Internal Office Communication
Release Date: February 1, 2021
Author: Martin Ripper

QUADRUS CORPORATION

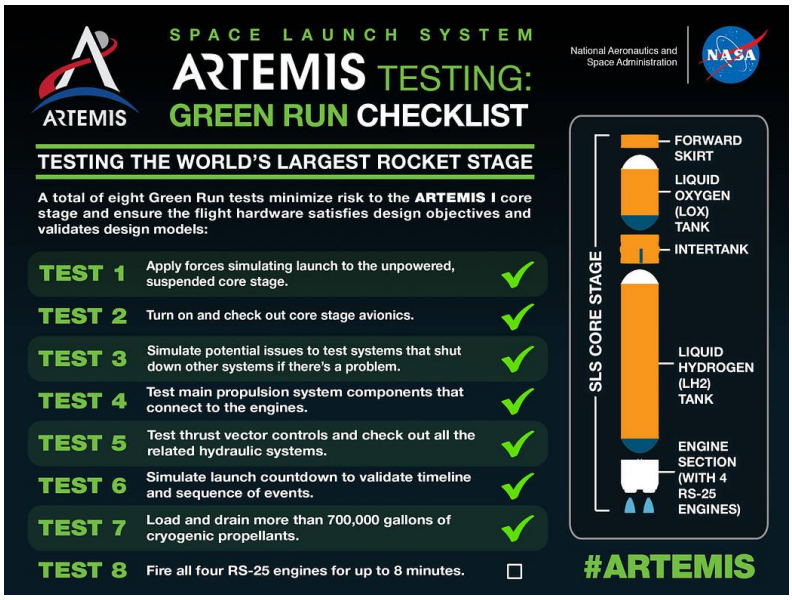
200 Clinton Ave W Ste 600 | Huntsville, AL 35801
256.327.3410 Office | QuadrusCorp.com

On January 16, 2021 NASA, Boeing, and Aerojet Rocketdyne conducted the first static fire test of the new heavy lift SLS Core Stage, designed to take us back to the Moon and on to Mars. Quadrus Corporation's Engineering Services Division had a strong presence helping Boeing get to this milestone. We first joined the SLS Team working in the Boeing Avionics Laboratory here in Huntsville in 2011, as part of the Boeing Avionics Team transitioning from Aries to the new Space Launch System program. We have been on this team from the very beginning!

Quadrus Corporation has made significant contributions to the program in multiple areas: we supported development and testing of the Electrical Ground Support Equipment (EGSE) used for static testing of Core Stage segments (Forward Skirt, Inter-Tank, Engine Section) during the assembly process, as well as a static testing of the assembled stage at the Michoud Assembly Facility (MAF) just North of New Orleans; we also supported development of Specialized Test Equipment for use in validating both the Flight Computers (FCs) and the Command and Telemetry Controllers (CTCs) at the production site in El Segundo California prior to incorporation into the Core Stage in MAF; we also supported the development and testing of the Stage Controller, which is the ground system used to conduct the Green Run Test at Stennis Space Center. In the process we have earned multiple Silver and Gold supplier awards from Boeing for our outstanding performance as members of the SLS team. Quadrus Corporation engineers, past and present, have a lot to be proud of for helping Boeing and NASA get to this point!

As most are likely aware, the scheduled 8-minute Green Run Test lasted a little over 1 minute, at which point the engines were shutdown automatically by the Flight Computers. As usual in (not so) social media, people are quick to declare failure and focus on the negative, as opposed to actually understanding what happened, how much actually went right, and how much we learned that will make the first test flight more predictable. I can address some of that here. I'll start with the Engine 4 Major Component Failure noted in the Test Conductor audio while the engines were running.

