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Paper Session II-A - History of the Shuttle Landing Facility at Kennedy Space Center

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History of the Shuttle Landing Facility at Kennedy Space Center

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Introduction

When NASA built a new revolutionary spacecraft, the design chosen was a delta-winged orbiter that would liftoff from existing launch pads and land like an airplane. This was a new concept in space travel that radically changed how the United States traveled to low earth orbit. Kennedy Space Center (KSC) in Florida and Vandenberg Air Force Base in California were selected as launch sites and Kennedy was also chosen as a landing site. The NASA Administrator, Dr. James C. Fletcher, announced his selection on April 14, 1972.[1] The official name is "Kennedy Space Center Shuttle Landing Facility", and the FAA locator designator is X-68.

To accommodate this reusable spacecraft, KSC was required to build a runway for end of mission landings. The space shuttle orbiter would launch into space using an external tank for main engine fuel in combination with solid rocket boosters. The space shuttle would orbit the earth completing pre-set mission directives and return to Earth without power in a controlled glide re-entry onto a runway. Unlike conventional aircraft, the orbiter lacks propulsion during the landing phase. There is no option for a missed approach to circle and try again. Its high-speed glide must land the first time.

Site and Construction

Different sites were considered before deciding on the current location. One of the sites considered was the Cape Canaveral Air Station (CCAS) Skid Strip. However, to accommodate the space shuttle not only required modifications of the Skid Strip, but also of the roads and bridges leading to KSC. The Skid Strip also had an approach angle that was too long. The next site considered was the beach near the launch pads; however the cost was too prohibitive. The preferred site was approximately three miles northwest of the Vehicle Assembly Building (VAB) in the Launch Complex (LC) 39 area. The runway would be the first facility built in reshaping LC-39. This site provided the space needed to build the research and development sized runway. This site was also better for transporting the orbiter to processing facilities located nearby. In preparation for dredging, an archeological survey was done to check for Indian mounds, but none were located.[2]

On March 18, 1974, NASA announced the $21,812,737 construction contract with Morrison-Knudsen Co., authorizing the company to begin constructing a space shuttle runway with overruns, apron, taxiway and access roads. Clearing of the site began shortly after a groundbreaking ceremony that included former KSC Center Director Dr. Kurt H. Debus.

Figure 1 shows a posed group photo of the groundbreaking ceremony for the then Orbiter Landing Facility (OLF); SLF was not used until around 1980. From left holding shovel are: Frank Callaham, Executive Vice President, Greiner, Architect-Engineer; Maj. Gen. Kenneth R. Chapman, Air Force Eastern Test Range; Dr. Kurt H. Debus, Center Director; Frank P. Robertson, Regional Vice President Morrison-Knudson, Maj. Gen. Robert H. Curtin, USAF Retired. Back row from left: NASA Director of Facilities. Raymond L. Clark, Director, Design Engineering, Peter Minderman, Director of Technical Support; Robert Yoder, Manager, Merritt Island National Wildlife Refuge; Dr. Robert H. Gray, Manager, Shuttle Projects Office; Miles Ross, Center Deputy Director, and Dr. Walter J. Kapryan, Director of Launch Operations.

Figure 1: Groundbreaking ceremony for Orbiter Landing Facility

Runway

The contractor could not get the borrow dirt out of the rivers. The fill was taken from the area adjacent to the runway. Once the fill was completed, work began on the runway surface. The material selected for the new runway was Portland cement.[2] There were some safety concerns about using asphalt. Residual Liquid Oxygen (LOX) could be absorbed in the asphalt and could possibly cause an explosion. Should a spill occur, the asphalt would have to be dug up and replaced. An asphalt runway could take the load of a C5A or a 747 airplane; but the wheel loading on the orbiter is far greater than a C5A aircraft. So, the decision to use concrete instead of asphalt was solely based on orbiter requirements. Concrete is very low maintenance. Using asphalt would require major periodic refurbishing and KSC planners were concerned about grooving and wear over a ten-year period in the hot sun. The decision was made to use concrete which is 16 inches thick in the center and 15 inches thick on the sides.

