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Kennedy Space Center Transformed and Transforming

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Kennedy Space Center Transformed and Transforming

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ABSTRACT

NASA's Kennedy Space Center in Florida is four years into a fundamental transition from a limited-use, specialized launch site to a unique, full-service spaceport capable of meeting the varied needs of a number of different spacecraft, rockets, research and supply payloads, and ground support systems. Arguably no field center of a federal agency aside from a base of the Department of Defense has been tasked with such a fundamental transformation as Kennedy has undertaken during the previous four years. The work ranged from changing the center's mission to adapting to a dramatically altered work force to the repurposing or decommissioning of scores of facilities to further development of launch and landing capabilities.

This transition is taking place with an eye on immediate, near-future and farther-future needs. After all, some of the structures NASA doesn't need now might be needed again in 15 to 20 years to meet a capability or design.

This paper will detail the transition steps that have been taken at facilities across all of Kennedy's 144,000 acres, unique approaches involved and what methods are being considered for future steps.

Birth of a Launch Center

NASA's Kennedy Space Center in Florida covers 144,000 acres on the northern end of Merritt Island in Florida. The vast amount of that land is undeveloped to provide an uninhabited buffer zone between launch pads and processing centers and the cities of Titusville on the western side of the Indian River and suburbs of Merritt Island south of the space center.

The launch center formally opened July 1, 1962, when NASA established it as a field center named the Launch Operations Center. The evolution of the land from scrub and citrus farm to rocket and spacecraft test facility is described in NASA's history of the space center:

Dr. (Kurt) Debus, representing NASA, and Lt. Gen. Leighton I. Davis, representing the Department of Defense, organized a joint study to find a new launch site. They considered Hawaii, Texas, the California coast, an island off the coast of Georgia, islands in the Caribbean, and Merritt Island (adjacent to the Cape) as possible sites.

The study concluded that Merritt Island offered compelling advantages. Several small communities were within easy driving range, and larger cities like Daytona Beach, Vero Beach, and Orlando were only slightly further. Locating on Merritt Island also would allow NASA to share facilities of the Atlantic Missile Range, avoiding costly duplication. Only at this location could the same

NASA launch organization continue operations on the Cape Canaveral complex while building the spaceport. Debus and General Davis recommended the acquisition of the northern part of Merritt Island. The choice was endorsed by NASA and the Defense Department. Congress authorized NASA to acquire the property.

The space agency began acquisition in 1962, taking title to 83,894 acres (33,952 hectares) by outright purchase. It negotiated with the state of Florida for use of an additional 55,805 acres (22,600 hectares) of state-owned submerged land, most of which lies within the Mosquito Lagoon. The investment in property reached approximately \$71,872,000.

In July 1962, the Launch Operations Directorate at the Cape was separated from the Marshall Space Flight Center by executive order. It became the Launch Operations Center, an independent NASA installation, with Debus as its first director. It was renamed the John F. Kennedy Space Center in December 1963, in honor of America's slain president. In December 1964, launch elements of Houston's Manned Spacecraft Center (now the Johnson Space Center) were transferred to the Kennedy Space Center. The following October, Goddard Space Flight Center's Field Projects Branch on the Cape was incorporated into the Kennedy Space Center.

Kennedy's work force grew rapidly from its creation in 1962 as NASA moved quickly from the pioneering effort of Mercury to the Gemini program through 1965 with an eye on Apollo. The needs of the Apollo spacecraft and massive Saturn V rocket, which dwarfed everything that came before it, dominated the planning, construction and infrastructure at Kennedy. Standing at 363 feet and weighing some 6.5 million pounds when fueled, the Saturn V depended on gigantic infrastructure for assembly, testing and launch. The Vehicle Assembly Building and Launch Complex 39A and B were built specifically for the Saturn V's needs. The VAB, comprised of 98,590 tons of steel and 65,000 cubic yards of concrete, remains a landmark that defines the space center today. The building covers 8 acres and reaches 525 feet into the Florida sky. The structure, the largest in the world by volume when built and still one of the biggest today, houses four high bays divided by a transfer aisle. It was built to process up to four of the giant rockets at once.

