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Room 2045, Building 19
NASA Ames Research Center
Moffett Field, CA 94035-1000
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Project name:
VMS OTW Cockpit Visual Infrastructure Project

Project reference:
60640340.0002

To:
Jonathan Ikan
Cultural Resources Manager
NASA Ames Research Center
Moffett Field, CA 94035-1000

From:
Trina Meiser, Senior Architectural Historian

Date:
October 30, 2020

CC:
Fabian Bonaldi, AECOM

Memo

Subject: Section 106 Consultation on the Restore Reliability of Vertical Motion Simulator (VMS) Out-the-Window (OTW) Cockpit Visual Infrastructure Fiscal Year (FY) 20 to FY22 Project, NASA Ames Research Center, Moffett Field, Santa Clara County, California

1. Introduction

The National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) proposes the Restore Reliability of the VMS OTW Cockpit Visual Infrastructure FY20 to FY22 Project (project or undertaking) at NASA ARC, Moffett Field, Santa Clara County, California. As the lead federal agency, NASA is responsible for compliance with Section 106 of the National Historic Preservation Act of 1966 (54 United States Code § 306108), as amended, which requires federal agencies to take into account the effects of their activities and programs on historic properties, and its implementing regulations in 36 Code of Federal Regulations (CFR) Part 800. The purpose of this memorandum is to provide necessary information for compliance with Section 106, including a description of the undertaking and the Area of Potential Effects (APE), the methodology used to identify and evaluate historic properties within the APE, a description of the affected historic properties, and an assessment of potential effects resulting from the undertaking.

1.1 Project Location

The project site is within the NASA Ames Campus at NASA ARC, Moffett Field, Santa Clara County, California (Figures 1 and 2 in Appendix A). The project is located in Building N243, which is the Flight and Guidance Simulation Laboratory, southeast of the intersection of King Road and Cooper Loop (Figure 3 in Appendix A).

1.2 Project Personnel

This study was conducted by cultural resources professionals who meet the Secretary of the Interior's Professional Qualifications Standards (48 Federal Register 44738). Trina Meiser, M.A., Senior Architectural Historian, served as the Principal Investigator; Lauren Downs, M.A., RPA, provided map figures; and Kirsten Johnson, M.A., served as the lead verifier of this document.

2. Description of the Undertaking

The project involves updating the VMS in Building N243, which is a type of activity that could cause an effect on a historic property and is considered an undertaking per 36 CFR § 800.3(a). Building N243 is listed in the National Register of Historic Places (NRHP) as the Flight and Guidance Simulation Laboratory, which is significant in part due to the VMS. The VMS is an apparatus in which operators are seated in an interchangeable cab (ICAB) with visual projectors that simulate the cockpits of aircraft or spacecraft for pilot/astronaut training purposes.

Currently, the ICAB OTW cockpit visual infrastructure is obsolete and partially inoperable. The existing Image Generator (IG), which produces the simulated imagery for the VMS, is currently within Room 242, approximately 500 feet away in the opposite end of the building from the VMS and the VMS Laboratory. The projection display systems used for visual scene presentation in the cockpits are outdated, with degraded image brightness and color fidelity that do not meet minimum standards for piloted flight simulation research. The OTW display systems currently employ a Wide-Angle-Collimated (WAC) optical projection package dating to the late 1970s with 4:3 aspect ratio cathode ray tube displays to simulate real world depth of field visual cueing. Outdated aspect ratio and display technology render the existing suite of WAC display systems incompatible with today's wide aspect ratio, high-definition display technologies. The existing video switch routing and distribution system also dates to the late 1970s, with analog Red, Sync on Green, Blue (RGsB) video formats, a degraded coaxial video cable plant, and distribution electronics that are nonoperational. Replacement or upgrade of these infrastructure components is required to maintain the ability to conduct piloted simulation research at VMS.

The project would relocate IG operations to Room 231, which is less than 100 feet from the VMS Laboratory to optimize infrastructure and improve performance. The video switching, projectors, and optics systems that distribute the imagery from the IG to the VMS would be upgraded to an all-digital infrastructure. The project would replace obsolete analog video switching components with modern digital and flexible video switchers and replace failed projectors and optics in all ICABs with modern projectors and optics. This would address issues with signal loss due to degraded, excessively long cable runs; outdated, degraded video switchers for which no replacement parts are available; and insufficient brightness levels and loss of color uniformity of obsolete and degraded projectors and optics. The purpose of the project is to restore reliability of the VMS with the installation of new equipment, increase operational efficiency by eliminating re-tuning each time an ICAB is set up or relocated, and enhance image fidelity with digital signals, resulting in a visual infrastructure compatible with modern and future video technologies.

The project would include:

- replacement of projectors for existing WAC and OTW display systems;
- consolidation and relocation of the existing analog video infrastructure to optimize performance and sustainability during migration to digital video infrastructure;
- replacement of legacy analog video switch routing, distribution, and post processing equipment with digital technology; and
- replacement of the WAC and OTW visual display systems with state-of-the-art digital visual technologies to support current and evolving high-definition display capabilities.

Additional information is provided in Appendix B.

3. Area of Potential Effects

The APE is defined to address both direct and indirect impacts on potential historic properties and encompasses areas that may be affected by both temporary and permanent construction activities. The project involves interior alterations that would not cause any type of ground disturbance; therefore, archaeological resources are not a concern and were not studied further. Activities are not anticipated to create visible, auditory, or atmospheric changes in the settings of adjacent historic properties; therefore, the APE is limited to the footprint of the Flight and Guidance Simulation Laboratory (Building N243) (Figure 4 in Appendix A).

4. Identification of Historic Properties

Historic properties are defined as any district, site, building, structure, or object that is included in or is eligible for listing in the NRHP. The APE includes the Flight and Guidance Simulation Laboratory, which was listed in the NRHP on January 11, 2017 (NR #100000469) (NRHP 2017). The NRHP nomination is included in Appendix C.

5. Affected Historic Properties

5.1 Flight and Guidance Simulation Laboratory (Building N243)

5.1.1 Property Description

Building N243 is a 108,670-square-foot Brutalist-style building at the southeast corner of King Road and Cooper Loop at ARC. The main portion of the building is a large rectangular form with a rounded southeast corner that is two stories tall with a basement level. A round, three-story circular wing (approximately 120 feet in diameter) is attached near the west end of the north elevation, and a five-story rectangular wing featuring several concrete buttresses and rounded southwest and southeast corners is attached to the south elevation. A seven-story concrete tower addition is attached to the east side of the main building and features a three-story-tall overhead steel door. The building elevations include several overhead steel warehouse doors and aluminum-framed doorways for personnel.

The VMS is within the seven-story addition, with a 110-foot-tall chamber and 60 feet of vertical and 40 feet of lateral motion capability. The basis of the motion system is a vertical platform that spans the width of the tower and is mounted on two columns that extend from 75-foot underground shafts (Plate 1). The vertical platform is restrained on both ends and in the center by wheel assemblies that ride along guide rails mounted to the tower walls. A lateral carriage mounted on the vertical platform provides horizontal motion. The lateral carriage is supported and restrained by wheel assemblies that ride along two guide rails attached to the top, front, and rear edges of the vertical platform. A detachable railing encircles the base structure for safety. The railing has an opening to accommodate a boarding ramp (Danek 1993:15–17).

The VMS uses ICABs to simulate the cockpits of aircraft and spacecraft, including helicopters, tilt-rotors, fighter jets, transport aircraft, supersonic transports, and the Space Shuttle orbiters (Plates 2 and 3). Five ICABs are currently used on the VMS. The ICABs are all constructed of lightweight welded aluminum. A single ICAB is mounted to the top of the VMS on a large, flat, aluminum base that serves as the floor of the ICAB. A fixed aluminum canopy is also mounted to the base, serves as the rear wall of the ICAB, and includes personnel and equipment access doors. Removable canopies enclose the equipment within the ICAB and serve as a barrier to exterior light and sound (Danek 1993:14–15).

Other associated features of the VMS include the host computers, interfaces, test operations and control, and cueing systems. The host computers solve the equations that represent the mathematical model of the aircraft, perform all the computations needed to command and control the other parts of the system, and allow the pilot to interact with the simulator in real time. Interfaces serve as communication paths between the host computers and other elements of the simulation system. Test operations and control are located within the VMS Laboratory, a work area for personnel who conduct and direct simulations that includes operating and control consoles and other testing and monitoring equipment (Plate 4). Cueing systems generate and present sensory stimuli to the pilot. All these associated features are housed within Building N243 (Danek 1993:1–3).