The width of the runway was built at three hundred feet with 50-foot asphalt shoulders later added on each side. Engineers and test pilots at the Johnson Space Center (JSC) recommended this width. The length of the paved runway is 15,000 feet with a 1,000 foot overrun on each end. This makes it one of the largest runways in the world. These specifications are the same as the runway at Edwards Air Force Base, CA.[3] Landing the orbiter at KSC's Shuttle Landing Facility instead of at Edwards Air Force Base saves at least an estimated three-quarter million dollars and about five days of processing time for its next mission. The landing strip is not perfectly flat due to a slope of 24 inches from the center-line to the edge. This helps to facilitate drainage along the small ¼ inch wide grooves that are also ¼ inch deep with 1 ? inch centers, that were cut into the concrete surface running from side to side. Grooving is designed to prevent hydroplaning of vehicles landing on the runway under wet operating conditions. Approximately 8,000 miles of grooves were cut into the 15,000-foot-long, 300-foot-wide runway[4]. The runway remained in this configuration until 1985. During the end-of-mission of STS 51-D that year, Discovery experienced extensive brake damage and a blown tire on landing roll-out. This incident raised serious questions about the runway surface. In response to a congressional committee hearing on the issue, the following conclusion was drawn.

> "Although there were valid programmatic reasons to land routinely at Kennedy, there are concerns that suggest that this is not wise under the present circumstances. While planned landings at Edwards carry a cost in dollars and days, the realities can not be ignored. Shuttle program officials must recognize that Edwards is a permanent, essential part of the program. The cost associated with regular scheduled landing and turnaround operations at Edwards is thus a necessary program cost.[5]"

The next 19 landings occurred at Edwards Air Force Base starting with STS 51-B in 1985 and continuing through STS 41 in 1990. After STS 51-L (Challenger) the decision to go to Edwards Air Force Base was sustained.

Figure 2: Orbiter Discovery experienced a blown tire during STS 51-D end of mission rollout.

It took all of 1988 to complete the process of grinding and re-grooving the runway. Sections at each end of the runway were resurfaced to improve orbiter-landing safety.[6] The original lateral cross grooves were ground down on the first 3,500 feet at both ends to reduce the friction and abrasion levels on the orbiter's tires at the time of touchdown. In 1994, the entire runway surface was abraded to a smoother texture to reduce tire wear even further. Thereafter, orbiters were installed with drag chutes to help reduce rollout speed after touchdown. Endeavour, delivered to KSC in 1991, was the first to have this drag chute modification.

Lights

Visual aids such as the Precision Approach Path Indicators (PAPI) system are also installed at the SLF. PAPI lights utilize arrays of red and white lights that indicate the proper glide slope. A ball/bar light system is used for inner glide slope information on final approach.

The centerline lights on the runway feature a series of 52 lights positioned every 200 feet. They begin 2,475 feet down the runway, the optimum touchdown point for an end-of-mission landing. The lights are FAA-approved 80-Watt Halogen bulbs with adjustable intensity. Originally the SLF was equipped with centerline lights located 50 feet apart, but they were removed prior to STS-1 because of concerns about damage to the orbiter tires as they rolled over the three-quarter-inch high bump presented by the old-style lights. The current SLF standard for any height variation is one-eighth inch or less and the new fixtures extend to just the one-eighth-inch mark above surface level[7]. The orbiter has no landing lights. Subsequently, the runway is illuminated by sixteen xenon lights, each putting out one billion candle power. There are eight xenon lights mounted on flatbed trailers at each end of the runway. They augment the centerline and runway edge lights during night landings. These xenon lights were given to NASA by the Air Force. As discussed later, the xenon lights pose a problem for controllers in the tower because of the blinding glare they experience from being inside the cone of the beam.

Facilities

The SLF is a fully functional airport. Although its primary purpose is to provide a safe landing area for the orbiter and her crew, it also supports military and civilian cargo carriers, astronauts' T-38 trainers, the G II Shuttle Training Aircraft (STA) and helicopters as well. Other elements that make up the Shuttle Landing Facility include the 30,000 square yard parking apron located on the southeastern end of the runway. Here other aircraft are staged for short-term visits. During times of peak traffic, such as launch and landing countdowns, when the apron is full, the overflow is transferred to the Cape Canaveral Air Force Station Skid Strip. There is also a 650-foot taxiway to the parking apron and a 9,150-foot tow-way from the runway to the vicinity of the Vehicle Assembly Building (VAB). The facility also encompasses 1.5 miles of access roads, a drainage system, an electrical distribution system, a water distribution system with approximately 7,000 feet of 12-inch water line, and an air field lighting vault.[8] The operational envelope for recovery of an orbiter returning via a nominal de-orbit maneuver begins with an un-powered approach to landing after communications are restored following the reentry blackout. This occurs approximately 13 minutes prior to touchdown and ends with the transfer of the orbiter to the Orbiter Processing Facility (OPF) via the tow way.[9]