Launch Complex 39 was, like the VAB, built for the Saturn V. There are two launch pads, A and B, and they were identical in construction. Each one was built with a base of 68,000 cubic yards of concrete that rose about 40 feet above the surrounding swamps. A 42-foot-deep flame trench lined with fire-resistant materials directs exhaust away from the rocket and launch structures at launch.

The entire sequence of processing, testing and launch were directed from firing rooms inside the Launch Control Center adjacent to the VAB. The four-story LCC is located about three miles from the launch pads and its firing rooms, each holding about 200 people, were situated facing the launch pads. Because the Saturn V would produce far more acoustic energy than any other booster, designers included hinged, metal louvers over the two-story-tall windows that could be closed if the sound vibrations threatened the glass. The building also contained scores of computer processors and large monitors to relay a wide assortment of data to the launch team during a countdown.

The Apollo spacecraft including the command and service modules along with the lunar module also required processing bays and equipment far above what had been used before. The Operations & Checkout Building's high bay was large enough to prepare the modules for their missions and also housed a pair of vacuum chambers for testing the spacecraft for leaks.

The communications and telemetry systems of the Apollo Program presented technical demands as challenging to NASA as the engineering demands. A number of special antenna stations were established around Kennedy's perimeter. The systems that would be used were built and tested at the Central Instrumentation Facility at Kennedy, known as the CIF.

Transformation Version 1: Apollo to Space Shuttle

The specialized facilities that were critical in readying Apollo spacecraft and Saturn V rockets for missions would find themselves modified and processes adapted so they could continue to be employed for NASA's next human-rated spacecraft, the Space Shuttle. Whereas each Apollo spacecraft and Saturn V rocket was built brand-new and used for one mission outside Earth orbit, NASA pursued reusability as a hallmark for the space shuttle and pushed toward a goal of making spaceflight routine. A commonly stated goal at the time was to replace the maintenance-heavy sports car of Apollo with a truck requiring minimal servicing in the form of the space shuttle.

The needs of readying three to four space shuttles at any one time for launches every two weeks required facilities designed to operate more like airplane hangars than research facilities. That is to say that planners sought repeatable processes and consistent processing steps that could be used each time to ready a shuttle for flight. The five space shuttles that were built during the program, Columbia, Challenger, Discovery, Atlantis and Endeavour, were identical and managers shared updated methods and practices throughout processing to add efficiencies to the processing and launch.

Although NASA had a new spacecraft and mission to make spaceflight routine, the budget environment was far more austere than it had been during Apollo and engineers set out to use whatever Apollo-generation structures they could for shuttle processing.

Nearly all of Kennedy's Apollo-era structures would continue in NASA service for three decades more as they were adapted to process and launch the space shuttle and its payloads. The Operations and Checkout Building's high bay was used to process payloads horizontally and the VAB was used to stack the solid rocket boosters and external tank before placing a shuttle orbiter in launch position. The launch control center retained its role as an overseeing location for all the processing as engineers watched over consoles modified for shuttle's uses.

The launch pads also were modified heavily to host space shuttles. Instead of taking its service tower with it out to the pad as the Saturn V did, the shuttles were rolled to the pad on platforms that had very little structure. Instead, each launch complex was outfitted with a pair of service structures: one called the Fixed Service Structure that stayed in place on the side of the shuttle in launch position and another called the Rotating Service Structure, or RSS. The RSS included a clean room that would roll into place over the shuttle's cargo bay so payloads such as the Hubble Space Telescope and innumerable satellites could be slid into the cargo bay without being exposed to the elements of the oceanside launch pads.

The processing needs for shuttle were substantially different than those for Apollo because the spacecraft were reusable and the payloads were generally larger than a completed Apollo command and service module. Those needs predicated a new generation of specialized facilities that were built for shuttle's use. Three Orbiter Processing Facilities, or OPFs, were built on the west side of the VAB.

Numerous new structures were added at Kennedy to suit the shuttle's needs as well as those of the International Space Station which the shuttle fleet would be tasked with building in orbit. First, a three-mile-long, 300-foot-wide runway called the Shuttle Landing Facility or SLF would be constructed in the swampy areas west of the VAB. Sand and dirt dug up from the surrounding lands was used to build up the 500 acres of the SLF and cement was poured to create the landing surface. The center of the runway

is 16 inches thick with the sides 15 inches thick. Though built from 1974 to 1976, the SLF remains one of the largest runways in the world.

