NPS Form 10-900 OMB No. 1024-0018

United States Department of the Interior

National Park Service

# National Register of Historic Places Registration Form

This form is for use in nominating or requesting determinations for individual properties and districts. See instructions in National Register Bulletin, *How to Complete the National Register of Historic Places Registration Form.* If any item does not apply to the property being documented, enter "N/A" for "not applicable." For functions, architectural classification, materials, and areas of significance, enter only categories and subcategories from the instructions.

## 1. Name of Property

Historic name: Arc Jet Complex

Other names/site number: Building N-234, Building N-238, Steam Vacuum System

Name of related multiple property listing:

N/A

(Enter "N/A" if property is not part of a multiple property listing

## 2. Location

Street & number: 980 Mark Avenue, NASA Ames Research Center

City or town: Moffett Field State: CA County: Santa Clara (085)

Not For Publication: ☐ Vicinity: ☐

## 3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act, as amended,

I hereby certify that this _X_ nomination ___ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60.

In my opinion, the property _X_ meets ___ does not meet the National Register Criteria. I recommend that this property be considered significant at the following level(s) of significance:

**_X_national ___statewide ___local**

Applicable National Register Criteria:

**_X_A ___B _X_C ___D**

1 Nov 2016

**Rebecca Klein, Federal Preservation Officer** **Date**

National Aeronautics and Space Administration

**State or Federal agency/bureau or Tribal Government**

In my opinion, the property _x_ meets ___ does not meet the National Register criteria.

10/13/16

**Signature of commenting official:** **Date**

Deputy State Historic Preservation Officer, California State Office of Historic Preservation

**Title :** **State or Federal agency/bureau or Tribal Government**

## 4. National Park Service Certification

I hereby certify that this property is:

___ entered in the National Register

___ determined eligible for the National Register

___ determined not eligible for the National Register

___ removed from the National Register

___ other (explain:) ______________________

Signature of the Keeper Date of Action

## 5. Classification

**Ownership of Property**

(Check as many boxes as apply.)

| | |
|---|---|
| Private: | |
| Public – Local | |
| Public – State | |
| Public – Federal | X |

**Category of Property**

(Check only **one** box.)

| | |
|---|---|
| Building(s) | X |
| District | |
| Site | |
| Structure | |
| Object | |

**Number of Resources within Property**
(Do not include previously listed resources in the count)

| Contributing | Noncontributing | |
|---|---|---|
| 2 | 0 | buildings |
| 0 | 0 | sites |
| 1 | 0 | structures |
| 0 | 0 | objects |
| 3 | 0 | Total |

Number of contributing resources previously listed in the National Register 0

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## 6. Function or Use

**Historic Functions**
(Enter categories from instructions.)
OTHER/Scientific Research Facility

**Current Functions**
(Enter categories from instructions.)
OTHER/Scientific Research Facility

## 7. Description

**Architectural Classification**
(Enter categories from instructions.)
MODERN MOVEMENT/Moderne, Streamline Moderne

**Materials:** (enter categories from instructions.)
Principal exterior materials of the property:
Foundation – concrete
Walls – steel and brick
Roof – concrete
Other – steel

## Narrative Description

(Describe the historic and current physical appearance and condition of the property. Describe contributing and noncontributing resources if applicable. Begin with **a summary paragraph** that briefly describes the general characteristics of the property, such as its location, type, style, method of construction, setting, size, and significant features. Indicate whether the property has historic integrity.)

## Summary Paragraph

The Arc Jet Complex is a research facility located between Walcott Road and Hunsaker Road on the west side of Mark Avenue at the National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) at Moffett Field, in Santa Clara County, California. The complex is composed of Building N-234, Building N-238, and the Steam Vacuum System (SVS). Building N-234 is a 24,670-square-foot, two-story laboratory and office building with an asymmetrical plan, flat roof, and concrete and corrugated metal exterior walls. Building N-238 is a 17,030-square-foot, one-and-1/2-story laboratory building with a rectangular plan, flat roof, and brick and corrugated metal exterior walls. Both buildings are designed with Modern architectural characteristics. Each building includes five interior test bays for specialized arc jet apparatuses that connect to the SVS. The SVS is composed of metal tubing, valves, structural supports, and tanks that generate vacuum power to operate arc jets. The SVS is connected to five cooling towers located to the northeast. The complex is surrounded by other laboratory buildings and equipment, utilitarian storage units, and other auxiliary buildings. Border lawn areas, a few trees and shrubs, and picnic tables are present along the building façades on Walcott Road and Hunsaker Road. The complex is in good condition, has had few exterior alterations since its completion in 1964, and retains historic integrity.

## Narrative Description

The Arc Jet Complex is a highly specialized research facility located between Walcott Road and Hunsaker Road on the west side of Mark Avenue at ARC. The complex is composed of Building N-234, Building N-238, and the SVS. Building N-234 is on the south side of the complex, Building N-238 is on the north side of the complex, and the two buildings are connected by the SVS.

Building N-234 is a 24,670-square-foot, two-story laboratory and office building with a basement, concrete foundation, an asymmetrical plan, reinforced concrete walls, and a flat roof. The building has two distinct sections: an office portion in the front (south side), and a laboratory portion at the rear (north side). The front of the building has concrete exterior walls that are scored in a grid pattern. Each story on the south side and east side contains a series of continuous aluminum-framed windows, mainly fixed panes with some hopper or awning sash, and a flat concrete awning projecting over the windows. The offset central entrance contains a recessed pair of glazed doors with a transom and projecting concrete awning above, asymmetrically flanked by full-height brick massing. The west side contains no fenestration and has an attached brick partition wall enclosing the area around it. The rear laboratory portion of the building has a rigid steel frame clad with corrugated metal siding, and has a rectangular plan. The east side contains a single glazed door and a roll-up steel utility door in the first story, and an exterior staircase leading to a single glazed door in the second story. The rear of the building is connected to SVS equipment.

The interior of Building N-234 contains offices in the front portion of the building along double-loaded corridors on the first and second floors. The main entrance leads to a lobby with stairs to the second floor. The laboratory area has a concrete floor and a basement level, and is open to the second story. On the east and west ends of the laboratory, interior staircases lead to the second floor. A control room is located on the second floor on the south side of the laboratory. The laboratory is divided into five test bays on the main floor, which are occupied with research apparatuses and equipment, including the Aerodynamic Heating Facility (AHF) and the 2x9 Turbulent Flow Duct (TFD) Facility.

