Transforming a Single-use Spaceport to Multi-use

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ABSTRACT

The end of the Space Shuttle program brought new challenges as well as new opportunities to the John F. Kennedy Space Center. The challenge is to engineer a more flexible Spaceport to be capable of supporting manufacturing, assembly, testing, processing and launch operations for multiple spacecrafts and launch vehicle configurations. The new spaceport must support multiple commercial as well as government entities while leveraging existing infrastructure to the greatest extent possible. This paper addresses key engineering challenges during Spaceport design and development and will look at possible engineering solutions while considering reusability of legacy systems and infrastructure adaptability with emphasis on flexibility and reduction of operating cost.

I. Introduction

Historically, infrastructure at the Kennedy Space Center (KSC) was designed to support a single launch vehicle architecture, with a single mission.

With the end of the Space Shuttle Program in June 2011, the mandate for a large-scale multiple vehicle processing capability and support for a large-scale manifest ended. [1, 2, 3]
The need to scale back from a reusable vehicle infrastructure to a non-reusable vehicle with fewer missions has required a complete reassessment of present assets and a thorough reexamination of how best to utilize them. KSC has been exploring the options for processing and launching multiple vehicle infrastructures and support to the Space Launch System (SLS) Program.

This paper will propose a possible solution to satisfy the needs of multiple customers using present assets. It will also propose some new ways of designing a more flexible ground infrastructure.

II. Shuttle Infrastructure

A. Space Shuttle Ground System Configuration

For the Space Shuttle Program, the requirements were to avoid massive ground infrastructure investments and use existing national investments in space launch infrastructure. As such, design proceeded with the Launch Complex 39 (LC39) mobile launch concept in mind. Specific differences in LC39 infrastructure for the Space Shuttle are discussed below. [4, 5, 7]

1. Vehicle Assembly Building (VAB) Characteristics

The Vehicle Assembly Building itself was sound and the only major adaptation to be made was with the extensible work platforms, which needed to be modified to conform to the complex outer mold line of the integrated Space Shuttle Vehicle. The other complicating factor was the additional hazard of handling segmented solid propellant motors with open grain in the facility. Hazard analyses, personnel restrictions, and operational constraints were imposed so as to allow this concept to be safely implemented.

Additionally, with four high bays available, advantage was taken in the utilization of these available assets. The two east-facing high bays became the Space Shuttle Vehicle integration cells. The other high bays were used for storage of the large external tanks and also used as surge storage for the growing fleet of Orbiters. The VAB was also modified to act as a vehicle safe haven for a completed stack rolled back from the launch pad during a hurricane.

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2. Mobile Launcher (ML) Characteristics

The mobile launchers were reused in the Space Shuttle configuration. However, the design approach was to eliminate swing arm type T-0 umbilicals, in favor of consolidated T-0 service masts, fixed and protected on the launcher deck, and connected to the aft compartment of the Orbiter vehicle. The tower was eliminated from the Mobile Launcher to lighten the transfer load produced by the heavy solid rocket boosters. The tower function was transferred to fixed structures on the Pad surface. The result was a new Space Shuttle Mobile Launch Platform (MLP) with no attached tower—hence the name change from "Mobile Launcher."

3. Crawler Transporter (C/T) Characteristics

With the transfer load alleviated for a clean launcher approach, no new transporters were required. Upgrades to the crawler's control systems were made which extended the life of these vital national investments.

4. Launch Control Center (LCC) Characteristics

The primary change to the Launch Control Center was in standardizing and automating the firing room equipment with what was then advanced, digital control systems. Advantage was taken of the new electronics and software revolution emerging in the 1970s, with rapid advancements being made in data storage technologies, integrated circuits, microprocessors, and so forth. A standardized test and checkout software language was developed and customized for launch systems engineers, referred to as Ground Oriented Aerospace Language, or GOAL. A set of standard consoles were designed, derived from existing hardware casings from the Apollo program. Each console would be standard in design and loaded with unique software applications for the function being performed. If a console failed, a backup could be loaded and prepared in the time it took for the operators to physically move to the backup console. For the few time-critical safety functions, special control logic was designed and hard wire circuits that bypassed the software functions were designed in. Special data storage areas were placed in the LCC for engineers to review data in real time and post-test. Three firing rooms were initially re-outfitted with this new Launch Processing System (LPS), but in practice only two were used for the flight rates that emerged. The other firing room became a software improvement and development firing room, and with the new flexibility, was also used for management oversight during launch countdown operations.

5. Launch Pad Characteristics

As mentioned, the Pad underwent several modifications to accommodate the Space Shuttle. Before addressing those, it is important to note what remained intact. The previous investment in the cryogenic storage and distribution systems, i.e., the cryo fuel farm, was sufficient in capability to support Shuttle operations, thus saving a tremendous amount of expense, design and development effort, and construction time.

