AEDC extends beyond Tennessee: Tunnel 9 and NFAC

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From AEDC's inception in 1951 to today, two other world-class aerospace testing complex's have closely paralleled Arnold's 60-year history in significant ways.

The Naval Ordnance Laboratory (NOL) at White Oak, Md., was established in 1944. The scope of work there would eventually lead to the development of the Navy's Hypervelocity Wind Tunnel 9 facility, which became the first of AEDC's two remote testing sites in 1997.

At the National Full-Scale Aerodynamic Facility (NFAC), in Mountain View, Calif., engineers have conducted aerodynamic testing at subsonic speeds since the 40-by-80-foot wind tunnel was built in 1944. NFAC was originally managed by the National Advisory Committee for Aeronautics (NACA), NASA's predecessor. In 2003, NFAC, now the site of the two largest wind tunnels in the world at the NASA Ames Research Center, was closed and deactivated as part of a NASA decision to reduce operating costs.

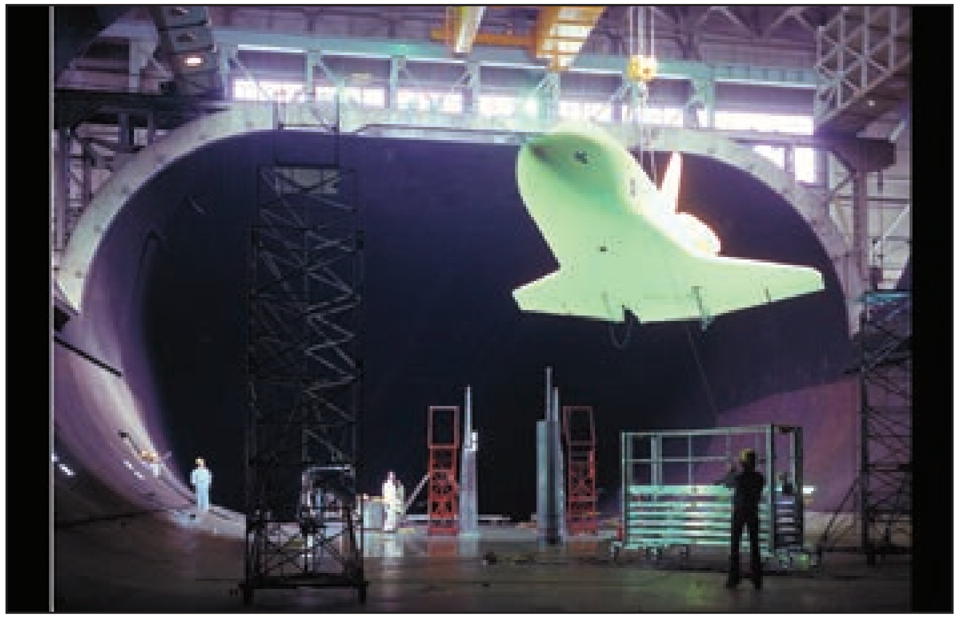
In 2006, NFAC became the second remote site to be managed by AEDC.

Hypervelocity Wind Tunnel 9

After World War II ended, the U.S. brought two German wind tunnels, T-1 and T-2, for use at the NOL. These tunnels played an important role in the genesis of a fledgling U.S. supersonic research program. Until 1995, T-1 was still used at the Tunnel 9 complex, but only as a calibration laboratory.

Dan Marren, Hypervelocity Wind Tunnel 9's site director, said the German tunnel was still in use when he first came to work at Tunnel 9 for the Navy.

"I came on board in 1984 as a co-op from the University of Cincinnati," he recalled. "We had modified T-1 from its original use; in 1984 we were still using it essentially as a vacuum source for putting smaller supersonic nozzles in place to do technology development.



In 1975, a scale model of the space shuttle orbiter is installed into the 40 by 80-foot wind tunnel at the NFAC for subsonic aerodynamic testing of what the vehicle would experience during the latter stages of re-entry. (NASA photo by Lee Jones)

"The predecessors, being Tunnel 1 and 2, existed for a very similar purpose to the facilities that exist in Tullahoma today. The beginning of high speed and really aeronautic technology was just being understood, with the aid of the German scientists that came over to help us develop and start that program. So that history is very similar in that we were looking at this technology that really was unknown to us and trying to understand its benefit."

