An Air Framer's Pursuit of AC 20-135 Testing

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Abstract

Northrop Grumman (NGC) is a prime military aircraft contactor. Not the type of company one would expect to do applied aircraft fire research. When presented with the opportunity to crate the capability to test materials for compliance to "fire resistant" or "fire-proof" requirements per the FAA's AC 20-135, POWERPLANT INSTALLATION AND PROPULSION SYSTEM COMPONENT FIRE PROTECTION TEST METHODS, STANDARDS, AND CRITERIA, NGC took it. To execute this project, NGC Engineering turned to one of our more obscure test facilities at our Space Park Center of Excellence, "Area 67". Once funding was secured, the team laid out a plan. With all of the readily accessible information on aircraft fire testing, including material from the FAA's Next Generation Burner accumulated from the FAA's Triennial International Fire & Cabin Safety Research Conference in hand, the team set off to work. This paper will describe the efforts and "adventures" that took Northrop Grumman from no fire test capability to operating a facility that would rival any specialty test house in the country. We offer this and our lessons learned so that anyone attempting to follow in our footsteps can avoid the hidden pitfalls (we managed to hit most of them) in setting up your test facility and join us in working to design aircraft fire protection systems that allow all of our military flight crews to make it home after every mission.

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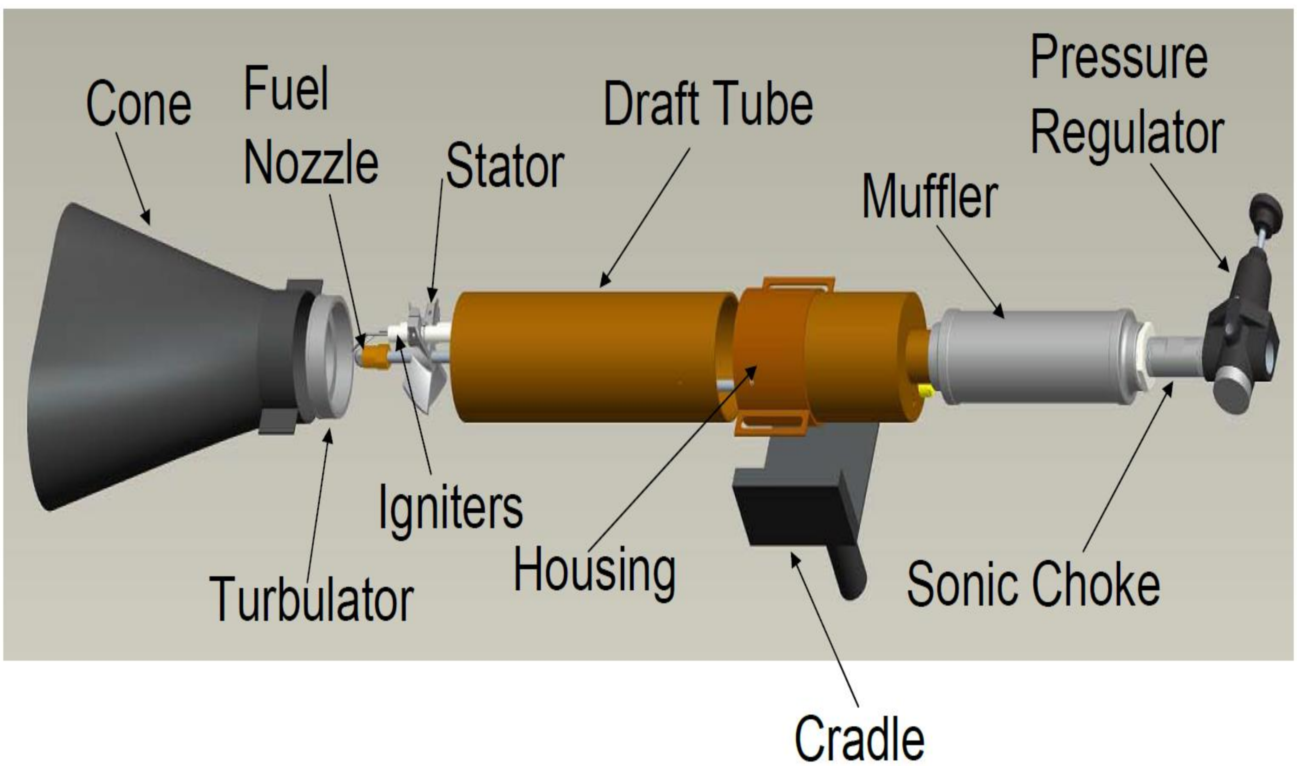
Introduction

Aircraft design engineers needed a way to challenge fire barrier material against fire. They turned to a facility located at the Space Park Center of Excellence in Redondo Beach California known as Area 67. Area 67 is a Concept Development, Rapid Design and Testing Facility. Through extensive concept and design discussions, the panel comprised of aircraft design engineers and Area 67 engineers agreed that in order to truly evaluate a fire barrier material, the material had to be challenged against the worst case scenario. Using the guidelines of the FAA AC20-135 and the Next Generation Fire Test Burner Plans, they procured the next generation burner.

