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

Criterion C – Design/Construction

- *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
- *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
- *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

Criterion D – Information Value

- *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

N-244 does not meet any of the NRHP criteria for listing in the National Register within the context of the Space Shuttle Program and does not qualify under any of the SSP Evaluation Criteria Eligibility Property Types.

Although N-244 contributed to Ames' Life Sciences Program, and was a center for the Pioneer missions, the building and its facilities do not embody a direct connection to the Space Shuttle Program. The Space Projects Facility was connected to the Life Science program at Ames, but it does not have the sustained connection to the Space Shuttle Program that is necessary to make the building eligible for listing in the National Register within the context of the Space Shuttle Program.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

Since N-244 does not meet sufficient the significance threshold for NR listing, it will not meet the appropriate criteria considerations.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-244 possesses integrity of location, design, setting, materials, feeling, and association. The building remains in its original location and appears to have had few exterior or interior alterations; therefore, it retains integrity of location and design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center, and therefore, maintains integrity of setting. The building retains its simple concrete exterior, and therefore, retains integrity of materials. The building does not contain any specialized equipment or technologies relating to the Space Projects Facility; therefore, the building does not retain integrity of workmanship. Finally the building's general appearance, character, and association with the Space Projects Facility appear to have been maintained, and therefore, the building retains integrity of feeling and association.

Conclusion: Although N-244 contributed valuable information to the Space Shuttle Program, it had a supporting and not a direct role to the SSP, therefore does not meet the general registration requirements for listing in the National Register of Historic Places within the context of the Space Shuttle Program. N-244 does not have significance as related to the Space Shuttle Program, and does not meet the appropriate Criteria Considerations.

Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices.

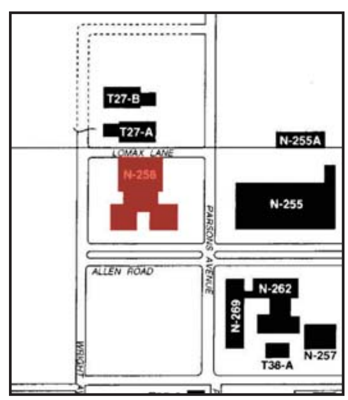
N-258, south facade, main entrance (Source: Page & Turnbull)

N-258: NASA ADVANCED SUPERCOMPUTING FACILITY

Location: 150 Allen Road, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1986

Brief Description: N-258 is a two-story office and research building located at the corner of Allen Road and Parsons Avenue. The building is 87,340 square feet (8,114 square meters) in size. It features a concrete foundation, a concrete exterior with aluminum-sash ribbon windows, and a flat roof. Its plan is configured into three square sections linked by a shared central connector. The building's exterior features chamfered edges and scored concrete panels. This building houses large supercomputers used for solving complex computational aerospace simulation problems.



Location Map, ARC (Source: NASA; Altered by Page & Turnbull)

Type/Function: Current use: NASA Advanced Supercomputing Facility (NAS); office and administrative facilities; research laboratories; computer and server facilities.

Historic Context: N-258 was dedicated in March 1987. Originally known as the Numerical Aerodynamic Simulation Facility, the building's name was changed to NASA Advanced Supercomputing Facility (NAS) in the mid-1990s. The building was constructed to house Ames' supercomputers, which are used by researchers at almost every NASA center. In 2004, the NAS Division co-developed, with industry partners SGI and Intel, what was intially the fastest supercomputer in the world. Named Columbia, the supercomputer is a 10,240-processor supercluster, and it remains NASA's fastest supercomputer.[1]

High-end computing and computational fluid dynamics (CFD) have played a role in the Space Shuttle Program from testing, to redesign, to accident investigation. NAS runs CFD simulations of the shuttle—both the orbiter and booster tanks—during flight and launch. NAS also had a part in the redesign of the Space Shuttle Main Engine (SSME). The SSME was redesigned to include a two-duct hot gas manifold. The new two-duct design, facilitated with the use of Cray XMP and Cray 2 supercomputers, and CFD techniques developed by NAS researchers, enhanced overall engine performance and reliability. CFD analyses showed that the two-duct design reduced pressure gradients within the system, and lowered temperatures in the engine during operation, which reduces stress on the turboprop and main injector. The newly designed powerhead made its first flight on Discovery's 20th mission (STS-70) in July 1995, and has been used in all subsequent Shuttle missions. As recently as August 2006, NAS tested CFD simulations of the orbiter during ascent to help analyze a potential update to the Space Shuttle's external tank.[2] More recently, the Cray supercomputers were replaced with newer equipment.