In those early years, Marren was part of a team focused on conducting aerodynamic research on bombs and, later, testing on the weapon systems like Sidewinder missiles. However, it wasn't long before his attention turned almost entirely to advancing the study of hypersonics.

"Even back in 1984, I was working more toward the Tunnel 9 effort than I was on the old tunnel efforts," he said. "Most of what I was doing was focused on things like re-entry and strategic systems, like Intercontinental and submarine-launched Ballistic Missiles [(ICBM), (SLBMs).]"

Marren said the level of testing "was actually quite active" his first year at Tunnel 9.

He recalled that Tunnel 9's team was also doing a lot of their work at AEDC.

"We were half way through some of the major Navy programs that were going on like the upgrades to the Navy [Trident fleet ballistic missile] MK4 and MK5 systems and the variants of those systems," he said. "We were actively testing in the AEDC arc heater facilities to get nose tip change shapes, and then we were looking at the aerodynamic and aerothermal qualities of those changed nose shapes that we got from AEDC in Tunnel 9.

"We were running 200 to 250 runs a year, which was keeping about 60 to 80 people here busy year-round, running all the facilities and the analysis that went with it."

Tunnel 9 is a blow-down facility capable of subjecting flight vehicles and component scale models to nitrogen gas at speeds as high as Mach 14 for up to 15 seconds.

Marren spoke about ground-breaking work done by scientists in the 1960s that led to the establishment of Tunnel 9 in 1975.

"They were looking at doing re-entry testing of full-scale re-entry and strategic systems as well as nose tips," he said. "The full simulation of what happens next to the body in the boundary layer became important.

"So, we started looking at higher pressure with tunnels, which can deliver the physics that occur in the boundary layer. So, they came up with a concept of building a tunnel which was to be Tunnel 9."

Ironically, the first funded program run in Tunnel 9 wasn't a Navy test, but an Air Force entry, on a boost glide maneuvering re-entry vehicle supporting the Advanced Ballistic Reentry System (ABRES).

In 1997, Tunnel 9 came under the management of AEDC.

"Now we're doing boost glide systems, albeit at a different performance level in technology, but we're back to the future I guess," said Marren, who was the technical director when Tunnel 9 became a remote site managed by AEDC.

"Tunnel 9 is the highest pressure wind tunnel in the world. And the reason that it needs that high pressure is to develop the right physics in the boundary layer. When you're looking at what guides heat transfer into a heat shield, now what guides accuracy and control? It turns out to be what happens very close to the body and that's only discovered if you recreate the boundary layer.

He said Tunnel 9 can do this naturally through high pressure.

"Other facilities that we have around the world have to actually put a device on the test article to make the flow less smooth or laminar and turbulent," he explained. "When you do that sometimes you can corrupt the data if you don't do it carefully."

Marren said the work being done currently at Tunnel 9 falls into two main categories.

"The new classes of re-entry vehicles that trace their roots to the ABRES maneuvering re-entry or boost-glide systems of the 1970s are really where we're pushing the technology to help them get into the development stage. One of the first Conventional Prompt Global Strike (CPGS) program concepts is the hypersonic technology vehicle 2 (HTV-2). This is a joint U.S. Air Force and DARPA partnership, which will be handed over this year to the Air Force, and will form the basis for the Conventional Strike Missile.

"The other category, you'll see a very heavy emphasis in the arc jet facilities at AEDC and Tunnel 9 where we'll actually take nose tips that maybe are from a different vendor because the vendors that made the original nose tips are all out of business. And the looms are different, that gives you a different product and it might ablate differently.

"Those shape changes then need to be understood and programmed in to know how these things are going to fly, that might have been different than their design. Those are the standard U.S. Air Force ICBMs like Minuteman and the Navy Trident program and those are the systems that are in the field."

Marren said even slight modifications to a weapon system, like outer mould lines, will be made as the mission changes, which includes missile defense.

"Although they're not coming back from space, they're accelerating in the atmosphere at very high speeds," he said. "It is not uncommon for a rocket-boosted interceptor to fly between Mach 7 and 10. Those systems are going to experience the same sort of physics and challenges that our re-entry vehicles did to be able to understand their heat shields and their heat protection and of course their accuracy and control."