Figure 1: NexGen Burner



Looking into other fire testing sites and testing documentation, they came to the conclusion that the standard orientation of the burner was either mounted at 45° angle

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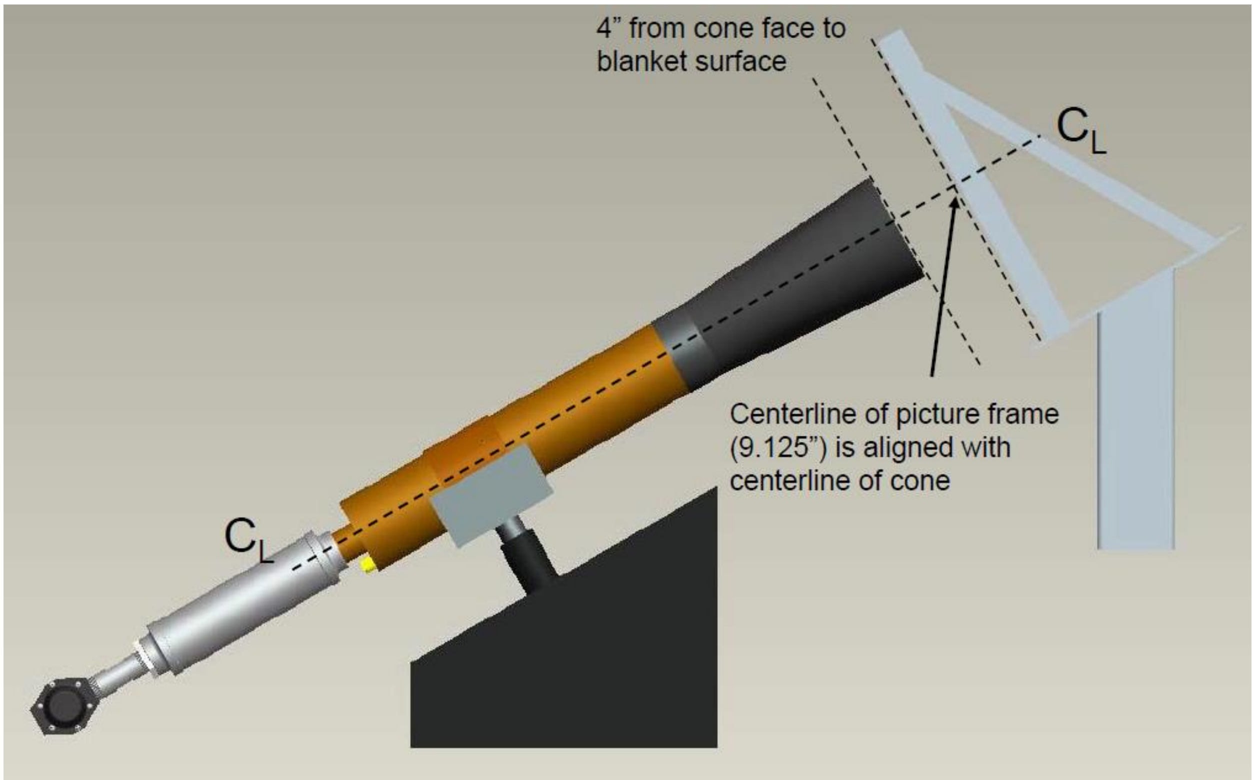
or an intermediate angle configuration shown in Figure 2. They believed that the worst case scenario was to subject the test articles in the vertical direction. This was the driving force behind the vertical orientation of the fire challenge test stand.

Figure 2: Burner Orientation



This paper will describe the efforts and “adventures” that took Northrop Grumman from no fire test capability to operating a facility that would rival any specialty test house in the country. We offer this and our lessons learned so that anyone attempting to follow in our footsteps can avoid the hidden pitfalls (we managed to hit most of them) in setting up your test facility and join us in working to design aircraft fire protection systems that allow all of our military flight crews to make it home after every mission.

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FAA Next Generation Fire Test Burner Fire Challenge Test Stand

After a lot of discussions with the entire design team, the decision was made to do the fire challenge outdoors. The test stand was made to be mobile for storage and quick refurbishment for test when needed. All of the other test components carts are built on wheels and can be moved into test position easily.

Figure 3: Fire Challenge Test Stand

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To address the thermal condition requirements, the engineering team built a heat exchanger cart to regulate the temperature of the fuel and air.

Figure 4: Air and Fuel Heat Exchanger Cart

The fuel line was special designed to control the temperature of the fuel coming into the burning using the cooling water jacket without contaminated the fuel supply. On the cart were the safety shut offs for both the igniter and the fuel supply as well the red light notifying all personnel when in the system was active. The cart is located 20ft away which allows for safe operations in case of emergency.