Building N-238 has a utilitarian design composed of two distinct sections: a one-story L-shaped portion with brick exterior walls in the front (north side), and a one and one-half story laboratory area with a rigid steel frame clad with corrugated metal siding that is situated within the ell of the brick portion and extends to the south and west. The building has a 17,030-square-foot rectangular plan with a basement and concrete foundation, a steel-frame structural system, and a flat roof. The façade (north elevation) of the brick portion contains two windows in the eastern portion and an entrance with glazed double-doors in the western portion. The east side of the brick portion extends the full width of the building and contains a steel overhead utility door. The west side of the corrugated metal portion contains a steel overhead utility door and a single man-door. The rear (south elevation) of Building N-238 is connected to the SVS.

The interior of Building N-238 contains a control room along the north wall in the brick portion of the building, five test bays in the laboratory, and other maintenance and work areas. The interior has exposed framing and a concrete floor with access to the basement level beneath the test bays. The test bays currently house the Panel Test Facility (PTF) and the 60-megawatt Interaction Heating Facility (IHF).

The SVS is composed of large-scale industrial-grade metal tubing, valves, structural supports, and tanks. The SVS was first built as part of Building N-234 in 1962 and was later expanded to connect to Building N-238. It is integral to the operation of the Arc Jet Complex. The SVS is currently powered by a boiler located in a separate building and operates with the cooling towers adjacent to the SVS to the east. The connected cooling towers consist of five aligned cylindrical towers with vents housed in a rectangular, two-story structure that is clad in corrugated metal and vented in the first story.

**Integrity**

The Arc Jet Complex retains integrity of location, design, setting, materials, workmanship, feeling, and association.

*Location.* The Arc Jet Complex remains in its original location.

*Design.* The design of the Arc Jet Complex has not had any substantial alterations to compromise the original intent of the design since 1964, when Building N-238 was completed. The utilitarian and industrial design is based on connecting the SVS to apparatus in the test bays in Buildings N-234 and N-238. The Arc Jet Complex retains integrity of design.

*Setting.* The Arc Jet Complex is set amid other laboratory buildings and research equipment. Its setting also includes utilitarian storage units and other auxiliary buildings. Its setting has consistently included other research facilities with similar utilitarian forms and materials. The Arc Jet Complex retains integrity of setting.

*Materials.* The Arc Jet Complex has a simple concrete, brick, and steel exterior with an industrial aesthetic. Very few apparent material alterations have been made to the Arc Jet Complex, and it retains integrity of materials.

*Workmanship.* The Arc Jet Complex’s most significant workmanship is related to its interior equipment; the building retains integrity of workmanship.

*Feeling.* The Arc Jet Complex retains its original appearance and function, and the feeling of a scientific research facility on a highly technical research campus. It retains integrity in its historic sense of place or feeling.

*Association.* The Arc Jet Complex continues to serve its original function as a highly specialized research facility. It retains integrity related to its historic associations.

## 8. Statement of Significance

**Applicable National Register Criteria**
(Mark "x" in one or more boxes for the criteria qualifying the property for National Register listing.)

[X] A. Property is associated with events that have made a significant contribution to the broad patterns of our history.

[ ] B. Property is associated with the lives of persons significant in our past.

[X] C. Property embodies the distinctive characteristics of a type, period, or method of construction or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components lack individual distinction.

[ ] D. Property has yielded, or is likely to yield, information important in prehistory or history.

**Criteria Considerations**
(Mark “x” in all the boxes that apply.)

[ ] A. Owned by a religious institution or used for religious purposes

[ ] B. Removed from its original location

[ ] C. A birthplace or grave

[ ] D. A cemetery

[ ] E. A reconstructed building, object, or structure

[ ] F. A commemorative property

[X] G. Less than 50 years old or achieving significance within the past 50 years

**Areas of Significance**
(Enter categories from instructions.)
Science
Engineering

**Period of Significance**
1962–2011

**Significant Dates**
1962 – Construction of the Gasdynamics Laboratory (Building N-234) and the SVS
1964 – Construction of the Mach 50 Helium Tunnel (Building N-238)
1972-73 – Construction of the 60-megawatt Interaction Heating Facility (Building N-238)
1976 – First Space Shuttle Program testing in the Interaction Heating Facility
2011 – End of the Space Shuttle Program

**Significant Person**
(Complete only if Criterion B is marked above.)
N/A

**Cultural Affiliation**
N/A

**Architect/Builder**
Goodwin, Glen (Building N-234 and the SVS)
Chapman, Dean Roden (Building N-234 and the SVS)
Jones, Robert E. (Building N-238)

**Statement of Significance Summary Paragraph** (Provide a summary paragraph that includes level of significance, applicable criteria, justification for the period of significance, and any applicable criteria considerations.)

The Arc Jet Complex is eligible for listing in the National Register at the national level of significance for its contributions in the areas of science and engineering related to arc jet research and development that occurred at this complex. The property is eligible under Criterion A for its association with advancements in arc jet technology and research and development of Thermal Protection Systems (TPS) for NASA's spaceflight programs, including the exceptional role of the 60-megawatt IHF arc jet in developing and refining TPS for the Space Shuttle Program (SSP). The property is also eligible under Criterion C for its design and engineering that allowed for significant innovations in arc jet technology. The period of significance is 1962 to 2011; from the year Building N-234 and the SVS were constructed to the end of the SSP. The property meets Criteria Consideration G for properties that have achieved significance within the past 50 years in relation to its exceptional significance within the context of the SSP.

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**Narrative Statement of Significance** (Provide at least **one** paragraph for each area of significance.)

The Arc Jet Complex, composed of Building N-234, Building N-238, and the SVS, was built in the early 1960s. Building N-234 with the SVS was designed and constructed as the Mass Transfer Cooling and Aerodynamics Facility in 1960–1961, and then was known as the Gasdynamics Laboratory when it was completed in 1962. Designed by ARC aeronautical engineers Glen Goodwin and Dean R. Chapman, the facility included test bays for arc jet units and a massive air-handling evacuator and collector system (the SVS), a 15-megawatt electrical power supply, wind tunnel controls, and data handling facilities. Arc jets were still in early development circa 1960, and the facility was designed for operational flexibility and changes to the arc jet equipment anticipated as it developed in future. Goodwin and Chapman first prepared separate specifications for the arc jet facility and later combined their efforts for the plans that NASA headquarters approved at an estimated cost of $4 million (Hartman 1970:336).

