CAPE CANAVERAL AIR FORCE STATION, LAUNCH COMPLEX 39, ORBITER PROCESSING FACILITY, HIGH BAY NO. 3
(John F. Kennedy Space Center)
Northeast of Orbiter Towway/Crawlerway intersection
Cape Canaveral
Brevard County
Florida

HAER No. FL-8-11-O

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
U.S. Department of the Interior
100 Alabama Street, SW
Atlanta, GA 30303

HISTORIC AMERICAN ENGINEERING RECORD

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Location: Northeast of Orbiter Towway/Crawlerway intersection
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The Orbiter Processing Facility, High Bay No. 3, is located at latitude: 28.587845, longitude: -80.653623. The coordinate represents the southwest corner of the facility. The coordinate was obtained on September 13, 2011, by converting their Universal Transverse Mercator coordinates (obtained March 2011). The coordinate's datum is North American Datum 1983.

Present Owner: National Aeronautics and Space Administration (NASA)
Kennedy Space Center, FL 32899-0001

Present Use: At the time of documentation, this facility was being used for post-flight and pre-flight processing of the Space Shuttle orbiter.

Significance: The Orbiter Processing Facility, High Bay No. 3 (OPF-3) is considered eligible for listing in the National Register of Historic Places (NRHP) in the context of the U.S. Space Shuttle program (1969-2011) under Criterion A in the area of Space Exploration and under Criterion C in the area of Engineering. Because it has achieved significance within the past 50 years, Criteria Consideration G applies. In addition to its individual eligibility, the OPF-3 is considered a contributing resource to the Orbiter Processing Historic District. The period of significance for OPF-3 is from 1987, the date of its completed construction, through 2011, the designated end of the Space Shuttle program. OPF-3 is significant as one of only two structures designed and built exclusively for orbiter pre-flight and post-landing processing. Included in this facility is the Space Shuttle Main Engine Processing Facility (SSMEPF), which is a one of a kind facility, designed specifically for the Space Shuttle's main engines. Under Criterion C, OPF-3 contains a large High Bay, with a platform system specifically designed around the shape of the orbiter. This system contains stationary platforms set at various levels, which provide access to the major areas of the orbiter. Each level is also fitted with moveable platforms for access to specific components. In addition, a clean room environment is provided

around the payload bay, when the doors are open. Learning from the first OPF (High Bay Nos. 1 and 2), OPF High Bay No. 3 was designed for the easier flow of the ground support equipment to support Shuttle processing. OPF-3 also houses the SSMEPF, which was designed specifically to process the Space Shuttle's main engines. Like the orbiter high bay, it contains platforms that fit around the engine, providing access to the main components. This uniquely designed equipment, rather than the building's exterior shell, provides the basis for the OPF-3's eligibility under Criterion C.

Historian: Patricia Slovinac, Architectural Historian
Archaeological Consultants, Inc. (ACI)
8110 Blaikie Court, Suite A
Sarasota, Florida 34240

Date: January 2012

Project Information: The documentation of the Cape Canaveral Air Force Station, Launch Complex 39, Orbiter Processing Facility, High Bay No. 3 was conducted in 2011 for the John F. Kennedy Space Center (KSC) by Archaeological Consultants, Inc. (ACI), under contract to Innovative Health Applications (IHA), and in accordance with KSC's Programmatic Agreement Regarding Management of Historic Properties, dated May 18, 2009. The field team consisted of architectural historian, Patricia Slovinac (ACI), independent photographer, Penny Rogo Bailes, and assistant photographer, Katherine Baar. Assistance in the field was provided by Shannah Trout, IHA's Cultural Resource Specialist, and Barbara Naylor, KSC Historic Preservation Officer. The written narrative was prepared by Ms. Slovinac; it was edited by Joan Deming, ACI Project Manager; Elaine Liston, KSC Archivist; Barbara Naylor and Nancy English of KSC; and Jane Provancha, Environmental Projects-Manager, IHA. The photographs and negatives were processed by Zebra Color, Inc., an independent photography/processing studio.

The Scope of Services for the project, which was compiled based on the Programmatic Agreement, specifies a documentation effort following HAER Level II Standards. Information for the written narrative was primarily gathered through informal interviews with current NASA and contractor personnel and research materials housed at the KSC Archives Department. Selected drawings were provided by KSC's Engineering Documentation Center, which serves as the repository for all facility

drawings. The available drawings for OPF-3 include the “as-built” drawings, as well as those depicting major modifications to the facility, or any small modifications that required a set of drawings (such as changes to the electrical or mechanical systems). KSC does not periodically produce drawings of their facilities to show current existing conditions.

LEGEND OF ACRONYMS

ACI	Archaeological Consultants, Inc.
aff	above the finished floor
CCAFS	Cape Canaveral Air Force Station
ET	External Tank
GSE	Ground Support Equipment
IHA	Innovative Health Applications
ISS	International Space Station
JSC	Johnson Space Center
KSC	Kennedy Space Center
LC	Launch Complex
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NRHP	National Register of Historic Places
OMRF	Orbiter Maintenance and Refurbishment Facility
OMS	Orbital Maneuvering System
OPF	Orbiter Processing Facility (High Bays No. 1 and No. 2)
OPF-3	Orbiter Processing Facility High Bay No. 3
OV	Orbiter Vehicle
RCS	Reaction Control System
SRB	Solid Rocket Booster
SSME	Space Shuttle Main Engine
SSMEPF	Space Shuttle Main Engine Processing Facility
STS	Space Transportation System
U.S.	United States
USA	United Space Alliance
VAB	Vehicle Assembly Building

Part I. Historical Information

A. Physical History:

1. Date of construction: The Orbiter Processing Facility, High Bay No. 3 (OPF-3) was constructed between 1986 and 1987 as the Orbiter Maintenance and Refurbishment Facility (OMRF). It became OPF-3 in 1989 to 1991.

2. Architect/Engineer: Burns and Roe Industrial Services Corp. of Cocoa Beach, Florida, served as the design architecture and engineering firm for the original facility. Available information at the Kennedy Space Center (KSC) archives did not specify a design architect or engineer; however, the architectural and structural drawings appear to have been signed by J.E. Sullivan (the signature is difficult to decipher). Daniel, Mann, Johnson & Mendenhall of Los Angeles, California, was the architecture firm of record for the conversion of the building into OPF-3. Burns and Roe Southeast of Orlando, Florida, served as the design firm for the expansion of the Low Bay area, and AJT & Associates, Inc of Cape Canaveral, Florida, was the architecture firm of record for the Space Shuttle Main Engine Processing Facility (SSMEPF).

3. Builder/Contractor/Supplier: W&J Construction Company of Cocoa, Florida, was the builder of the original facility, its conversion into OPF-3, and for the expansion of the Low Bay. Ivey's Construction Company of Merritt Island, Florida, served as the builder for the SSMEPF.

4. Original plans and construction: The original plans for OPF-3 were drawn between April and November of 1985, with revisions throughout 1986 and 1987. The facility was constructed between March 1986 and September 1987.

5. Alterations and additions: The building was converted into OPF-3 from 1989 to 1991; the work was completed in two phases. The first phase was the expansion of the Low Bay area, with the work completed between April 1990 and October 1991. The second phase, completed between February 1990 and September 1991, included the installation of the orbiter work platforms in the High Bay. The SSMEPF addition was completed between 1996 and 1998.

B. Historical Context:

On April 14, 1972, NASA selected KSC as the primary launch and landing site for the Space Shuttle program. KSC would be responsible for all mating, prelaunch testing, and launch control

ground activities until the vehicle cleared the launch pad tower.[1] KSC engineers adapted and modified many of the Apollo launch facilities to serve the needs of the Space Shuttle program. New facilities were constructed only when a unique requirement existed. One such facility was the Orbiter Processing Facility (OPF), designed and built between 1975 and 1983, exclusively to prepare the orbiter for flight. The OPF contained two High Bays, each of which could process one orbiter at a time.[2] Operations performed within the OPF include draining and purging the fuel systems, removing ordnance, repairing/replacing damaged components, inspecting/ refurbishing the thermal protection system, inspecting/testing orbiter systems and installing/ removing payloads.

During the first few years of Space Shuttle flights, the two OPF High Bays were assigned to one of the three flight orbiters, *Columbia*, *Challenger*, or *Discovery*, on a "first available" basis; the third orbiter was typically stowed in the Vehicle Assembly Building (VAB). However, with the impending arrival of a fourth flight orbiter, *Atlantis*, additional space was required to "enhance the center's [KSC] abilities to meet anticipated future demands on Shuttle turnaround capabilities."[3]

Beginning in 1985, Burns and Roe Industrial Services Corporation of Cocoa Beach, Florida, began design work on the OMRF, now OPF-3.[4] Gene Baker of Lockheed Space Operations Company served as the project engineer.[5] In March 1986, ground was broken for the construction of the facility, which was completed by the W&J Construction Company of Cocoa, Florida, for a cost of approximately $9.9 million. This new facility would "provide needed space in which to perform modifications, rehabilitation and overhaul on Space Shuttle orbiters outside of the facilities used in the normal operational flow."[6]

During construction, smaller contracts were awarded to other firms for specific tasks, including the fabrication and installation of a paging system, an $84,963 contract awarded to Joan F. Kennedy, Inc. of Cape Canaveral, Florida. Another task was the installation of a piping system to provide heat and air conditioning to the facility, an $838,000 contract awarded to Butler Construction Company of Rockledge, Florida.[7] On September 9, 1987, *Columbia* was the first

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[1] Dennis R. Jenkins. *Space Shuttle, The History of the National Space Transportation System. The First 100 Missions* (Cape Canaveral, Florida: Specialty Press, 2001), 112.
[2] See Appendix B for additional information about the OPF.
[3] "Ground Broken for $10 Million Orbiter Facility." *Spaceport News* (25, 5), March 14, 1986: 3.
[4] Burns and Roe Industrial Service Corp. "Orbiter Modification and Refurbishment Facility." November 1985.
[5] Beth Dickey. "New Garage Open for Orbiter Mods." *Spaceport News* (26, 20), September 25, 1987: 3. Lockheed Space Operations Company was KSC's contractor for the Shuttle Processing Contract, which had been awarded in 1983. Ken Nail, Jr. "Chronology of KSC and KSC Related Events for 1983." KHR-8, October 1, 1984, 60.
[6] "Ground Broken," 3.
[7] Ken Nail, Jr. "Chronology of KSC and KSC Related Events for 1985." KHR-10, March 1986, 85, 99.

orbiter to enter the OMRF for modifications.[8] For the next two years, the facility was used to perform extensive, non-hazardous modification, rehabilitation, and overhaul of the orbiter fleet.
In January 1989, KSC released a budget that included $26 million for the conversion of the OMRF into OPF-3, a project that was completed in two phases.[9] Jim Bean, of KSC's Design Engineering department, served as the project manager.[10] W&J Construction Company received a $6.4 million design-build contract for the first phase in February 1990. This included a 61,000-square foot addition to the Low Bay; KSC's base operations contractor, EG&G Florida, Inc., supervised the work. The expansion gave the facility the same capabilities as the original OPF Low Bay, including a mass spectrometer room, a logistics storage area, a launch processing system checkout area, and various mechanical and electrical shops.[11] W&J Construction Company, with the assistance of Burns and Roe Southeast and Roe/Eliseo Inc., the latter two from Orlando, Florida, completed the design for the expansion between April 1990 and October 1991.[12]

The contract for the second phase of the project, which included converting the OMRF High Bay "into one identical to those in the present OPF," was awarded to Lockheed Space Operations Company.[13] They completed the design between 1989 and 1990, using the drawings prepared by Daniel, Mann, Johnson & Mendenhall, and TMSI, both of Los Angeles, California.[14] Additional work included procuring roughly $16 million of new ground support equipment and relocating about $40 million of Shuttle-unique work platforms from Vandenberg Air Force Base in California.[15] Prior to shipping, the platforms were cut into twelve pieces. They were loaded on a barge, which sailed through the Panama Canal on its way to KSC. Once the platform sections were within the OPF-3 High Bay, they were welded back together. Bean noted, "When we welded the pieces back together, they were within an eight to a quarter inch of their original location."[16] Compared with OPF High Bay Nos. 1 and 2, OPF-3 was designed for an easier flow of ground support equipment (GSE) within the High Bay. For example, the aft platforms slide east-west on tracks, as opposed to swinging open like those in the first OPF. Major improvements included a new built-in computerized cooling system and new hydraulic pumps

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[8] Ken Nail, Jr. "Chronology of KSC and KSC Related Events for 1987." KHR-12, March 1988, 71.
[9] Frank E. Jarrett. "Chronology of KSC and KSC Related Events for 1989." KHR-14, March 1990, 4.
[10] Lisa Malone. "Third Orbiter Processing Facility to Open." KSC News Release No. 105-91, August 30, 1991.
[11] "Another Orbiter Processing Facility planned at KSC." *Spaceport News* (29, 4), February 23, 1990: 4.
[12] W&J Construction Corporation. "Orbiter Processing Facility #3 Low Bay Expansion." October 1991.
[13] "Another Orbiter," 4.
[14] Daniel, Mann, Johnson, and Mendenhall. "Orbiter Processing Facility High Bay 3, Orbiter Access Platform Installation." February 1990.
[15] Early in the Space Shuttle program, there were plans to activate Space Launch Complex 6 at Vandenberg Air Force Base for polar launch capabilities and basic facilities, such as an orbiter processing facility, were constructed. Following the *Challenger* accident in January 1986, these plans were cancelled. ACI, with contributions by Weitze Research. *NASA-wide Survey and Evaluation of Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program: Roll-up Report*. June 2008. On file, NASA Headquarters, Section 2.
[16] "KSC Dedicates Third Orbiter Processing Facility." *Spaceport News* (30, 18), September 13, 1991: 1 and 8.

located inside a support building instead of outside in the weather.[17] The Orbiter *Discovery* was the first vehicle processed in OPF-3; it entered the High Bay on September 27, 1991, following STS-48, launched September 12, 1991, for processing in support of STS-42.[18]

During 1996, AJT & Associates of Cape Canaveral, Florida, completed the design for the SSMEPF, based on specifications developed by representatives from Pratt & Whitney Rocketdyne-SSME, NASA Design Engineering, and United Space Alliance.[19] Ivey's Construction of Merritt Island, Florida, received the roughly $5.3 million contract for the construction of the SSMEPF. The groundbreaking ceremony for the facility, located at the east end of the OPF-3 Low Bay, occurred on November 20, 1996.[20] The 34,600-square foot addition was completed on June 26, 1998; the official ribbon-cutting ceremony was held on July 6, 1998.[21] Afterwards, the engine pedestals, pneumatic panels, hydraulic test equipment, and engines were moved to the facility from the VAB; the first engines processed at the SSMEPF were the three scheduled to fly on *Endeavour* for STS-88.[22] The SSMEPF was originally used only for post-flight inspections of the engines, which following a standard ten flight cycle at KSC, would be returned to Boeing-Rocketdyne (now Pratt & Whitney Rocketdyne) facilities in Canoga Park, California, for refurbishment and assembly. These operations were consolidated at KSC in February 2002, and the first Space Shuttle Main Engine (SSME) to be fully assembled in the SSMEPF was Engine 2058, completed in August 2004.[23]

NASA's John F. Kennedy Space Center (KSC)

The National Aeronautics and Space Administration's (NASA) KSC is responsible for launch and landing operations, vehicle processing and assembly, and related space exploration programs in support of manned missions. It is located on the east coast of Florida, about 150 miles south of Jacksonville and to the north and west of Cape Canaveral, in Brevard and Volusia Counties, and encompasses almost 140,000 acres. The Atlantic Ocean and Cape Canaveral Air Force Station (CCAFS) are located to the east, and the Indian River is to the west.