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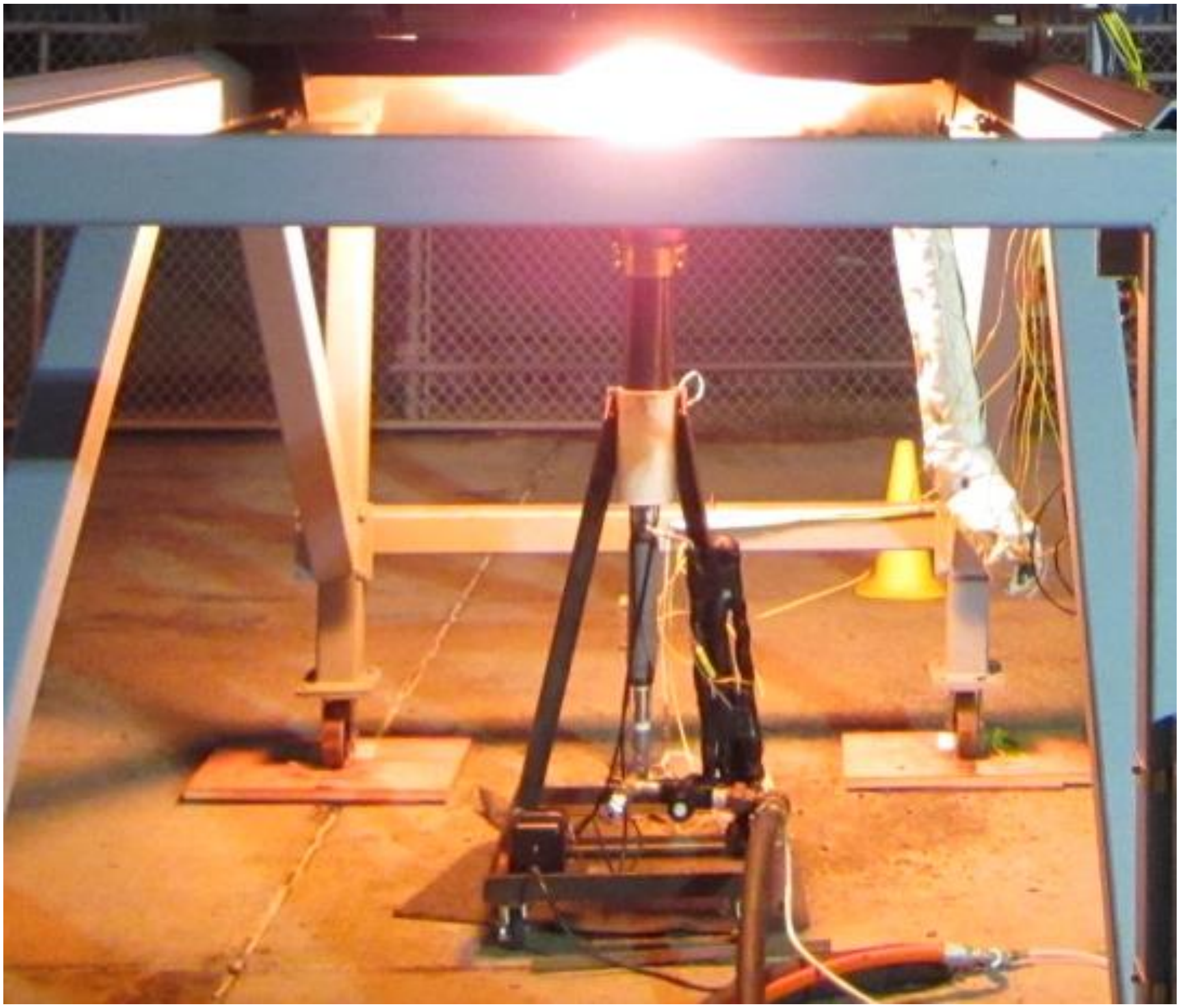
Figure 5: Burner Cart



The fire challenge test stand centers around the burner with a test article mounted directly over it. To prevent fire from wrapping around the test article a steel plate 0.875” thick, 57.75” width by 60” length with a test article size hole cut out in the center was machined and angles were welded into place.

