On June 14, 2017, NASA celebrated the 50th anniversary of Launch Complex 39B (LC39B). My recent visit to the site took me back to Friday, May 5, 1961 when I was 11 years old. Astronaut Alan B. Shepard, Jr. went into a 15 minute, 26 second suborbital flight as the first American in space inside the very small Freedom 7 Mercury spacecraft. That’s the day I began my quest to be an electronics engineer. The Mercury Redstone 3 rocket, with Freedom 7 atop, launched from Launch Complex 5 at Cape Canaveral Air Force Station. I watched ABC all that day, not missing any of the coverage. This effort began our quest to set foot on the Moon.

Now in 2017, I had the awesome privilege of being behind-the-scenes at Launch Complex 39B. The Orion Spacecraft will be launched from here atop the Space Launch System (SLS) – the most powerful rocket in history – in two years, on Exploration Mission-1 (EM-1), and ultimately will carry us to our first stop in deep space: the Red Planet, Mars. In the late 2030s, we will set foot on a planet other than Earth for the first time.
For my journey at NASA’s Kennedy Space Center Complex, I was escorted by Matthew Miller from the NASA Communication Office, who introduced me to Nick Moss, Deputy Project Manager, LC-39B, a young man who is a mechanical engineer by trade, but knew every aspect of the Launch Complex and gave me an excellent overview of the electronics and other key features of the area being renovated for the Orion spacecraft and SLS rocket.
Figure 2  Matthew Miller (right) and I posed in front of NASA’s Vehicle Assembly Building (VAB), the only building to assemble a rocket that carried humans to the surface of another world. Next stop, Mars. For 30 years, it served as the final assembly point for the Space Shuttle as the orbiter was attached to an external fuel tank and solid rocket boosters for launch. Without Matthew’s help, I would not have such
Some history

Launch Pad 39B was originally constructed in the 1960s and was the starting point for Apollo, which led to America’s landing on the Moon. The new renovations will bring humanity to Mars.

![Workers pouring concrete at Launch Pad 39B on March 7, 1966. (Image courtesy of NASA)](image)

Originally, NASA planned to use Ares I to launch Orion, the Mars spacecraft intended for human spaceflight missions after the Space Shuttle was retired in 2011. Ares I was cancelled by U.S. president Barack Obama in October 2010 so NASA commissioned the Space Launch System (SLS) as its new vehicle for human exploration beyond Earth's orbit.

Renovations

Some of the key renovations in progress are:

- adding a new communications and wiring system
- replacing the Environmental Control System
- new heating, ventilation and air conditioning systems
- replacement of various water system pipes within the pad perimeter

In addition, there is:
• installation of new ignition overpressure/sound suppression bypass valves at the valve complex
• reinforcement and replacement of the pad surface crawlerway
• refurbishment of the pad’s cryogenic propellant storage spheres

Later in this article we have more details about these additions as well as the Flame Trench (Figure 4).

Figure 4 Here you see Nick Moss (left) and Editor Steve T (right) directly in front of the Flame Trench. The SLS exhaust will be directed straight back away from where we are standing (thank goodness!) to the north, in the direction of the water. Towards the north side the flame trench is about 571 feet long, 58 feet wide, and 42 feet high. (Image courtesy of Loretta Taranovich)

Two side flame deflectors, repurposed from space shuttle launches, are being refurbished, and will be reinstalled at pad level on either side of the flame trench to help reduce damage to the pad and the SLS rocket.

In the background of Figure 4, you will see on the right a black numeral 3 on a cylindrical post, and on the left, a black numeral 6 on an identical post. These are two of six posts that will be a major part of a support system that will hold the SLS Launch Platform. In Figure 5 is the crawler that will transport the SLS Launch Platform (Figure 7) to Pad 39B. The SLS will be on the Launch Platform when the Crawler moves underneath the Launch Platform and raises it up off the ground for the slow journey to LC39B.

The crawler

NASA’s crawler-transporters are two of the largest vehicles ever built. They have carried NASA rockets and spacecraft to the launch pad for the last 50 years, and will continue to be the "workhorses" of the nation's space program.
The crawlers are being modified to carry NASA's Space Launch System (SLS) with the Orion spacecraft atop it.

