JAKE GARN MISSION SIMULATOR AND TRAINING FACILITY

BUILDING 5

HISTORICAL DOCUMENTATION

Prepared for:
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

Prepared by:
Archaeological Consultants, Inc.
Sarasota, Florida

March 2010

PREFACE

In response to President George W. Bush's announcement in January 2004 that the Space Shuttle Program (SSP) would end in 2010, the National Aeronautics and Space Administration (NASA) completed a nation-wide historical survey and evaluation of NASA-owned facilities and properties (real property assets) at all its Centers and component facilities. The buildings and structures which supported the SSP were inventoried and assessed as per the criteria of eligibility for listing in the National Register of Historic Places (NRHP) in the context of this program. This study was performed in compliance with Section 110 of the National Historic Preservation Act (NHPA) of 1966 (Public Law 89-665), as amended; the National Environmental Policy Act (NEPA) of 1969 (Public Law 91-190); Executive Order (EO) 11593: Protection and Enhancement of the Cultural Environment; EO 13287, Preserve America, and other relevant legislation.

As part of this nation-wide study, in September 2006, historical survey and evaluation of NASA-owned and managed facilities at was conducted by NASA's Lyndon B. Johnson Space Center (JSC) in Houston, Texas. The results of this study are presented in a report entitled, "Survey and Evaluation of NASA-owned Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program, Lyndon B. Johnson Space Center, Houston, Texas," prepared in November 2007 by NASA JSC's contractor, Archaeological Consultants, Inc. As a result of this survey, the Jake Garn Mission Simulator and Training Facility (Building 5) was determined eligible for listing in the NRHP, with concurrence by the Texas State Historic Preservation Officer (SHPO). The survey concluded that Building 5 is eligible for the NRHP under Criteria A and C in the context of the U.S. Space Shuttle program (1969-2010). Because it has achieved significance within the past 50 years, Criteria Consideration G applies.

At the time of this documentation, Building 5 was still used to support the SSP as an astronaut training facility. This documentation package precedes any undertaking as defined by Section 106 of the NHPA, as amended, and implemented in 36 CFR Part 800, as NASA JSC has decided to proactively pursue efforts to mitigate the potential adverse affects of any future modifications to the facility. It includes a historical summary of the Space Shuttle program; the history of JSC in relation to the SSP; a narrative of the history of Building 5 and how it supported the SSP; and a physical description of the structure. In addition, photographs documenting the construction and historical use of Building 5 in support of the SSP, as well as photographs of the facility documenting the existing conditions, special technological features, and engineering details, are included. A contact sheet printed on archival paper, and an electronic copy of the work product on CD, are also provided.

ACKNOWLEDGEMENTS

Archaeological Consultants, Inc. (ACI) of Sarasota, Florida extends their gratitude to Perri E. Fox, NASA JSC's Shuttle Transition Manager, and Sandra J. Tetley, NASA JSC's Real Property Officer and Historic Preservation Officer (HPO), for making all arrangements for access and information gathering in support of this documentation. We also thank the staff of the JSC Imagery Repository for their cooperation in providing historical photographs; and the staff of the Engineering Drawing Control Center for their cooperation in providing architectural drawings of the facility. We deeply appreciate the efforts of Jerry Swain, Building 5 Facility Manager, and Carl Brainerd, Lockheed Martin's Shuttle Transition and Retirement Project Lead of the Mission Management and Integration Office, for serving as ACI's point of contact at the facility and providing valuable information on its use in support of the Space Shuttle program. Finally, we would like to thank Rebecca Wright and Jennifer Ross-Nazzal of Tessada & Associates, for conducting oral histories, which greatly enhanced our discussion of the buildings.

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JAKE GARN MISSION SIMULATOR AND TRAINING FACILITY
BUILDING 5
JOHNSON SPACE CENTER
HOUSTON, TEXAS

Basic Information

Location:	West of Fifth Street between Avenue B and Avenue D Johnson Space Center Houston Harris County Texas U.S.G.S. 7.5. minute League City, Texas, quadrangle, Universal Transverse Mercator coordinates: 15.297975.3271392
Date of Construction:	1964-1965
Architect/Engineer:	Brown & Root, Inc., Houston, Texas; Brooks & Barr, Austin, Texas; Harvin C. Moore, Houston, Texas; MacKie & Kamrath, Houston, Texas; and Wirtz Calhoun Tungate & Jackson, Houston, Texas Bernard Johnson Engineers, Inc. (mechanical engineers), Houston, Texas
Builder:	W.S. Bellows Construction and Peter Kiewit Sons' Company, Houston, Texas
Present Owner:	National Aeronautics and Space Administration Johnson Space Center, Houston, Texas
Present Use:	Used to train astronauts in vehicle operations
Significance:	The Jake Garn Mission Simulator and Training Facility is considered eligible for listing in the NRHP in the context of the U.S. Space Shuttle Program (1969-2010) 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. Building 5 is a premier NASA facility for preparing astronauts for Space Shuttle missions, including launch and landing situations, as well as

critical on-orbit operations. The simulators, which provide realistic sensory feedback to the astronauts, were uniquely designed to replicate the Shuttle vehicle and its launch, orbit, and landing environment. Building 5 retains exceptional integrity, as it is in its original location and setting, and continues to convey its historic functions through the physical aspects of design, materials, workmanship, feeling, as well as association.

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The U.S. Space Shuttle Program

On January 5, 1972, President 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."[1] The Space Task Group (STG), previously established by President Nixon in February 1969 to recommend a future course for the U.S. Space Program, presented three choices of long-range plans. All included an Earth–orbiting space station, a space shuttle, and a manned Mars expedition.[2] Although none of the original programs presented was eventually selected, the National Aeronautics and Space Administration (NASA) implemented a program, shaped by the politics and economic realities of the time, which served as a first step toward any future plans for implementing a space station.[3]

On January 5, 1972, President Richard Nixon instructed NASA to proceed with the design and building of a partially reusable space shuttle consisting of a reusable orbiter, three reusable main engines, two reusable solid rocket boosters (SRBs), and one non-reusable external liquid fuel tank (ET). NASA's administrators vowed that the shuttle would fly at least fifty times a year, making space travel economical and safe. NASA gave responsibility for developing the shuttle orbiter vehicle and overall management of the Space Shuttle program (SSP) to the Manned Space Center (MSC, now the Johnson Space Center [JSC]) in Houston, based on the Center's experience. The Marshall Space Flight Center (MSFC) in Huntsville, Alabama, was responsible for development of the Space Shuttle Main Engine (SSME), SRBs, the ET, and for all propulsion-related tasks. Engineering design support continued at MSC, MSFC and NASA's Langley Research Center (LaRC), in Virginia, and engine tests were to be performed at NASA's Mississippi National Space Technology Laboratories (NSTL, later named Stennis Space Center [SSC]) and at the Air Force's Rocket Propulsion Laboratory in California, which later became the Santa Susana Field Laboratory (SSFL).[4] NASA selected the Kennedy Space Center (KSC) in Florida, as the primary launch and landing site for the SSP. KSC, responsible for designing the launch and recovery facilities, was to develop methods for shuttle assembly, checkout, and launch operations.[5]

On September 17, 1976, the full-scale orbiter prototype, *Enterprise* (OV- 101), was completed. Designed for test purposes only and never intended for space flight, structural assembly of this

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[1] Marcus Lindroos. "President Nixon's 1972 Announcement on the Space Shuttle." (NASA Office of Policy and Plans, NASA History Office, updated April 14, 2000).
[2] NASA, History Office, NASA Headquarters. "Report of the Space Task Group, 1969."
[3] Dennis R. Jenkins. *Space Shuttle, The History of the National Space Transportation System. The First 100 Missions*. (Cape Canaveral, Florida: Specialty Press, 2001), 99.
[4] Jenkins, 122.
[5] 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.

orbiter had started more than two years earlier in June 1974 at Air Force Plant (AFP) 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 (ALT) aimed at checking out both the mating with the shuttle carrier aircraft (SCA) for ferry operations, as well as the orbiter's unpowered landing capabilities.

The first orbiter intended for space flight, *Columbia* (OV-102), arrived at KSC from the shuttle assembly facility in Palmdale in March 1979. Originally scheduled to lift off in late 1979, the launch date was delayed by problems with both the SSME components, as well as the thermal protection system (TPS). *Columbia* spent 610 days in the Orbiter Processing Facility (OPF), another thirty-five days in the Vehicle Assembly Building (VAB), and 105 days on Pad 39A before finally 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 at Edwards Air Force Base (AFB) in California. This launch demonstrated *Columbia's* ability to fly into orbit, conduct on-orbit operations, and return safely.[6] *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% of its objectives completed. After the end of the fourth mission, President Ronald Reagan declared that with the next flight the Shuttle would be "fully operational."

A total of 129 Space Shuttle missions have been launched from the KSC between April 1981 and December 2009. 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 two decades, the SSP has launched a number of planetary and astronomy missions including the Hubble Space Telescope (HST), 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.[7] 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 hiatus in the aftermath of the *Challenger* disaster, 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.[8] In addition to astronomical,

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[6] Jenkins, 268.
[7] NASA. *NASA Shuttle Reference Manual.* (1988).
[8] STS-90, which landed on May 3, 1998, was the final Spacelab mission. NASA. "Shuttle Payloads and Related Information." *KSC Factoids.* Revised November 18, 2002.

atmospheric, microgravity, and life sciences missions, Spacelab was also used as a supply carrier to the HST and the Soviet space station *Mir*.

In 1995, a joint U.S./Russian Shuttle-*Mir* Program was initiated as a precursor to construction of the International Space Station (ISS). *Mir* had been launched in February 1986 and remained in orbit until March 2001.[9] The first approach and flyaround 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. All but the last two of these docking missions used the Orbiter *Atlantis*. Many of the activities carried out were types they would perform on the ISS.[10]

On December 4, 1999, *Endeavour* (STS-88) launched the first component of the ISS into orbit. As noted by Williamson, 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."[11] STS-96, launched on May 27, 1999, marked the first mission to dock with the ISS. Since that time, most Space Shuttle missions have supported the continued assembly of the space station. As currently planned, ISS assembly missions will continue through the life of the Space Shuttle Program.

The SSP 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 SSP 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 SSP, concluded "that the drive to declare the Shuttle operational had put enormous pressures on the system and stretched its resources to the limit."[12] 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; an upgrade 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 SSP. NASA moved the management of the program from JSC to NASA Headquarters, with the aim of preventing communication deficiencies.[13] 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.[14] 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

[9] Tony Reichhardt (editor). *Space Shuttle, The First 20 Years.* (Washington, D.C.: Smithsonian Institution, 2002), 85.

[10] 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.

[11] Williamson, 191.

[12] Columbia Accident Investigation Board (CAIB). *Report Volume I.* (August 2003), 25.

[13] CAIB, 101.

[14] Cliff Lethbridge. "History of the Space Shuttle Program." (2001), 4.

payloads.[15] The launch of *Discovery* (STS-26) from KSC Pad 39B on September 29, 1988, marked a Return to Flight after a 32-month hiatus in manned spaceflight following the *Challenger* accident.

In the aftermath of the 2003 *Columbia* accident, a seven month investigation ensued, concluding with the findings of the Columbia Accident Investigation Board (CAIB), which determined that both technical and management conditions accounted for the loss of the orbiter and crew. According to the CAIB Report, the physical cause of the accident was a breach in the TPS 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.[16] NASA spent more than two years researching and implementing safety improvements for the orbiters, SRBs and ET. Following a two-year hiatus, 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. . . Our second goal is to develop and test a new spacecraft, the Crew Exploration Vehicle, by 2008, and to conduct the first manned mission no later than 2014. . . Our third goal is to return to the Moon by 2020, as the launching point for missions beyond ...*[17]

Following the President's speech, NASA released The Vision for Space Exploration, which outlined the Agency's approach to this new direction in space exploration.[18] *In 2006, NASA announced the start of the Constellation Program, which included development of the Crew Exploration Vehicle (CEV) and a launch vehicle to place the CEV into space. As part of this initiative, NASA will continue to use the Space Shuttle to complete assembly of the ISS. The Shuttle will not be upgraded to serve beyond 2010 and, after completing the ISS, the Space Shuttle program will be retired. The next generation of human-rated spacecraft, the CEV, named Orion, will transport humans to low-Earth orbit for missions to support the ISS, and will also be the vehicle used to carry a crew to lunar orbit. The Constellation Program will develop the new class of exploration vehicles to launch both crew and cargo and associated infrastructure in exploring the Moon, Mars, and beyond.* *****Sandra-what is your opinion on this italicized section?**

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[15] Lethbridge, 5.
[16] CAIB, 9.
[17] The White House. "A Renewed Spirit of Discovery – The President's Vision for Space Exploration." (January 2004).
[18] NASA Headquarters. "The Vision for Space Exploration." (February 2004).

Johnson Space Center

The Lyndon B. Johnson Space Center (JSC) officially opened on-site in June 1964 as the Manned Spacecraft Center (MSC).[19] This approximately 1,620-acre facility is located near Clear Lake, Texas, about 25 miles from downtown Houston, in Harris County. Many of the approximate 140 buildings are specialized facilities devoted to spacecraft systems, materials research and development, and/or astronaut training. JSC also includes the Sonny Carter Training Facility, located roughly 4.5 miles to the northwest of JSC, close to Ellington Field. Opened in 1997, this facility is situated on land acquired through a lease/purchase agreement with the McDonnell Douglas Corporation. In addition, NASA JSC owns some of the facilities at Ellington Field, which are generally where the aircraft used for astronaut training are stored and maintained.

The origins of JSC can be traced to the summer of 1958 when three executives of the National Advisory Committee for Aeronautics (NACA), Dr. Hugh L. Dryden, Dr. Robert R. Gilruth, and Dr. Abe Silverstein, began to formulate a space program.[20] Almost immediately, Gilruth began to focus on manned spaceflight, and subsequently convened a group of his LaRC associates, who compiled the basics of what would become Project Mercury, the first U.S. manned space program. Eight days following the activation of NASA, with the approval of NASA's first administrator, Dr. T. Keith Glennan, the Space Task Group (STG) was created to implement this program. The group was formally established on November 3, 1958, with Gilruth named as Project Manager. The initial staff of the STG came from LaRC, but was soon supplemented with engineers from the Lewis Flight Propulsion Laboratory (now Glenn Research Center) and AVRO Aircraft, Ltd. of Canada.[21]

At first, the STG offices were located at LaRC. With the establishment of the Goddard Space Flight Center in Greensbelt, Maryland, in May 1959, plans were made to incorporate the STG into it, creating a new "space projects center."[22] It was later decided to leave the STG at LaRC until the completion of Project Mercury; however, by January 1961, it was obvious that the STG would need to develop into an autonomous center, and on January 3, it was designated as such.[23] The May 25, 1961, announcement by President John F. Kennedy to send a man to the Moon by

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[19] Following the death of former President Lyndon B. Johnson, the U.S. Senate passed a resolution to rename the Manned Spacecraft Center in his memory. "MSC Is Renamed 'JSC'." *Roundup* (12, 8), March 2, 1973, 1; "Capacity Crowd View Dedication Ceremonies." *Roundup* (12, 20), August 31, 1973, 1 and 3. For ease of reference, JSC will be used throughout the text, with the exception of direct quotations from sources.

[20] Dryden was the Director of NACA; Gilruth was the head of the flight research section of NACA's Langley Aeronautical Laboratory (now Langley Research Center) in Hampton, Virginia; and Silverstein was the Director of NACA's Lewis Flight Propulsion Laboratory (now Glenn Research Center) in Cleveland, Ohio. As part of NASA's establishment, NACA, was deactivated and all of its personnel and facilities were transferred to NASA. James M. Grimwood. *Project Mercury: A Chronology.* (Washington, D.C.: NASA, Office of Scientific and Technical Information, 1963); Roger D. Launius. *NASA: A History of the U.S. Civil Space Program.* (Malabar, Fla.: Krieger Publishing Company, 2001), 29.

[21] Grimwood; Loyd S. Swenson, Jr., James M. Grimwood and Charles C. Alexander. *This New Ocean: A History of Project Mercury.* (Washington, D.C.: NASA, Office of Technology Utilization, 1966), 153.

[22] Swenson, et al., 115.

[23] Swenson, et al., 251.

the end of the decade reinforced the idea that the STG needed its independence, and soon. Thus, in August 1961, John Parsons, Associate Director of the Ames Research Center (ARC), was charged with establishing a survey team to locate a site for the new center.[24]

On September 19, 1961, James Webb, NASA Administrator, announced that Houston, Texas, would be the site for NASA's new Center for manned spaceflight.[25] Numerous factors influenced the choice of Houston as the home of the new Center. First of all, Rice University was willing to donate 1000 acres of land for the Center. Additionally, Houston met all of the requirements set forth in the selection criteria. For example, Ellington Air Force Base was located nearby, as were Clear Lake and Galveston Bay; these facilities could support air and barge traffic, respectively. Houston also has a year-round moderate climate, and both Rice University and the University of Houston were in close proximity to the new site.[26]

On November 1, 1961, the STG officially became the "Manned Spacecraft Center," with Gilruth as its first Director.[27] The first JSC employees officially transferred to Houston from LaRC were Ed Campagna of the Facilities Division, John Powers, from Public Affairs, and Martin Byrnes, Site Manager; their first offices were two vacant dress shops in the Gulfgate Shopping Center, which were donated by its site manager, Marvin Kaplan.[28] The trio was assigned the responsibilities of procuring temporary office space, hiring new personnel, and meeting with local organizations to help facilitate the needs of those co-workers who would soon be joining them.[29] From November 1961 until April 1962, nearly 400 additional employees were transferred from LaRC to Houston; the new Center officially became operational in Houston on March 1, 1962, when Gilruth moved the JSC's headquarters there.[30]

To supplement the 1000 acres of land promised by Rice University, NASA purchased an additional 620 acres, mainly to provide highway access for the estimated 4000 employees.[31] In

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[24] Swenson, et al., 363-364.

[25] Glennan resigned effective January 22, 1961 when President Eisenhower left office. Webb was sworn into office on February 15, 1961. Grimwood.

[26] From a political viewpoint, Houston was located within the district of U.S. House Representative, Albert Thomas, chairman of the House Appropriations Committee, and Texas was the home state of Vice President Lyndon B. Johnson. Dr. Robert Gilruth Oral History Interview, February 27, 1987, 273-275, *The Glennan-Webb-Seamans Project,* National Air and Space Museum.

[27] "STG Renamed; Will Move." *Space News Roundup* (1, 1), November 1, 1961, 1.

[28] Martin A. Byrnes, Jr., interview by Robert Merrifield, December 12, 1967, (Houston, TX, Archives Department, Lyndon B. Johnson Space Center), 6.

[29] Temporary offices were located in buildings throughout the Houston area, including the Phil Rich Building, the Farnsworth-Chambers Building, the Lane-Wells Building, the Canada Dry Bottling Building, and a Veterans Administration Building; and at Ellington Field. "Houston Site Offices Move to Rich Building." *Space News Roundup* (1, 3), November 29, 1961, 1; "Move To Houston Area Is On Schedule." *Space News Roundup* (1, 6), January 10, 1962, 1; "Photo Captions." *Space News Roundup* (1, 18), June 27, 1962, 2.

[30] Henry C. Dethloff. *Suddenly, Tomorrow Came...A History of the Johnson Space Center.* (Houston: Lyndon B. Johnson Space Center, 1993), 48.

[31] "Interview with I. Edward Campagna, Assistant Chief, Technical Services Division, Maintenance and Operations." August 24, 1967, Box MERR1, Oral History Series. Johnson Space Center History Collection, University of Houston-Clear Lake; Dethloff, 48.

September 1961, the Fort Worth Division of the U.S. Army Corps of Engineers (ACOE), under District Engineer, Colonel R. Paul West, was designated the construction agency for the new Center. Their first task was to hire an architecture/engineering (A/E) team to complete the initial design work for the new Center. Twenty teams were considered for the initial contract, and after three rounds of reviews and cuts, an A/E team headed by Brown & Root, Inc., of Houston, Texas, was selected. Partnered with them were master planners Charles Luckman Associates, Los Angeles, California; and the architectural firms of Brooks & Barr, Austin, Texas; Harvin C. Moore, Houston, Texas; MacKie & Kamrath, Houston, Texas; and Wirtz, Calhoun, Tungate, & Jackson, Houston, Texas.[32] The nearly $1.5 million contract was officially awarded in December 1961, and included general site development; master planning; design of the flight project facility, the engineering evaluation laboratory and the flight operations facility; and various site utilities.[33]

Charles Luckman Associates developed the master plan of the JSC, and "did an outstanding job of meeting the functional requirements that had been set forth in developing a campus-like atmosphere for the facility."[34] The central "quad" area, bounded by 2nd Street on the west, Avenue D on the south, 5th Street on the east, and Avenue C on the north, included three "lagoons" surrounded by small, man-made hills, as well as various walkways, trees, and shrubs.[35] Luckman Associates also advocated the use of a modular design system for the buildings with materials that could be manufactured off-site, which aided in the tight schedule for completion. Most of the buildings incorporated a poured concrete foundation, and skeletal steel walls faced with precast exposed aggregate facing (PEAF) panels. This allowed for the fabrication of the steel components while the foundation was being poured, and subsequently the manufacture of the PEAF panels while the steel skeleton was being erected.[36]

Initial construction of the JSC was completed in three main phases. The contract for the first phase, preliminary site development, was awarded on March 29, 1962, to a joint venture of Morrison-Knudsen Construction Company of Boise, Idaho, and Paul Hardeman of Stanton, California; it amounted to $3,673,000. They began the work in early April; it was completed on July 18, 1963.[37] The task included "overall site grading and drainage, utility installations including an electrical power system, a complete water supply and distribution system, sanitary and storm drainage systems, basic roads, security fence and street lighting."[38]

The invitations to bid for the Phase II contract of the construction, which was the first to include actual buildings, were distributed in early July 1962. At first, the task included an office

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32 "Photo Captions." *Space News Roundup* (1, 12), April 4, 1962, 2.

33 "Design Work Contract Is Let For Clear Lake." *Space News Roundup* (1, 5), December 27, 1961, 8.

34 "Interview with James L. Ballard, Jr." August 1, 1968, Box MERR1, Oral History Series. Johnson Space Center History Collection, University of Houston-Clear Lake.

35 Campagna, August 24, 1967.

36 Ballard, August 1, 1968; Campagna, August 24, 1967.

37 "First Construction Contract Work Underway at Clear Lake." *Space News Roundup* (1, 13), April 18, 1962, 1; "Clear Lake Site Commitment Now Stands At $38,911,458." *Space News Roundup* (3, 4), December 11, 1963, 3.