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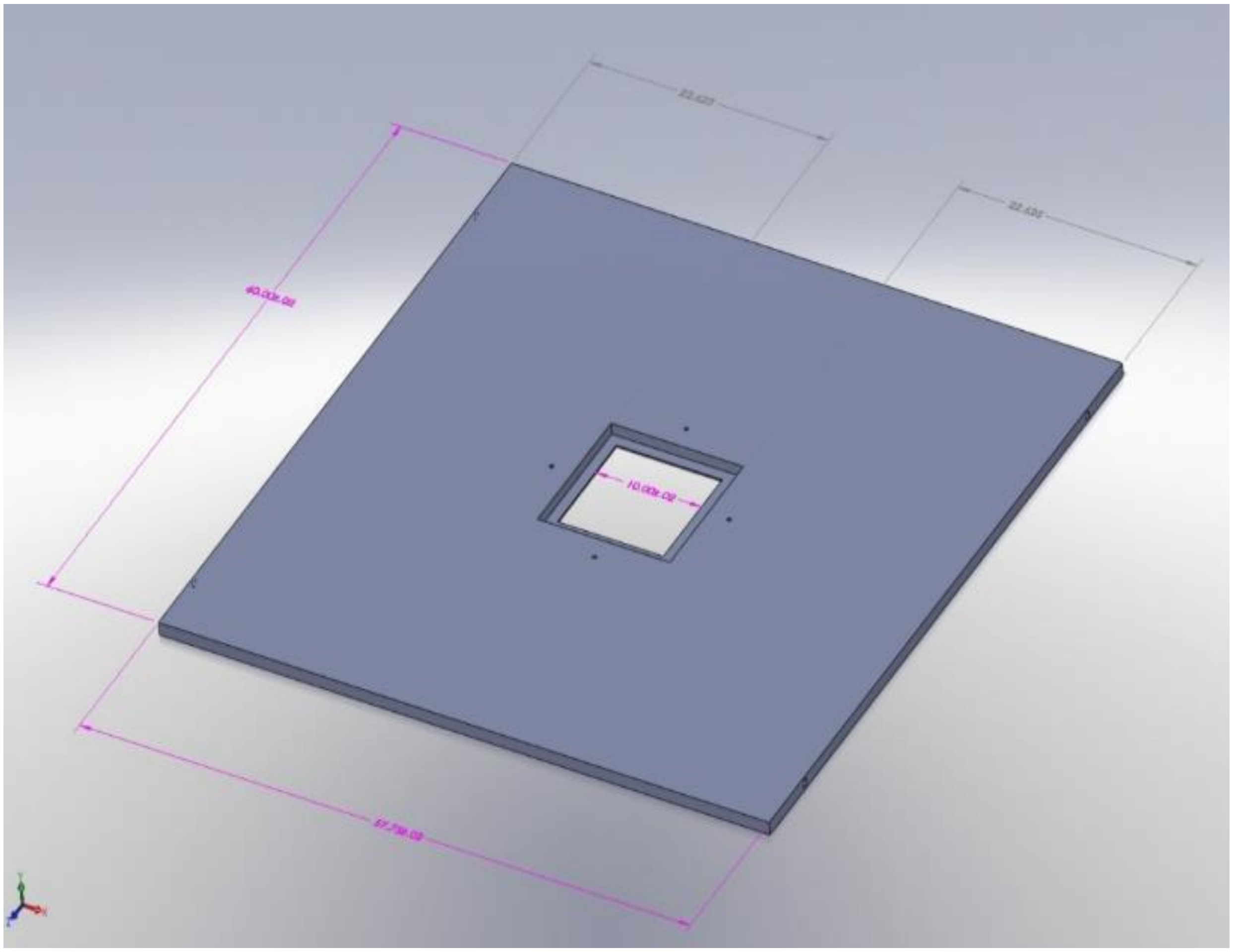
Figure 6: Steel Plate



This design created a fire “infinity” ceiling. This orientation created several issues. The first issue was how the test articles were going to be installed and removed safely without injuring the test support personnel. The second issue is how the test articles were going to be consistently burned because it takes the burner time to settle into the temperature.

The design engineers decided to move the test samples from a staging position to the test position by installing a railing system for the plate. To move the heavy plate, the engineers designed and fabricated an air ram cylinder. When the actuator was powered on the plate would deploy over the burner, when the off the system would return into the staging position.

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Figure 7: Plate Staging Position