Following the launch of Sputnik I and Sputnik II, which placed Soviet satellites into Earth's orbit in 1957, the attention of the American public turned to space exploration. President Dwight D. Eisenhower initially assigned responsibility for the U.S. Space Program to the Department of

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[17] "KSC Dedicates," 8.
[18] "KSC Dedicates," 8.
[19] AJT & Associates. "Modifications to OPF-3 for SSME Processing." April 1996.
[20] "Ground Broken for Shuttle Processing Building." *Spaceport News* (35, 24), December 6, 1991: 4.
[21] United Space Alliance (USA). "Space Shuttle Main Engine Processing." Kennedy Space Center presentation materials provided by Matthew McClelland, no date; Elaine E. Liston. "Chronology of KSC and KSC Related Events for 1998." October 1999, 117.
[22] "Space Shuttle Maine Engine Processing Facility Opens." *Spaceport News* (37, 14), July 17, 1998: 2.
[23] "KSC Completes First Full Shuttle Main Engine." *Spaceport News* (43, 17), August 13, 2004: 8.

Defense. The Development Operations Division of the Army Ballistic Missile Agency, led by Dr. Wernher von Braun, began to focus on the use of missiles to propel payloads, or even a man, into space. The United States successfully entered the space race with the launch of the Army's scientific satellite Explorer I on January 31, 1958, using a modified Jupiter missile named Juno I.[24]

With the realization that the military's involvement in the space program could jeopardize the use of space for peaceful purposes, President Eisenhower formed NASA on October 1, 1958, as a civilian agency with the mission of carrying out scientific aeronautical and space exploration, both manned and unmanned. Initially working with NASA as part of a cooperative agreement, President Eisenhower officially transferred to NASA a large portion of the Army's Development Operations Division, including the group of scientists led by Dr. von Braun, and the Saturn rocket program.[25]

NASA became a resident of Cape Canaveral in 1958 when the Army Missile Firing Laboratory, then working on the Saturn rocket project under the direction of Dr. Kurt Debus, was transferred to the agency. Several Army facilities at CCAFS were given to NASA, including various offices and hangars, as well as launch complexes (LCs) 5, 6, 26, and 34. The Missile Firing Laboratory was renamed Launch Operations Directorate and became a branch office of Marshall Space Flight Center (MSFC). As the American space program evolved, the responsibilities of the Launch Operations Directorate grew, and NASA Headquarters separated the Directorate from MSFC, officially designating it an independent field installation called the Launch Operations Center.[26]

In May 1961, President John F. Kennedy charged NASA and the associated industries to develop a space program that would surpass the Soviet program by landing a man on the Moon by the end of the decade. With the new, more powerful Saturn V rocket and the accelerated launch schedule, it was apparent that a new launch complex was required, and CCAFS, with twenty-two launch complexes, did not have the space to accommodate new rocket facilities. Merritt Island, an undeveloped area west and north of the Cape, was selected for acquisition, and in 1961, the Merritt Island Launch Area (which, with the Launch Operations Center, would become KSC) was developed. In that year, NASA requested from Congress authority to purchase 80,000 acres of property, which was formally granted in 1962. The U.S. Army Corps of Engineers acted as the agent for purchasing the land, which took place between 1962 and 1964. NASA began gaining title to the land in late 1962, taking over approximately 83,903 acres by outright purchase, which included several small towns, such as Orsino, Wilson, Heath and Audubon, many farms, citrus groves, and several fish camps. Negotiations with the State of Florida provided submerged lands,

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[24] Charles D. Benson and William B. Faherty. *Gateway to the Moon. Building the Kennedy Space Center Launch Complex* (Gainesville, University Press of Florida, 2001), 1-2.
[25] Benson and Faherty, *Gateway*, 15.
[26] Benson and Faherty, *Gateway*, 136.

resulting in the acquisition of property identified on the original Deed of Dedication. Much of the State-provided land was located south of the Old Haulover Canal and north of the Barge Canal.
The American program to put a man in space and land on the Moon proceeded rapidly with widespread support. In November 1963, the Launch Operations Center and Merritt Island Launch Area were renamed John F. Kennedy Space Center to honor the late President.[27] The space program was organized into three phases: Projects Mercury, Gemini, and Apollo. Project Mercury, initiated in 1958, was executed in less than five years. Begun in 1964, Project Gemini was the intermediate step toward achieving a manned lunar landing, bridging the gap between the short-duration Mercury flights and the long-duration missions proposed for the Apollo Program.[28]

Apollo, the largest and most ambitious of the manned space programs, had as its goal the landing of astronauts on the Moon and their safe return to Earth. Providing the muscle to launch the spacecraft was the Saturn family of heavy vehicles. Saturn IB rockets were used to launch the early unmanned Apollo test flights and the first manned flight, Apollo 7, which carried astronauts on a ten-day earth orbital mission.[29]

Three different launch vehicles were used for Apollo: Saturn I, Saturn IB and Saturn V; and three different launch complexes were involved: LC 34 and LC 37 on CCAFS, and LC 39 on KSC (LC 37B and LC 39 are still active). Altogether, thirty-two Saturn flights occurred (seven from LC 34, eight from LC 37, and seventeen from LC 39, including Skylab and the Apollo-Soyuz Test Project) during the Apollo era. Of the total thirty-two, fifteen were manned, and of the seven attempted lunar landing missions, six were successful. No major launch vehicle failures of either Saturn IB or Saturn V occurred. There were two major command/service module failures, one on the ground (Apollo 1) and one on the way to the Moon (Apollo 13).[30]

The unmanned Apollo 4 mission, which lifted off on November 9, 1967, was the first Saturn V launch and the first launch from LC 39 at KSC. The next launch from LC 39 was Apollo 6, on July 14, 1967. Beginning with the launch of Apollo 8 on August 14, 1968, all manned missions have launched from LC 39.[31] On July 20, 1969, the goal of landing a man on the Moon was achieved when Apollo 11 astronauts Neil Armstrong, "Buzz" Aldrin, and Michael Collins successfully executed history's first lunar landing. Armstrong and Aldrin walked on the surface of the Moon for two hours and thirty-one minutes, and collected 21 kilograms of lunar material.

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[27] Harry A Butowsky. *Reconnaissance Survey: Man in Space* (Washington, D.C.: National Park Service, 1981), 5; Benson and Faherty, *Gateway*, 146.
[28] Butowsky, 5.
[29] Butowsky, 5.
[30] NASA. *Facts: John F. Kennedy Space Center*. (1994), 82.
[31] Apollo 5 launched from CCAFS's LC 37B; Apollo 7 launched from LC 34 at KSC. Benson, Charles D. and William Barnaby Faherty. *Moon Launch! A History of the Saturn-Apollo Launch Operations* (Gainesville, University Press of Florida, 2001), 532.

Apollo 17 served as the first night launch in December 1972. An estimated 500,000 people viewed the liftoff, which was the final launch of the Apollo Program.[32]

Skylab, an Earth-orbiting mission that was a follow on to the Apollo Program, served as an early type of space station. With 12,700 cubic feet of work and living space, it was the largest habitable structure ever placed in orbit, at the time. The station achieved several objectives: scientific investigations in Earth orbit (astronomical, space physics, and biological experiments); applications in Earth orbit (Earth resources surveys); and long-duration spaceflight. Skylab 1 orbital workshop was inhabited in succession by three crews launched in modified Apollo command/service modules (Skylab 2, 3 and 4). Actively used until February 1974, Skylab 1 remained in orbit until July 11, 1979, when it re-entered Earth's atmosphere over the Indian Ocean and Western Australia after completing 34,181 orbits.[33]

The Apollo-Soyuz Test Project of July 1975, the final application of the Apollo Program, marked the first international rendezvous and docking in space, and was the first major cooperation between the only two nations engaged in manned space flight. As the first meeting of two manned spacecraft of different nations in space, and the first docking and visits by astronauts and cosmonauts into the others' spacecraft, the event was highly significant. The Apollo-Soyuz Test Project established workable joint docking mechanisms, taking the first steps toward mutual rescue capability of both Russian and American manned missions in space.[34]

On January 5, 1972, President Richard M. Nixon delivered a speech in which he outlined the end of the Apollo era and the future of a reusable space flight vehicle, the Space Shuttle, which would provide "routine access to space." By commencing work at this time, Nixon added, "we can have the Shuttle in manned flight by 1978, and operational a short time after that."[35] The Space Task Group, previously established by President Nixon in February 1969, recommended three choices of long-range space plans. All included an Earth–orbiting space station, a space shuttle, and a manned Mars expedition.[36] Although none of the original programs presented was eventually selected, NASA implemented a program, shaped by the politics and economic realities of its time that served as a first step toward any future plans for implementing a space station.[37]

During this speech, President Nixon instructed NASA to proceed with the design and building of a partially reusable Space Transportation System (STS; commonly referred to as the Space

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[32] NASA. *Facts*, 86-90.
[33] NASA. *Facts*, 91.
[34] NASA. *Facts*, 96.
[35] Marcus Lindroos. "President Nixon's 1972 Announcement on the Space Shuttle." (NASA Office of Policy and Plans, NASA History Office, updated, April 14, 2000).
[36] NASA Headquarters, History Office. "Report of the Space Task Group, 1969."
[37] Jenkins, 99.

Shuttle) consisting of a reusable orbiter, three reusable main engines (SSME), two reusable solid rocket boosters (SRBs), and one non-reusable external liquid fuel tank (ET). NASA's administrators vowed that the Space Shuttle would fly at least fifty times a year, making space travel economical and safe. NASA gave responsibility for developing the Space Shuttle's orbiter vehicle and overall management of the Space Shuttle program to the Manned Spacecraft Center (now known as the Johnson Space Center [JSC]) in Houston, Texas, based on the Center's experience. MSFC in Huntsville, Alabama, was responsible for development of the SSME, the SRBs, the ET, and for all propulsion-related tasks. Engineering design support continued at JSC, MSFC, and NASA's Langley Research Center, in Hampton, Virginia, and engine tests were to be performed at NASA's National Space Technology Laboratories (later named Stennis Space Center) in south Mississippi, and at the Air Force's Rocket Propulsion Laboratory in California, which later became the Santa Susana Field Laboratory.[38] NASA selected KSC as the primary launch and landing site for the Space Shuttle program. KSC, responsible for designing the launch and recovery facilities, was to develop methods for shuttle assembly, checkout, and launch operations.[39]

On September 17, 1976, the full-scale Orbiter Vehicle (OV) prototype *Enterprise* (OV- 101) was completed. Designed for test purposes only and never intended for spaceflight, structural assembly of OV-101 had started more than two years earlier in June 1974 at Air Force Plant 42 in Palmdale, California. Although the *Enterprise* was an aluminum shell prototype incapable of space flight, it reflected the overall design of the orbiter. As such, it served successfully in 1977 as the test article during the Approach and Landing Tests aimed at checking out both the mating with the Boeing 747 Shuttle Carrier Aircraft for ferry operations, as well as the orbiter's unpowered landing capabilities.

The first orbiter intended for spaceflight, *Columbia* (OV-102*)*, arrived at KSC from Air Force Plant 42 in March 1979. Originally scheduled for liftoff in late 1979, the launch date was delayed by problems with both the SSME components as well as the thermal protection system. *Columbia* spent 610 days in the OPF, another thirty-five days in the VAB and 105 days on LC 39A before lifting off on April 12, 1981. STS-1, the first orbital test flight and first Space Shuttle program mission, ended with a landing on April 14, 1981, at Edwards Air Force Base in California. This launch demonstrated *Columbia's* ability to fly into orbit, conduct on-orbit operations, and return safely.[40] *Columbia* flew three additional test flights in 1981 and 1982, all with a crew of two. The Orbital Test Flight Program ended in July 1982 with 95 percent of its

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[38] Jenkins, 122.
[39] Linda Neuman Ezell. *NASA Historical Databook Volume III Programs and Projects 1969-1978*. The NASA History Series, NASA SP-4012 (Washington, D.C.: NASA History Office, 1988), Table 2-57; Ray A. Williamson. "Developing the Space Shuttle." *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume IV: Accessing Space* (Edited by John M. Logsdon. Washington, D.C.: U.S. Printing Office, 1999), 172-174.
[40] Jenkins, 268.

objectives accomplished. After the end of the fourth mission, President Reagan declared that with the next flight the Shuttle would be "fully operational."

During the Space Shuttle program, a total of 135 missions were launched from KSC. From April 1981 until the *Challenger* accident in January 1986, between two and nine missions were flown yearly, with an average of four to five per year. The milestone year was 1985, when nine flights were successfully completed. The years between 1992 and 1997 were the most productive, with seven or eight yearly missions. Since 1995, in addition to its unique responsibility as the Shuttle launch site, KSC also became the preferred landing site.

Over the past three decades, the Space Shuttle program has launched a number of planetary and astronomy missions including the Hubble Space Telescope, the Galileo probe to Jupiter, Magellan to Venus, and the Upper Atmospheric Research Satellite. In addition to astronomy and military satellites, a series of Spacelab research missions were flown, which carried dozens of international experiments in disciplines ranging from materials science to plant biology. Spacelab was a manned, reusable, microgravity laboratory flown into space in the rear of the Space Shuttle cargo bay. It was developed on a modular basis allowing assembly in a dozen arrangements depending on the specific mission requirements.[41] The first Spacelab mission, carried aboard *Columbia* (STS-9), began on November 28, 1983. Four Spacelab missions were flown between 1983 and 1985. Following a stand-down in the aftermath of the *Challenger* accident, the next Spacelab mission was not launched until 1990. In total, twenty-four Space Shuttle missions carried Spacelab hardware before the program was decommissioned in 1998.[42]

In 1995, a joint U.S./Russian Shuttle-*Mir* Program was initiated as a precursor to construction of the International Space Station (ISS). *Mir* was launched in February 1986 and remained in orbit until March 2001.[43] The first approach and fly around of *Mir* took place on February 3, 1995 (STS-63); the first *Mir* docking was in June 1995 (STS-71). During the three-year Shuttle-*Mir* Program (June 27, 1995 to June 2, 1998), the Space Shuttle docked with *Mir* nine times. The Orbiter *Atlantis* flew all but the last two of these docking missions. In 1995, Dr. Norman Thagard was the first American to live aboard the Russian space station. Over the next three years, six more U.S. astronauts served tours on *Mir*. The Shuttle served as a means of transporting supplies, equipment, and water to the space station in addition to performing a variety of other mission tasks, many of which involved Earth science experiments. It returned to Earth experiment results and unneeded equipment. The Shuttle-*Mir* program served to acclimate

[41] NASA. *NASA Shuttle Reference Manual* (1988).
[42] STS-90, which landed on May 3, 1998, was the final Spacelab mission. NASA KSC. "Shuttle Payloads and Related Information." KSC Factoids, Revised, November 18, 2002.
[43] Tony Reichhardt (editor). *Space Shuttle, The First 20 Years* (Washington, D.C.: Smithsonian Institution, 2002), 85.

the astronauts to living and working in space. Many of the activities carried out were types they would perform on the ISS.[44]

On December 4, 1998, *Endeavour* (STS-88) launched the first U.S. component of the ISS into orbit. This event marked, "at long last the start of the Shuttle's use for which it was primarily designed – transport to and from a permanently inhabited orbital space station."[45] STS-96, *Discovery*, launched on May 27, 1999, marked the first mission to dock with the ISS. Since that time, most Space Shuttle missions supported the assembly of the space station. The last major component of the ISS was delivered in May 2011, during the final flight of *Endeavour* (STS-134).