Goodwin and Chapman were distinguished engineers affiliated with flight research at ARC and were fellows of the American Institute of Aeronautics and Astronautics. Goodwin, a mechanical engineer, worked at Ames from 1946 to 1973, and initially worked in flight engineering focused on high-speed, high-altitude aerodynamic forces. His focus also turned to the heating that occurred in relation to these forces, and Goodwin became an innovator in heat transfer research, which was instrumental in the advancement of space flight, and was a driving force in the development of new facilities at ARC. Goodwin worked on a variety of research topics and held several positions at ARC including Chief of the Heat Transfer Branch, Chief of the Thermo and Gas Dynamics Branch, and eventually Director of Astronautics (NASA ARC 1973:2; Jonas 2003:2).

Chapman, an aeronautical engineer, worked at Ames between 1944 and 1979, and studied hypersonic heat transfer, skin friction, and aerodynamic pressures. He experimented with hypersonic flow and ablation related to atmospheric reentry, studying the physical transformation of materials under enormous aerodynamic heat friction. Chapman is particularly known for his ingenuous research related to tektites, which he theorized were meteorite debris with wave patterns formed as they melted during entry into Earth's atmosphere. In 1956, he developed the Chapman equation, a calculation for the optimum trajectory for space vehicle reentry from the moon back to Earth, which is still used today. Chapman also served as the Director of the Thermo and Gas Dynamics Branch, and later as Director of Astronautics after Goodwin. During his career, TPS for several space vehicles, including the Space Shuttle, were developed at ARC. Chapman was a leading authority on skin friction, boundary layers, base pressure, separated flows, turbulence, use of gas mixtures in wind tunnels, arc jet development, entry aerodynamics, ablation analysis, thermal protection, hypersonic real gas flows, computational aerodynamics, shock wave analysis, and tektites (Stanford University 1997).

The Gasdynamics Laboratory was built for the purpose of furthering arc jet innovation and the theoretical and empirical study of the aerodynamic characteristics of ablative materials suitable for reentry into Earth's atmosphere (Hartman 1970:336; Bugos 2014:104). NASA defines an arc jet as follows:

> 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 and pressure and the gas enthalpy found in a high velocity, supersonic flow of the kind experienced by a vehicle on atmospheric entry (NASA ARC n.d.).

Two types of arc jets were originally installed in the laboratory, a concentric-ring arc jet and a constricted-arc arc jet. Arc jet technology was further developed in the facility. In 1964, ARC engineers Howard A. Stine, Charles E. Shepard, and Velvin R. Watson submitted a patent for a breakthrough design for a high-enthalpy constricted-arc heater, which would become the basic design for all modern high-powered arc jets. Also in 1964, a new building (Building N-238) was constructed on the north side of the Gasdynamics Laboratory to house the Mach 50 Helium Tunnel. The building provided additional test bays for arc jet experimentation that connected to the SVS infrastructure. By 1965, ARC had a dozen arc jets that researchers could use to test ablative materials developed for space vehicle TPS (Bugos 2014:104). By 1970, the Mach 50 Helium Tunnel was removed, and the complex was mainly used for arc jet research. The facility's infrastructure was further upgraded to increase the power supply and the wind speeds in the SVS to better simulate high altitude atmospheric conditions (Bugos 2014:105).

The Arc Jet Complex has been instrumental in the development of every NASA Space Transportation and Planetary program including Mercury, Apollo, SSP, Viking, Pioneer-Venus, Galileo, Mars Pathfinder, Stardust, NASP, X-33, X-34, SHARP-B1 and B2, X-37, and Mars Exploration Rovers (NASA ARC n.d.). The complex has been involved in the three major areas of TPS development: selection of TPS materials; validation of TPS thermal models, heat shield designs, and repairs; and flight qualification. ARC led TPS research for the SSP supported by additional research conducted at Johnson Space Center and Langley.

ARC further improved its arc jets to simulate aerothermodynamic heating during entry into Earth's atmosphere in support of the SSP. Simulations require a few minutes to tens of minutes to test TPS in the hot gas flow environment, and ARC increased its capacity to tens of minutes. The IHF was constructed in 1972-73, and became operational in 1974. Its first formal test program was for the Space Shuttle in late 1976, and it was used exclusively to test reusable TPS for the Space Shuttle for several years. It was one of the highest-power arc jets ever constructed, and could test larger samples in both a stagnation and flat plate configuration (Page & Turnbull 2007:38). The IHF was "used for studies of aerodynamic heating in the thermal environment resulting from the interaction of a flow field with an irregular surface" (NASA ARC 1974:41, quoted in Page & Turnbull 2007:42). In 1975, Howard K. Larson, chief of the Ames Thermal Protection Branch, stated that ARC had NASA's largest collection of arc- or plasma-heated facilities with three of its major units dedicated to shuttle support, including the IHF that was "probably the highest-powered unit operating in the U. S." (Page & Turnbull 2007:38).

The IHF, located in Building N-238, was used to test different types of TPS, including the reinforced carbon-carbon system designated for the nose cap and wing leading edge of the shuttle, and the silica tile reusable surface insulation employed on the remainder of the vehicle. The capability of the facility to test a 2-foot by 2-foot section of TPS tile in conditions duplicating aeroconvective heating and reacting boundary layer chemistry during simulated entry conditions was a crucial element in the development of the Space Shuttle (Page & Turnbull 2007:39). ARC scientists developed concepts on the properties of TPS and produced TPS prototypes to be tested in the Arc Jet Complex. As a result of testing with arc jets, including the IHF, ARC scientists developed the TPS technology for the Space Shuttles, including materials known as LI-2200, FRCI, RCG, TUFI, and the Ames Gap Fillers (Page & Turnbull 2007:39).

Currently, the Thermo-Physics Facilities Branch operates the Arc Jet Complex. The mission of the Arc Jet Complex is:

> *Providing ground-based hyperthermal environments in support of the Nation's Research & Development activities in Thermal Protection Materials, Vehicle Structures, Aerothermodynamics, and Hypersonics.*

The Arc Jet Complex includes the AHF, the TFD, the PTF, and the IHF, whose magnitude and capacity "makes the Ames Arc Jet Complex unique in the world" (NASA ARC n.d.).

**SIGNIFICANCE**

The Arc Jet Complex is eligible for listing in the National Register at the national level of significance for its contributions in the areas of science and engineering related to arc jet research and development under Criterion A and Criterion C. The Arc Jet Complex is associated with scientific innovation and the development of arc jet and TPS technology. The unique high-powered arc jets in the Arc Jet Complex that simulated the aerothermodynamic conditions upon reentry into Earth's atmosphere to develop TPS technology have significant scientific and engineering associations.