Other components of the facility include the Landing Aids Control Building (LACB), the Mate Demate Device (MDD), the Air Traffic Control (ATC)Tower, Weather Station-B, and the water moat. JSC wanted the water moat (located around the runway) since it would serve as a visual aid to identify the runway. It is also required by the Environmental Protection Agency (EPA) as a retention pond for storm water runoff from the concrete runway, and provides a barrier against the animals for the Merritt Island National Wildlife Refuge (MINWR).

Landing Aids Control Building

The LACB is a one level structure with approximately 4,500 square feet of floor space. It is used for housing systems and equipment associated with flight control, flight operations and flight operations support. It is in this building that astronauts, pilots and other flight crews rest after their flights, conduct flight planning, get weather briefings, pick up and drop off passengers. The Military Radar Unit (MRU), an Eastern Range Controller, is currently operating in the LACB during landings and launch countdowns. In the future, this person will be transferred to the tower where he will occupy one of the console positions.

Mate Demate Device

The contract to build the KSC MDD was awarded during the first quarter of calendar year 1977. It was completed in June 1978. The MDD is located on the northeast corner of the ramp. This device is used to lift and mate or demate the orbiter with the 747 Shuttle Carrier Aircraft. The open-truss steel structure is equipped with hoists, adapters and movable platforms for access to certain orbiter components and equipment.[10] It measures 150 feet long, 93 feet wide and 105 feet high with a total lifting weight of 230,000 pounds; orbiters typically weigh approximately 200,000 pounds. The MDD was not always a dedicated structure. In the past, it served as the platform for the SLF's first air traffic control tower. Perched at approximately the 100-foot level, nestled between the antennas, is the small cab where controllers could stick their heads up and pan around looking for traffic.

Air Traffic Control Tower

To replace the ATC tower on top of the MDD, a control tower was installed temporarily near the center of the runway on the east bank. This tower was an improvement. It was assembled from a 1952-vintage portable military field tower. This cab was mounted atop a fixed-based radar structure rising 30 feet above the palmetto scrub. From its cramped quarters, antiquated non-critical equipment, to the lack of indoor plumbing and rural access, it supported approximately 7,000 operations per year prior to September 11, 2001. Since, the airspace has become more restricted to civilian traffic, the number of operations per year has decreased. In September 2003, this old tower will complete its semi-temporary assignment, and give way to an 82-foot state of the art ATC tower located at the SLF Midfield Viewing Site. For the first time, SLF controllers will escape the glare of the xenon lights, have an unobstructed view of both ends of the runway and work in a typical control room with a break room, restrooms and an elevator. Below the tower cab, at the 40-foot level, will be the new Weather observation deck that will replace Weather Station-B, which will share similar amenities as the tower cab. The weather deck will feature a "walk-in" window where the observer can have a field of view of 180^o to see outside conditions. Figures 3 and 4 show the existing tower and the new tower respectively.

Figure 3: Old Tower

Figure 4: New Tower

Weather Station-B

There are two weather observation stations, one located at the SLF and the other located at Patrick Air Force Base. These facilities provide surface weather observations including both visual observations (i.e., sky condition, visibility, cloud amount and type, weather, and obstruction to vision) and measured weather elements (i.e., wind direction, speed and gust/peak, temperature, dew point, barometric pressure, and height of sky cover).