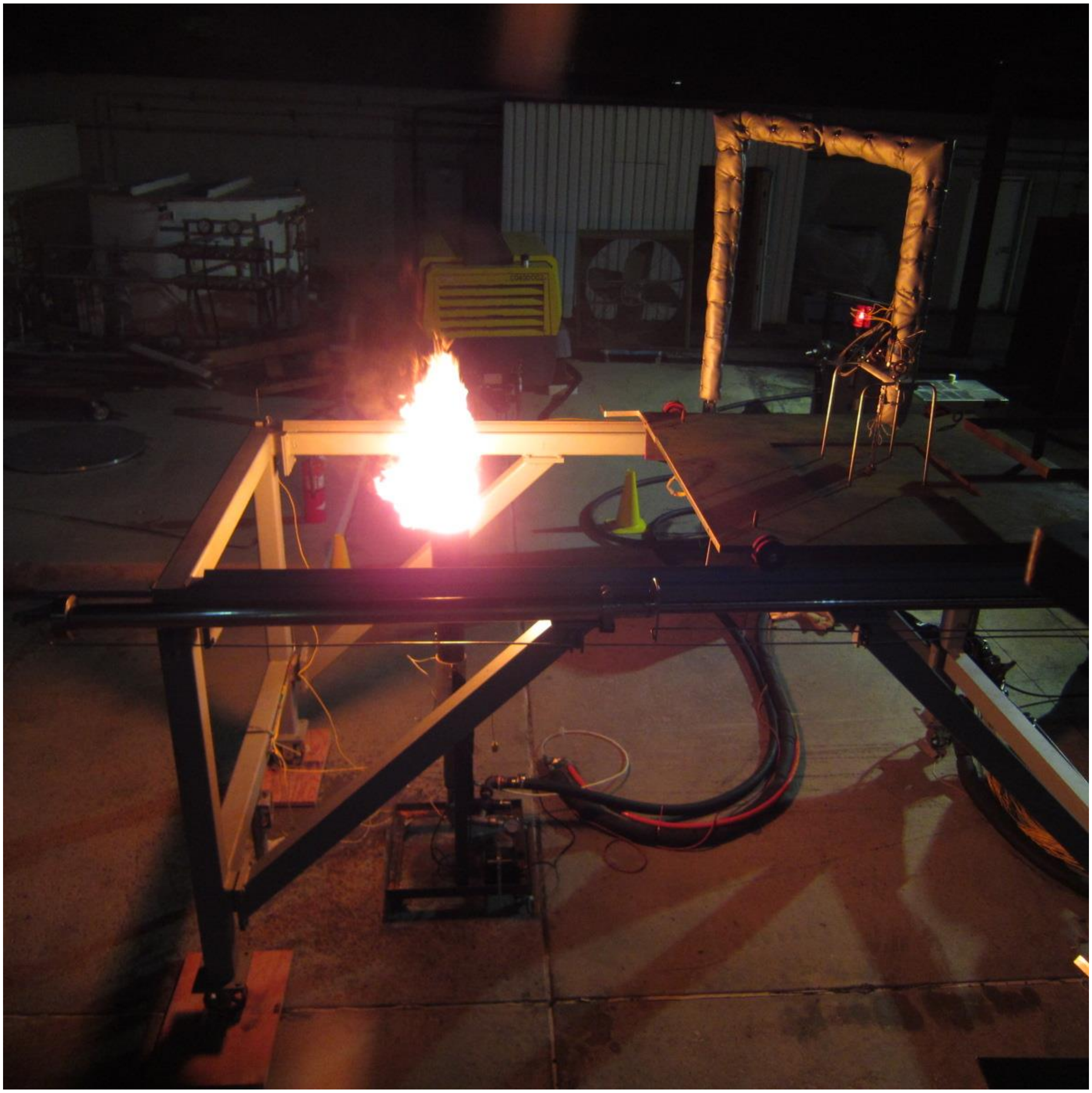

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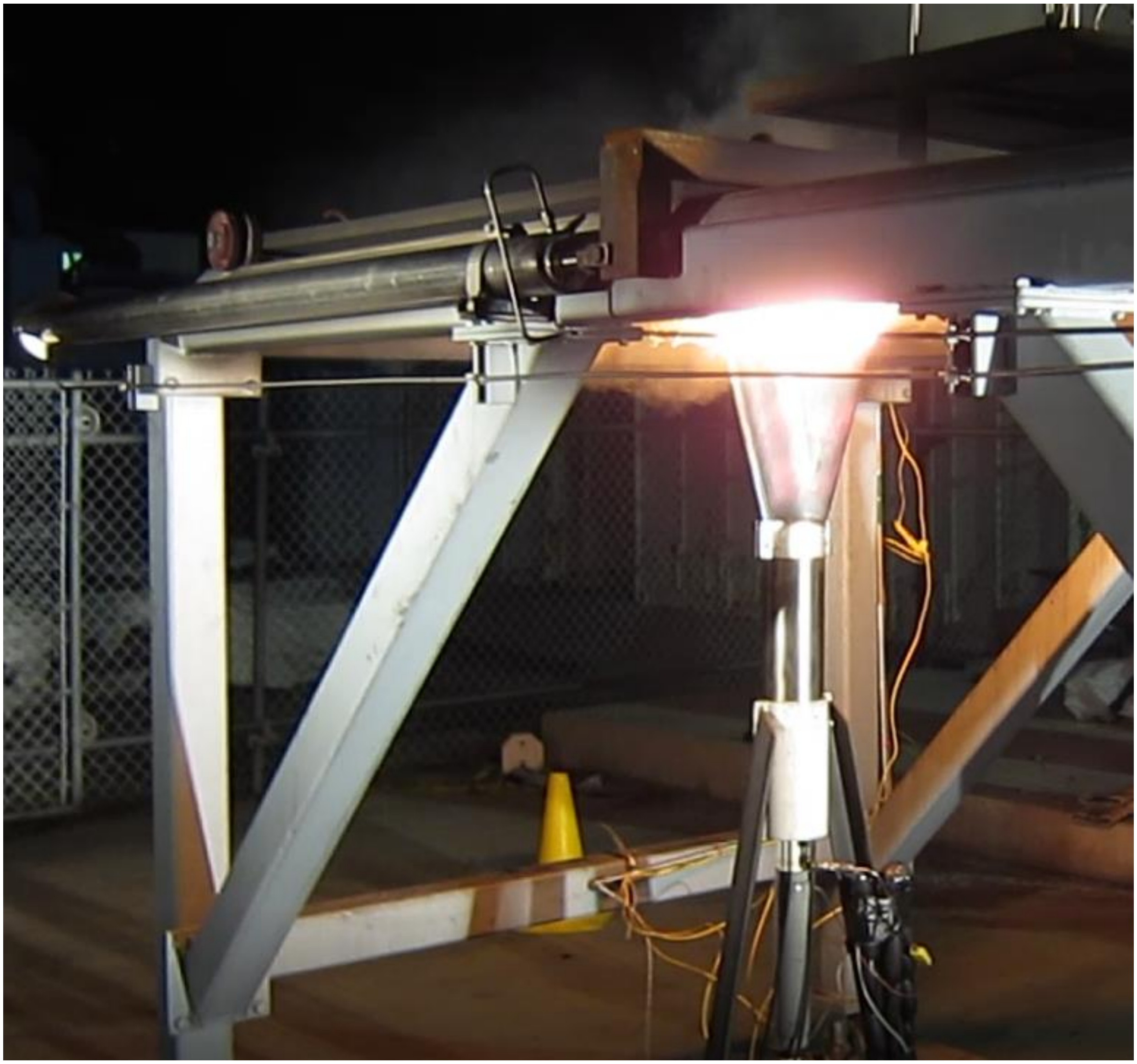
Figure 8: Plate Test Position



This was purposely designed that way in case of loss of power or emergency the plate would return back to staging position out of the burner.