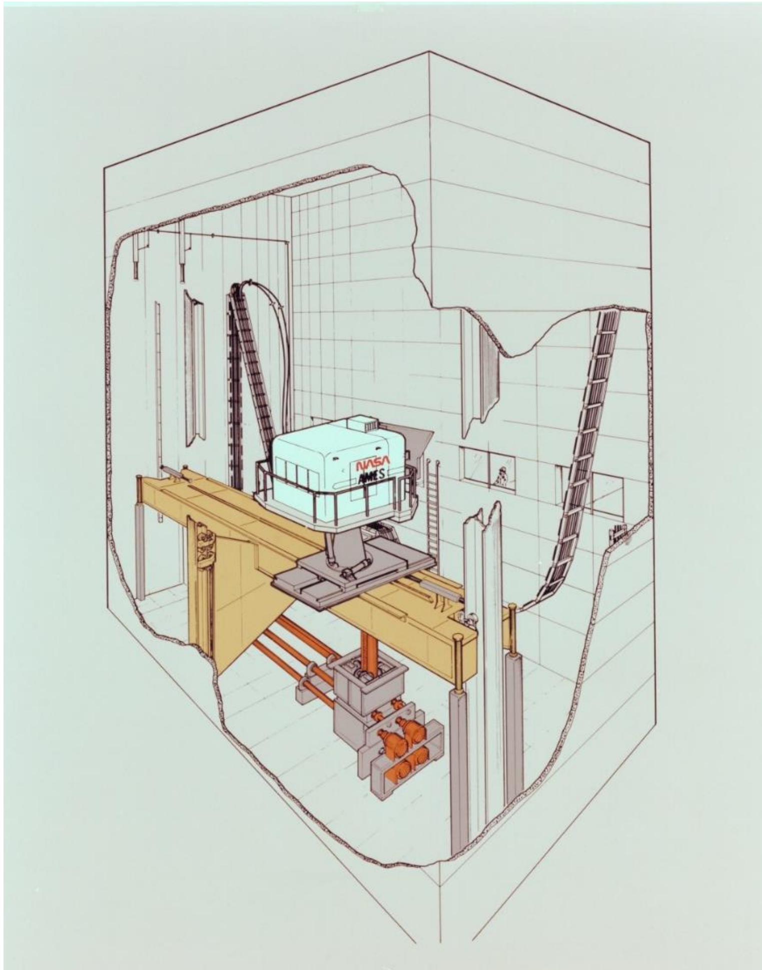


Plate 1. Cutaway rendering of the VMS

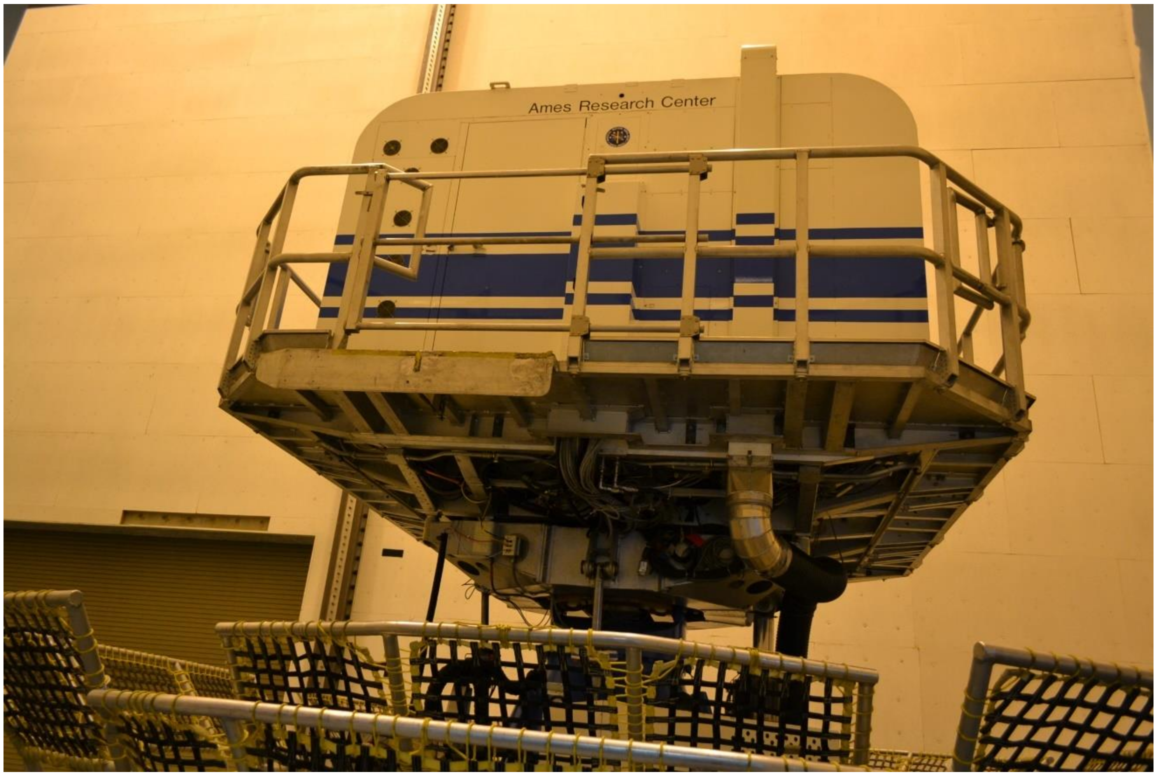


Plate 2. ICAB mounted in the VMS

Plate 3. ICAB interior showing simulation display monitors

Plate 4. VMS Laboratory

5.1.2 Property Significance

The Flight and Guidance Simulation Laboratory was listed in the NRHP at the national level of significance for its contributions in the areas of science and engineering related to the Space Shuttle Program (SSP) as a resource associated with the training of astronauts. The property is eligible under Criterion A for its association with training pilots and testing component features of the SSP, and under Criterion C for the design and engineering of the VMS, which is the world's largest motion-based simulator and widely regarded as the best simulator during its time for its engineering design and role in Space Shuttle pilot training. The property meets Criteria Consideration G for properties that have achieved significance within the past 50 years because of its exceptional significance within the context of the SSP for its contribution to the advancement of the SSP and the development and operation of the Space Shuttle orbiter by providing research and essential astronaut training in an accurately simulated orbiter. The period of significance is 1967 to 2011. NASA previously determined Building N243 is eligible for the NRHP under Criterion A and Criteria Consideration G, and the California State Historic Preservation Officer concurred in a letter dated May 8, 2007.

Building N243 was designed by Skidmore, Owings & Merrill and completed in 1967. Originally the Space Flight Guidance Research Laboratory, the building housed simulators for flight training. In 1979, NASA constructed a seven-story concrete tower addition, designed by the architectural and design firm of Anshen & Allen, on the east side of Building N243 to house the VMS. The VMS, which started operation in April 1980, is the world's largest motion-base simulator. The simulator was a significant part of pilot training for the SSP because it not only allowed for system improvements, but also exposed pilots and NASA engineers to a wide array of conceivable failures that could take place during spacecraft take-offs and landings, such as blown tires, crosswinds, or failed auxiliary power units (Page & Turnbull 2007:III-11).

The VMS was widely regarded as the best simulator during its time for its role in engineering design and pilot training. Nearly every pilot astronaut in the SSP trained with the VMS, in over 65,000 simulated landings, rollout trainings, and engineering evaluations. Astronauts and the engineering designers from Johnson Space Center and ARC all collaborated to improve the safety and operation capabilities of the Space Shuttle. Nose wheel steering, brakes, Multifunction Electronic Display System (MEDS) (glass cockpit), drag parachute engineering, flight control automation for the Extended Duration Orbiter (EDO) (which involved microgravity research), and "return to flight" studies following the 1986 *Challenger* accident were among those features NASA redesigned as a result of VMS training. In addition, more than 80 VMS engineering studies led to 20 flight rule modifications for the Space Shuttle (Beard et al. n.d.:2, 15; Page & Turnbull 2007:IV-61, IV-62).

NASA used the VMS twice a year to research the landing and rollout of the Space Shuttle orbiter. The VMS was unique because it featured a high-fidelity cockpit and visual aids that mimicked the motion and visual environment of the orbiter. It could provide the pilot with the most realistic sense of a true orbiter experience by simulating the final descent and landing of the orbiter, and all testing involving these procedures was validated by the VMS. The simulator was involved in tire wear, brakes, drag-and-chute design, and crew evaluation and testing. It also made important contributions to development of head-up display symbology, determination of wind, visibility, and ceiling limits, and landing of the orbiter as it was carried atop a Boeing 747 aircraft (Page & Turnbull 2007:iii-10).

The VMS remained a viable part of the SSP for decades because it could be customized for various testing scenarios by upgrades to hardware and software, frequently made to accommodate any improvements or modification in the SSP. The VMS operated as part of the SSP until 2011 and continues to be used in training and research for the aerospace community as a general aircraft flight simulator (Beard et al. n.d.:15).

6. Assessment of Effects

The Criteria of Adverse Effect pursuant to 36 CFR § 800.5(a)(1) are applied to assess effects of the undertaking on historic properties within the APE:

> (1) Criteria of adverse effect. An adverse effect is found when an undertaking may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the NRHP in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Consideration shall be given to all qualifying characteristics of a historic property, including those that may have been identified subsequent to the original evaluation of the property's eligibility for the NRHP. Adverse effects may include reasonably foreseeable effects caused by the undertaking that may occur later in time, be farther removed in distance, or be cumulative.

The project would directly alter the VMS, a significant characteristic of the Flight and Guidance Simulation Laboratory (Building N243) for which it qualifies for the NRHP under Criterion C. The project proposes to relocate the IG, replace analog equipment with digital equipment, and replace the video displays for VMS operations. These alterations would allow the property to continue to be used for its historic purpose, retain the historic character of the property, and maintain reference to historic significance of the property's change over time. The alterations would not introduce conjectural historic features, apply chemical or physical treatments, or affect significant archaeological resources, and the alterations would be differentiated from original features and be compatible with the property. However, the project activities would replace deteriorated equipment with modern equipment, and the changes would not be reversible for practical purposes.

The main consideration for the assessment of effects is whether the alteration of the VMS will diminish the integrity of the Flight and Guidance Simulation Laboratory. Therefore, the following assessment discusses each of the seven aspects of integrity related to the historic property.

Location. Building N243 would remain in its original location at the southeast corner of King Road and Cooper Loop at ARC, and the VMS would remain within the building's seven-story tower. Although VMS equipment would be moved from Room 242 to Room 231, the equipment would remain within Building N243, and the project would not significantly diminish this aspect of integrity.

Design. Building N243 was built in 1967 and the seven-story addition that houses the VMS was constructed in 1969. The exterior of Building N243, which reflects the Brutalist style, would not be affected by the project. Although changes have substantially altered the interior of the building, including the conversion of some testing areas to offices, it retains most of its original floorplan. The project proposes interior relocation and upgrades of equipment used for the VMS but would not result in any changes to Building N243's floorplan. The overall design of the VMS would remain intact, including the mechanical aspects of the VMS within the tower that create the physical vertical motion simulation. The standard design of the ICABs would change as a result of the project to accommodate the cutting-edge digital configuration for visual simulation; however, the interchangeable and evolving nature of the ICABs is, and has historically been, integral to the VMS's original design. Overall, the design of the VMS would remain intact and continue to be a significant characteristic of Building N243. The project would not significantly diminish the integrity of Building N243's design.

Setting. The project is limited to interior changes and would have no effect on the integrity of Building N243's setting, which has changed minimally since 1969.

Materials. Building N243 has undergone minimal changes to its exterior. Interior finishes are also intact, with the exception of the previous removal of original simulation equipment. The project would relocate or replace visual infrastructure components of the VMS, which includes some original equipment, including cables, wiring, distribution switches, and monitors that date to the period of significance defined for the VMS (1967 to 2011). Materials for electrical and digital distribution, such as wiring and cables, would be replaced with similar materials. Obsolete materials, including analog switches and monitors, would be replaced with upgraded versions. The modernization of the visual infrastructure to meet both current and future digital standards would allow continued simulation research at VMS and maintenance of its historic purpose. Other materials that make up the mechanical portion of the VMS that produce the physical simulation would not be altered. New ICABs would use modern materials and configurations (see Appendix B for rendering of new ICAB concept), but the existing ICABs would also be retained, including SSP-related ICABs. Overall, the project would not substantially diminish the integrity of Building N243's materials.

Workmanship. The project would have no effect on Building N243's exterior workmanship, which reflects the building's integrity related to its architectural significance. The equipment within the interior of Building N243 has undergone modifications over time to keep pace with mission needs. The proposed project would involve similar changes to continue use of the VMS as a large amplitude simulator. These changes are necessary to continue the building's use as a state-of-the-art laboratory and the portions of the building constructed to house the VMS would remain intact. Overall, the project would not diminish the integrity of Building N243's workmanship.

Feeling. Building N243 retains the feeling of a Brutalist-style, highly technical laboratory for specialized scientific experimentation. It retains integrity in its historic sense of place or feeling. Changes to the VMS would have minimal impact on the interior feeling of the laboratory. The VMS would be upgraded to enhance and improve its continued use as a large amplitude simulator. The project would not diminish the integrity of Building N243's feeling.

Association. Building N243 has continuously functioned according to its original purpose as an aircraft and spacecraft simulator facility since its inception, including significant technological advancements related to the safety, design, and operation of the Space Shuttle and as a location where most of the SSP astronauts completed training. Changes to the VMS would not alter the association; therefore, the project would not diminish the integrity of Building N243's association.

In summary, the VMS and Building N243 would retain integrity of location, design, setting, materials, workmanship, feeling, and association after implementation of the project. The continued function of the VMS as a large amplitude simulator for pilot and astronaut training align with the VMS's historical associations, and its improvement will reflect the changing nature of a highly technical facility as addressed in the Advisory Council for Historic Preservation's 1991 Program Comment *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities* (ACHP 1991).

7. Summary of Findings

The APE for this undertaking was limited to the footprint of Building N243, the Flight and Guidance Simulation Laboratory, which is listed in the NRHP. The project would directly alter the VMS, a significant characteristic of Building N243 for which it qualifies for the NRHP under Criterion C. The project was assessed under the criteria of adverse effect, and this study found that the changes to the VMS would not substantially diminish the integrity of Building N243's location, setting, design, materials, workmanship, feeling, or association. Therefore, the proposed undertaking would have no adverse effects on the historic property per 36 CFR § 800.5(b). A finding of No Adverse Effect is recommended.

8. References

Advisory Council for Historic Preservation (ACHP), 1991. *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities.* Excerpts available online at http://www.achp.gov/balancingsum.html.

Beard, Stephen D., et al. n.d. The NASA Ames Vertical Motion Simulator – A Facility Engineered for Realism. Abstract prepared for the Royal Aeronautical Society Spring 2009 Flight Simulation Conference, London, UK. June 3-4, 2009. Prepared by Stephen D. Beard, Birnal L. Aponso, and Jeffery A. Schroeder, NASA Ames Research Center, Moffett Field, CA.

Danek, George L. 1993. Vertical Motion Simulator Familiarization Guide. National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

National Register of Historic Places (NRHP), 2017. Flight and Guidance Simulation Laboratory, Moffett Field, Santa Clara County, California, NRHP # 100000469. Included in Appendix C.

Page & Turnbull, 2007. *Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center*. On file at ARC.