During the *Columbia* (STS-107) accident investigation, NAS used state-of-the-art CFD codes to simulate steady and unsteady flow fields around *Columbia* during ascent.[3] CFD has also become a part of standard shuttle operations. According to John Parks, Assistant Chief for Operations and Engineering at NAS, risk assessment and functionality tests run on an ongoing basis during Space Shuttle missions.[4] In general, N-258 is on standby status during Shuttle flight operations, in order to allow for immediate access should a problem occur.

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[1] NASA Ames Research Center, NASA Advanced Supercomputing Division (NAS), "Columbia Supercomputer," [*http://www.nas.nasa.gov/About/Projects/Columbia/columbia.html*].
[2] NASA Ames Research Center, NAS, "Columbia Speeds Evaluation of Proposed Shuttle Tank Redesign," [*http://www.nas.nasa.gov/News/Archive/2006/09-13-06.html*].
[3] NASA, NASA Facts, "The Impact of High-End Computing on the Space Shuttle Program," [*http://www.nasa.gov/centers/ames/research/Fact-Sheet-Collection_archive_1.html*].
[4] John Parks, Assistant Chief for Operations and Engineering, NAS, interview, 6 September 2006, Moffett Field, CA.

Additional information on the building's historic context has been included in the Appendices.

Evaluation: As stated in "Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)," to qualify for listing in the National Register in the context of the Space Shuttle Program, resources must meet all of the following general registration requirements:[5]

- *Is real or personal property owned or controlled by NASA;*

N-258 is owned and controlled by NASA Ames Research Center.

- *Was constructed, modified, or used for the Space Shuttle Program between the years 1969 and 2010 (or the actual end of the Space Shuttle Program);*

N-258 was not constructed or modified for the Space Shuttle Program, but has been utilized for programs related to the Space Shuttle Program.

- *Is classified as a structure, building, site, object, or district;*

N-258 is classified as a building.

- *Is eligible under one or more of the four NRHP Criteria. All properties considered eligible for listing under*

  Criterion A - Events
  - *must be of significance in reflecting the important events associated with the Space Shuttle Program during the period of significance (1969-2010); or,*
  - *must be distinguished as a place where nationally significant program-level events occurred regarding the origins, operation and/or termination of the Space Shuttle Program; or*

  Criterion B - Significant Persons
  - *must be associated with a person whose individual significance to the goals, missions, development and design of the Space Shuttle Program can be identified and documented; or*
  - *must be distinguished as a place where persons of significance to the Space Shuttle Program worked or trained; or*
  - *best represents the important achievements or the cumulative importance of prominent persons; or*
  - *has consequential association with a person who gained national prominence relative to the Space Shuttle Program during the period of significance.*

[5] NASA, "Evaluating Historic Resources," 3.

Criterion C – Design/Construction

- *was uniquely designed and constructed or modified to support the pre-launch testing, processing, launch and retrieval of the Space Shuttle and its associated payloads; or*
- *reflects the historical mission of the Space Shuttle in terms of its unique design features without which the program would not have operated; or*
- *reflects the distinctive progression of engineering and adaptive reuse from the Apollo-era to the Space Shuttle-era*

Criterion D – Information Value

- *As this criterion is primarily used for archeological sites and this document is focused on historic properties, it is inappropriate to use this criterion as a discriminator, therefore, it will not be a valid criterion for surveys used as part of the Space Shuttle Transition activities.*