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To monitor temperature of the flame on the fire side of the test sample, a thermocouple rake was mounted directly to the bottom of the plate at the specific distance according the FAA AC20-135 guidelines.

Figure 9: Thermocouple Rake

To measure the heat flux density, an external chiller unit cooled calibrated Vatell TG-1000-1A heat flux density sensor is mounted in the center of a heavy reinforced steel plate known as the calorimeter plate.

Figure 10: Calorimeter Plate

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With the burner on, the calorimeter plate was deployed into the burner measure the heat flux density. After measurement was taken, the steel plate was retracted and then the calorimeter plate was swapped with a test sample article.

The temperatures were monitored and recorded by a LabVIEW Data Acquisition system. Video cameras and lighting were placed around the test stand to record live video of the testing in action.

Testing Campaigns

Testing with the 12” test sample panels

Figure 11: 12" sample panel testing

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The first test campaign used 12” panels. Several problems arose during testing. The fire was difficult to start and it was thought the air and fuel mixture were affected by the cold temperature of the heat exchanger. The decision was made to test without cooling the fuel. Once the fire was started, the flame engulfed the sample and penetrated through the gaps of the sample plate and the steel plate cutout. The test team sealed the flame leak paths with fireproof felt to prevent flame penetration. But this led design engineers to questioning the size of the panel.

Testing with the 24” sample panels

With the lessons learned from the 12” penetration issue, a new 24” cutout plate was designs and machined. The design engineers thought that a 24” panel might prevent flames from wrapping around the sample because the 24” panel was larger than the flame from the burner. Another addition to the test stand was a larger 24” calorimeter plate. This posed an issue for the testing team to remove and install the heavy calorimeter plate. This led to led to the installation of the JIB BOOM crane system.

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Figure 12: JIB Boom Crane

Just like the previous test campaign, the burner was difficult to ignite. Although the testing team had taken great precaution to install all of the fuel lines, air lines and coolant lines, the burner still did not ignite. After a deep dive into the air system, the testing team discovered water buildup in the air lines from the both the facility air compressor and condensation while chilling the fuel. This led to the installation of low point drains to purge the water build up from the system before and after testing. With this solved, we were able to return back to chilling the fuel per the AC-135.

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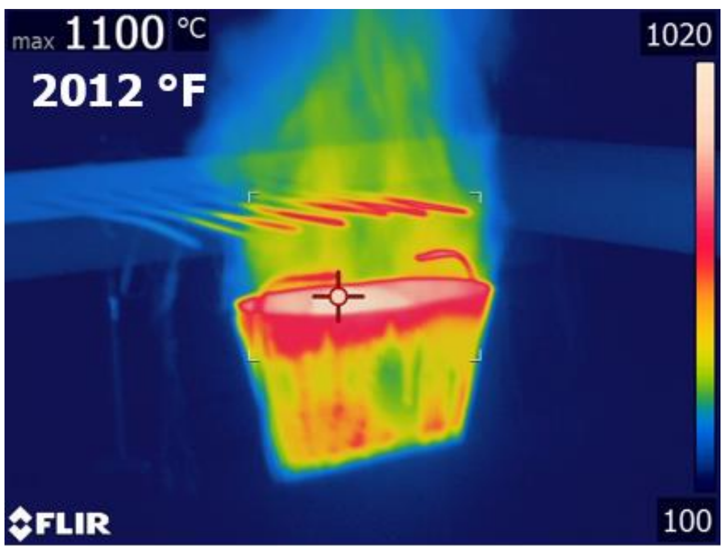
Figure 13: Water and Low Point Drain

To provide additional data, a thermal imaging camera was introduced to the fire challenge test stand. This capability was able to show the thermal profile of the burner, the calorimeter plate and the test articles.

Figure 14: Thermal Image Photo



As more thermocouples were added to the monitor temperatures, a faster thermocouple switching interface was designed and incorporated in the testing process to reduce the queue time between test samples. This method allowed the test team to safely swap the calorimeter plate and test sample in the staging position while the burner was still activated. This allowed the testing team to spend more time analyzing the data and they discovered uneven flame exposure because of the unique shape of the burner cone.

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The testing team assumed thought that the actual hottest flame temperature exposure was focus towards the middle of the sample test articles. But the data shows that the shape of the burner cone creates a flame with two lobes. This is not as noticeable on 12” test article because the flame engulfs the entire 12” surface area. But on a 24” test article, the two lobe flame creates an uneven flame exposure. To better understand this flame phenomenon, a thermocouple plate was designed and fabricated called the flame characterization plate.