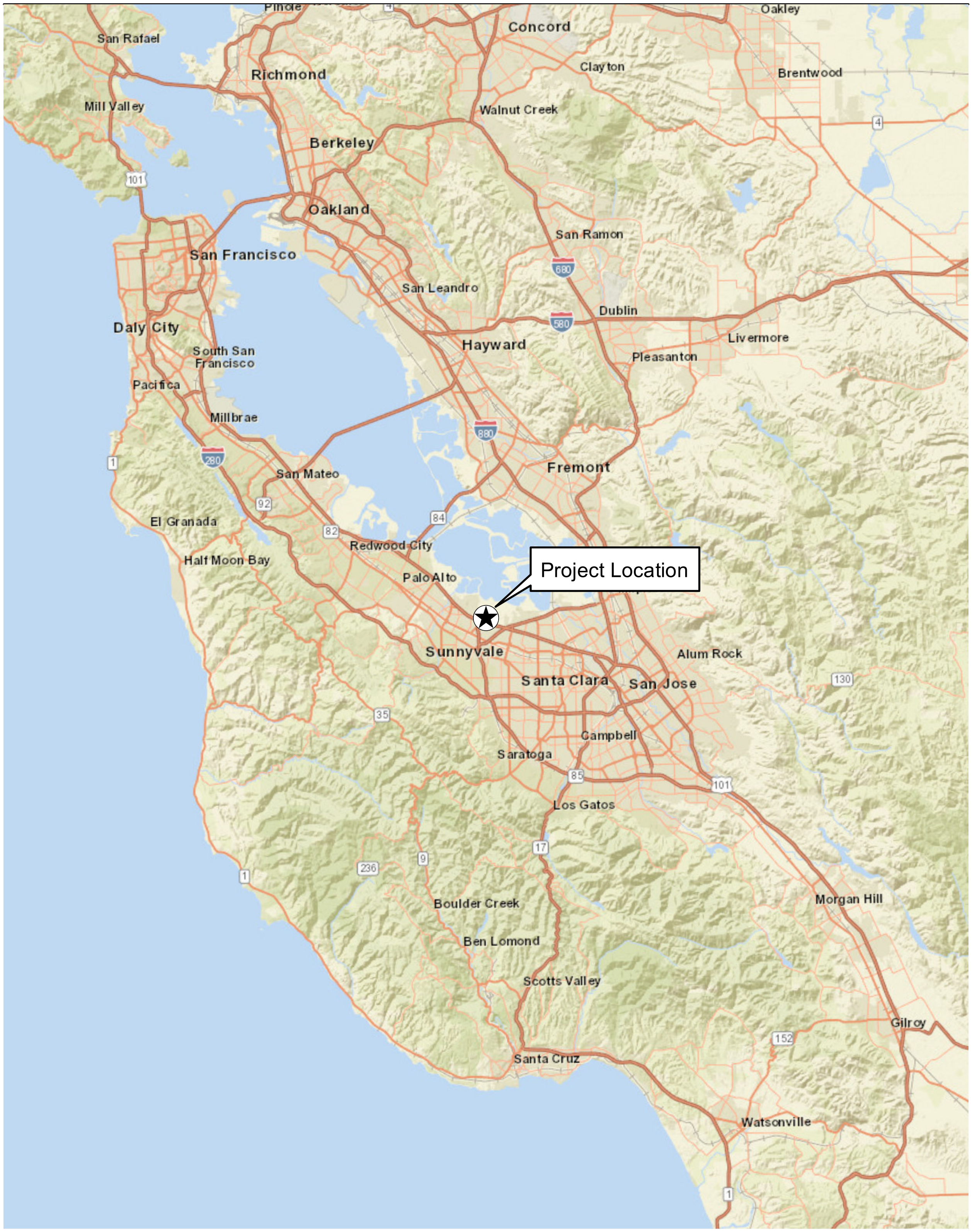
Appendices

A. Figures

B. Project Exhibits

C. NRHP Nomination

Appendix A – Figures



Source: ESRI, AECOM, NASA

0 5 10 20 Miles

Scale: 1 = 633,600; 1 inch = 10 mile(s)

Figure 1
Project Location

VMS OTW Cockpit Visual Infrastructure Project

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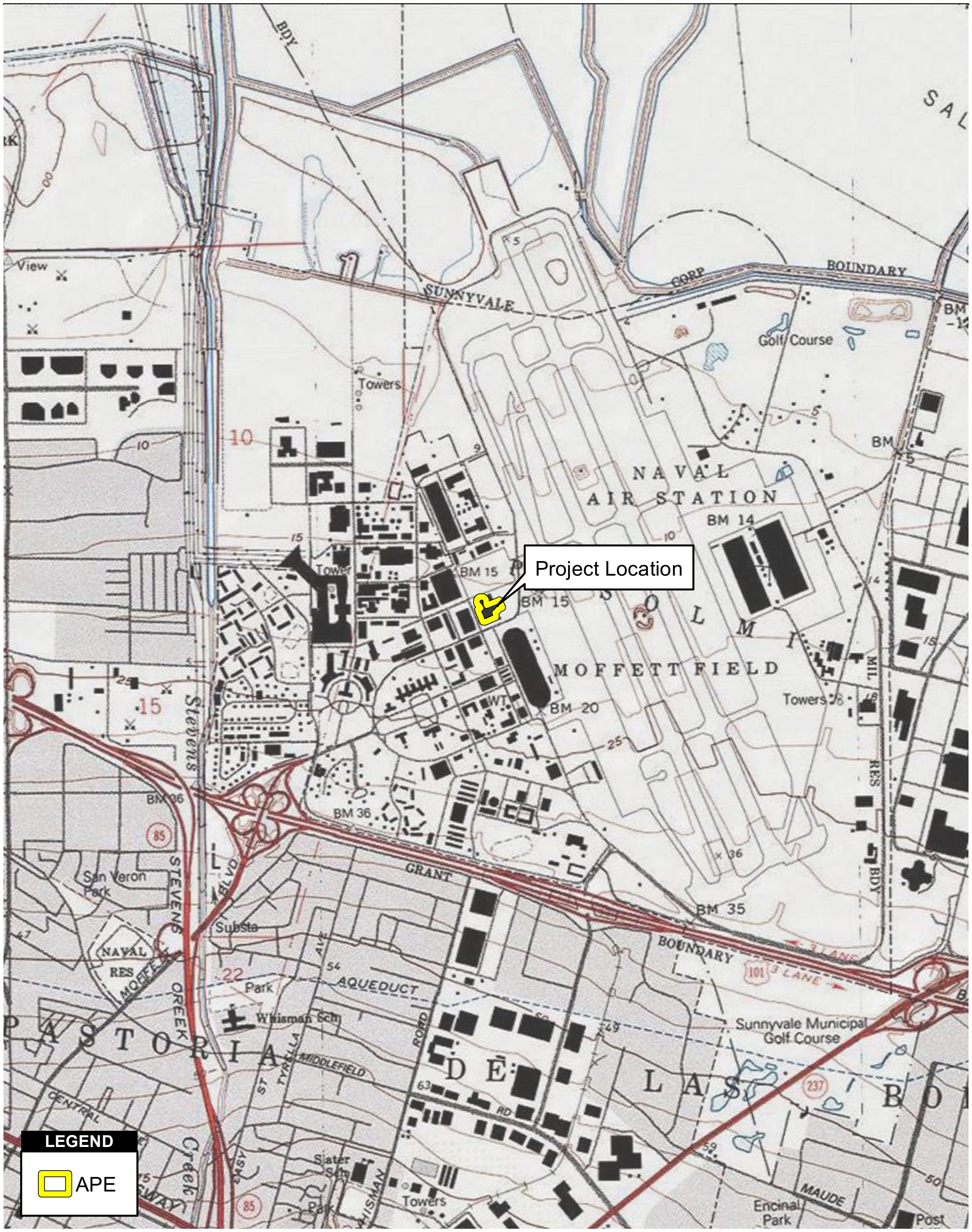
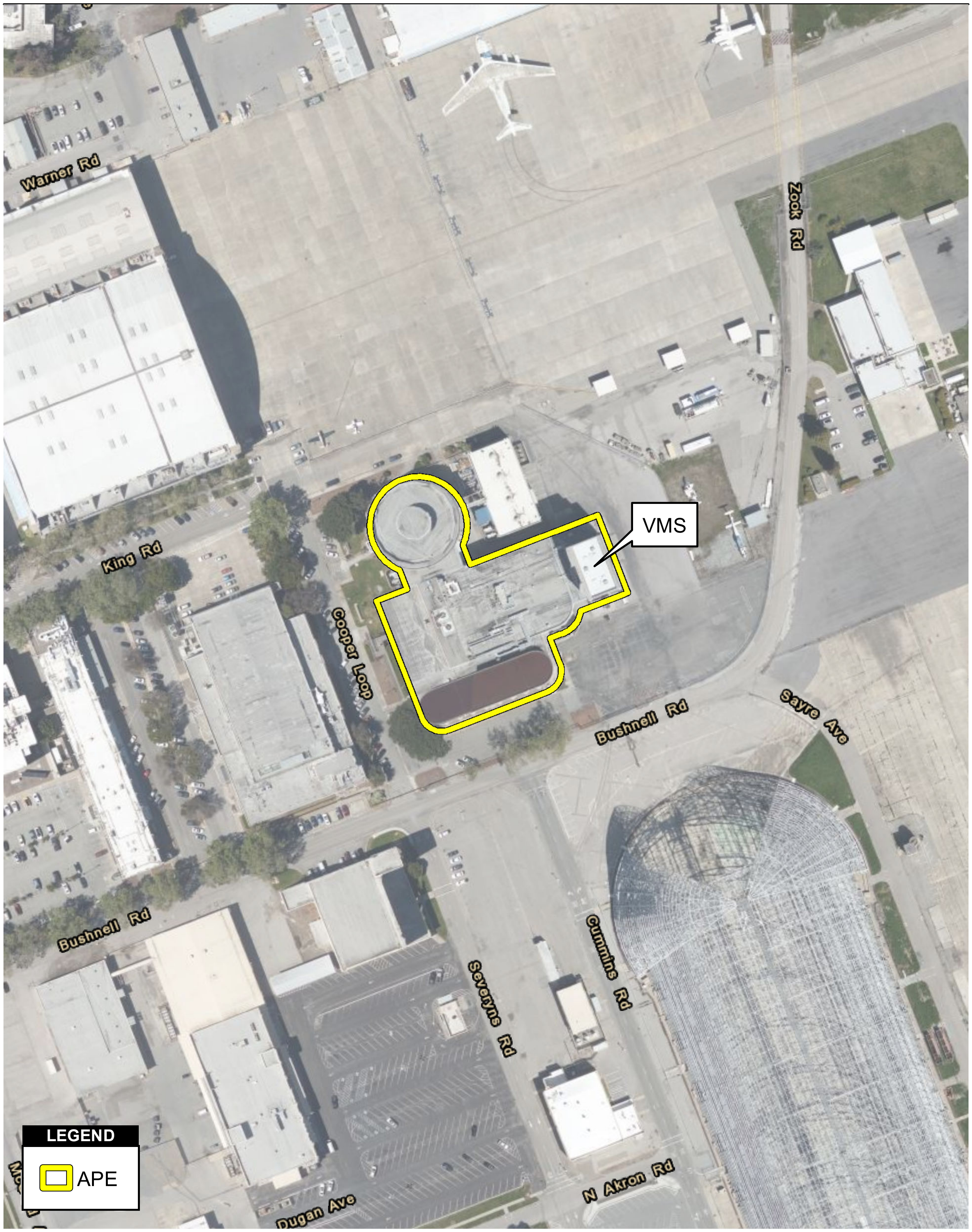


Source: ESRI, AECOM, NASA, National Geographic Society; USGS 7.5' Topographic Quadrangle: Mountain View

0 1,000 2,000 4,000 Feet

Scale: 1 = 24,000; 1 inch = 2,000 feet

Figure 2
Project Vicinity Map



Source: ESRI, AECOM, NASA

0 100 200 400 Feet

Scale: 1 = 2,400; 1 inch = 200 feet

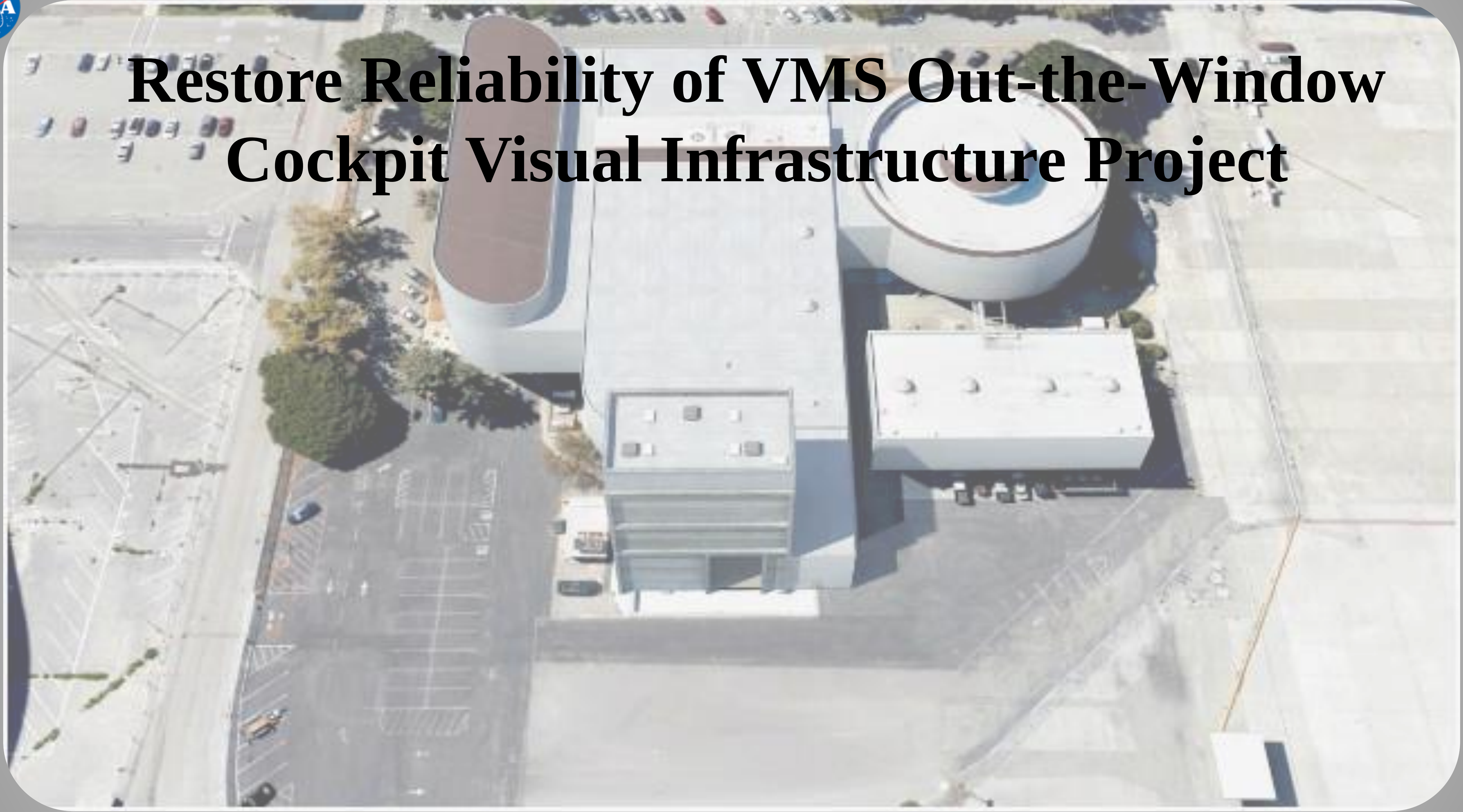
Figure 3
APE Map

The following content was redacted from this public posting:

Figure 4
Building N243, 2nd Floor Plan

Appendix B – Project Exhibits

Restore Reliability of VMS Out-the-Window Cockpit Visual Infrastructure Project



SimLabs Facilities

Unique facilities capable of a wide range of aerospace systems research

VMS	FFC	CVSRF

Vertical Motion Simulator (VMS)

The VMS is the world’s largest motion system for aircraft research

- **60 ft. vertical travel, 40 ft. lateral travel**
- **Six independent degrees-of-freedom**
- **Five Interchangeable Cabs**

VMS NOMINAL OPERATIONAL MOTION LIMITS

Axis	**Displacement** *(ft)*	**Velocity** *(ft/sec)*	**Acceleration** *(ft/sec^2)*
Vertical	±30	16	24
Lateral	±20	8	16
Longitudinal	±4	4	10
	(deg)	*(deg/sec)*	*(deg/sec^2)*
Roll	±18	40	115
Pitch	±18	40	115
Yaw	±24	46	115

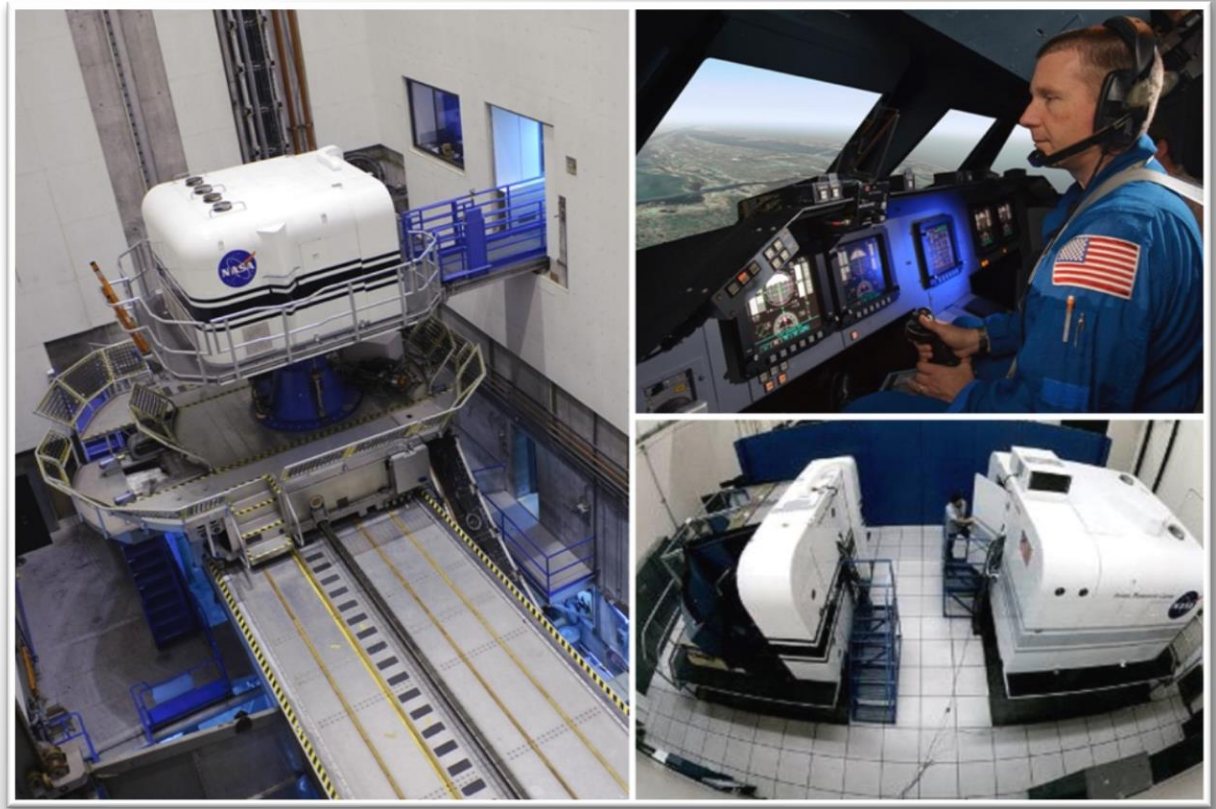
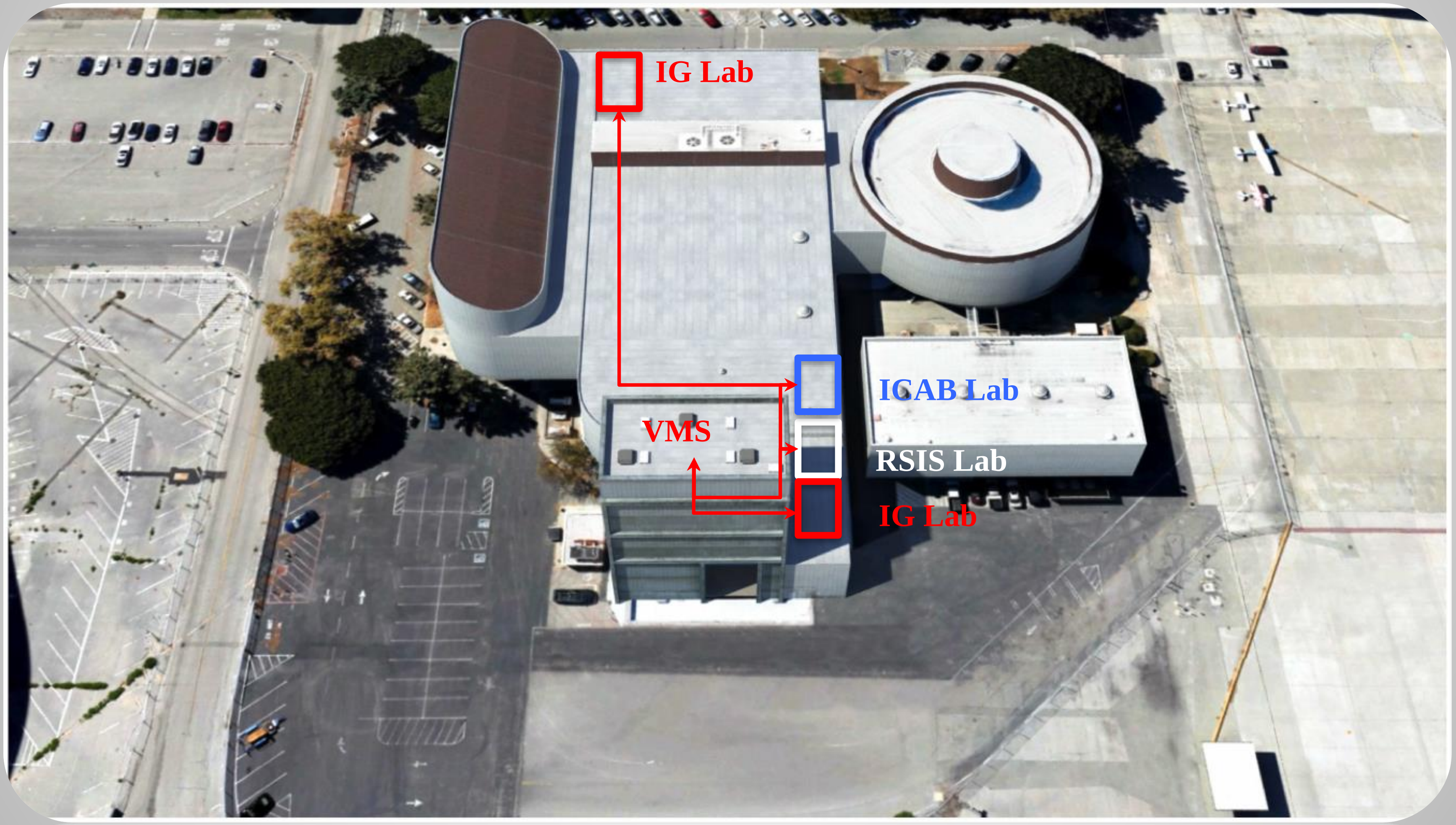