National Full-Scale Aerodynamic Facility

In 1944, a Douglas XSBD-2 model became the first aircraft to be tested in the NACA Ames 40-by-80-foot wind tunnel, the largest wind tunnel in the world at the time.

One highlight of earlier work done in the 40-by-80-foot wind tunnel was testing on the space shuttle conducted in the 1970s.

The work at NFAC following that test closely paralleled emerging threats and challenges AEDC met with its complimentary test capabilities and the hypersonic testing done by the facilities that evolved into Tunnel 9.

The facility became NFAC in 1987 after the 80-by-120 foot test section was added and other improvements made. This section is the world's largest wind tunnel and is capable of testing a full-size Boeing 737 at speeds up to 100 knots.

When the NFAC was deactivated in 2003, a large Army contingent and the rotary wing division of NASA Ames expressed their interest in keeping NFAC accessible and maintained to develop new and future rotor systems for rotorcraft. With help from people like AEDC Fellow Dr. James Mitchell and others, the Office of the Secretary of Defense was convinced that the NFAC was a valuable ground testing complex worth keeping viable.

The Air Force assumed responsibility for operations at the NFAC in February 2006, with AEDC conducting the 8 Meter Magnus Wind Turbine Test in February 2007.

NFAC is a unique facility, primarily used for determining aerodynamic characteristics of large and full-scale rotorcraft and powered-lift Vertical/Short Take-Off and Landing (V/STOL) aircraft, as well as testing of wind turbines, parachutes, trucks and other non-traditional types of testing.

Dave Duesterhaus, the director of NFAC, said the facilities complement AEDC's aeronautical capabilities. Having spent approximately 35 years at Arnold, primarily overseeing propulsion testing, he has had an opportunity to see ground testing from many perspectives.

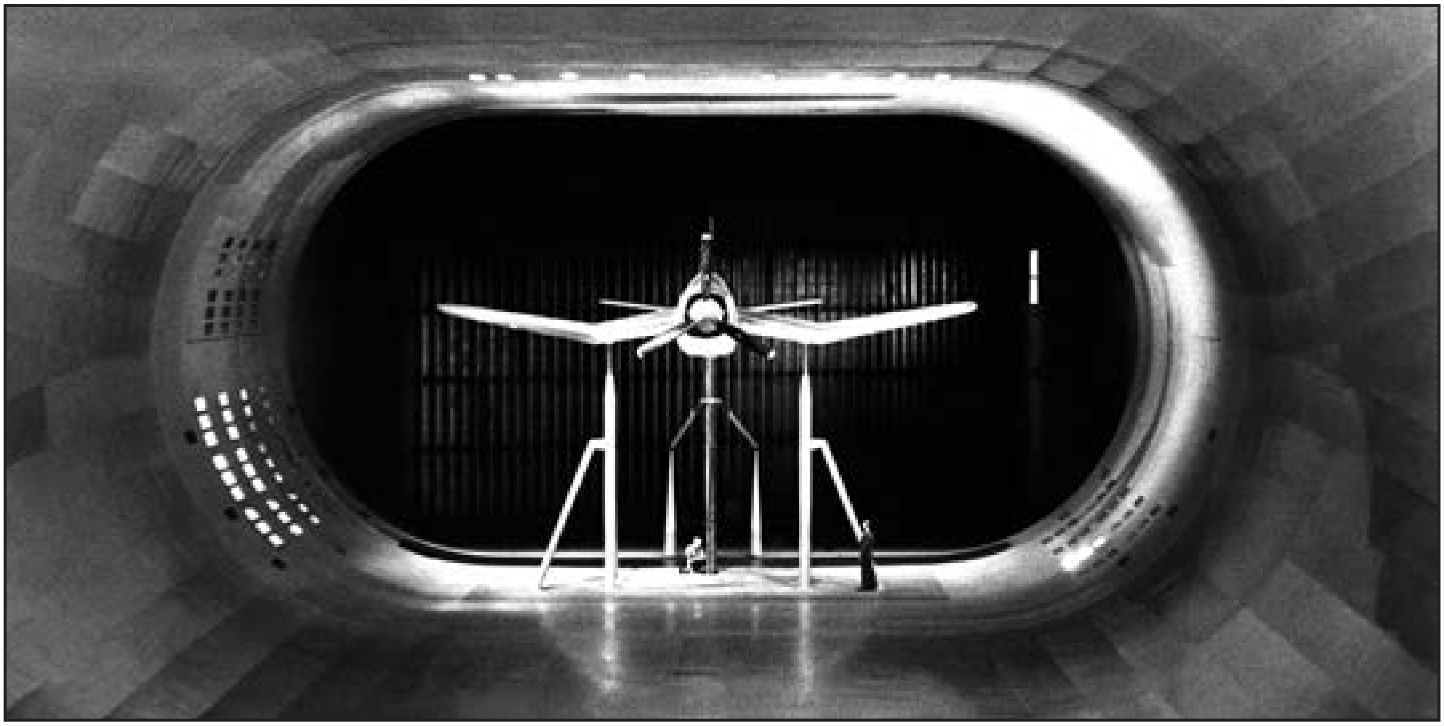
"AEDC has had little involvement in rotorcraft development and only a few turbo shaft engine tests that they've done over the years," he said. "The other thing is NFAC really bridges the gap from a subscale to full scale because what NFAC allows you to do is [study] where you have aerodynamic interactions with aero-structures."