The Space Shuttle program suffered two major setbacks with the tragic losses of the *Challenger* and *Columbia* on January 28, 1986, and February 1, 2003, respectively. Following the *Challenger* accident, the program was suspended, and President Ronald Reagan formed a thirteen-member commission to identify the cause of the disaster. The Rogers Commission report, issued on June 6, 1986, which also included a review of the Space Shuttle program, concluded "that the drive to declare the Shuttle operational had put enormous pressures on the system and stretched its resources to the limit."[46] In addition to mechanical failure, the Commission noted a number of NASA management failures that contributed to the catastrophe. As a result, among the tangible actions taken were extensive redesign of the SRBs; upgrading of the Space Shuttle tires, brakes, and nose wheel steering mechanisms; the addition of a drag chute to help reduce speed upon landing; the addition of a crew escape system; and the requirement for astronauts to wear pressurized flight safety suits during launch and landing operations. Other changes involved reorganization and decentralization of the Space Shuttle program. NASA moved the management of the program from JSC to NASA Headquarters (Washington, D.C.), with the aim of preventing communication deficiencies.[47] Experienced astronauts were placed in key NASA management positions, all documented waivers to existing flight safety criteria were revoked and forbidden, and a policy of open reviews was implemented.[48] In addition, NASA adopted a Space Shuttle flight schedule with a reduced average number of launches, and discontinued the long-term practice of launching commercial and military payloads.[49] The launch of *Discovery* (STS-26) from LC 39B on September 29, 1988, marked a Return-to-Flight after a thirty-two-month stand-down in manned spaceflight following the *Challenger* accident.

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[44] Judy A. Rumerman, with Stephen J. Garber. *Chronology of Space Shuttle Flights 1981-2000*. HHR-70 (Washington, D.C.: NASA History Division, Office of Policy and Plans, October 2000), 3.
[45] Williamson, 191.
[46] Columbia Accident Investigation Board. *Report Volume I* (August 2003), 25.
[47] Columbia Accident Investigation Board, 101.
[48] Cliff Lethbridge. "History of the Space Shuttle program." (2001), 4.
[49] Lethbridge, 5.

In the aftermath of the 2003 *Columbia* accident, a seven month investigation ensued, concluding with the findings of the Columbia Accident Investigation Board, which determined that both technical and management conditions accounted for the loss of the orbiter and crew. According to the Board's Report, the physical cause of the accident was a breach in the thermal protection system on the leading edge of the left wing, caused by a piece of insulating foam, which separated from the ET after launch and struck the wing.[50] NASA spent more than two years researching and implementing safety improvements for the orbiters, SRBs and ET. Following a two-year stand-down, the launch of STS-114 on July 26, 2005, marked the first Return to Flight since the loss of *Columbia*.

On January 14, 2004, President George W. Bush outlined a new space exploration initiative in a speech given at NASA Headquarters.

> *Today I announce a new plan to explore space and extend a human presence across our solar system . . . Our first goal is to complete the International Space Station by 2010 . . . The Shuttle's chief purpose over the next several years will be to help finish assembly of the International Space Station. In 2010, the Space Shuttle – after nearly 30 years of duty – will be retired from service. . .*[51]

Following the President's speech, NASA released *The Vision for Space Exploration*, which outlined the Agency's approach to the new direction in space exploration.[52] As part of this initiative, NASA decided that the Space Shuttle would not be upgraded to serve beyond 2010 and, after completing the ISS, the Space Shuttle program will be retired.

Development of KSC's LC 39 and Vehicle Assembly Building Areas

Today, KSC maintains operational control over 3,800 acres, all located in Brevard County. The major facilities are located within the Industrial Area, the LC 39 Area, the VAB Area, and the Shuttle Landing Facility Area. The LC 39 and VAB Areas were developed primarily to support launch vehicle operations and related launch processing activities. They contain the VAB, the Launch Control Center, the OPF and OPF-3, the two Launch Pads, 39A and 39B, and other support facilities.

Following completion of the Apollo-Soyuz Test Project in 1975, the facilities at KSC were modified to support the Space Shuttle program. KSC was originally one of three possible launch sites evaluated, along with Vandenberg Air Force Base in California and the White Sands Missile Range in New Mexico. Compared with the other two locations, KSC had the advantage

[50] Columbia Accident Investigation Board, 9.
[51] The White House. "A Renewed Spirit of Discovery – The President's Vision for Space Exploration." (January 2004).
[52] NASA Headquarters. "The Vision for Space Exploration." (February 2004).

of approximately $1 billion in existing launch facilities. Thus, less time and money would be needed to modify existing facilities at KSC rather than to build new ones at another location. The estimate of $200 to $400 million to modify the existing KSC facilities was roughly half the cost of new construction. In addition, only KSC had abort options for a first revolution return of the low cross-range orbiter.[53]

To help keep costs down, beginning ca. 1976, KSC engineers adapted and modified many of the Apollo launch facilities to serve the needs of the Space Shuttle program. Among the key facilities undergoing change were the VAB, the Launch Control Center, and LC 39 Pads A and B. New facilities were constructed only when a unique requirement existed. The major new structures included the Shuttle Landing Facility, OPF, and OPF-3. Multi-million dollar contracts for design and construction were awarded to both national and local firms, including Reynolds, Smith and Hills of Jacksonville, Florida; the Frank Briscoe Company, Inc. of East Orange, New Jersey; Algernon Blair Industrial Contractors, Inc. of Norcross, Georgia; the Holloway Corporation of Titusville, Florida; and W&J Construction Corporation of Cocoa, Florida.

Alterations to the VAB included modification of two of the four high bays for assembly of the Space Shuttle vehicle, and changes to the other two high bays to accommodate the processing and stacking of the SRBs and ET. The north doors were widened by almost 40’ to permit entry of the towed orbiter. Work platforms shaped to fit the Shuttle configuration were added to High Bays 1 and 3 where Shuttle assembly occurred, and internal structural changes were also made to High Bays 2 and 4, where the ETs were processed.

Major changes were made to LC 39, Pads A and B. Modifications were completed in mid-1978 at Pad A and in 1985 at Pad B. With the exception of the six fixed pedestals, which support the Mobile Launcher Platform, all of the structures on the hardstands of each pad were removed or relocated. Fuel, oxidizer, high-pressure gas, electrical, and other service lines were rerouted. New hypergolic fuel and oxidizer support areas were constructed at the southwest and southeast corners, respectively, of the pads; the Saturn fuel support area was removed, a new Fixed Service Structure was erected using an original Apollo-era Launch Umbilical Tower, a Rotating Service Structure was added, the Saturn flame deflectors were replaced, and a Payload Changeout Room and a Payload Ground Handling Mechanism were added. A sound suppression water system was installed on the pads to reduce the acoustical levels within the orbiter’s payload and thus, to protect it and its payloads from damage. A related system, the Overpressure Suppression System, was installed to reduce the pressure pulse at SRB ignition.[54]

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[53] Jenkins, 112.

[54] Wallace H. Boggs and Samuel T. Beddingfield. “Moonport to Spaceport. The Changing Face at KSC.” *Astronautics & Aeronautics*, July-August 1982, 28-41.

Additional changes were made to Pad A and Pad B in the aftermath of the 1986 *Challenger* accident; other modifications followed the Return-to-Flight in 1988. Among the modifications were the installation of new weather protection structures to supplement the Rotating Service Structure; improvements in temperature and humidity controls for the Payload Changeout Room; upgrades to the emergency exit system, including the addition of two slidewire baskets; installation of new elevators on the Rotating Service Structure; and improvements to the pad communications system. Changes were first made at Pad B, followed by identical changes at Pad A.

Part II. Structural/Design/Equipment Information

A. General Statement:

1. Character: OPF-3 (Photo Nos. 1 through 8) is an Industrial Vernacular style facility. It is composed of a structural steel skeleton, faced with metal siding, and has a poured concrete slab foundation and a flat, built-up roof. Spatially, the facility is comprised of three main areas: the High Bay, the SSMEPF, and the Low Bay; the High Bay and SSMEPF are the areas that contribute to the building's significance. The Low Bay sits between the High Bay and the SSMEPF; it shares its west wall with the former and its east wall with the latter. Throughout the remainder of this section, each of these areas will be addressed separately, as appropriate, for clarity of discussion.

2. Condition of fabric: Due to periodic maintenance and continual use of the facility, the building's structural skeleton and external envelope are in good condition.

B. Description of Exterior:

1. Overall dimensions: OPF-3 has approximate overall dimensions of 520' in length (east-west), 250' in width (north-south), and 95' in height. The irregular-shaped facility is comprised of three distinct areas, the High Bay, the SSMEPF, and the Low Bay.

The OPF-3 High Bay (Photo Nos. 1 through 5) is at the west end of the building, and has approximate overall dimensions of 197' in length (north-south), 150' in width (east-west), and 95' in height.

The SSMEPF (Photo Nos. 1, 6 through 8) sits at the east end of OPF-3, and has approximate overall dimensions of 190' in length (north-south) and 169' in width (east-west); it varies from 22' to 50' in height.

The Low Bay (Photo Nos. 1, 5) has rough dimensions of 247' in length (north-south), 202' in width (east-west), and 42' in height.

2. Foundations: OPF-3 has a foundation of poured concrete, supported by precast concrete piles with steel reinforcement bars.

3. Walls: The walls of OPF-3 are comprised of a structural steel skeleton, faced with corrugated insulated metal panel siding (High Bay); pre-finished metal sandwich panels (SSMEPF); and flat insulated metal panel siding (Low Bay). The sizes of the panels were not specified within the architectural and structural drawings.

4. Structural system, framing: The structural system for OPF-3 is comprised of steel I-beam columns and girders, with diagonal bracing to provide additional support in specified areas. Steel I-beam joists also are used in areas that have a second level. The roof is supported by an open web joist roof system.

5. Stoops: All of the doors into the Low Bay have a poured concrete pad and a 5'-deep metal canopy.

6. Stacks: The west elevation of the High Bay (Photo No. 3) features 54"- and 64"-diameter horizontal and vertical return air ducts in the lower half of the façade, and a 76"-diameter vertical supply air duct located about 79' to the north of the south edge of the elevation. This vertical supply air duct extends out from a 35' x 34' air-handling unit, which is flanked on either side by an environmental control building. The building to the north is original to the facility, and has approximate dimensions of 45' in length and 27' in width. The environmental control building to the south was constructed in 1994, following the conversion of the OPF-3 (see pages 6-7). The horizontal return air duct is positioned approximately 58'-6" above grade; one of its companion vertical ducts is situated roughly 78' south of the north end of the elevation, the other is about 208' from the north end of the elevation. The horizontal duct continues around the northwest corner of the building, and extends across the entire length of the north elevation.

7. Openings:

a. Doorways and doors: The south elevation of the High Bay (Photo No. 147) served as the point of entry for the Space Shuttle orbiter. Centered on the elevation is a 95'-wide x 36'-high, four-section metal sliding door for the orbiter, with a 10'-wide by 26'-high, metal vertical lift door for the vehicle's tail fin (Photo No. 9). The sliding sections move along rails that are mounted in a 4'-deep pocket above the opening, and in the concrete floor. In addition, each is fitted with a 7'-wide x 4'-9"-high mechanical access panel, and the westernmost sliding section contains a personnel access door. The north elevation (Photo No. 146) contains one single metal swing door for personnel, a 12' x 12' metal rolling door, through which the orbiter tug exited the facility, and a 31' x 30' metal sliding door for equipment and payloads (Photo No. 11).

The south elevation of the SSMEPF (Photo No. 164) features two metal rolling doors, for equipment and engines, and three single metal swing doors for personnel. The east elevation features two single metal swing doors (Photo No. 164). The north elevation (Photo No. 164) also features one single metal swing door and one double metal swing door, as well as two vertical ladders for roof access.

The south elevation of the Low Bay (Photo No. 161) contains one single metal swing door, five double metal swing doors, and one metal rolling door at the first floor level.

The north elevation of the Low Bay (Photo No. 161) features eight double metal swing doors and one single metal swing door.

b. Windows and shutters: The High Bay contains no window openings.

The south elevation of the SSMEPF contains twelve independent aluminum-bronze fixed windows across the elevation. There are seven windows of the same style along the east elevation, and four windows across the north elevation.

At the first floor level of the Low Bay, there are two groups of three fixed, aluminum-framed windows on the south elevation. On the second floor of the south elevation, there are three groups of fixed, aluminum-framed windows. The group at the west end of the façade contains thirteen windows, while the groups at the center and east end of the elevation contain ten windows. There are no window openings on the north elevation.

8. Roof:

a. Shape, truss type, covering: The entire facility is covered by a "4-ply" flat roof. The four layers are a metal deck on bottom, on top of which is a layer of rigid insulation, followed by a layer of built-up roofing, and topped by a layer of gravel. The roof is supported by an open web joist truss system.

d. Antennae: At the southwest corner of the High Bay roof is a group of four antennae (Photo No. 12), supported by a metal platform. There are also three antennae at the northeast corner of the High Bay roof. They were used to test the orbiter's communications and navigational systems.[55]

C. Description of Interior:

High Bay

1. Floor plans: The OPF-3 High Bay is comprised of one open area, and is typically accessed from the Low Bay via a pair of airlocks that are located along the east wall of the High Bay. Each airlock has approximate dimensions of 9' in length and 5' in width, and contains a metal swing door on both its east and west walls. The south airlock provides access into the High Bay, while the north airlock is used as the exit. Three metal swing doors on the west wall of the High Bay provide access to the environmental control buildings along the exterior. In addition, the east and west walls contain rails for the facility's two bridge cranes, mounted approximately 64' above the finished floor (aff). The cranes (Photo Nos. 91, 92) can move along these rails to the north and south, with each crane hook adjustable along

[55] Don Crouse. Personal communication with Patricia Slovinac, February 22, 2011.

the east-west axis; this allows crane access to virtually every location in the High Bay. A catwalk on the east wall, just below the crane rail, provides personnel access to the cranes.