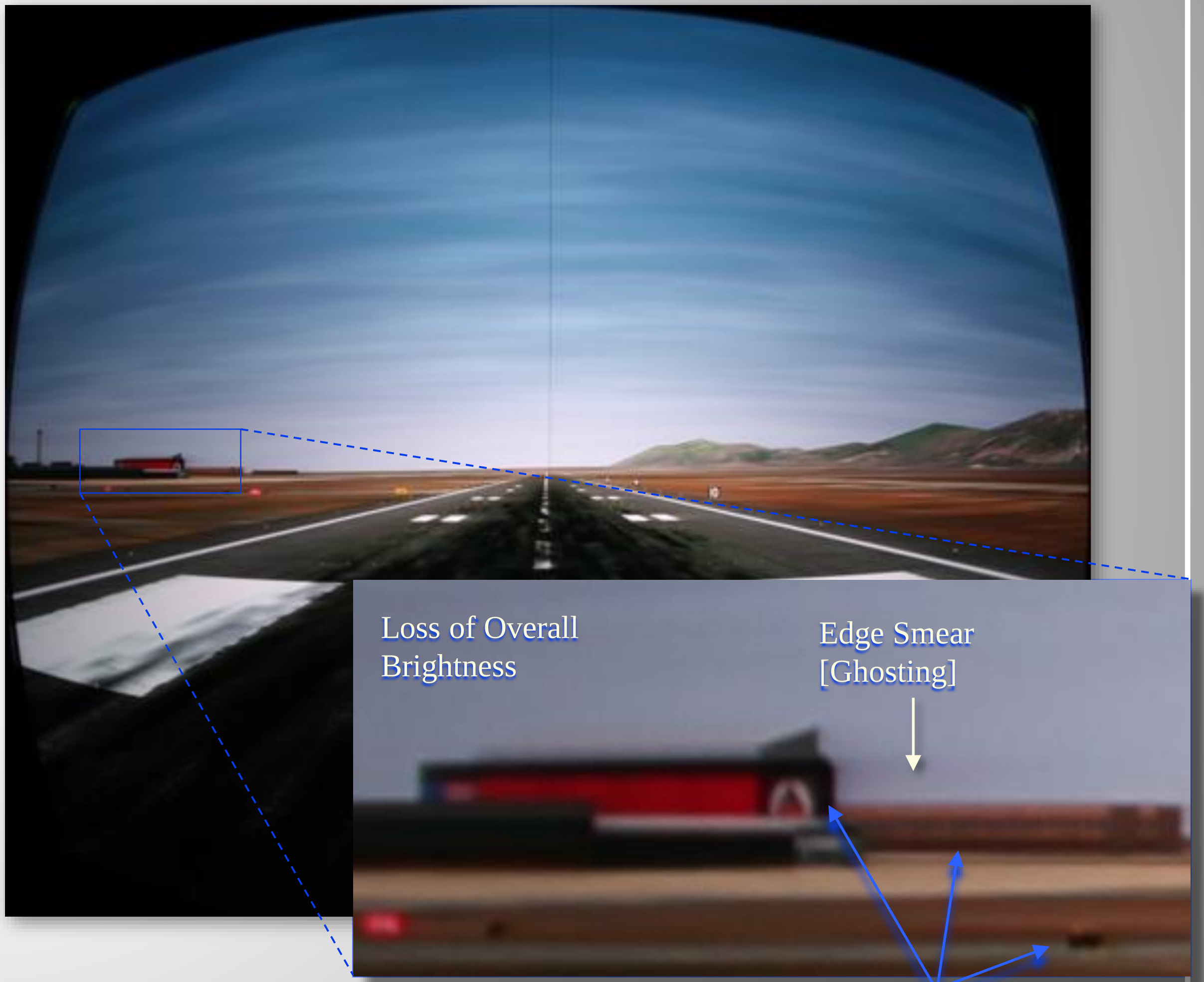
Image Generation Lab Relocation



Example of Video Signal Degradation Impact

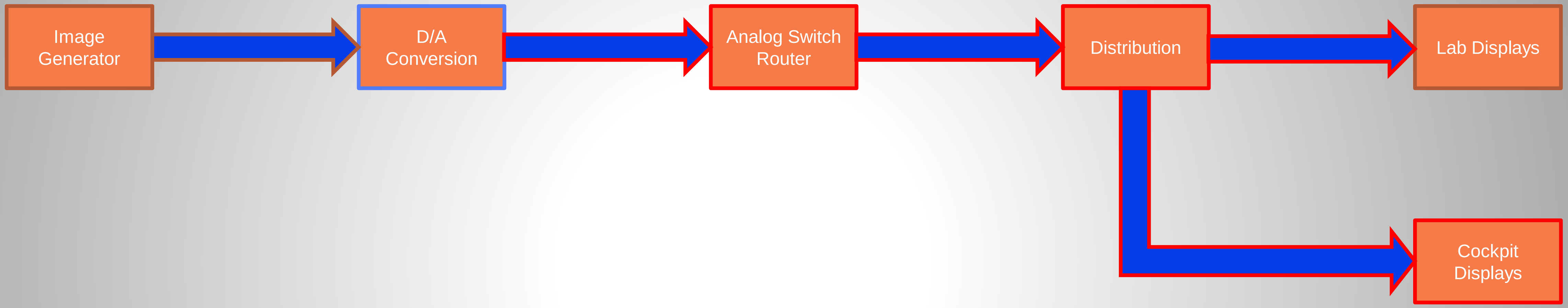
Source Image

Cockpit Display



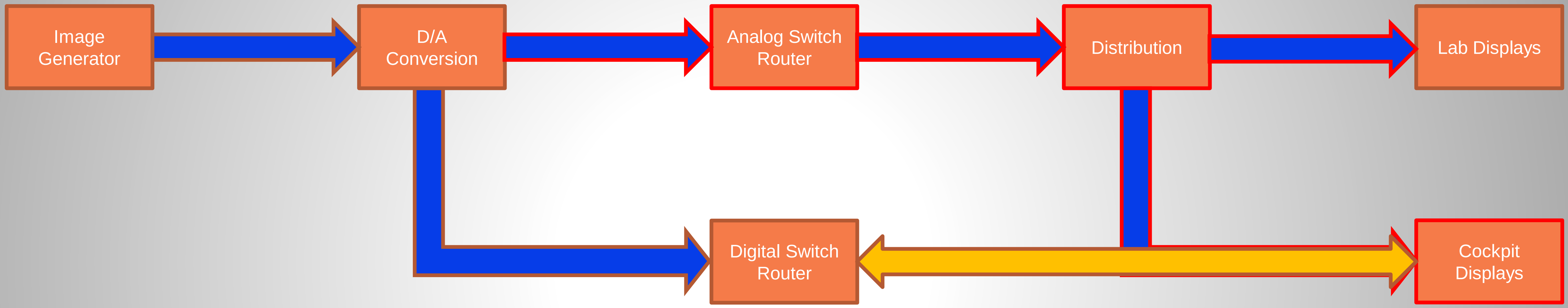
Both photos taken from the same display
Source Photo taken with display connected directly to EPX
Cockpit Photo taken with display mounted in ICAB

Analog Video Infrastructure Overview



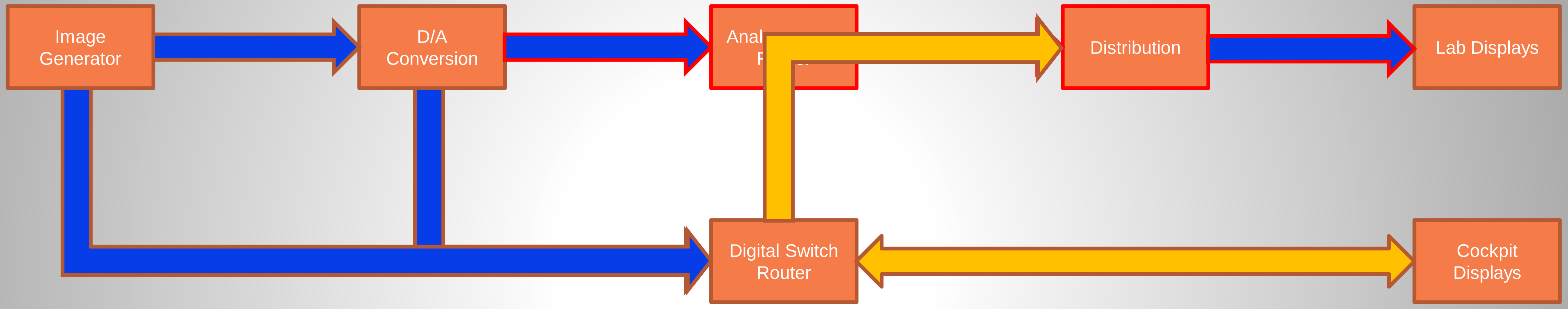
- Items Outlined in Red are as Risk
- Digital Video From IG Converted To Analog
- Converted Video Feeds Into Analog Video Switch Router
- Switch Router Directs Video To The Video Distribution System
- Video Distributed To Lab And Cockpit Displays

Transition Cockpit Video Infrastructure To Digital



- Install A Digital Video Switch Router In Parallel With Analog System
- Conversion D/A Buffered Loop-through Input Passes Digital Video Signal To Digital Switch Router Input
- Install Bi-directional Fiber Optic Cable Plant Between Cockpit And Digital Switch

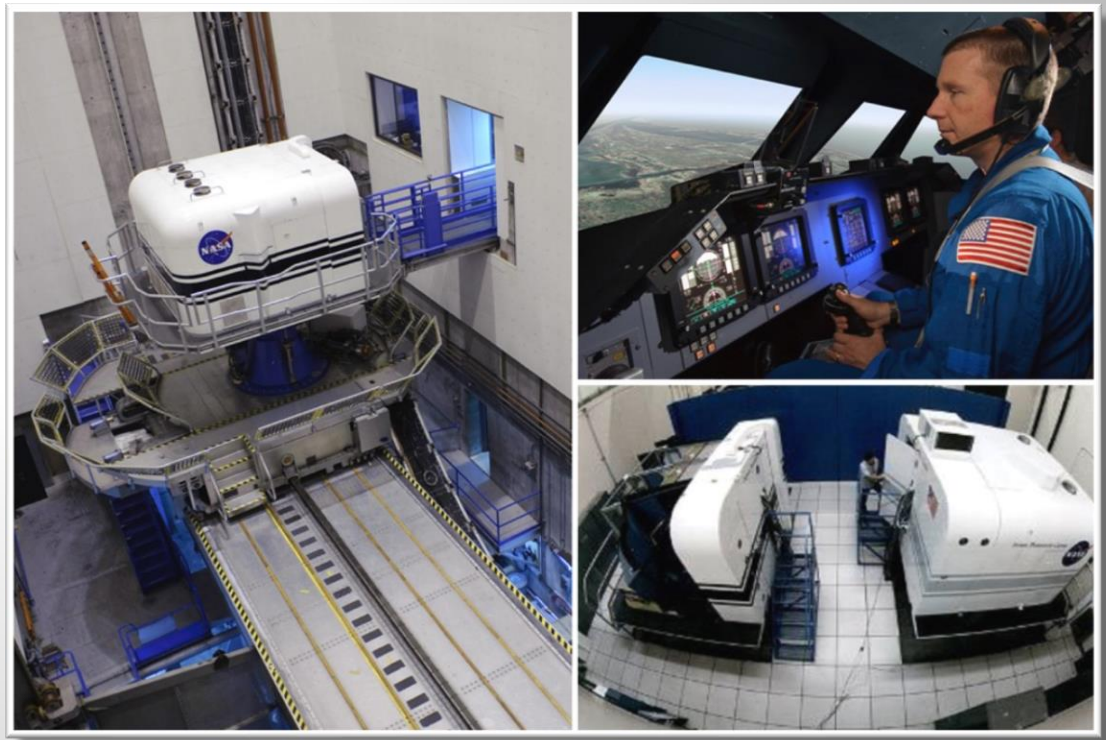
Convert Lab Video Systems To Digital



- Replace Analog Video Processing, Recording And Display Systems With Digital Technologies
- Install Digital Video Switch and Fiber Optic Video Distribution In Operations Labs
- Connect Image Generation Sources Directly To The Digital Switch Router

Current OTW Visual Display System

- Interchangeable Cockpit System
  - Wide Angle Collimated Optical Display System
    - Unique Window Arrangement For Each Interchangeable Cockpit
    - Entire Cockpit Assembly is Exchanged for Each Simulation
    - Segmented Windows
    - Limited FOV
    - Limited Resolution
    - 4:3 Aspect Ratio