38 "Interview with Jack P. Shields." August 1, 1968, Box MERR4, Oral History Series. Johnson Space Center History Collection, University of Houston-Clear Lake; "First Construction Contract Work."

building, a shop building and warehouse, a garage, a central heating and cooling plant, a fire station, and a sewage disposal plant, as well as all necessary paving and utilities for these structures.[39] By the time bids were received and opened, the statement of work had been revised to exclude the office building, the shop building, and the warehouse, all of which were replaced by the Data Processing Center (Building 12). By the time the contract was let in October 1962, the task had changed a second time. In the end, the ACOE signed a contract with the joint venture of W.S. Bellows Construction Corporation and Peter Kiewit & Sons Corporation, both of Houston, in the amount of $4,145,044, for the construction of Building 12, the sewage disposal plant, the central heating and cooling plant, the fire station, and a water treatment plant and associated building.[40] Of these facilities, the fire station was the first to be completed in September 1963; the central heating and cooling plant was last, finished in December 1963.[41]

Phase III of JSC's construction incorporated the largest grouping of buildings under one contract. The invitations to bid on this phase were issued on September 25, 1962, and listed ten buildings with an approximate total area of 760,000 square feet.[42] Similar to Phase II, the statement of work was revised prior to the submittal of the bids to include eleven office and lab buildings, and the temperature and humidity control machinery for the entire site. Interested firms were also asked to submit alternate proposals that incorporated additional facilities, which NASA was hoping to add to the contract if funding became available.[43] On December 3, 1962, Colonel Francis P. Koish, the new ACOE District Engineer, signed the official contract, which amounted to roughly $19 million, with the joint venture of C.H. Leavell and Company of El Paso, Texas, Morrison-Knudsen Construction Company, and Paul Hardeman. Eleven major facilities were part of this contract, including the project management building, the cafeteria, the flight operations and astronaut training facility, the crew systems laboratory, the technical services office and shop buildings, the systems evaluation laboratory, a spacecraft research lab and office building, and a data acquisition building. Funding for the additional facilities had become available by this time, so additional support buildings, such as the shop building and warehouse, were also included. Per the contract, the buildings were to be ready for occupancy in 450 calendar days.[44]

In October 1963, the Logistics Division became the first to move into its complete facility, the Support Office (Building 419) and its shops and warehouse (Building 420). By the end of 1963,

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[39] "Second Major Clear Lake Building Contract Awarded." *Space News Roundup* (1, 17), June 13, 1962, 8.
[40] "Bids Open On Phase Two Of Clear Lake Work." *Space News Roundup* (1, 23), September 5, 1962, 1; "Phase II Contract Goes to Bellows, Peter Kiewet, Sons." *Space News Roundup* (1, 25), October 3, 1962, 8; Shields, August 1, 1968.
[41] "Photo Captions." *Space News Roundup* (2, 23), September 4, 1963, 3; "Central Heating and Cooling Plant Completed." *Space News Roundup* (3, 5), December 25, 1963, 8.
[42] "First Building Contract To Be Let In November." *Space News Roundup* (1, 20), July 25, 1962, 8.
[43] "Bids Open On Phase 3 Of Center Construction." *Space News Roundup* (2, 2), November 11, 1962, 1-2.
[44] "19 Million Dollar Construction Contract Signed." *Space News Roundup* (2, 4), December 12, 1962, 1; "MSC 'Site' Three-Fourths Complete, First Move Scheduled Next Month." *Space News Roundup* (2, 24), September 18, 1963, 1; Shields, August 1, 1968.

twelve additional buildings were certified as operational.[45] The major relocation to the new Center occurred between February and April 1964, and included the occupation of facilities such as the Auditorium and Public Affairs Building (Building 1), the Flight Crew Operations Office (Building 4), the Flight Crew Operations Lab (Building 7), the Systems Evaluation Lab (Building 13), and the Spacecraft Technical Lab (Building 16). The Director's office officially moved on March 6, 1964. During May, the Instrument and Electronics Lab (Building 15) was occupied, followed by the Manned Spaceflight Control Center, Houston (Building 30) at the end of June, when all leases on the temporary facilities expired.[46]

Since its beginnings as the STG, JSC has had four main tasks with regard to manned spaceflight: spacecraft development; mission control; research and development; and astronaut selection and training.[47] The basic design guidelines for each space vehicle used during the Mercury, Gemini, Apollo, and Space Shuttle programs were developed by JSC engineers. JSC subsequently managed the contracts with private firms for spacecraft manufacture. It was also the responsibility of JSC engineers to develop the proper interfacing between the spacecraft and its respective launch vehicle, which was developed separately by NASA's MSFC (Mercury-Redstone, Apollo-Saturn, Shuttle SRBs, ET, and SSMEs) or the U.S. Air Force (Mercury-Atlas, Gemini-Titan).[48]

In addition to spacecraft development and astronaut training, JSC is also responsible for mission control. Mission control begins once the space vehicle has cleared the launch pad, and ends when the vehicle lands.[49] The key figure of mission control is the Flight Director, who makes all final decisions with regards to the proceedings. All communication between the ground and the spacecraft is coordinated through the Spacecraft Communicator. The mission control team also includes personnel who monitor all aspects of the space vehicle, such as flight dynamics, communications links, data processing, and instrumentation. Between missions, the controllers plan for the next flight, conduct various in-house training exercises, and aid with astronaut training.[50]

In conjunction with vehicle design, JSC has historically conducted related research and development, which generally falls into four categories: materials, electrical systems, life

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[45] "MSC 'Site' Three-Fourths Complete;" "Major Move To Clear Lake Begins February 20." *Space News Roundup* (3, 6), January 8, 1964, 1.
[46] "Majority of MSC Personnel Relocated At New Site." *Space News Roundup* (3, 11), March 18, 1964, 2; "Final Relocation Of Center Employees Begins Today." *Space News Roundup* (3, 18), June 24, 1964, 1.
[47] "Gilruth Cites MSC Progress Despite Difficult Relocation." *Space News Roundup* (1, 19), July 11, 1962, 1.
[48] Archaeological Consultants, Inc. (ACI). *Survey and Evaluation of NASA-owned Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program. Lyndon B. Johnson Space Center, Houston, Texas.* November 2007, Section 4.3.1.
[49] Likewise, those who designed the launch vehicle generally handled the actual launch process. It should be noted that the Kennedy Space Center, which has conducted all launches for Apollo and Space Shuttle, grew from MSFC's Launch Operations Directorate, which controlled the initial Mercury-Redstone launches.
[50] All Mercury missions and the first four Gemini missions were controlled from the old Mercury Control Center at Cape Canaveral, Florida. The Mission Control Center at Houston took over starting with Gemini IV. ACI, Section 4.3.3.

systems, and life sciences. The materials category includes development and testing of active thermal control systems as well as spacecraft structure testing. Electrical systems includes testing of the various interfaces with spacecraft hardware and software, ensuring there are no anomalies within the wiring and electronics systems, and confirming the ability of the spacecraft's communications systems to connect to relay satellites and ground stations. Life systems and life sciences are inherently connected to one another and include the astronauts' spacesuits and backpacks, as well as ensuring that their meals meet nutritional guidelines, taste good and store well.[51]

The last major task of JSC, and probably the most well-known besides mission control, is astronaut selection and training. From the original "Mercury 7," JSC has determined the criteria for astronaut selection and handled all interviews and examinations during the selection procedure. Additionally, the Center has established all training curricula, which provide astronauts with the basic knowledge needed to fly a mission and survive in emergency circumstances, as well as more specific training for tasks associated with a particular mission. Since Project Gemini, program-specific spacecraft simulators and trainers have been located within various buildings at JSC for astronaut training.[52]

[51] ACI, Section 4.3.4.
[52] ACI, Section 4.3.2.

Jake Garn Mission Simulator and Training Facility (Building 5)

Construction

The Jake Garn Mission Simulator and Training Facility (MSTF) was designed in the early 1960s by a combination of A/E firms headed by Brown & Root, Inc. of Houston.[53] It was built by the W.S. Bellows Construction Corporation, in conjunction with Peter Kiewit & Sons Corporation, both of Houston, Texas, under the direction of the ACOE, at a cost of roughly $1.6 million. Construction of the facility occurred between January 1964 and April 1965, as part of the second major phase of construction at JSC.[54] As originally designed, the building's north wing contained astronaut training simulators for both Project Gemini and the Apollo Program; the south wing held the Gemini Translation & Docking Trainer.[55]

Over the next few years, many modifications were made to the facility. After Project Gemini ended (ca. 1966), all of its simulators were replaced by ones needed for the Apollo Program. Around 1967, a Water Immersion Facility (WIF), essentially a large pool used for training astronauts to maneuver in a zero-gravity environment, was installed in the east end of the north wing.[56] Additionally, some of the original open work areas were subdivided into smaller offices and laboratories. When Skylab (1973-74), an application of the Apollo Program, was implemented, simulators specific to its needs were placed in the south wing.

Between 1976 and 1978, the MSTF underwent renovations to support the Space Shuttle program. At this time, any remaining simulators from the previous programs were removed, and again, some open work areas were subdivided into smaller rooms. The north wing's high bay was prepared for the new shuttle simulators, which were installed in the northeast corner and center of the High Bay. In addition, following the completion of the new Weightless Environment Training Facility (WETF) in Building 29 in 1980, the WIF was removed from the MSTF and its old space was subdivided.[57]

Beginning ca. 1988, plans were underway to construct a three-story, 23,356 square foot addition, on the south wing of the MSTF for the Space Station Program; the addition was accepted for occupancy in June 1992.[58] In December 1992, the MSTF was designated the Jake Garn Mission

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[53] Brown & Root Inc., et al., Houston. "Building No. 5, Mission Simulation & Training Facility." October 5, 1963. On file, JSC EDCC.

[54] NASA JSC. "Real Property Record-Building 5." On file, JSC Real Property Office, Center Operations Directorate. Brown & Root Inc., et al. See pages 9-10 for more information regarding the phases of construction at JSC.

[55] Brown & Root Inc., et al., A-5-2, A-5-3; Lewis Jerry Swain, interview by Jennifer Ross-Nazzal, October 2, 2009, Houston, TX, Manuscript on file, Tessada & Associates, Houston, TX, 2.

[56] NASA JSC, "Real Property Record;" "Photo Captions." *Roundup* (11, 4), January 7, 1972, 1; Swain, interview, 19.

[57] Swain, interview, 19; ACI, 6.3.

[58] "NASA FY88 Budget is $9.5 billion." *Space News Roundup*. (26, 1), January 9, 1987, 1 and 2; "JSC planning biggest year of construction." *Space News Roundup*. (28, 37), September 15, 1989, 1 and 4; NASA JSC, "Real Property Record.

Simulator and Training Facility as a result of an amendment introduced by Senator Barbara Mikulski of Maryland, to honor Senator Garn, who flew in mission STS-51D as a payload specialist in April 1985.[59] The last major physical changes to Building 5 were two mezzanine additions in 1993.[60]

MSTF Simulators

At the time of documentation, the MSTF contained three simulators used for SSP training: the Motion Base Simulator (MBS), the Fixed Base Simulator (FBS), and the T-38 Simulator.[61] The MBS and the FBS, along with the Guidance and Navigation Simulator (GNS) in Building 35, are part of the Shuttle Mission Training Facility (SMTF). The SMTF is operated by the Flight Training Branch of the Training Division, which falls under the Mission Operations Directorate (MOD).[62] The SMTF is a high-fidelity simulator facility that, for over three decades, has provided realistic training, for astronauts and ground controllers, for all phases of a mission, including "prelaunch checkout, ascent, aborts, on-orbit operations (including payload deployment, rendezvous, and Space Station docking/undocking), entry, landing, powerdown and contingency operations."[63]

The MBS was built for NASA in 1976 by the Link Division of the Singer Company. In its original configuration as the Orbiter Aeroflight Simulator, the MBS was used to train crews for the Approach and Landing Test (ALT) program from 1976-77.[64] While this was underway, the FBS was being installed in the High Bay, to the west of the MBS. Following the end of the ALT program, both simulators underwent the final preparations to train astronaut crews for the Orbital Flight Test (OFT) missions.[65] For the FBS, this included final qualification tests. The MBS, on the other hand, required a change-out of the flight deck controls and displays from the ALT configuration to the OFT configuration.[66] In addition, the extended pitch motion system, used to

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[59] "New crew training facility to bear Garn's name." *Space News Roundup.* (31, 46), December 4, 1992, 4.
[60] NASA JSC, "Real Property Record."
[61] The T-38 will be discussed separately later in the report.
[62] Prior to 2008, the SMTF also included the Space Habitability Simulator (SHAB) within Building 5. It was removed to make room for the T-38 simulator. NASA MOD. "Integrated Training Facility, Information Sheet;" Swain, interview, 20. The GNS in Building 35 is a near-exact replica of the FBS in Building 5. The only difference is the GNS does not have a Waste Collection System simulator. Jerry Swain, personal communication with Joan Deming and Trish Slovinac of ACI, October 31, 2006, Houston, TX.
[63] NASA MOD, "Information Sheet."
[64] The ALT program was conducted at NASA's Dryden Flight Research Center in California between February and October 1977, using the Orbiter *Enterprise.* It was "intended to certify the low-speed airworthiness of the Shuttle orbiter, as well as its pilot-guided and automatic approach and landing capabilities." Richard P. Hallion and Michael H. Gorn. *On the Frontier: Experimental Flight at NASA Dryden.* 2nd Edition. (Washington and London: Smithsonian Books, 2003), 430.
[65] The OFT program consisted of the first four Space Shuttle missions, which occurred between April 1981 and July 1982. Each flight had a crew of two (a commander and a pilot), and was used to "evaluate the Shuttle's engineering design, thermal characteristics, and performance in space." Judy A. Rumerman, et al. *U.S. Human Spaceflight: A Record of Achievement, 1961-2006.* (Washington, D.C.: NASA History Division, Office of External Relations, December 2007), 35.
[66] "There's no "lull" from the inside looking out." *Roundup.* (17, 4), March 3, 1978, 4.

place the simulator into launch position, which was not necessary for the ALT program, had to be activated and certified.

These original two simulators have been used throughout the operational phase of the SSP to train astronaut crews and ground controllers; however, they have been retrofitted many times due to updated technology or specific mission requirements.[67] Typically, updated technology has resulted in permanent modifications to the MBS and FBS. Sometimes, these upgrades were to specifically enhance the simulators' operations. An example would be the 1996-97 replacement of the computer consoles, which are used to run the simulators.[68] More often, technical upgrades to the MBS and FBS are due to changes made to the orbiters. One such example is the replacement of the flight deck's original Multifunction CRT Display System by the new Multifunction Electronic Display System, or "glass cockpit."[69] In addition, when the orbiters received new general purpose computers, identical ones were supplied for the simulators.[70] The vast majority of changes to the simulators were temporary modifications due to the specific requirements of a mission, or the astronauts' personal preference. Examples include the storage of certain tools in a specific locker or the location of the various flight data file books.[71]

Space Shuttle Program Training

The FBS and MBS were first used by Space Shuttle crews on January 9, 1979.[72] These two simulators help the astronauts prepare for launch, landing, and on-orbit activities. Each simulator has a specific function and is configured accordingly. The FBS is used by all members of the Shuttle crew, including pilots and commanders, and mission and payload specialists, and is strictly for on-orbit training. This simulator contains an exact replica of the orbiter's full flight deck, a partial-scale replica of the mid-deck, and an exact replica of the Waste Collection System (WCS). The flight deck, which is equipped with fully-functioning circuit breakers, switches, knobs, dials, etc., as well as an audio/visual system, includes both the forward deck and the aft crew station. With this simulator, the forward deck is used to train astronauts in on-orbit maneuvering and environmental control, while the aft crew station is used to practice payload and docking operations. The mid-deck features fully-functioning replicas of control panels on a real mid-deck, although they are not necessarily located in their exact position. Their function is to train the crew members in their operation.[73] The WCS portion of the simulator is also not positioned in its actual location on the mid-deck. Due to the personal nature of the training, the WCS replica is located in a separate room to the west of the mid-deck area. Here, there are two stations. One is comprised only of the seat, with a video camera mounted below the opening that is connected to a TV screen. This allows astronauts to practice proper alignment on the seat,

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[67] Swain, interview, 3.
[68] "Cooperation key to success of new shuttle training facility." *Space News Roundup.* (36, 14), April 25, 1997, 3.
[69] Swain, interview, 3.
[70] Pam Alloway. "Simulators get new computers." *Space News Roundup.* (29, 26), June 29, 1990, 1 and 4.
[71] Swain, interview, 5-6.
[72] "Crew Training countdown, Pre-launch sims underway in FOD." *Roundup.* (18, 2), January 26, 1979, 1.
[73] Unlike the flight deck, their location does not matter since the astronauts are moving freely when using them, as opposed to being strapped in to a seat. Mock-ups in Building 9 are used for location and access training.

using the camera and screen as positioning aids. The other is a complete replica of the WCS, which trains the crew members in the overall operations of the system. It should be noted that the FBS is the simulator generally used for real-time support, since it contains all on-orbit equipment.[74]

The MBS is used "for the aerodynamic phases of flight when the students, the astronauts primarily of course, want to experience motion sensations," i.e., launch and landing procedures.[75] It has both a visual display and audio sound system, and, to aid in motion cues, the simulator is fitted with a hydraulic system. This system tilts the crew compartment backwards placing it in the actual launch position, as well as provides more subtle movements in response to crew commands, such as pitch, roll, and yaw.[76] This simulator is typically only used by the four astronauts who sit on the flight deck during launch and landing, and unlike the FBS, is equipped with only the forward flight deck. Like the FBS, all of the circuit breakers, switches, knobs, dials, etc. are fully-functioning. Aside from normal launch and landing procedures, the MBS can simulate a Return-to-Launch-Site landing, a normal landing at EAFB, a contingency landing at the White Sands Space Harbor (WSSH), or an emergency landing at any of the world-wide Transatlantic Abort Location (TAL) sites. All landing simulations (aside from emergency situations) can be started at Earth reentry, or any other altitude depending on what the crew or instructor feels is necessary. Additionally, the visuals can reflect any type of atmospheric condition, such as day or night, or various weather phenomena.[77]

Once a crew has been designated for a particular mission, they are assigned a team of simulator instructors who stays with the astronauts for the entire training period. The instructor team is composed of five lead figures: the Team Leader, the Control and Propulsion Instructor, the Data Processing Systems and Navigation Instructor, the Communications Instructor, and the Systems Instructor. The Team Leader is responsible for designing a training program that meets the mission objectives, for serving as a liaison to the astronaut training manager (who budgets the astronauts' time between the various training facilities), and oversees the operations of a particular training session. The Control and Propulsion Instructor is responsible for teaching the crew how to operate the main propulsion system, the OMS, the RCS, the fuel cells, and flight control. The Data Processing Systems and Navigation Instructor trains the crew in the use of the orbiter's five general purpose computers and the use of the navigation system; while the Communications Instructor is responsible for training the crew in the use of all communications systems between the shuttle and Mission Control; the shuttle and crew members conducting an EVA, as well as the use of the S-band, Ku-band, and UHF links and internal systems of the orbiter. Finally, the Systems Instructor teaches the crew about the orbiter's electric power production and distribution, environmental control and life support, auxiliary power units and hydraulics, mechanical systems, and caution and warning systems. There could be additional

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[74] Swain, interview, 3; Swain, personal communication, 2006; Jerry Swain, Personal communication with Patricia Slovinac and Christine Newman, September 17, 2009; "No lull."
[75] Swain, 15.
[76] "No lull."
[77] Swain, interview, 13-15; NASA MOD, "Information Sheet;" "No lull."

instructors as well, depending on the mission, such as a Rendezvous Instructor, a Robotics Instructor, or a number of payload experts.[78]

Training in the two simulators typically begins with general training, and then moves to more mission-specific training. Simulations can be run with the astronauts in "street-clothes" or suited-up. A typical training session lasts four hours, but longer ones are sometimes scheduled. These can last six or eight hours, or even multiple days, with the crew taking meal breaks and returning home to sleep. They can be stand-alone simulations, i.e., just the simulator and instructor team, or they can link to the Mission Control Center, the Neutral Buoyancy Laboratory at JSC, the Payload Control Center at MSFC, or even Moscow or Japan. Each simulation has a script that tells instructors where to begin a malfunction sequence, etc. The team can insert additional malfunctions into the session, or remove some, depending upon the crew experience.[79]

Generally, there are approximately 100 people throughout the MSTF working during a simulation, including the instructors and technicians. The technicians have their own "command area" during simulation runs, where they monitor the simulators to make sure everything is operating smoothly and make any hardware/software repairs should something fail. Additionally, although they are not cosmetic changes, there are different software packages for each mission that are programmed into the simulators for training purposes, and real-time support.[80]

In the event of a real-time support need, if there is a crew undergoing some routine training, their session is terminated, and the technicians have two to four hours to get the simulator in to the proper configuration (i.e., software installed) to match the current mission. Additionally, since all of the computers within the simulators are the exact same as those on-board the actual vehicle, they can "run test cases in our simulation [sic] just to see how the vehicle is going to react" or to check "if the systems will support a particular configuration."[81]

T-38 Simulator

The T-38 Simulator was installed in the MSTF around 2003, and consists of the forward and aft cockpit of a T-38 jet. Rumor has it, that it was an actual T-38 jet, which had its front and rear ends, as well as the wings, cut off.[82] The simulator is managed by the flight instruction group stationed at Ellington Field, and is used to train astronauts in the operation of the T-38 astronaut training aircraft. The T-38 jets are used by all astronauts to help them "become adjusted to unusual attitudes that they will experience in space." They can also be used to simulate orbiter landings.[83]

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[78] Swain, interview, 12; "TRUST is a MUST." *Space News Roundup*. (26, 6), March 20, 1987, 3.
[79] Swain, interview, 13-14.
[80] Swain, interview, 5-6.
[81] Swain, 9.
[82] Swain, interview, 20-21.
[83] NASA JSC. "Fact Sheet: Ellington Field Aircraft." Last updated September 25, 2006.

Physical Description

The MSTF has approximate overall dimensions of 265' in length (north-south), 264' in width (east-west), and 56' in height. The entirety sits on a reinforced concrete slab foundation and features a flat roof composed of a steel and concrete deck faced with rigid insulation, a five-ply built-up roof, and gravel.[84] Additionally, all of the walls are composed of a steel skeleton faced with PEAF panels. The facility is divisible into three areas: a south wing (Wing S), a central connector, and a north wing (Wing N).

Wing S roughly measures 199' in length (east-west), 106' in width (north-south), and stands 56' in height. Openings to this wing include two metal rolling doors and two metal swing doors on the south elevation, and one metal swing door on both the east and west elevations. Internally, there are three floor levels and one smaller mezzanine level, all of which contain open work areas, a few smaller offices, and other support rooms. The one-story central connector measures approximately 152' in length (east-west), 73' in width (north-south), and stands 14' in height. There is one pair of metal swing doors on both the east and west elevations, and the west facade also has one metal swing door. Internally, this area is comprised of a central corridor with administrative offices to either side.

Wing N measures approximately 266' in length (east-west), 88' in width (north-south), and has a height of 37'. Around the top of the walls is a band of horizontally-oriented PEAF panels; the remainder of the walls are faced with vertically aligned PEAF panels. Access to this wing is provided by five pairs of sound retardant metal swing doors (with metal rolling doors behind), and one additional metal rolling door on the north elevation; one set of metal swing doors on the west elevation leads to the enclosed transformer area. Internally, the north wing is divided into a High Bay within the northwest corner, with three levels of support rooms to its south and east.