Figure 15: Flame Characterization Plate Top View

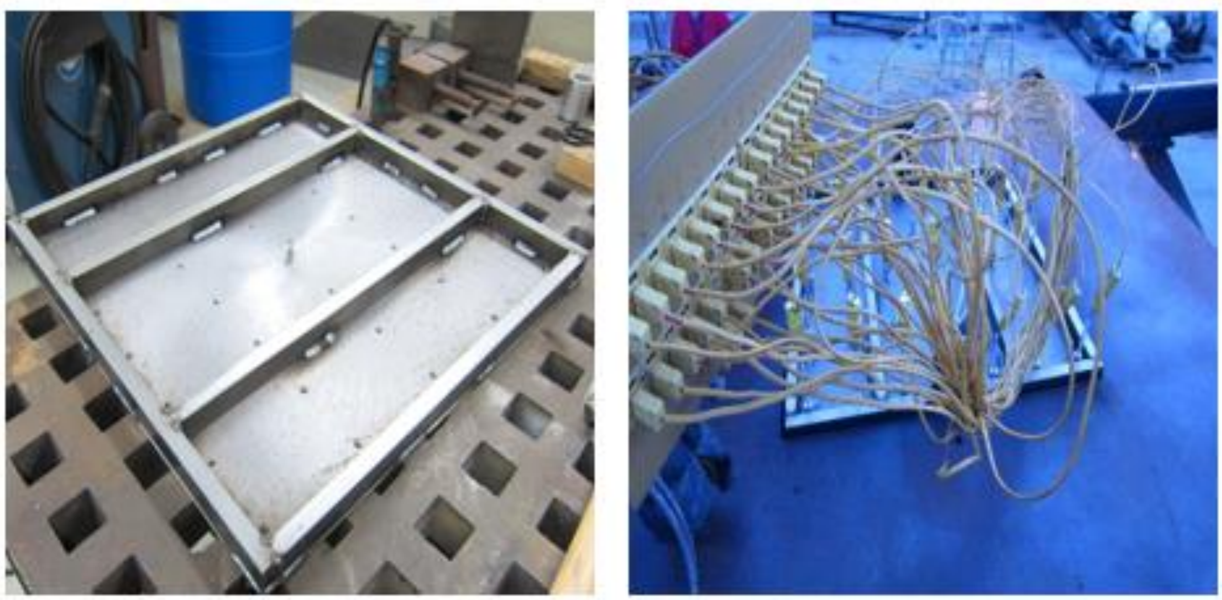

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Figure 16: Flame Characterization Plate Bottom View

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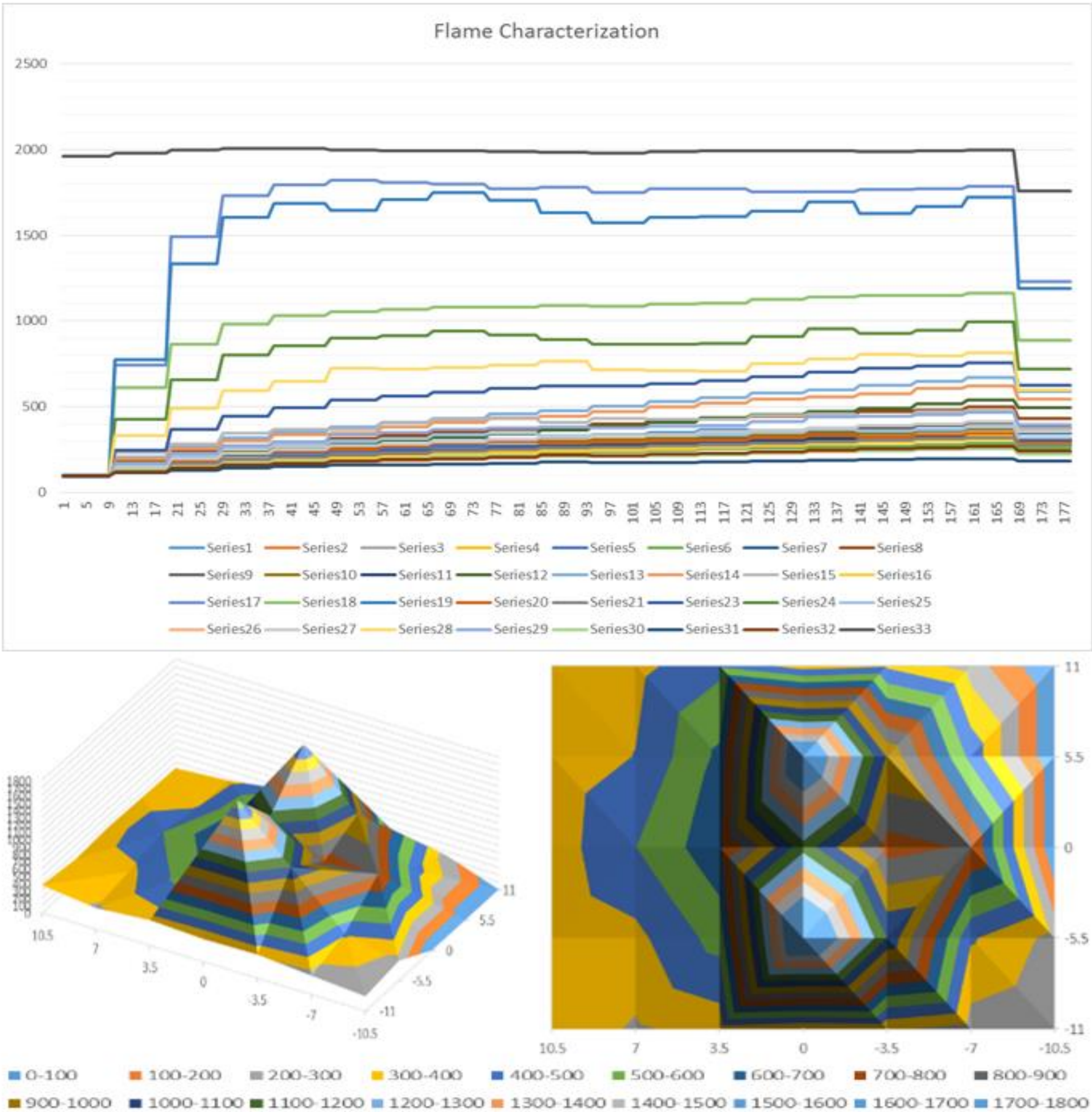
Figure 17: Flame Characterization Plots