The Arc Jet Complex is eligible under Criterion A for its association with advancements in arc jet technology and TPS for NASA's spaceflight programs, including the exceptional role of the 60-megawatt IHF arc jet in developing and refining TPS for the SSP. The period of significance extends from 1962, the year that the Gasdynamics Laboratory was completed, to 2011, the end of the SSP and NASA-directed manned spaceflight.

The property's contributions to science at a national level relate to the implementation of arc jets to test and develop TPS for the successful reentry of spacecraft related to every NASA Space Transportation and Planetary program, including Mercury, Apollo, the SSP, Viking, Pioneer-Venus, Galileo, Mars Pathfinder, MER, Stardust, NASP, X-33, X-34, SHARP-B1 and B2, X-37 WLE, CEV/Orion heatshield development, and the Mars Science Laboratory. The research and development of TPS for the SSP was specifically conducted in the IHF from 1976 to the end of the SSP. The contributions of this scientific research on TPS technology were integral to the success of the SSP.

The property is also significant for its role in the advancement of arc jet technology, and the innovations in engineering arc jets that occurred at the complex. Based on the development of arc jets in the complex, Stine, Shepard, and Watson patented what would become the standard design for high-enthalpy constricted-arc heaters, and the Arc Jet Complex set the benchmark for all modern high-powered arc jets around the world. In particular, the development of the IHF was significant as one of the highest-powered arc jets in the world with the capacity to test larger TPS materials for extended periods of time.

The Arc Jet Complex is also eligible under Criterion C for its unique design, engineering, and technological capabilities that represent significant innovations in arc jet technology, particularly the IHF. The period of significance ranges from 1962, the date of completion of the Gasdynamics Laboratory, to 1974, the date the IHF was constructed.

The property is significant at the national level for its contributions to engineering as it contains NASA's largest collection of arc- or plasma-heated facilities, including the IHF, which is important for its high-power capability of simulating atmospheric entry heating conditions. Arc jets developed in the complex have evolved since it was first constructed to meet the scientific needs for research on TPS. The technology was specifically designed to simulate aerothermodynamic heating during entry into Earth's atmosphere to scientifically study the potential effects of reentry on TPS materials. This capacity was pivotal in TPS development, and consequently in the success of spaceflight.

The design and operation of the IHF represented a major engineering achievement, and significantly contributed to the success of the SSP. The significance of the IHF (Building N-238) was previously evaluated according to NASA's guidelines published in *Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for listing in the National Register of Historic Places (NRHP)* (NASA 2006). Pursuant to these guidelines, to qualify for listing in the National Register within the context of the SSP, a property must be:

(1) real or personal property owned or controlled by NASA;
(2) constructed, modified, or used for the SSP between the years 1969 and 2011;
(3) classified as a structure, building, site, object, or district;
(4) eligible under one or more of the four National Register criteria;
(5) meet appropriate Criteria Considerations, and
(6) retain enough integrity to convey its historical significance.

The Arc Jet Complex is owned and controlled by NASA (1); was used for the SSP between the years 1969 and 2011 (2); is classified as a building (3); and is eligible under National Register Criteria A and C within the context of the SSP (4). NASA previously determined Building N-238, part of the Arc Jet Complex, eligible for the National Register under Criterion A within the SSP context (Page & Turnbull 2007), and the California State Historic Preservation Officer concurred in a letter dated May 8, 2007.

The Arc Jet Complex, as described above, is eligible for the National Register under Criteria A and C related to significant arc jet research and development and its unique contributions to NASA's Space Transportation and Planetary programs, including the SSP. The establishment of the SSP introduced a new era for the U.S. Space Program, which involved the use of reusable space flight vehicles. The Arc Jet Complex played a prominent role in the development and improvement of TPS for the Space Shuttle orbiter, which allowed the United States to achieve successful Space Shuttle missions and advance the country's space program.

The Arc Jet Complex relates to the SSP context as an Engineering and Administrative Facility (Property Type 7). As such, the Arc Jet Complex meets the significance criteria of the property type, because:

- It is a test facility directly associated with activities of significance which were associated with component testing and the implementation of the SSP;
- It is a place where persons who made lasting achievements to the SSP worked or convened; and
- It clearly embodies the distinctive characteristics of a type or method of construction.

Under Criterion A, a SSP property:

- Must be of significance in reflecting the important events associated with the SSP during the period of significance (1969–2011); or
- Must be distinguished as a place where significant program-level events occurred regarding the origins, operation and/or termination of the SSP.

The Arc Jet Complex is significant under Criterion A within the SSP context for its direct association with the development of TPS for the SSP. It played a key role in the research and design of TPS that was integral in the operation of the Space Shuttle. The arc jets in the complex, including the IHF, were the only facilities where Space Shuttle TPS was tested, allowing engineers to improve the safety and design of the Space Shuttle orbiter. Because the complex was the site of important events associated with the SSP and nationally significant program-level events regarding the origins and operation of the SSP, the Arc Jet Complex is eligible under Criterion A.

Under Criterion C, a SSP property:

- 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.

The Arc Jet Complex is also significant under Criterion C within the SSP context. Arc jets were designed and constructed for the purpose of simulating reentry conditions to test TPS, and the Arc Jet Complex clearly embodies the distinctive characteristics of a type or method of construction specifically designed for spacecraft materials testing, and has a direct association with the SSP. Designed by ARC engineers, the Arc Jet Complex is the only facility that simulated reentry conditions for the orbiter, and was essential in the development of TPS.

The Arc Jet Complex meets Criteria Consideration G for properties that have achieved significance within the past 50 years due to its exceptional significance within the context of the SSP (5). It is exceptionally significant within the context of the SSP for its contribution to the Space Shuttle by providing essential research on TPS from 1976 through the end of the SSP in 2011. The IHF is exceptionally significant for its simulation of atmospheric reentry to study TPS. As outlined in Section 7, the Arc Jet Complex retains its integrity of location, design, setting, materials, workmanship, feeling, and association to its period of significance (6).

Therefore, the Arc Jet Complex is eligible for the National Register under Criterion A and Criterion C related to significant arc jet research and development and its unique contributions to NASA's Space Transportation and Planetary programs, and meets Criteria Consideration G for its exceptional significance related to the SSP. The property retains integrity of location, design, setting, materials, workmanship, feeling, and association to convey its historical significance.

## HISTORIC CONTEXT

To relate the property to important themes in the history of national aerospace research, the following contexts describe the development of the National Advisory Committee for Aeronautics (NACA), NASA, ARC, and the SSP. This information illustrates the significance of the Arc Jet Complex as a unique property and the historical themes it represents.