As originally defined by the "Survey and Evaluation of NASA-owned Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program, Lyndon B. Johnson Space Center, Houston, Texas," the significance of the MSTF is derived from Room No. 117D/117E, which contains the Fixed Base Simulator (FBS), the Motion Base Simulator (MBS), and the T-38 Simulator.[85] However, it should be noted that at the time of this documentation package, the T-38 simulator had been relocated to the High Bay.

The Wing N High Bay measures approximately 150' in length (east-west) and 62' in width (north-south); the floor to ceiling height is roughly 31'. It has four metal rolling doors on the north wall. On the south wall, there is one single metal swing door and three pairs of metal swing doors to the large computer room, one metal swing door to the corridor, and one pair of metal swing doors into the simulator control area. The inner wall surfaces of the High Bay are faced

[84] Five-ply refers to the number of alternating layers of roofing felt and asphalt.

[85] ACI, 6.2.3. It should be noted that at the time of the original survey, the T-38 simulator was within Room 1150 of the South Wing. The T-38 Simulator was removed from Room 1150 ca. 2008, sent out for refurbishment, and relocated to Room 117 in the North Wing upon its return. Swain, personal communication, 2009.

with gypsum wall board; the ceiling surface is corrugated metal. The High Bay also has a raised floor comprised of removeable tiles, which allow all necessary cabling to be run underneath.

Motion Base Simulator

The MBS, which has approximate overall dimensions of 18' in length, 18' in width, and 22' in height,[86] is located in the northeast corner of the High Bay. This simulator is composed of two main elements: the motion system and the crew compartment. The crew compartment is a full-scale replica of the orbiter's forward flight deck, oriented so that the crew is facing north; thus the north wall of the compartment contains all of the forward control panels, and the east and west walls contain the forward starboard and forward port panels, respectively. These three walls also contain replicas of the orbiter's six forward windows. These are not real windows, but rather display monitors for the visual images produced to support the simulations. These monitors are connected to projectors attached to the box encasing the front end of the crew compartment. The crew compartment's ceiling includes all of the overhead panels found in the orbiter, and a replica center console sits between the front commander (port) and pilot (starboard) seats. One discrepancy between the MBS and the orbiter is that the simulator contains three seats in the second row, the extra of which is used by the training instructor. Access to the crew compartment is provided by a door in the south wall, which is reached via a separate, moveable platform. Large cable trays for equipment wiring, as well as air conditioning ducts, are attached to the underside of the crew compartment.

The MBS' motion system is comprised of two subsystems: a six-degree-of-freedom synergistic system and an extended pitch system. The extended pitch system is attached directly to the crew compartment, and is composed of a tilt platform, two actuators, two tilt pivot support frames, a drive mechanism, and various stabilizers and shock absorbers. The tilt platform is fitted to the bottom of the crew compartment, and is subsequently connected to the synergistic system through two hydraulic actuators with drive mechanisms to raise and lower the platform. On the east and west sides of the crew compartment is a truss-like pivot support, around which the compartment rotates. The pitch system also has numerous stabilizers and shock absorbers to hold the compartment in place and protect the crew and simulator components should the drive system, or a sub-component, fail.

The six-degree-of-freedom synergistic system serves as the base of the simulator, and incorporates numerous components, including a platform frame, six actuator legs, three swivel mounts, various accumulators, and a hydraulic system. The platform frame is the piece to which the extended pitch system is connected. Three upper joint assemblies are spaced around the underside of the frame, each of which has two of the six actuator legs attached to it. From each assembly, the two actuator legs extend diagonally to the floor, in opposite directions. At the floor, each of the six actuator legs is attached to the lower joint assembly that is connected to one of three, 6'-square swivel mounts. An array of small pipes connects the actuators, through the

[86] L.J. Swain, e-mail message to Shashi Gowda, June 3, 2009.

swivel mounts, to the main manifold with the hydraulic pumps and accumulators, located to the northwest of the simulator.

Fixed Base Simulator

The FBS, which sits to the west of the MBS near the center of the High Bay, has approximate overall dimensions of 33' in length and 26' in width, and a height of 26' that includes the video projectors.[87] Internally, the FBS is comprised of two levels that correspond to the orbiter's flight deck and mid-deck, and is oriented so that the forward side of each deck faces north. Surrounding the exterior of the FBS is a three-level set of access platforms. The lowest level, which corresponds to the floor of the High Bay, provides access to the interior of the FBS (through doors on the east and west of the mid-deck), as well as the WCS simulator. The upper two levels are for maintenance access to the various projectors and other external compartments of the FBS.

The mid-deck is a partial-scale replica of the one found on the orbiter; it contains all of the mid-deck control panels, although not necessarily in their proper location. Since nearly all of these panels are used only while the vehicle is in-orbit, it is not necessary for the crew to practice reaching them, just using them. Such panels are mounted on all four walls of the mid-deck, as well as the ceiling. In addition, the simulator contains a few crew and equipment lockers along the north and south walls. Major discrepancies between the FBS mid-deck and an actual mid-deck are the absence of the WCS, the galley, and the airlock hatch. Additionally, there is a more-substantial-than-the-real-thing metal ladder in the southwest corner to provide access to the flight deck above.

The flight deck is an exact replica of that found on the orbiter, and unlike the MBS, includes the aft section of the flight deck. As mentioned above, the flight deck is oriented so that the crew is facing north; thus the north wall of the compartment contains all of the forward control panels, the east and west walls contain the starboard and port panels, respectively, and the south wall contains all of the aft control panels. These west, north, and south walls also contain replicas of the orbiter's six forward windows; the south wall has replicas of the rear windows (only usable while in orbit); the ceiling contains replicas of the overhead windows. These are not real windows, but rather display monitors for the visual images produced to support the simulations. These monitors are connected to projectors attached to the box encasing the flight deck. Additionally, the flight deck's ceiling includes all of the overhead panels found in the orbiter, and a replica center console sits between the front commander (port) and pilot (starboard) seats. Unlike the MBS, the FBS contains the "proper" two seats in the second row.

Also included in the FBS is the WCS simulator, which sits to the west of the mid-deck. This 14' x 10' room contains two stalls along the west wall. The north stall, which sits in the northwest corner directly across from the door, replicates the seat of the WCS only. A camera, which is hooked into a TV monitor oriented to be viewed from the simulator, sits just below the seat. Just

[87] Swain, email.

to its south is the south stall that replicates the entire orbiter WCS. A sink and mirror are located within the southeast corner of the room.

T-38 Simulator

The T-38 Simulator sits in a small enclosure within the northwest corner of the High Bay. This space has approximate dimensions of 33' in length and 15' in width that has a raised floor for cables. The simulator contains the entire T-38 cockpit area, which includes two tandem seats but not the glass windshield. Each crew position is equipped with the controls and visuals found in an actual T-38; those for the student in the front seat and those for the instructor in the back seat. Two small metal stepladders on the port side of the cockpit provide access into the crew seats.

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Figure 1. Location of Jake Garn Mission Simulator and Training Facility.
Source: JSC, 2006.

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Photographs MSTF-1 through MSTF-74 were taken by Patricia Slovinac, ACI; September 2009. Historic photographs (MSTF-75 through MSTF-88) are courtesy of the NASA JSC Imaging Center (Building 424), Houston, Texas; the negative number is given in parentheses.

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MSTF-89 Photocopy of drawing
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NASA, Manned Spacecraft Center, Texas
Drawing A-5-2, Brown & Root, et al., 1963
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BUILDING NO 5
NASA, Lyndon B. Johnson Space Center, Texas
Drawing A-5-7A, NASA JSC, 2008
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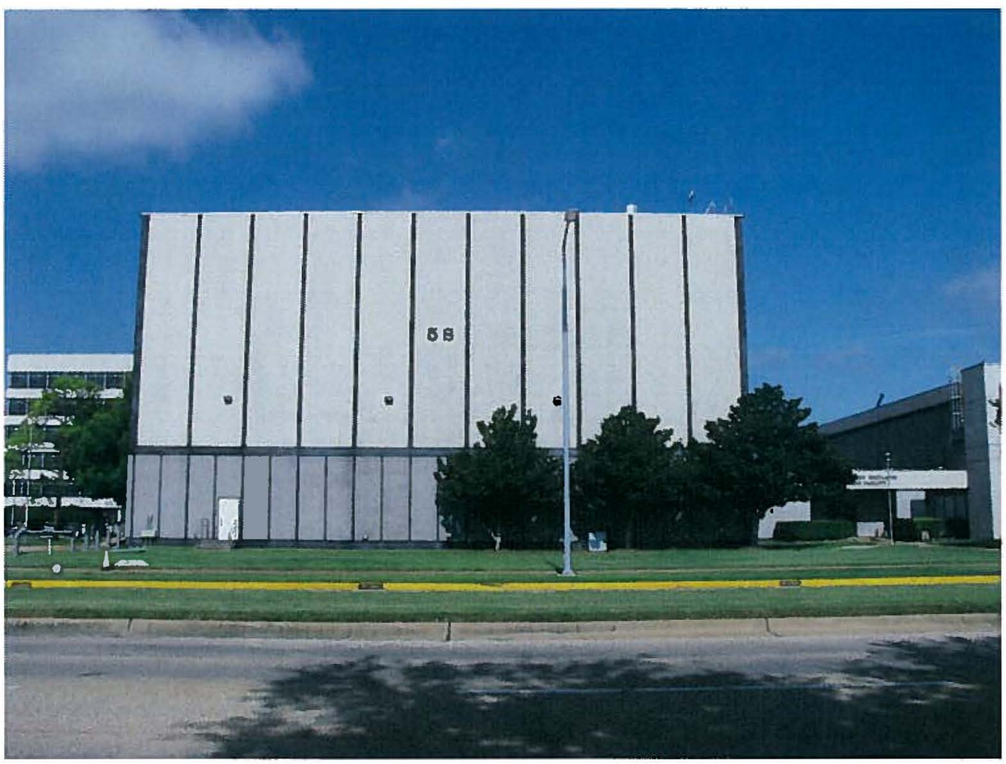

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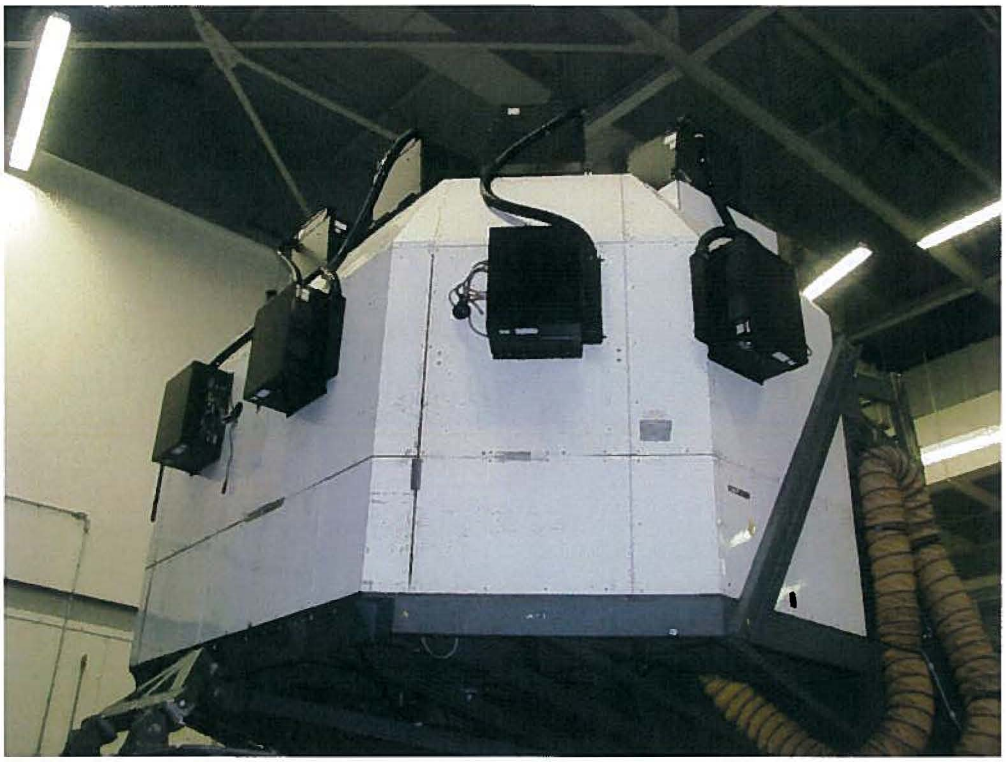

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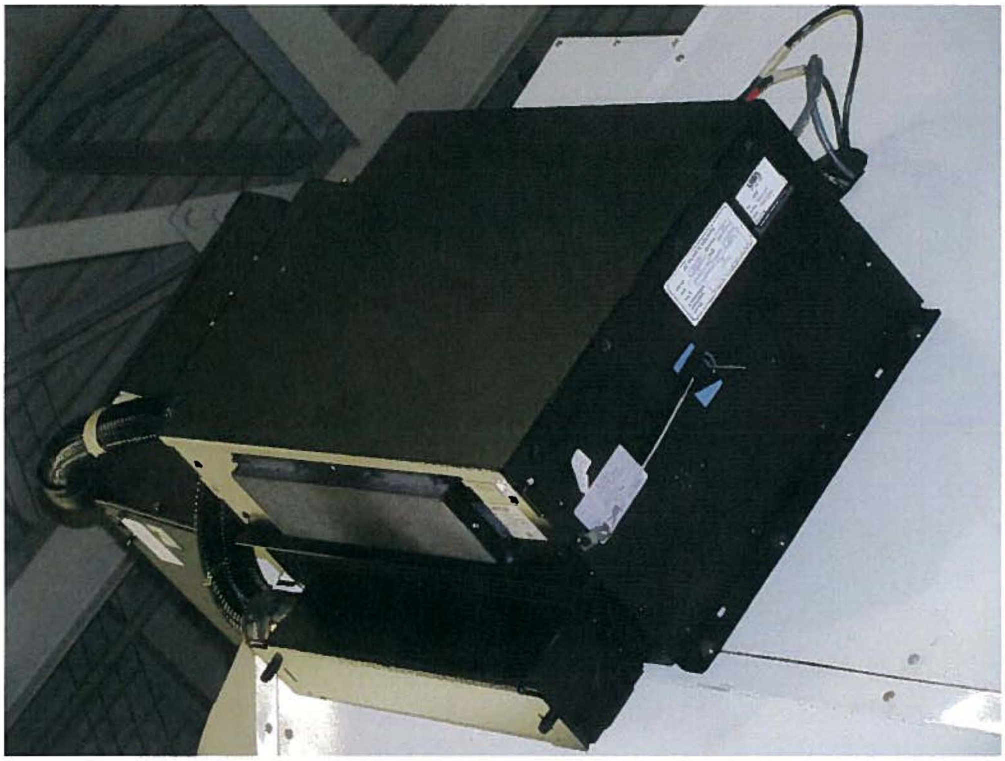

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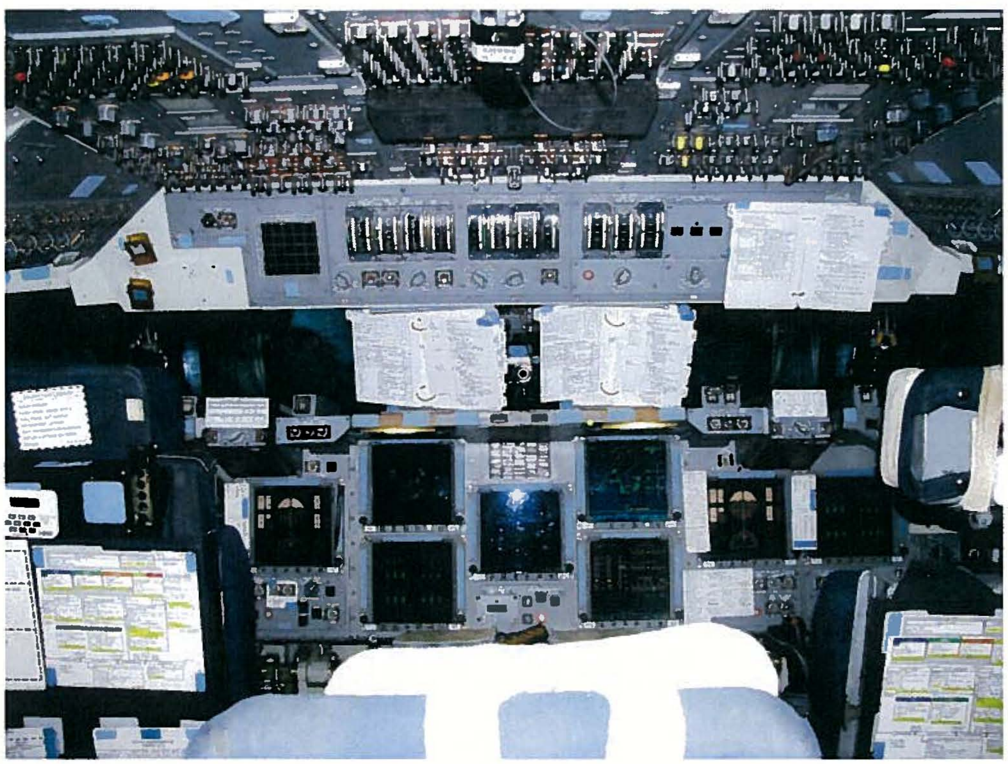

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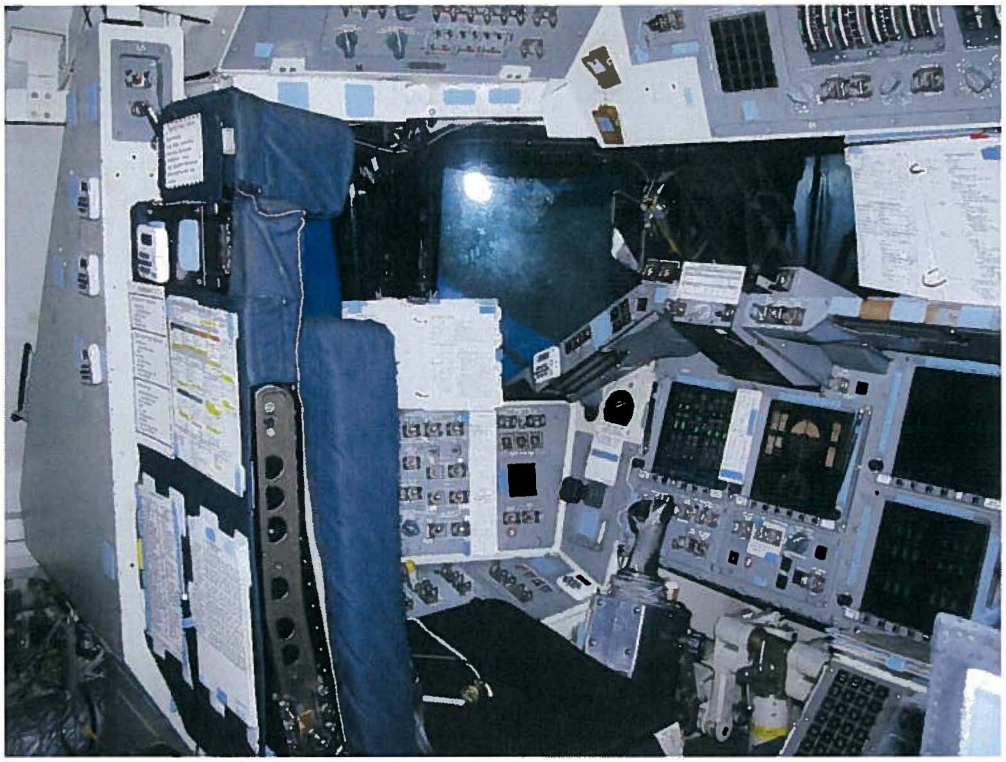

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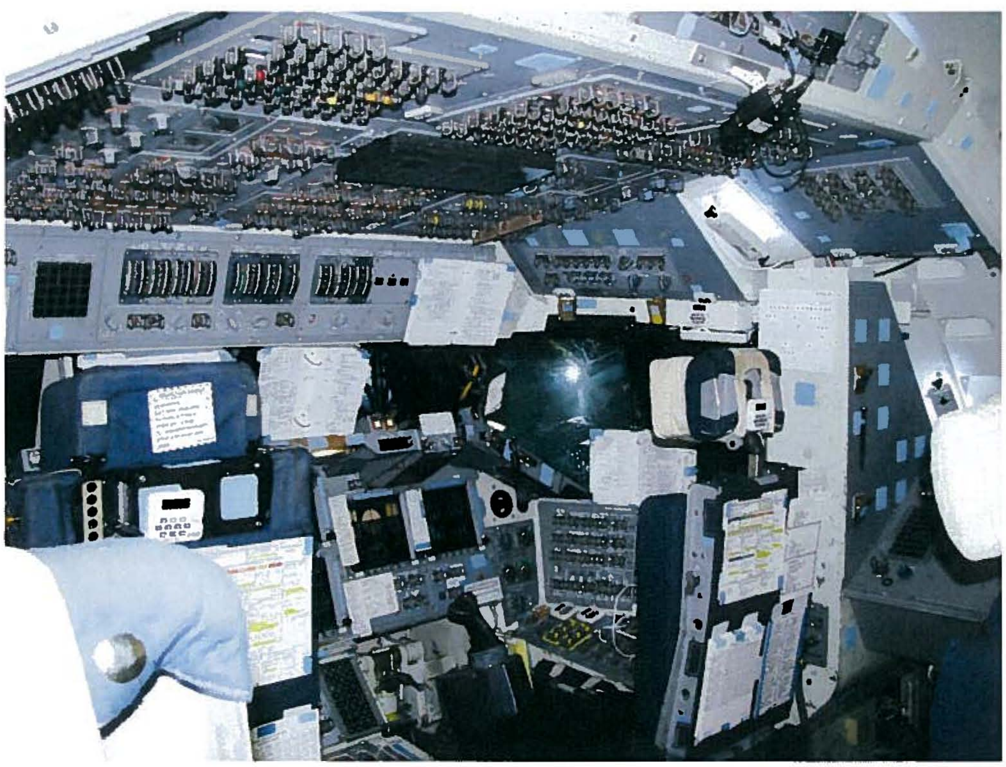

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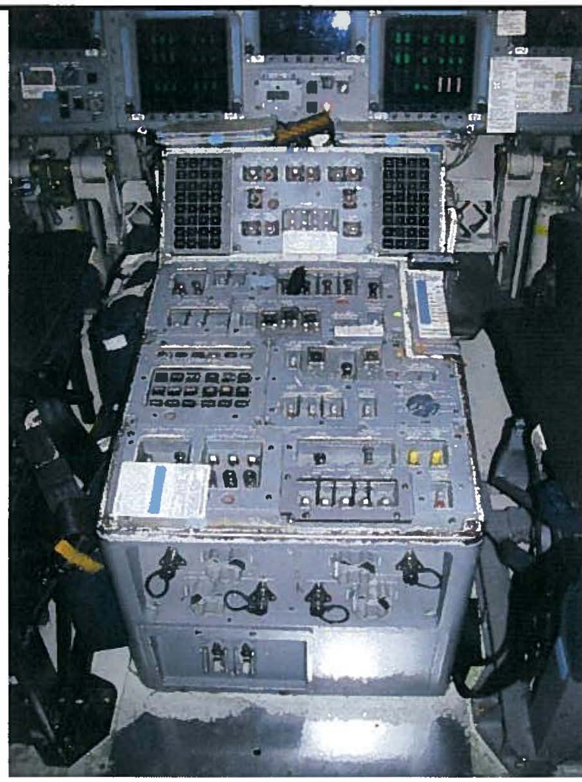