Within the floor of the High Bay is a system of utility trenches, which are approximately 5' in width and 4' in depth (Photo Nos. 145, 151). There are also three hydraulic floor lifts; one was used for the orbiter's nose landing gear, and two were used for the main landing gear (Photo Nos. 18 through 20). The lift was comprised of a 5' x 8' platform, on which the wheels of the landing gear sat, supported by a steel frame; the platform/frame rest within an 8'-long x 8'-wide pit that is either 12'-2"-deep (nose landing gear) or 7'-4"-deep (main landing gear).

The main feature of the High Bay was the platform structure, comprised of both stationary and moveable platform sections. The structure was centered on the orbiter access door and was oriented so that the orbiter's nose sat at the north end when positioned within the hangar (Photo Nos. 13 through 18, 151). The stationary portion of the platform structure was composed of a steel I-Beam skeleton that supported aluminum decking shaped around the contours of the orbiter. Some areas of the decking were fitted with moveable platforms, which were also constructed of steel I-Beams and aluminum decking and shaped to fit around the orbiter. All of the platform levels were connected by stairs, ladders, and ramps, and were fitted with handrails for safety purposes.

Although interconnected, the platform structure was functionally divided into three areas: the nose access area (forward fuselage, forward reaction control system [RCS] module, crew compartment, and flight deck windows), the midbody access platforms (payload bay/doors, midfuselage, and wings), and the aft access platforms (orbital maneuvering system [OMS] pods, aft compartment, vertical stabilizer, and body flap). In general, there were a few standard platform levels among the three areas, but the majority sat at different heights based on processing requirements. There were also loose platforms that could be fitted to specific areas of the main platform structure, or moved into place around or within the orbiter.

The nose access area platforms (Photo No. 29) were situated at the north end of the hangar, and were shaped around the orbiter's nose. The first platform level at this area was known as Level 1A, and sat roughly 6'-7" aff. There were two halves to the level, one to the port side of the vehicle (west) and one to the starboard side of the vehicle (east); there was no direct access between the two. The west half of Level 1A (Photo Nos. 30, 31) held the fuel valve complex for servicing the forward RCS module. The east half of Level 1A (Photo No. 32), on the other hand, contained the oxidizer valve complex for servicing the forward RCS module. The second platform level in the nose access area was called Level 1 (Photo No. 33) and sat approximately 14'-3" aff. This level was comprised of an open platform that wrapped around the nose of the orbiter, and contained four hinged platforms on either side. It provided access to the forward RCS module and the vehicle's air data probes. In addition, a "white

room" (Photo No. 35), which provided access to the crew compartment, sat on the port side of the level.

Level 2 and Level 3 of the nose access area (Photo No. 36) sat at 19'-9" aff and 24'-9" aff, respectively. These two platforms wrapped around the upper area of the vehicle's nose cone; Level 2 specifically provided access to the orbiter's star trackers through a pair of hinged platforms (Photo No. 37). Level 5, also at 24'-9" aff, provided access to the primary windows of the crew cabin, i.e., those located around the commander's and pilot's stations. There was also a Level 6 in the nose access area, at 27'-7" aff and on the port side only. This level contained the filters for the crew cabin's environmental control system, when it was connected to the facility (Photo No. 38).

The midbody access platforms (Photo No. 41) were located to either side of the orbiter; the two sides were not directly connected. Regardless, the different levels on each side had the same designation, and sat at the same height above the floor. The lowest platform level in the midbody area was known as Level 8; it sat roughly 7'-11" aff, and was contoured around the orbiter's wing (Photo Nos. 42, 43). This open level contained two hinged platforms and provided access to the orbiter's wings. The second level within the midbody access area was called Level 4. This platform sat 16'-5" aff, and like Level 8, was shaped around the orbiter's wing (Photo No. 43). On each side, this level contained a built-in compartment for umbilical connections (Photo No. 46), and supports for the orbiter's payload bay doors (Photo No. 47). The level also contained various panels to control and monitor the commodities used during vehicle processing, such as gaseous helium, hydrogen, oxygen, and nitrogen, and liquid hydrogen and oxygen. At the north end of the starboard side Level 4 platform was a small enclosure for the vehicle's Ku-band antenna; the enclosure was used to absorb radiation.[56] In addition, the starboard side platforms extended to the east wall of the High Bay to provide work areas for the orbiter processing technicians.

The next set of platforms was referred to as Level 13, or just as the 13s. The platforms sat roughly 23'-6" aff and provided access to the payload bay (Photo Nos. 52, 53). The 13s were divided into two sections, each of which was hinged at the bottom and was connected to four winches that raised and lowered the platforms as required. To the vehicle side of each section were fourteen smaller access platforms that could extend and retract via a sliding mechanism for an approximate length between 4'-6" and 6'-10" (see Photo No. 53). To the east of the starboard 13s, a stationary platform extended to the east wall of the High Bay. This area, known as Level 6, sat 27'-7" aff, contained the orbiter window inspection area (Photo No. 56), and technician work areas. It also provided access to the winches for the "13s."

[56] Crouse.

The highest level in the midbody access area was designated Level 7 (Photo Nos. 58, 59). The sole purpose of this level, which sat 36' aff, was to provide the technicians access to the two midbody bridge bucket cranes (Photo No. 60). The two cranes had wheels at each end of the bridge structure that rolled north to south along tracks within the floor deck on each half of Level 7. Suspended from each bridge were two buckets (Photo No. 61), which could move east to west along rails in the bottom of the bridge. These buckets could also be raised and lowered through a hoist to carry the technicians into and out of the payload bay; the buckets were rotatable through 350 degrees. When not in use, one of the bridge bucket cranes was stowed at the north end of the platform structure, while the other was stored at the south end. These cranes were required to be in their stowage position when the main High Bay bridge cranes were in use.[57]

The aft access platforms (Photo Nos. 63, 64, 79) were also located to either side of the orbiter. The lower levels in this area were contoured in the shape of the orbiter's wings, while the upper levels were shaped around the aft fuselage/OMS pods. The first platform in this area was referred to as Level 11 (Photo No. 65, 69); it sat 16'-11" aff, and each side contained four moveable platform sections. One of these moveable platforms was used by technicians to access the interior of the aft fuselage (Photo No. 66). The main portion of this level included various commodities panels that were used for processing the ET umbilicals, the auxiliary power units, and the RCS thrusters. The second level in this area was designated Level 12 (Photo No. 71) and sat 27'-7" aff. It had two moveable platforms, which provided access to the OMS pods. Each side contained a spill aspirator and purge manifolds for the OMS oxidizer and fuel (Photo Nos. 72, 73, 75, 76). The port side also contained panels for processing the SSMEs (Photo Nos. 73, 74). In addition, the starboard side platform extended to the east wall of the High Bay; this extension contained filters for the vehicle environmental control system (Photo No. 77).

The next three platform levels in the aft area were Level 16, Level 17, and Level 18; they sat 35'-1", 43'-9", and 50'-11" aff, respectively (Photo No. 80). Each side of Level 16 held three moveable platforms, all of which extended and retracted on tracks. This level provided access to the OMS pods and the lower portion of the rudder/speed brake. Each side of Level 17 and Level 18 was fitted with two moveable platforms. Both of these were operated with the use of a winch, one was lowered into its use position while the other was raised into its use position. Level 17 provided access to the central part of the rudder/speed brake and Level 18 (Photo No. 81) provided access to the rudder and the top of the vertical stabilizer.

At the south end of the High Bay was the 513 workstand (Photo No. 83), which consisted of a starboard and port half that extended and retracted along two sets of tracks in the floor (Photo No. 84). Each half of the workstand contained three platform levels to provide access

[57] Steve Wachowski. Personal communication with Patricia Slovinac, February 24, 2011.

to the SSMEs and OMS pods. The first level sat 4'-1" aff (Photo No. 85), and the second level sat 14'-1" aff (Photo No. 88). Below each half of the second level were two moveable platforms, called the 10s that extended and retracted along rollers attached to the underside of the deck (Photo No. 86). The top level (Photo No. 89), which sat 24'-1" aff, included a walkway over the orbiter between the two halves of the workstand; the walkway was only useable when the workstand was in its use position. It also had a small crane for use in processing operations (Photo No. 90).

2. Work flow: In between missions, each orbiter was subject to a series of processing activities within one of the three OPF High Bays. Prior to the *Columbia* accident in February 2003, when there were four active orbiters, the High Bays were assigned on a "first available" basis. Afterwards, the OPF-3 High Bay was dedicated to the Orbiter *Discovery*.[58] Each processing task typically fell into one of four designations: end-of-mission roll-in operations; system safing and deservicing; system testing, verification, and servicing; or vehicle closeouts/preparations for rollover to the VAB. The entire sequence nominally required 125 days to complete.[59] The various moveable platforms attached to the main platform structure were extended and retracted as required for each task.

The first set of activities performed in the High Bay were generally referred to as the "end-of-mission roll-in operations."[60] Approximately four hours after landing, a tractor tow vehicle pulled the orbiter from the SLF Runway to the High Bay through the sliding door on the south elevation. Once inside, the vehicle was precisely aligned using a laser system, with each set of landing gear resting atop one of the three hydraulic floor lifts. The tractor tow was then disconnected from the vehicle, and it exited the hangar through the 12' metal rolling door on the north wall. Afterwards, the orbiter's "T-0" umbilicals were connected to ground equipment within the facility, the orbiter's systems were connected to facility-provided utilities, and the vehicle's fuel cells were powered down. The orbiter was raised with the floor lifts, and mated to four orbiter jacks, two at the forward end and two at the aft end. The vehicle was then leveled, the connections were tightened, and the floor lifts were lowered.[61]

Two additional activities were begun during the "end-of-mission roll-in operations," and finished during the second set of operations. One such task involved the purging of the three SSMEs to remove any moisture that was produced by the combustion of the liquid hydrogen and liquid oxygen. In addition, the cryogenic tanks for the orbiter's fuel cells were drained of

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[58] The two bays in the OPF, High Bay No. 1 and High Bay No. 2, were devoted to *Atlantis* and *Endeavour*, respectively.
[59] United Space Alliance (USA). "Orbiter Processing Facility (Day One)." Kennedy Space Center presentation materials provided by Stephanie Stilson, no date, 44.
[60] USA. "Orbiter Processing Facility (Day Two)." Kennedy Space Center presentation materials provided by Stephanie Stilson, no date, 3.
[61] Terry White. Personal communication with Patricia Slovinac, February 22, 2011.

residual reactants, and filled with gaseous nitrogen (oxidizer tanks) or gaseous helium (fuel tanks) to render them inert.[62] Another task was to open the payload bay doors, install access platforms as required to support processing, and safing any hazardous payloads. Because of the design of the payload bay doors, they could not operate on their own outside of a zero-gravity environment. Therefore, when inside the High Bay, counterweights (Photo No. 48) were attached to each door in order to "trick" it into thinking the vehicle was in space. Jib hoists were then used to open the doors, which were then supported by strongbacks and column supports (Photo Nos. 47, 142).[63]

The second general set of operations performed in the OPF-3 High Bay included "system safing and deservicing" activities.[64] During this period, any remaining OMS and RCS oxidizer and fuel were drained, and then the systems were purged. If necessary, the OMS pods and the forward RCS module were removed and sent to KSC's Hypergol Maintenance Facility.[65] In addition, the three SSMEs were removed from the orbiter and taken to the SSMEPF for processing.[66] Other activities included in the safing process were the removal, deservicing, and flushing of the waste control system; draining, filter removal, and purging of the potable water system and the water spray boilers; venting high pressure gases from the vehicle's environmental control and life support system; and draining and purging the auxiliary power units. For many of these activities, the entire High Bay, or just the immediate surroundings, were cleared of all non-essential personnel.[67]

The major phase of orbiter processing operations was the "system testing, verification, and servicing" of every required functional orbiter system. This included the OMS/RCS, the fuel cell system, the window cavity conditioning system, the guidance, navigation, and control system, the communications system, the orbiter boom sensor system, the remote manipulator system, the auxiliary power units, the mechanical systems, and structural inspections.[68] As part of these routine operations, individual components of each system could be removed, inspected, tested independently, and then reinstalled. If the component sustained significant wear or damage, it was generally replaced and tested as part of the system to ensure compatibility. At the same time, if a particular component presented problems during the mission, the troubleshooting of those problems occurred during this phase, and included removal of the element and its repair or replacement.[69]

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[62] USA, "Day One," 44; USA, "Day Two," 3; NASA. "Space Shuttle: Orbiter Processing, From Landing to Launch." 2006, 3.
[63] White.
[64] USA, "Day One," 44, USA, "Day Two," 6.
[65] USA, "Day Two," 6; NASA, "Orbiter Processing," 3.
[66] USA, "Day Two," 6; NASA, "Orbiter Processing," 3. See pages 30-31 for a description of the SSMEPF work flow.
[67] USA, "Day Two," 6-8; NASA, "Orbiter Processing," 3.
[68] USA, "Day Two," 9.
[69] NASA, "Orbiter Processing," 3.