In relation to the Space Shuttle Program, N-258 qualifies under SSP Evaluation Criteria Eligibility Property Type: *7. Engineering and Administrative Facilities* as a resource that was "…directly associated with critical activities of national significance which impacted the development, implementation and termination of the Space Shuttle Program or missions."[6]

N-258 does not meet any of the NRHP criteria for listing in the National Register within the context of the Space Shuttle Program. In terms of the SSP, researchers and engineers did not complete work related to the initial design and flight of the Shuttle at N-258. Computational fluid dynamics is most heavily used in the parameter variation used in the preliminary design of a spacecraft, and the Space shuttle system had already flown by the time the NAS was operational. Although the NASA Advanced Supercomputing Facility (NAS) is important for its embodiment of the shift in aeronautic and astronautic research from wind tunnel tests to increasing reliance upon computational fluid dynamics (CFD), N-258 is not eligible for listing in the National Register under any of the SSP evaluation criteria.

- *Meets appropriate Criteria Considerations (Criteria Consideration B: Moved Properties or Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years);*

  [Note: Since the entire Space Shuttle Program is less than 50 years old, Criterion G cannot be a discriminator for determining eligibility, as some properties utilized by the Space Shuttle Program may be over 50 years old.]

N-258 does not meet "Criteria Consideration G: Properties that have Achieved Significance within the Past 50 Years," since it is not exceptionally significant within the context of the Space Shuttle

[6] Ibid., 7.

Program. As stated above, the NASA Advanced Supercomputing Facility (NAS) contributed to recent development of aerospace technology, including a shift in aeronautic and astronautic research from wind tunnel tests to increasing reliance upon computation fluid dynamics (CFD), though this information is of secondary importance in the context of the Space Shuttle Program. Therefore, N-258 is not considered exceptionally significant in the context of the Space Shuttle Program.

- *Retains enough integrity to convey its historical significance;*

  [Note: As a general rule, in the case of highly technical and scientific facilities, "there should be continuity in function, and thus in integrity of design and materials, and there may always be integrity of association"]

N-258 possesses integrity of location, design, setting, materials, workmanship, feeling, and association. The building remains in its original location and does not appear to have had alterations over its lifetime; therefore, it retains integrity of location and design. The building is located in the vicinity of other scientific and technical resources at NASA Ames Research Center, and therefore, maintains integrity of setting. The building retains its concrete exterior and anodized aluminum ribbon windows, and therefore, retains integrity of materials. Although the computing resources inside the building have undergone substantial change, by virtue of the replacement of the original computers with larger supercomputers, the original computational function remains intact and the building retains integrity of workmanship. Finally the building's general appearance, character, and association with the NAS facility appear to have been maintained, and therefore, the building retains integrity of feeling and workmanship.

Conclusion: Although N-258 contributed valuable information to the Space Shuttle Program, it had a supporting and not a direct role to the SSP, therefore does not meet the general registration requirements for listing in the National Register of Historic Places within the context of the Space Shuttle Program. While N-258 provided valuable information to the SSP, its role was not directly associated with critical activities of national significance, which impacted the development, implementation, and termination of the SSP or its missions. Therefore, it does not convey exceptional significant within the SSP context.