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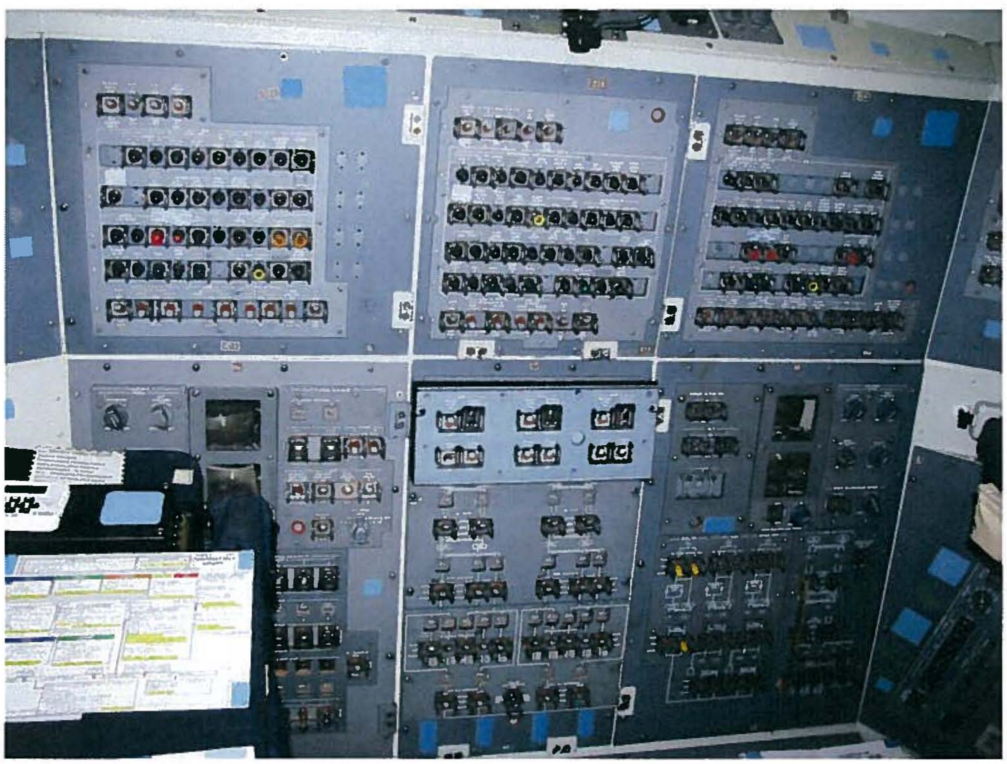

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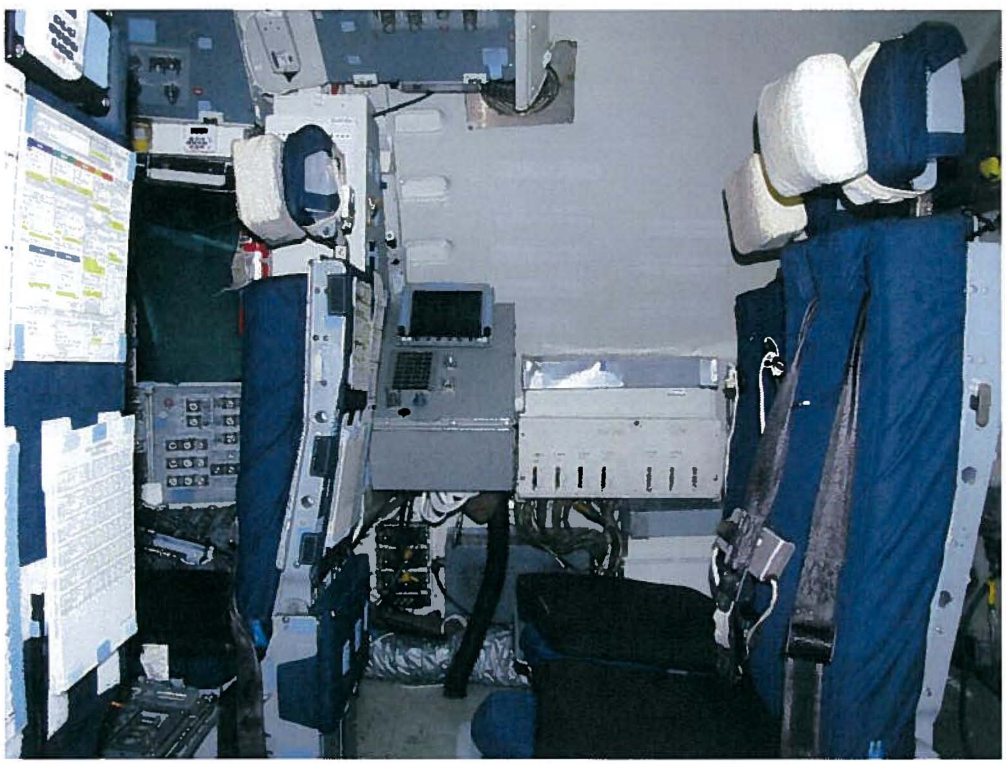

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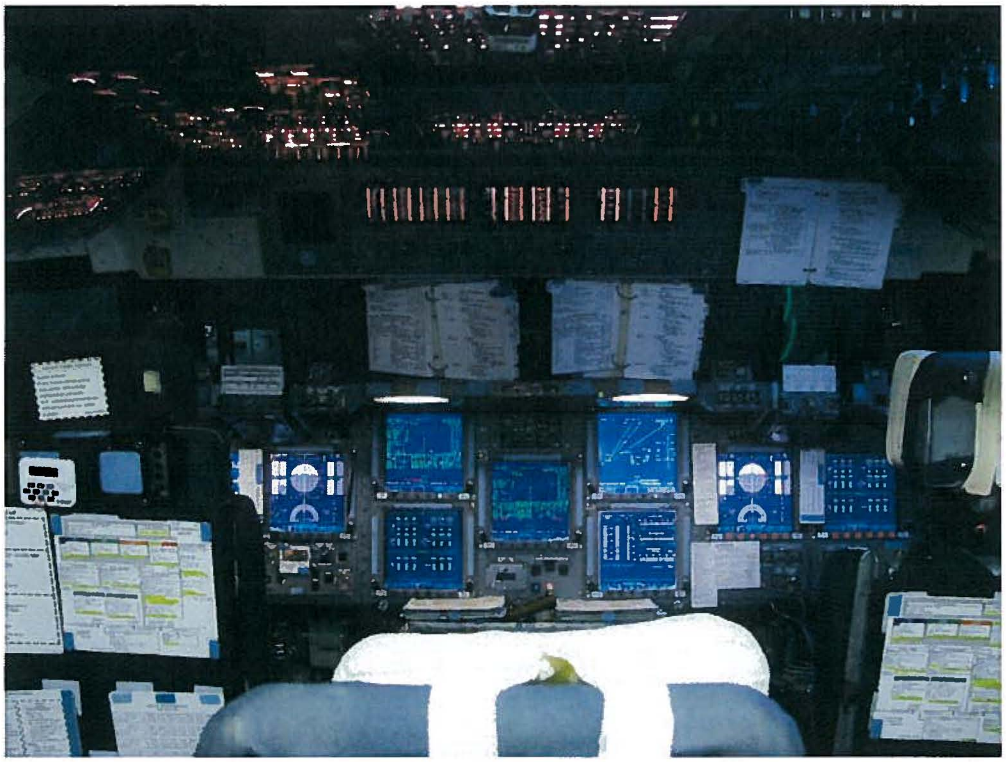

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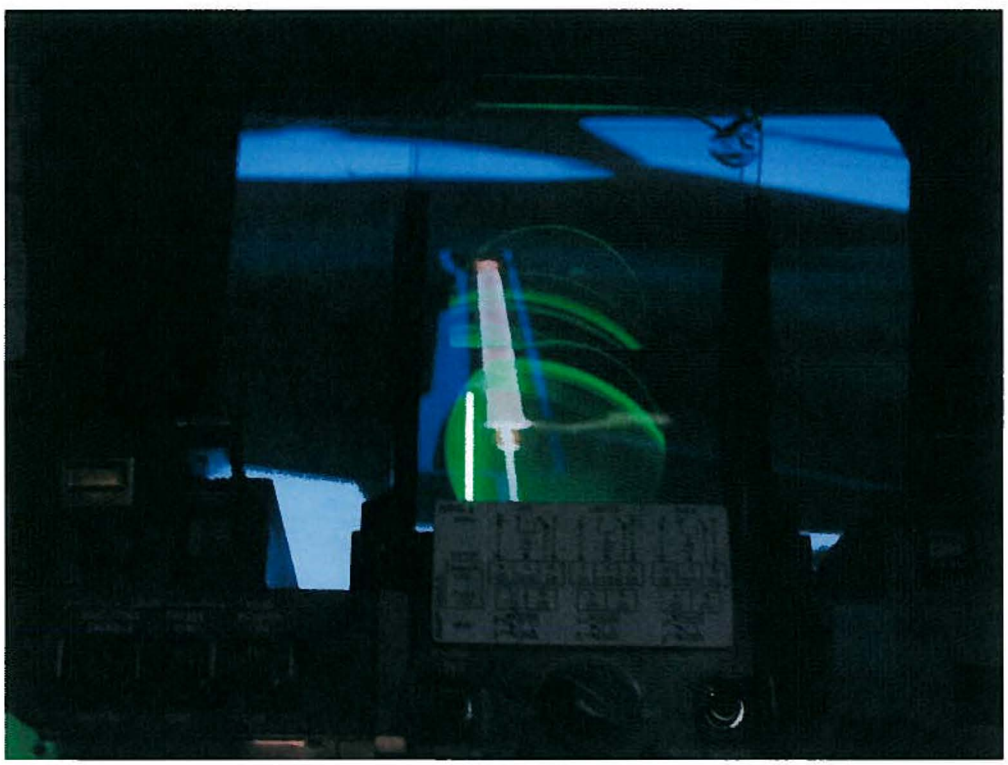

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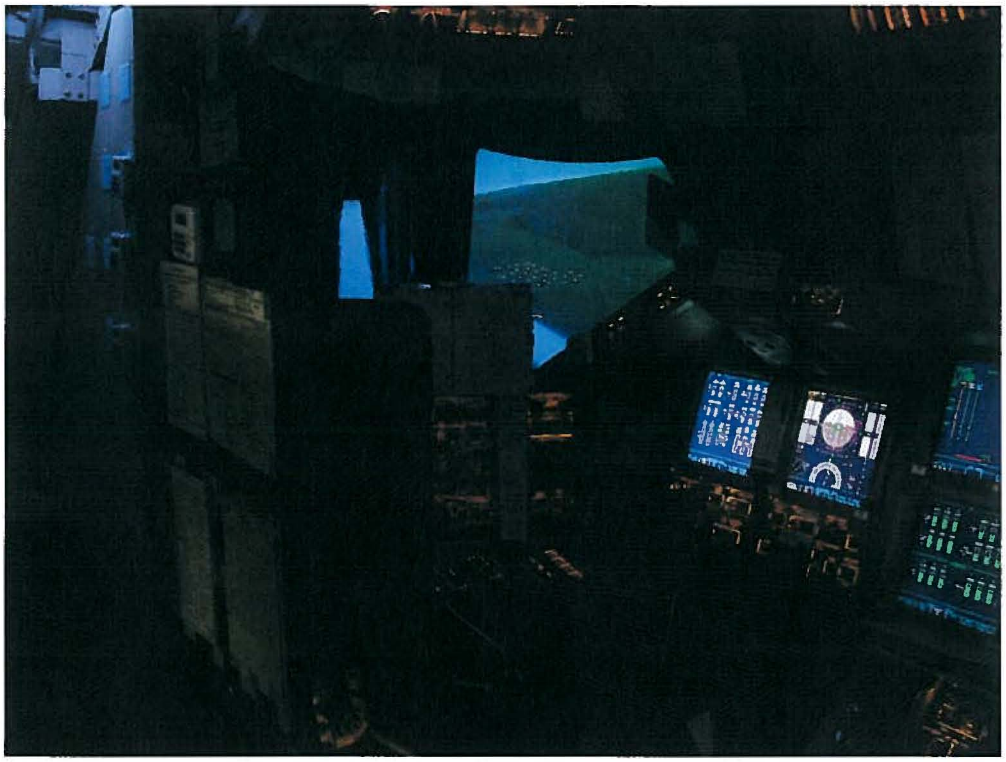

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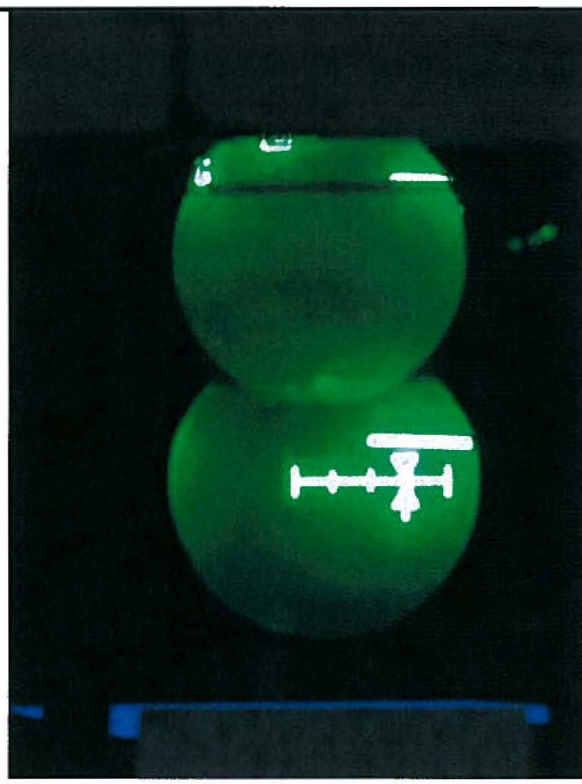

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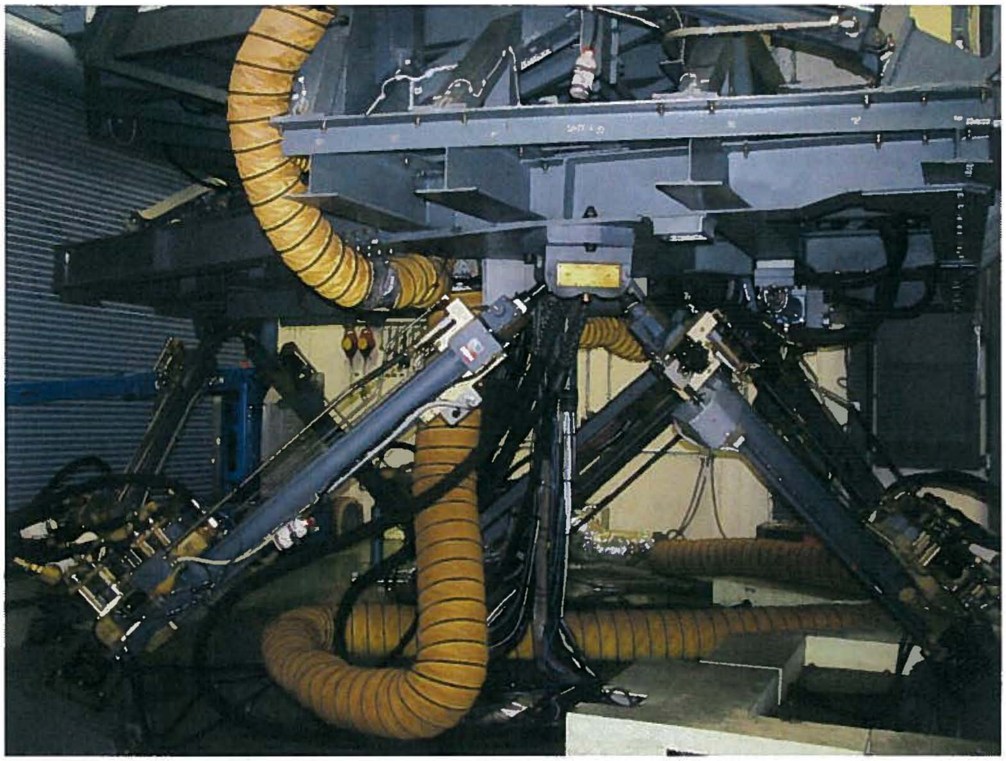

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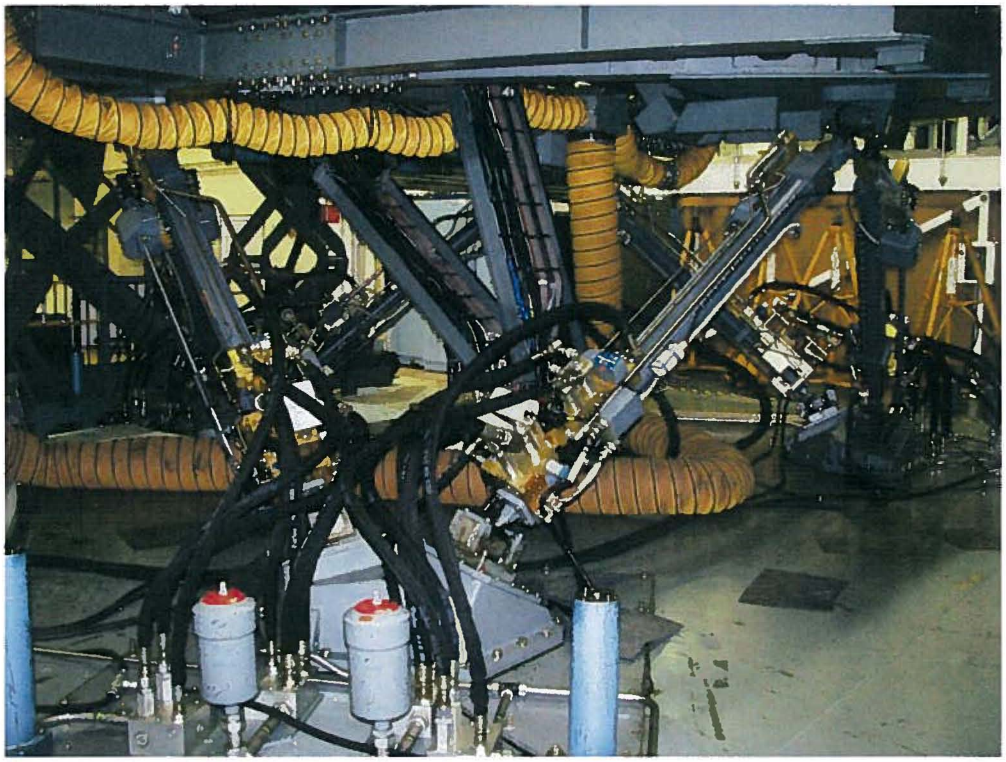

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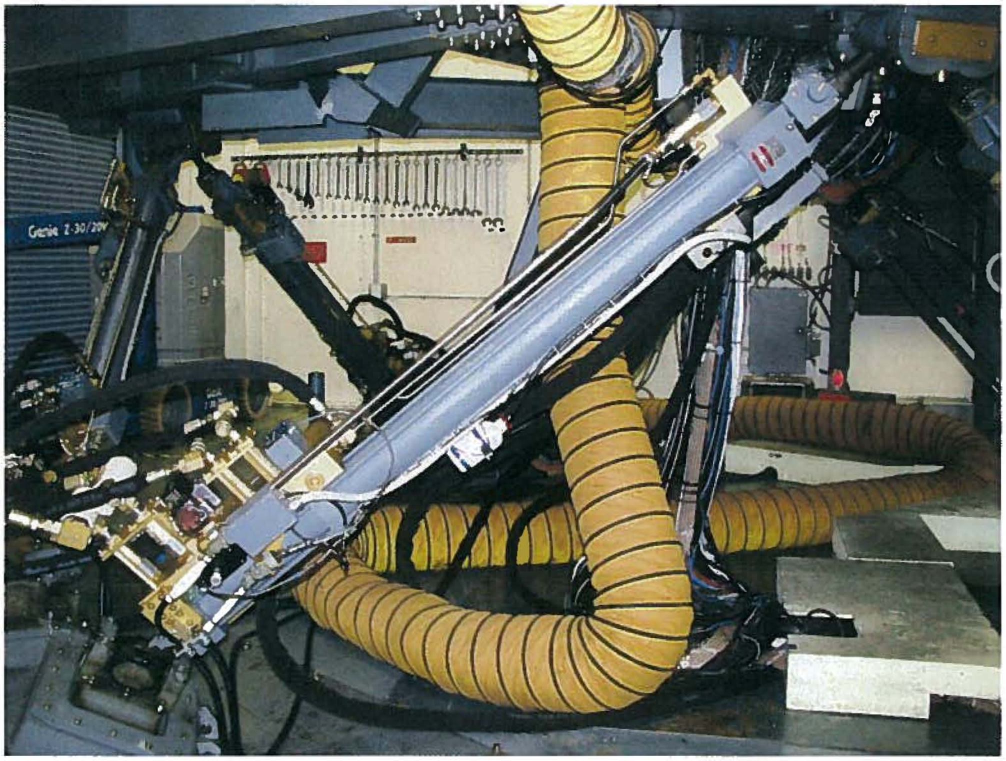

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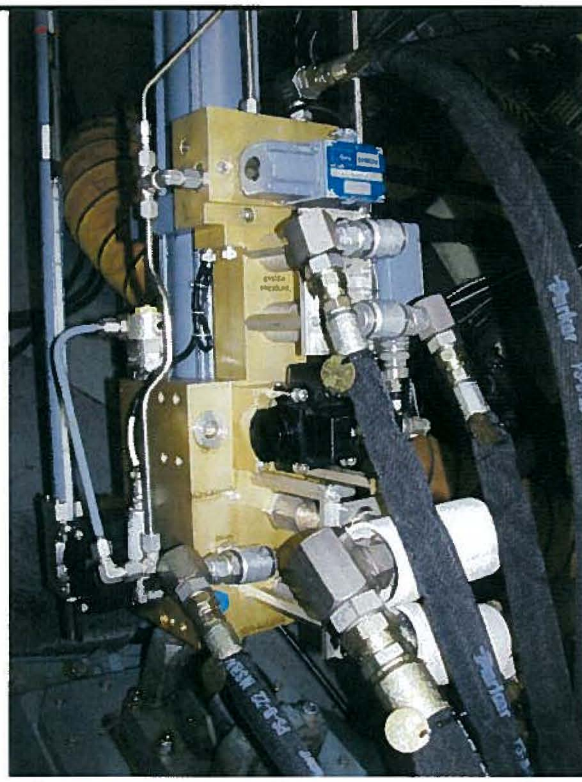