Also during this phase of operations, visual inspections were conducted on the thermal protection system, the landing gear, and selected structural elements to determine if they sustained any damage during the flight.[70] If technicians discovered significant damage to a tile, either they created a foam version of the tile using the tile cavity as a mold, or they took a set of photographic images of the tile cavity. The image was forwarded to the Thermal Protection System Facility, where a new tile was produced and delivered to the OPF for installation. If damage to a soft goods component was discovered, the component could be removed and sent to the Thermal Protection System Facility for repair if appropriate, or to be used as a pattern for a replacement.[71]

Another key task conducted during this phase of operations was payload processing. The first step was to deconfigure the vehicle from the previous mission. This included disconnecting any vehicle power or mechanical systems that were attached to the previous payloads, removing any remaining payloads and their supports, and deconfiguring the appropriate control panels on the aft flight deck. The vehicle was then reconfigured for the next mission's payload requirements. Tasks included in this process were to install payload support mechanisms in designated places, perform payload pre-mate testing, configure the appropriate control panels on the aft flight deck, install the payloads, connect the payloads to the vehicle power and mechanical systems as required, and completing a payload integration verification test.[72] The bridge bucket cranes (Photo Nos. 60, 61) were widely used during these operations.[73]

OPF technicians also used this time to perform planned vehicle modifications, which were carried out in conjunction with the routine procedures. These changes to the vehicle were made based on future mission requirements, the need to resolve an identified deficiency, or to replace existing equipment with new, improved components designed to enhance the orbiter's performance.[74] The OPF High Bay also periodically served as the location for two additional procedures: Orbiter Maintenance Down Periods and Orbiter Major Modifications.[75] An Orbiter Maintenance Down Period was a period of time that an orbiter

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[70] NASA, "Orbiter Processing," 3.
[71] NASA, "Orbiter Processing," 3; Patricia Slovinac. "Cape Canaveral Air Force Station, Launch Complex 39, Thermal Protection System Facility (John F. Kennedy Space Center)," HAER No. FL-8-11-L. Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, April 2011, 18-21.
[72] USA, "Day Two," 16-19.
[73] White.
[74] NASA, KSC. "Space Transportation System: Facilities and Operations, Kennedy Space Center, Florida." April 1984, 2-14.
[75] Up through February 2001, the OPFs at KSC shared this duty with the Shuttle Orbiter Final Assembly Building (Building 150) at Air Force Plant 42 in Palmdale, California. Beginning with *Discovery's* third Orbiter Maintenance Down Period in September 2002, all Down Period and Major Modifications were completed at KSC. ACI and Weitze Research. *NASA-wide Survey and Evaluation of Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program, Air Force Plant 42, 1 North, Palmdale, California*. November 2007.

was taken out of service for structural inspections and modifications.[76] During Orbiter Maintenance Down Periods, the "orbiters are disassembled almost down to the airframe…for an extensive and vigorous inspection process."[77] An Orbiter Major Modification was a subset, but not a requirement, of an Orbiter Maintenance Down Period. Each orbiter typically underwent an Orbiter Major Modification every eight flights or three years. Work included component changes, routine and special inspections, modifications, deferred work, and correcting "stumble-ons."[78]

One of the last tasks in the "system testing, verification, and servicing" phase of operations was a crew equipment interface test. For this procedure, the crew members for the mission traveled to KSC. They inspected the payload bay for sharp edges, which could pose a hazard to on-orbit operations, and familiarized themselves with the locations of specific payloads and how they would be accessed during the mission. In addition, the crew familiarized themselves with the arrangement of the middeck level of the crew cabin, including the stowage locations of equipment planned for use during the mission, as well as the airlock configuration.[79]

The final set of operations conducted in the OPF-3 High Bay was referred to as "vehicle closeouts/preparations for roll-over."[80] One of the tasks included reinstalling the SSMEs, which then underwent a leak test to ensure the integrity of the entire main propulsion system.[81] The maneuvering capabilities of the engine gimbals, as well as all vehicle aerosurfaces, were then checked. Also during this time period, any issues discovered during the crew equipment interface test were resolved, an orbiter compartment positive pressure check was performed, and a final checkout of the thermal protection system was conducted. Technicians also serviced the potable water system, the gaseous nitrogen pressure vessels, and installed the electrically-initiated pyrotechnic devices. As the final checks were completed for each of the systems, the access panels were reattached to the vehicle.[82]

There were also various activities completed just prior to the vehicle's roll-over to the VAB. First, a weight and center of gravity verification of the vehicle was performed. Then, the orbiter transporter was brought into the High Bay through the south door, and the orbiter was mated to it through one forward attach point and two aft attach points. Then, the final landing gear strut inspection was performed, the tires were pressurized, and the wheel wells were inspected. Following these steps, the landing gear was retracted, and the doors closed. Once

[76] NASA, Headquarters. "Followup Audit on Orbiter Maintenance Down Periods at KSC, IG-98-016." 1998.
[77] "Where next, Columbia? Palmdale, California." *Spaceport News* (38, 19), September 17, 1999, 1.
[78] Columbia Accident Investigation Board, 415.
[79] USA, "Day Two," 20.
[80] USA, "Day Two," 21.
[81] NASA KSC, "Facilities and Operations," 2-15.
[82] USA, "Day Two," 21; NASA KSC, "Facilities and Operations," 2-15.

this was completed, the technicians performed the final power down of the vehicle and removed of all connections to facility services. All extendible platforms were then retracted, the attach points between the orbiter and the transporter were confirmed, the south door was opened, and the transporter carried the orbiter out of the High Bay.[83]

3. Stairways: All stairways within the High Bay were embedded within the platform structure.

4. Flooring: The floor of the High Bay is exposed poured concrete, except for the two airlocks where the concrete is faced with resilient tile.

5. Wall and ceiling finish: The walls and ceiling of the High Bay are exposed metal and concrete block; the two airlocks have exposed concrete block walls and poured concrete plank ceilings.

6. Openings:

a. Doorways and doors: There are four internal doors within the High Bay, all of which are associated with the airlocks. Each is a 4' x 7' hollow metal swing door.

7. Mechanical equipment:

a. Heating, air conditioning, ventilation: The High Bay contains its own centralized, heating, ventilating, and air conditioning system. It is also fitted with an emergency ventilation system for hypergol vapors.

b. Lighting: The lighting system for the High Bay includes high pressure sodium pendant and wall-mounted fixtures, surface-mounted and pendant fluorescent fixtures, and fluorescent emergency lighting.

c. Plumbing: The High Bay contains its own plumbing system, one for chilled water and one for heated water.

d. Other: The High Bay is fitted with its own fire suppression system.

SSMEPF

1. Floor plans: The SSMEPF has a roughly cross-shaped plan, which is divisible into four main areas (west, south, east, and north), excluding the mechanical and electrical equipment rooms. The west portion of the facility was designated the GSE area; the south part of the SSMEPF contained a staging area, a battery charging area, and the Horizontal Processing

[83] USA, "Day Two," p. 22-25; NASA KSC, "Facilities and Operations," p. 2-17; NASA, "Orbiter Processing," 3.

Area. Within the east portion of the facility were the High Bay area and the Drying Room. The north section contained the Vertical Processing Area, a Hydraulic Pump Room, and other support areas

The GSE area has approximate overall dimensions of 101’ in length and 52’ in width, and a floor-to-ceiling height of roughly 9’. The south portion of this area was referred to as the Ground Support Staging Area (Photo No. 138). It was a rectangular space that measured about 70’ in length and 52’ in width. At the northwest corner were two small storage rooms, and in the center of the north wall was an equipment elevator. The remainder of the space featured storage cabinets, shelves, and worktables. At the north end of the GSE area was the Inspection Room (Photo No. 139), which had approximate dimensions of 24’ in length and 20’ in width. The south wall of this space was fitted with a one-light, metal swing door for personnel, and a 7’-4”-wide overhead metal rolling door for equipment. The room also featured a ceiling mounted crane to assist technicians with their inspection activities. Directly to the south of the west end of the GSE area was the designated Staging Area, which had rough dimensions of 29’ in length, 24’ in width, and 20’ in height. On its east wall there was a pair of metal swing doors that provided personnel access between the Staging Area and the Horizontal Processing Area, as well as a 14’-wide overhead metal rolling door (Photo No. 106) for SSME and equipment access between the two spaces.

The Horizontal Processing Area (Photo Nos. 104, 105) measured approximately 76’ in length, 33’ in width, and 30’ in height. It featured painted metal walls, a painted concrete floor, and an open ceiling. A 24”-wide, 24”-deep utility trench, located approximately 4’ from the south wall, extended east to west within the floor. The area was comprised of one open space, with three designated work areas denoted by yellow lines painted on the floor that accommodated an engine horizontally mounted on a Horizontal Engine Handler (Photo No. 107). An opening in the east wall provided access to the SSMEPF High Bay, while a one-light, metal swing door, and a 15’-wide overhead metal rolling door on the north wall provide access to the Vertical Processing Area. Rolling equipment carts are stored along the south wall, as is the Encapsulation Test Panel (Photo No. 108). To the southwest corner of the Horizontal Processing Area is the separate 18’-long x 10’-wide battery charging area (Photo No. 138).

The eastern portion of the facility contained a 75’-long x 60’-wide High Bay to the south, with a 60’-long x 30’-wide Drying Room/Control Room to its north. The High Bay (Photo Nos. 109 through 111) had painted metal walls on the west, south, and east, and a concrete block north wall. The floor was painted concrete block, and the room had an open ceiling, situated 46’ above the finished floor. Attached to the east and west walls were rails for the 15-ton overhead bridge crane (Photo No. 112). There is a 28’-wide rolling metal door on the south wall for equipment access from the exterior, and a one-light metal swing door on either side for personnel access. Similar to the Horizontal Processing Area, the High Bay consisted

of one open space with yellow painted lines on the floor, depicting the activity locations. Storage shelves and desks were situated along the east wall. At the time of documentation, the High Bay also contained a SSME weight simulator, commonly known as a “bar stool” (Photo No. 114), a horizontal engine installer (Photo No. 115), a SSME lift (Photo No. 116), and the horizontal engine installation and removal lift truck (Photo No. 117). This area also contained a 15-ton bridge crane, which moved north to south along rails mounted to the east and west walls (Photo No. 112).

The Drying Room (Photo Nos. 118, 119) measured approximately 56’ in length and 30’ in width. Like the Horizontal Processing Area and the High Bay, it was comprised of one open space with yellow lines painted on the floor to denote the path and three resting locations for the SSME Horizontal Handlers. Adjacent to each of the lines was an accompanying utility trench, all three of which ran north to south (see Photo No. 119); on the north wall are three vents, one for each utility trench (Photo No. 120). The south wall of the Drying Room is fitted with two metal rolling doors; the one to the west is 13’-4”-wide, while the one to the east is 27’-4” wide. To the west of the Drying Room is its Control Room, which measures roughly 30’ in length and 14’ in width (Photo No. 121). This room contains all of the panels and gauges to control and monitor activities within the Drying Room.

The central area of the SSMEPF contained the Vertical Processing Area, which further extended into the north arm of the plan (Photo Nos. 123, 124), and measured approximately 150’ in length and 57’ in width. It is comprised of one open space with a series of six workstations along the west wall. On the south wall is a 15’-wide opening with metal rolling door that leads to the Horizontal Processing Area; on the east wall is the 22’-wide opening into the High Bay and a metal swing door that leads to the control area for the Drying Room. On the west wall, at the first level, there are two pairs of metal swing doors, one into the GSE area and the other into a hardware disposition area (Photo No. 162); there is also a single metal swing door that provides access to the hydraulic pump room. At the second level, there are three single metal swing doors and one pair of metal swing doors; one leads to an external staircase, the others lead to different support rooms (Photo No. 163). The Vertical Processing Area also contains a 10-ton bridge crane that moved north to south along rails mounted to the east and west walls; the hook was capable of being moved east to west.

The six workstations on the west wall were comprised of steel I-beam skeletons; the floor of the second level was composed of a 1 ½” composite steel deck with a 2” reinforced concrete slab on top. The stands were paired in twos, with metal stairs from the ground level to the second level separating the pairs (Photo No. 162). Each workstation (Photo Nos. 126, 129) measured roughly 24’ in length and 22’ in width. The lower level of the work stand provided access to the SSME output nozzle. At the center of this level, in each workstation, was an 8’-3”-diameter engine pedestal, supported by three, 3’-high I-beams (Photo Nos. 127, 129). The floor of the second level for each workstation was shaped to fit around the SSME (Photo

Nos. 128, 130). There was a trapezoidal cutout at the east (see Photo No. 127), which was removable with the aid of a lifting cart (Photo No. 131), that allowed the engine to be positioned within the workstand. The second level of the workstations, which provided access to SSME's systems, contained various desks and storage carts around the perimeter, leaving the center area open for access to the engines. To the west of each pair of workstations was a pressure supply panel (Photo No. 132), which supplied and monitored commodities such as gaseous helium, nitrogen, and hydraulic supply and return distribution, used in engine processing activities.

2. Work flow: Following the landing of the orbiter, and initial post-flight processing within the OPF High Bay, the three engines entered the SSMEPF via the Hyster lift truck (Photo No. 117), and were positioned in one of the three work areas in the Horizontal Processing Area on a Horizontal Handler (Photo Nos. 107, 119). Here, post-flight leak checks and inspections were conducted on each engine's pumps, valves, and nozzles. The engines were then moved with the Horizontal Handler through the High Bay and into the Drying Area. Within this area, heated gaseous nitrogen was pumped through each engine to remove all water.[84] Following the drying process, the engines, each still supported by a Horizontal Handler, were moved into the Vertical Processing Area. Here, each was connected to the overhead crane, rotated to the vertical position, and moved into one of the six workstands. As positioned within the dual-level workstand, processing operations on the nozzle occurred on the ground level, while all access to the engine was at the second level (Photo No. 129).[85]

Once the engines were set within a vertical workstand, each SSME underwent additional leak checks, which centered on the main combustion chamber and the oxidizer heat exchanger. Afterwards, any major components of the SSME were removed for repairs if required, such as the high pressure fuel and oxidizer turbopumps, the main engine controller, the nozzles and valves, the actuators, and the ducts.[86] The individual components were then inspected and refurbished, prior to being reinstalled. The reassembly sequence generally followed the same pattern, beginning with the attachment of the main combustion chamber to the nozzle (Figure No. A-13). This was followed by the installation of the powerhead, the attachment of high pressure oxidizer turbopump and the high pressure fuel turbopump (Figure No. A-14). Then, the engine ducts and lines were attached, followed by the installation of the low pressure fuel and oxidizer turbopumps. Afterwards, the main fuel and oxidizer valves and

[84] Matt McClelland. Personal communication with Patricia Slovinac, March 7, 2011; USA. "Space Shuttle Main Engine: KSC Processing." Kennedy Space Center presentation materials provided by Matthew McClelland, June 22, 2010.
[85] McClelland; USA, "KSC Processing."
[86] In general, these components were referred to as line replacement units, typically defined as modular units that can be easily replaced.

actuators were installed, followed by the main engine controller.[87] All of these processes were assisted by a boom crane located on the second level of each workstation (see Photo No. 130).

Once reassembly was complete, leak checks and valve flow checks were performed on the engine, while it was still mounted in the vertical workstand. In addition, flight readiness tests were conducted on the avionics and pneumatics subsystems, a checkout was performed on the main engine controller, and liquid air insulation was installed as required. Afterwards, the engine was removed from the vertical workstand and rotated to the horizontal position. It was then mounted onto a Horizontal Handler and moved to the Horizontal Processing Area, where an encapsulation test using the "big can" (Photo Nos. 135, 136) was performed.[88] This involved positioning the can around the engine, and then running gaseous helium through the engine to check for weld and other leaks.[89] Technicians then performed pre-installation preparations on each engine, including the installation of thermal protection system materials to the nozzles. When all processing activities were complete, the engines were stored in the SSMEPF until technicians in the OPF High Bay were ready to install them into the orbiter.[90]

3. Stairways: Aside from the metal steps associated with the workstations in the Vertical Processing Area, there is one other stairway within the SSMEPF. It is a U-shaped staircase located near the southwest corner, and is accessed through the GSE area.

4. Flooring: The floor of all levels of the SSMEPF is painted concrete, except for one room on the second level, which contains a raised floor comprised of high pressure laminate tiles.

5. Wall and ceiling finish: The walls throughout the SSMEPF are comprised of a combination of painted concrete block metal panels, and painted gypsum board. The ceilings are either exposed structure, painted concrete, or suspended 2' x 2' acoustical ceiling tile.

6. Openings:

a. Doorways and doors: The various internal doors within the SSMEPF are comprised of hollow metal swing doors with a window, insulated hollow metal swing doors with a window, hollow metal rolling doors and insulated hollow metal rolling doors. The swing doors are typically 3' x 7', while the rolling doors range in size from 7'-4" x 7'-4" to 22' x 18'.