The SLF operates as a full airport with an air traffic control tower on-site, a ramp and parking area and administration building. A fire station is adjacent to the runway, as well, along with a 50,000-square-foot hangar built in 2000.

Separate facilities for handling the vertical payloads of the shuttle such as NASA's Hubble Space Telescope and for fueling spacecraft were also built. Later, the 457,000-square-foot Space Station Processing Facility, or SSPF, was constructed east of the Operations and Checkout Building for the purpose of readying components of the International Space Station for launch aboard the shuttles. Engineers and technicians would also use rooms in the SSPF to pack general and specialized scientific cargo for station missions. At its height of station processing, the 46,000-square-foot high bay of the SSPF was loaded with station components in various levels of preparation for launch. All of the American, European, and Japanese segments of the space station passed through the SSPF before they went into orbit.

Transformation Version 2: Shuttle to Multi-User

The retirement of the space shuttle provided a catalyst that is unique in NASA history and very rare in federal property and asset management: A specialized field center established for a well-defined mission conducted by a single customer would no longer serve that single customer and would instead focus on broader uses of its facilities by a range of customers with needs different from each other. The transformation also put NASA in a position in many cases of acting as a supplier of services instead of a customer.

It is generally accepted that turning around a large organization or major company akin to the size of Kennedy takes about seven years. Using that scale, Kennedy is about halfway through its transformation period that began in 2010 and picked up steam in 2011 when NASA retired the space shuttle fleet.

The most dramatic element of the transition came in the months leading up to the last flight of the space shuttle and for about a year following the last flight as the orbiters were serviced for disposition to museums across the country. It was during this time that Kennedy released the vast majority of the contractor work force that processed, launched and recovered the shuttles and reassigned or allowed the retirements of the civil service employees attached to the shuttle program. Kennedy's work force dropped from about 14,700 to 8,000 in this time frame. The number has remained steady for the past two years, indicating that the current work force is correctly sized to the needs of the center, including the processing and launch of uncrewed missions by NASA's Launch Services Program.

More than 40 buildings at Kennedy were used at one point to launch, process and recover a space shuttle, including office space built for contractor and NASA work forces. A large part of the transformation at Kennedy has centered on finding new uses and partners for the specialized buildings and deconstructing those that were either too old to be maintained economically or without a foreseeable use by NASA's future missions or with commercial partners. The center also has practiced caution in releasing tools and equipment NASA paid for that were used in shuttle processing.

The retirement of the space shuttles also reduced the amount of funding Kennedy received from NASA. Shuttle funding accounted for a considerable amount of Kennedy's annual budget so much of the transformation since then has been funded through Kennedy's center maintenance and operations budget. One of the first objectives of the transformation was to catalog and prioritize the modernization of Kennedy's facilities such as the VAB and launch pads. The infrastructure had not been upgraded in up to 50 years in some cases. Miles of cables, wiring and plumbing in the VAB were pulled out and replaced

for the first time since the structure was completed in 1967. Copper cables leading from the Launch Control Center to the launch complexes at 39A and B were also removed and replaced with state-of-the-art fiber-optic cables that can carry at least 100 times more data in less than half the space. Space Florida paid to refurbish the Operations and Checkout Building's high bay which made it the choice of Lockheed Martin for assembling and processing NASA's Orion spacecraft that is in development to carry astronauts into deep space for the first time since Apollo 17 returned from the moon in 1972.

Overall, the modernization program has made Kennedy's facilities far more attractive to commercial partners who expect to work in an environment equal to modern offices, research labs and facilities.

A New Way of Doing Business

The catalyst for Kennedy's transformation is adapting to a new way of doing business at the space center. NASA remains at the top of the list for consideration for Kennedy facilities, of course, but much of the focus on utilizing the work force and center assets has turned to how private industry or other government agencies can put them to use. The emergence of a commercial market for small satellites, research flights and space tourism are showing what options are viable as Kennedy considers partnerships and its own service needs.