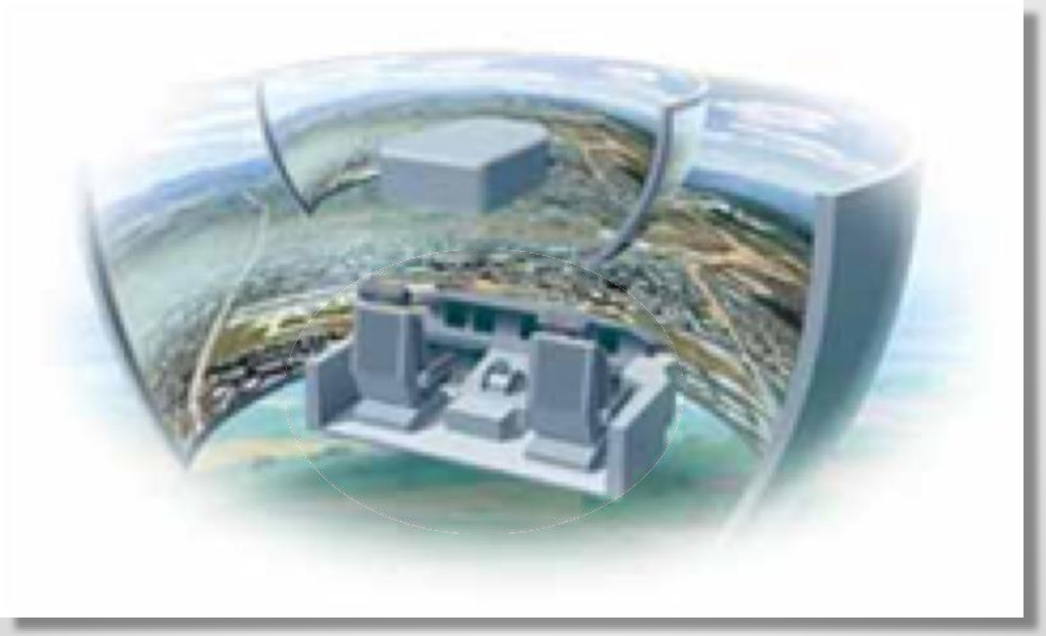
OTW Visual Display Replacement

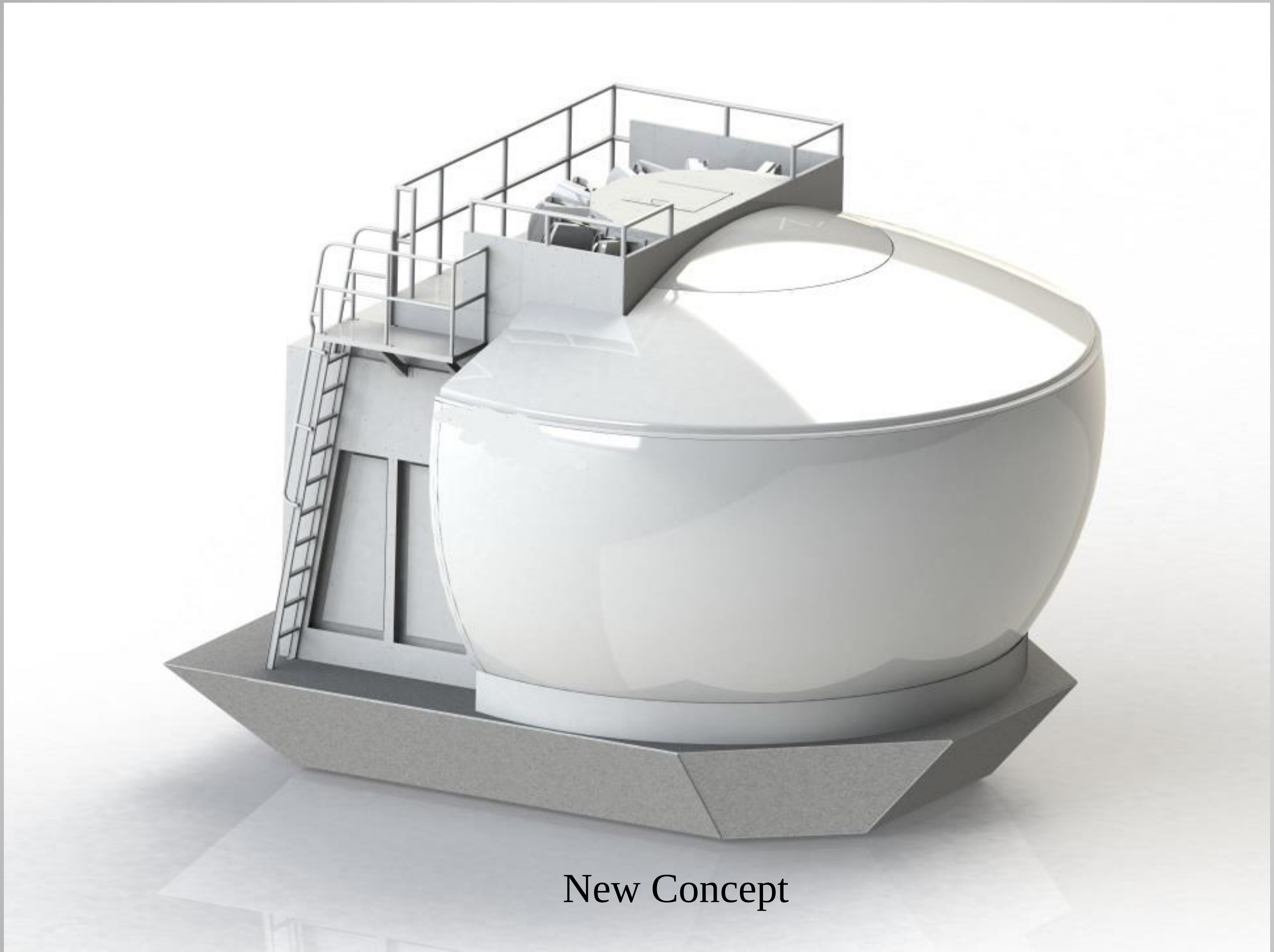
- **Concept**
  - **Stationary Collimated Wide Projection Display System With Interchangeable Flight Deck**
    - **10’ Radius Collimated Wide Display System**
    - **Up To 50˚ Vertical X 200˚ Horizontal Continuous FOV**
    - **Collimated Projection**
    - **Cross Cockpit Viewing**
    - **4k+ Resolution**
  - **Interchangeable Flight Deck**
    - **Includes Seating, Inceptors, Controls, Head-Down Displays, Support Electronics And Visual Masking**
    - **Retains “Interchangeable” Capabilities SimLab Is Known For**

OTW Visual System Replacement Concept

Install Stationary Collimated Wide Display System

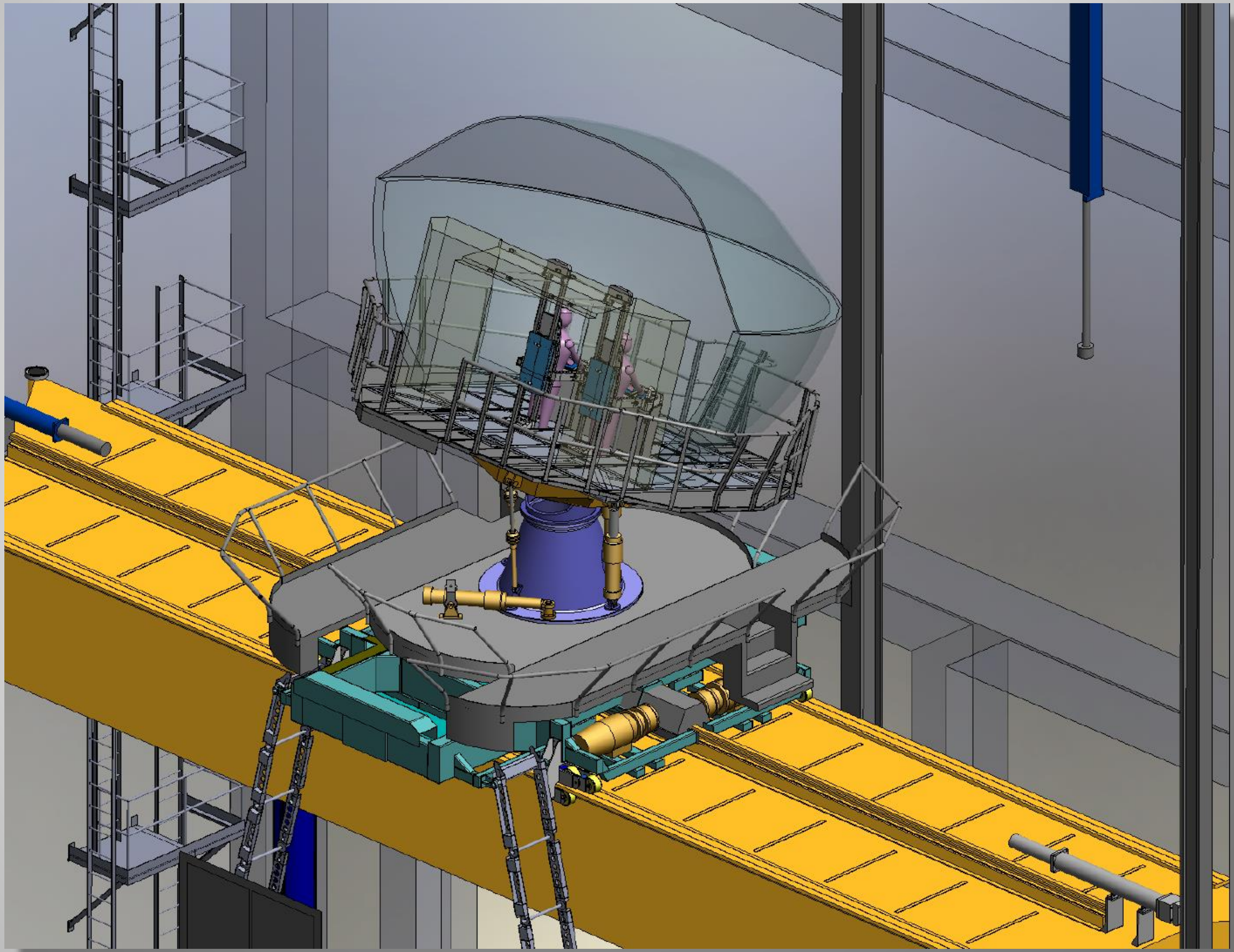
Insert Simulation Specific Interchangeable Flight Deck





New Concept

10 FT Dome on VMS Beam



Appendix C – NRHP Nomination

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: Flight and Guidance Simulation Laboratory
Other names/site number: Building N-243
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: 655 Cooper Loop, 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**

Rebecca Klein (signature) 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.

(signature) 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	
1	0	buildings
0	0	sites
0	0	structures
0	0	objects
1	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/Research and Experimentation Facilities
OTHER/Administrative Offices

Current Functions
(Enter categories from instructions.)
OTHER/Research and Experimentation Facilities
OTHER/Administrative Offices

7. Description

Architectural Classification
(Enter categories from instructions.)
MODERN MOVEMENT/Brutalism

Materials: (enter categories from instructions.)
Principal exterior materials of the property:
Foundation – concrete
Walls – steel
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 Flight and Guidance Simulation Laboratory (Building N-243) is located at the National Aeronautics and Space Administration (NASA) Ames Research Center (ARC), Moffett Field, on the eastern side of ARC, adjacent to the runway of Moffett Federal Airfield. The facility is a large building designed in the Brutalist style. It covers 108,670 square feet and included three flight simulation machines. One of the simulators, the Vertical Motion Simulator, is a significant feature of the building. The building retains historic integrity to its period of significance.

Narrative Description

Building N-243 is a 108,670-square-foot Brutalist-style building at the southeast corner of King Road and Cooper Loop at ARC. The main portion of the building is a large rectangular form with a rounded southeast corner that is two stories tall with a basement level. A round, three-story circular wing (approximately 120 feet in diameter) is attached near the west end of the north elevation, and a five-story rectangular wing featuring several concrete buttresses and rounded southwest and southeast corners is attached to the south elevation. A seven-story concrete tower addition is attached to the east side of the main building and features a three-story-tall overhead steel door. The building elevations include several overhead steel warehouse doors and aluminum-frame doorways for personnel. Building N-243A is a free-standing, one-story building with an interior mezzanine and a basement located north of the main portion of Building N-243 and east of the circular wing. It is connected to the circular wing of Building N-243 by steel scaffolding, but is considered a separate building.

The roof of the building is primarily flat. The circular wing has a setback metal roof and the southern rectangular wing features an angled roof design. The exterior wall surfaces are primarily composed of vertically and horizontally scored concrete punctured with regularly spaced "point" marks. The west elevation features an extruded concrete frame that fronts inset aluminum-sash windows and a prominent exterior metal and concrete staircase, which identify the main entry into the complex. The west elevation is the only façade with fenestration. The circular wing features an aluminum personnel entryway covered by a prominent block awning as well as an overhead steel door decorated with the NASA insignia.

Closely surrounded by paved area and streets, the landscape associated with the building is limited to some established trees located at the north and south ends of the building. Lawn and some shrubs are located along the west side of the building and behind the prominent entry stairway.

Building N-243 contains the Vertical Motion Simulator (VMS). The VMS is located within the seven-story addition, with a 110-foot-tall chamber and 60 feet of vertical and 40 feet of lateral motion capability. The basis of the motion system is a vertical platform that spans the width of the tower and is mounted on two columns that extend from 75-foot underground shafts. The vertical platform is restrained on both ends and in the center by wheel assemblies that ride along guide rails mounted to the tower walls. A lateral carriage mounted on the vertical platform provides horizontal motion. The lateral carriage is supported and restrained by wheel assemblies that ride along two guide rails attached to the top, front, and rear edges of the vertical platform. A detachable railing encircles the base structure for safety. The railing has an opening to accommodate a boarding ramp (Danek 1993:15-17).

The VMS uses an interchangeable cab (ICAB) to simulate the cockpit of helicopters, tilt-rotors, fighter jets, transport aircraft, supersonic transports, and the Space Shuttle orbiters. There are five ICABs currently used on the VMS. The ICABs are all constructed of lightweight welded aluminum. A single ICAB is mounted to the top of the VMS on a large, flat, aluminum base that serves as the floor of the ICAB. A fixed aluminum canopy is also mounted to the base, serves as the rear wall of the ICAB, and includes personnel and equipment access doors. Removable canopies enclose the equipment within the ICAB and serves as a barrier to exterior light and sound (Danek 1993:14-15).

Other associated features of the VMS include host computers, interfaces, test operations and control, and cueing systems. The host computers solve the equations that represent the mathematical model of the aircraft, perform all the computations needed to command and control the other parts of the system, and allow the pilot to interact with the simulator in real time. Interfaces serve as communications paths between the host computers and other elements of the simulation system. Test operations and control are located within the VMS Laboratory, a work area for personnel who conduct and direct simulations that includes operating and control consoles and other testing and monitoring equipment. Cueing systems generate and present sensory stimuli to the pilot. All these associated features are housed within Building N-243 (Danek 1993:1-3).

Integrity

Building N-243 retains integrity of location, design, setting, materials, workmanship, feeling, and association.

Location. Building N-243 remains in its original location, at the southeast corner of King Road and Cooper Loop at ARC.

Design. Built in 1967, the exterior of the building has not had any substantial alterations to compromise the original intent of the design. Character-defining features of the exterior reflect Brutalist style, including its addition. The 1969 addition of the seven-story tower to house the VMS was designed to be complementary to the original building, and has acquired its own significance since it was built. Although changes have substantially altered the interior of the building, including the removal of some of its original simulation facilities, most testing spaces have remained unchanged. The building retains most of its original floorplan, although some testing areas have been converted to offices. Overall, Building N-243 retains its integrity of design.

Setting. The setting of Building N-243 has changed minimally since it was first completed in 1967 and modified in 1969. Most of the buildings surrounding Building N-243 predate its construction. Newer buildings also are research facilities that reflect the setting of the scientific research campus. Building N-243 retains its integrity of setting.

Materials. Building N-243 has undergone minimal change to its exterior since the addition of the seven-story tower in 1969, which matches the original building in materials and design. Interior finishes are intact, with the exception of the removal of some original simulation equipment. Overall, the building retains its integrity of materials.

Workmanship. Building N-243 demonstrates its workmanship in its exterior concrete finish and forms and in the VMS. These elements are in good condition and reflect the building's integrity of workmanship. The equipment within the interior of Building N-243 has undergone modifications over time to keep pace with changes that occurred within NASA's Space Shuttle Program (SSP), including the removal of the Flight Simulator for the Advanced Aircraft (FSAA) and the human-carrying motion generator and centrifuge. However, these changes were required to continue the building's use as a state-of-the-art testing facility and the portions of the building constructed to house the original simulation devices remain intact.