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[87] Jerry Cook, Dewayne Collins, and Daniel McCranie. "SSME Historical Recordation." Huntsville: MSFC presentation materials provided by Daniel McCranie. June 12, 2009.
[88] USA, "KSC Processing."
[89] McClelland.
[90] USA, "KSC Processing."

7. Mechanical equipment:

a. Heating, air conditioning, ventilation: The SSMEPF contains its own centralized, heating, ventilating, and air conditioning system.

b. Lighting: The lighting system for the SSMEPF includes recessed and surface-mounted fluorescent fixtures, wall-mounted and recessed low pressure sodium fixtures, and fluorescent emergency lighting.

c. Plumbing: The SSMEPF contains its own plumbing system, one for chilled water and one for heated water.

d. Other: The SSMEPF is fitted with its own fire suppression system.

Low Bay

1. Floor plans: The Low Bay, inclusive of the addition, contained the service and support rooms for the High Bay and the SSMEPF. In the center of the first floor (Photo No. 159) was a staging and holding area, which provided storage space for different types of equipment. Along the south wall, moving west to east, were the Operational Intercommunication System Battery and Communications Rooms, with the Launch Processing System Room and the Communications and Tracking Station Room to its north, the Logistics Room, and various break rooms, support rooms, and offices. Along the north wall of the Low Bay, from west to east, were the Facility Communications and Electrical Equipment Rooms, a Mass Spectrometer Shop, a Blanket Shop, the Welding and Brazing Shop, and the Ground Support Equipment Shop. Interspersed among these were a few electrical, mechanical, and janitorial rooms. Extending across the west wall were restrooms and other support areas, while the east wall contains restrooms, mechanical and electrical shops, and the Flex Hose Shop. The second floor of the Low Bay (Photo No. 160) was entirely office space. Although all of these spaces provided support to the personnel and their tasks at hand, two were critical to the success of the post-flight and pre-flight preparations of the orbiter. These were the Communications and Tracking Station Room in the south part of the Low Bay, and the Welding and Brazing Shop along the north wall.

The Communications and Tracking Room (Photo No. 99) has approximate dimensions of 50’ in length (east-west) and 28’ in width (north-south); it has a floor to ceiling height of 12’. There is one entrance to this space, a double metal swing door, which is located on the east wall. The walls are comprised of painted gypsum board, the ceiling is formed with 2’ x 4’ acoustical tile, and it has a raised tile floor that allows cables to be run underneath between the different pieces of equipment. The main feature of the room was three rows of equipment consoles and cabinets, which form a “U” shape. All of the

panels faced the center of the room, where there were two technician workstations. The consoles in the north row monitored television, S-band, and Ku-band signals. Those within the west row included hardware interface modules, Tactical Air Command and Navigation system interfaces, Microwave Scanning Beam Landing System interfaces, Navigational Aids interfaces, and radar interfaces. In the south row, there were payload testing panels, laboratory patch panels, graphical recording panels, digital and analog recording panels, ultra high frequency panels, and range safety system panels. Behind the west row of panels were more workstation and storage areas. In addition, at the northwest corner of the room was a gaseous nitrogen purge panel (Photo No. 100), which helped maintain the proper pressure through all of the lines.

The Welding and Brazing Shop is an "L"-shaped room (Photo No. 101), with approximate overall dimensions of 52' in length (north-south) and 40' in width (east-west). Its floor to ceiling height is roughly 9'. This room is typically accessed from either the single metal swing door or the pair of metal swing doors on its south wall, but there is also a pair of metal swing doors on the north wall, which leads directly to the exterior of the building. The walls are comprised of painted gypsum board and the ceiling is formed with 2' x 4' acoustical tile; it is fitted with a conductive floor. The southwest corner of the room contained desks for the personnel, as well as typical office storage equipment. At the southeast corner sat an Electro-Metal Disintegrator (Photo No. 102), which was used for removing bolts and other hardware that were stuck or damaged. At the north end of the room were various pieces of metal bending equipment, used to make replacement tubing for the orbiter. Also stored in this room were brazers and welders that were also used in the tubing manufacturing process (Photo No. 103).

3. Stairways: There are three enclosed stairwells within the Low Bay to provide access to the second floor level (Photo No. 159). One is near the northwest corner within the original portion of the Low Bay. The other two are within the south third of the floor area. Each is located off one of the two hallways that extend from a south exterior door to the central staging and logistics area.

4. Flooring: The first floor of the Low Bay has a variety of finishes, including exposed concrete, conductive flooring, vinyl composition tile, raised flooring, and ceramic tile. The second floor finishes include carpeting, vinyl composition tile, and ceramic tile.

5. Wall and ceiling finish: The walls of both levels of the Low Bay have a variety of finishes, including painted gypsum board, fabric, vinyl, and ceramic tile. The ceilings on each level are 2' x 4' acoustical tile.

6. Openings:

a. Doorways and doors: The numerous internal doors within the Low Bay are typically 3' x 7' and comprised of hollow metal swing doors; those on the second floor generally are fitted with a 10" x 10" window. There is one 18' x 9' metal rolling door on the first level.

7. Mechanical equipment:

a. Heating, air conditioning, ventilation: The Low Bay contains its own centralized, heating, ventilating, and air conditioning system.

b. Lighting: The lighting system for the Low Bay includes recessed and surface-mounted fluorescent fixtures, recessed and surface-mounted incandescent fixtures, surface-mounted high pressure sodium fixtures, and fluorescent emergency lighting.

c. Plumbing: The Low Bay contains its own plumbing system, one for chilled water and one for heated water.

d. Other: The Low Bay is fitted with its own fire suppression system.

E. Site Layout: OPF-3 is situated in the Vehicle Assembly Building area of KSC. The VAB is located to the southeast of OPF-3, and the OPF (High Bays No. 1 and No. 2) and the Thermal Protection System Facility sit to the southwest. To the west of OPF-3 is the Crawler Transporter parking site and to the north is the Mobile Launcher Platform parking site.

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APPENDIX A: OPF-3 Historic Photographs

Figure A-1. Aerial view of OPF-3 construction, March 17, 1987.
Source: John F. Kennedy Space Center Archives, KSC-387C-565-7.

Figure A-2. Aerial view of SSMEPF construction, May 23, 1997.
Source: John F. Kennedy Space Center Archives, KSC-97PC-836.

Figure A-3. Detail view of SSMEPF construction, May 23, 1997.
Source: John F. Kennedy Space Center Archives, KSC-97PC-835.

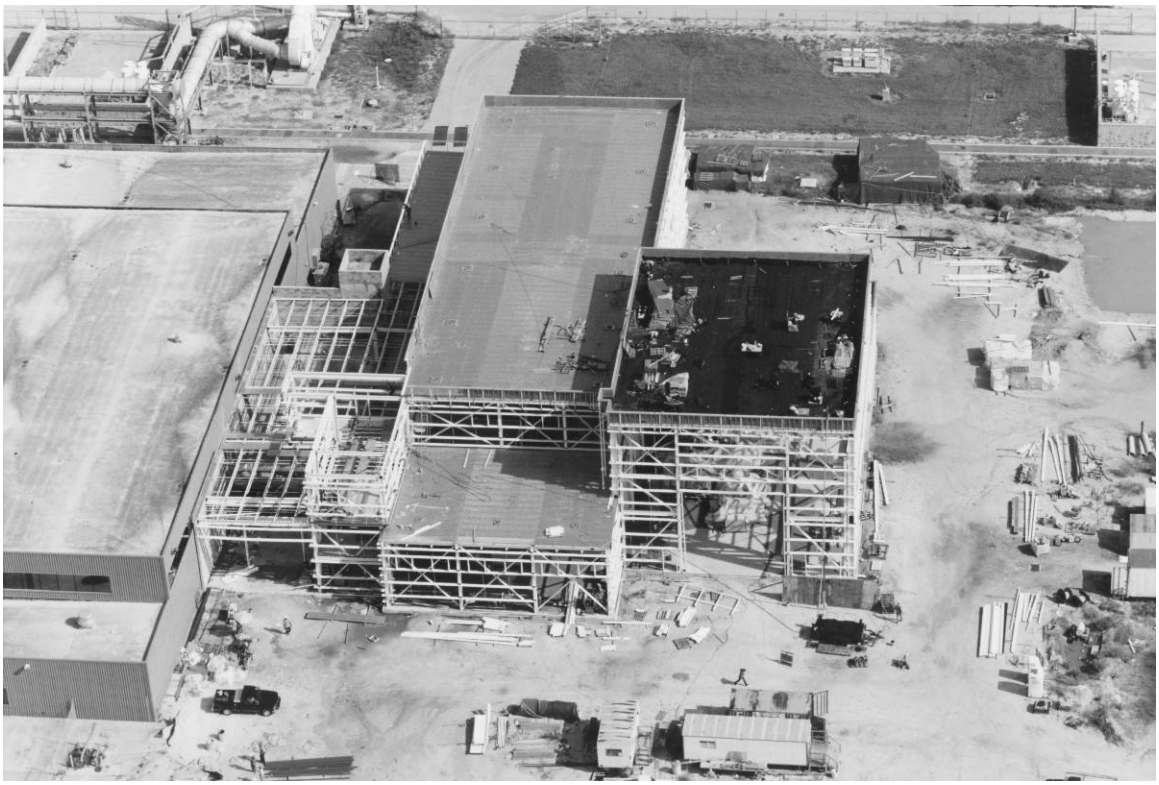

Figure A-4. Aerial view of SSMEPF construction, August 11, 1997.
Source: John F. Kennedy Space Center Archives, KSC-97PC-1223.

Figure A-5. Aerial view of OPF-3, March 14, 1998.
Source: John F. Kennedy Space Center Archives, KSC-98PC-369.

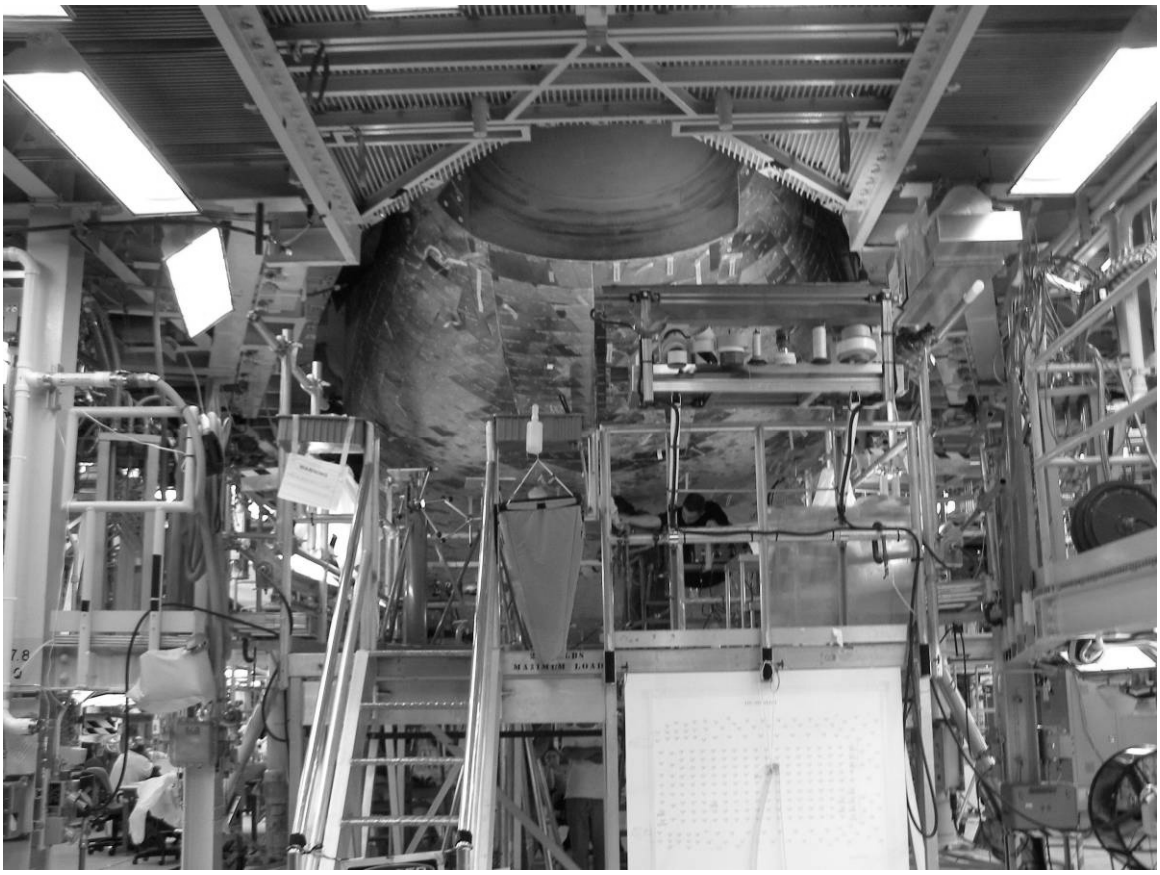

Figure A-6. Orbiter Processing Facility High Bay No. 3, orbiter nose and platforms, looking south, July 31, 2006.
Source: Archaeological Consultants, Inc.

Figure A-7. Orbiter Processing Facility High Bay No. 3, orbiter underside with moveable platforms, looking north, July 31, 2006.
Source: Archaeological Consultants, Inc.

