The Smithsonian's new National Air and Space Museum at Washington Dulles International Airport offers valuable lessons for outside-the-box, performance-based design


Flying into Dulles International, home to architect Eero Saarinen's landmark terminal, one might not easily spot the Smithsonian Institution's contribution to the airport, despite its expansive 760,000 sq. ft. That's because the museum's new facility, the Steven F. Udvar-Hazy Center, very much resembles any other large airport hangar. And that was St. Louis-based architect HOK's intent. The facility is essentially a collection of aircraft garages spanning the length of three football fields. On display are some of aviation's most prized treasures, including the space shuttle Enterprise, an Air France Concorde and the infamous SR-71 Blackbird spy plane, which, until now, has never been viewed by the public. This massive, multi-purpose complex, which includes an IMAX theater, is expected to host 3 million visitors annually. And with so many people present, special fire-protection and life-safety measures are added to protect both building guests and the more than 300 rare aircraft on display.

Best performance

One of the principal fire-safety challenges was dealing with egress distances without compromising the unique architectural design that supports the dramatically suspended aircraft. In the facility's main chamber, aircraft are displayed on three levels in an open 500,000-sq.-ft. atrium. Larger aircraft are at ground level, while smaller planes are hung from arches. These structural elements also support the roof via cables and brackets on two separate levels. Lower-level aircraft are hung approximately 25 ft. above the floor, while upper-level aircraft hang roughly 42 ft. above the floor.

In order for visitors to have the best possible view of the suspended aircraft, elevated walkways were constructed along the sides of the main atrium/hangar. A gentle slope, in compliance with Americans with Disabilities Act requirements, was incorporated into the walkway design. However, this ADA-friendly ramp, along with the massive size of the hangar created an immediate conflict with applicable building codes for maximum exiting travel distance allowed. A means of safe egress had to be identi-

An upper and lower level aircraft suspension configuration of 25 and 42 ft., respectively, gives this Monocoupe 110 Special Little Butch and other aircraft a live, in-flight feel and takes advantage of the museum's massive open volume.

Photography: (Above) Chuck Moore; (Right) Carolyn Russo/NASM
fied to address the 650-ft.-plus distance from the most remote part of the walkway to the nearest exit, but in a way that did not destroy the function of the walkways or HOK's overall architectural design.

Prescriptive building codes did not adequately address assembly occupancy in such a massive hangar-like structure, so the team had to take on a performance-based approach. The first step in that plan involved an exercise with the National Institute of Standards and Technology's Fire Dynamic Simulator (FDS) fire-modeling tool. The FDS model was chosen to create a fire scenario addressing the museum's biggest concern—ensuring that fire tenability could be maintained while the public traveled to the distant exits. The FDS model was also used to determine roof temperatures created by the design fires to help analyze how the light, unprotected hangar roofs might perform during a fire.

The design fire itself had to be reasonable yet realistic to the kinds of hazards the museum might face. Therefore, proper input was critical to the model. Fortunately, the Smithsonian had already identified the load of the display contents, thus the hazard was limited to these materials.

Other worst-case scenarios were simulated, such as the sprinkler system not functioning, to maximize the heat release and the burn rate. The data was also compared with results generated by the egress models to ensure its accuracy.

In the end, the FDS model clearly demonstrated that the worst-case scenario would not have a significant impact on the level of life safety. The shear space in the main hangar would act as a smoke and heat sink for any combustion product. In addition, simulations demonstrated that the design fire fuel would be completely consumed and that the harmful upper smoke layer that would be generated by a fire within such a space would have no effect on life safety.

The next major step was to identify the appropriate method of fire suppression. A sprinkler system was chosen. The minimum sprinkler design criteria for the museum's particular hazard classification is Ordinary
It was not practical to install evacuation notification devices and related wiring in the middle of the display space. Therefore, the building's intelligent public address system was enlisted for double duty.

Hazard Group 2, which includes administrative space as well as exhibit areas. This classification exceeds the requirements of NFPA 13, *Installation of Sprinkler Systems*, and most of time prediction models currently available are not accurate for heights 100 ft. and greater. Once again, the FDS modeling program came to the rescue. In this case, modeling analysis was based on a 10-ft. by 10-ft. sprinkler spacing. Appropriate response time index (RTI) values and temperature ratings were plugged in along with borrowed data and input used in the initial egress analysis.

The results indicated that fewer sprinklers than expected were required in the design areas and that the criteria set in NFPA 13 was adequate. Furthermore, the model proved that the response time and coverage were sufficient without compromising any of NFPA 13's requirements. (Continued on page 40)

Attention on Deck

Although not required by applicable building codes, a voice general evacuation system was selected for the museum. This alternative has many advantages over the horn or bell-type general evacuation signals, for example, live voice instructions and the capability to generate selected messages in different zones. But it was a code requirement that the voice alarm system not only had to provide an alarm message—typically 15 dBA above the ambient noise level—but it also had to deliver a clear and understandable message throughout.

The speakers initially selected for the facility, at their maximum setting, could produce a sound level of 90 dBA at 10 ft. from the speaker. As a rule of thumb, the output of an audible notification appliance is reduced by 6 dBA if the distance between the speaker and the listener is doubled. At 20 ft., the output is reduced to 84 dBA. Instead, the building's intelligent public address system was repurposed, as many features of a fire-alarm system were inherent in it. Noise sensors, however, were installed in the exhibit areas to adjust the PA volume appropriately.
Naturally, no fire-protection scheme is complete without a fire-alarm system. To meet building code requirements, a microprocessor-based, analog-point addressable fire-alarm and detection system, including pull stations, smoke detectors and notification devices, was designed and installed. However, designing a fire-alarm system for such a unique facility with multiple occupancies required special considerations. Early detection and early warning are only a few of the design objectives that had to be achieved in order to adequately protect the lives of the occupants and the displays.

The most demanding of these criteria was the selection of the detection system. First, the entire facility had to be protected with an automatic smoke or heat-detection system, in accordance with Smithsonian standards. When considering smoke detectors, spot-type detectors were the initial choice. The most common type of detection, these devices have the capability to adjust their sensitivity, thus enabling them to differentiate between real fire and nuisance alarms caused by dust. They also use state-of-the-art microprocessor circuitry with error check, detector self-diagnostics and supervision programs to reduce nuisance alarms.

**With heights in excess of 100 ft., smoke detection was a major issue.** The debate was over spot or projected-beam devices.

The reflecting prism, which has the shape of a pyramid with lateral faces formed by isosceles orthogonal triangles, enables the beam entering the prism to reflect back to the transceiver along the same path, thus minimizing the effect of vibration and structural movement. Furthermore, wiring and power can be provided at one location. The reflector can be mounted at the apex, and once aimed, does not need to be accessible. Additionally, such devices can blend aesthetically with building finishes. Multi-level detection also eliminates the stratification effect, as service can be performed at an accessible level. Finally, the technology is the least expensive of the two.

Beam detection was chosen, but there was still one major disadvantage that had to be resolved: The beam path can wind up being blocked by exhibits or lighting. This was resolved by coordinating the location of the detectors and the exhibits layout.

**Encore**

Having already hosted more than half a million visitors since its opening on Dec. 15, 2003, the Udvar-Hazy Center will likely see plenty of activity in the coming months and years. A performance-based design approach yielded a unique avenue to meet the museum's design challenges, while providing a fire and life-safety system capable of protecting lives and aviation treasures that also reduced construction costs. Furthermore, it proves that designing via the prescriptive codes is not the only way to design a safe building.