The flame characterization testing showed the two lobe flame and also showed the uneven heat exposure to the area. According to the FAA AC20-135, the temperature must be held at 2000°F (+/- 150°F) and maintain a heat flux density of at least 9.3 BTU/ft^2-sec. In order to maintain the 2000°F average temperature, the burner air and fuel mixture had to be leaned out which increased the temperature and subsequently increased the heat flux density. Because the increased heat flux density caused the test articles to be over exposed, this led to higher backside temperatures.

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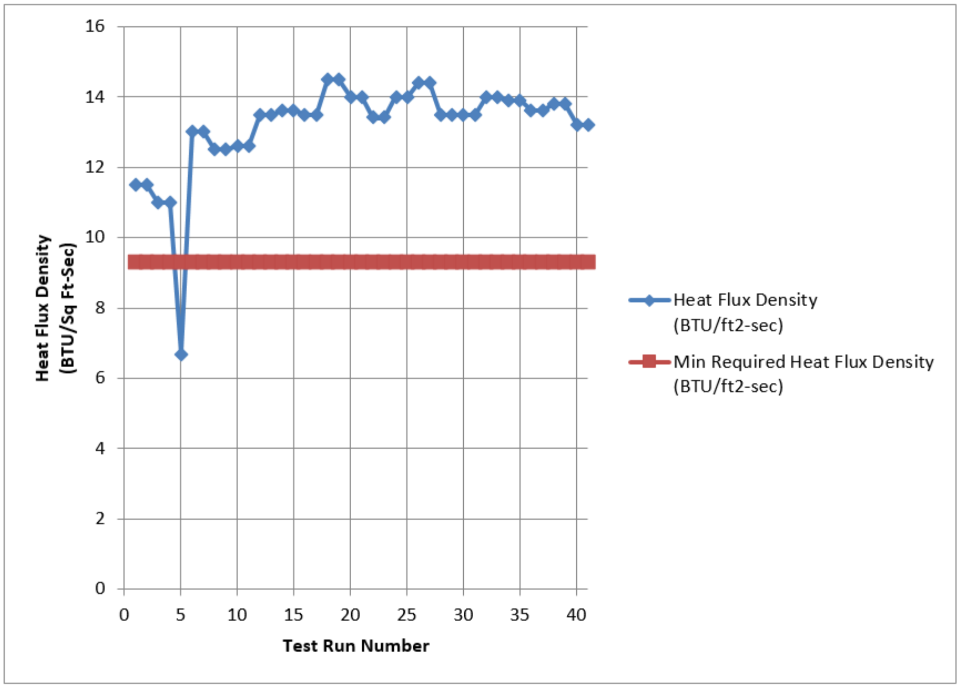
Figure 18: Heat Flux Density Plot



Despite our best effort to optimize the burner to required temperature and minimum heat flux density, the flame temperature and heat flux density are linked. You cannot change one without affecting the other.

Lessons Learned

We successfully executed our statement of work without any major injuries. The success of the fire challenge test stand was due to the entire team's focus on safety. From the early engineering design process, the Northrop Grumman Corporation Environmental, Health and Safety (EHS) organization had an active role. EHS personnel gave many requirements that focused on the safety of personnel and hardware. Have a pre-task and post-test briefing before each testing day, a stay out zone during testing, trained fire extinguisher safe watch personnel and operational safety hardware shutoff systems in case of emergencies.

We learned a lot during testing. A large sample holding plate reduces the wrap-around of the test flame that may skew the results. A larger sample panel will also minimize the edge effects of the flame. Vertically orienting the fire provides a worst-case test. Air lines must be periodically drained to facilitate ignition of the fire. The hottest place in the fire is the not the center of the test sample. It's the peak of the two loads. Having a safe and handy way to change out the calorimeter plate for the test samples saves a lot of time. Given the design of the burner, once the burner has been adjusted to get the flame temperature to 2000°F, the heat flux density is fixed. Generally > 9.3. The fire challenge burner is an amazing test stand. Applying these testing lessons learned and respecting theses safety rules will result in better testing and keeping everyone safe.

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