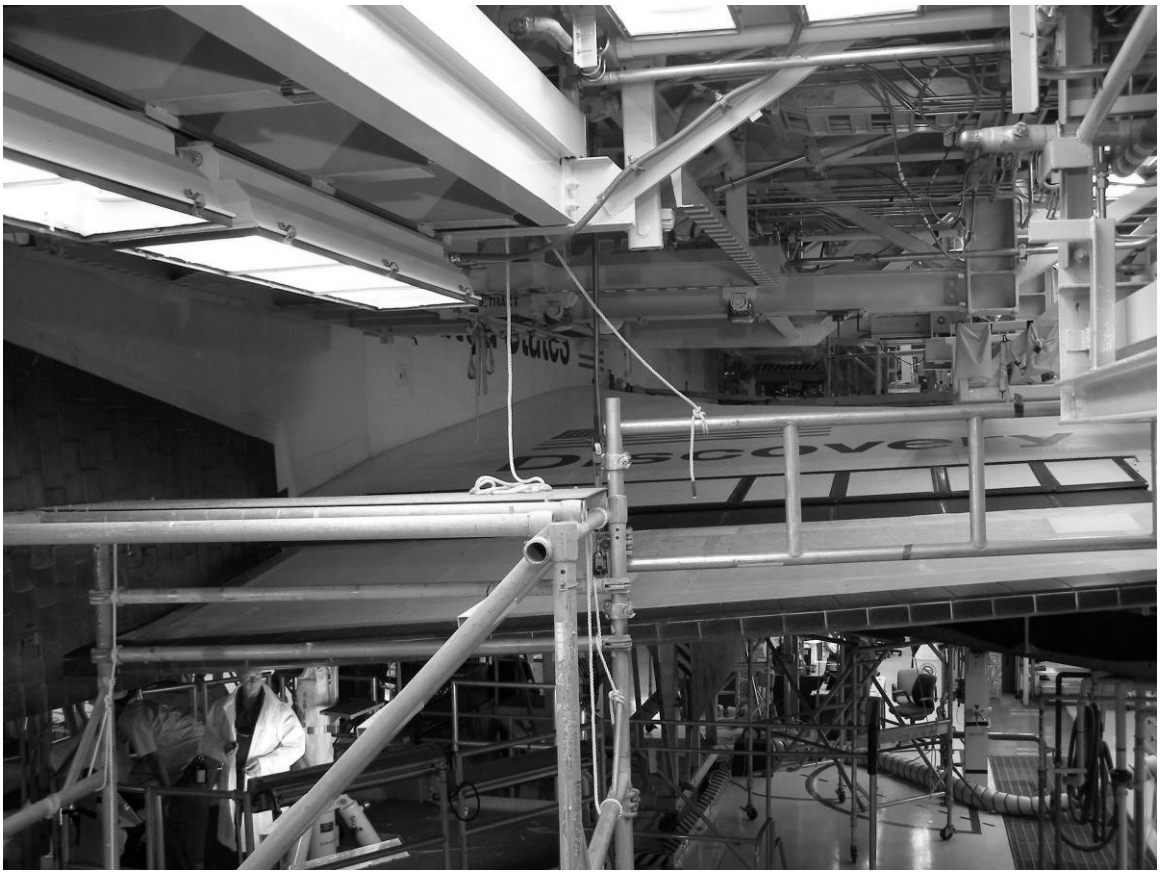

Figure A-8. Orbiter Processing Facility High Bay No. 3, second level, looking northeast, July 31, 2006.
Source: Archaeological Consultants, Inc.

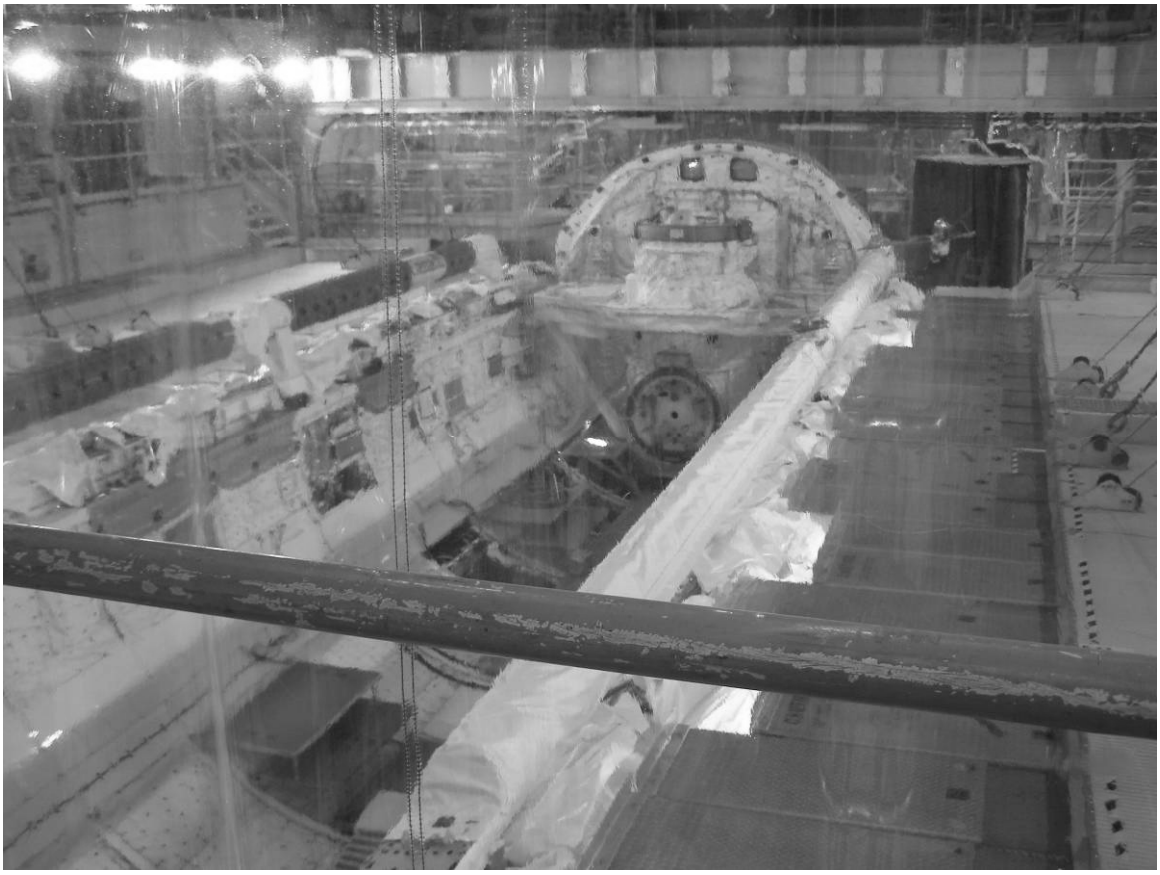

Figure A-9. Orbiter Processing Facility High Bay No. 3, “13 platforms” and payload bay, looking northeast, July 31, 2006.
Source: Archaeological Consultants, Inc.

Figure A-10. Orbiter Processing Facility High Bay No. 3, OMS pod with moveable platform, July 31, 2006.
Source: Archaeological Consultants, Inc.

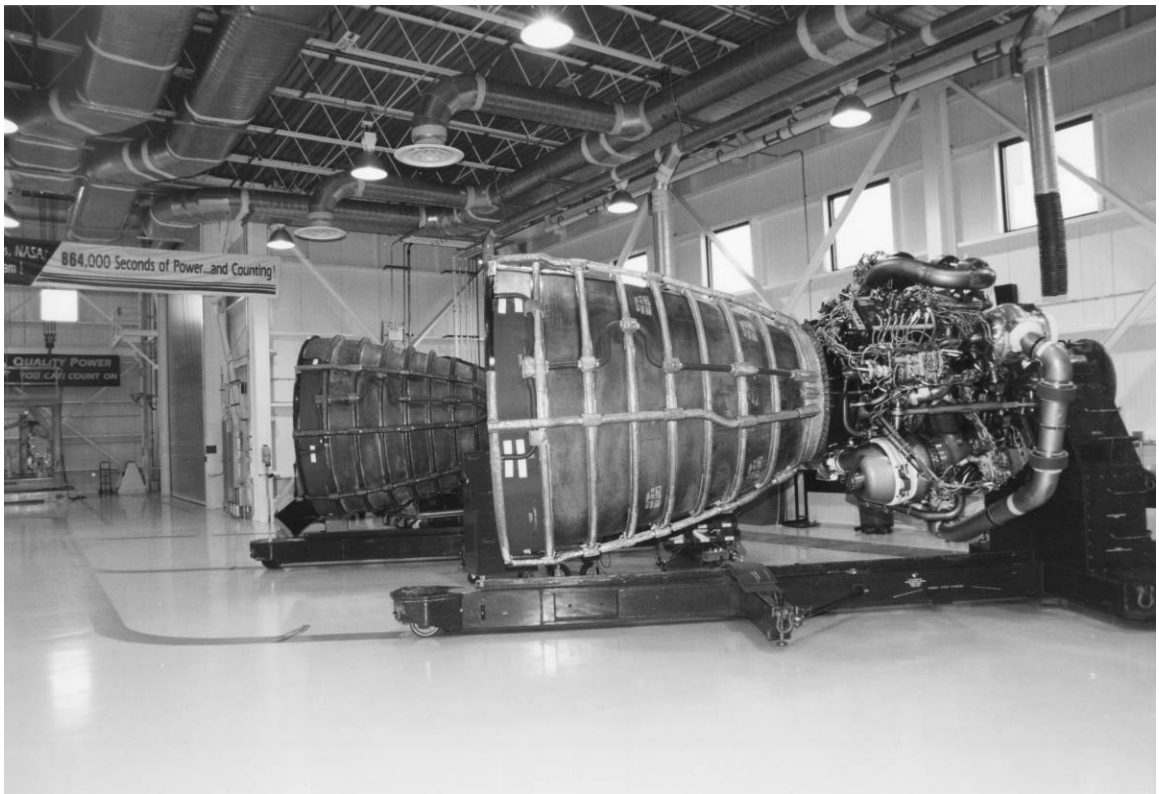

Figure A-11. View of the Horizontal Processing Area, SSMEPF, August 17, 1998.
Source: John F. Kennedy Space Center Archives, KSC-98PC-926.

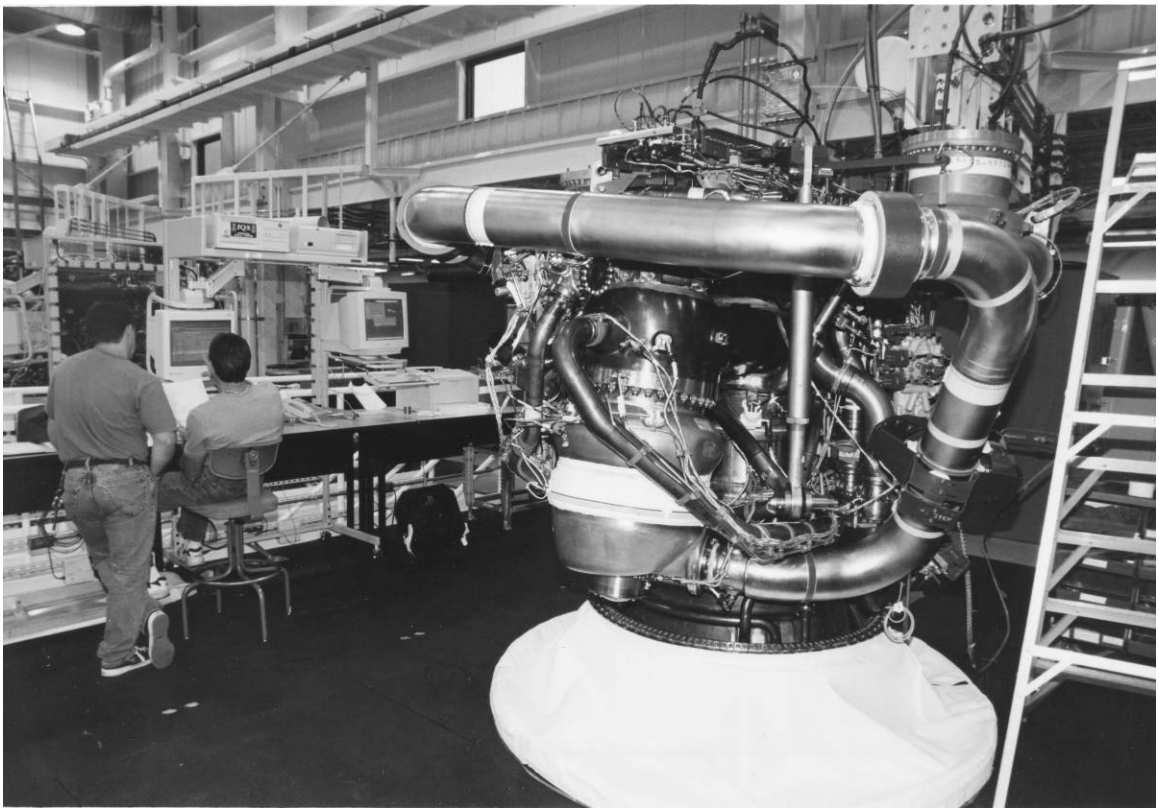

Figure A-12. View of the second level in the Vertical Processing Area, SSMEPF, August 17, 1998.
Source: John F. Kennedy Space Center Archives, KSC-98PC-927.

Figure A-13. Technicians attach the Main Combustion Chamber to the nozzle in the SSMEPF at Kennedy Space Center, looking northeast, November 2005.
Source: George C. Marshall Space Flight Center.

Figure A-14. A technician attaches the High Pressure Oxidizer Turbopump to the SSME, SSMEPF, looking northeast, December 2005.
Source: George C. Marshall Space Flight Center.

APPENDIX B: Orbiter Processing Facility High Bay Nos. 1 and 2

Introduction:

The Orbiter Processing Facility High Bay Nos. 1 and 2 (OPF) is considered eligible for listing in the NRHP in the context of the U.S. Space Shuttle program (1969-2010) under Criteria A in the area of Space Exploration and under Criterion C in the area of Engineering. Because it has achieved significance within the past 50 years, Criteria Consideration G applies. In addition to its individual eligibility, the OPF is considered a contributing resource to the Orbiter Processing Historic District. The period of significance for the OPF is from 1977, the date of its completed construction, through 2011, the designated end of the Space Shuttle program. Under Criterion A, the OPF is the first of only two structures designed and built exclusively for orbiter pre-flight and post-landing processing, and each orbiter was processed for its first operational flight in this facility. Under Criterion C, the OPF, which was constructed specifically for the Space Shuttle program, contains two large high bays, designed for the size of the orbiter, each with a platform system specifically designed around the shape of the orbiter. This system contains stationary platforms set at various levels, which provide access to the major areas of the orbiter. Each level is also fitted with moveable platforms for access to specific components. In addition, a clean room environment is provided around the payload bay when the doors are open. This uniquely designed equipment, rather than the building's exterior shell, provides the basis for the OPF's eligibility under Criterion C. The OPF is of exceptional importance to the Space Shuttle program, and because it is less than 50 years in age, Criteria Consideration G applies.

As noted on Page 1 of this report, there are only two sites at KSC that were used to process the orbiter vehicles between missions: the OPF and OPF-3. Pursuant to the "Programmatic Agreement among the National Aeronautics and Space Administration John F. Kennedy Space Center, Advisory Council on Historic Preservation, and the Florida State Historic Preservation Officer regarding Management of Historic Properties at the Kennedy Space Center, Florida," Stipulation V.A.2, if there are multiple assets of a specific property type that are 95 percent identical, only one of the assets will be recorded. In this case, OPF-3 was chosen for documentation because the facility includes the SSMEPF. This appendix has been included as part of the documentation package to provide a brief summary of the history of the OPF and note any major physical differences, between the original OPF and OPF-3.