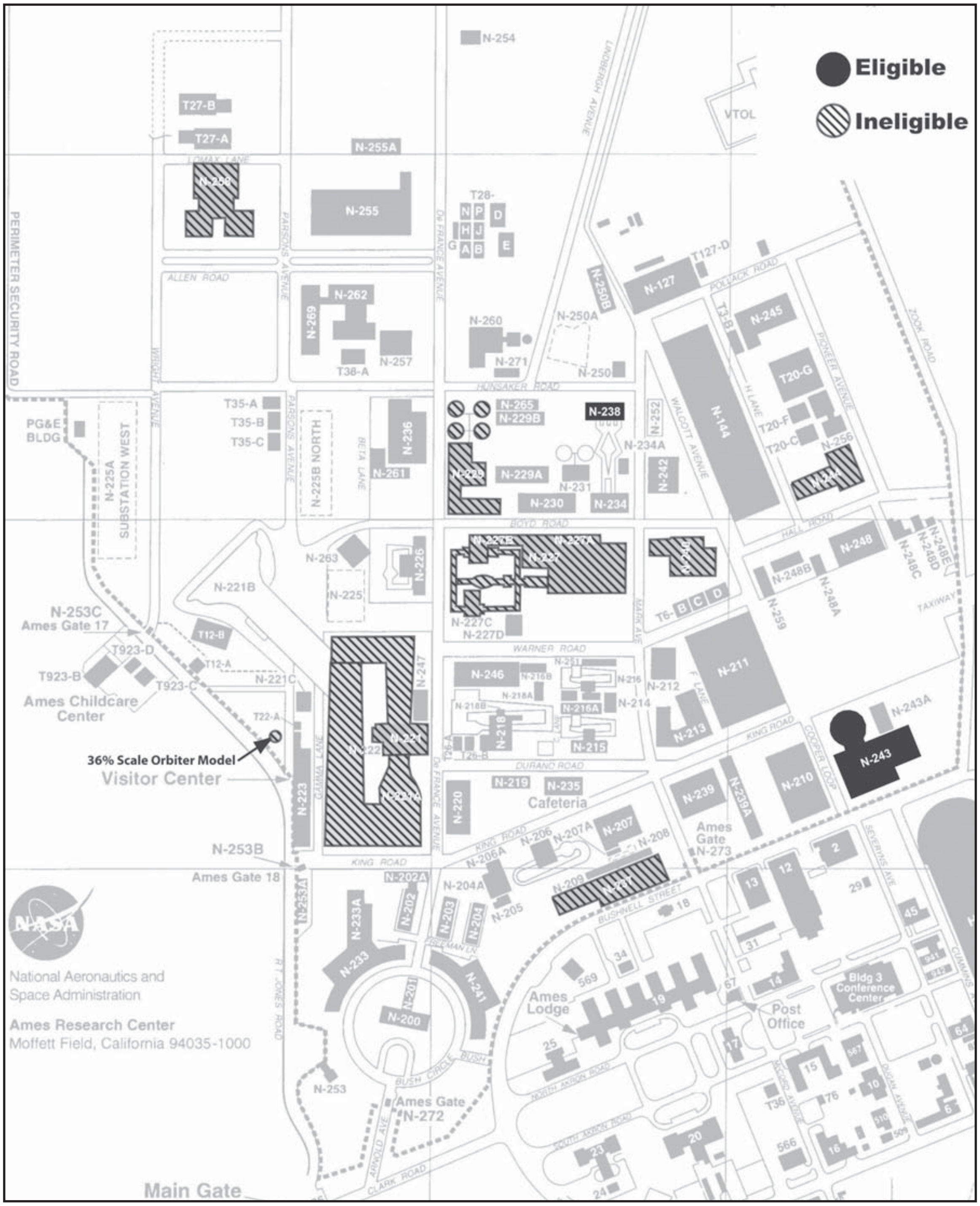
Additional images (ex: photographs, illustrations, diagrams, etc.) can be found in the Appendices, along with Supplemental Information on the history of N-258.

V. Properties Determined to be Eligible for Listing

Of the eleven resources identified on the preliminary list of properties utilized by or supporting the Space Shuttle Program at NASA Ames Research Center, N-238 and N-243 were found by Page & Turnbull to meet the general registration requirements for listing in the National Register of Historic Places in the context of the Space Shuttle Program. These two resources retain historic integrity and are eligible for listing under one or more of the four (A, B, C & G) NRHP Criteria. The 36% Scale Orbiter Model, N-221, N-227A to D, N-229, N-237, N-240, N-240A, N-244, and N-258 do not to meet the general registration requirements, and as a result, are not eligible for listing in the National Register in the context of the Space Shuttle Program (See Map 2). These conclusions have been accepted by the Ames Facilities Historic Preservation Officer.

N-238
(Source: Page & Turnbull)

N-243
(Source: Page & Turnbull)



Map 2. Space Shuttle Program Eligibility Map
(Source: NASA Ames Research Center; altered by Page & Turnbull)

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