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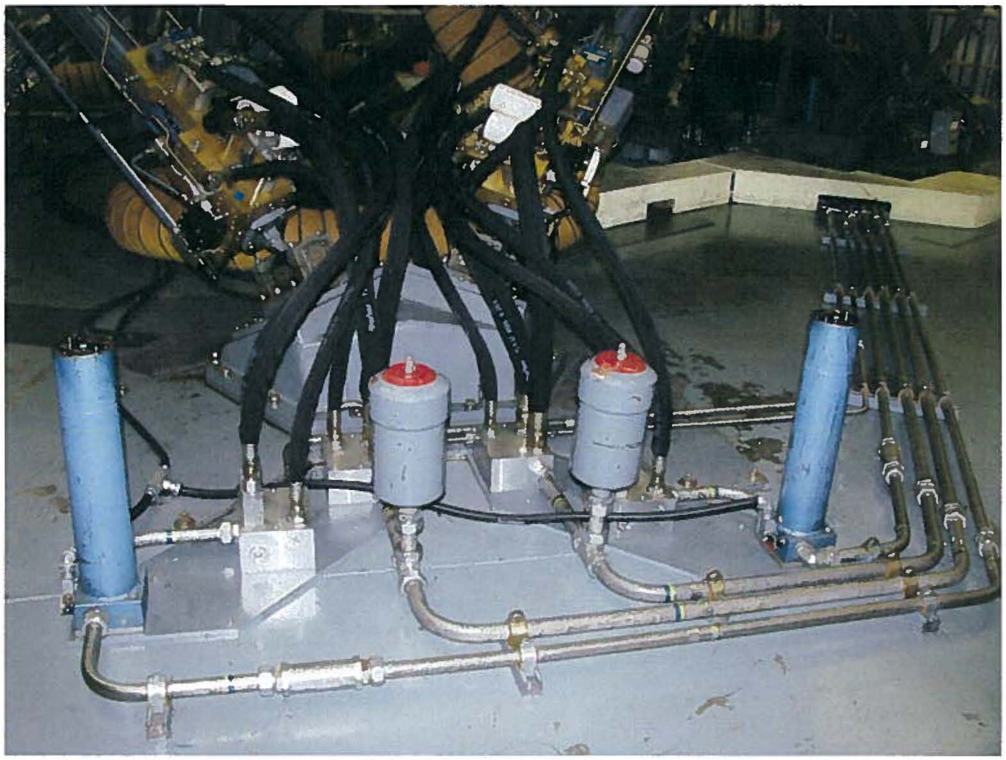

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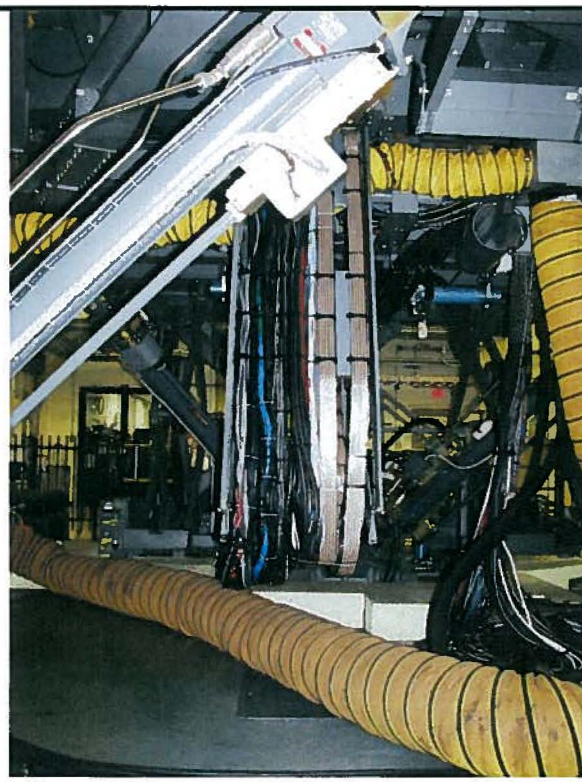

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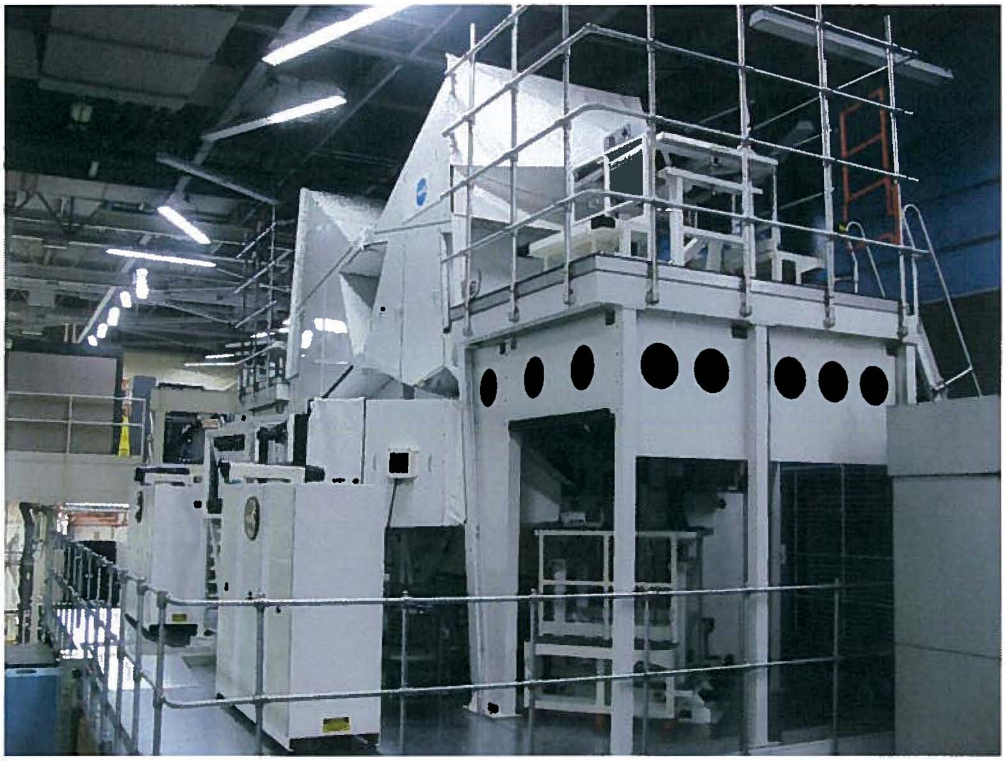

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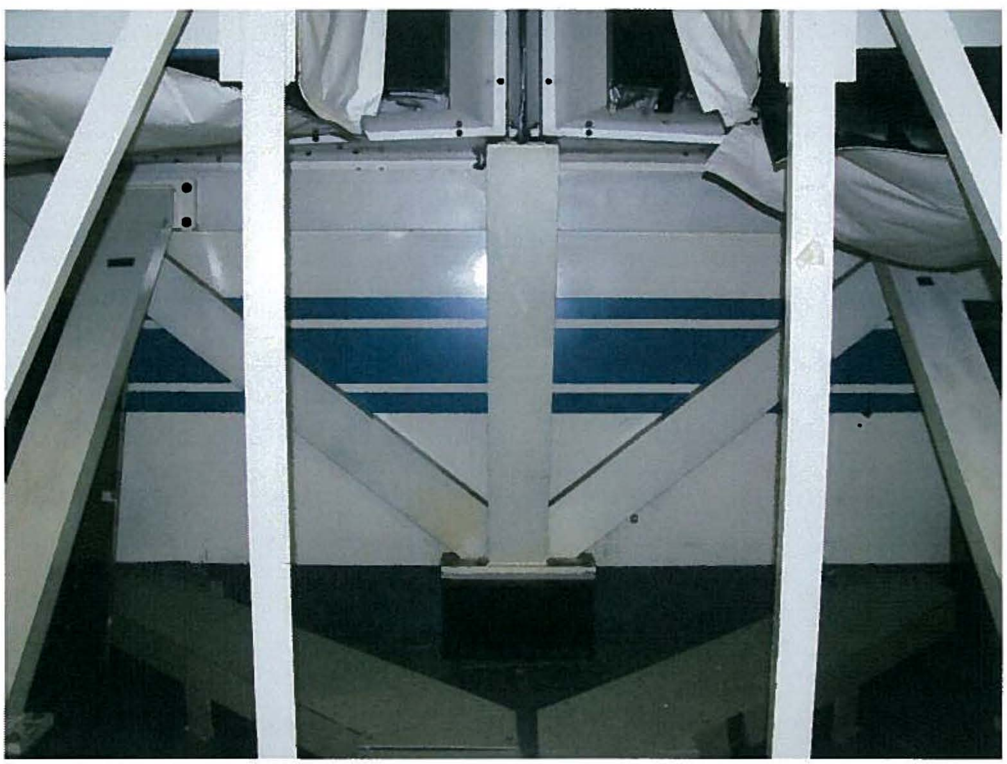

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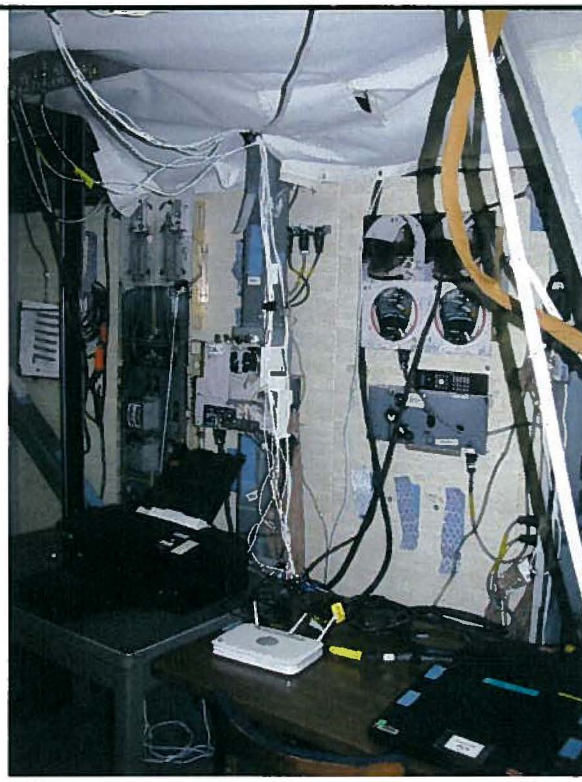

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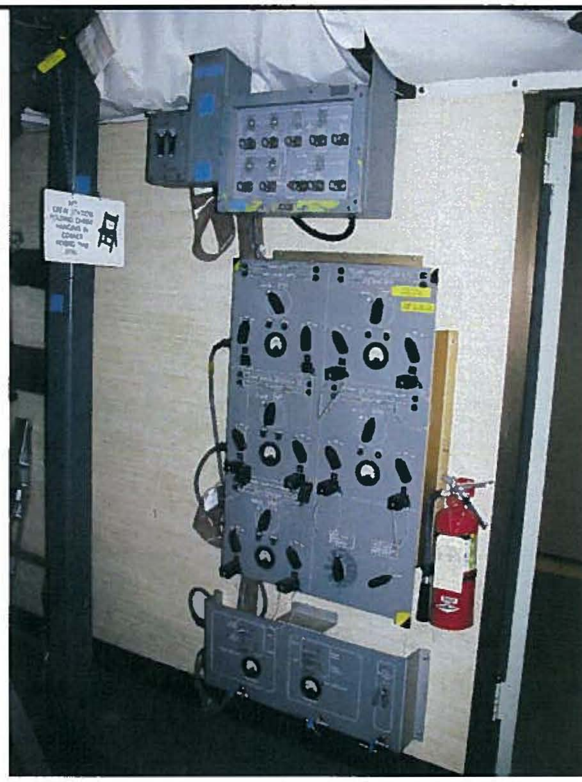
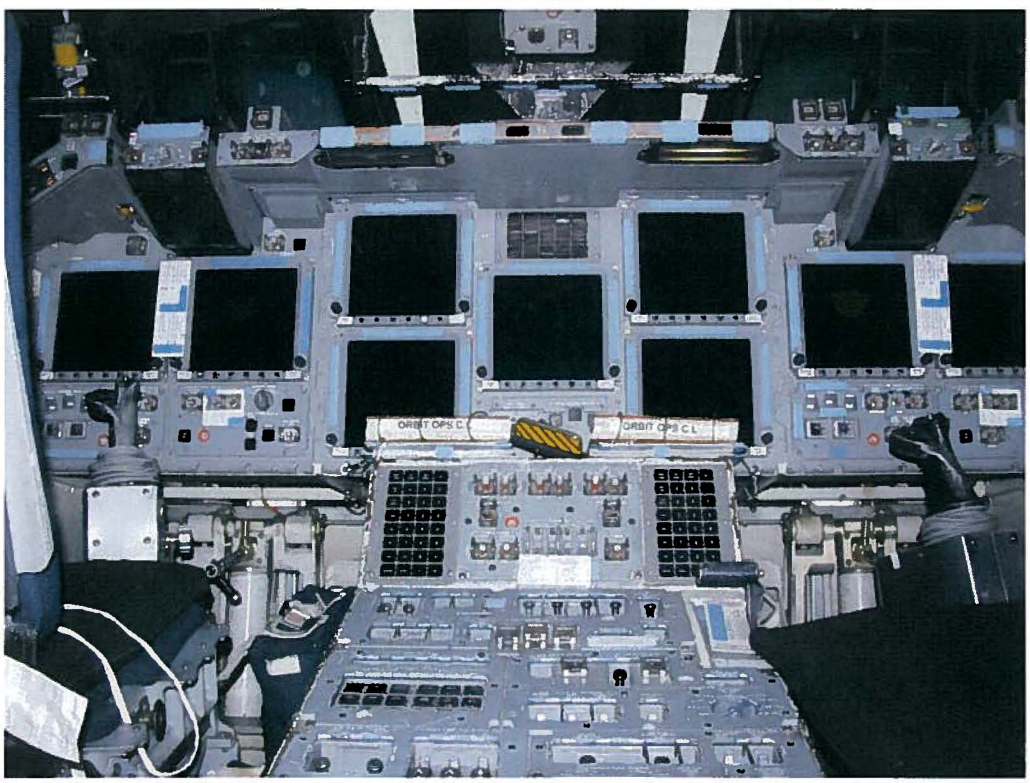