### The NACA and NASA

NASA originated from the National Advisory Committee for Aeronautics (NACA). The NACA was created in 1915 as a civilian agency of the federal government (Rosholt 1966:3). Even after the first flight of Orville and Wilbur Wright in 1903, the United States failed to develop a long-term committed interest in aviation. Europeans, however, recognized the utility of aeronautics and promoted advancement and use of this new technology, particularly for military purposes. For example, at the start of World War I, thousands of aircraft existed in Europe but only 23 were in the United States (Chambers 2014:1). The Secretary of the Smithsonian Institution, Charles D. Wolcott, encouraged Congress to create an agency devoted to research and design in aeronautics. In 1915, Congress attached a rider to the Naval Appropriations Act to create the Advisory Committee for Aeronautics, modeled after a similar committee in England. At the first meeting, the committee renamed itself the NACA (Chambers 2014:1; Rosholt 1966:20). The President appointed 12 members to NACA, including members from the U.S. Army, U.S. Navy, the Smithsonian Institute, the National Bureau of Standards, and the Weather Bureau. The Committee reported directly to the President (Chambers 2014:1).

As war approached in Europe, the importance of the NACA grew. The number of personnel increased from 130 in 1925 to 300 in 1935. In 1939, Congress authorized a second research laboratory and a new laboratory was established at Naval Air Station Sunnyvale (Moffett Field) in California. The Lewis Flight Propulsion Laboratory in Cleveland, Ohio, was established in 1942 (Rosholt 1966:21). The work performed at these facilities contributed greatly to the air success of the Allies during World War II, which built on the aeronautical research done in the 1930s. During the war years, much of the NACA’s work focused on perfecting and improving existing aircraft based on information available at the time. After the war, the NACA was able to redirect its focus on advancing aeronautical research, including speed, high altitudes, and jet and rocket engines (Rosholt 1966:21). To aid in this research, the NACA built the Pilotless Aircraft Research Station at Wallops Island, Virginia, in 1945. This new facility was used for launching rockets. In 1947, the High Speed Flight Station was established at Edwards Air Force Base (AFB) in southern California (Rosholt 1966:21). Post-World War II research by the NACA contributed to the success of transonic and supersonic flight, particularly the flights of the X-I and the X-15 rocket research aircrafts (Rosholt 1966:21). By 1957, nearly 50 percent of the NACA’s work was devoted to space-related research.

In October 1957, Russia launched *Sputnik I*, the first artificial satellite to orbit Earth. In November of that year, Russia launched *Sputnik II*. In response, Congress held several hearings centered on developing a space program. In July 1958, President Eisenhower signed the National Aeronautics and Space Act (Van Nimmen et al. 1976:3). This act created NASA and arranged for the transfer of personnel, functions, and facilities from the NACA to NASA.

NASA officially began functioning on October 1, 1958. In its infancy, NASA focused on organizing itself, building a national program out of several existing programs to create a fully integrated research and development agency. This reorganization included: the transfer of the U.S. Department of Defense’s

(DOD) Advanced Research Projects Agency (ARPA); creation of the International Geophysical Year Satellite program, Vanguard; and establishment of the Army-owned Jet Propulsion Laboratory, operated by the California Institute of Technology in Pasadena (Van Nimmen et al. 1976:4).

Project Mercury, NASA's manned space flight program, was the agency's top priority and, by 1959, it made significant progress in its effort to send the first American into space orbit. That same year, NASA worked on scientific investigations in space and launched eight scientific Earth satellites and two lunar probes. It also developed engines, including the F-1, constructed tracking networks, and continued aeronautical research programs started by the NACA (Rosholt 1966:77). In November 1959, DOD transferred its Saturn rocket booster program from the ARPA to NASA (Rosholt 1966:1144).

Under the Eisenhower administration, NASA's programs competed with many of the President's other long-range national programs. The administration viewed NASA's progress as adequate and determined that no "space race" was being waged against the Soviet Union. This changed with the election of President John F. Kennedy, who very much believed in the "space race" and that the United States was losing. He wanted the situation reversed (Rosholt 1966:183–184). After the Soviet Union successfully sent a cosmonaut into space on April 12, 1961, President Kennedy gave the directive that NASA was to put a man on the moon within the decade. This accelerated NASA's Apollo program and substantially increased NASA's budget to accomplish Kennedy's goal (Van Nimmen et al. 1976:4). It also increased NASA's personnel by 50 percent from early 1962 to mid-1963. NASA hired nearly 18,000 new employees, mostly scientists, engineers, and aerospace professionals (Rosholt 1966:243–244).

In 1963, the successful Project Mercury was completed. All facilities and staff associated with the Mercury program turned their focus on the Gemini and Apollo programs (Rosholt 1966:247). During the early 1960s, NASA continued to make achievements in space science, research, and development.

**ARC**

In 1936, the Special Committee on the Relations of the NACA to National Defense in Time of War was established by the United States, in anticipation of potential international hostilities. The committee recommended a second NACA aeronautical laboratory to supplement the Langley Research Center (Langley), which the NACA established in Virginia 1917 as the first national civil aeronautics laboratory. A second laboratory was needed because of Langley's vulnerability to attack and its need for expansion (Hartman 1970:5-9; Muenger 1985:3). Langley was quickly outgrowing its facilities with a labor force that had grown from three employees in 1918 to almost 500 in 1938 (Muenger 1985:3). By late 1938, the NACA's Special Research Committee of Future Research Facilities was seeking a new site for the NACA's second aeronautical laboratory, and recommended Moffett Field between Mountain View and Sunnyvale, California, as the preferred location to the NACA's governing Executive Committee. In 1939, the NACA officially selected Moffett Field for its new site, and planning for new buildings and wind tunnels commenced with fervor at Langley (Hartman 1970:18, 25).

The NACA created its Western Coordination Office at Ames, led by Russell Robinson, as liaison between the new laboratory and the military, the aviation industry, and academic institutions. Defense-related aeronautical research was in high demand, and the purpose of the new laboratory, particularly its proposed wind tunnels, was to lead or supplement military and industrial research. The first NACA building constructed in 1940 was a utilitarian building that served as the construction office.

When the United States entered World War II in December 1941, research at Ames immediately shifted to solving specific problems with military aircraft assigned by the NACA to its laboratories. This research included testing military aircraft prototypes, evaluating aerodynamics and handling, and refining designs for immediate application (Hartman 1970:69–77; Muenger 1985:20–22).