The Range Technical Services Contractor personnel take weather observations for KSC from a facility northeast of the SLF. The range contractor from CCAS takes upper-air observations. A variety of weather balloons as well as meteorological rockets are launched to acquire wind, temperature, humidity, and other data for 45th Space Wing and NASA operations.[11]

Landing Aids Instrumentation

The Microwave Scanning Beam Landing System (MSBLS) is an air-derived microwave landing system consisting of synchronized beams that transmit pulse-coded information to the orbiter. The MSBLS is used starting with heading alignment acquisition and ending with runway rollout. Information is provided to the orbiter guidance navigation and control subsystems, which control the un-powered vehicle's energy during approach and landing.[12]

A dual Tactical Air Navigation (TACAN) System is a standard navigation system, used to provide approach information to the orbiter from 300 nautical miles range to the point of the automatic system take over. The TACAN beacon is located approximately midfield of the runway.[13]

Operations and Improvements

The KSC SLF is the primary landing site for all space shuttle orbiters returning to Earth. There are a total of four Transoceanic Abort Landing Sites chosen partly because they are near the nominal ascent ground track of the orbiter.

Although considered a single landing strip, it is actually two runways built northwest, Runway 15 to southeast, Runway 33. 60% of shuttle landings occur from the southeast approach, while 40% have made the northwest approach. Therefore, runway personnel must be prepared for approaches to either runway. Upon landing, the ATC turns over control of the runway to the NASA Convoy Commander (NCC) who directs an approximately 70-vehicle convoy to conduct external checks of the orbiter for safing, positioning of access stands, connecting ground cooling, egress of the crew and making preparations for towing. Monitoring of on-board systems of the orbiter and payloads and providing ground support equipment are also under the guidance of the NCC. Other operations include attaching and detaching the orbiter from the Shuttle Carrier Aircraft during MDD operations. A new 40-foot state-of-the-art convoy command vehicle was commissioned June 27, 2002, replacing a 15-year-old model.[14]

Operations Testing

One of the Challenger Commission recommendations was that NASA must take actions to improve landing safety. NASA established a Landing Safety Team to develop an implementation plan to comply with this recommendation. Tire, brake, and runway surface tests were conducted and a plan to standardize landing aids and to install arresting barriers at all runways was put in place. The arresting barrier was base-lined but was not implemented. It was to be used as an emergency stop, a rope barrier, in case the brakes didn't work and the orbiter lands too far down the runway. This barrier would stop the orbiter before it went into the swamp. However, the damage that the orbiter would sustain from the Kevlar rope outweighed the benefits of the arresting barriers. Improved weather forecasting and reporting capabilities were implemented. After Challenger, KSC would not land an orbiter until test and landings at Edwards demonstrated adequate safety margins.[15] As a result, no space shuttle orbiter landed at KSC until 1990.

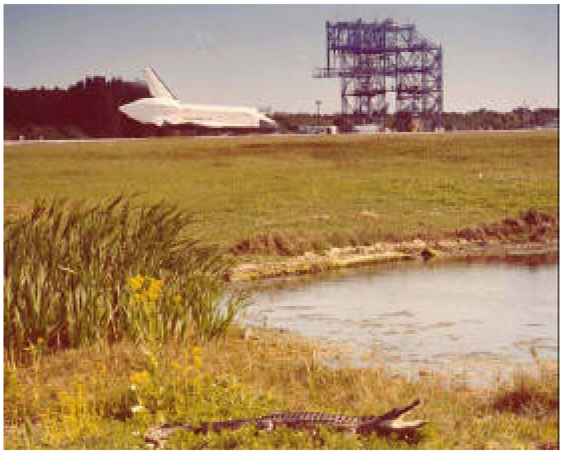
NASA tested space shuttle tires using a modified Convair 990 jet transport. The CV-990 project, with its Landing Systems Research Aircraft (LSRA), arrived at KSC on September 8, 1993. A space shuttle landing gear fixture was installed on the lower fuselage of the CV-990 between the aircraft's own main landing gear. During the tests, after the CV-990's landing gear had contacted the ground, the shuttle tire was lowered onto the runway at the same speed as it would have hit the runway when the shuttle lands (the landing speed of the orbiter ranges from 213 to 226 miles per hour). Test results showed shuttle program managers how much wear the shuttle tires can withstand under a variety of operational conditions.[16] Up to 25 missions over a six-week period were carried out at the SLF.