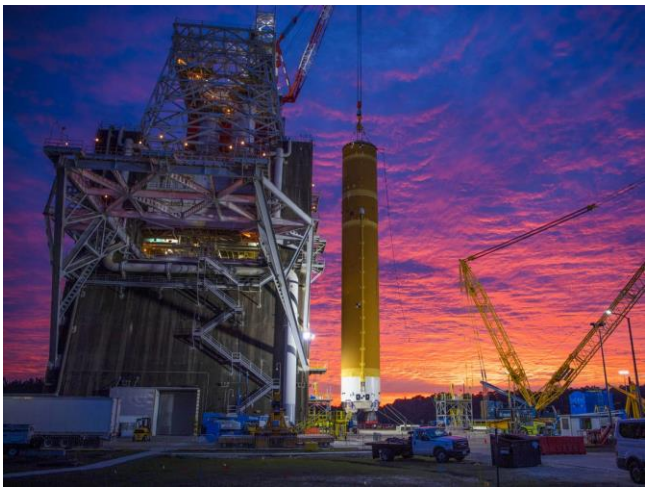
That particular failure was with a redundant system, and so was not a criterion for terminating the test, once started. Post test data analysis and vehicle inspections determined the failure was due to a bad sensor reading, which has since been addressed. There was also discussion of a fire at or near the "top" of one of the engines. There is, in fact, video of flames being briefly present near the insulating blankets that separate the business end of the engine from its mechanical and electrical components. All engine temperatures remained nominal, and thus could not have caused a premature shutdown. Additionally, post-test inspections showed some minor scoring on the thermal blanket, but that its integrity was not compromised and that neither the test nor the Core Stage was ever in danger of a critical failure from this issue. So, what really happened? Of note in the Test Conductor audio is the fact that the shutdown occurred immediately after the first engine gimbal sequence started. It turns out that one of the parameters the Flight Computers monitor for vehicle safety, one of the parameters affected by gimbal operations of Engine 2, exceeded the pre-established Test Commit Criteria (TCC). At that point, the Flight Computers are programmed to "Advance To Shutdown" – basically shutdown the engines and terminate the test. Post-test analysis of the data showed that the actual values reached were considered safe for flight, but the test limits were more conservative. The test limits were set conservatively because the test article is also the flight vehicle and every effort was made to prevent "rapid unplanned disassembly" as the CEO of one prominent rocket company famously put it, after his rocket demonstrated the process.



So, was the Green Run a failure, as social media and the press like to claim? Not in my opinion. We breathed life into a 212-foot-tall rocket stage, filled it with 730,000 gallons of hydrogen and oxygen, and safely maintained enough explosive power to destroy everything within a one-mile radius. We started and ran all four RS-25 engines, maintaining propellent flow for over a minute. That's the first time 4 RS-25 engines have been tested simultaneously on the same vehicle. The sight of those engines breathing fire was truly stunning! We demonstrated we can monitor thousands of critical parameters and safely shut down when any one of them is outside the expected range… We preserved the integrity of the flight vehicle when an unexpected condition arose in a demanding test environment.

The number of pieces that MUST work perfectly to make that happen is truly astounding. I can't see how all we accomplished and everything that worked as planned can be considered a failure!

We did what you're supposed to do during a test: detect something you don't expect, don't destroy the test article, shutdown, look at the data to see what happened, and live to test another day. It's why we test. We learned a lot which, of course, is another reason why we test. There are several things that showed up in the data that were unexpected. None of these smaller issues would have endangered the Hot Fire, but they provide lessons learned which will be incorporated into Hot Fire #2 and the eventual launch at Kennedy Space Center. Yes, Hot Fire #2 is coming to Stennis Space Center sometime around mid to late February. The specific dates are still a bit in flux. I'm looking forward to it!



As Werner Von Braun once said, "One test result is worth a thousand expert opinions". We now have our test result and can move forward smarter because of it – and we didn't destroy our test article to get it. If we didn't learn anything, yes, the Green Run would have been a failure. BUT, we learned a LOT, so I consider it to be a pretty major success. One that we all should be proud of.

QUADRUS CORPORATION

HUBZone Historically Underutilized Business Zone CERTIFIED

Quadrus Corporation is a small business that provides expert Software, Systems, Test, and Integration Engineering, Technical Services, and Process Development / Training support to complex and highly demanding defense, space, and commercial projects at every lifecycle stage from initial requirements development through verification, certification, and deployment. From research and development to design, testing, and production, our engineers are at the forefront of using cutting edge technology to support our customers needs. Our process enables us to deliver cost reduction and production efficiencies to equip customers for mission success.

Martin Ripper is the Director of Engineering Services for Quadrus Corporation. Ripper also fills the role of Chief Software Engineer and Senior Consultant for the organization. An engineer at heart, Ripper is also responsible for the management of Quadrus Corporation's field engineering force. As Chief Software Engineer, he oversees software development on our COTS products and some of our IR&D software projects. Ripper enforces and maintains the company's reputation of technical excellence with all our field engineers, ensuring our people perform at the level our customers expect.