In the post-war period, the government dedicated itself to maintaining the level of scientific and technological progress seen during World War II. As a result, Ames reverted to its progressive aeronautical research on a steady and encouraging platform of coordinated industrial and scientific interests and research efforts. In 1946, Robert Thomas (R.T.) Jones arrived at Ames from Langley. While at Langley, Jones produced the theory of sweepback to avoid high drag of straight wings at transonic speeds, but his findings were not publicized until they were confirmed by experimentation. At Ames, Jones continued to refine the narrow and swept-wing performance at supersonic and high-subsonic speeds (Vincenti 2001:145–149).

In the late 1940s, the NACA spearheaded the Unitary Plan, to unify and coordinate research and development among the national stakeholders in aeronautical research (Hartman 1970:150–151). Congress passed the Unitary Plan Act on October 27, 1949. The appropriations for the Unitary Plan allocated $75 million to each of the NACA laboratories for new facilities. At Ames, the Unitary Plan Wind Tunnel complex was designed and under construction by 1950, at a cost of $27 million. Completed in 1956, the complex was powered by a new power plant that generated up to 240,000 horsepower to operate three wind tunnels (Butowsky 1984; Muenger 1985:54). For versatility, three tunnels were constructed—an 11-by-11-foot transonic, a 9-by-7-foot supersonic, and an 8-by-7-foot supersonic wind tunnel—with 20-foot valves connecting them (Butowsky 1984). Eventually in the 1960s and 1970s, the Unitary Plan Wind Tunnel complex was used to test almost all crewed space vehicles (Butowsky 1984).

After Sputnik in 1957, the United States was propelled into the space age, and Ames along with the other NACA laboratories turned towards the technological challenges of space travel on the foundation of their long-standing aeronautical and aerodynamics research. The NACA sought to be the leader of the planned space agency, based on its dramatic discoveries and long-standing dedication to fundamental research, and as a service institution to serve industrial, military, and academic research. The NACA transitioned naturally to lead the newly formed NASA in 1958 (Muenger 1985:81–83).

**Development of Space Shuttle Program**

The idea of a reusable launch vehicle in space goes back as far as the early 1950s, when DOD explored such a concept for U.S. military operations. Over the next 10 years, efforts were made to determine the best technology to develop a vehicle that resembled a rocket, a spacecraft, and an airplane. Little further movement occurred until 1969, when President Richard Nixon created the Space Task Group, whose goal was to explore the future of NASA and its space program, ushering in a new era for space exploration. Three years later, after the task group recommended a new course for the Space Program, NASA's shuttle program (known as the Space Transportation System) officially was launched (Archaeological Consultants, Inc. 2008:2–1, 2; Science Applications International Corporation 2007).

The SSP operated from 1981 to 2011 as the U.S. government's manned launch vehicle program. When originally created, the SSP was meant to work with an International Space Station (ISS). However, delays in establishment of an ISS temporarily halted those plans. Despite this initial setback, NASA moved forward with its goal of creating a Space Shuttle orbiter. The proposed shuttle was unique in resembling a reusable manned space vehicle that would launch vertically into space like a rocket and land back on

Earth similar to an airplane. After launch, the Space Shuttle was to serve several purposes, including carrying and recovering large payloads into orbit, performing service missions, and providing crew rotations for the ISS after it was created. Each orbiter was to support a crew of four to seven astronauts and carry up to 65,000 pounds. The shuttle was to land at either Kennedy Space Center in Florida or Edwards AFB in California. When built, the shuttle had a projected lifespan of 100 launches or 10 years of operation (Archaeological Consultants, Inc. 2008:2-4; Dutton & Associates 2010:33).

In 1972, NASA awarded Rocketdyne Division of North American Rockwell a contract to develop and produce the Space Shuttle main engine. The manufacturing location was in Canoga Park, California, and test facilities were in California and Mississippi. For the next several years, tests were conducted on vehicle engine performance, vehicle components, and complete propulsion systems, as well as design and manufacturing techniques of the Space Shuttle orbiter (Archaeological Consultants, Inc. 2008:2-3).

By now, efforts were well underway to create a laboratory in space to be used together with the Space Shuttle. In September 1973, the European Space Agency and NASA agreed to design and develop a Spacelab. The lab was to be a manned, reusable, microgravity lab, flown in space at the rear of the Space Shuttle cargo bay. Construction was started in 1974, and the first space lab mission was in 1983, lasting nearly a year. Five Spacelab missions were flown between 1983 and 1985. NASA stopped missions briefly after the *Challenger* disaster but resumed the missions in 1990 (Archaeological Consultants, Inc. 2008:2-22).

During this period, NASA also was looking for an aircraft that could transport the orbiter vehicle across the country. In 1974, it awarded Boeing the contract after studies found the 747 could be effectively modified as an orbiter carrier. The altered 747 was put into service in 1977. Its first task was to move the test shuttle Enterprise to Edwards AFB (Archaeological Consultants, Inc. 2008:2-10).

Additional tests for the SSP took place in the ensuing years, as efforts continued to move the shuttle into service. Initial testing focused on the approach and landing phases of the shuttle as well as structural integrity. Testing was essentially complete by 1979, and led to significant but successful redesign of the orbiter. As development of the Space Shuttle was well underway, NASA's focus turned to manning the vehicle. In 1976, NASA recruited astronauts who would serve as pilots or mission specialists for the shuttle. Two years later, it selected a group of eight from candidates consisting of 21 military officers and 14 civilians. Within that group, 15 of the applicants were assigned to the position of pilots and 20 as mission specialists. The inaugural class included Sally Ride, the first woman in space; Guion Bluford, the first African-American in space; and Kathryn Sullivan, the first woman to complete a spacewalk (Archaeological Consultants, Inc. 2008:2-15).

Several orbiters were built under the SSP, including *Enterprise*, *Columbia*, *Challenger*, *Discovery*, *Atlantis*, and *Endeavor*. *Enterprise* was built as a prototype of the Space Shuttle orbiter and had its first flight in February 1977. The original name of *Enterprise* had been Constitution in honor of the Bicentennial, but later it was changed to *Enterprise* after Star Trek's Starship Enterprise. *Columbia* was the first successful launch of the manned spaceship and proved that the new technology was effective. *Columbia* carried a crew of two, Commander John W. Young and pilot Robert L. Crippen. After launching on April 12, 1981, *Columbia* landed without incident two days later at Edwards AFB. The launch showed that the shuttle could fly into orbit, conduct successful operations, and return safely. *Columbia* flew additional test flights through 1982. Space Shuttle *Challenger* joined the fleet in 1982, *Discovery* in 1983, and *Atlantis* in 1985. *Endeavor* was the last shuttle launched (1992) under the program. Between 1982 and 1985, *Columbia, Challenger, Discovery*, and *Atlantis* flew an average of four to five launches per year. During their years of operations, the Space Shuttle orbiters flew various missions, including science missions with the Spacelab module, and the retrieval and repair of communication satellites. Nearly 80 percent of the missions landed at Edwards AFB in California (Archaeological Consultants, Inc. 2008:2-9, 2-14, 2-15; Page & Turnbull, Inc. 2007:III-5, 8, 114).