Kennedy has worked closely with the Space Coast Economic Development Council, Space Florida, the Central Florida Partnership, Canaveral Port Authority, Florida Department of Transportation, 45th Space Wing and others to succeed in this new climate. The groups collaborate on tactics, serve on panels and attend conferences together in an effort to adapt the center and their own facilities to the commercial environment where companies make their decisions based on the complete business ecosystem that can be offered. This approach is one that was not foreseen when Kennedy opened its gates in 1962.

Competition from start-up spaceports in other parts of the country is also a new factor for Kennedy planners to consider as they develop plans that retain the Florida site's status as the world's only super-spaceport, i.e. a spaceport that can handle processing and launch of the smallest rockets and payloads, medium-sized commercial satellites, large, complex spacecraft that are considered national assets plus the recovery of winged spacecraft returning from space and Earth orbit. Later this decade will see the return of Kennedy's ability to launch humans into deep space when the Space Launch System rocket and Orion spacecraft make their first flight tests from Launch Complex 39B. There is nothing in the spaceflight portfolio that Kennedy has not achieved already and remains capable of executing.

Strategic Priorities

Kennedy has taken a holistic approach to its transformation in that planning has centered on structures, equipment and work force assets and how they can all be marketed and applied as a single unit to a given program or partnership. After all, although Kennedy is known for its landmarks and contributions to human exploration, we know those accomplishments were not achieved by structures and facilities alone, that it took thousands of dedicated workers uniquely qualified for the demanding scope of aerospace.

Kennedy planners developed four strategic priorities for the Master Plan that will help guide the transition from federal launch site to multi-user spaceport:

- **Supporting NASA Mission and Program** – Ensuring that NASA's spaceflight programs – Space Launch System, Orion, Commercial Crew, International Space Station, Ground Systems Development and Operations and Launch Services Program – are fully operational and have fully capable facilities assets and resources.
- **Evolving to a Multi-User Spaceport** – Move from a monolithic NASA program field installation to a multi-user spaceport on federal property.

- **Divesting without Diminishing** – Divesting the center of assets without eliminating capability to serve both critical government missions and programs while encouraging the growth of commercial space transportation market needs.
- **Going Leaner and Greener** – Improve operations, fiscal and environmental sustainability.

Partnerships

We found out early in the process that the facilities and work force at Kennedy would be in high demand from the private and public sectors in America. As soon as we opened the door wider to industry's ideas for Kennedy, we began getting inquiries that continue to come in. We've acted on 267 proposals since October 2011. Although 50 have been declined, more than 200 are in different stages of development.

Facilities Leased to Partners

Orbiter Processing Facilities 1 and 2:

The Air Force partnered with Kennedy for two of the Orbiter Processing Facilities that had served as the space shuttle hangars. The armed service is expected to process its spacecraft in the hangar bays of the OPFs and use other Kennedy facilities in the operational aspects of the spacecraft.

Shuttle Landing Facility:

Space Florida, the space industry organization for the State of Florida, is in the final stages of partnering with Kennedy to lease, maintain and operate the Shuttle Landing Facility. The three-mile-long runway, its associated buildings and capabilities have been in demand for years and this partnership is expected to serve that demand in ways NASA is not set up to accomplish effectively itself. The SLF is already home to Starfighters, a company that will launch small satellites on suborbital missions using F-104 supersonic jets.

Moon Express also is on the verge of signing a partnership agreement that will allow the company to use a testbed built for NASA's experimental Morpheus lander at the north end of the SLF. Many companies that are expected to use winged spacecraft for missions ranging from satellite launches to carrying tourists into space on short missions have stated intents to use the SLF.

Orbiter Processing Facility 3 and Space Shuttle Main Engine Processing Facility:

The Boeing Company, working with Space Florida, leased the third of the space shuttle hangars along with the Space Shuttle Main Engine Processing Facility, which used to be known as the Engine Shop for the assembly and processing of its CST-100 spacecraft being developed with NASA's Commercial Crew Program. Boeing said previously the CST-100 program would eventually employ up to 550 people as it operates the spacecraft that is one of the two selected to carry astronauts to the International Space Station.