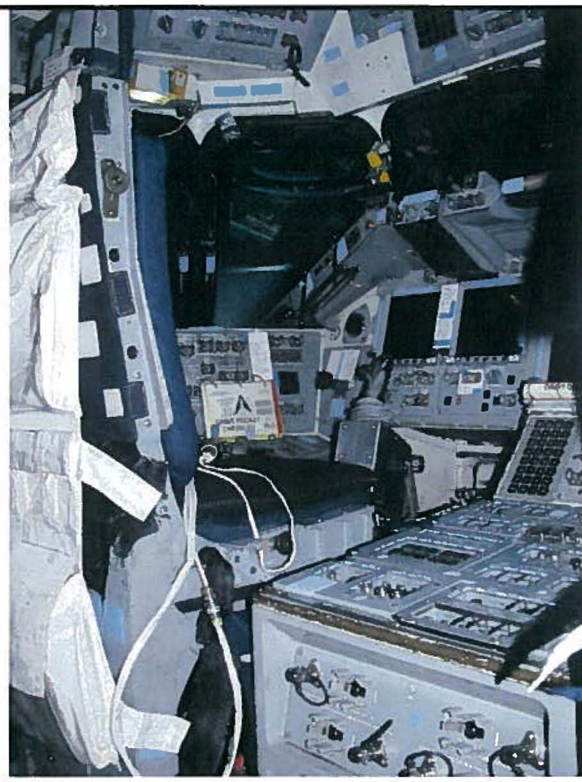
MSTF-53

MSTF-54

MSTF-55



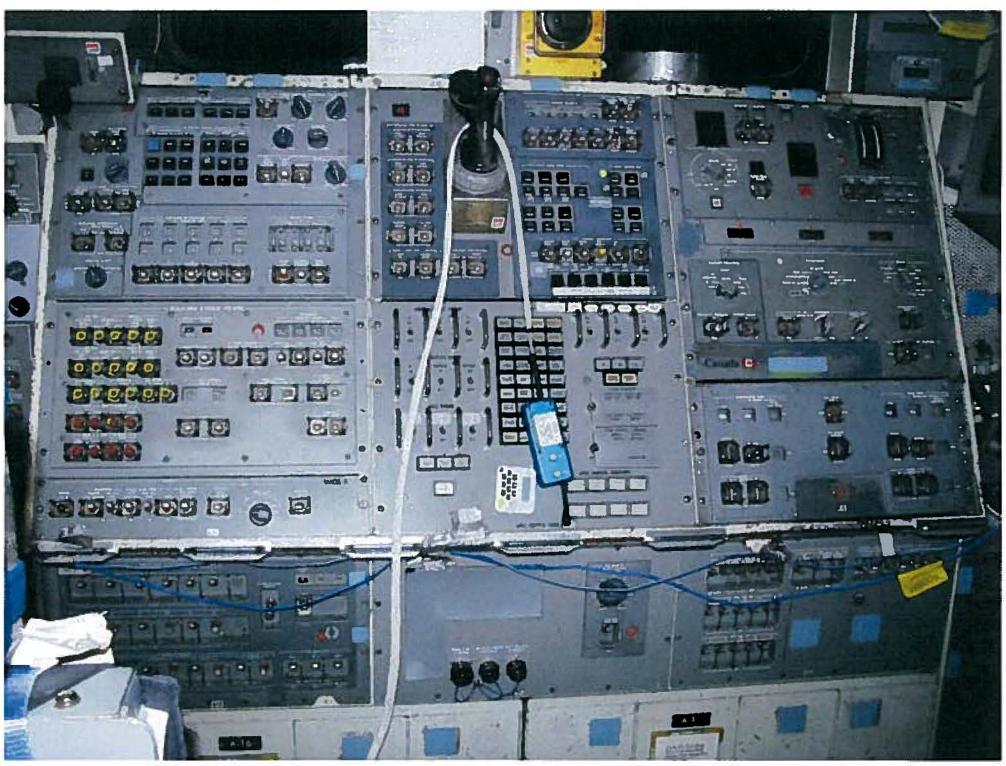
MSTF-56



MSTF-57

MSTF-58

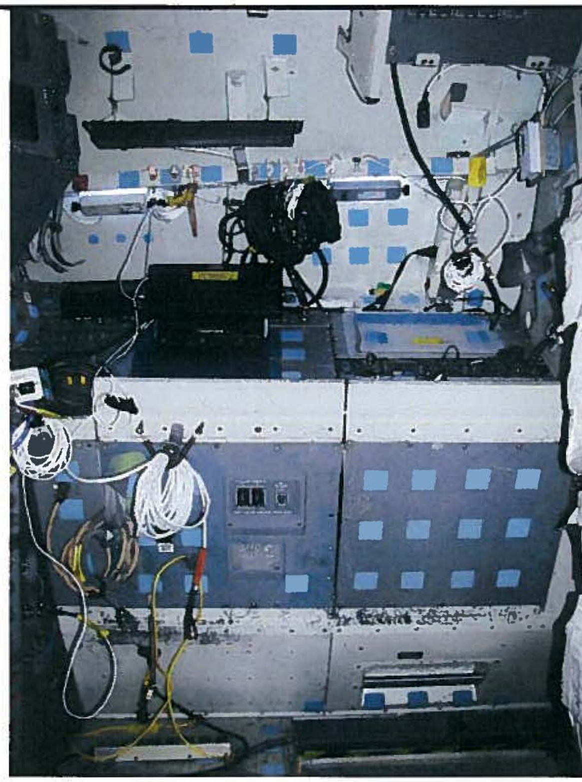
MSTF-59



MSTF-60

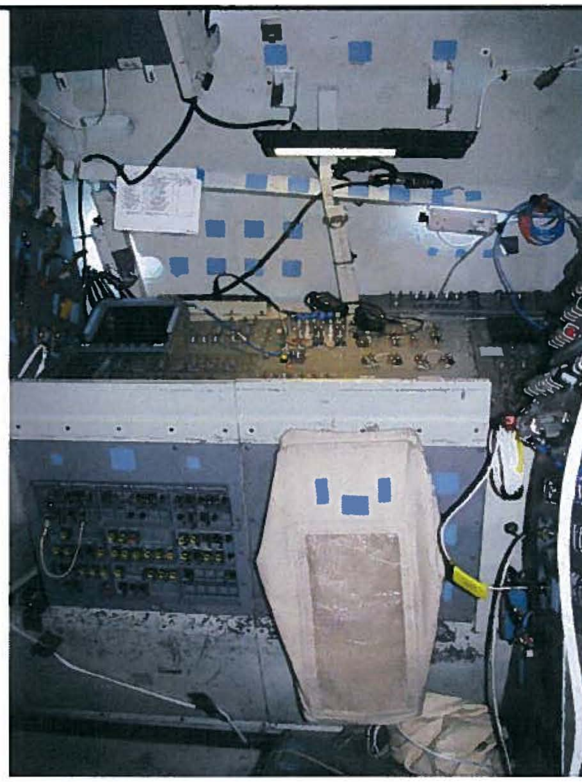
MSTF-61

MSTF-62

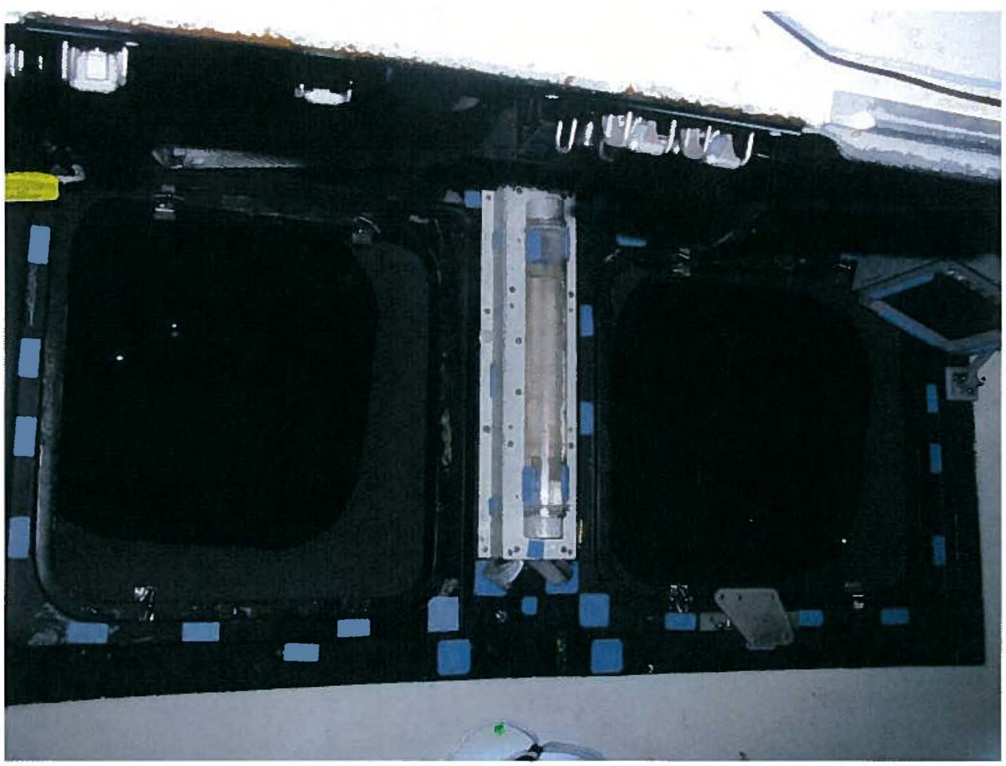


MSTF-63

MSTF-64



MSTF-65

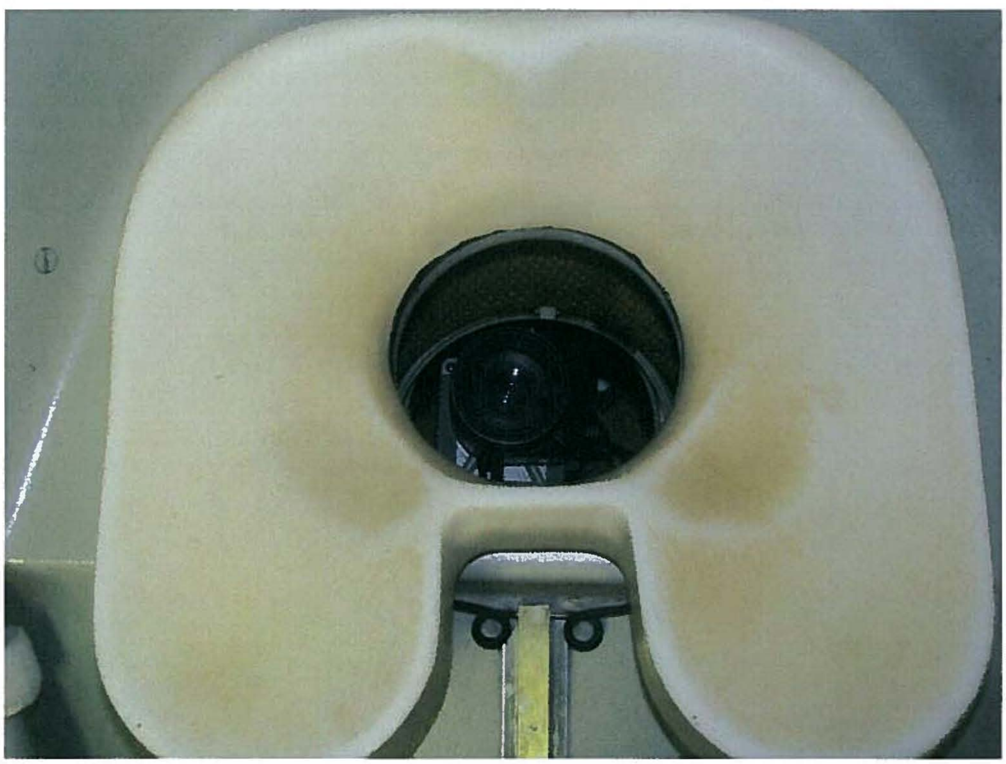


MSTF-66

MSTF-67

MSTF-68

MSTF-69



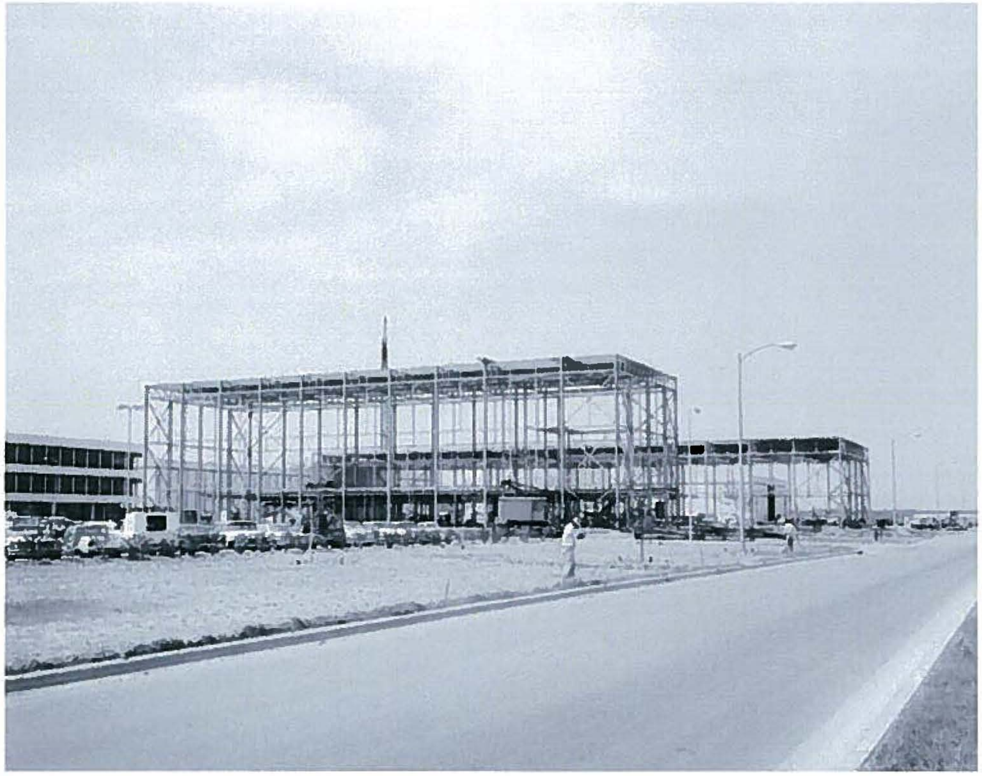
MSTF-70

MSTF-71

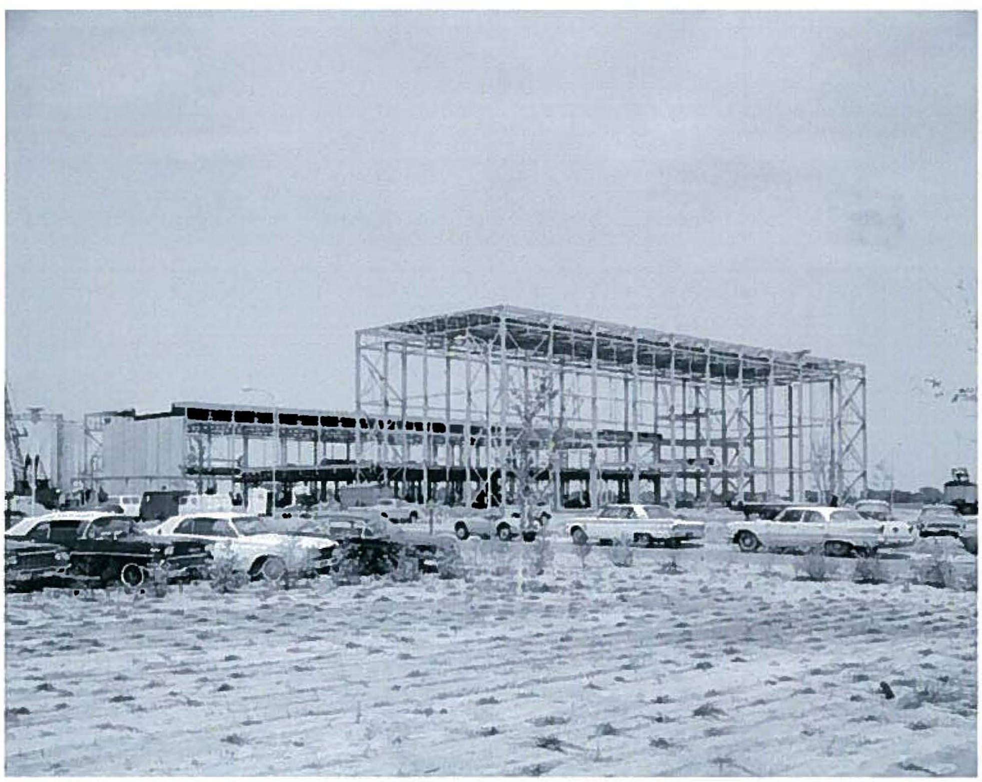
MSTF-72

MSTF-73

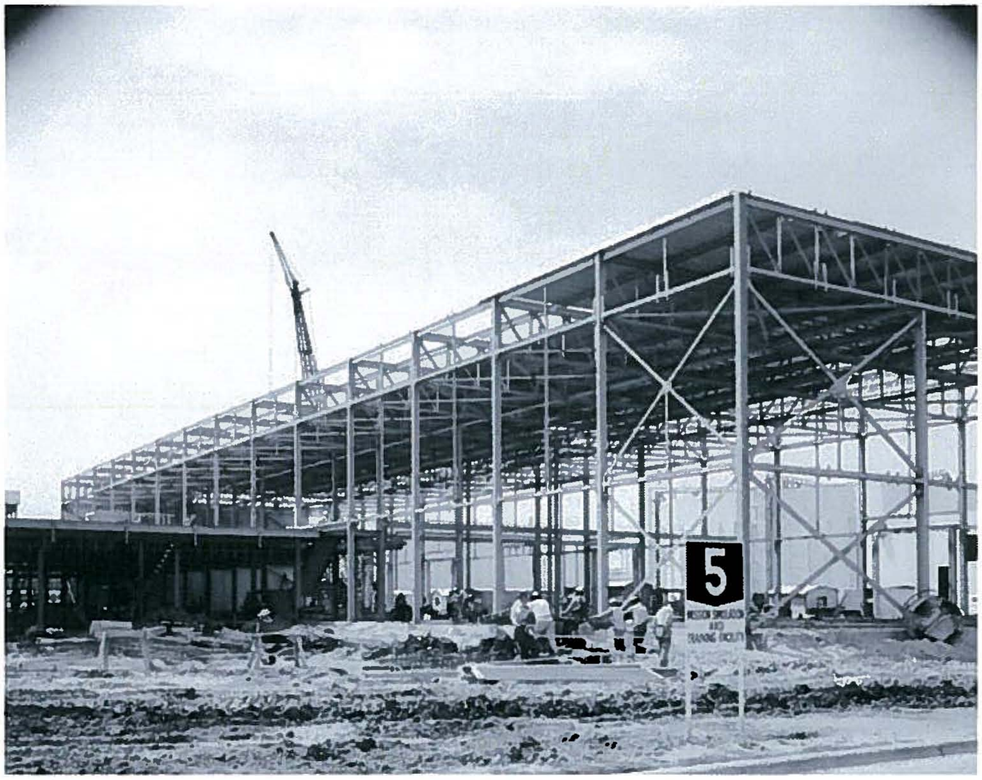
MSTF-74



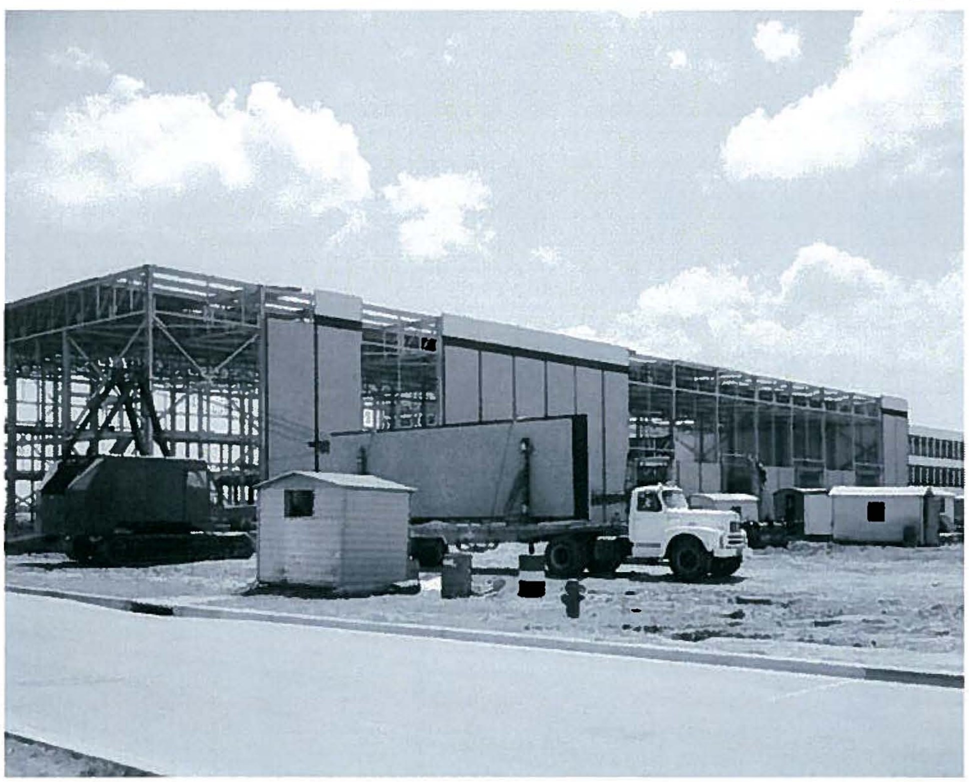
MSTF-75



MSTF-76



MSTF-77



MSTF-78

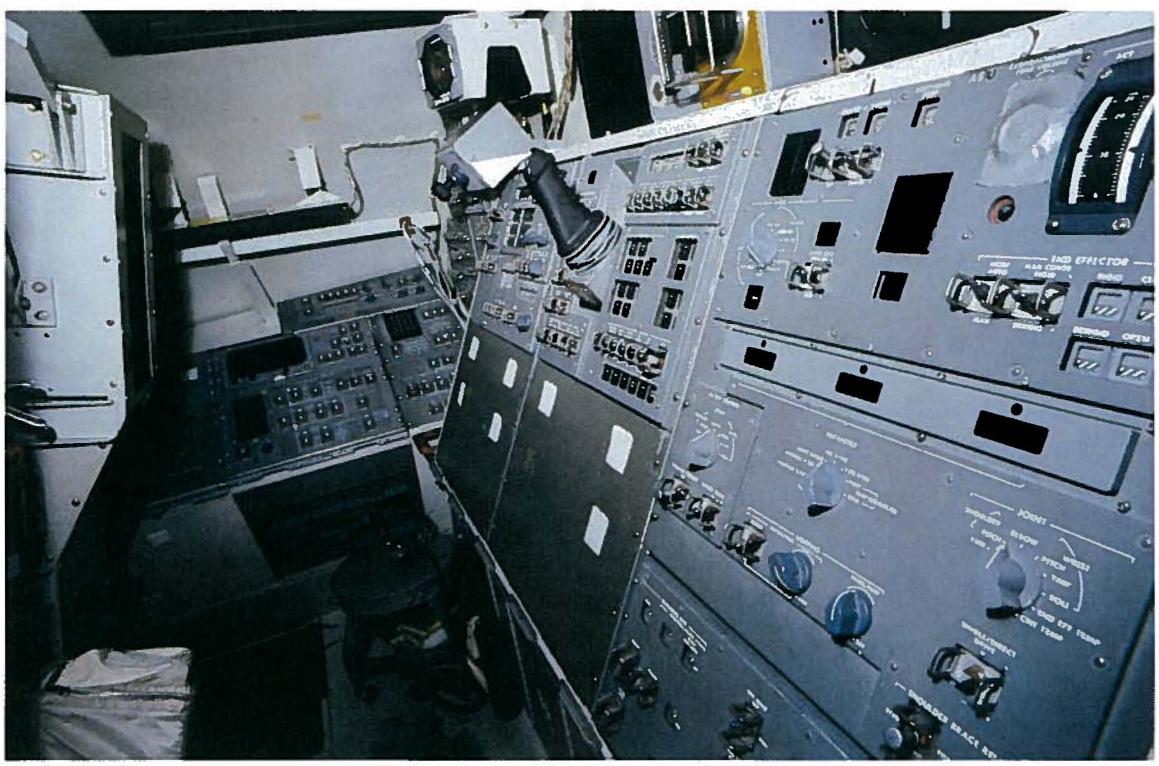
MSTF-79

MSTF-80

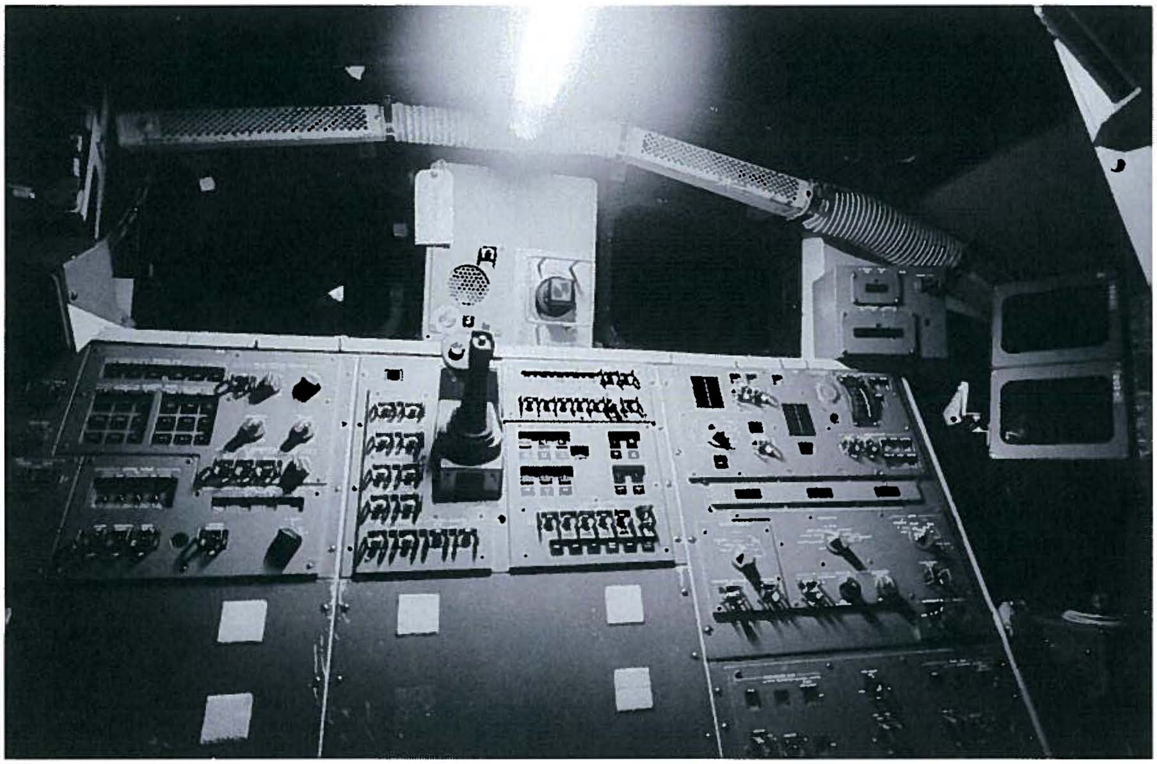
MSTF-81

MSTF-82

MSTF-83



MSTF-84

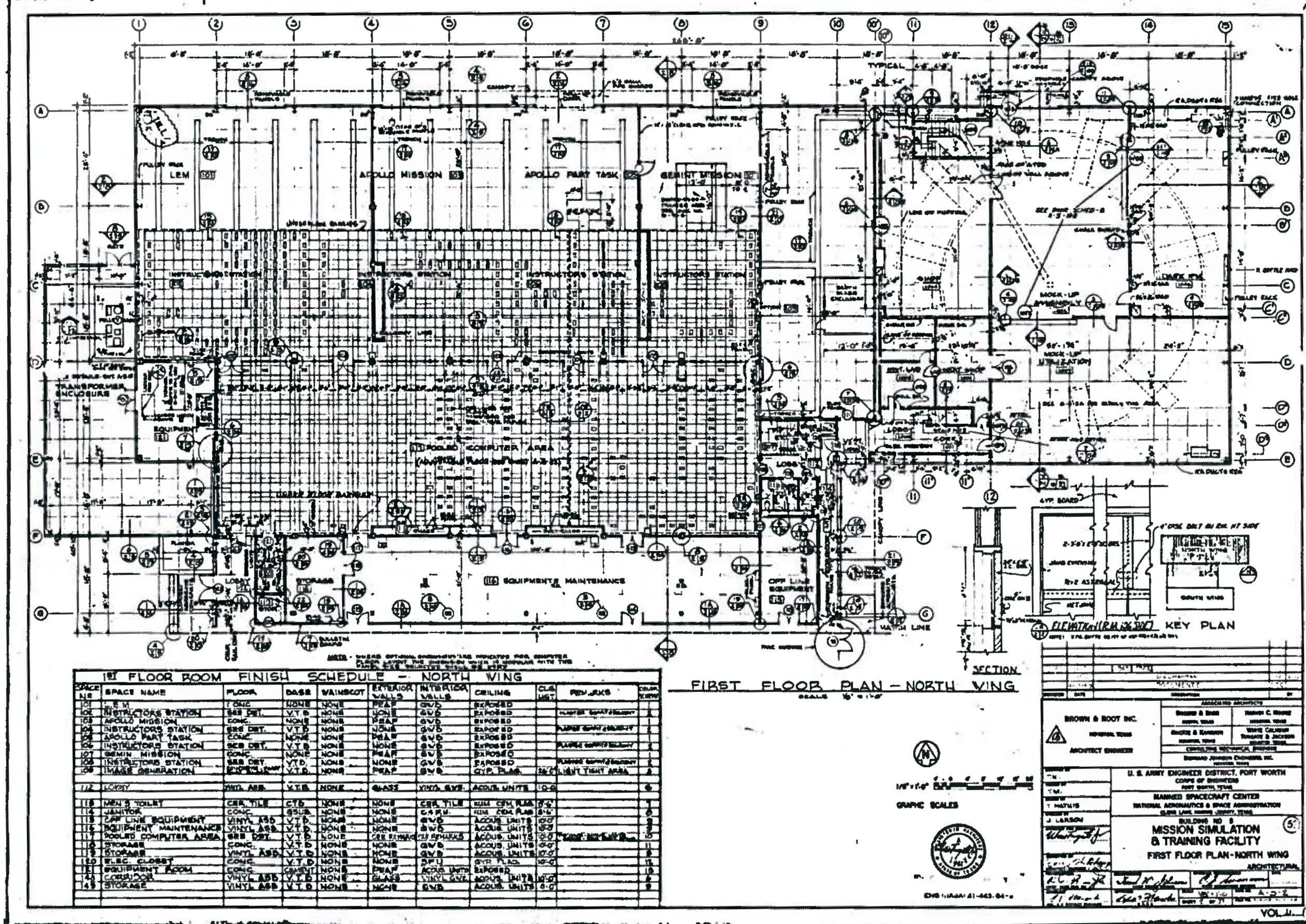


MSTF-85

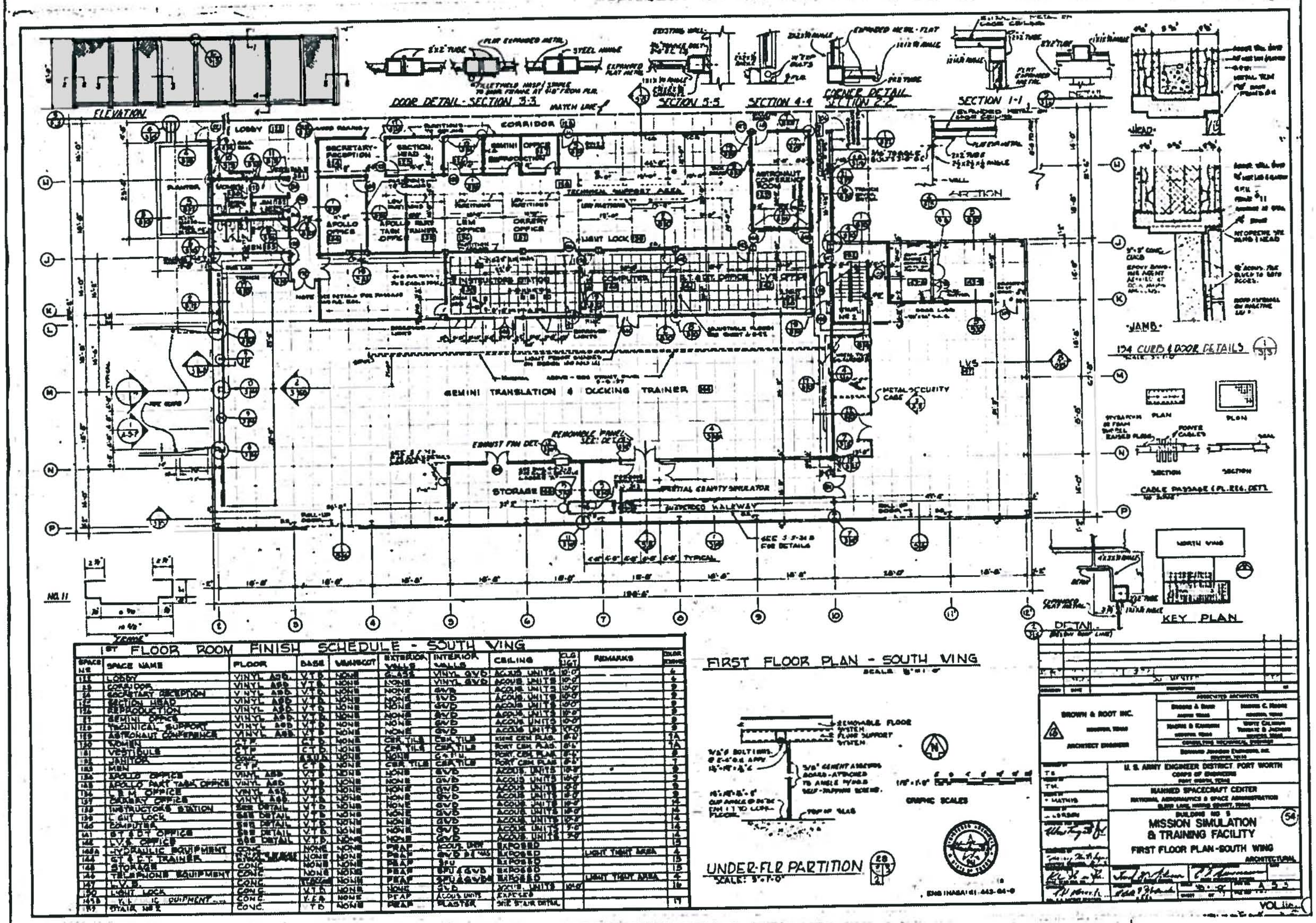
MSTF-86

MSTF-87

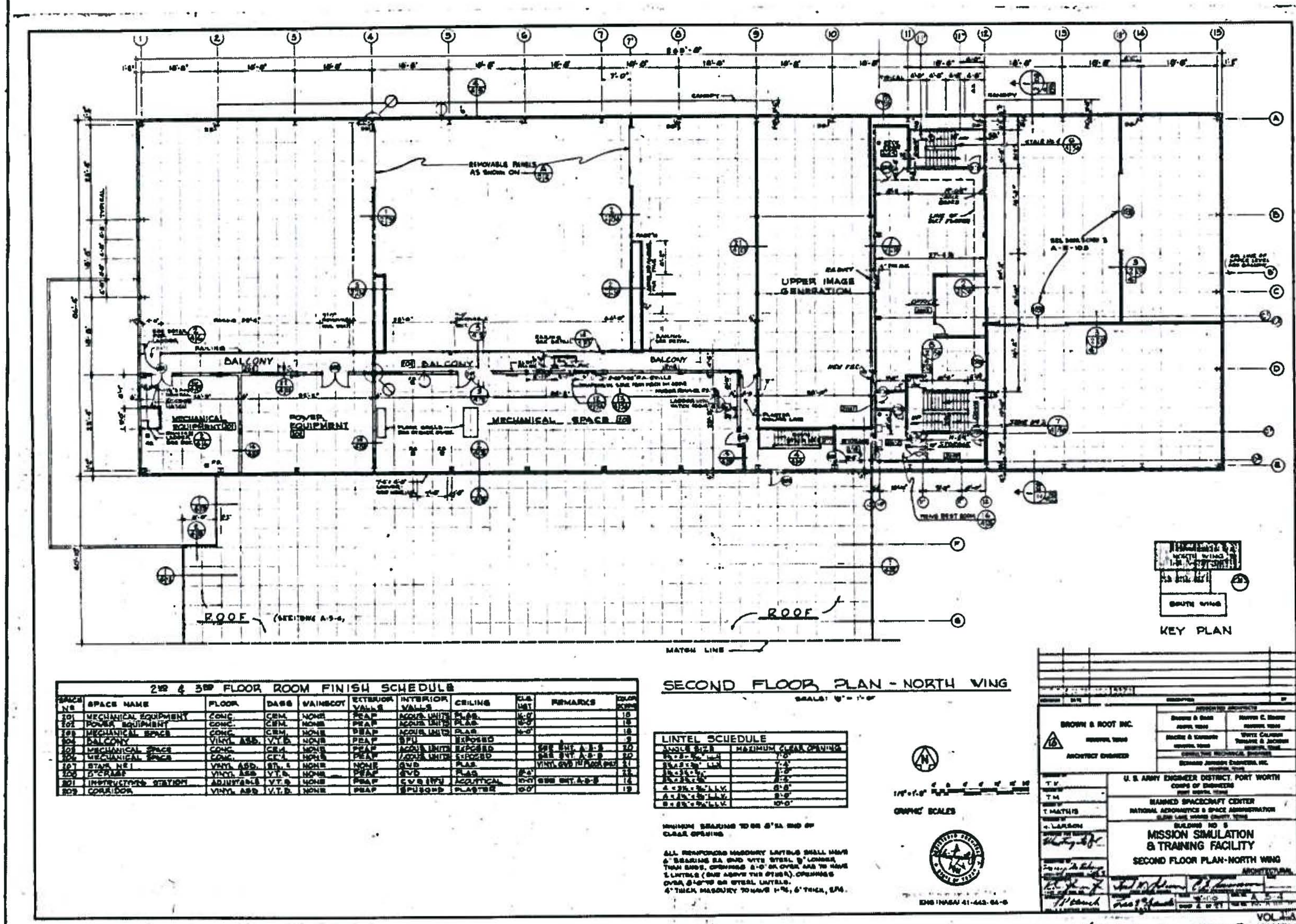
MSTF-88


LEM
APOLLO MISSION
APOLLO PART TASK
GEMINI MISSION
POOLED COMPUTER AREA
EQUIPMENT MAINTENANCE
TRANSFORMER ENCLOSURE
STORAGE
LOBBY
OFF LINE EQUIPMENT
MOCK-UP UTILIZATION
MATCH LINE
SECTION
KEY PLAN
SOUTH WING
1ST FLOOR ROOM FINISH SCHEDULE - NORTH WING
FIRST FLOOR PLAN - NORTH WING
GRAPHIC SCALES
BROWN & ROOT INC.
ARCHITECT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
MANNED SPACECRAFT CENTER
MISSION SIMULATION & TRAINING FACILITY
FIRST FLOOR PLAN-NORTH WING
ARCHITECTURAL
VOL.

MSTF-89

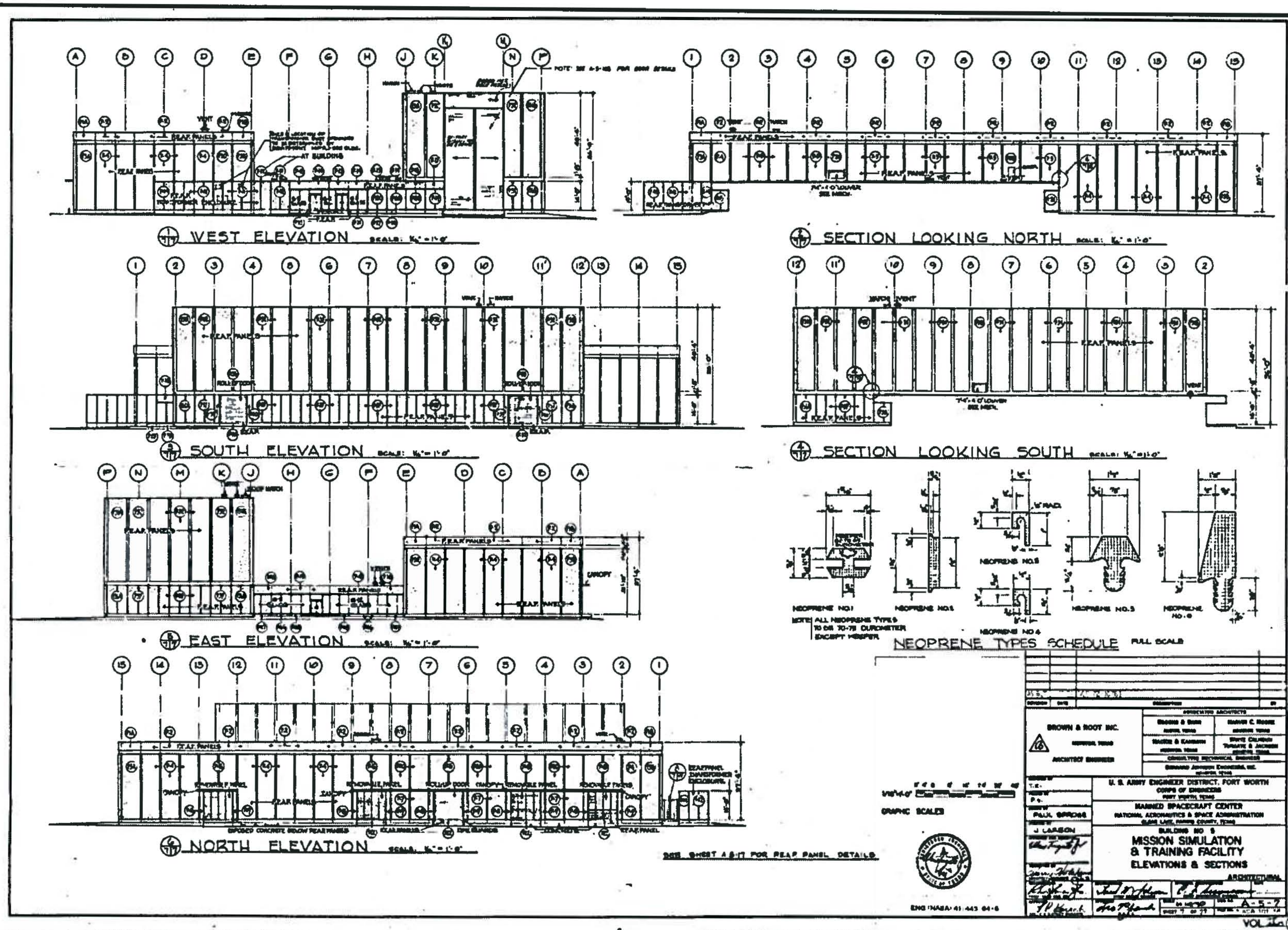

ELEVATION