In 1983, NASA suffered a major setback with the *Challenger* disaster. On January 28, *Challenger* broke apart 73 seconds after lift-off with a crew of seven on-board. After the accident, the SSP was suspended for about two and a half years. A government committee, known as the Rogers Commission, investigated the incident and concluded that it was related to failure of a seal in the solid rocket booster. The commission also reviewed the overall SSP and determined the program was under significant strain and pressure to be successful, which further stressed its resources. Additional failures were found in management. As a result of the findings, focus shifted to redesign of the shuttles and astronaut gear. Also, some reorganization and decentralization of the program occurred. The flight schedule was reduced to fewer launches and some payloads were scrapped (Archaeological Consultants, Inc. 2008:2-16).

*Discovery* launched in September 1988, which marked a return to flight after a hiatus of 32 months in manned spaceflights following the *Challenger* disaster. The new shuttle *Endeavor* was completed in 1990, and its inaugural launch occurred in 1992. Improvements were made to the new shuttle, and NASA reduced its overall number of flights per year. NASA shifted most shuttle landings from Edwards AFB to Kennedy Space Center (Archaeological Consultants, Inc. 2008:2-15, 2-17, 2-18).

A total of 123 Space Shuttle missions took place from Kennedy Space Center between April 1981 and May 2008. Before the *Challenger* accident, between two to nine missions were flown each year. After 1988, NASA averaged six missions annually until the *Columbia* accident in 2003. The most productive years for the SSP were between 1992 and 1997, with approximately seven to eight annual missions (Archaeological Consultants, Inc.2008:2-18).

In more recent years, the shuttle was involved in several planetary and astronomy missions, including the Galileo probe to Jupiter; the development of the Hubble Space Telescope, which was launched in April 1990; the joint U.S./Russian Shuttle Mir Program (started in 1996); and the creation of the ISS in 1998. *Discovery* was the first mission to dock with the ISS in 1999. After the ISS was launched, the Spacelab was retired mainly because all Spacelab experiments could now be carried out in the new ISS (Dutton & Associates 2010:33).

By 2000, Space Shuttle launches were mostly routine. However, on January 16, 2003, another tragedy struck the SSP. That morning, *Columbia* launched with a crew of seven. It was to return to Earth following a 16-day mission. Minutes prior to its touchdown at Kennedy Space Center, the spacecraft was lost during reentry over Texas, and all aboard died. Following the accident, an investigation was conducted, and it was determined the craft went down because of technical and management errors. A breach occurred in the thermal protection system on the leading edge of the left wing during liftoff that resulted in the destruction of the Space Shuttle orbiter on landing. NASA spent the next two years improving the safety of its Space Shuttles. Following a two-year hiatus, the launch of Orbiter *Discovery* in July 2005 marked the first return to flight. A year later, *Atlantis* was launched (Archaeological Consultants, Inc. 2008:2-24). Meanwhile in 2004, President George W. Bush announced that the SSP would be concluding. The shuttle was officially retired in August 2011, after *Atlantis* completed its last mission one month before (Archaeological Consultants, Inc. 2008:2-1).

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**Previous documentation on file (NPS):**

____ preliminary determination of individual listing (36 CFR 67) has been requested
____ previously listed in the National Register
_ _ _ previously determined eligible by the National Register
____designated a National Historic Landmark
____ recorded by Historic American Buildings Survey #___________
____recorded by Historic American Engineering Record # __________
____ recorded by Historic American Landscape Survey # ___________

**Primary location of additional data:**

____ State Historic Preservation Office
____ Other State agency
_X_ Federal agency
____ Local government
____ University
_X__ Other
Name of repository: National Archives, San Bruno, CA

**Historic Resources Survey Number (if assigned): ________________**

## 10. Geographical Data

**Acreage of Property** Less than 1 acre

**Latitude/Longitude Coordinates (decimal degrees)**
Datum if other than WGS84:__________
(enter coordinates to 6 decimal places)

1. Latitude: 37.418307 Longitude: -122.059453

**Verbal Boundary Description** (Describe the boundaries of the property.)

The boundary includes Building N-234, Building N-238, and the SVS.

**Boundary Justification** (Explain why the boundaries were selected.)

The boundary includes the buildings and structure that are historically associated with the Arc Jet Complex, are directly associated with the significance of the property, and maintain historic integrity. The boundary does not include adjacent facilities in Building N-234A (boiler), as these have auxiliary functions and are not directly associated with the significance of the complex.

## 11. Form Prepared By

name/title: Maria Katharina Meiser, Patricia Ambacher, and Madeline Bowen
organization: AECOM
street & number: 401 W. A Street, Suite 1200
city or town: San Diego state: CA zip code: 92101
e-mail: trina.meiser@aecom.com
telephone: 619-610-7600
date: September 2016

## Additional Documentation

Submit the following items with the completed form:

- **Maps:** A **USGS map** or equivalent (7.5 or 15 minute series) indicating the property's location.
- **Sketch map** for historic districts and properties having large acreage or numerous resources. Key all photographs to this map.
- **Additional items:** (Check with the SHPO, TPO, or FPO for any additional items.)

## Photographs

Submit clear and descriptive photographs. The size of each image must be 1600x1200 pixels (minimum), 3000x2000 preferred, at 300 ppi (pixels per inch) or larger. Key all photographs to the sketch map. Each photograph must be numbered and that number must correspond to the photograph number on the photo log. For simplicity, the name of the photographer, photo date, etc. may be listed once on the photograph log and doesn't need to be labeled on every photograph.

## Photo Log

| | |
|---|---|
| Name of Property: | Arc Jet Complex |
| City or Vicinity: | Moffett Field |
| County: | Santa Clara |
| State: | California |
| Photographer: | Maria Katharina Meiser |
| Date Photographed: | January 15 and May 6, 2016 |
| Location of Original Digital Files: | AECOM, 401 W. A Street, Suite 1200, San Diego, CA, 92101 |

Description of Photograph(s) and number, include description of view indicating direction of camera:

Photograph #1 (CA_Santa Clara County_Arc Jet Complex_0001)
Building N-234, south and east elevations, camera facing northwest.

Photograph #2 (CA_Santa Clara County_Arc Jet Complex_0002)
Building N-234, south elevation, camera facing north.