Historical Information:

In March 1975, Seelye Stevenson Value & Knecht Inc. of New York, New York, with Max O. Urbahn Associates Inc., completed the design work for Phase I of the OPF. Included in the design was the site work for the entire facility, the Orbiter Towway from the OPF to the VAB, the foundation and shell of High Bay No. 1, and the Low Bay.[1] In December 1975, the same two firms completed the design work for Phase II of the OPF, which included the foundation and

[1] Seelye Stevenson Value & Knecht Inc. "Orbiter Processing Facility, Phase I." March 1975.

shell of High Bay No. 2.[2] While Phase II was in the design stage, the contract for the construction of Phase I, which amounted to roughly $8.7 million, was awarded to Frank Briscoe Company Inc. of East Orange, New Jersey, in July 1975. The same firm also received a contract for the construction of Phase II, for approximately $3.9 million, in June 1976.[3]

In March 1976, Seelye Stevenson Value & Knecht Inc. finished the drawings that detailed the installation of the orbiter work platform structure within High Bay No. 1; similar drawings were completed by Planning Research Corporation of Cape Canaveral, Florida, in November 1976.[4] In May 1977, a roughly $3.1 million was awarded to the Beckman Construction Company of Fort Worth, Texas for "fabricating and installing the main access platform, piping and cabling in one of the OPF's two high bays," as well as the construction of a two-story 10,000-square foot service and support annex on the north end of the Low Bay.[5] In February 1980, large areas of High Bay No. 2 were turned into a tile densification processing facility to prepare tiles for the Orbiter *Columbia*. In January 1981, Briscoe was awarded an approximately $3.9 million contract to activate and modify High Bay No. 2.[6]

On-going modifications were made to the facility over its lifetime; however, the basic structure has remained unchanged. In 1981, Fandino & Sons, Inc. of Hialeah, Florida, received a contract to manufacture a counterweight device, which would allow the payload bay doors to be opened in a non-zero gravity environment.[7] In the mid-1980s, hydraulic floor lifts were installed in the two High Bays. Between 1987 and 1988, a $3 million annex was constructed to the north of the original Low Bay annex.[8]

High Bay No. 1 was the first operational High Bay of the OPF, accommodating the Orbiter *Columbia* upon its arrival at KSC in March 1979; High Bay No. 2 was not used for orbiter processing until *Challenger's* arrival in 1982.[9] Prior to the *Columbia* accident, the high bays were assigned on a "first available" basis. Afterwards, the two High Bays were each devoted to a single Orbiter, *Atlantis* in High Bay No. 1 and *Endeavour* in High Bay No. 2.

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[2] Seelye Stevenson Value & Knecht Inc. "Orbiter Processing Facility, Phase II." December 1975.
[3] Frank E. Jarrett. "Chronology of KSC and KSC Related Events for 1976." KHR-2, November 1, 1977, 27.
[4] Seelye Stevenson Value & Knecht Inc. "Orbiter Processing Facility, Orbiter Access Platform, Task I." March 1976; Planning Research Corporation. "Orbiter Processing Facility, High Bay 2 Access Platform." December 1976.
[5] Frank E. Jarrett. "Chronology of KSC and KSC Related Events for 1977." KHR-3, November 1, 1978, 33.
[6] Ken Nail, Jr. and Elaine Liston "Chronology of KSC and KSC Related Events for 1981." KHR-6, September 1, 1983, 29.
[7] Nail and Liston, p. 150.
[8] "Long-awaited OPF Annex Addition opens." *Spaceport News* (27, 9), April 22, 1988: 1.
[9] "OPF Is Full First Time Since Built." *Spaceport News* (21, 15), July 23, 1982: 1.

Physical Differences of the OPFs:

The OPF is located to the east of Kennedy Parkway, at the southwest corner of the intersection of the Orbiter Towway and Utility Road, in the VAB Area of the KSC. Unlike OPF-3, the original OPF contains two high bays (High Bay 1 and High Bay 2), one each on either side of the Low Bay. To the north of the Low Bay is an office and training annex, while to the south of the facility are fuel and oxidizer deservicing pads, gaseous hydrogen and oxygen storage pads, a hypergol storage tank, and a fire pump house.

The facility has approximate overall dimensions of 398’ in length (north-south axis), 398’ in width (east-west axis), and 95’ ft in height. Both High Bay No. 1, to the east, and High Bay No. 2, to the west, have the same measurements as the OPF-3 High Bay. The orientation of these bays, however, is opposite that of OPF-3. Whereas the south elevation serves as the main façade for OPF-3, the north elevation of the original OPF serves as its main façade. It is on this elevation, for each High Bay, that the four-section sliding door for the orbiter is situated. Likewise, the rolling door for the orbiter tug and the sliding door for equipment and payloads are located on the north elevation of each OPF High Bay.

The main differences between the OPF High Bays and the OPF-3 High Bay were located within the internal platform structure. The first was the different configuration of the 513 workstand, situated at the aft end of the vehicle. In High Bay Nos. 1 and 2, the 513 workstand was divided into two halves that opened and closed similar to a swing door (Photo No. 140). Each half was attached to the main platform structure by a hinge situated at the outboard side of the structure, and supported at the base by two drive trucks, each with eight wheels; these trucks were used to move the platform between its use and stow position.

The second difference between High Bay Nos. 1 and 2 and the OPF-3 High Bay was the configuration of the Level 13 platforms that provided access to the payload bay. In the OPF High Bay Nos. 1 and 2, the 13s were divided into eight sections, which were hinged to raise and lower via a winch (Photo No. 141). In OPF-3, the 13s were modified to include sliding segments (see page 22).

Figure B-1. View of OPF High Bay No. 1 and Low Bay construction, 1976.
Source: John F. Kennedy Space Center Archives, 108-KSC-76-1545.

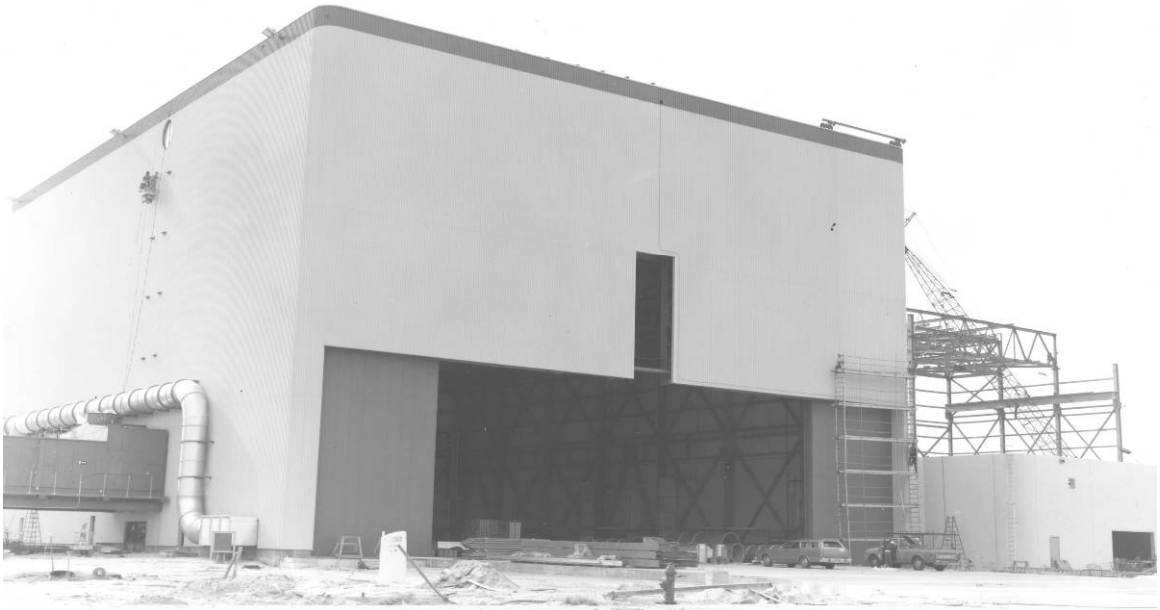

Figure B-2. View of OPF High Bay No. 1 construction, 1976.
Source: John F. Kennedy Space Center Archives, 108-KSC-76-2493.

Figure B-3. View of OPF High Bay No. 2 construction, 1976.
Source: John F. Kennedy Space Center Archives, 108-KSC-76-2986.

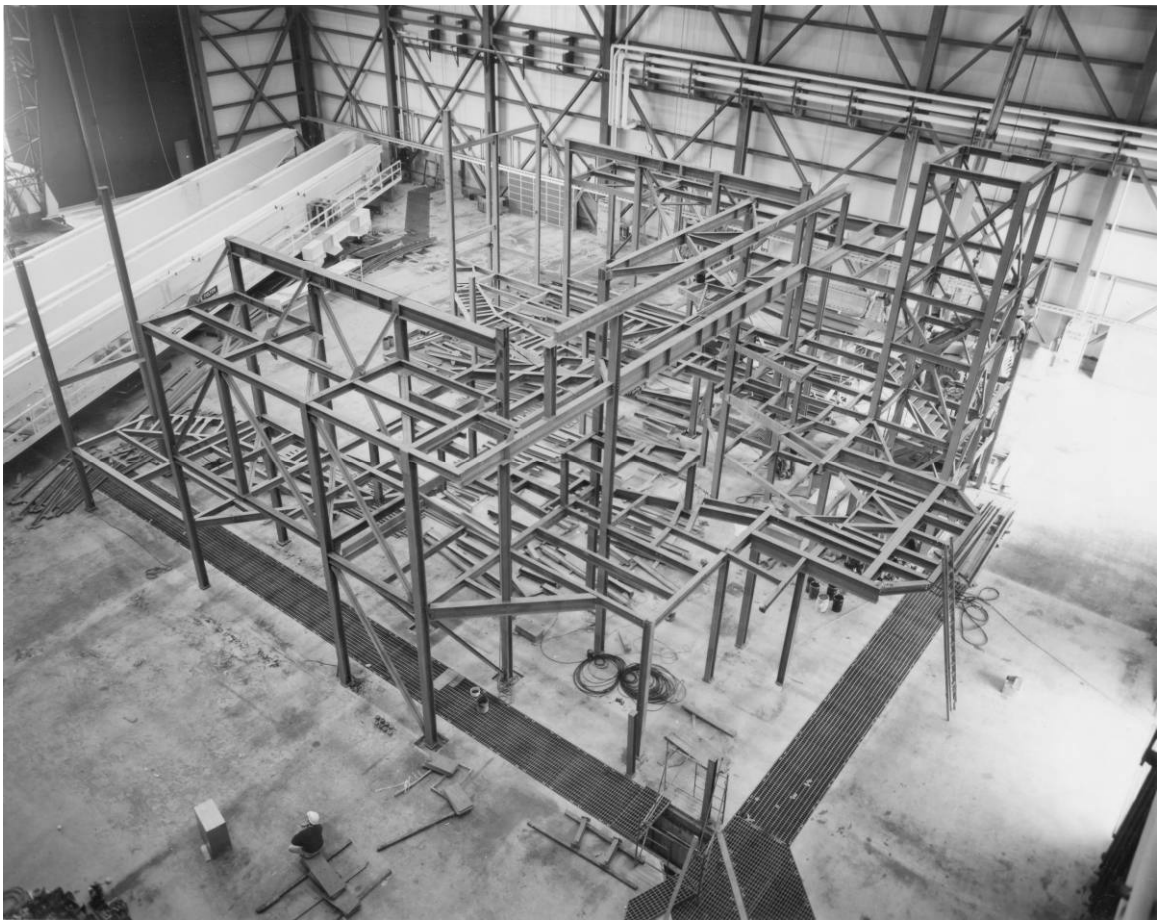

Figure B-4. View of OPF High Bay No. 1, nose area platform installation, March 11, 1977.
Source: John F. Kennedy Space Center Archives, 108-KSC-77C-410.
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Figure B-5. View of OPF High Bay No. 1, Level 13 platform installation, July 8, 1977.
Source: John F. Kennedy Space Center Archives, 108-KSC-77C-1228.

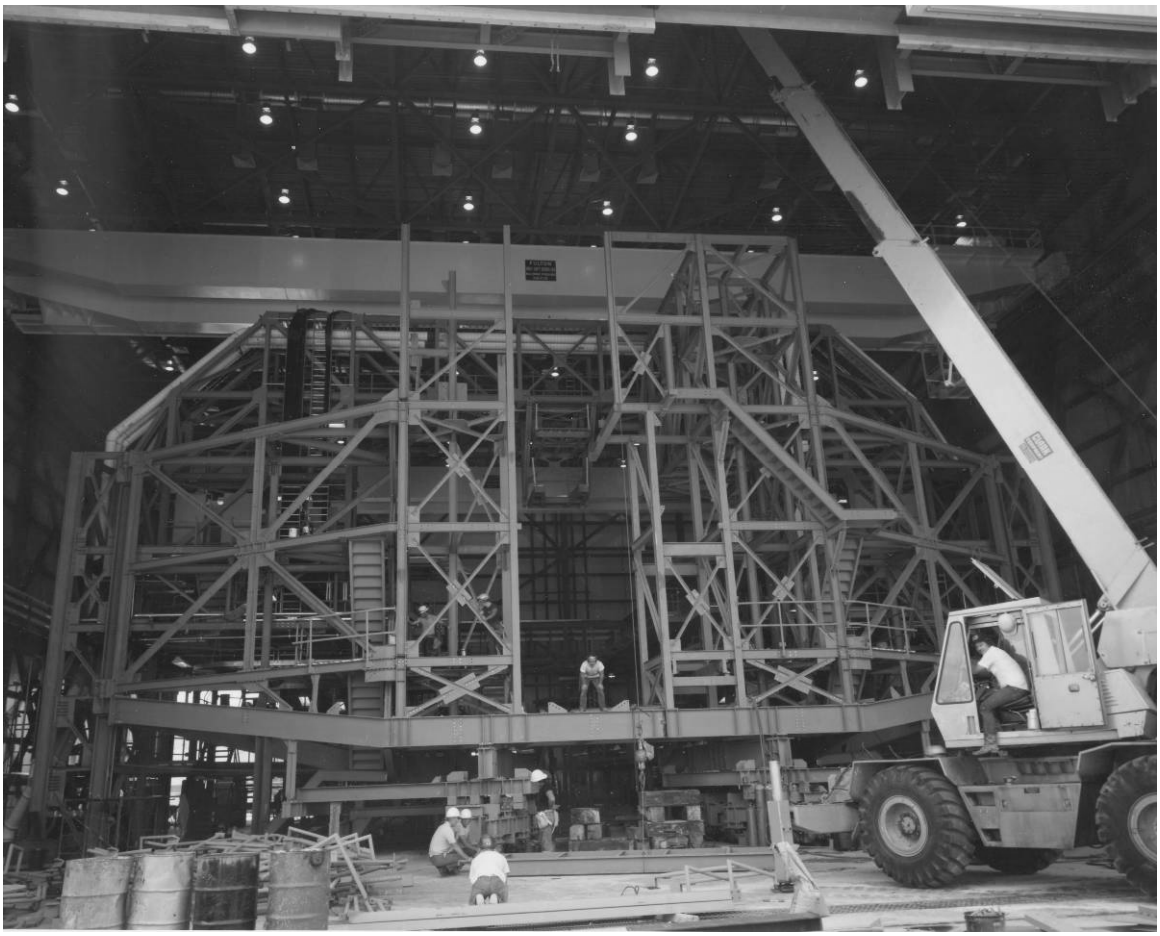

Figure B-6. View of OPF High Bay No. 1, 513 workstand installation, August 23, 1977.
Source: John F. Kennedy Space Center Archives, 108-KSC-77C-1410.

Figure B-6. View of original OPF, March 29, 1978.
Source: John F. Kennedy Space Center Archives, 108-KSC-378C-202, Frame 35.