DOOR DETAIL - SECTION 3-3
SECTION 5-5
SECTION 4-4
CORNER DETAIL SECTION 2-2
SECTION 1-1
LOBBY
CORRIDOR
SECRETARY-RECEPTION
TECHNICAL SUPPORT AREA
APOLLO OFFICE
LEM OFFICE
GEMINI OFFICE
LIGHT LOCK
INSTRUCTORS STATION
COMPUTER
ASTRONAUT CONFERENCE ROOM
GEMINI TRANSLATION & DOCKING TRAINER
METAL SECURITY CAGE
STORAGE
PARTIAL GRAVITY SIMULATOR
SUSPENDED WALKWAY
1/4 CURB & DOOR DETAILS
CABLE PASSAGE (FL. REG. DET.)
KEY PLAN
NORTH WING
1ST FLOOR ROOM FINISH SCHEDULE - SOUTH WING
FIRST FLOOR PLAN - SOUTH WING
UNDER-FLR PARTITION
GRAPHIC SCALES
BROWN & ROOT INC.
U. S. ARMY ENGINEER DISTRICT FORT WORTH
MANNED SPACECRAFT CENTER
MISSION SIMULATION & TRAINING FACILITY
FIRST FLOOR PLAN-SOUTH WING
ARCHITECTURAL

MSTF-90

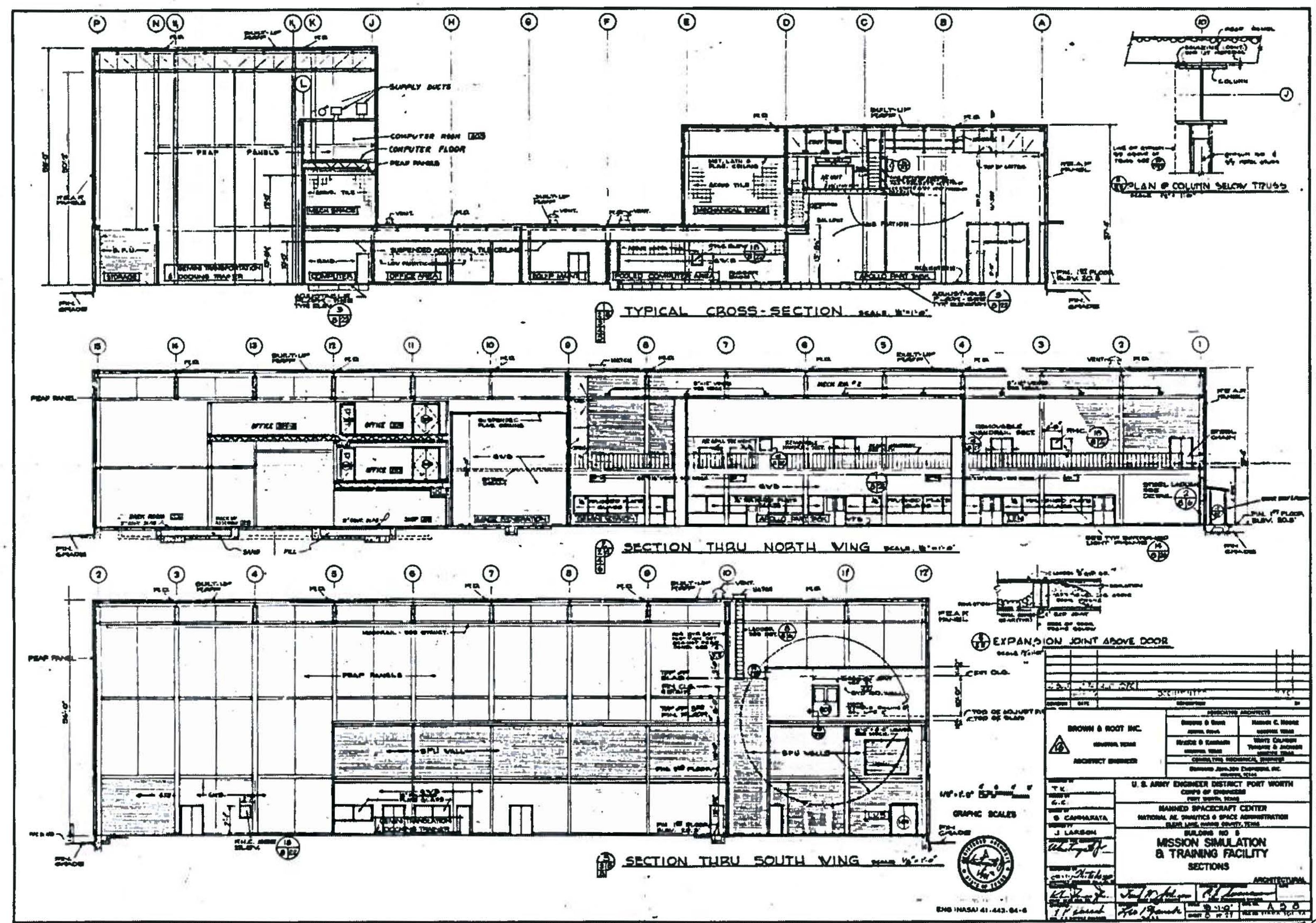


SECOND FLOOR PLAN - NORTH WING
2ND & 3RD FLOOR ROOM FINISH SCHEDULE
LINTEL SCHEDULE
KEY PLAN
SOUTH WING
UPPER IMAGE GENERATION
BALCONY
MECHANICAL SPACE
POWER EQUIPMENT
MECHANICAL EQUIPMENT
ROOF
MATCH LINE
GRAPHIC SCALES
BROWN & ROOT INC.
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
MANNED SPACECRAFT CENTER
MISSION SIMULATION & TRAINING FACILITY
SECOND FLOOR PLAN-NORTH WING

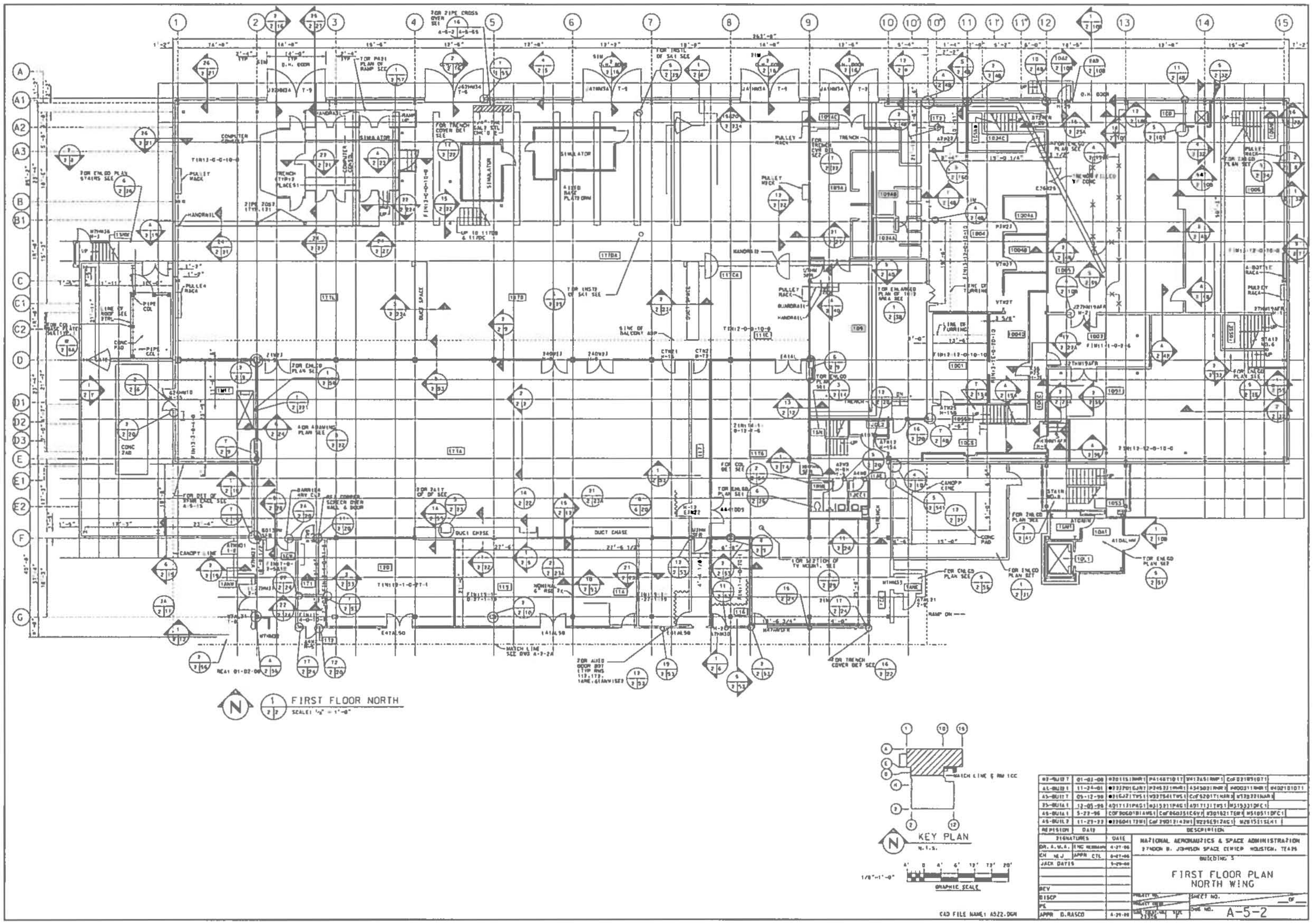
MSTF-91


WEST ELEVATION
SECTION LOOKING NORTH
SOUTH ELEVATION
SECTION LOOKING SOUTH
EAST ELEVATION
NORTH ELEVATION
NEOPRENE TYPES SCHEDULE FULL SCALE
SEE SHEET A-5-17 FOR REAF PANEL DETAILS
BROWN & ROOT INC.
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
MANNED SPACECRAFT CENTER
MISSION SIMULATION
& TRAINING FACILITY
ELEVATIONS & SECTIONS