Shuttle Training Aircraft

In 1976, Grumman delivered 2 Shuttle Training Aircraft (STA), which are highly modified Gulfstream II corporate jets. The STA is used to train Astronauts to fly and land the shuttle and to perform engineering and Astronaut evaluations of proposed Shuttle changes. The aircraft were modified to simulate the Space Shuttle orbiter vehicle during the approach and landing phase of flight. During these approaches, the aircraft descends at rates in excess of 10,000 feet per minute on a glide path angle of up to 20 degrees. This aircraft duplicates the Shuttle approach profile and handling qualities so that the astronaut pilot can see and feel many simulated landings before attempting an actual Shuttle landing. The STA is also used as a weather aircraft before launches and landings. The purpose of these flights is to observe cloud coverage, winds, lighting conditions and other atmospheric properties that may affect a Shuttle landing. [17]

Wildlife Control

The SLF is always prepared to support an orbiter landing. A visual inspection of the runway takes place up to one hour before space shuttle launches and landings. The fence surrounding the landing facility is used as a safety measure for keeping large animals off the runway.



Alligators are living inside the fence territorially in the water moat that surrounds the runway as deterrents for any other types of animals that may want to cross the moat to get to the runway. Birds are another matter. During the period of 1974 and 1981, several memos were exchanged between NASA managers, the Merritt Island National Wildlife Refuge and academic institutions to define and mitigate bird strike problems. One popular issue is the dilemma of maintaining a natural habitat while providing a safe area for air and spacecraft operations. "The species of most concern at KSC include waterfowl, wading birds, nocturnal migrating birds, soaring birds and those birds that swarm in great numbers."[18] Several options such as falconry, varying grass height to modify the habitat, Border Collie dogs and scare devices were considered. Currently, SLF personnel use scare devices to clear the immediate area for aircraft traffic. Warning sirens, screamers shot from a pistol, and concussion shells expelled from a 12-gage shotgun are used. Least Terns were a serious problem because the gray color of the concrete over-runs provided excellent camouflage for Least Tern eggs. To solve this problem, the overruns were painted black[3]. Since the black paint on concrete could not last from year-to-year, the over-runs are now paved asphalt, which is naturally black and doesn't have any properties that are appealing to the Least Terns.

Key Dates

April 14, 1972

Dr. James C. Fletcher, NASA Administrator, announced the selection of Kennedy space Center in Florida as launch and landing site for space shuttle program.

December 10, 1973

Kennedy Space Center requested bids from 50 construction firms on the 15,000-ft runway to be built for the space shuttle.

March 18, 1974

NASA announced Morrison-Knudsen Co., Inc. had been given a $21,812,737 contract to construct a space shuttle runway with overruns, apron, taxiway, and access roads.

April 1, 1974

Construction of the $22 million runway for space shuttle was begun at KSC after a brief ground-breaking ceremony with KSC's first Center Director, Dr. Kurt H. Debus.

1976

Orbiter Landing Facility opened in 1976 when it received an FAA certification identifying the runway as X-68. Center Director Lee Scherer made the first landing.

March 1979

The first space shuttle orbiter, Columbia, arrived at KSC aboard 747 Shuttle Carrier Aircraft.

June 1983

First scheduled landing of space shuttle to KSC, STS-7, was diverted due to poor weather conditions.

February 11, 1984

STS 41-B mission ended when the orbiter Challenger made the first shuttle landing at KSC.

November 16, 1984

Discovery landed at KSC for the first time at the end of STS 51-A mission.

November 20, 1990

Atlantis ended mission STS-38 with its first landing at KSC.

July 9, 1992

Orbiter Columbia, the flagship of the space shuttle fleet, made its first KSC landing.

September 20, 1992

Orbiter Endeavour completed mission STS-47 with its first landing at KSC while using the drag chute.

September 22, 1993

Discovery made the first night landing at KSC to end the STS-51 mission.

1997

STS-81, STS-82, STS-83, STS-84, STS-94, STS-85, STS-86, STS-87; all returned to KSC after their missions ended.

Figure 5: President Carter and family arrive at SLF 1979

Conclusion

The KSC SLF with its 23 years of operational experience has a rich history. Many memories are born there as it continues to shape the future of air and space travel. Landing is considered a critical phase of flight. Entry and landing of the shuttle are dynamic and demanding with all the risks and complications inherent in flying a heavyweight glider with a very steep glide path safely to the runway.

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