A shorter service structure was fixed to the Pad to provide launch crew and flight crew access to the integrated Space Shuttle Vehicle. A rotating service structure hinged to the fixed tower swung on a railed track around and over the flame trench to wrap around the Orbiter vehicle payload bay to allow for vertical insertion of payloads at the Pad. Additionally, a hydrogen vent arm was required due to the placement of the hydrogen tank and the venting approach used in the external tank. The slide wire emergency egress approach was also used and became more effective with the crew cabin lowered in height relative to the towering Saturn vehicle configuration. The RP-1 fuel storage area was no longer needed. Due to the anticipated high flight rates, the servicing of toxic propellants was permanently fixed to the Pad area in fuel and oxidizer hypergol fuel farms.

6. Mobile Service Structure Characteristics

The mobile service structure was eliminated in favor of the rotating service structure and the fixed hypergolic fuel farms.

7. Orbiter Processing Facility (OPF) Characteristics

A separate set of hangars capable of horizontal processing of the Orbiters were created. Ultimately, three were constructed for the fleet. Additionally, it became necessary to create a set of auxiliary facilities, such as: a mate/demate device at the landing field for use with the 747 Shuttle Carrier Aircraft (SCA); a dedicated thermal protection system (TPS) shop; a dedicated shop for overhaul and inspection of the reusable Space Shuttle Main Engines (SSMEs); a wheel and tire shop, and dedicated Orbiter logistics facilities.

B. KSC Industrial Area Configuration

The Industrial Area, too, underwent some changes in support of the Shuttle Program.

1. Operations and Checkout (O&C) Building Characteristics

The newly organized European Space Agency (ESA) contributed a modular, reusable Spacelab to take full advantage of the Space Shuttle's capabilities to return and reuse large payloads. The O&C building was re-outfitted to manage the assembly and reconfiguration of these payloads.

2. Hypergolic Maintenance Facility (HMF) Characteristics

The design of the Orbiter vehicle included modular, detachable reaction control and orbital maneuvering pods so that separate maintenance of these toxic, hazardous systems could occur away from the rest of the Orbiter vehicle and its work crew. This created the need to convert a portion of the old fluid test complex into a Hypergolic Maintenance Facility, or HMF. This facility had the necessary toxic fuel and oxidizer storage and disposal capability, emergency exhaust systems, and spill handling equipment. It also used a localized LPS control room, but isolated from the hazardous operations in the maintenance bay. Due to the challenges in reusing hypergolic systems, creation of the HMF turned out to be a wise decision.

3. Launch Equipment Test Facility (LETF) Characteristics

To avoid the expensive qualification of separate umbilical devices as encountered in the Apollo program, a launch equipment test facility was created to develop and certify critical Pad and MLP equipment. Specifically, the hydrogen vent arm, the new Tail Service Masts (TSMs), and their complex T-0 umbilical plates. When the time came to load and operate the Shuttle stack for the first time, a great deal of risk had already been retired through this investment.

III. Constellation Ground System Configuration

In 2005, a new initiative was announced by the White House making a commitment to a specific spaceflight architecture for exploration. In some cases the physical architectural differences are obvious, as in the case of the Vehicle Assembly Building (VAB) access platforms configuration, the Mobile Launcher (ML) / transporter configuration and the Launch Pads. However, trade studies determined new and unique mobile launchers would be required for both the Orion/Ares I and the Altair/Ares V space vehicles. The fixed structures at Pads 39A and B would be abandoned for a cleaner pad approach. For spacecraft processing, both the Orion and the Altair lunar lander were envisioned to perform pre-integration operations in the Industrial Area, much as was done in the Apollo era. Once again, launch vehicle and spacecraft launch operations would be separated, a departure from the Shuttle Orbiter that combined crew cabin/spacecraft functions and launch vehicle functions. This also freed up certain landing and reusable Orbiter facilities for other space flight opportunities not directly related to Constellation Orion-Ares-Altair operations. [2, 3, 6, 7]

A. Launch Complex 39 Configuration

As mentioned, the primary elements of the mobile launch complex were retained. Some of the system characteristics are noted below.

1. Vehicle Assembly Building (VAB) Characteristics

As with the Space Shuttle, the VAB itself was sound and the only major adaption to be made is with the extensible platforms, which need to be modified to conform with the outer mold line of the space vehicles and the provision of required facility services to the Mobile Launcher.

2. Mobile Launcher (ML) Characteristics

Using the mobile launch concept, the launcher becomes the main functional "adapter" between the new space vehicles and the existing ground infrastructure. The launcher not only connects the space vehicles physically, it is also the means for loading the flight system propellants, service fluids, gasses, electrical power, hard line data transfer and certain RF communications equipment. It connects the vehicle stack to the launch pad, to the VAB—and through them to the Launch and Mission Control Centers.

The Mobile Launcher (ML) is composed of a Mobile Launcher Base (MLB) and a Mobile Launch Tower (MLT). The launch base is all new and does not reuse the MLP of the Space Shuttle (which in turn was used from the Apollo era). It connects to the VAB and the Launch Pad through a common interface. The MLT has two high-speed elevators, a dedicated crew access arm, tilt-up T-0 umbilicals, and swing-type umbilicals.