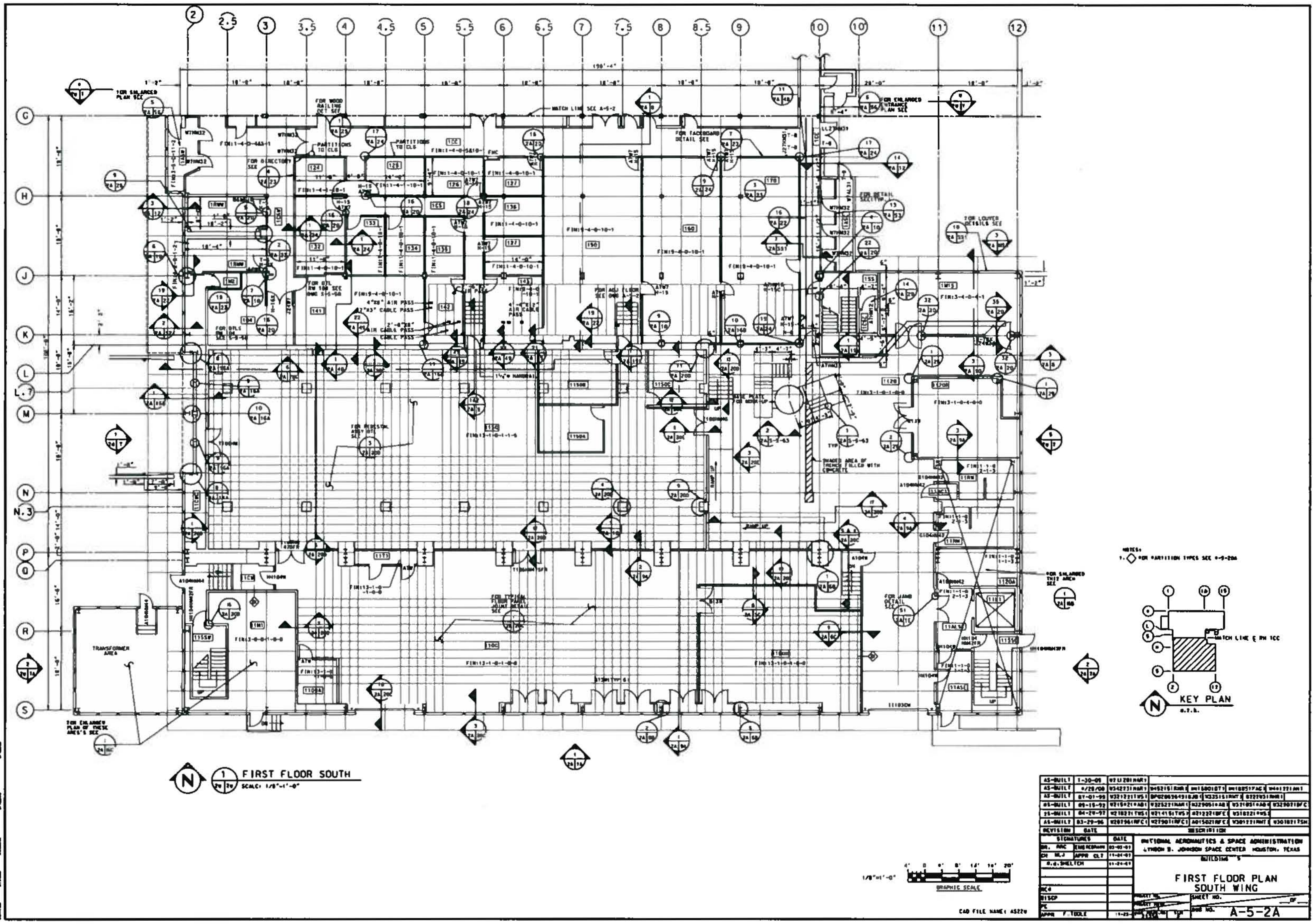
MSTF-92


TYPICAL CROSS-SECTION
SECTION THRU NORTH WING
SECTION THRU SOUTH WING
PLAN @ COLUMN BELOW TRUSS
EXPANSION JOINT ABOVE DOOR
SUPPLY DUCTS
COMPUTER ROOM
COMPUTER FLOOR
PEAP PANELS
SUSPENDED ACOUSTICAL TILE CEILING
GRAPHIC SCALES
BROWN & ROOT INC.
U. S. ARMY ENGINEER DISTRICT FORT WORTH
MANNED SPACECRAFT CENTER
MISSION SIMULATION
& TRAINING FACILITY
SECTIONS
ARCHITECTURAL

MSTF-93

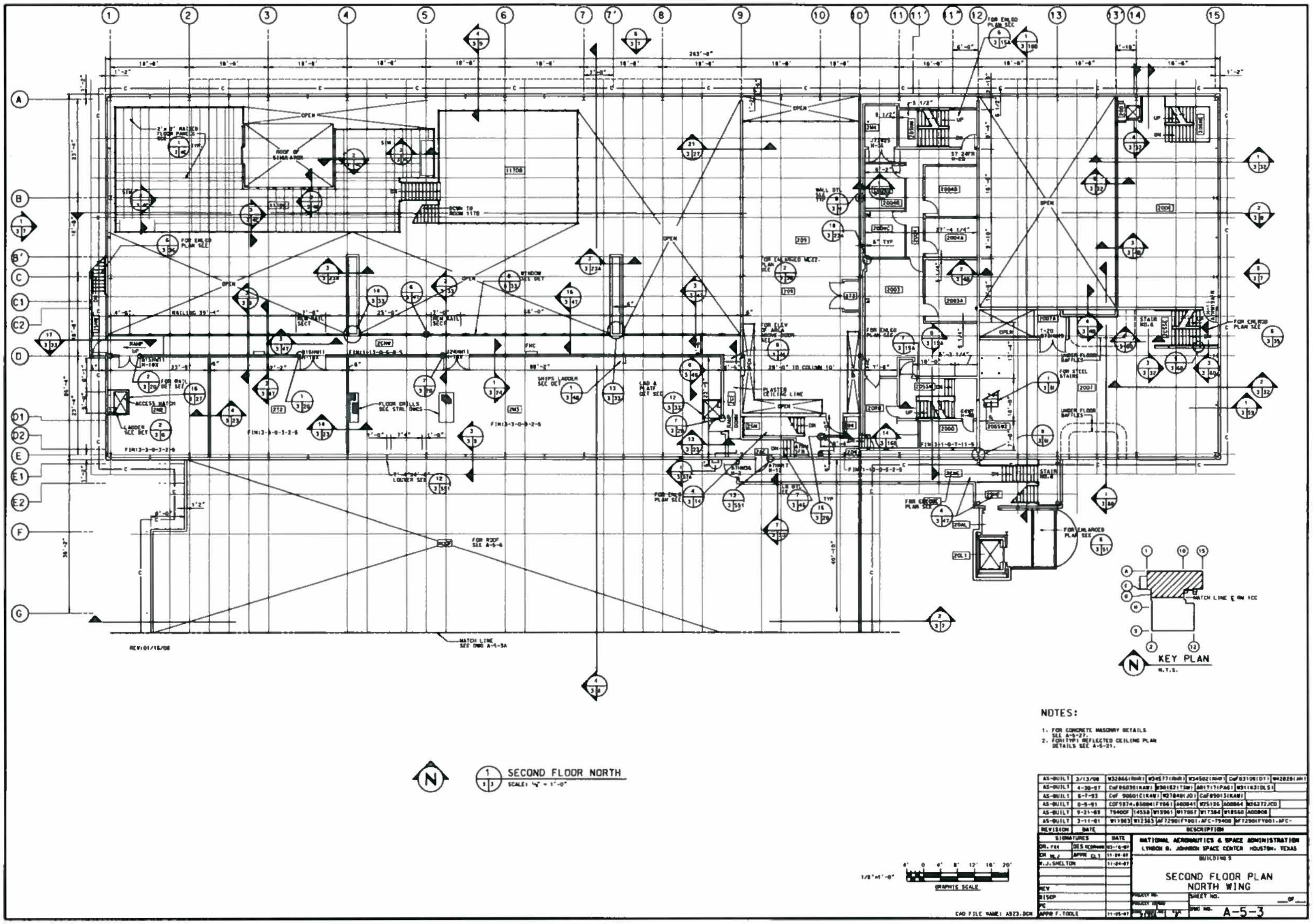

FIRST FLOOR NORTH
KEY PLAN
GRAPHIC SCALE
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
FIRST FLOOR PLAN
NORTH WING
A-5-2

MSTF-94

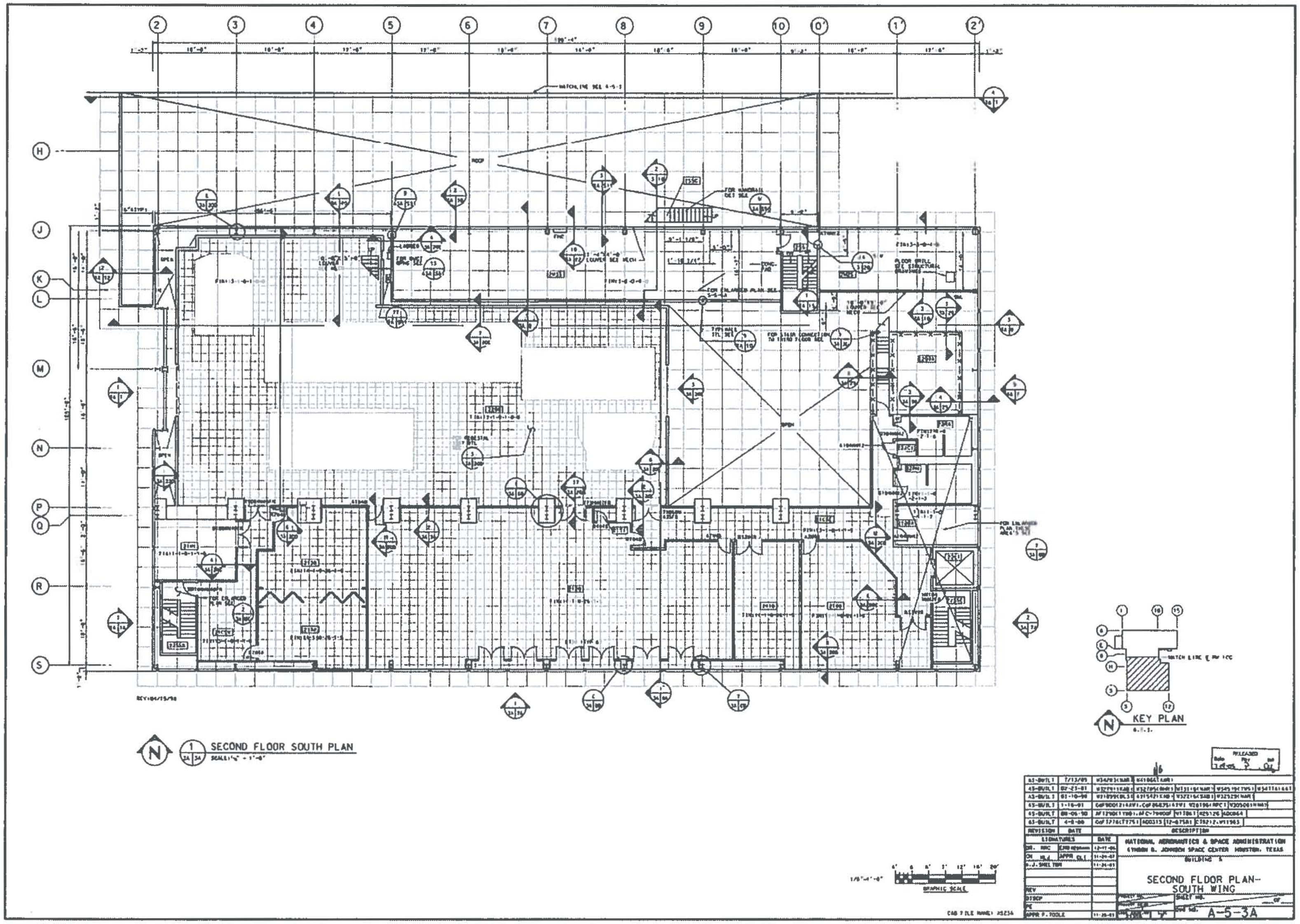


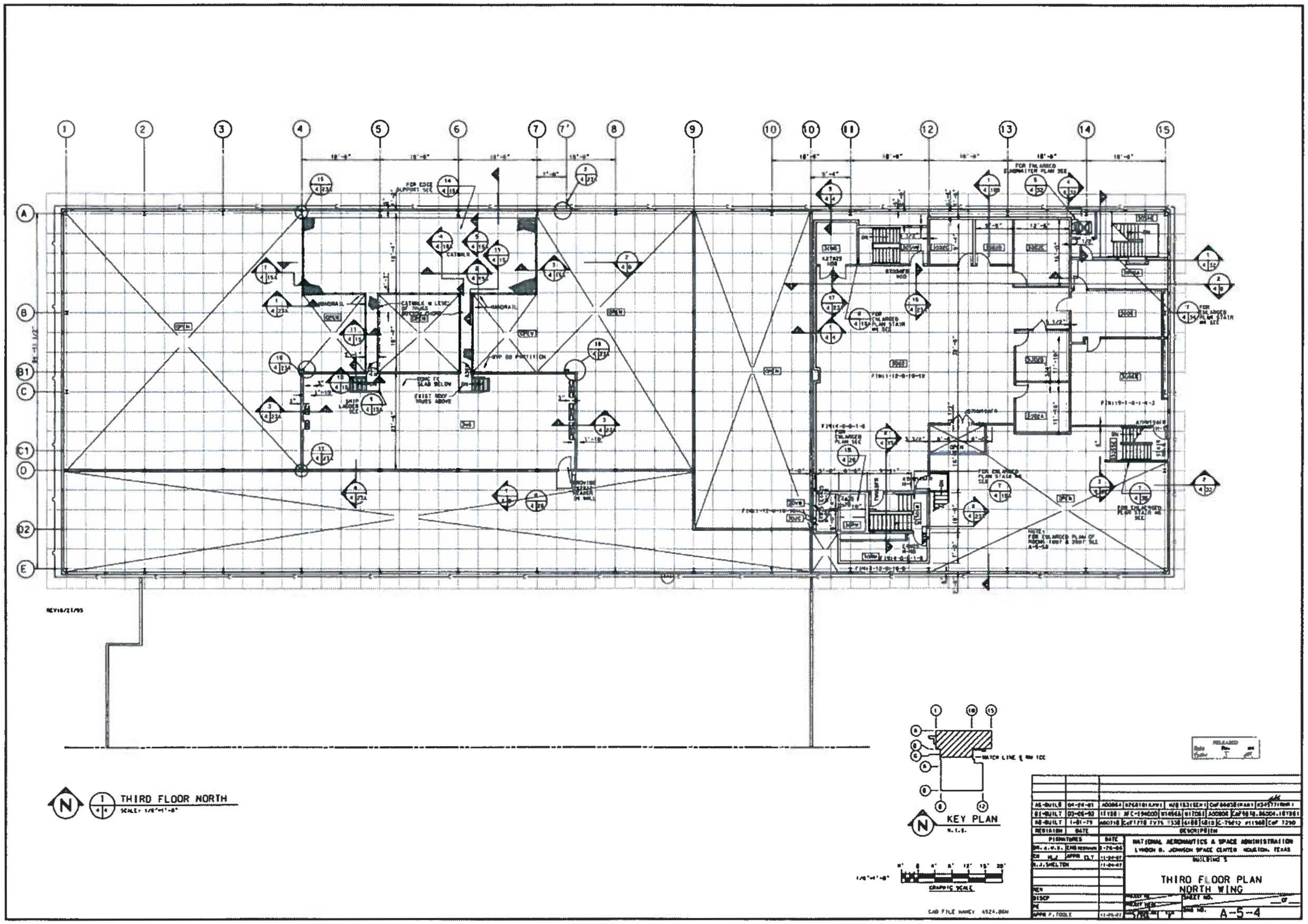
FIRST FLOOR SOUTH
SCALE: 1/8"=1'-0"
KEY PLAN
TRANSFORMER AREA
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
FIRST FLOOR PLAN
SOUTH WING
A-5-2A
GRAPHIC SCALE

MSTF-95

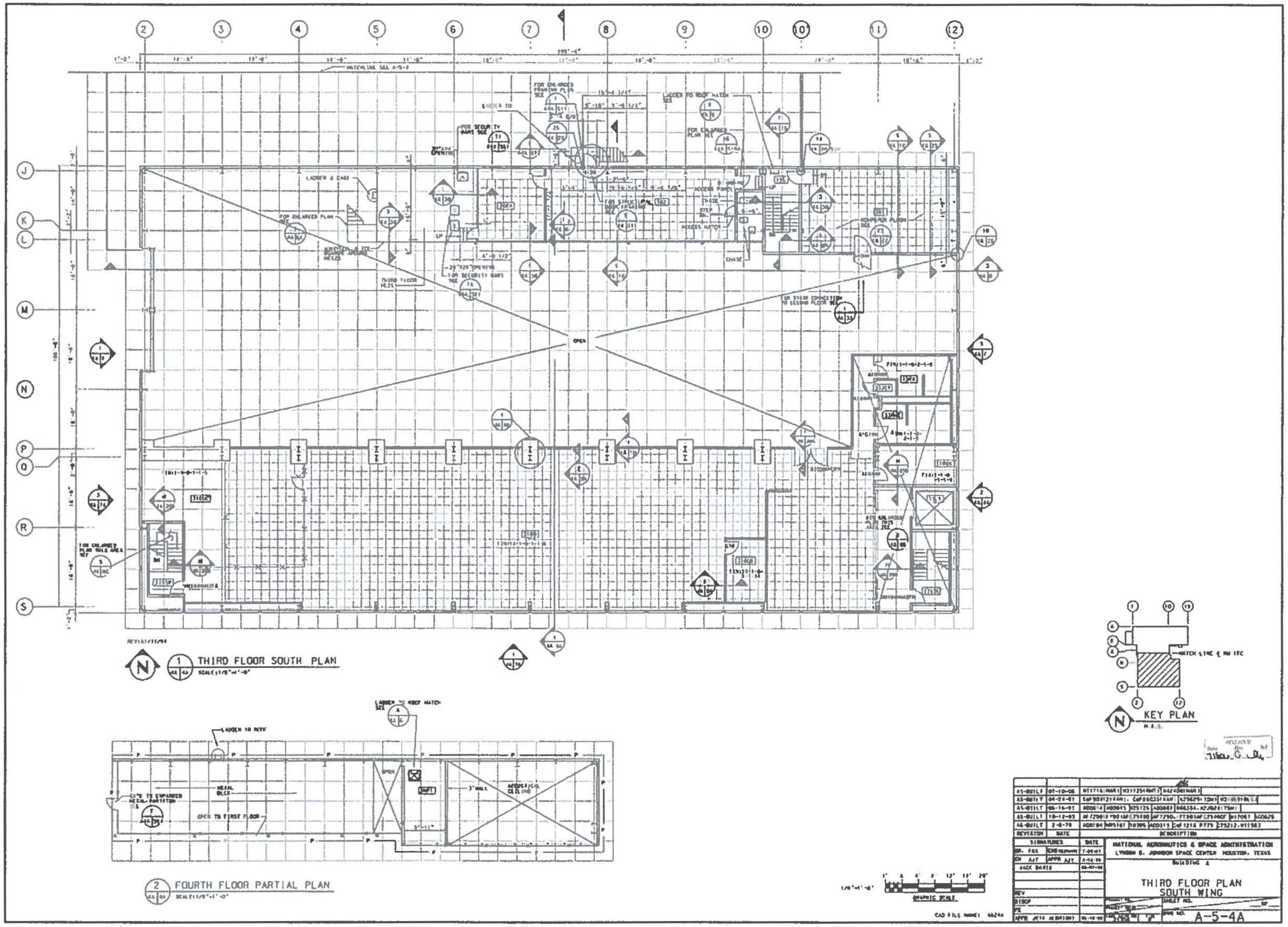

SECOND FLOOR NORTH
SCALE: 1/8" = 1'-0"
KEY PLAN
N.T.S.
NOTES:
1. FOR CONCRETE MASONRY DETAILS SEE A-5-27.
2. FOR TYP. REFLECTED CEILING PLAN DETAILS SEE A-5-21.
GRAPHIC SCALE
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
BUILDING 5
SECOND FLOOR PLAN
NORTH WING
A-5-3

MSTF-96

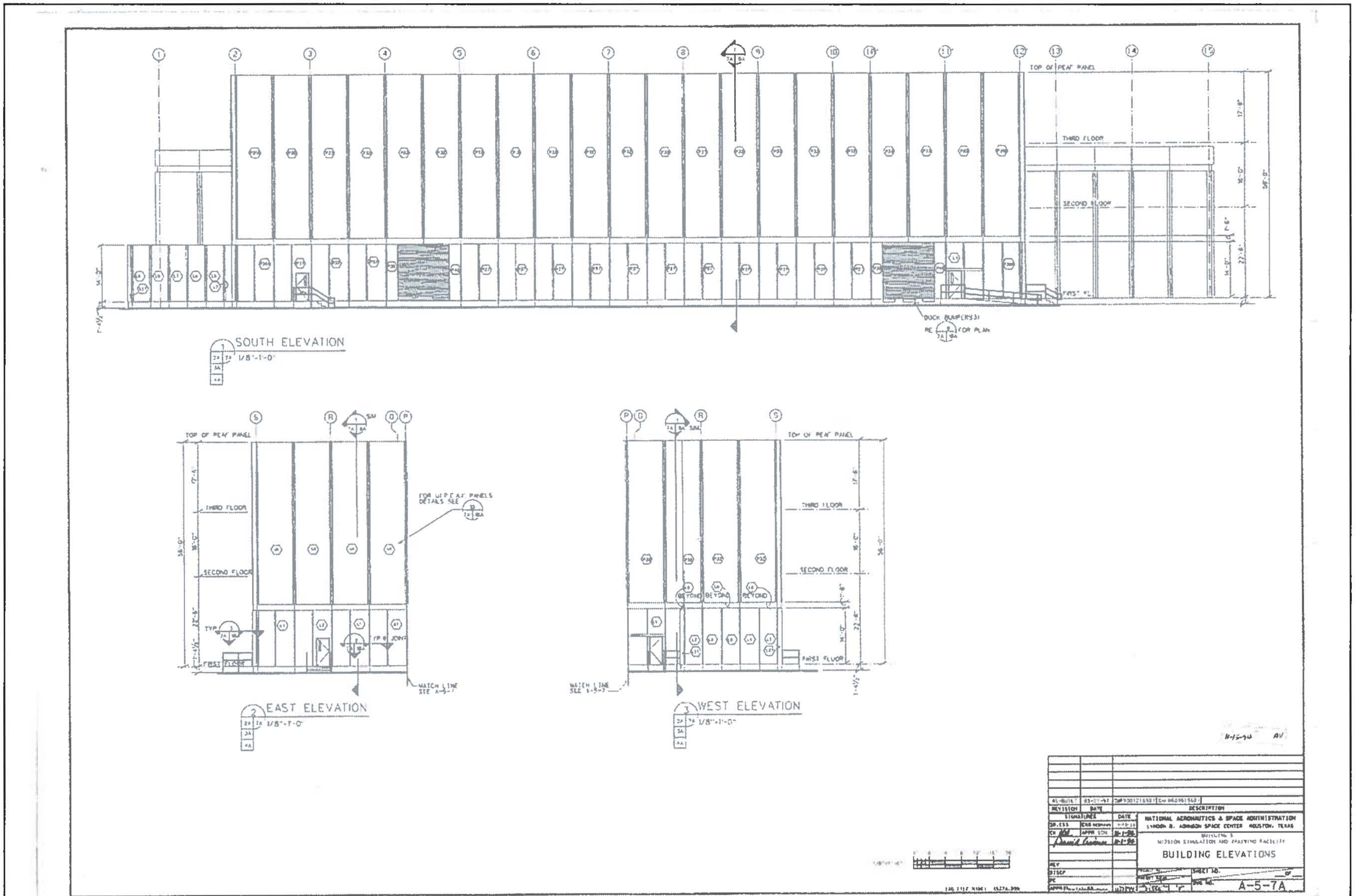

SECOND FLOOR SOUTH PLAN
KEY PLAN
RELEASED
REVISION
DATE
DESCRIPTION
SIGNATURES
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
SECOND FLOOR PLAN-
SOUTH WING
A-5-3A
GRAPHIC SCALE
OPEN
ROOF


THIRD FLOOR NORTH
KEY PLAN
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
THIRD FLOOR PLAN
NORTH WING
A-5-4

MSTF-98


THIRD FLOOR SOUTH PLAN
FOURTH FLOOR PARTIAL PLAN
KEY PLAN
OPEN
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
THIRD FLOOR PLAN
SOUTH WING
A-5-4A
GRAPHIC SCALE

MSTF-99


SOUTH ELEVATION
1/8"=1'-0"
EAST ELEVATION
1/8"=1'-0"
WEST ELEVATION
1/8"=1'-0"
TOP OF PEAK PANEL
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
DOCK BUMPERS
FOR PLAN
FOR UPPER PANELS DETAILS SEE
MATCH LINE SEE A-5-7
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
BUILDING ELEVATIONS
A-5-7A

MSTF-100