Feeling. Building N-243 retains the feeling of a Brutalist-style, highly technical laboratory for specialized scientific experimentation. It retains integrity in its historic sense of place or feeling. The building maintains its overall appearance and continues to house the VMS, and it retains its integrity of feeling.

Association. Even with these modifications including the removal of some of its original simulation facilities, Building N-243 has continued to function according to its original purpose as a research facility for aircraft and spacecraft simulators where significant technological advancements related to the safety, design, and operation of the Space Shuttle occurred historically, and the location where most of the SSP astronauts completed training. Therefore, Building N-243 retains its integrity of association.

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
Invention
Engineering

Period of Significance
1967–2011

Significant Dates
1969 – Construction of the Flight Simulator for Advanced Aircraft
1979 – Construction of the Vertical Motion Simulator

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

Cultural Affiliation
N/A

Architect/Builder
Skidmore, Owings & Merrill (Building N-243)
Anshen & Allen (Vertical Motion Simulator addition)

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 Flight and Guidance Simulation Laboratory (Building N-243) is eligible for the National Register at the national level of significance for its contributions in the areas of science and engineering related to the SSP as a resource associated with the training of astronauts. The property is eligible under Criterion A for its association with training pilots and testing component features of the SSP, and under Criterion C for the design and engineering of the VMS, which is the world's largest motion-based simulator and widely regarded as the best simulator during its time for its engineering design and role in Space Shuttle pilot training. The property meets Criteria Consideration G for properties that have achieved significance within the past 50 years because of its exceptional significance within the context of the SSP for its contribution to the advancement of the SSP and the development and operation of the Space Shuttle orbiter by providing research and essential astronaut training in an accurately simulated orbiter. NASA previously determined Building N-243 eligible for the National Register under Criterion A and Criterion Consideration G, and the California State Historic Preservation Officer concurred in a letter dated May 8, 2007.

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

ARC began building flight simulators in the early 1950s to study how pilots worked with aircraft, and pioneered development of sophisticated flight simulators using analog, reprogrammable computers for research (Bugos 2014:200-201). Flight simulators typically consisted of a computer, a cockpit with controls, a motion generator, and a visual display recreating an external scene through the windshield of the cockpit. ARC engineers constructed the first flight simulators for piloting supersonic transport aircraft out of spare parts, but they eventually received support from NASA Headquarters to develop new facilities for research on piloting spacecraft in microgravity. In 1959, ARC built a five-degree-of-motion simulator that simulated the G-forces of supersonic flight. It consisted of a simulated cockpit on a 30-foot centrifuge arm, and successfully represented airplane flight. In 1963, ARC built three simulators to train Apollo astronauts: the six-degree-of-freedom simulator, a moving cab simulator, and a midcourse navigation simulator. The six-degree-of-freedom simulator was the largest and most expensive of the early simulators, and simulated vertical and/or short take-off and landing (V/STOL) aircraft. The midcourse navigation simulator included an Apollo-sized crew compartment mounted on an air bearing, which allowed for small angular motions controlled either manually or by computer. The compartment included appropriate instrumentation and an externally generated star field (Bugos 2014:201; Hartman 1970:430-431).

In late 1963, ARC engineers began designing four flight simulators for the proposed Space Flight Guidance Research Laboratory, including the FSAA, a human-carrying motion generator and centrifuge, a midcourse navigation simulator, and a satellite attitude control facility. The FSAA was designed to simulate supersonic transport, and was capable of all six degrees of angular and translational motion. The human-carrying motion generator and centrifuge was designed to research gravity and the physiological effects of space travel. The midcourse navigation simulator replicated deep space navigation and consisted of a three-person cabin on a spherical air bearing. The satellite attitude control facility studied stabilization systems and was used to teach ground controllers how to stabilize robotic spacecraft

(Hartman 1970; Bugos 2014:201). With the new facility, ARC emerged as a leader in flight simulators, becoming "the best in the world at adding motion generators to flight simulators, and connecting them with programmable analog computers to simulate aircraft not yet built" (Bugos 2014:201).

NASA hired the architectural firm of Skidmore, Owings & Merrill to design Building N-243 to specifically house the flight simulators. Building N-243 was constructed between 1965 and 1967 (Hartman 1970; Page & Turnbull 2007:IV-60). The main portion of the building housed the midcourse navigation simulator and the satellite attitude control facility, as well as locker rooms, restrooms, shop and vehicle maintenance areas, offices, meeting rooms, medical examination rooms, computer rooms, and control rooms. The round, three-story circular wing attached to north side of the main building housed the human-carrying motion generator and centrifuge, which consisted of a 50-foot arm with an attached three-person or one-person cabin that could accelerate at a rate of 7.5 G-forces per second. The centrifuge device contributed to the study of hyper-gravity and its physiological effects in spaceflight. As-built drawings indicate that the area connecting the circular wing to the main building included an area to maneuver and transport large equipment, work areas, and an emergency room in the first story, and an observation area and control rooms in the second story.

The five-story rectangular wing on the south side of the main building was designed to house the FSAA, which cost $2.6 million to construct and was expected to be the largest and most sophisticated airplane flight simulator ever constructed. The FSAA was designed to simulate supersonic transport, and was capable of all six degrees of angular and translational motion. A projector mounted to the top of a three-person cabin simulated external views. In the early 1970s, the FSAA was used for landing simulation research for the Space Shuttle orbiter. In the years prior to the first Space Shuttle flight, all pilot astronauts spent time in the FSAA. Through the FSAA testing, pilots could feel the G-forces generated in landing the Space Shuttle, and this helped them to identify any handling issues or control system shortcomings in a controlled environment. ARC engineers also used the FSAA to determine design and safety issues, and any improvements necessary for the successful landing of the Space Shuttle. NASA dismantled the FSAA in the early 1990s (Page & Turnbull 2007:IV-60).

In the late 1970s, the human-carrying motion generator and centrifuge was dismantled, and a new facility was planned for the Space Flight Guidance Research Laboratory, which became the Flight and Guidance Simulation Laboratory (SimLab) in 1980. In 1979, NASA constructed a seven-story concrete tower addition designed by the architectural and design firm of Anshen & Allen on the east side of Building N-243 to house the VMS. The VMS, which started operation in April 1980, is the world's largest motion-base simulator. The simulator was a significant part of pilot training for the SSP, because it not only allowed for system improvements, but also exposed pilots and NASA engineers to a wide array of conceivable failures that could take place during spacecraft take-offs and landings, such as blown tires, crosswinds, or failed auxiliary power units (Page & Turnbull 2007:III-11).

The VMS was widely regarded as the best simulator during its time for its role in engineering design and pilot training. Nearly every pilot astronaut in the SSP trained with the VMS, in over 65,000 simulated landings, rollout trainings, and engineering evaluations. Astronauts and the engineering designers from Johnson Space Center and ARC all collaborated to improve the safety and operation capabilities of the Space Shuttle. Nose wheel steering, brakes, Multifunction Electronic Display System (MEDS) (glass cockpit), drag parachute engineering, flight control automation for the Extended Duration Orbiter (EDO) (which involved microgravity research), and "return to flight" studies following the 1986 *Challenger* accident were among those features NASA redesigned as a result of VMS training. In addition, more than

80 VMS engineering studies led to 20 flight rule modifications for the Space Shuttle (Beard et al. n.d.:2, 15; Page & Turnbull 2007:IV-61, IV-62).

NASA used the VMS twice a year to research the landing and rollout of the Space Shuttle orbiter. The VMS was unique because it featured a high-fidelity cockpit and visual aids that mimicked the motion and visual environment of the orbiter. It could provide the pilot with the most realistic sense of a true orbiter experience by simulating the final descent and landing of the orbiter, and all the testing involving these procedures was validated by the VMS. The simulator was involved in tire wear, brakes, and drag-and-chute design, and crew evaluation and testing. It also made important contributions to development of head-up display symbology, and to determination of wind, visibility, and ceiling limits, and landing of the orbiter as it was carried atop a Boeing 747 aircraft (Page & Turnbull 2007:iii-10).

The VMS remained a viable part of the SSP for decades, because it could be customized for various testing scenarios by upgrades to hardware and software, frequently made to accommodate any improvements or modification in the SSP. The VMS operated as part of the SSP until 2011, and continues to be used in training and research for the aerospace community as a general aircraft flight simulator (Beard et al. n.d.:15).

SIGNIFICANCE

Building N-243 was evaluated pursuant to NASA's guidelines *Evaluating Historic Resources Associated with the Space Shuttle Program: Criteria of Eligibility for Listing in the National Register of Historic Places* (NASA 2006). 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.

Building N-243 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-243 eligible for the National Register under Criterion A (Page & Turnbull 2007), and the California State Historic Preservation Officer concurred in a letter dated May 8, 2007.

Building N-243 is eligible for the National Register under Criteria A and C at the national level of significance for its contributions in the areas of science and engineering related to 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. Building N-243 and the flight simulators within it played a prominent role in the development and improvement of the Space Shuttle orbiter and in training virtually all of the Space Shuttle astronauts, which allowed the United States to achieve successful Space Shuttle missions and advance the country's space program. Therefore, the property represents an important aspect of the history of the Nation.

Building N-243 relates to the SSP context as a Resource Associated with the Training of Astronauts (Property Type 10). As such, Building N-243 meets the significance criteria of the property type, because:

- It was designed and constructed for the unique purpose of astronaut training and is directly associated with preparing astronauts for the completion of a Space Shuttle mission;
- It clearly embodies the distinctive characteristics of a type or method of construction specifically designed for aeronautical training; and
- It has a direct historical association with the Space Shuttle.

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.

Building N-243 is eligible for listing in the National Register under Criterion A for its direct association with SSP astronaut training, specifically for the role of the VMS from 1969 to 2011. Building N-243 is representative of the preeminent flight simulation program at ARC during the SSP. By the 1960s, ARC was at the forefront of flight simulation, and activities in Building N-243 were pivotal in SSP testing and research. The building, which was originally known as the Space Flight Guidance Laboratory, was specifically designed to house flight simulators designed by ARC engineers to advance the space program through the training of astronauts and the testing and refinement of spacecraft capabilities. The FSAA, which opened in1969, performed cutting edge simulation technology for that time, and played a key role in the research, design, and training in the use of the Space Shuttle orbiter in the years prior to the first flight. The VMS, which was constructed in 1979, was used to train nearly every astronaut in the SSP, and simulations performed using the VMS allowed astronauts and engineers to improve the safety and design of the Space Shuttle orbiter. Because the building was the site of important events associated with the SSP and nationally significant program-level events regarding the origins and operation of the SSP, Building N-243 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.

Building N-243 is also eligible for listing in the National Register under Criterion C. Building N-243, specifically the VMS, was designed and constructed for the unique purpose of astronaut training, is directly associated with preparing astronauts for completion of a Space Shuttle mission, clearly embodies the distinctive characteristics of a type or method of construction specifically designed for aeronautical training, and has a direct association with the Space Shuttle. The VMS was instrumental in preparing astronauts for the conditions of spaceflight in the Space Shuttle orbiters as the sole training simulator for landing and rollout of the orbiter. Designed by ARC engineers, the VMS is the world's largest motion-based simulator and widely regarded as the best simulator during the SSP. Almost every pilot astronaut involved with the SSP trained using the VMS. The VMS is the only facility that simulated final descent and landing of the orbiter, and was an essential training facility for the SSP. 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 (Page & Turbull 2007:IV-62). The VMS continues to possess the largest and most realistic motion system, and is the world's largest motion-base flight simulator (Beard et al. nd:1).

Building N-243 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 advancement of the SSP and the development and operation of the Space Shuttle orbiter by providing research and essential astronaut training in an accurately simulated orbiter. The VMS is exceptionally significant as the only flight simulator for the SSP that simulated landing and rollout, and as the world's largest motion-base flight simulator.

As outlined in Section 7, Building N-243 retains its integrity of location, design, setting, materials, workmanship, feeling, and association to its period of significance (6). 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. Because highly technical and scientific facilities are constantly changing in response to technological advancements, workmanship and association are the aspects of integrity given the most consideration when assessing the integrity of these types of resources (Page & Turnbull 2007:II-14). Building N-243 retains its integrity of workmanship and association, as it has undergone few exterior alterations and continues to house the VMS and other flight simulation programs.

In summary, Building N-243 is eligible for the National Register at the national level of significance, in the areas of science and engineering, under Criteria A and C within the context of the SSP. It meets Criteria Consideration G as a property with exceptional significance related to the SSP, and it retains sufficient integrity for listing in the National Register.

HISTORIC CONTEXT

To relate the property to important themes in the history of national aeronautical and aerospace research, the following context describes the development of the NACA and NASA, the role of Ames in the development of these programs, and the development of the SSP. This information illustrates the significance of Building N-243 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: 37.415107 Longitude: -122.055737

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

The boundary is the footprint of Building N-243.

Boundary Justification (Explain why the boundaries were selected.)

The boundary includes the building area that was historically associated with flight and guidance simulation research and limited exterior hardscape and greenscape associated with the building.