**Figure 5** A crawler similar to the one seen here will slide under the SLS Launch Platform and carry it to Launch Complex 39B, a short distance away (Image courtesy of Loretta Taranovich)
Figure 6  A Crawler Tread Belt "Shoe". Each one is 7.5 feet long, 1.5 feet wide, and weighs over one ton. There are eight tracked tread belts on the Crawler, each with 57 tread belt shoes like this. (Image courtesy of Loretta Taranovich)
Figure 7 The SLS Launch Platform under which the Crawler will slide, lift up, and slowly move towards Launch Complex 39B. The SLS will be mounted to this platform before the journey to LC39B. (Image courtesy of Loretta Taranovich)
Lightning arrester towers/cables

Lightning can be a very big problem in Florida’s thunderstorm-filled skies. This could be disastrous to a rocket launch if the vehicle is struck. Lightning struck Apollo 12 as it climbed through the Florida clouds which produced a weak electric field. The spacecraft triggered two strikes, but not from naturally occurring lightning. This raised NASA’s attention to natural and triggered lightning strikes. Years later, lightning struck the launch pad of the Challenger Space Shuttle before its launch on Mission STS-8.

NASA has developed some pretty clever ways to prevent this natural occurrence from endangering astronauts and equipment on the launch pad, which have culminated in a design using three tall steel masts with down conductors to divert the surging electrical current from a powerful lightning strike safely away from the rocket and into the ground.
There are three of these towers at the Launch Complex and all are connected at the top to each other with stainless steel cables arranged in a pattern. The construction of the foundation of these towers includes 216 concrete pilings under the ground as far as 55 feet. (Image courtesy of Loretta Taranovich)
**Meteorological and lightning systems**

Mounted on these towers are weather monitor systems that could lead to better on-time launches of rockets. In **Figure 8**, you can see four arms protruding from the right side of the tower which contain the weather instruments. From the bottom up, we see Levels A, B, C, and D, which each measure wind speed, wind direction, temperature, and relative humidity. Why so many? Well, the wind can vary significantly at different altitudes, and it is critical to know how that force may affect the Launch Vehicle. There are also other meteorological stations that measure rain precipitation and accumulation.

There are also lightning detectors and cameras mounted on these masts. The cameras monitor and record every aspect of the launch and pre-launch as well as high-speed cameras to capture lightning strike images.

NASA is extremely safety-conscious, down to the most minute detail.

These stations can also operate on their own for 280 days, so if a tropical storm forces the area to be evacuated, the instruments will send data at one sample per second to be stored in computers in the Pad Terminal Connection Room (PTCR), which is in a basement area below the Launch Pad surface.

**Figure 9** The Orion spacecraft, atop the Space Launch System (SLS) rocket, will fly through an opening in between the stainless-steel cables tightly strung above and connected to three masts. (Image courtesy of Loretta Taranovich)
This fairly new design strings large stainless steel cables between three 594-foot tall towers constructed of steel and fiberglass. This is known as a catenary wire system. Alltec Global Systems explains this lightning arrester technique best here.

The Launch Pad perimeter has nine down-conductors and also four B-dot (The time-derivative of an Inductive magnetic field or dB/dt) and five D-dot (The time-derivative of electric flux density or dD/dt) stations that will identify when and where lightning has struck, how strong it was, and how much disruption was caused. These sensors are monitored by high-speed transient video and data recorders down in the PTCR, and operate at high-speed. The integration of the probe outputs will give instantaneous values for electric and magnetic fields due to lightning.