He said at AEDC it might be possible to model aerodynamics and structures, but only separately.

"When you couple those two together, then it becomes too big of a problem to try to solve and you need a numerical simulator called NFAC where you can couple those two together," he said. "That is why rotorcraft [testing] plays such a big role in our customer base. Rotors are highly affected by the aerodynamics and the structures together. And coupling those two together is really what makes this facility valuable."

Duesterhaus also spoke about some of the work on testing Army helicopter rotors that began around 2009 and has continued to the present day.

"We just completed a series for the Army with a Sikorsky test, all involving active rotor systems with flaps on the rotor blades to effect and improve performance,



This Douglas XSBD-2 model was the first aircraft to be tested in the NACA Ames 40-by-80-foot wind tunnel, the largest wind tunnel in the world at the time. Drag reduction studies were performed on the airplane. (NASA file photo)

either lift, cruise and noise reduction."

Duesterhaus said the upcoming testing at the NFAC will allow NASA to continue to take advantage of the facilities' unique capabilities.

"In the near term, we're actually going to look at some space decelerators for NASA in the next fiscal year," he said. "Those are called Hypersonic Inflatable Aerodynamic Decelerators (HIAD), and there's also a supersonic aerospace decelerators, but those are coming in maybe the next year or so."

Regarding what the future holds for them at NFAC, he said, "From NASA, we'll continue to get things like the parachutes and aerodynamic decelerators for any planetary expeditions that they might do or some Earth re-entry systems that they're looking at for satellites. We'll also probably have a role to play in whatever replaces the CEV, if there's an aerodynamic issues with those decelerators or parachute systems – we'll likely get involved with that."

Duesterhaus said, "We are also doing a short take-off and landing (STOL) airplane for NASA."

Other upcoming work will include aerodynamic testing on a smaller scale of an aircraft demonstrator like the Air Force Research Lab's Speed Agile airlifter.

"That will kind of be a technology development demonstrator," he said. "The other big thing that we see for the future is the possibility of [testing] for NASA and the Army Joint Heavy Lift program applications of large tiltrotor test aircraft using the new $20 million Tiltrotor Test Rig or the TTR. They're looking at 90-passenger short hop tiltrotor aircraft that would actually be very useful at places like upper northeast corridor primarily.

"Those aircraft could get to high speeds, similar to what they have with the V-22 [Osprey], up to 250 to 300 miles per hour, so it becomes a very viable commercial alternative to hub-and-spoke aircraft support, particularly in high density environments.

"At the same time, the Army is thinking that they want a large-built rotor or vertical lift platform for doing large entries into battlefield situations. Having those two requirements together, they jointly funded this tilt rotor test rig and that'll give us the capability to evaluate new concept for tiltrotor systems. One of the big things in rotorcraft has been active controls on the rotors; much like we did for the integral blade controller (IBC) and previously Boeing applied it on a technology demonstrator. So, those held great promise for future applications as well."

From subsonic to hyerpsonic, the additional capabilities provided by NFAC and Tunnel 9 and their teams bring AEDC to the next level of aerospace ground testing in the world.