11. Form Prepared By

name/title: Madeline Bowen, Maria Katharina Meiser, Kirsten Johnson, Patricia Ambacher, and Mark 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:	Flight and Guidance Simulation Laboratory
City or Vicinity:	Moffett Field
County:	Santa Clara
State:	California
Photographer:	Mark Bowen and Patricia Ambacher
Date Photographed:	December 8 and 9, 2014
Location of Original Digital Files:	AECOM, 401 W. A Street, San Diego, CA, 92101

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

Photo #1 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0001)
West elevation, camera facing northeast.

Photo #2 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0002)
South elevation, camera facing northwest.

Photo #3 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0003)
East and south elevations, camera facing northwest.

Photo #4 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0004)
North elevation, camera facing southwest.

Photo #5 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0005)
North and west elevations, camera facing southeast.

Photo #6 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0006)
VMS cabin, interior, camera facing east.

Photo #7 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0007)
VMS control room, interior, camera facing northeast.

Photo #8 (CA_Santa Clara County_Flight and Guidance Simulation Laboratory_0008)
VMS cabin, interior detail.

Index of Figures

Note: Original historic photographs are located at NASA Headquarters, Washington, D.C. and ARC.

Figure 1. Location Map

Latitude: 37.415107 Longitude: -122.055737

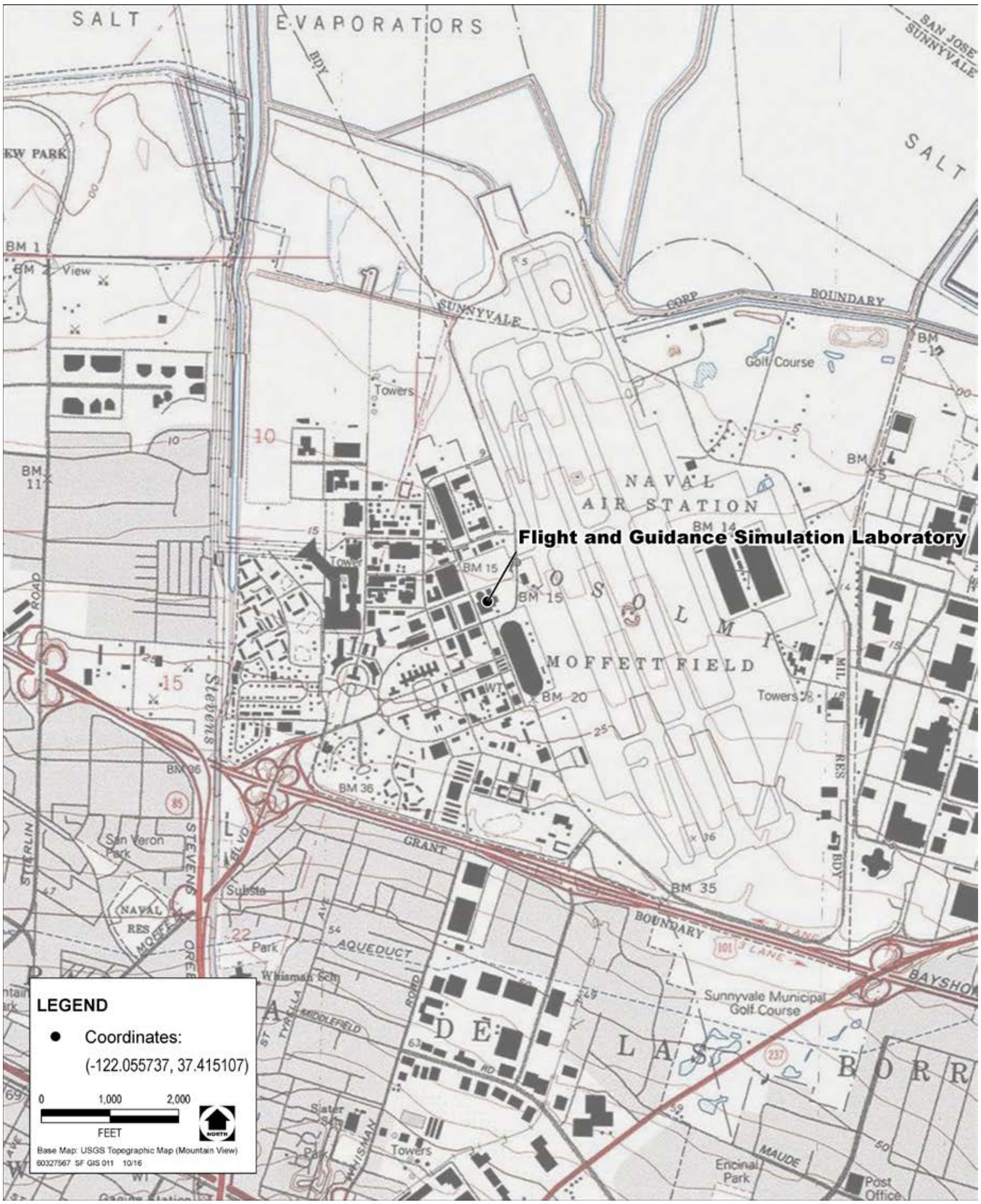

Figure 2. Boundary Map

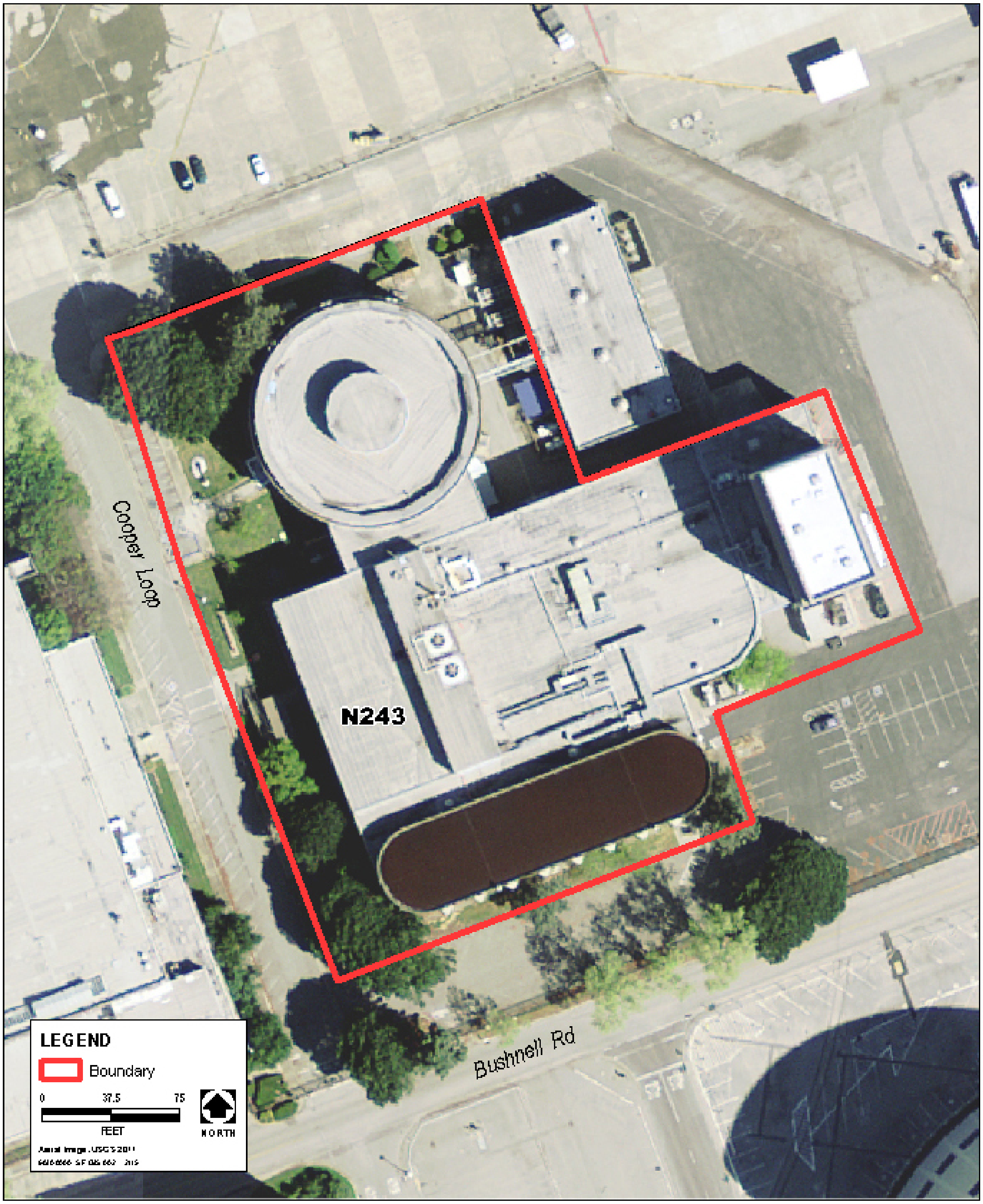

Figure 3. Building N-243 under construction, October 4, 1965

Figure 4. Cutaway illustration of the Vertical Motion Simulator (VMS)

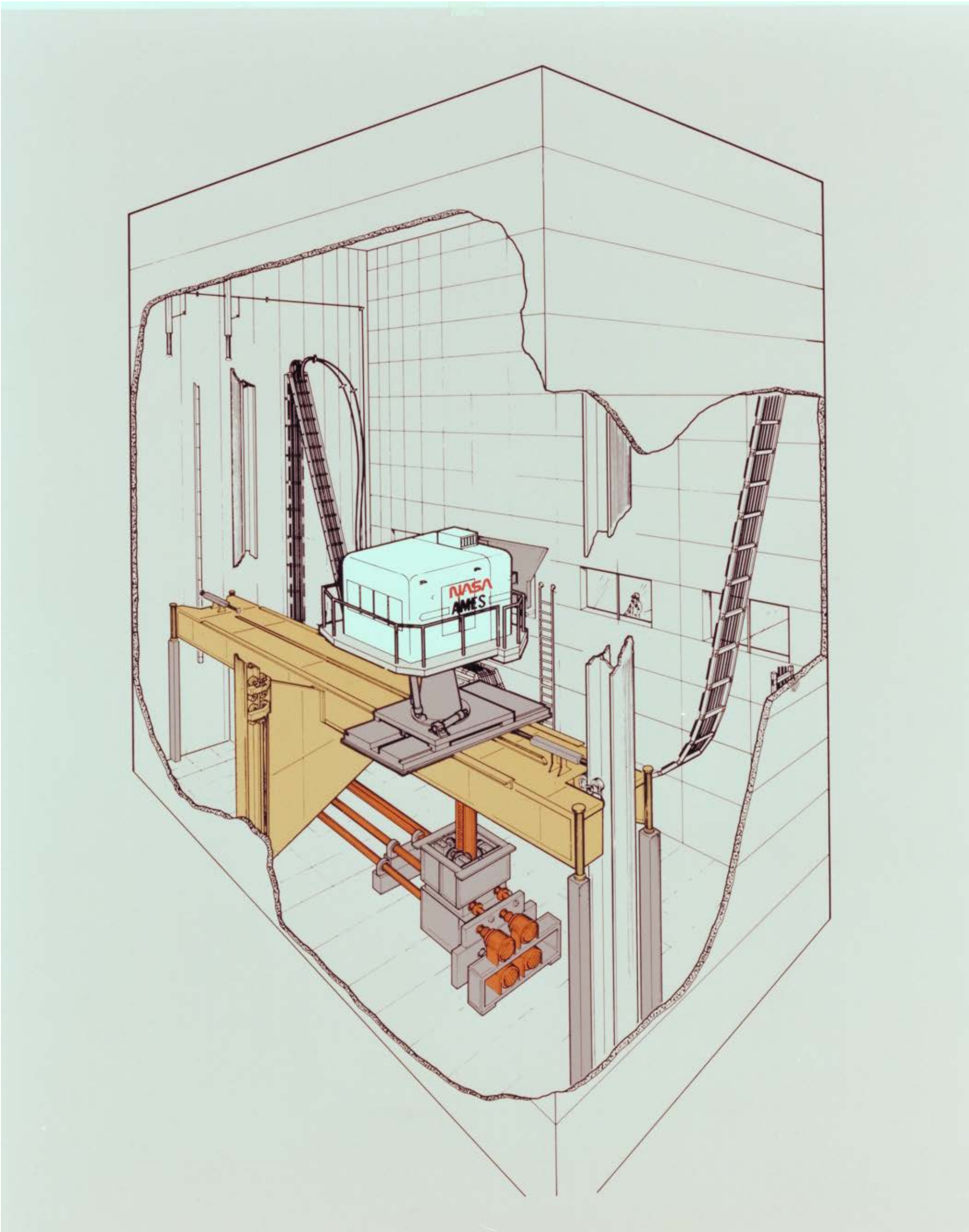

Figure 5. VMS cabin in motion, 1997