Launch Complex 39A

SpaceX, formally known as Space Exploration Technologies, leased Launch Complex 39A as the east coast launch site for the Falcon Heavy and the sole launch site for the Crew Dragon, a spacecraft being developed with NASA's Commercial Crew Program to carry astronauts to the International Space Station. The company is expected to alter the look of LC-39A slightly as it modifies the fixed service structure and rotating service structure to serve the Falcon Heavy and Crew Dragon. The launch pad holds significant advantages over others in that it is already outfitted for astronauts and technicians as they get ready for launch. The complex area also has sizeable propellant tanks and lines required of large boosters.

Operations and Checkout Building High Bay

Lockheed Martin, working with Space Florida, leased the high bay at the Operations and Checkout Building for the processing and assembly of the Orion spacecraft, NASA's next craft designed to take astronauts into deep space on missions to asteroids and eventually Mars. Space Florida paid to modernize the facility from its time as a servicing area for Apollo spacecraft to make it more attractive for commercial companies.

Space Life Sciences Laboratory and Exploration Park

The Space Life Sciences Laboratory and Exploration Park are showcase emblems of Kennedy's utility in research and development outside the realm of launch and processing. Again working closely with Space Florida, Kennedy has dedicated a parcel of land on the southwest portion of the center for use as a research campus anchored by the SLSL and expected to house new buildings specified for commercial or university use. Kennedy adjusted the fence-line of the center so that those working at the SLSL and Exploration Park would not have the same strict security conditions applied to them as they are on other parts of the center.

Horizontal Infrastructure

Kennedy and the State of Florida are in discussions about a partnership that would turn over the maintenance of the center's roads and bridges to the state to allow better planning as an integrated part of Florida's infrastructure instead of a facility that handles those issues itself. The move would also open new avenues for hurricane evacuation by allowing the center's roads to be used in some conditions to alleviate traffic as people leave the beachside headed for the mainland during a storm warning.

Laboratories

Because Kennedy's laboratories remain essential elements for research into launching and ground support equipment, we have not turned over these facilities in total to use by a partner. Instead, companies are allowed to buy time and expertise from our contractors working inside the labs to perform research and testing to a company's needs. Aerodynamic tests, materials evaluation and many other scientific studies can be performed in Kennedy's settings and we have seen numerous proposals for different studies that would find the labs useful.

Midpoint of Transition

The transition to a multi-user spaceport was not expected to be easy on any level, but Kennedy has enjoyed numerous successes that encourage us to continue the hard work needed to complete the transition.

The center recently released its Master Plan, a deeply involved study and survey that establishes land uses for the center during the next 20 years. It sets a road map, if you will, for maintaining Kennedy's role as America's premiere space launch center and envisions a center offering launch and processing capabilities for every class of booster and spacecraft. It also set up processes to reaching the goals of producing a modern space center that is more efficient, economically viable and environmentally friendly than it has been in the past.

We have seen enormous interest from outside government agencies and the private sector in using our facilities and work force in ways that would not necessarily occur to a center focused on launch work and space travel.

The partnerships Kennedy has begun have been useful in many ways, most important of which is utilizing the space center's facilities in effective ways. Kennedy remains committed to entering into new partnership agreements that are in keeping with the center's goals.

Many elements of the plan and approach are working well but the process remains in its early stages. Future success will depend on how well smaller companies are able to thrive on their goals and partnership elements.

The center is exploring partnerships outside traditional space-related work after seeing an interest from companies in the fields of energy research and hydrogen fuel handling. Kennedy's expertise in dealing with hydrogen, liquid oxygen and other potentially hazardous materials has been shown to be a preferred specialty in industries outside launch and we are seeing how commercial needs in that arena can be met here.

Because Kennedy has testing stands engineered to evaluate the forces of launch on gigantic structures, companies have approached the center with suggestions to use our equipment to evaluate large structures used by industries outside of space exploration. We continue to consider these proposals and may enter into partnerships as long as Kennedy's own needs for testing the equipment needed for future NASA missions is not compromised.

In Closing

Kennedy has made enormous strides in the past four years and is already accomplishing goals and partnerships that some considered impossible. There remain many more partnership possibilities for the center that indicate continuing demand from industry for sites with the assets our Florida center offers. However, the center's culture is still adapting to the different parameters of commercial businesses and those partnerships may not happen until some institutionalized perceptions are adequately dealt with. In the meantime, Kennedy continues to take steps to advance the speed of partnership development to show private industry that the center is open for business and welcoming of their ideas.