Figure 10  A B-dot sensor at LC39B. Here you can see that the protective fiberglass dome is removed so the sensors can be easily seen in this image. (Image courtesy of NASA)

Above Level D, on the Level E masts, there are six high-definition, full-color cameras, two at the base of each mast, which all record when they are triggered and capture high-speed video to give engineers a full set of data regarding lightning events. The output trigger of the transient recorder is fully buffered and conditioned before it is sent to the high-speed cameras via fiber-optic cables. The camera’s memory is also segmented. The cameras will not likely miss an event, due to the B-dot sensor stations that can be used to locate the lightning strikes for more than one camera, with overlapping fields of view and a trigger offset equal to the dead time.
Figure 11  A high-speed camera enclosure at Level E on one of the three LC39B Lightning Protection Towers. Shown here are also two redundant AC units and the power enclosure can be seen on the lower left corner of the camera instrumentation enclosure. (Image Courtesy of NASA)

The high-speed cameras are triggered by the trigger output of one of the transient recorders down in the PTCR when any of the recorders perceive a qualified trigger. Transient recorders are GEN7t and GEN16t (now replaced by HBM with GEN17tA) models by HBM. Isolated digitizers are also used in this system.

The Flame Trench

The older style Flame Trench used at LC39B for the Space Shuttle needed to be redesigned in order to handle the massive heat from the plume exhaust of the SLS. The old flame deflector design for the Shuttle was an inverted, V-shaped steel structure covered in high-temperature concrete five inches in thickness across the center of the flame trench. This V-shape was necessary due to the main engine flames being deflected on one side, with the Solid Rocket Boosters (SRB) being deflected on the opposite side.
The SLS does not have that unique configuration, so the “universal flame deflector” was installed in place of the older system. The design is now similar to the Apollo-era system.

Next, the bricks lining the trench needed replacement under the guidance of the Ground Systems Development and Operations (GSDO) team. 100,000 heat-resistant bricks, in three sizes, were secured to the trench walls with bonding mortar and adhesive anchors. This new design will allow the north side of the Flame Trench to withstand over 2,000°F at launch.

In the Flame Trench, some of the sensors used to measure rocket plume pressure and heat-rate are a calorimeter, pressure transducers, and accelerometers.

NASA typically uses Commercial Off-The-Shelf (COTS) sensors in launch environments to provide data complementary to the Tungsten Piston Calorimeter (TPC). The TPC uses tungsten for hardness and good thermal properties. Tungsten is best at resisting erosion and has the highest melting point to resist the rocket’s plume heat. The TPC is composed of three spring-loaded tungsten-rhenium thermocouples which contact the bottom of thermal wells in a steel piston. The piston is connected via a rod to a load cell in order to also measure the force of the plume.

**Ignition over pressure/sound suppression (IOP/SS) post-liftoff bypass**

The IOP/SS uses a large volume of water to prevent damage to the rocket from the exhaust and acoustic shock wave during launch. See Figure 12 for the LC39B water tower.
Bypass valves to be used in the post-liftoff portion of the IOP/SS system at the Pad B valve complex have been installed. These new bypass valves will enable the flow of water through the mobile
launcher deck’s water nozzles, also known as rainbirds, just before liftoff (T-0) to prevent the water from spraying the SLS in case an on-pad abort occurs after the IOP/SS water flow has started. At T-0, the main 48-inch valves located in the IOP/SS valve complex will open to ensure that the flow of water and timing requirements are achieved. See Figure 13 for a view of the 54 inch “rain water” pipes and Figure 14 for the large water pipe at the bottom of the Flame Trench.

Figure 13 The cylinder labeled “3” is the #3 post that will hold the SLS Launch Platform shown in Figure 4. To the left of that post are, from right to left, 54” and 60” water tubes that provide the “rain water” to cover the deck in order to soften noise and vibration (The tube with the black band on the far left is a left-over from the old LC39B). There are ultrasonic heaters on these pipes. (Image courtesy of Loretta Taranovich)
Figure 14  A steel complex was built and the installation of the large Ignition Over-Pressure/Sound Suppression (IOP/SS) manifold pipe can be seen here at the far bottom-backside of this steel construction. The deflector will be built around this foundation. There are two holes in the top of the pipe for two large standpipes that will feed water to the deluge sprinkler heads that line the top of the deflector. The deflector is shaped like a quarter-pipe skateboard ramp facing the north that will direct the exhaust plume of the SLS Core Stage and SRBs all in one direction out the other end of the Flame Trench. The water, 400,000 gallons, will be coming from the water tower in Figure 12. (Image courtesy of Loretta Taranovich)

Work on the design of the deflector involved the use of NASA Ames’ supercomputer, which helped draw up the deflector design: one that could withstand the high heat from plume exhaust, that did not result in plume blow-back, and whose surface pressure was within design-margin limits.