3. Launch Control Center (LCC) Characteristics

Command, control, and communications with flight and ground systems are still accomplished through a centralized, four-story control center. However, the Shuttle Launch Processing System (LPS) is being replaced with a more modern Launch Control System (LCS) for outfitting in the Firing Rooms.

IV. On-Going Transformation of the Post-Shuttle Infrastructure

As stated previously, the change from a large program that had a reusable vehicle architecture to a non-reusable vehicle architecture has required a reassessment of assets.

Starting at Pad B, the configuration was completely changed by going to a clean Pad concept. The fixed service structure, the rotating service structure, and the hypergol tank farms have been removed. Three lightning protection towers have been erected.

The Operations and Checkout Building highbay facility has been re-certified for final vehicle assembly and check out of the crew vehicle.

The Orbiter Processing Facilities are being converted to accommodate some manufacturing and check out by private companies developing infrastructure to support the Commercial Crew Initiative.

The Crawler Transporter (CT) is being modified to allow the transporter to handle the larger load associated with the SLS Program future architecture.

VAB platforms are being modified to support the SLS configuration architecture.

Pad B improvements have been to continue to upgrade Pad infrastructure in support of the SLS Program with a new electrical wiring system, cryogenic tank farm upgrades and major refurbishment to Pad structures and support systems.

Pad A status, although still evolving and open for possibilities of use by NASA or others for future commercial launches, is being kept in a “mothballed” state.

The common element is the retention of a crawler/mobile launcher architecture for vertical stacking and transportation to the Launch Pad.

V. Proposed Concept Solutions

A. Launch Base Adapters

The use of adapters in order to accommodate different vehicle configurations goes back to the Apollo era. The use of a structural adapter (milk stool) was developed to accommodate the launch of SpaceLab from LC39 at the Kennedy Space Center. By using such a device, it allowed the vehicle to utilize existing umbilical connections without making major design changes.

Adapters can be used on a modified Mobile Launcher Platform (MLP). The proposed solution uses a concept of launch mount adapters that would be designed to accommodate the different vehicle configurations and architectures. The mounts would be designed to provide common connections for services, such as; fluids, gases, and electrical connections. It would also provide structural support for the vehicle. These launch mount adapters would be pre-installed and ready for vertical vehicle integration.

B. Sheltered Flight Vehicle-to-Ground Connections

Umbilical and Tower connections would be performed in the VAB in the vertical position from either modified platforms or from the ML modified tower. The tower would provide minimal access to the different vehicle configurations. It would also provide fluids, gases, and electrical connections. The tower will be constructed in such a manner that a series of simple structure appendages capable of moving up or down the face of the tower with telescoping capabilities to accommodate the different vehicle architectures. The whole system revolves around the principle of standard connections for fluids, electrical and gases with minimal change from the ground umbilical connection back. The tower will service the most basic needs of the vehicle and payload with limited access. This configuration can be accomplished at either KSC Pad A or Pad B as the schedule will support.

C. Common Launch Accessories

The design of common hardware interfaces would allow the connections for fluids, gases and electrical to be made using common standard connections. A couple of examples include:

- *Tail Service Mast* would be handled in the same manner, it would use an adapter to support the different configurations and architectures as needed.
- *Access arms* would be attached as needed and configured for the different architectures, including a crew access arm, if required.

VI. Summary

The Post-Shuttle Era – Although it has presented a formidable challenge in transition, it has also provided unlimited possibilities for the Kennedy Space Center's Mobile Launcher Architecture.

The ability to support the SLS Program and various vehicle architectures and configurations through the use of adapters and interface commonality will allow the Kennedy Space Center to move forward as a multi-vehicle spaceport.

References

[1] Stanley, D., et al, "NASA's Exploration Systems Architecture Study," NASA TM-2005-214062, November, 2005.

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[3] Griffin, Michael D., Administrator, National Aeronautics and Space Administration; speech given to the Space Transportation Association, Washington, D.C, January, 2008.

[4] Debus, Kurt H., Dr., and Davis, Leighton I., Maj. Gen. (USAF), "Joint Report on Facilities and Resources Required at Launch Site to Support NASA Manned Lunar Landing Program (Debus-Davis Report)," NASA KSC Archives, 31 July 1961.

[5] D. D. Buchanan, "Space Shuttle Launch Operations Center Study," NASA TR-1078-1; KSC, Florida, December 1, 1971.

[6] Stanley, D., et al, "NASA's Exploration Systems Architecture Study," NASA TM-2005-214062, November, 2005.

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Back Up

The Skylab/ASTP Evolved Launch Configuration

Mobile Launcher 1 was modified to accommodate the Saturn 1B vehicle for manned earth orbiting missions.

Space Shuttle Launch Structure

Pad 39B Shuttle Structure

Clean Pad B

Ares I-X Vehicle on MLP at Pad B