Photograph #3 (CA_Santa Clara County_Arc Jet Complex_0003)
Building N-234, windows, south elevation, camera facing northeast.

Photograph #4 (CA_Santa Clara County_Arc Jet Complex_0004)
Building N-234, main entrance, south elevation, camera facing north.

Photograph #5 (CA_Santa Clara County_Arc Jet Complex_0005)
Building N-234, east elevation, camera facing west.

Photograph #6 (CA_Santa Clara County_Arc Jet Complex_0006)
Building N-234, south and west elevations, camera facing northeast.

Photograph #7 (CA_Santa Clara County_Arc Jet Complex_0007)
Building N-234, north and west elevations, and the SVS (at left), camera facing southeast.

Photograph #8 (CA_Santa Clara County_Arc Jet Complex_0008)
Building N-234, test bays with arc jet facilities, interior, camera facing west.

Photograph #9 (CA_Santa Clara County_Arc Jet Complex_0009)
Building N-234, control room, interior, camera facing northwest.

Photograph #10 (CA_Santa Clara County_Arc Jet Complex_0010)
Building N-238, north and east elevations, camera facing southwest.

Photograph #11 (CA_Santa Clara County_Arc Jet Complex_0011)
Building N-238, north and west elevations, camera facing southeast.

Photograph #12 (CA_Santa Clara County_Arc Jet Complex_0012)
Building N-238, main entrance, north elevation, camera facing south.

Photograph #13 (CA_Santa Clara County_Arc Jet Complex_0013)
Building N-238, east elevation, camera facing southeast.

Photograph #14 (CA_Santa Clara County_Arc Jet Complex_0014)
Building N-238, north and west elevations, camera facing southeast.

Photograph #15 (CA_Santa Clara County_Arc Jet Complex_0015)
Building N-238, test bays with equipment, interior, camera facing southeast.

Photograph #16 (CA_Santa Clara County_Arc Jet Complex_0016)
Building N-238, the IHF (exterior), camera facing southeast.

Photograph #17 (CA_Santa Clara County_Arc Jet Complex_0017)
Building N-238, the IHF (interior), camera facing southwest.

Photograph #18 (CA_Santa Clara County_Arc Jet Complex_0018)
Building N-238, control room, interior, camera facing east.

Photograph #19 (CA_Santa Clara County_Arc Jet Complex_0019)
The SVS, west side, camera facing northeast.

Photograph #20 (CA_Santa Clara County_Arc Jet Complex_0020)
The SVS, east side, camera facing west.

Photograph #21 (CA_Santa Clara County_Arc Jet Complex_0021)
Cooling towers connected to the SVS, camera facing northwest.

**Figure 1. Location Map**

Latitude: 37.418307 Longitude: -122.059453

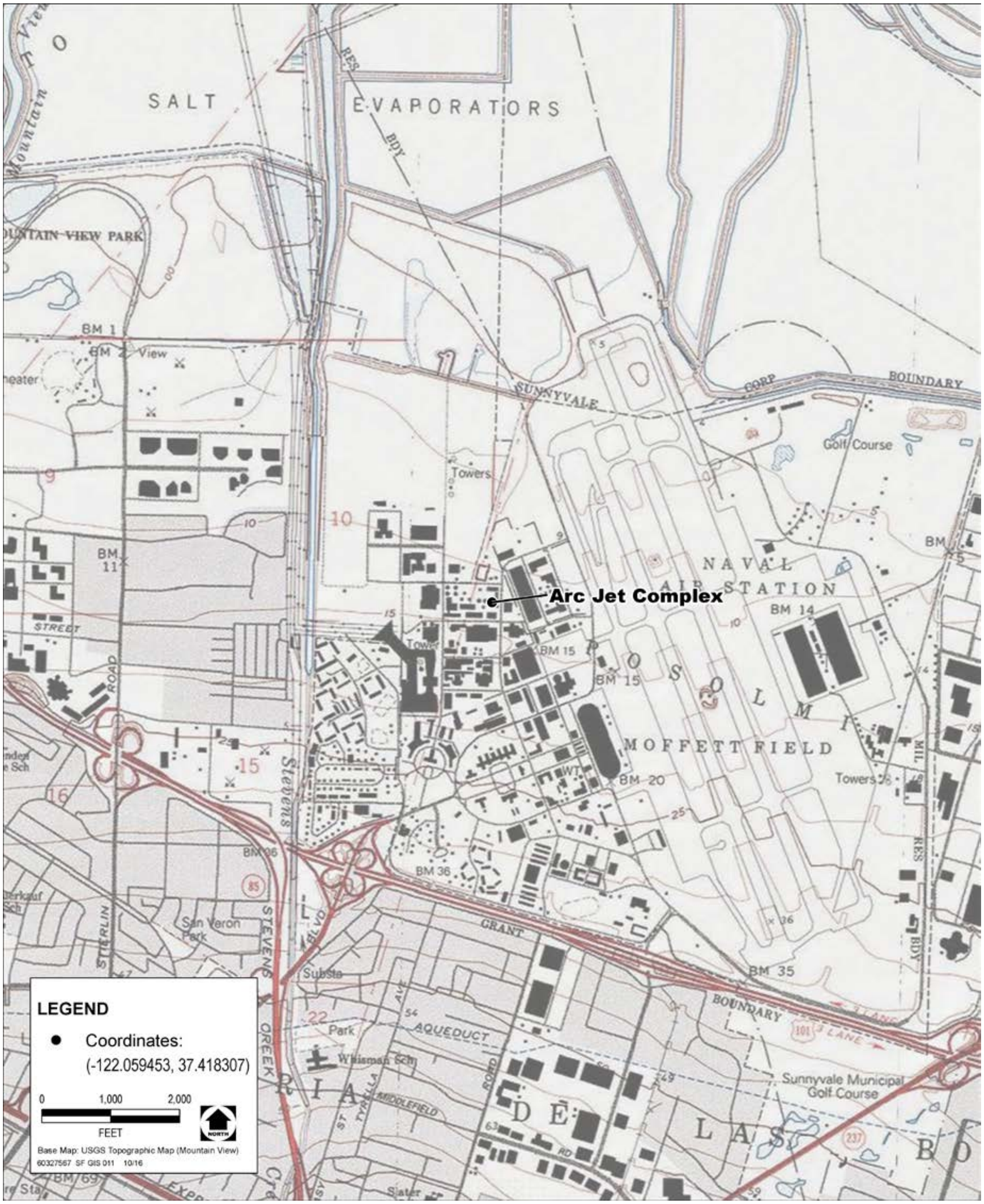

**Figure 2. Boundary Map**