The SLS rocket fuel

In combination with an oxidizer, such as liquid oxygen, liquid hydrogen yields the highest specific impulse – or efficiency in relation to the amount of propellant consumed – of any known rocket propellant.

For the SLS, NASA is also using hydrogen for engine cooling. Because of the amount of hydrogen being used, when it’s drained back, it may not all be in gaseous form when it hits the flare stack, so the separator acts as a kind of above-ground septic tank, where it will gather the liquid and allow it to warm up.

After this it goes from liquid to gas and is sent out over to the flare stack to be burned off. This ensures that the flare stack is not hit with “liquid”.

The additional consumption of hydrogen was one of the factors that drove the construction project for an additional liquid hydrogen sphere at Pad B, although it won’t be required until the SLS Block 1B vehicle flies, which is planned to debut on the second SLS launch.
Refurbishment and upgrade of the water system also included installation of a new sewage lift system that will pump sewage from the pad's liquid hydrogen and liquid oxygen areas to the main pad sewage line.

**Figure 15** The Liquid Hydrogen tank is part of the fuel mixture for the SLS. This is right beside LC39B. Underground pipes flow right to the SLS on its Launch Platform at LC39B. There will also be a Liquid Hydrogen Tank. Both will be filled at the appropriate time of launch. It will take almost 900,000 gallons to fill both over a six-month timeframe. It’s a long procedure since they need to be filled with cryogenics first (they will be at Florida ambient temperatures to start off) and the procedure must be done carefully and methodically. (Image courtesy of Loretta Taranovich)

**Other new electronics and sensors**

A new, state-of-the-art communications system has replaced the Apollo and space shuttle era equipment in the PTCR and the pad perimeter. The new system will enable users to service spacecraft and launch vehicles on the launch pad during pre-mission checkout and countdown on launch day. All legacy switches, electronic devices, paging speakers, digital keysets, telephones, communication racks, and more than 592,000 pounds of cabling were removed. Updated communication equipment was installed, including new network switches, timing, cameras, telephones, paging speakers, and more than 104,000 feet of new cabling.

Underground fiber-optic cables now replace older copper to the Launch Control Center (LCC). There are 3 to 13.8 kV feeds going to the LC39B and then converted to 480V in some areas. The mobile Launcher will need the 13.8 kV as well.

A modern sensor Data Acquisition System (DAS) has been implemented for the myriad of sensors at this complex. NASA has made some very important contributions to sensors for their space exploration endeavors. Most of these designs benefit us on Earth as well. See some of these creations [here](#).

Communication Systems upgrades included new fiber optics from the pad to the Launch Control
Center via the outdoor cable plant and into various communications rooms.

The new communications system will support staff and customers at the pad with modern network, video, and audio communications, as well as support for pad safety operations, leak detection and monitoring, range safety, radio frequency, and telemetry. The new system will also support advanced RF monitoring, cryogenics, the Environmental Control Subsystem, fire alarms, ground special power, the Kennedy Ground Control Subsystem, the Kennedy Complex Control System, security, the sensor data acquisition system, and the weather subsystem. Stay tuned for my next EDN NASA exclusive article on the Launch Control Center (LCC).

I am excited to see the next steps on humankind's journey to Mars, and hope to be at the STS/Orion Launch at Kennedy Space Center in 2019. So much new technology is being developed for this effort, but this technology will benefit mankind on Earth as well as it has in NASA’s past.

Keep an eye out over the coming weeks for more EDN exclusive articles about my NASA visit, as well as for Planet Analog blogs. It’s a great time to be in the electronics industry!

References

1. A new comprehensive lightning instrumentation system for pad 39B at the Kennedy Space Center, Florida, C. Mata, V. Rakov, T. Bonilla, A. Mata, E. Navedo, G. Snyder, 30th International Conference on Lightning Protection - ICLP 2010 (Cagliari, Italy - September 13th -17th, 2010)

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